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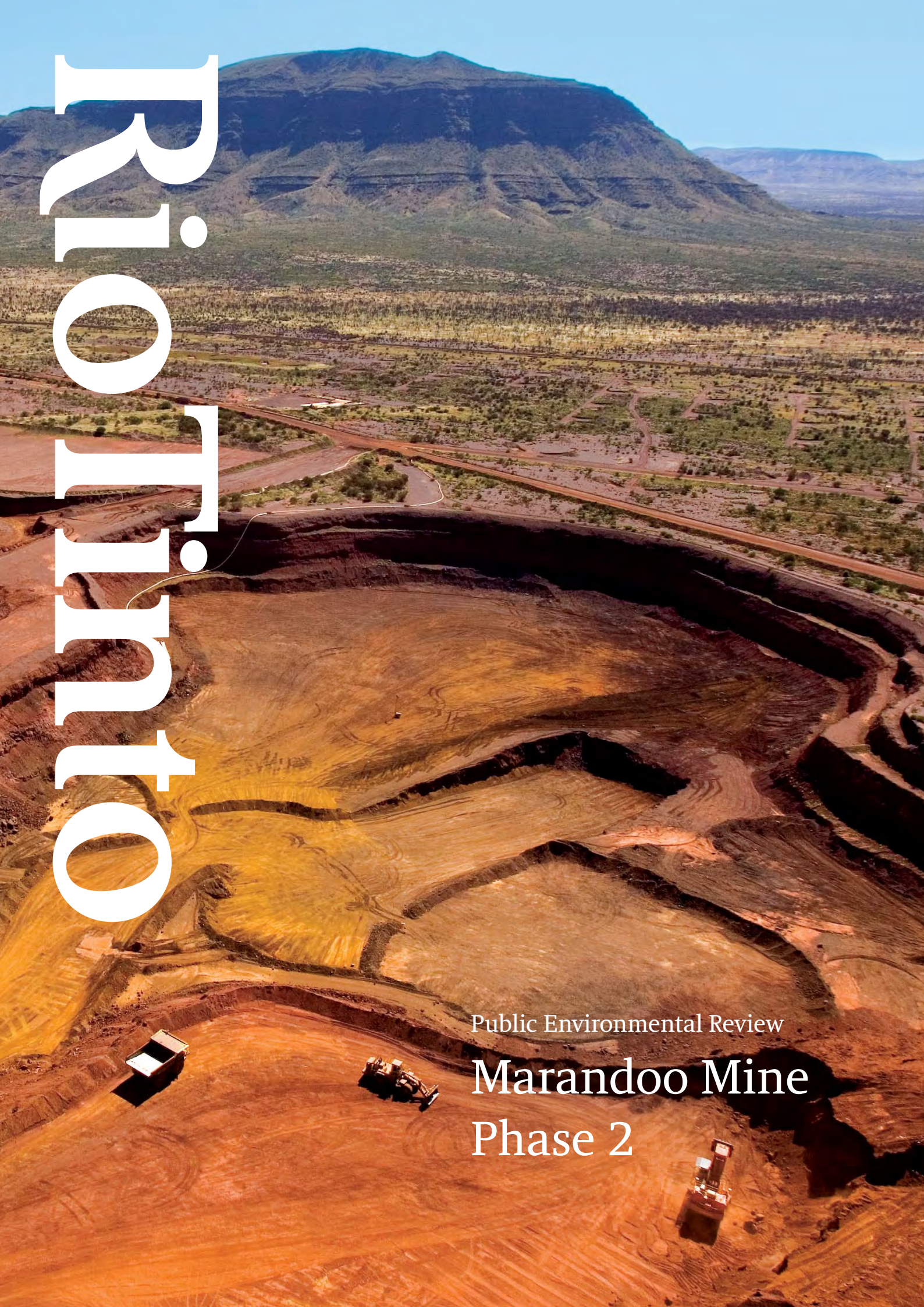

Public Environmental Review

Marandoo Mine Phase 2

Important information

This publication includes “forward-looking statements” within the meaning of Section 27A of the *Securities Act* of 1933, as amended, and Section 21E of the *Securities Exchange Act* of 1934, as amended. All statements other than statements of historical facts included in this publication, including, without limitation, those regarding Rio Tinto’s financial position, business strategy, plans and objectives of management for future operations (including development plans and objectives relating to Rio Tinto’s products, production forecasts and mineral positions), are forward-looking statements. Forward-looking statements are based on numerous assumptions and involve known and unknown risks, uncertainties and other factors which may cause the actual results, performance or achievements of Rio Tinto, or industry results, to be materially different from any future results, performance or achievements expressed or implied by such forward-looking statements.

Invitation to Comment

Marandoo Mine Phase 2

The Environmental Protection Authority (EPA) invites people to make a submission on this Proposal. Both electronic and hard copy submissions are most welcome.

Hamersley Iron (a member of the Rio Tinto Group) proposes to extend mining operations at the existing Marandoo Iron Ore Mine (Marandoo) in the central Pilbara region, Western Australia. Marandoo operates under the *Iron Ore (Hamersley Range) Agreement Act 1963* (WA), within a mining lease excised from Karijini National Park in 1991. Mining commenced at Marandoo in 1994 and approximately 15 million tonnes per annum (Mtpa) of high-grade Marra Mamba iron ore is currently produced through above watertable operations at the mine. Current predictions show that the Marandoo deposit will be mined to its maximum above watertable extent by 2012. Further development of the Marandoo deposit below the watertable is required to produce ore to meet market demand. The Proposal includes identifying sufficient ore reserves below the watertable which would be mined at a production rate of approximately 15 Mtpa thereby increasing the size of the existing mine pit[1].

In accordance with the *Environmental Protection Act 1986* (WA), a Public Environmental Review (PER) has been prepared which describes this Proposal and its likely effects on the environment. The PER is available for a public review period of eight weeks from 29 September 2008, closing on 25 November 2008.

Comments from government agencies and from the public will assist the EPA to prepare an assessment report in which it will make recommendations to government.

Where to get copies of this document

Printed copies of this document may be obtained from:

Name: Una Phelan
Address: Expansion Projects, Rio Tinto
Central Park 152-158 St Georges Tce Perth WA 6000
GPO Box A42 Perth WA 6837
Phone: (08) 9327 2759
Email: una.phelan@riotinto.com

Hard copies of the PER may be purchased at a cost of $10.00 per copy, or a CD-ROM version will be provided (no charge). Copies may also be obtained from www.riotintoironore.com/ENG/media/337.asp

Why write a submission?

A submission is a way to provide information, express your opinion and put forward your suggested course of action - including any alternative approach. It is useful if you indicate any suggestions you have to improve the Proposal.

All submissions received by the EPA will be acknowledged. Submissions will be treated as public documents unless provided and received in confidence subject to the requirements of the *Freedom of Information Act 1992* (WA), and may be quoted in full, or in part in the EPA's report.

Why not join a group?

If you prefer not to write your own comments, it may be worthwhile joining with a group or other groups interested in making a submission on similar issues. Joint submissions may help to reduce the work for an individual or group, as well as increase the pool of ideas and information. If you form a small group (up to ten people) please indicate the names of all participants. If your group is larger, please indicate how many people your submission represents.

---

1 There are currently insufficient Ore Reserves to supply the forecast/estimated production for this Project. Accordingly, such production is subject to defining satisfactory Ore Reserves for the Project from the current and any further identified mineralisation.

Invitation to Comment

Marandoo Mine Phase 2

Developing a submission

You may agree or disagree with, or comment on, the general issues discussed in the PER or with the specific Proposal. It helps if you give reasons for your conclusions, supported by relevant data. You may make an important contribution by suggesting ways to make the Proposal more environmentally acceptable.

When making comments on specific elements of the PER:

- clearly state your point of view
- indicate the source of your information or argument if this is applicable
- suggest recommendations, safeguards or alternatives.

Points to keep in mind

By keeping the following points in mind, you will make it easier for your submission to be analysed:

- attempt to list points so that the issues raised are clear; and a summary of the submission is helpful
- refer each point to the appropriate section, chapter or recommendation in the PER
- if you discuss different sections of the PER, keep them distinct and separate, so there is no confusion as to which section you are considering
- attach any factual information you wish to provide and give details of the source. Make sure your information is accurate.

Remember to include:

- your name
- your address
- the date
- whether and the reason why you want your submission to be confidential.

Information in submissions will be deemed public information unless a request for confidentiality of the submission is made in writing and accepted by the EPA. As a result, a copy of each submission will be provided to the proponent but the identity of private individuals will remain confidential to the EPA.

The closing date for submission is 25 November 2008.

The EPA prefers submissions to be made electronically using one of the following:

- the submission form on the EPA's website: www.epa.wa.gov.au/submissions.asp
- by email to submissions.eia@dec.wa.gov.au
- by email to the officer vanessa.angus@dec.wa.gov.au.

Alternatively submissions can be:

- posted to: Chairman, Environmental Protection Authority, Locked Bag 33, CLOISTERS SQUARE WA 6850, Attention: Vanessa Angus
- delivered to the Environmental Protection Authority, Level 4, The Atrium, 168 St Georges Terrace, Perth, Attention: Vanessa Angus
- faxed to (08) 6467 5562.

If you have any questions on how to make a submission, please ring the EPA assessment officer, Vanessa Angus on 6467 5256.

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Appendix 2. Environmental Management Plan

Marandoo Mine Phase 2

The Proposal described in this PER (entitled 'Marandoo Mine Phase 2') relates to the continuation of mining at the existing Marandoo iron ore mine in the Pilbara region of Western Australia for up to 20 years. Dewatering of the ore body is required so that mining can take place below the watertable. Hamersley Iron, a member of the Rio Tinto Group, is the Proponent of the Proposal.

Introduction

The Proposal described in this Public Environmental Review PER (entitled 'Marandoo Mine Phase 2') relates to the continuation of mining at the existing Marandoo iron ore mine in the Pilbara region of Western Australia. Hamersley Iron, a member of the Rio Tinto Group, is the Proponent of the Proposal.

To date, all mining from the ore body at Marandoo has taken place above the watertable. This Proposal seeks to dewater the same ore body so that mining can take place below the watertable, maintaining the current rate of production at approximately 15 million tonnes per annum (Mtpa) for up to 20 years. Current predictions are that the Marandoo deposit will be mined to its maximum above watertable extent by 2012[2]. The low phosphorus iron ore found at Marandoo is a critical component of the 'Pilbara blend', which is the cornerstone of the Rio Tinto Group's Western Australian iron ore export business. The Pilbara blend is comprised of varying quality iron ore from several of the Rio Tinto Group's Pilbara mines and is exported from Cape Lambert and Dampier to markets overseas. Production from the Proposal will help to ensure the sustainability of the Pilbara blend and Rio Tinto business activities in the region. The Proposal will involve an increase in the size of the existing mine pit, and associated development of waste dumps to access the ore body.

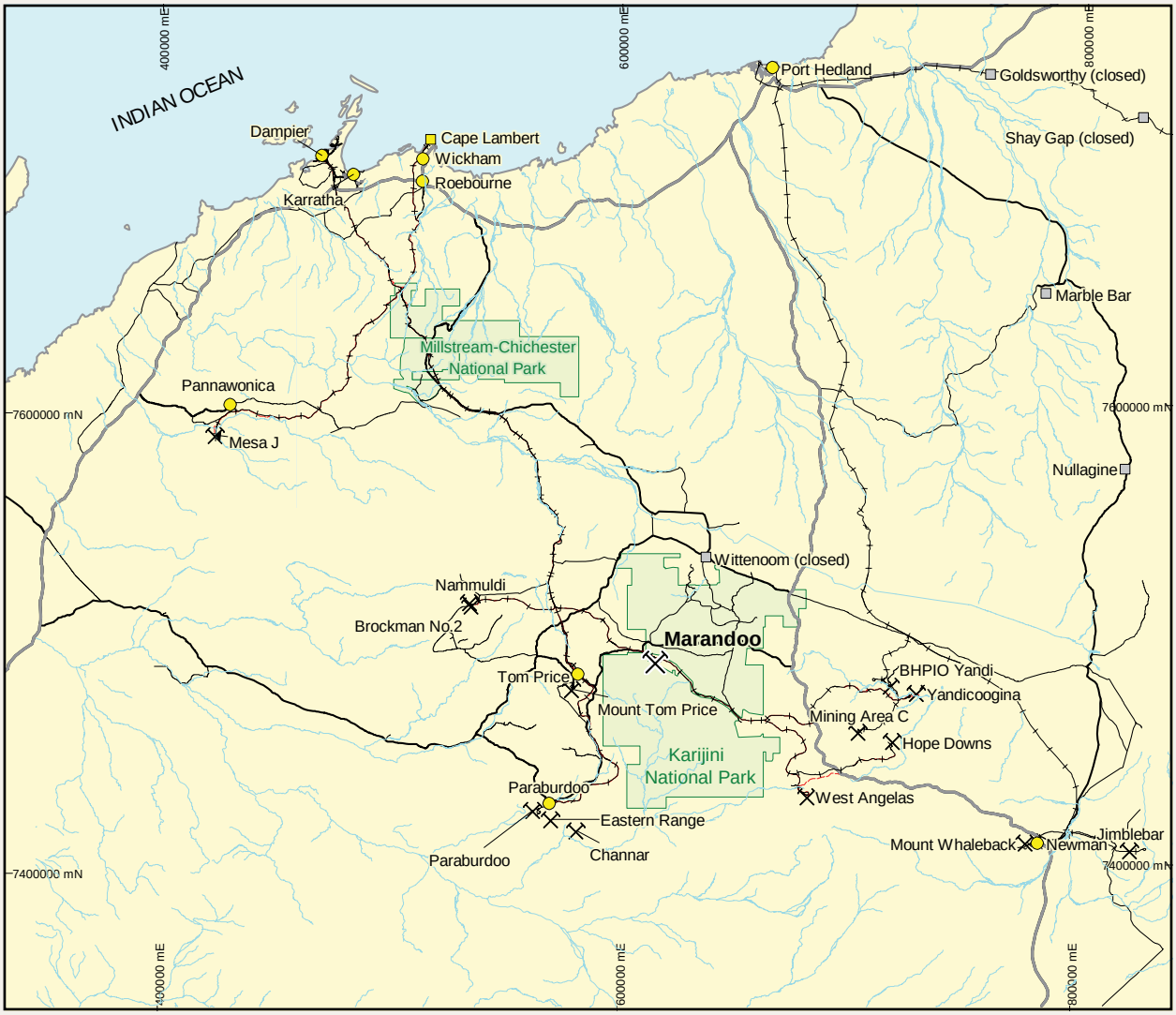
Location

The Proposal is located in the central Pilbara region of Western Australia, approximately 37 km east of Tom Price and 77 km north-east of Paraburdoo (Figure ES1). The mining component of the Proposal is confined to the existing Marandoo mine lease, which was excised from Karijini National Park in 1991. Dewatering water will be piped from Marandoo to the existing Southern Fortescue borefield, approximately 30 km to the north-west (Figure ES2), and to the Tom Price water supply system. An operations camp is proposed to the north of Karijini Drive within Hamersley Station, approximately 13 km north-west of Marandoo (Figure ES2).

Tenure

The Proposal involves mining of iron ore at, and adjacent to the existing Marandoo mining area, within State Agreement Lease AML 70/272. Southern Fortescue borefield infrastructure will be located partially within existing Special Leases L3166/6045 and L3116/6044 and on additional tenure. The operations camp will be sited on Miscellaneous Licence L47/234.

2 There are currently insufficient Ore Reserves to supply the forecast/estimated production for this Project. Accordingly, such production is subject to defining satisfactory Ore Reserves for the Project from the current and any further identified mineralisation.



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Strategic Assets - Perth

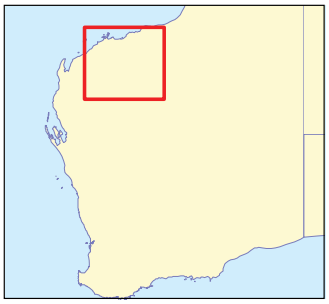
Figure ES1 Regional Location of Marandoo

Drawn: TC
Date: Feb 2007
Plan No. PDE0049509v1
Proj: MGA94-50

LEGEND

- National Park
- Highway
- Road
- Private Road
- Railway
- Major River
- Major Town
- Town
- Mine (operating)
- Port

LOCATION MAP



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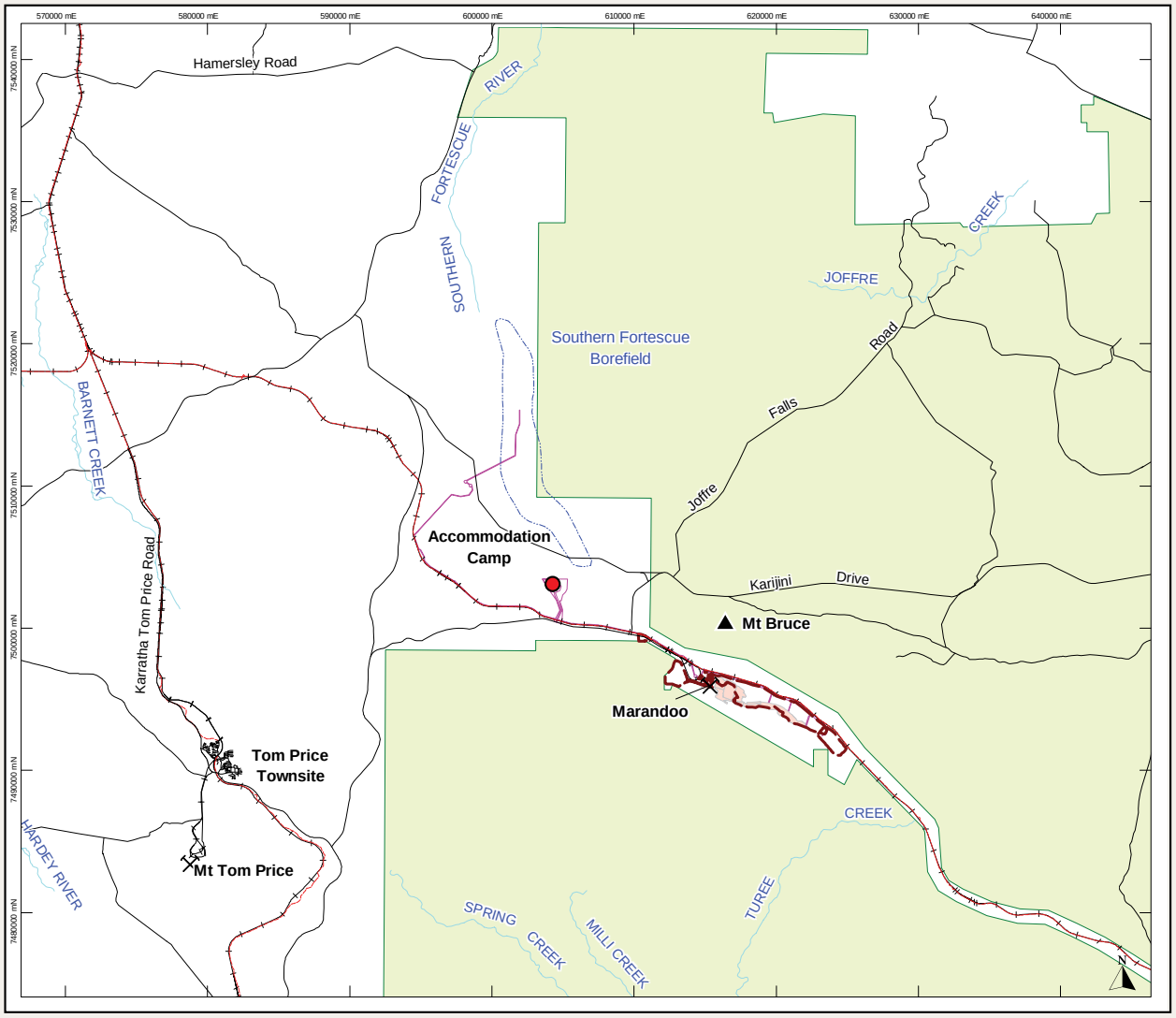


RioTinto

Strategic Assets - Perth

Figure ES2 General Location Plan of Marandoo

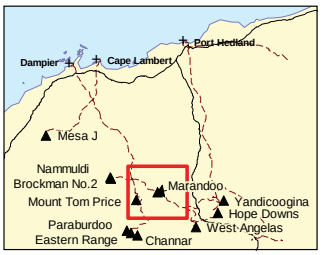
Drawn: TC
Date: Feb 2008

Plan No. PDE0049509v1
Proj: MGA94-50

LEGEND

- Railway
- Road
- Private Road
- River/creeks
- Existing Mine
- Accommodation Camp
- Karijini National Park
- Current Approved Pit
- Proposed MMP2 Disturbance Footprint
- MMP2 Project Disturbance

LOCATION MAP



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Assessment process and EPA advice

The Proposal was referred to the Environmental Protection Authority (EPA) under section 38 of the *Environmental Protection Act 1986* (WA) (EP Act) on 3 July 2007. In December 2007, the EPA determined the Proposal would be assessed at the level of Public Environmental Review (PER) with an eight week public review period.

An Environmental Scoping Document was prepared describing the scope of the environmental assessment of the Proposal and a timeline for the assessment process. The Environmental Scoping Document was submitted to the EPA on 17 December 2007 and approved on 20 March 2008.

The PER and Environmental Scoping Document were prepared in accordance with the Environmental Impact Assessment (Part IV Division I) Administrative Procedures 2002 for environmental assessment prescribed under the EP Act.

Description of the Proposal

The Proponent proposes to expand existing mining operations at Marandoo by mining below the watertable, which will entail expansion of the existing mine pit and development of new waste dumps. The Proposal will utilise existing infrastructure and services associated with current Marandoo mine operations; however, there will still be a need to construct new infrastructure to service the expanded operations. The construction of the dewatering infrastructure and the construction camp are subject to separate approvals; however, the operation of this infrastructure is considered part of this PER. The key components of the Proposal are:

- expansion and deepening of the existing open-cut pit below the watertable (up to 150 m below ground level)
- utilisation, expansion and modification of the existing 'run of mine' ore stockpile, waste dumps, product, topsoil and subsoil stockpiles, and drainage management structures at Marandoo
- conventional drill and blast using surface mining or other methods
- modification and extension of the existing dry processing plant to accommodate wet processing
- construction and operation of a Residue Storage Facility (RSF)
- expansion of existing unsealed haul roads for transport of ore from the mine pit
- operation of a dewatering borefield and associated infrastructure to allow dewatering of the confined bedrock aquifer
- operation of a dewatering pipeline from Marandoo to the Southern Fortescue borefield to allow for a conjunctive disposal strategy for excess dewatering water
- adaptation of existing Southern Fortescue borefield production bores and associated pipelines for re-injection, and development of approximately four new re-injection bores and associated infrastructure such as intrafield pipelines to allow for disposal of excess dewatering water
- disposal of dewatering water in accordance with the following hierarchy:
  a) re-use on-site
  b) supply to Tom Price
  c) re-injection into the depleted Southern Fortescue borefield
  d) controlled discharge to natural drainage lines
- development of sewage treatment facilities and establishment of a spray irrigation area at Marandoo mine
- construction of additional buildings and infrastructure within the existing disturbed Marandoo operations area
- construction and upgrade of power supply infrastrucutre and removal of redundant infrastructure
- construction and use of an operations camp.

The environmental footprint of the Proposal is presented in Table ES1.

Exclusions from the Proposal

Aspects excluded from the MMP2 Proposal include:

- the provision of a construction camp
- construction of the dewatering infrastructure
- construction and operation of a pipeline from the existing rail corridor (south of the Southern Fortescue borefield) to Tom Price.

These aspects will be subject to separate environmental approvals processes under the provisions of the EP Act and in accordance with outher relevant statutes.

Stakeholder consultation

The Proponent has conducted ongoing stakeholder consultation since 2004 as part of the existing Marandoo operations. In addition, consultation specific to this Proposal commenced at the start of 2007, prior to the submission of the environmental referral of the Proposal to the Environmental Protection Authority Service Unit (EPASU) in July 2007. Key stakeholders were identified through the Proponent's ongoing experience at Marandoo and other mining projects in the region, as well as through discussion with the EPASU. Some of those consulted during the preparation of the PER were:

- Commonwealth Department of the Environment, Water, Heritage and the Arts (DEWHA)
- Environmental Protection Authority Service Unit (EPASU)
- Department of Environment and Conservation (DEC) - Pilbara regional office (Karratha) and Perth office
- Department of Industry and Resources (DoIR)
- Department of Indigenous Affairs (DIA)
- Department of Water (DoW) - Pilbara regional office (Karratha) and Perth office
- Shire of Ashburton
- Conservation Council of Western Australia
- Eastern Guruma people
- Gumala Aboriginal people
- communities in Tom Price and Paraburdoo
- Pilbara Gorge tours.

Key issues raised

The main issues raised by stakeholders related to impacts to Aboriginal heritage, the Coolibah woodland, visual amenity, Karijini National Park, fauna, as well as closure and the disposal strategy for surplus dewatering water.

Table ES1
Environmental footprint of the new Proposal

Proposal characteristic	Detail
Total area of vegetation disturbance	Clearing of approximately 940 ha within the area Localised impact to riparian vegetation along drainage lines
Ore location	Above and below watertable
Waste rock disposal	In surface dumps and/or progressive backfilling of mine pits within the area
Water disposal	Re-injection in the vicinity of the Southern Fortescue borefield Discharge to drainage lines Off-site discharge of stormwater from the mine pit at locations
Slurry from wet processing of ore	Residue Storage Facility (RSF)
Greenhouse Gases	Greenhouse gas emissions of approximately 190 000 t CO_2-e/yr

Abbreviations
Mtpa - Million tonnes per annum, ha - Hectares

Environmental impact assessment and management

Environmental aspects and factors relevant to this Proposal were identified through the scoping process and are presented in this document along with additional environmental considerations identified during the detailed assessment process. The key environmental factors addressed in the PER are:

- Karijini National Park
- groundwater and water supply
- watercourses and surface water quality
- flora and vegetation units
- Coolibah woodland and Mulga communities
- terrestrial fauna
- subterranean fauna
- Aboriginal heritage
- visual amenity and landscape character
- closure.

Some environmental factors have not been addressed to the same level of detail as the Proposal would present a low, or negligible risk to them. Environmental impacts to these factors can be managed either through routine or existing management measures and plans and/or under other legislation.

These factors include:

- geodiversity (negligible impact)
- waste (existing environmental management procedures and controls under Part V of the EP Act)
- emissions of dust, noise and vibration (remoteness from sensitive premises, existing environmental management procedures and controls under Part V of the EP Act)
- greenhouse gases (existing environmental reporting and management procedures)
- recreation and tourism (management procedures)
- public risk and safety (remoteness and existing management procedures).

Karijini National Park

The Marandoo mine lease was excised from Karijini National Park in 1991. The Park provides for the conservation of approximately 10% (greater than 600 000 ha) of the Hamersley sub-region. An area within the Park to the north of Marandoo (known as the Mount Bruce Flats) supports a *Eucalyptus victrix* (Coolibah) woodland (listed as a Priority Ecological Community) and Mulga communities. The operations camp and dewatering infrastructure are located within Hamersley Station, outside Karijini National Park.

The existing Marandoo mine site is already visible from Mount Bruce (located to the north of the mine within the adjacent Karijini National Park), including at the summit and the lowest public viewpoint. The Proposal will result in additional modification of an already highly-modified landscape. The proposed operations camp and dewatering infrastructure (assuming the dewatering pipeline will be installed above ground) have been evaluated as having a minor perceivable change to the landscape. Areas of significant perceived change as a result of the Proposal, in particular the expanded mine operations, are restricted to public viewing locations that are not frequently used, for example, the Mount Bruce eastern summit lookout.

The Proposal involves an increase in the size of the Marandoo workforce. The operations camp will be located several kilometres from the boundary of Karijini National Park. Site personnel will not have to travel through Karinini National Park to access the camp. The fly-in/fly-out roster type, combined with the length of working days (12 hours) will limit the time available to personnel to undertake recreational pursuits including within the Karijini National Park. The Proposal is not expected to affect the existing social, recreational and tourist values in the area.

Noise emissions are unlikely to affect visitor enjoyment of the Park, especially those visiting Mount Bruce (approximately 2.5 km from the mine site), because changes in noise levels will be imperceptible. Blast sizes are not expected to be any greater than existing blasts at Marandoo.

The predicted magnitude and rate of groundwater drawdown within the unconfined aquifer is not anticipated to affect either the Coolibah woodland or subterranean fauna communities across the Mount Bruce Flats. The springs and gorges within Karijini National Park are not considered likely to be affected by the Proposal, with the possible exception of Minthicoondunna Spring (refer to Groundwater and Aborignal Heritage).

There will be no significant additional modification of the Marandoo Ridge hydrological regime as a result of the Proposal. This will ensure there is no 'drainage shadow' effect on vegetation in downstream areas of Karijini National Park as a result of the Proposal.

Mitigation and management measures that will address potential impacts to Karijini National Park include:
- implementing a comprehensive induction program to control and prevent potential impacts to the ecological and recreational values of Karijini National Park
- implementing a monitoring program and (as a contingency) an adaptive management plan to ensure any potentially significant impacts to the Coolibah woodland are identified and rectified early
- continuing to implement existing surface water management practices to ensure Mulga on the Mount Bruce Flats are not affected as a result of the Proposal.

Contributing offsets will include:
- investigations and research to address threats to Mulga communities such as fire and climate change
- continuing to assist with fire and weed management across the Mount Bruce Flats in collaboration with the DEC and other Karijini National Park management bodies, including improving on-site fire-fighting capability to assist with fires in the Park and the support of DEC/indigenous prescribed burning in the area
- rehabilitation of a defined area of vegetation within Coondawanna Flats which is due to be relinquished to Karijini National Park in 2015.

The Proposal is consistent with EPA objectives, as the significant environmental values of Karijini National Park will be maintained through implementation of mitigation and management measures to maintain recreational and social values in the locality and preserve the abundance and diversity of native flora and fauna consistent with Karijini National Park Management Plan objectives.

Groundwater

The hydrogeological system at Marandoo is a focus for the Proposal because of the requirement to dewater the ore body to allow mining below the watertable. The Southern Fortescue borefield has been identified as a re-injection site for a significant volume of this excess dewatering water. The Southern Fortescue borefield has been heavily abstracted from for more than 30 years and groundwater levels are therefore greatly depressed.

There two main aquifers at Marandoo comprise a shallow, unconfined aquifer and a deeper, confined lower Tertiary aquifer. The confined and unconfined aquifers are separated by a thick clay layer commonly up to 40 m in thickness, which acts as an effective aquitard between the two aquifers.

Dewatering at Marandoo will result in a reduction in pressure (drawdown) in the confined deep aquifer of approximately 120 m at the mine site to 43 m at the far margins of the Mount Bruce Flats. The potential for this reduction to result in groundwater drawdown within the unconfined aquifer is predicted to be negligible due to the intervening clay layer.

Intersection of the unconfined aquifer by the northern margin of the proposed mine pit is predicted to result in maximum drawdown of the watertable (due to seepage into the mine pit) of approximately 10–20 m at the mine pit margin after approximately eight years. Drawdown is predicted to be approximately 0.3 m/year at the Coolibah woodland on the Mount Bruce Flats over the initial eight years. Groundwater levels in the unconfined aquifer across Mount Bruce Flats are naturally highly variable, with groundwater monitoring indicating up to 9.5 m variation when a heavy rain period follows a dry period. There is not expected to be any risk to any of the springs or pools located in northern Karijini National Park. A possibility exists that Minthicoondunna Spring, located 10 km east of the pit may be affected from dewatering activities toward the end of the mine life as the cone of depression extends in a south-easterly direction. Studies are ongoing to determine the degree of risk, if any, to the spring.

The re-injection capacity of the Southern Fortescue borefield is not entirely confirmed. Modelling shows that re-injection of 15 ML/day over 16 years would result in groundwater levels being 10–20 m below ground level. Up to 30 ML/day will be re-injected for a period of time, if trials and modelling deems it possible.

There is a risk of sinkhole formation from dewatering or re-injection in the vicinity of Marandoo and the Southern Fortescue borefield.

Mitigation and management measures that will address potential impacts to groundwater include:
- analysing the results of a re-injection trial conducted at the Southern Fortescue borefield to update the Marandoo and Southern Fortescue groundwater models
- developing and implementing a rotational bore maintenance schedule to minimise potential for water to seep into the mine pit
- optimising the location of the re-injection bores within the Southern Fortescue borefield to spread the rise in groundwater level across the borefield
- undertaking further hydrogeological investigation between Marandoo and Minthicoondunna spring to determine the hydraulic parameters of the Upper Tertiary sediments, and any hydraulic connection between the superficial calcrete aquifer and the confined aquifer
- monitoring the water level at Minthicoondunna Spring, and groundwater levels between Marandoo and Minthicoondunna Spring
- conducting an investigation into the mechanism of sinkhole formation at the Southern Fortescue borefield and completing an assessment of high risk areas at the Southern Fortescue borefield, Marandoo and surrounding areas

- undertaking studies to monitor sinkholes in the vicinity of Marandoo and the Southern Fortescue borefield, including investigating the number and size of existing sinkholes to provide a baseline for future monitoring.

The full suite of measures is consolidated in the Groundwater Management Plan.

Consistent with EPA objectives, dewatering of groundwater from the confined aquifer and intersection of the unconfined aquifer at Marandoo are not expected to have an adverse effect on groundwater quantity and quality. Re-injection of excess dewatering water into the Southern Fortescue borefield is likely to assist in restoring this system to previous natural groundwater levels at this site.

Watercourses and surface water quality

A number of ephemeral drainage lines on Marandoo Ridge that flow towards the Mount Bruce Flats will already have been diverted by drains constructed as part of the existing above watertable operations. These diversion drains will capture water from the drainage lines and convey it to the Mount Bruce Flats via existing culverts through the rail embankment. The Proposal will increase the catchment area intersected by the Marandoo mine site from 19 km^2 (6.7% of the Mount Bruce Flats catchment) to 24 km^2 (8.5% of the Mount Bruce Flats catchment).

The general integrity, function and environmental values relying on surface flow from the Proposal area will therefore be maintained through the construction of new drainage structures designed to maintain natural surface flows, reduce erosion and minimise ponding of water.

The Proponent has considered a range of options for the management of excess water in line with the Department of Water hierarchy of water management methods. The fallback option is controlled discharge to tributaries of the ephemeral Southern Fortescue River system. Approximately 30–60 ML/day of excess dewatering water may be discharged intermittently to natural drainage lines throughout the life of the Proposal. Approximately 15 ML/day may be discharged continuously to natural drainage lines during the first three years of the Proposal.

Continuous discharge of up to 15 ML/day during the first three years of the Proposal (if required) is expected to result in perennial surface flows for some distance along the Southern Fortescue River system. Unless the creek line is already saturated, the proposed intermittent discharge of larger volumes of water is much less likely to result in persistent surface flows than continuous discharge, but will create pools that will remain for several weeks or months, depending on local rains, temperature and evaporation when dewatering rates will be at their maximum to advance the pit shell.

Alteration of the hydrological regime of the Southern Fortescue River system from episodically-flowing to continuously-flowing may result in the loss of aquatic fauna species adapted to intermittent flow and colonisation by species adapted to perennial flow. Any permanent residents lost from affected areas of the Southern Fortescue River system would re-colonise these areas during and following mine closure.

Alteration of the hydrological regime of the Southern Fortescue River system may result in an increase in localised physiological stress in vegetation along tributaries downstream of the proposed discharge, with localised deaths in areas of prolonged saturation of the soil profile.

Water quality within the Southern Fortescue River system will not be affected by the proposed discharge of excess dewatering water, due to the high quality of groundwater in the confined aquifer.

Management of heavy rainfall is governed by the Mine Site Hydrology Report in accordance with the Proponent's Pilbara Surface Water Management Strategy. Mitigation and management measures that will address potential impacts to surface water include:

- monitoring dewatering water quality
- regularly monitoring channel morphology, riparian vegetation condition, erosion and (if pools are present) pool water quality along natural drainage lines downstream of discharge outlet(s)
- investigating alternative discharge regimes should surface flow extend beyond the 20 km length of channel surveyed
- developing and refining a discharge hydrograph to minimise erosion, prevent overtopping of drainage lines and where practicable, match the pattern of the natural hydrograph downstream of proposed discharge outlet(s)
- treating surface runoff from the workshop, vehicle washdown and processing plant areas prior to re-use on site or discharge to the environment
- ensuring that drainage channels do not cross areas of active mining, or any locations where there is potential for hydrocarbon contamination.

The full suite of measures is consolidated in the Surface Water Management Plan.

Consistent with EPA objectives, alterations to surface water flows as a result of the Proposal will not have a significant adverse impact to identified beneficial or environmental uses of the water. Any water discharged to the natural environment will not cause the quality of receiving surface or groundwater systems to exceed the ANZECC Water Quality Guidelines, ensuring that emissions do not adversely affect environmental values or the health, welfare or amenity of people and land uses.

Flora and vegetation

The Proposal will result in the progressive removal and rehabilitation of approximately 940 ha of native vegetation over the life of the Proposal. The Proposal is not expected to have any significant effect on regional vegetation values, as the vegetation units recorded from the Proposal area occur more broadly in the Marandoo locality, and also are not expected to be restricted to the locality. Approximately 90% of the proposed disturbance will be to vegetation of low conservation significance.

No Threatened Ecological Communities, Declared Rare Flora species or vegetation of high conservation significance have been recorded within the Proposal area. Four Priority flora species have been recorded as scattered individuals in the Proposal area, including the Priority 1 species *Goodenia lyrata* and *Rhagodia* sp. Hamersley. Some locations of Priority flora species will be disturbed by the Proposal; however, as the Priority flora species to be disturbed occur relatively broadly throughout the Pilbara and are not restricted to the Marandoo locality, the Proposal will not affect the conservation status of these Priority flora species.

The vegetation condition of the Southern Fortescue borefield is described as Good to Poor, although some vegetation particularly on higher ground can be considered Very Good. Intensive grazing and erosion of flowlines is evident. There is potential for waterlogging to affect the vegetation units present.

Weed occurrences in the vicinity of the Proposal area were identified. All weeds recorded are commonly found in the Marandoo area.

Mitigation and management measures that will address potential impacts to flora and vegetation units include:

- preventing unnecessary clearing of vegetation through locating infrastructure such as the wet processing plant and RSF within, or adjacent to already disturbed areas as far as practicable
- surveying the Southern Fortescue borefield prior to any ground disturbance to ensure protection and avoidance of areas containing vegetation of high conservation significance and/or populations of significant flora where possible
- optimising the location of the re-injection bores within the Southern Fortescue borefield to spread the rise in groundwater level across the borefield
- monitoring observation bores within Southern Fortescue borefield to ensure groundwater levels do not exceed 5 m of original (pre-abstraction) groundwater levels due to re-injection
- identifying and mapping the extent and distribution of target weed species occurring within, and adjacent to the Proposal area and eradicating weed occurrences on an ongoing basis.

The full suite of measures is consolidated in the Vegetation and Flora Management Plan.

The Proposal will not contravene EPA Position Statement No. 2, as all potential on-site and off-site impacts have been identified and management measures proposed. No flora species or vegetation units will become threatened or cease to exist as a result of the Proposal. Consistent with EPA objectives, the abundance, species diversity, geographic distribution and productivity of flora at species and ecosystem levels will be maintained, thereby conserving regional biological diversity.

Coolibah woodland and Mulga communities

The Coolibah woodland on the Mount Bruce Flats is an example of a vegetation type that is both in good condition and uncommon in the Pilbara region. The woodland is seasonally inundated and is considered a wetland of national importance. The Coolibah woodland is listed by the DEC as a Priority Ecological Community and is not commonly found in the Pilbara.

Mulga in the Pilbara is close to the northern edge of its range and considered to be at risk primarily from fire damage, grazing and climate change. The stands on the Mount Bruce Flats are particularly important to the ongoing representation and conservation of Mulga in the region.

The predicted groundwater drawdown is well within the magnitude of natural groundwater level fluctuations within the unconfined aquifer in the vicinity of the Coolibah woodland and is not anticipated to affect the Coolibah woodland. Difficulties may arise for Coolibah when conditions change too quickly compared to natural patterns of changes in water availability; however, the predicted rate of drawdown of 0.3 m/year over the initial eight years is significantly lower than the rapid rise and fall in groundwater levels (up to 10 m over three months) across the Mount Bruce Flats. Therefore, it is likely that the Coolibah woodland at this site would have developed sufficient adaptability in their root structure to respond to these changes.

The majority of surface water runoff generated on Marandoo Ridge during low-intensity rainfall events infiltrates the soil and does not reach the Mount Bruce Flats. Surface water runoff from the ridge is significant only after major rainfall events. The Proponent will continue to implement existing surface water management practices at Marandoo to ensure there is no further change to the already modified hydrological regime of Marandoo Ridge and the Mount Bruce Flats.

Mitigation and management measures that will address potential impacts to the Mount Bruce Flats Coolibah woodland and Mulga communities include:

- implementing a comprehensive monitoring program and as a contingency an adaptive management plan including:
  a) monitoring the Mount Bruce Flats Coolibah woodland (impact site) and a control site for tree health
  b) development and continual refinement of appropriate trigger values for each aspect monitored/measured
  c) implementation of remedial contingency actions (in liaison with the DEC) in the event that trigger values are approached or exceeded
- discharging stormwater collected within mine pits to culverts through the railway embankment.

The full suite of measures is consolidated in the Coolibah Management Plan and the Fire Management Plan.

Contributing offsets will include undertaking investigations and research to address:

- researching Coolibah water use requirements
- investigations and research to address threats to Mulga communities such as fire and climate change
- continuing to assist with fire and weed management across the Mount Bruce Flats in collaboration with the DEC and other Karijini National Park management bodies, including improving on-site fire-fighting capability to assist with fires in the Park and the support of DEC/indigenous prescribed burning in the area

Consistent with EPA objectives, the Proposal is not anticipated to affect the values, functions or integrity of the Mount Bruce Flats Coolibah woodland and Mulga communities.

Terrestrial fauna

The Proposal will result in the progressive loss of approximately 940 ha of fauna habitat over the life of the Proposal and, as a result, may potentially affect the local abundance of fauna populations. No fauna habitat of high conservation significance will be affected by the Proposal and, as such, significant impacts to fauna of conservation significance at a regional, state, national or international level are considered highly unlikely.

A total of 125 vertebrate species was recorded in the area, comprising 54 avifauna species, 20 mammal species and 51 herpetofauna species. Three groups of invertebrate fauna were also recorded.

Mitigation and management measures that will address potential impacts to fauna include:

- keeping vegetation clearing within designated areas based on the minimum necessary for safe construction and operation of the Proposal, particularly in areas adjacent to habitat of higher conservation significance
- undertaking progressive rehabilitation to re-establish fauna habitat
- implementing and sign-posting appropriate speed limits for both mining equipment and light vehicles on the Marandoo access road

The full suite of measures is consolidated in the Fauna Management Plan.

Consistent with EPA objectives, the abundance, species diversity, geographic distribution and productivity of terrestrial fauna at species and ecosystem levels will be maintained, thereby conserving regional biological diversity. The zoological studies undertaken by the Proponent and implementation of the proposed management measures will ensure that direct disturbance to important fauna habitat is kept to that which is necessary and that fauna and fauna habitat are protected from indirect disturbance as far as practicable.

Subterranean fauna

Stygofauna sampling has occurred in the Marandoo area on several occasions and at the Southern Fortescue borefieldin 2008. No stygofauna were collected from the Southern Fortescue borefield during the 2008 sampling phase, however any stygofauna that may potentially occur at the Southern Fortescue borefield would not be affected by the proposed re-injection as the chemistry of groundwater within the confined aquifer at Marandoo is similar to that naturally occurring at the Southern Fortescue borefield.

The Proposal is not expected to present a threat to stygofauna, as all species recorded in the areas that will be affected by the Proposal (defined as areas where groundwater drawdown is predicted to be 2 m or greater) have also been recorded outside these areas. Stygofauna at Marandoo appear to be associated with only the unconfined aquifer (which will be subject to minimal groundwater drawdown as a result of the Proposal); no stygofauna have been collected from the confined aquifer (which will be dewatered as part of the Proposal).

Based on a detailed risk assessment (which considered aspects such as the regional geology mapping, geotechnical, hydrological and hydrogeological information, previous sampling efforts in the area and qualitative results from down-hole video camera work), the likelihood of troglofauna occurring in the proposed mining area was considered unlikely and a dedicated sampling program was not considered warranted.

The studies indicate that disturbance to subterranean fauna and their associated habitat will not be significant. Implementation of the proposed management measures will further protect subterranean fauna and their habitat and will ensure the EPA objective is fulfilled.

Aboriginal heritage

The Proponent and the Eastern Guruma people have a comprehensive relationship which is documented in a commercial agreement and Indigenous Land Use Agreement (ILUA). The state is also a party to the ILUA. The agreement between the parties is one of the most comprehensive of its kind in Australia. It covers the determined area of the Eastern Guruma native title claim including the Tom Price mine site, the Brockman No 2 mine site, the Marandoo mine site and part of the railway between Tom Price and Dampier.

Numerous archaeological and ethnographic surveys have been carried out in and around Marandoo, including recent surveys undertaken 2008 in consultation with the Eastern Guruma people.

Ground disturbance within the Proposal area will affect some recorded archaeological sites and any associated ethnographic values. The Proposal is unlikely to affect any Aboriginal heritage sites of high significance, but may affect sites of low significance. Most of the highly significant Aboriginal heritage sites occur on the upper slopes of the surrounding escarpments, which are outside the Proposal area.

Minthicoondunna Spring is a registered Aboriginal site and protected by law. The area is an important ethnographic site for Eastern Guruma people, as well as other Aboriginal people in the Pilbara. The Proposal may possibly result in reduced groundwater levels at Minthicoondunna Spring (refer to Groundwater).

Mitigation and management measures that will address potential impacts to Aboriginal heritage include:
- avoiding disturbance to heritage sites where possible
- undertaking additional survey work and ethnographic studies within the Proposal area to identify heritage and ethnographic sites
- undertaking further hydrogeological investigations between Marandoo and Minthicoondunna Spring to determine the hydraulic parameters of the upper Tertiary sediments, and any hydraulic connection between the surficial calcrete aquifer and the confined aquifer
- monitoring the water level at Minthicoondunna Spring, and groundwater levels between Marandoo and Minthicoondunna Spring
- continuing consultation with the Eastern Guruma people and other relevant stakeholders.

The full suite of measures is consolidated in the Cultural Heritage Management Plan.

The Proposal is likely to avoid physical disturbance to all highly significant sites recorded in the vicinity of the Proposal area.

Visual amenity and landscape character

The existing Marandoo mine site is already visible from Mount Bruce, including at the summit and the lowest public viewpoint. The Proposal will result in additional modification of an already highly-modified landscape. The proposed operations camp and dewatering infrastructure (assuming the dewatering pipeline will be installed above ground) have been evaluated as having a minor perceivable change to the landscape. Areas of significant perceived change as a result of the Proposal are restricted to public viewing locations that are not frequently used, for example, the Mount Bruce eastern summit lookout.

Views of the proposed operations camp are likely to be restricted to limited, transient views from roads in the vicinity of the infrastructure including Karijini Drive and Hamersley Gorge-Mount Bruce Road.

Mitigation and management measures that will address potential impacts to visual amenity and landscape character include:
- undertaking a visual assessment of the Proposal in relation to visibility of the Marandoo ridgeline from the Mount Bruce visitor carpark lookout at finalisation of the mine plan and every five years thereafter during operations and at closure
- progressively rehabilitating the Proposal area to come as close as possible to local landscape values and surrounding environment
- selecting colour schemes for buildings and infrastructure that blend in with the surrounding landscape.

The Proposal is consistent with EPA objectives for visual amenity and landscape and landforms, given existing effects on visual amenity in the area and proposed management measures that will be implemented throughout the Proposal.

Closure

The Proponent has developed a Conceptual Closure Plan for the Proposal, which outlines the closure vision, post-closure land use options, objectives and targets for final decommissioning and decontamination of the site. The Plan will be updated in consultation with stakeholders every five years and will be finalised at least five years prior to planned final closure of the mine.

The key areas of environmental risk related to closure of the Proposal include: visual impact; re-establishment of surface water flows; impacts to groundwater; future land-use; rehabilitation.

The current mine plan assumes that pits will require backfilling to at least 1 m above the watertable. The decision to backfill the pit to above the watertable will not be solely based on protection of water quality, but will also include aesthetic and stakeholder considerations.

A Rehabilitation Plan has been developed for Marandoo as part of the Closure Plan. The Rehabilitation Plan will be incorporated into the site rehabilitation plan upon commencement of the proposed operations and will be regularly reviewed and updated during site operations to ensure it remains accurate and relevant. Rehabilitation monitoring at Marandoo will commence upon completion of rehabilitation works at the site.

The early consideration of closure in the development of the Proposal is expected to ensure closure concepts are fully integrated into short- and long-term mine planning activities and that acceptable and cost-effective closure outcomes are achieved. The proposed mitigation and management strategies will be utilised to ensure that closure is achieved to be consistent with the EPA objective.

Environmental management

The Proponent acknowledges the environmental protection principles listed in Section 4A of the EP Act:
- precautionary principle
- principle of intergenerational equity
- principle of the conservation of biological diversity and ecological integrity
- principles relating to improved valuation, pricing and incentive mechanisms
- principle of waste minimisation.

These principles are reflected in the Proponent's corporate environmental policy, Iron Environmental Management System and the corporate environmental standards that are applied across the Rio Tinto Group.

The environmental aspects of the Proposal will be primarily managed through the site Iron Environmental Management System (IEMS), Environmental Management Plans (EMPs) and relevant licenses.

Environmental Management System

During construction and operation, the Proponent will operate under an ISO14001 framework. The ISO14001 framework is an internationally recognised continuous improvement model. The key elements include assessing environmental risk and legal requirements, developing objectives and targets for improvement, training, operational control, communication, emergency response, corrective actions, audits and review.

Environmental Management Plans

As part of the Proposal, the Proponent has committed to the implementation of EMPs to address potential construction and operational impacts of the Proposal. The EMPs have been prepared to specifically address management of environmental issues that may arise from the implementation of the Proposal and will be regularly reviewed and revised as required.

Proposed outcome-based conditions

The Proponent proposes outcome-based conditions for the management of relevant key environmental issues that may arise from the implementation of the Proposal.

Conclusion

In summary, the potential environmental impacts of the Proposal are:

- progressive removal of 940 ha of native vegetation over the life of the Proposal
- increased risk of the spread of weeds - controlled through implementation of the Proponent's existing weed control and hygiene procedures
- loss of fauna habitat leading to a reduction in the local abundance of some fauna populations - no effect on the representation of fauna at a local or regional level
- some loss of visual amenity at infrequently used public viewing points in Karijini National Park - mitigated and managed through design, colour schemes and rehabilitation
- temporary change to aquatic fauna communities
- potential increase in localised physiological stress in vegetation along tributaries downstream of dewatering discharge points, with localised deaths in areas of prolonged saturation of the soil profile
- drawdown in the confined aquifer across the Proposal area at Mount Bruce Flats - this will not affect any beneficial or environmental use
- localised drawdown in the unconfined aquifer well within the range of normal seasonal fluctuation - not anticipated to affect the Coolibah woodland Priority Ecological Community or stygofauna, and as a contingency an adaptive management plan will address any unanticipated impacts
- possible sinkhole formation in the vicinity of Marandoo and the Southern Fortescue borefield as a result of dewatering and re-injection.

Several EMPs have been prepared and are provided in this document to demonstrate that all reasonable measures will be taken to reduce environmental impacts.

Table ES2 provides more detail on potential impacts, proposed management and environmental outcomes for each of the environmental factors assessed.

Environmental offsets

Environmental offsets are proposed to mitigate predicted impacts of the Proposal to critical assets.

As a direct offset, the Proponent will rehabilitate a defined area within Coondawanna Flats at Juna Downs pastoral station that includes Coolibahs due to be relinquished to Karijini National Park in 2015. Rehabilitation of this area will help to create habitat linkages into Karijini National Park.

Contributing offsets will include:

- researching Coolibah water use requirements
- investigations and research to address threats to Mulga communities such as fire and climate change
- continuing to assist with fire and weed management across the Mount Bruce Flats in collaboration with the DEC and other Karijini National Park management bodies, including improving on-site fire-fighting capability to assist with fires in the Park and the support of DEC/indigenous prescribed burning in the area
- rehabilitation of a defined area of vegetation within Coondawanna Flats which is due to be relinquished to Karijini National Park in 2015
- contribution of funding to assist with the management of recreation within Karijini National Park.

Environmental Risks and Manageability

The Proponent has extensive experience in managing the development, operation and environmental compliance of similar projects and this experience is anticipated to lead to a greater certainty in achieving desirable environmental outcomes.

The Proponent has consulted with key stakeholders (including government agencies) to scope the potential impacts of the Proposal and to determine the significance of environmental issues and the acceptability of mitigation and management controls. This process substantially improves the likelihood that all significant environmental issues have been identified, investigated, mitigated and managed as far as practicable.

Table ES2
Summary of key environmental issues, potential impacts and management

Environmental factor	EPA objective	Existing environment	Potential impacts
Biophysical			

1. Karijini National Park	To protect the environmental values of areas identified as having significant environmental attributes.	• Karijini National Park lies on an incised plateau surface and contains deep gorges, waterfalls and plunge pools.
		• Landscape diversity has contributed to the maintenance of diverse flora and fauna communities.
		• The Park encompasses bioclimatic and phytogeographic transition zones, which also increase community diversity.
			• Dewatering of the confined aquifer and/or intersection of the unconfined aquifer may potentially result in:
			  • decreased health and extent of the Coolibah woodland on the Mount Bruce Flats
			  • altered groundwater discharge to springs and water levels in groundwater-fed pools in the Park
			  • decreased discharge from the Mount Bruce Flats to Turee Creek
			  • modification to subterranean fauna habitat
			  • sinkhole formation.
			• Interception of surface water flows from the mining area may reduce flows to Mulga on the Mount Bruce Flats and decrease discharge from the Flats to Turee Creek.
			• Access to the Park by the Proposal workforce may decrease amenity and increase traffic and associated public safety risks within the Park.
			• Mining operations may introduce and/or spread weeds and feral animals into adjoining areas of the Park.
			• Ignition sources on the mine site may result in increased frequency and/or intensity of fire events resulting in the loss of fire-sensitive vegetation (particularly Mulga).
			• Hydrocarbon spills on the mine site may contaminate groundwater and/or surface runoff to adjoining areas of the Park.
			• Dust emissions, mine site infrastructure and altered landforms may affect visual amenity at Mount Bruce.
			• Noise and vibration emissions from general mine operations and blasting may increase noise/ vibration levels at Karijini National Park.

	Proposed management	Predicted outcomes
	• Implementing a comprehensive monitoring and adaptive management plan to protect the Coolibah woodland on the Mount Bruce Flats. • Gathering information to further develop the conceptual models for springs and pools in Karijini National Park, with the aim of determining flow and transport mechanisms of individual systems through characterisation of water sources using hydrochemistry and environmental isotopes of surface water and groundwater. • Undertaking further hydrogeological investigation between Marandoo and Minthicoondunna spring to determine the hydraulic parameters of the Upper Tertiary sediments, and any hydraulic connection between the superficial calcrete aquifer and the confined aquifer. • Monitoring the water level at Minthicoondunna Spring, and groundwater levels between Marandoo and Minthicoondunna Spring • Continuing consultation with the Eastern Guruma people and other relevant stakeholders. • Optimising the location of the re-injection bores within the Southern Fortescue borefield to spread the rise in groundwater level across the borefield. • Monitoring observation bores within Southern Fortescue borefield to ensure groundwater levels do not exceed 5 m of original (pre-abstraction) groundwater levels as a result of re-injection. • Consulting with Karijini National Park management bodies in accordance with existing arrangements under the SMU and MOU (regular SMU meetings will continue to be held and will include discussion of the Proposal). • Continuing to assist with fire and weed management across the Mount Bruce Flats in collaboration with the DEC and other Karijini National Park management bodies, including improving on-site fire-fighting capability to assist with fires in the Park and the support of DEC/indigenous prescribed burning in the area. • Divert any water detected as being contaminated with hydrocarbons to the on-site hydrocarbon treatment facilities. • Ensuring any water discharged to the natural environment does not cause the quality of receiving surface or groundwater systems to exceed the ANZECC Water Quality Guidelines (ANZECC/ARMCANZ 2000). • Educating mine staff and contractors as to appropriate, low-impact behaviour at popular visitor nodes within Karijini National Park (particularly the northern gorges) and informing mine staff and contractors of relevant National Park policies and requirements. • Undertaking a visual assessment of the Proposal in relation to Marandoo ridgeline from Mount Bruce visitor car park lookout at finalisation of the mine plan and every five years thereafter during operations and at closure. • Re-establishing disturbed landforms that are consistent with local landscape values and resemble the local environment as closely as possible. • Incorporating the Coolibah woodland into a regional study by the University of New South Wales (UNSW) to provide input into the monitoring and adaptive management plan. • Undertaking studies to monitor sinkholes in the vicinity of Marandoo and the Southern Fortescue borefield, including investigating the number and size of existing sinkholes to provide a baseline for future monitoring, this may include: visual monitoring and differential photogrammetry with respect to a baseline image.	• Areas of significant perceived change to the landscape will be restricted to public viewing locations that are not frequently used (such as the Mount Bruce eastern summit lookout). • The predicted magnitude and rate of groundwater drawdown within the unconfined aquifer is not anticipated to significantly affect either the Coolibah woodland or subterranean fauna communities across the Mount Bruce Flats. • There will be no significant additional modification of the Marandoo Ridge hydrological regime as a result of the Proposal. • There is a risk of sinkhole formation in the vicinity of Marandoo and the Southern Fortescue borefield. • The proximity of the Proposal to Karijini National Park will not affect the existing social, recreational and tourist values of the Park, as the fly-in/fly-out roster type, combined with the length of working days (12 hours) will limit the time available to personnel to undertake recreational pursuits. • Noise from the Proposal will not perceptively increase above existing operation, and vibration will not increase as a result of the Proposal. • There is a possibility of affecting water levels at Minthicoondunna Spring towards the end of the mine life, however, further hydrogeological investigations are planned to determine the level of risk, if any.

Environmental factor	EPA objective	Existing environment	Potential impacts

2. Groundwater	To maintain the quantity of water so that existing and potential environmental values, including ecosystem maintenance, are protected.
	
	To ensure that emissions do not adversely affect environment values or the health, welfare, and amenity of people and land uses by meeting statutory requirements and acceptable standards.
		• The Proposal area is situated across two hydrogeological systems: one at Marandoo and the other in the Southern Fortescue area, approximately 30 km to the north-west of Marandoo.
		• The Marandoo system consists of a shallow, unconfined aquifer in calcrete, separated by a thick clay layer from a deeper, confined aquifer in the Marra Mamba Iron Formation and Wittenoom Formation.
		• Recharge of the unconfined aquifer occurs primarily around the Coolibah woodland over the Mount Bruce flats, and spreads radially outward from the resulting groundwater mound.
		• Recharge of the confined aquifer occurs primarily around the dolomite outcrops of the northern and eastern margins of the Mount Bruce Flats, and flows west, following the Southern Fortescue River catchment.
		• The Southern Fortescue system consists of an unconfined aquifer primarily located in the Wittenoom Formation.
		• Recharge to the Southern Fortescue aquifer system occurs via groundwater throughflow from the Mount Bruce Flats catchment area and infiltration through banded iron formation outcrops to the west and east of the borefield, and flows north along the streamline of the Southern Fortescue River.
			• Aquifer dewatering near the mine pit will lead to drawdown of groundwater levels in the confined aquifer, reduced throughflow west of Marandoo and may result in the formation of sinkholes throughout the cone of depressurisation (which may in turn harm native fauna and alter surface flows or groundwater recharge rates).
			• Intersection of the unconfined aquifer by the proposed mine pit will cause seepage and subsequent drawdown in the unconfined aquifer.
			• Hydrocarbon spills may lead to groundwater contamination.
			• Re-injection of dewatering water at Southern Fortescue borefield will lead to an increase in groundwater levels and may:
			  • cause, or enhance, sinkhole formation
			  • increase water levels in streams, pools and springs fed by the mixed aquifer system.

3. Surface water	To maintain the quantity of water so that existing and potential environmental values, including ecosystem maintenance, are protected.	• The Marandoo mine site is located on the north side of Marandoo Ridge, on the southern boundary of the Mount Bruce Flats sub-catchment.	• Discharge of excess dewatering water may alter local hydrological regimes and may potentially:
			  • affect aquatic fauna
			  • cause riparian vegetation to become dependent on the artificial flow
			  • increase prevalence of weeds and alter the composition of riparian vegetation
			  • increase erosion and sedimentation along discharge pathways.

	Proposed management	Predicted outcomes
	• Managing sinkhole risk through early detection of the onset of surface deformation and/or reactivation of existing features. • Fencing sinkholes and implementing other measures to reduce any potential risk to public safety. • Applying controls to hydrocarbon transport, handling and disposal in accordance with the Proponent's corporate standard. • Setting blast exclusion zones to eliminate risks to public safety, including vibration-related impacts such as rock falls. • Restricting public access within blast exclusion zones and enacting procedures for evacuating these areas. • Publishing typical blast times at the Mount Bruce lookout visitor car park to manage recreational concerns in consultation with DEC.	
	• Using the results of the Southern Fortescue borefield re-injection trial to more accurately characterise the Southern Fortescue hydrogeological system to allow for the incorporation of updated information into the Southern Fortescue and Marandoo groundwater models. • Developing and implementing a rotational bore maintenance schedule to minimise potential for water to seep into the mine pit. • Optimising the location of the re-injection bores within the Southern Fortescue borefield to spread the rise in groundwater level across the borefield. • Undertaking further hydrogeological investigations between Marandoo and Minthicoondunna spring to determine the hydraulic parameters of the Upper Tertiary sediments, and any hydraulic connection between the superficial calcrete aquifer and the confined aquifer. • Monitoring the water level at Minthicoondunna Spring, and groundwater levels between Marandoo and Minthicoondunna Spring. • Continuing consultation with the Eastern Guruma people and other relevant stakeholders. • Investigating the chemistry of groundwater at Marandoo and the Southern Fortescue borefield to understand the carbonate chemistry and any potential implications for clogging or dissolution of the formation matrix. • Conducting an investigation into the mechanism of sinkhole formation at the Southern Fortescue borefield and completing an assessment of high risk areas at the Southern Fortescue borefield, Marandoo and surrounding areas. • Undertaking studies to monitor sinkholes in the vicinity of Marandoo and the Southern Fortescue borefield, including investigating the number and size of existing sinkholes to provide a baseline for future monitoring, this may include visual monitoring and differential photogrammetry with respect to a baseline image. • Managing sinkhole risk through early detection of the onset of surface deformation and/or reactivation of existing features. • Fencing sinkholes and implementing other measures to reduce any potential risk to public safety. • Applying controls to hydrocarbon transport, handling and disposal in accordance with the Proponent's corporate standards. • Applying existing hydrocarbon clean-up procedures. • Safe storage, handling and disposal of ablution effluent.	• Dewatering will result in a reduction in pressure (drawdown) in the confined aquifer of approximately 120 m at Marandoo, which will reduce to 43 m at the far margins of the Mount Bruce Flats. Based on the current proposed mine plan, which indicates peak dewatering during the first eight years or more, the estimated maximum rate of drawdown in the confined aquifer is approximately 15 m/year at the mine site and 5.5 m/year at the far margin of the Mount Bruce Flats. • Dewatering of the confined aquifer is not expected to result in groundwater drawdown within the unconfined aquifer due to the intervening clay layer. • Intersection of the unconfined aquifer by the northern margin of the proposed mine pit is predicted to result in a groundwater drawdown within the unconfined aquifer due to seepage into the mine pit of approximately 10–20 m at the pit margin to 0–2.5 m at the Coolibah woodland. The estimated rate at which this drawdown would occur is approximately 0.3 m/year at the Coolibah woodland, based on the total drawdown occurring during the initial eight years of dewatering (as a result of rapid pit advancement during this period). • Re-injection of water into the Southern Fortescue borefield will allow the active recharge and recovery of the aquifer system, which has been significantly drawn down since the commencement of operations at Tom Price. This will allow water levels to return to pre-production levels. The supply of excess dewatering water to Tom Price will also allow the passive recovery of the Mount Lionel and Hardey River borefields, which would no longer be drawn upon to supply Tom Price. • There is a risk of sinkhole formation being caused or accelerated by the Proposal in the vicinity of Marandoo and the Southern Fortescue borefield. • There is a possibility of affecting water levels at Minthicoondunna Spring near the end of the mine life; however, further hydrogeological investigations are planned to determine the level of risk, if any.
	• Managing heavy rainfall though implementation of the Mine Site Hydrology Report in accordance with the Proponent's Pilbara Surface Water Management Strategy. • Installing diversion drains around the RSF if required. • Stabilising diversion structures and drains to reduce erosion and water quality impacts. • Designing erosion protection at discharge outlets.	• Approximately 30–60 ML/day of excess dewatering water may be discharged intermittently to natural drainage lines throughout the Proposal. Approximately 15 ML/day may be discharged continuously to natural drainage lines during the first three years of the Proposal if it can not be reinjected.

Environmental factor	EPA objective	Existing environment	Potential impacts
	To ensure that emissions do not adversely affect environmental values or the health, welfare, and amenity of people and land uses by meeting statutory requirements and acceptable standards.	• The Mount Bruce Flats sub-catchment forms the upper reaches of the Turee Creek regional catchment, an ephemeral river which generally flows only following significant rainfall events. • Rainfall events in excess of 80 mm are generally required to generate significant surface water runoff. • The Southern Fortescue borefield, operations camp, and dewatering infrastructure route are located within the upper reaches of the Southern Fortescue River Valley. • The Southern Fortescue River Valley discharges into Hamersley Gorge or Weelumurra Creek, and then continues northwards to meet Fortescue River. • Fortescue River is ephemeral and the southern branch is fed by surface water runoff from the upper Southern Fortescue River Valley catchment.	• Physical presence of mine pit and infrastructure may alter surface water flow paths. • Discharge of stormwater has the potential to affect water quality through contamination by sediments and hydrocarbons. • Final landforms will lead to permanent changes to natural surface water flows.
4. Vegetation and flora	To maintain the abundance, diversity, geographic distribution and productivity of flora at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge.	• The Proposal area is located within the Fortescue Botanical District of the Eremaean Botanical Province, which typically contains open vegetation dominated by spinifex, wattles, and occasional eucalypts. • All of the vegetation units recorded from the Proposal area occur more broadly in the Marandoo locality and none are expected to be restricted to the locality. • None of the observed vegetation units represent Threatened Ecological Communities. The Coolibah woodland is listed as a Priority Ecological Community by the DEC. • No Declared Rare Flora were observed. • Four Priority flora species have been recorded as scattered individuals in the Proposal area, including the Priority 1 species *Goodenia lyrata* and *Rhagodia* sp. Hamersley.	• Vegetation clearing will directly disturb vegetation units and Priority flora species. • Alteration of surface water flows through construction of diversion structures, mine pits, waste dumps and infrastructure may affect local water availability for some plant species. • Vehicle and earth movements could potentially introduce and/or spread weed species. • Groundwater drawdown within the unconfined aquifer due to seepage into the mine pit may reduce water availability for some plant species. • Ignition sources resulting in increased fire frequency/intensity may favour the establishment of weeds and prevent the regeneration of native vegetation, particularly fire-sensitive species, such as Mulga. • Dust may have physical effects on plants, although this is likely to be restricted to immediate peripheral vegetation and will be mitigated by removal during periodic high rainfall events.

	Proposed management	Predicted outcomes
	• Ensuring any water discharged to the natural environment does not cause the quality of receiving surface or groundwater systems to exceed the ANZECC Water Quality Guidelines (ANZECC/ARMCANZ 2000). • Monitoring dewatering water quality at the water collector tanks. • Regularly monitoring channel morphology, riparian vegetation condition, erosion and pool water quality if pools are present along natural drainage lines downstream of proposed discharge outlet(s). • Developing and refining a discharge hydrograph to minimise erosion, prevent overtopping of drainage lines and where practicable, match the pattern of the natural hydrograph downstream of proposed discharge outlet(s). • Investigating alternative discharge regimes should surface flow extend beyond the 20 km length of channel surveyed. • Designing waste dumps to incorporate water management features to reduce the potential for sediment-laden surface water runoff. • Installing sediment traps/basins where appropriate to reduce sediment loads in runoff from the mine area. • Treating surface runoff from the workshop, vehicle washdown and processing plant areas for sediment and hydrocarbons prior to re-use on site or for discharge to the natural environment. • Ensuring that drainage channels do not cross areas of active mining, or any locations where there is potential for hydrocarbon contamination. • Designing all sumps to fully contain the likely maximum volume of a one year ARI rainfall event, with an annual revision to ensure sump capacity increases in accordance with increasing catchment and pit area. • Inspecting sedimentation basins and drainage structures regularly and undertaking cleaning prior to the onset of the wet season each year. • Protecting the pit crest from erosion through provision of large boulders, rock armour and/or vegetation. • Undertaking progressive backfill of pits.	• Continuous discharge of up to 15 ML/day during the first three years of the Proposal (if required) is expected to result in perennial surface flows for some distance along the Southern Fortescue River system. Unless the creek line is already saturated, the proposed intermittent discharge of larger volumes of water is less likely than continuous discharge to result in extensive surface flows, but will create pools that will remain for several weeks or months, depending on local rains, temperature and evaporation. • Alteration of the hydrological regime of the Southern Fortescue River system from episodically-flowing to continuously-flowing may result in the loss of aquatic fauna adapted to intermittent flow and colonisation by aquatic fauna adapted to perennial flow. Any permanent residents lost from affected areas of the Southern Fortescue River system would re-colonise these areas during and following mine closure. • Alteration of the hydrological regime of the Southern Fortescue River system may result in an increase in localised physiological stress in vegetation along tributaries downstream of the proposed discharge, with localised deaths in areas of prolonged saturation of the soil profile. • Water quality within the Southern Fortescue River system will not be affected by the proposed discharge of excess dewatering water, due to the high quality of groundwater in the confined aquifer • Discharge of water to the natural environment will not cause the quality of receiving surface or groundwater systems to exceed the ANZECC Water Quality Guidelines (ANZECC/ARMCANZ 2000). • Flows within the mining area will be locally concentrated by diversion structures, which will result in localised increases in flow velocity and potentially soil erosion; however, the installation of sediment traps will reduce sediment load in surface water runoff. • The operations camp will not significantly affect surface water quantity or quality in the area.
	• Obtaining an Approvals Permit for all areas to be cleared in accordance with the Proponent's Approvals Request System. • Preventing unnecessary clearing of vegetation through locating infrastructure such as the wet processing plant and RSF within, or adjacent to already disturbed areas. • Undertaking progressive rehabilitation of disturbed areas with local native flora species. • Identifying and mapping the extent and distribution of target weed species occurring within, and adjacent to the Proposal area and eradicating weed occurrences on an ongoing basis. • Implementing weed hygiene procedures for mining machinery entering and leaving the Proposal area. • Surveying the Southern Fortescue borefield prior to any ground disturbance to ensure protection and avoidance of areas containing vegetation of high conservation significance and/or populations of significant flora where possible. • Monitoring observation bores within Southern Fortescue borefield to ensure groundwater levels do not exceed 5 m of original (pre-abstraction) groundwater levels as a result of re-injection.	• The progressive removal and rehabilitation of approximately 940 ha of native vegetation over the life of the Proposal. • No significant effect on regional flora and vegetation values, as the vegetation units recorded from the Proposal area occur more broadly in the Marandoo locality and are not expected to be restricted to the locality. • No Threatened Ecological Communities, Declared Rare Flora species or vegetation of high conservation significance will be affected by the Proposal. • Some locations of Priority flora species, including scattered individuals of the Priority 1 species *Goodenia lyrata* and *Rhagodia* sp. Hamersley (M.E. Trudgen 17794) will be disturbed by the Proposal. However, these species are not restricted to the Marandoo locality and occur relatively broadly throughout the Pilbara, hence, the Proposal will not affect the conservation status of these species. • The proposed management measures will ensure the Mulga component of vegetation units 1a and 4d at the Southern Fortescue borefield is not affected by re-injection.

Environmental factor	EPA objective	Existing environment	Potential impacts
		• The number of species recorded (536) is higher than would be expected for a study area of this size in this locality.	
5. Mulga and Coolibah	To maintain the abundance, diversity, geographic distribution and productivity of flora at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge.	• The *Eucalyptus victrix* (Coolibah) woodland on the Mount Bruce Flats, to the north of Marandoo within Karijini National Park represents an uncommon vegetation type in the Pilbara region. The woodland is in good condition, is considered a wetland of national importance and is listed by the DEC as a Priority Ecological Community. • *Acacia aneura* (Mulga) stands on the Mount Bruce Flats are of conservation significance as they represent the northern extent of the Mulga's range and are considered to be at risk in the Pilbara.	• Dewatering of the confined aquifer may lead to drawdown of groundwater levels in the unconfined aquifer, which may reduce groundwater availability for the Coolibah woodland. • Intersection of the unconfined aquifer by the proposed mine pit will cause seepage and subsequent drawdown in the unconfined aquifer, which may reduce groundwater availability for the Coolibah woodland. • Physical presence of mine pit and infrastructure will alter surface water flow paths and may reduce the volume of surface water runoff reaching Mulga on the Mount Bruce Flats. • Ignition sources at Marandoo may increase the frequency and/or intensity of fire events, which may result in the loss of fire sensitive Mulga communities. • Vehicle and earth movements could potentially introduce and/or spread weed species into Karijini National Park.
6. Terrestrial fauna	To maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge.	• The habitats within the Proposal area support a range of fauna species, including several that are endemic to the region and/or listed for protection under state and Commonwealth conservation legislation. • Three species listed as Priority 4 by the DEC were recorded within the proposed disturbance area, as well as one species listed as Migratory under the EPBC Act. • *Dasyurus hallucatus* (northern quoll), listed as Endangered under the EPBC Act and Schedule 1 of the *Wildlife Conservation Act 1950* (WA), and *Pseudomys chapmani* (western pebble-mound mouse), listed as Priority 4 by the DEC, were both recorded outside of the area of proposed disturbance.	• Vegetation clearing for mine pit, waste dumps and associated infrastructure, will directly disturb terrestrial fauna habitat and may result in the loss of individual terrestrial fauna. • Groundwater drawdown may affect vegetation and consequently reduce the area of fauna habitat available. • Alterations to surface hydrology may affect habitats and result in the loss of individual terrestrial fauna through ponding. • Vehicle movements in mining areas and on mine access roads could potentially result in the loss of individual terrestrial fauna, especially less-mobile species.

	Proposed management	Predicted outcomes
	• Undertaking basic fire awareness and fire fighting training for all personnel (including contractors) prior to commencing work on-site. • Maintaining adequate fire breaks across the mine site and around working areas where required. • Ensuring a fire spotter is present when clearing vegetation near sensitive environmental areas. • Optimising the location of the re-injection bores within the Southern Fortescue borefield to spread the rise in groundwater level across the borefield.	
	• Monitoring of the Coolibah woodland (impact site) and a control site for tree health. • Development and continual refinement of appropriate trigger values for each aspect monitored/measured. • Implementing of remedial contingency actions in liaison with the DEC in the event that trigger values are approached or exceeded. • Discharging stormwater collected within mine pits to culverts through the railway embankment. • Ensuring any water discharged to the natural environment does not cause the quality of receiving surface or groundwater systems to exceed the ANZECC Water Quality Guidelines (ANZECC/ARMCANZ 2000). • Providing basic fire awareness and fire fighting training to all site personnel and ensuring appropriate fire fighting equipment is available on-site at all times. • Maintaining adequate fire breaks across the mine site and around working areas where required. • Ensuring ongoing consultation and provision of assistance to the DEC and other Karijini National Park management bodies with regard to fire management practices/buffers in adjoining pastoral leases, as well as mosaic burning. • Continuing to assist with fire and weed management across the Mount Bruce Flats in collaboration with the DEC and other Karijini National Park management bodies, including improving on-site fire-fighting capability to assist with fires in the Park and the support of DEC/indigenous prescribed burning in the area. • Implementing feral animal control measures across the Marandoo mine site to reduce the potential for proliferation of introduced species across the adjacent Mount Bruce Flats.	• The Coolibah woodland is not anticipated to be affected by the Proposal, as the estimated magnitude and rate of groundwater drawdown in the unconfined aquifer are much lower than the magnitude and rate of natural groundwater level fluctuations across the Mount Bruce Flats. An adaptive management plan will be implemented with the objective of protecting the Coolibah woodland should there be any variation from the predicted impact to the woodland resulting from the Proposal. • There will be no further significant change to the already modified hydrological regime of Marandoo Ridge and the Mount Bruce Flats and hence no indirect impacts to Mulga or Coolibah. • There will be no further impact to Mulga due to implementation of fire and weed management across the Mount Bruce flats.
	• Undertaking feral animal control. • Keeping vegetation clearing within designated areas based on the minimum necessary for safe construction and operation of the Proposal, particularly in areas adjacent to habitat of higher conservation significance. • Maintaining natural drainage flows wherever practicable and preventing ponding of water. • Implementing standard dust suppression measures across the Proposal area during construction and operation to mitigate effects on surrounding fauna habitat. • Undertaking progressive rehabilitation to re-establish fauna habitat. • Including fauna protection specifications in all construction-related contracts and subcontracts. • Implementing and sign-posting appropriate speed limits for both mining equipment and light vehicles on the Marandoo access road. • Providing reflectors on all barbed wire fencing to deter bats. • Providing workforce environmental education programs and training.	• The Proposal will result in the progressive loss and subsequent revegetation of approximately 940 ha of terrestrial fauna habitat over the life of the Proposal. Disturbed areas will be progressively rehabilitated to restore original fauna habitat values. • No fauna habitat of high conservation significance will be affected by the Proposal and significant impacts to fauna of conservation significance at a regional, state, national or international level are highly unlikely. • The Proposal will not conflict with the *Wildlife Conservation Act 1950* (WA), as no terrestrial vertebrate or invertebrate fauna species will cease to exist as a result of the Proposal.

Environmental factor	EPA objective	Existing environment	Potential impacts
7. Subterranean fauna	To maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge.	• All records of stygofauna were within the unconfined aquifer; no individuals were recorded from the confined aquifer. • No stygofauna species have been recorded at the Southern Fortescue borefield. • Troglofauna are considered highly unlikely to occur in the proposed mining area based on the results of a detailed risk assessment.	• Groundwater drawdown from groundwater abstraction may lower the watertable sufficiently to dry the zone that stygofauna inhabit. • Mining will result in direct habitat loss and potentially the loss of some individual subterranean fauna. • Spills of hydrocarbons and discharge of wastewater may degrade the subterranean environment by contaminating surface water and groundwater. • Vibration from blasting activities has the potential to cause changes to geological formations and may decrease (or increase) the habitat available to troglofauna. • Re-injection of dewatering water may affect subterranean fauna habitat through introduction of contaminants and/or altered water chemistry.
Social surrounds			
8. Aboriginal heritage	To ensure that changes to the biophysical environment do not adversely affect historical and cultural associations and comply with relevant heritage legislation.	• The Hamersley Iron - Eastern Guruma Indigenous Land Use Agreement covers an area of the Central Pilbara, including the Proposal area, and allows mining, exploration and infrastructure development to proceed whilst delivering a range of benefits to the Eastern Guruma people. • Numerous archaeological and ethnographic surveys have been carried out in and around the Marandoo mine lease. The most recent has located 14 previously unrecorded sites within the Proposal area.	• Site works during construction and operation have the potential to disturb heritage sites and affect ethnographic values. • Dewatering of the confined aquifer and/or intersection of the unconfined aquifer may potentially reduce groundwater discharge to Springs of heritage significance.
9. Visual amenity and landscape	To ensure that aesthetic values are considered and measures are adopted to reduce visual impacts on the landscape as low as reasonably practicable. To maintain the integrity, ecological functions and environmental values of landscapes and landforms.	• The Proposal area is located on an area of flats surrounded by several escarpments including Mount Bruce, Marandoo Hills, Marra Mamba Ridges, the Prider Hills and Eastern Uplands. These surrounding features of gorges, cliffs and mountain ranges are mostly located within the boundary of the Karijini National Park and are largely natural and undisturbed.	• Landform modification may reduce the aesthetic value and visual quality of the area (for example, removal of native vegetation, excavation of mine pits, creation of waste dumps and loss of rural character). • Dust emissions may detract from the visual quality of the area. • Physical presence of mine pit and infrastructure may detract from the visual quality of the area.

	Proposed management	Predicted outcomes
	• Implementing a groundwater level monitoring program across the Mount Bruce Flats. • Implementing controls to reduce the occurrence and effect of hydrocarbon spills.	• The Proposal is unlikely to have a significant effect on stygofauna, as the estimated drawdown in the unconfined aquifer, which supports stygofauna, is within, or similar to the range of natural fluctuations. Furthermore, all species recorded in the Proposal impact zone are also represented outside this zone. • Troglofauna should not be directly disturbed by the Proposal as there is an absence of suitable habitat in the proposed mining area. • Existing data suggest the Southern Fortescue borefield area does not support a stygofauna community. Re-injection of dewatering water would not affect any stygofauna that may potentially occur in this area, as there is little difference in water chemistry between the dewatering water from Marandoo and the groundwater in the Southern Fortescue aquifer system.
	• Avoiding disturbance to heritage sites where possible. • Undertaking additional survey work and ethnographic studies within the Proposal area to identify heritage and ethnographic sites. • Preventing unauthorised ground disturbance activities through implementation of the Proponent's Approvals Permit system for all areas to be disturbed. • Including education regarding Aboriginal sites in inductions for contractors and personnel working on the development. • Stopping work and contacting the DIA where human remains or archaeological material is uncovered during the clearing process; then assessing the site using a heritage consultant and managing the site in accordance with the Proponent's Cultural Heritage Management Plan. • Marking the location of known Aboriginal heritage sites on site plans. • Ensuring a fire spotter is present when clearing vegetation near sensitive environmental or heritage areas. • Undertaking further hydrogeological investigations between Marandoo and Minthicoondunna Spring to determine the hydraulic parameters of the upper Tertiary sediments, and any hydraulic connection between the surficial calcrete aquifer and the confined aquifer. • Monitoring the water level at Minthicoondunna Spring, and groundwater levels between Marandoo and Minthicoondunna Spring. • Continuing consultation with the Eastern Guruma people and other relevant stakeholders.	• The Proposal is unlikely to directly affect any Aboriginal heritage sites of high significance, but may affect sites of low significance. Most of the highly significant Aboriginal heritage sites occur on the upper slopes of the surrounding escarpments, which are outside the Proposal area. The Proposal is likely to avoid all highly significant sites in the valley and floodplain areas. • There is a possibility of affecting water levels at Minthicoondunna Spring towards the end of the mine life, however, further hydrogeological investigations are planned to determine the level of risk, if any.
	• Undertaking a visual assessment of the Proposal in relation to visibility of the Marandoo ridgeline from the Mount Bruce visitor carpark lookout at finalisation of the mine plan and every five years thereafter during operations and at closure. • Rehabilitating disturbed areas with the aim of achieving safe, stable and self-sustaining landforms. • Progressively rehabilitating the Proposal area to come as close as possible to local landscape values and the surrounding environment. • Utilising local provenance species and matching local relative plant densities in rehabilitation areas. • Preventing unnecessary clearing of vegetation. • Locating infrastructure in, or near previously disturbed areas where possible. • Selecting colour schemes for buildings and infrastructure that blend in with the surrounding landscape.	• The Proposal will result in additional modification of an already highly modified landscape. • Likely impacts relate largely to the proposed mine pit, waste dumps and RSF, with the potential visual effects of the proposed development varying spatially between visual receptors near the Proposal area. • Visitors to Mount Bruce will experience significant impacts to visual amenity, particularly from the car park/visitor lookout at the western extent of the mountain. The most significant impact will be experienced at the Mount Bruce eastern summit lookout; however, this location is not frequently used. • The impact of the proposed waste dumps on the visibility of the Marandoo ridgeline is not expected to be significant and will be largely indiscernible from a visual perspective. • Final landforms will strive to be consistent with local landscape values and the surrounding environment.

Environmental factor	EPA objective	Existing environment	Potential impacts
		• The area surrounding and incorporating the Proposal area can be considered a 'valued' landscape as it contains a number of landscapes and features that are highly valued by the community.	
Other			
10. Rehabilitation and closure	To ensure, as far as practicable, that rehabilitation achieves a stable and functioning landform which is consistent with the surrounding landscape and other environmental values.	• Mining and the establishment of associated infrastructure will require clearing of vegetation and disturbance to soil profiles and landforms. The Proponent aims to rehabilitate all areas of land that it disturbs whilst carrying out its operations.	• The following considerations have been included in the current planning for the Proposal to mitigate potential impacts of closure: • provision for backfilling of the mine pit void to achieve acceptable post-mining landforms and groundwater quality • location and design of infrastructure (including camps, water pipelines and processing facilities) to minimise potential post-closure impacts • design of surface water diversion structures to minimise impacts to downstream flows.

	Proposed management	Predicted outcomes
		• Views of the proposed operations camp are likely to be restricted to limited, transient views from roads in the vicinity of the infrastructure, including Karijini Drive and Hamersley Gorge-Mount Bruce Road. • Replacement of the existing above-ground 33 kV power line between the proposed Marandoo switchyard and Tom Price with a new below-ground power line will improve visual amenity.

	• A final Closure Plan will be developed at least five years prior to planned final closure of the mine and will address:
	  • suitable end land uses and objectives for closure, in consultation with relevant stakeholders and the community
	  • identification and evaluation of closure options and determination of preferred options
	  • establishment of completion criteria
	  • closure monitoring requirements
	  • cost estimates and fund allocation for future closure
	  • management measures to facilitate future closure.
		• The early consideration of closure in the development of the Proposal is expected to ensure closure concepts are fully integrated into short and long-term mine planning activities and that acceptable and cost-effective closure outcomes are achieved. The proposed mitigation and management strategies will ensure that closure is consistent with the EPA objective.

Public Environmental Review

This document is a Public Environmental Review: a requirement under Part IV of the *Environmental Protection Act 1986* (WA).

1.1 Overview

The Proponent, Hamersley Iron Pty Ltd, proposes to extend mining operations at the existing Marandoo Iron Ore Mine (Marandoo) in the central Pilbara region, Western Australia.

Mining at Marandoo commenced in 1994 and currently approximately 15 million tonnes per annum (Mtpa) of high-grade Marra Mamba iron ore is produced at the mine through mining operations above the watertable. Marandoo operates under the *Iron Ore (Hamersley Range) Agreement Act 1963* (WA), within a mining lease excised from Karijini National Park in 1991.

The Proposal includes mining below the watertable and increasing the size of the existing mine pit, whilst maintaining the same production rate of approximately 15 Mtpa[3]. The title of the Proposal is 'Marandoo Mine Phase 2' ('MMP2').

1.2 Purpose of the PER

This document is a Public Environmental Review (PER) prepared in accordance with the Environmental Impact Assessment (Part IV Division 1) Administrative Procedures 2002 of the *Environmental Protection Act 1986* (WA) (EP Act).

The purpose of the PER is to present an environmental review of the Proposal, including a detailed impact assessment and description of proposed mitigation and management measures for relevant environmental aspects. The PER is subject to an eight week public review period. In support of the PER, the Proponent has committed to the implementation of an Environmental Management Plan (EMP) to address potential construction and operational impacts of the Proposal.

1.3 Project background

1.3.1 Location

The Proposal is located in the central Pilbara region of Western Australia, approximately 37 km east of Tom Price and 77 km north-east of Paraburdoo (Figure 1). The mining component of the Proposal is confined to the existing Marandoo mine lease (State Agreement Lease AML 70/272), which was excised from Karijini National Park in 1991. Dewatering water will be piped from Marandoo to the existing Southern Fortescue borefield, approximately 30 km to the north-west (Figure 2), and to the Tom Price water supply system. An operations camp is proposed to the north of Karijini Drive within Hamersley Station, approximately 13 km north-west of Marandoo (Figure 2).

1.3.2 Description

The Proponent currently has approval to mine above the watertable at Marandoo. The MMP2 Proposal involves both widening and deepening the existing mine pit to mine ore below the watertable. The Proposal is intended to extend the Marandoo mine life by approximately 15–20 years[3].

As detailed in Section 4, the major components of the MMP2 Proposal are:

- expansion in spatial extent and depth of existing mine pits above and below the watertable
- expansion of existing and establishment of new waste dumps, stockpiles and haul roads
- operation of dewatering infrastructure (including bores, dewatering pipeline and intrafield pipelines, collector tanks and associated power supply infrastructure)
- re-injection of water to the Southern Fortescue borefield and controlled discharge to tributaries of the Southern Fortescue River
- modification and extension of the existing dry processing plant to accommodate wet processing
- construction and operation of a Residue Storage Facility (RSF)
- construction and upgrade of power supply infrastructure and removal of existing infrastructure
- construction and use of an operations camp.

1.4 Proponent

The Proponent for the MMP2 Proposal is Hamersley Iron Pty Ltd (the 'Proponent'), a wholly owned subsidiary of Rio Tinto. Pilbara Iron operates the Marandoo mine on behalf of Hamersley Iron.

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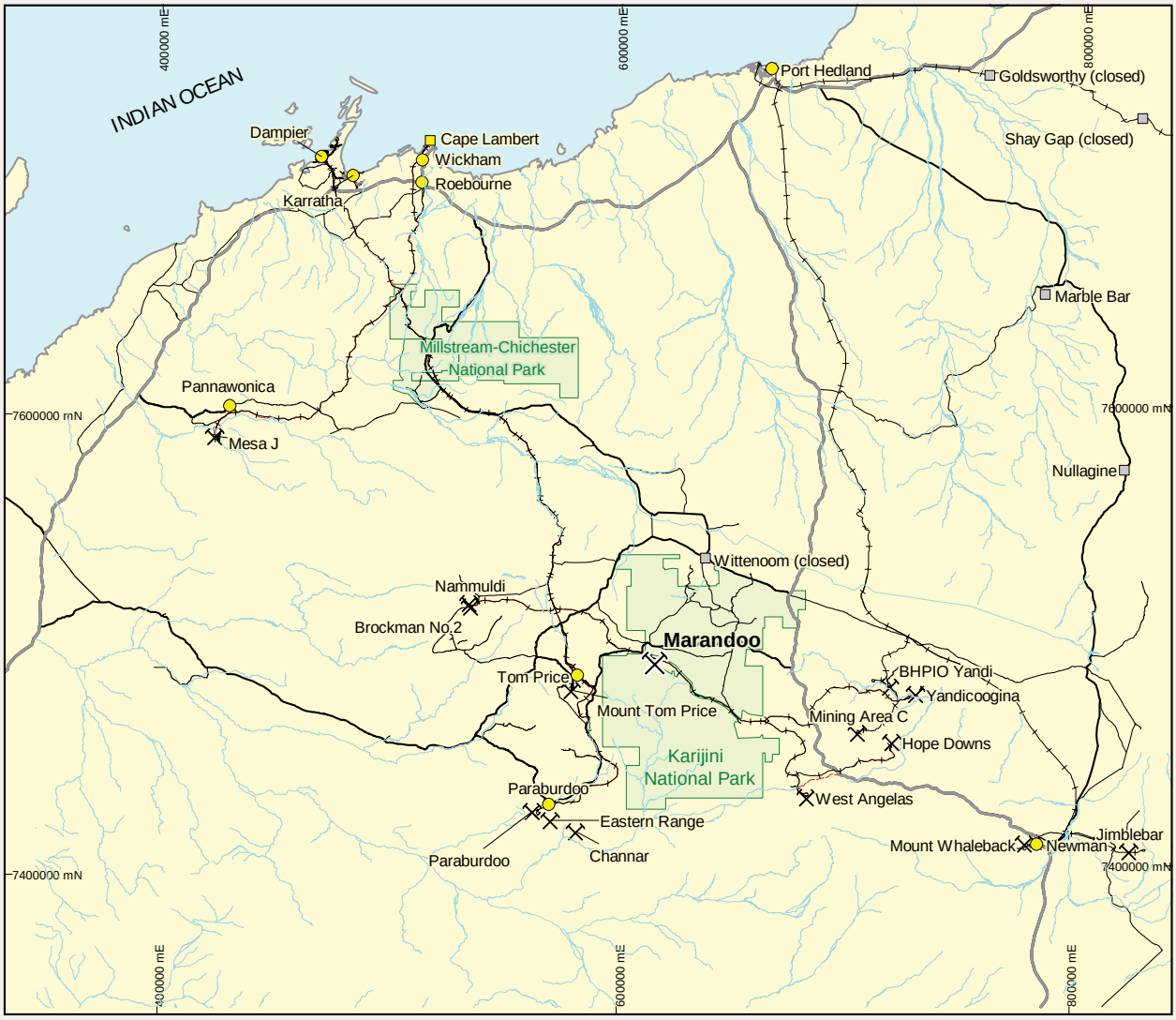
3 There are currently insufficient Ore Reserves to supply the forecast/estimated production for this Project. Accordingly, such production is subject to defining satisfactory Ore Reserves for the Project from the current and any further identified mineralisation.



RioTinto

Strategic Assets - Perth

Figure 1
Regional Location of Marandoo

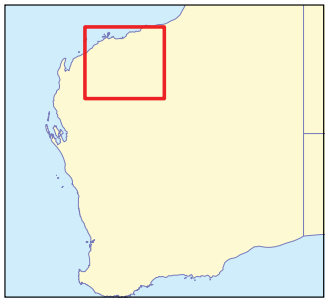
Drawn: TC
Date: Feb 2007

Plan No. PDE0049509v1
Proj: MGA94-50

LEGEND

- National Park
- Highway
- Road
- Private Road
- Railway
- Major River
- Major Town
- Town
- Mine (operating)
- Port

LOCATION MAP



SCALE

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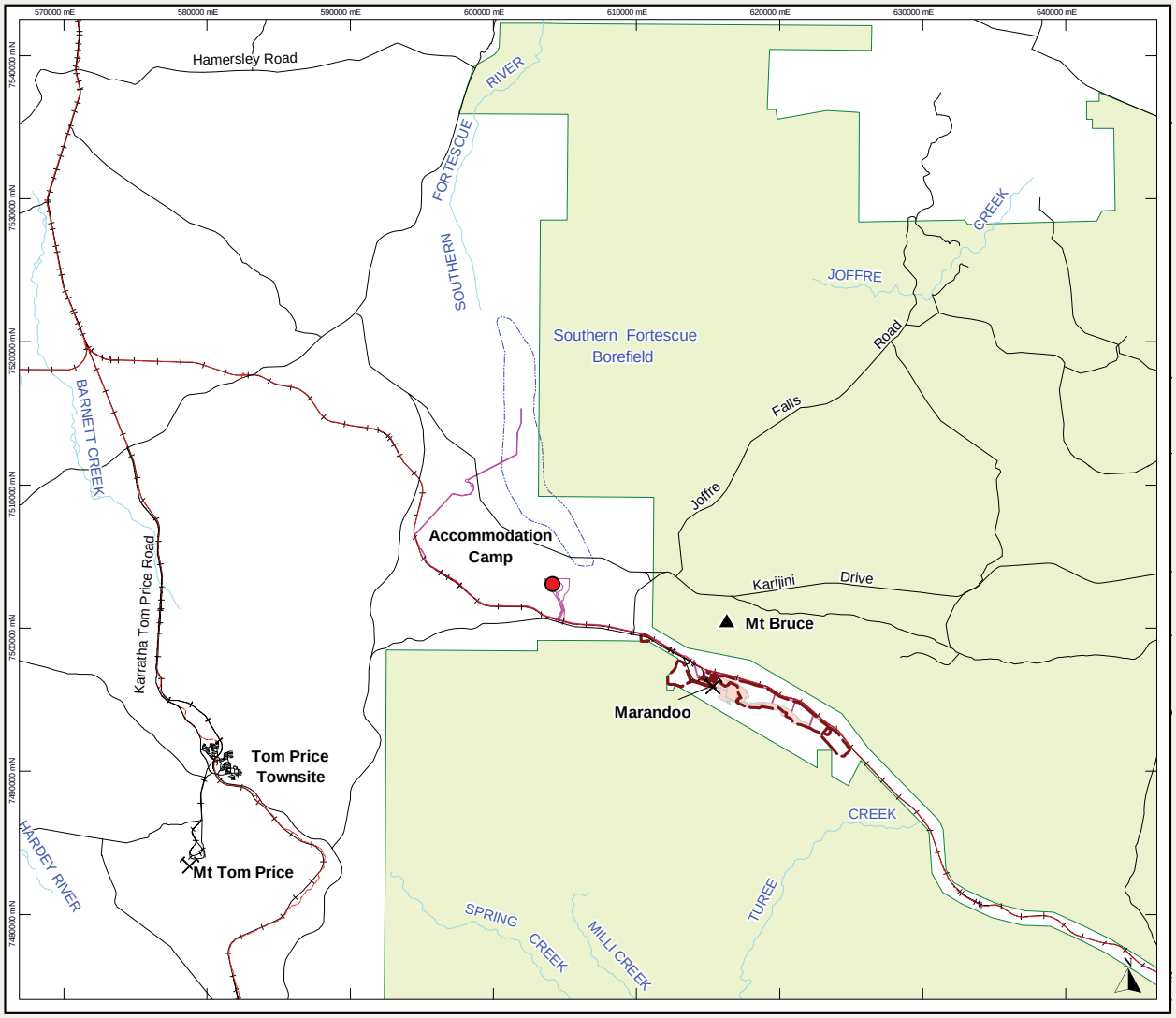


RioTinto

Strategic Assets - Perth

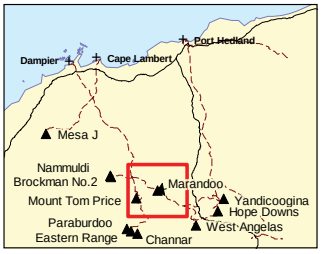
Figure 2
General Location Plan of Marandoo

Drawn: TC
Date: Feb 2008
Plan No. PDE0049509v1
Proj: MGA94-50

LEGEND

- Railway
- Road
- Private Road
- River/creeks
- Existing Mine
- Accommodation Camp
- Karijini National Park
- Current Approved Pit
- Proposed MMP2 Disturbance Footprint
- MMP2 Project Disturbance

LOCATION MAP



SCALE

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1.5 Project justification and development alternatives

1.5.1 Demand for iron ore

The Proposal is considered critical to the continued operation of the Proponent's business activities at Marandoo. Based on current production of 15 Mtpa, the remaining above watertable resource at Marandoo will be mined out by the end of 2012[4]. Additional ore reserves will be required to be identified and developed to continue operations at Marandoo as proposed.

Iron ore is now the largest individual mineral sector by value in Western Australia, accounting for 30% of the value of Western Australian resources output for 2007 (DoIR 2008). Recent growth in the world sea-borne iron ore trade has been driven by China, whose iron ore imports have risen from 70 million tonnes (Mt) in 2000 to 325 Mt in 2006. Western Australian iron ore exports reached record sales values of over $16.1 billion in 2007, an increase of over 9% from 2006 sales (DoIR 2008).

Customers require long-term, good-quality supplies that will be reliably delivered. The Marandoo mine produces a high-grade Marra Mamba ore with low phosphorus levels that is incorporated into the Proponent's 'Pilbara blend' supplied to many steel producing companies in China, Japan, Korea and Europe. An adequate proportion of Marra Mamba ore is essential to this blend and the MMP2 Proposal is critical in assisting the Proponent to continue to meet the global demand for iron ore by maintaining production of Marra Mamba ore.

1.5.2 Alternative deposits considered

Alternative deposits were considered; however, it was concluded that they would not be able to achieve the supply required from the Pilbara. The expansion of the Marandoo mine was chosen because:

- there is a scarcity of other low phosphorous, high-grade Marra Mamba ore deposits
- much longer timeframes would be involved in bringing new deposits online
- there is a reduced environmental impact in utilising an already disturbed mine site (Marandoo) than developing a greenfields site
- there is a reduced environmental impact in commencing below watertable operations in association with above watertable operations, rather than leaving the site dormant until a decision regarding below watertable operations was made, or sterilising the remaining ore by rehabilitating the above watertable pit
- there is increased efficiency in utilising existing infrastructure at Marandoo.

4 There are currently insufficient Ore Reserves to supply the forecast/estimated production for this Project. Accordingly, such production is subject to defining satisfactory Ore Reserves for the Project from the current and any further identified mineralisation.

1.5.3 Project design alternatives

Mining method

Three mining methods were considered for the handling of in-pit material:

- Truck and shovel: This is the mining method currently employed at Marandoo (and most other mines) and involves the use of a fleet of haul trucks to undertake all transportation of material.
- Semi-mobile crushing and conveying: This method requires a short haulage of material from the active pit face by haul truck to an in-pit crusher. The in-pit crusher is moved every few years to minimise haulage. Subsequent transportation of material is via conveyor.
- Fully mobile crushing and conveying: This method involves feeding material directly from the active pit face into a fully mobile in-pit crusher. Material is subsequently transported out of the pit via conveyor systems. All transportation of material is via conveyor, with no use of haul trucks.

The semi-mobile and fully mobile methods are termed in-pit crushing and conveying, and due to the size and geometry of the pit were considered for this Proposal.

As ore and waste material is handled independently using separate transportation systems, a different mining method may be used for each material type. For transportation of ore, both truck and shovel and semi-mobile crushing and conveying systems were considered. For transportation of waste, all three methods were considered.

Due primarily to the large amount of clay that must be handled during mining, fully mobile and semi-mobile in-pit crushing and conveying were deemed the least preferred options for the transportation of both ore and waste.

Truck and shovel will be used for the transportation of both ore and waste and is discussed in detail in Section 4.7.2.

Residue Storage Facility (RSF) location

Below watertable mining and wet processing of ore will produce a benign residue that will need to be stored safely at the site. Several potential locations for an RSF were assessed by the Proponent and ranked according to their suitability for storage of waste residue. Factors considered in this assessment included:

- sensitivity of the receiving environment
- location and elevation relative to the existing plant (which determine residue pipeline length and pumping requirements)
- topography
- hydrology, catchment area and flood control requirements
- quantity and moisture content of natural borrow material available nearby
- potential for seepage losses
- foundation suitability
- direction of potential seepage movement and potential for groundwater contamination.

Following assessment of nine sites inside the Marandoo mining lease and two sites outside the lease (to the west), a location to the south-west of the existing Marandoo rail loop (inside the lease) was selected because:

- the location is in proximity to the existing plant, resulting in a relatively short residue pipeline and reduced pumping requirements
- the location is in proximity to an existing waste dump and hill to the south-east, which would confine the facility and retain residue on the south-east side, as well as providing sufficient material of suitable quality for construction of the remainder of the RSF
- the location has a relatively small catchment area and no significant drainage lines, resulting in minimal surface water management.

In-pit residue storage was investigated but was determined not to be viable as:

- the mining schedule requires the wet plant (and hence, the RSF) to be operational before any cell of the pit would become available for use as an RSF, as the pit needs to be excavated deeper to access the below watertable ore to commence mining
- pit space that becomes available is required for backfilling of mineral waste.

In addition, Biota Environmental Sciences (Biota 2008a) conducted a desktop review and assessment of the site to the south-west of the rail loop (option 1) and a site further east on Marandoo Ridge (option 2). The assessment considered the potential environmental impacts to flora and fauna. Biota (2008a) determined that option 1 would have the least potential environmental impact of the two sites, given:

- the location is already predominantly disturbed, unlike option 2
- one vegetation community that is regionally extensive dominates the site and weeds are prevalent in the area, whereas option 2 has larger areas of intact creekline vegetation and would be expected to have a lower prevalence of weeds
- no Declared Rare Flora (DRF) or Priority flora species have been recorded at the preferred site; however, the available habitat (based on topography and relative intactness) at option 2 indicates that Priority species are more likely to be present at this site than at option 1
- the location is less likely to support threatened fauna species than option 2.

Dewatering pipeline infrastructure

A Multi-Criteria Analysis was conducted by the Proponent and hydrogeological consultants (MWH) to determine the optimum route for a dewatering pipeline to transfer dewatering water from Marandoo to the Southern Fortescue borefield. Although the construction of the dewatering infrastructure will be subject to a separate environmental approvals process under the EP Act (Section 4.2), operational impacts are considered in the scope of this PER.

The Multi-Criteria Analysis considered 12 parameters for each of the following three dewatering pipeline routes:

- Option 1: The dewatering pipeline would be constructed within the existing rail reserve for approximately 25 km west of the Marandoo rail loop, before being diverted north-east towards the Southern Fortescue borefield.
- Option 2: The dewatering pipeline would run approximately 1 km to the north of the existing rail reserve, within an undisturbed Class C Reserve. The route would then be diverted north-east towards the Southern Fortescue borefield at the same point as option 1
- Option 3: The dewatering pipeline would be constructed predominantly within the existing road reserve and would run north from the Marandoo access road along Karijini Drive for approximately 3 km, before being diverted north-west towards the Southern Fortescue borefield along the Hamersley-Mount Bruce Road

The parameters considered in the Multi-Criteria Analysis were:

- operational risk
- approval requirements
- tenure
- environmental impact
- visual amenity
- upfront capital expenditure
- ongoing operating costs
- simplicity of system and ease of maintenance
- potential for fauna habitat segmentation
- safety
- potential future infrastructure requirements
- cultural heritage.

All options assumed a gravity-fed system, and a pumping system was also considered for option 1.

The Multi-Criteria Analysis resulted in option 1 being selected for several reasons, including the reduced impact of its alignment through previously disturbed areas or degraded vegetation. This option also consolidates infrastructure requirements, as the pipeline will run along the existing rail corridor from Marandoo westwards and along an existing pipeline between the rail corridor and the Southern Fortescue borefield, thereby reducing visual impact and disturbance impacts.

Operations camp location

The existing Marandoo operational workforce resides in dedicated accommodation (200 person Single Persons Quarters (SPQ)) in the town of Tom Price. The Proposal requires approximately 500 personnel during construction and 500 during operations, plus an additional 200 personnel during shutdown maintenance periods.

The four accommodation options for the operational workforce investigated were:

- an expanded SPQ village at Tom Price
- a remote SPQ village within proximity of Marandoo (assessed at six potential locations; Figure 3)
- permanent residential housing at Tom Price
- a remote SPQ village (assessed at six potential locations) and a nominal provision of permanent residential housing at Tom Price.

The assessment considered several factors for each of the four options including:

- location relative to the Karijini National Park including visual impact
- water, power and wastewater infrastructure upgrade requirements
- tenure
- proximity to Marandoo
- topography
- access to existing roads.

The construction of a remote village operations camp and a nominal housing provision at Tom Price was selected as the preferred option. The other accommodation options investigated were eliminated for the following reasons:

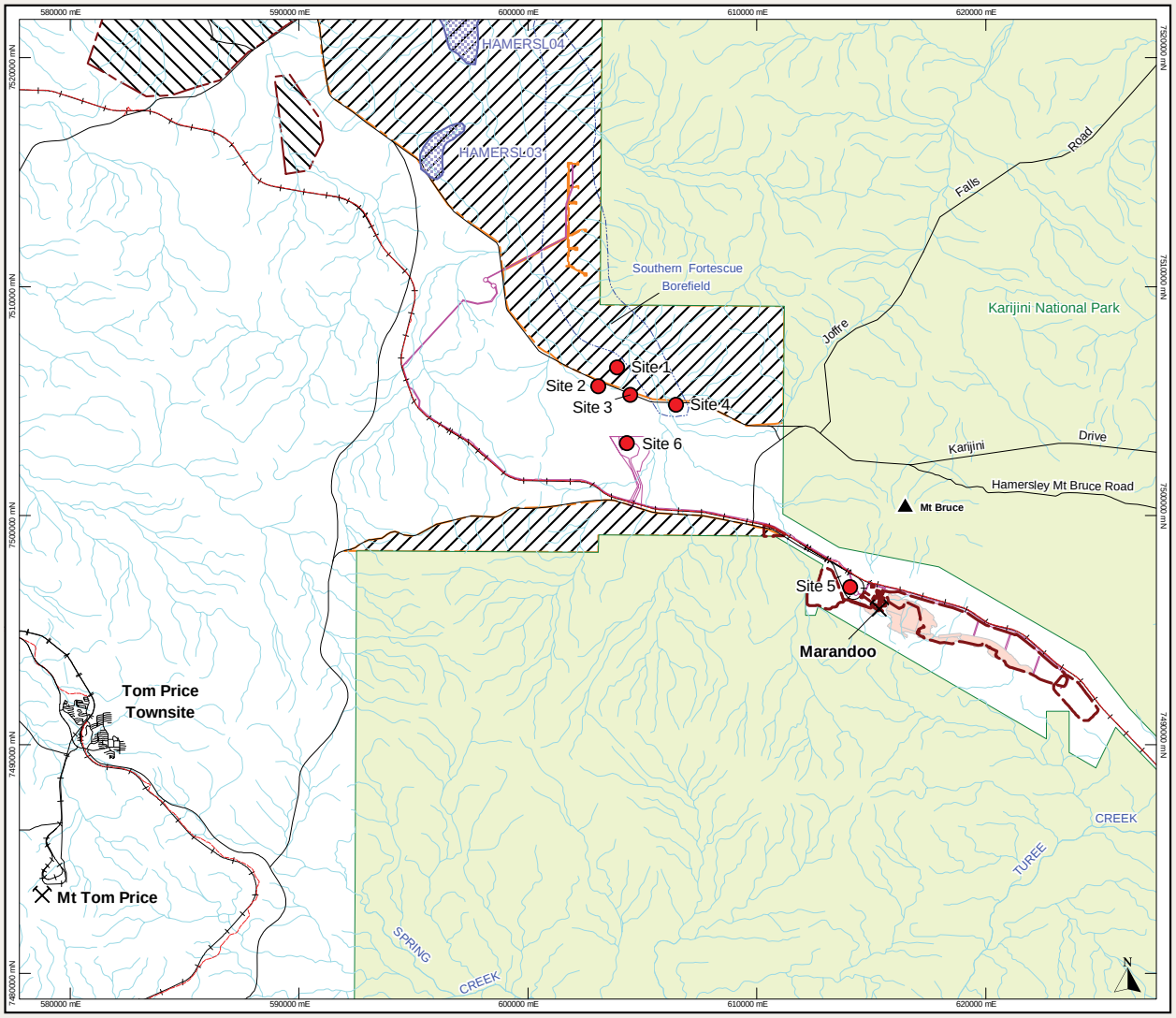
- an expanded SPQ village at Tom Price was not considered feasible as the Shire of Ashburton is likely to impose size restrictions on in-town SPQ villages
- the establishment of permanent residential housing at Tom Price was not viable in the timeframe for the Proposal as there are no suitably large sites zoned for residential development available, in accordance with the existing town planning scheme for Tom Price.

Six sites were identified as potential locations for the remote SPQ village (Figure 3). Of these, Site 6 (Figure 3) was determined as the preferred location primarily because it is close to Marandoo and is located outside Karijini National Park and outside the area that will be returned to the Park in 2015. The location also provides synergies with other projects in the area. The remote SPQ village will be constructed as a common facility to cater for both the Proposal workforce and the 320 Rail Project[5] construction workforce`. The timeline for construction of the camp is earlier than that for the MMP2 Proposal. Therefore, construction of the camp does not form part of the MMP2 Proposal and will be subject to a separate environmental approvals process under the EP Act. However, this PER does incorporate approvals for the operations camp, which will be located at the same site as the construction camp.

The other camp site locations (Sites 1–5) were eliminated for one or more of the following reasons:

- they are located within an area designated for return to Karijini National Park in 2015
- they have greater potential to degrade visual amenity of Karijini National Park
- they are located close to a significant creek system requiring substantial engineering for flood protection
- they are situated on tenure not held by the Proponent
- they are located on a potential mineral deposit
- the location conflicted with other potential land uses.

5 The 320 Rail Project is a large-scale construction project involving duplication of the existing rail network servicing the Proponent's operations throughout the Pilbara region.



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Strategic Assets - Perth

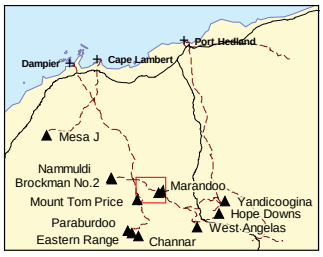
Figure 3 Accommodation Camp Options

Drawn: B Jackson
Date: August 2008
Plan No. PDE0049509v1
Proj: MGA94-50

LEGEND

- Railway
- Road
- Private Road
- River/creeks
- Existing Mine
- Accommodation Camp Options
- Karijini National Park
- Current Approved Pit
- Proposed MMP2 Disturbance Footprint
- MMP2 Project Disturbance
- Proposed Exclusion Area
- Proposed Management Agreement Area
- Themeda Grasslands

LOCATION MAP



SCALE

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1.5.4 Benefits of the Proposal

Extension of the existing mine at Marandoo means that existing transport infrastructure and mine site processing facilities can continue to be utilised. Development of a stand-alone iron ore deposit would require the development of substantially more site infrastructure and transport facilities, leading to a greater disturbance footprint than the MMP2 Proposal.

The Proposal will result in economic benefits for Australia and Western Australia through:

- contribution to the value of mineral exports
- royalties and taxation payments
- capital investment
- increasing direct and indirect employment opportunities in the region
- increasing demand for goods and services supporting the regional economy.

The ongoing activities of the Proponent will continue to support a range of social and economic development projects in the Pilbara region, including:

- funding for a range of organisations in the region, including sporting and cultural groups
- increasing the education, training and employment options for local Aboriginal people.

1.6 Scope of the PER

This PER includes:

- a description of the stakeholder engagement and consultation process undertaken for the Proposal
- a description of the existing environment
- a detailed description of the Proposal
- a factor-by-factor assessment of the environmental impact of the Proposal
- a description of key environmental management measures.

1.7 Environmental approvals process

The PER level of assessment requires the Proponent to fulfil the requirements of the Environmental Impact Assessment (Part IV Division 1) Administrative Procedures 2002 for environmental assessment prescribed under the EP Act (Figure 4).

The Proponent was required to prepare an Environmental Scoping Document (ESD) setting out the environmental factors raised by the Proposal and the Proponent's intended environmental studies. An ESD was prepared describing the scope of the assessment of the Proposal, as well as providing an indicative timeline for the assessment process. The ESD was submitted to the Environmental Protection Authority (EPA) on 17 December 2007 and included a summary of:

- potential environmental impacts, their significance and potential management responses
- proposed scope of work to obtain information for the PER
- key legislation
- stakeholder consultation program
- project and assessment schedule
- study team
- peer review mechanisms.

The ESD was approved by the EPA on 20 March 2008; the Proponent is required to prepare this PER in accordance with the agreed ESD.

The purpose of the PER is to present an Environmental Impact Assessment (EIA) of the Proposal. The environmental review of the Proposal addresses the scope set out in the approved ESD through a risk assessment process, where the risk rating arising from relevant aspects of the Proposal was determined by both the likelihood of an effect occurring and the extent of the effect (consequence). In the risk assessment process, a qualitative risk analysis matrix comprising likelihood and consequence was used to identify both the inherent and residual level of risk associated with each aspect of the Proposal. The EIA process utilised various EPA Position Statements and Guidance Statements in determining the significance of the environmental effects of the Proposal.

The EPA Position Statements and Guidance Statements considered relevant to the Proposal were:

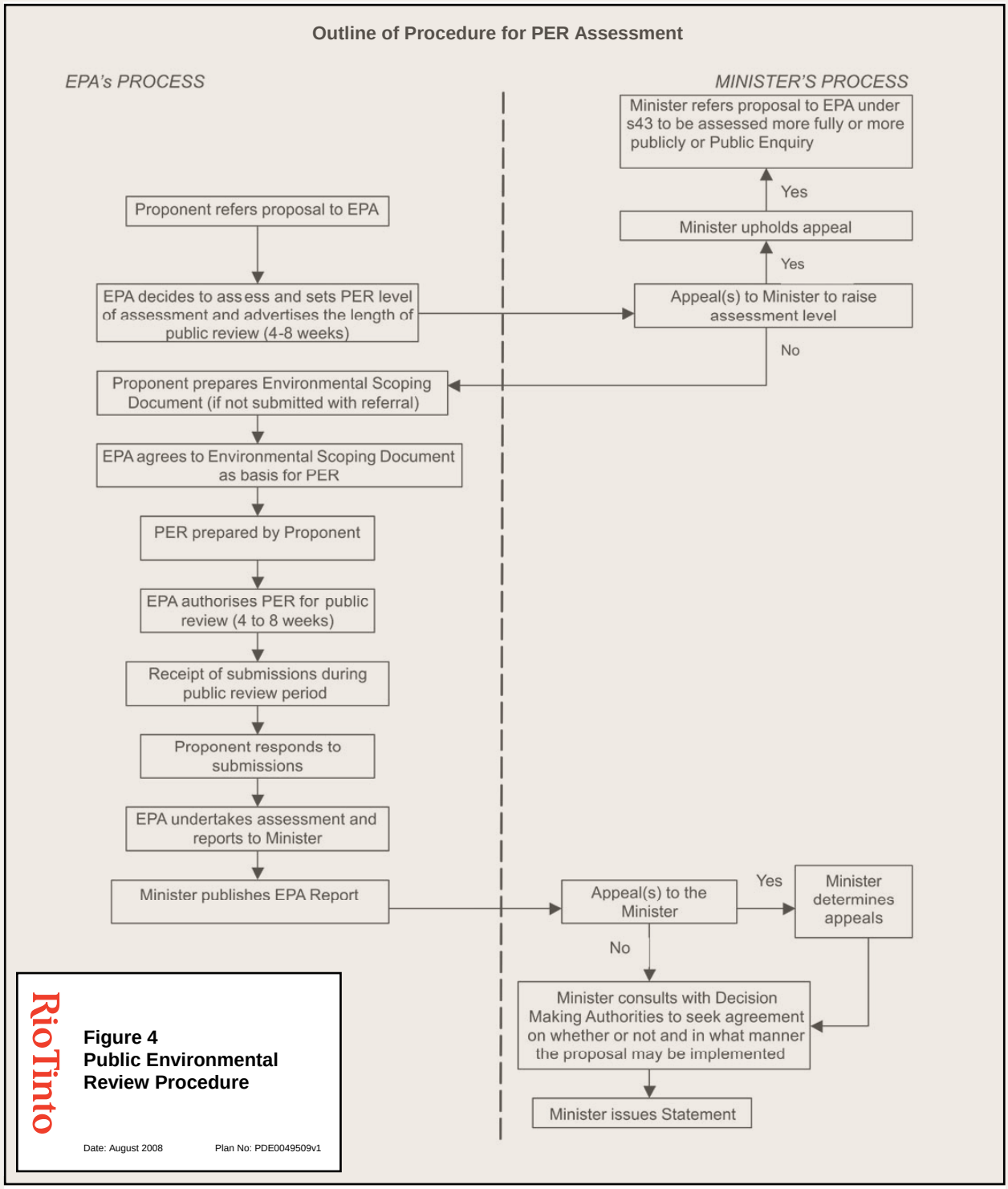
- EPA Position Statement No. 2 Environmental Protection of Native Vegetation in Western Australia (EPA 2000)
- EPA Position Statement No. 3 Terrestrial Biological Surveys as an Element of Biodiversity Protection (EPA 2002a)
- EPA Position Statement No. 7 Principles of Environmental Protection (EPA 2004a)
- EPA Position Statement No. 9 Environmental Offsets (EPA 2006a)
- EPA Guidance Statement No. 6 Rehabilitation of Terrestrial Ecosystems (EPA 2006b)
- EPA Draft Guidance Statement No. 8 Environmental Noise (EPA 2007a)
- EPA Guidance Statement No. 12 Guidance Statement for Minimising Greenhouse Gas Emissions (EPA 2002b)
- EPA Draft Guidance Statement No. 19 Environmental Offsets (EPA 2007b)
- EPA Guidance Statement No. 33 Environmental Guidance for Planning and Development (EPA 2008a)
- EPA Guidance Statement No. 41 Assessment of Aboriginal Heritage (EPA 2004b)
- EPA Guidance Statement No. 51 Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia (EPA 2004c)
- EPA Draft Guidance Statement No. 54 Consideration of Subterranean Fauna in Groundwater and Caves during Environmental Impact Assessment in Western Australia (EPA 2003)
- EPA Draft Guidance Statement No. 54a Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia (EPA 2007c)
- EPA Guidance Statement No. 56 Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia (EPA 2004d).

When the EPA is satisfied the PER document has adequately addressed all of the environmental factors and studies identified in the ESD, the Proponent will be required to release it for a public review period (normally between four and eight weeks), during which time the public may make submissions to the EPA regarding the Proposal. Following the public review, the EPA will provide copies of the submissions (with the names of private individuals removed) to the Proponent.

The Proponent will be required to prepare a summary of the key issues and matters raised in the submissions and will then be required to respond to issues and matters raised in submissions on the PER document, to the satisfaction of the EPA.

The EPA will assess the PER document, submissions, Proponent's response to submissions, and obtain advice from any other persons it considers appropriate and submit its report to the Minister for the Environment. This report to the Minister will address the environmental factors relevant to that Proposal, conditions and procedures to which the implementation of the proposal should be subject, and any recommendations it sees fit.

The Minister publishes and circulates the report as soon as the Minister is reasonably able to do so. In accordance with Section 100(2) of the EP Act, any person may lodge an appeal with the Minister for the Environment against the contents and/or recommendations of the EPA assessment report within 14 days of the publication of the report.


Outline of Procedure for PER Assessment
EPA's PROCESS
MINISTER'S PROCESS
Minister refers proposal to EPA under s43 to be assessed more fully or more publicly or Public Enquiry
Yes
Minister upholds appeal
Yes
Proponent refers proposal to EPA
EPA decides to assess and sets PER level of assessment and advertises the length of public review (4-8 weeks)
Appeal(s) to Minister to raise assessment level
No
Proponent prepares Environmental Scoping Document (if not submitted with referral)
EPA agrees to Environmental Scoping Document as basis for PER
PER prepared by Proponent
EPA authorises PER for public review (4 to 8 weeks)
Receipt of submissions during public review period
Proponent responds to submissions
EPA undertakes assessment and reports to Minister
Minister publishes EPA Report
Appeal(s) to the Minister
Yes
Minister determines appeals
No
Minister consults with Decision Making Authorities to seek agreement on whether or not and in what manner the proposal may be implemented
Minister issues Statement
RioTinto
Figure 4
Public Environmental Review Procedure
Date: August 2008
Plan No: PDE0049509v1

1.8 Relevant legislation and policies

State legislation, policy and strategies

Western Australian legislation relevant to the environmental aspects of the Proposal includes the following:

- *Aboriginal Heritage Act 1972*
- *Aboriginal Heritage (Marandoo) Act 1992*
- *Agriculture and Related Resources Protection Act 1976*
- *Bush Fires Act 1954*
- *Conservation and Land Management Act 1984*
- *Contaminated Sites Act 2003*
- *Country Areas Water Supply Act 1947*
- *Dangerous Goods Safety Act 2004*
- *Dangerous Goods (Transport) Act 1998*
- *Electricity Act 1945*
- *Environmental Protection Act 1986*
- *Explosives and Dangerous Goods Act 1961*
- *Health Act 1911*
- *Iron Ore (Hamersley Range) Agreement Act 1963*
- *Land Administration Act 1997*
- *Local Government Act 1995*
- *Main Roads Act 1930*
- *Mining Act 1978*
- *Native Title (State Provisions) Act 1999*
- *Occupational Safety and Health Act 1984*
- *Rail Safety Act 1998*
- *Rights in Water and Irrigation Act 1914*
- *Soil and Land Conservation Act 1945*
- *Waterways Conservation Act 1976*
- *Wildlife Conservation Act 1950.*

In addition to existing legislation, the following government strategies and policies are of relevance to the environmental assessment and management of this Proposal:

- Hope for the future: The Western Australian State Sustainability Strategy (Government of Western Australia 2003a)
- Draft Greenhouse Strategy for Western Australia (Government of Western Australia 2003b)
- A Nature Conservation Strategy for Western Australia (Government of Western Australia 1987)
- EPA Red Book Recommendations for Conservation Reserves of Western Australia (Government of Western Australia 1975)
- State Water Quality Management Strategy (Government of Western Australia 2001).

Commonwealth legislation, policy and strategies

Commonwealth legislation relevant to the Proposal includes the following:

- *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* (which operates concurrently with any existing state laws in so far as those laws would not be consistent with this Act)
- *Environment Protection and Biodiversity Conservation Act 1999*
- *Native Title Act 1993.*

The following Commonwealth environmental strategies are also relevant to the Proposal:

- National Strategy for Ecologically Sustainable Development (Ecologically Sustainable Development Steering Committee 1992)
- Intergovernmental Agreement on the Environment (Commonwealth of Australia 1992)
- National Greenhouse Strategy (Commonwealth of Australia 1998)
- National Conservation Strategy for Australia (Department of Home Affairs and Environment 1983)
- National Strategy for Conservation of Australia's Biological Diversity (Commonwealth of Australia 1996).

The Proposal was referred to the Commonwealth Department of the Environment, Water, Heritage and the Arts (DEWHA) under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwth) (EPBC Act) on 13 September 2007. On 19 October 2007, the DEWHA confirmed that the Proposal does not constitute a 'controlled action' as defined by the EPBC Act. That is, it will not have, or is not likely to have, a significant impact to any matter of National Environmental Significance and does not require assessment under the EPBC Act.

1.9 Environmental principles and sustainability

1.9.1 Principles of environmental protection

The Proponent recognises that environmental responsibilities go beyond those required for compliance and encompass strong commitments to environmental management, leadership in sustainable development and social obligations.

In 2003, the EP Act was amended to include a core set of Principles that are applied by the EPA in formal assessments (EPA 2004a). As listed in Section 4A of the EP Act, these are:

- precautionary principle
- principle of intergenerational equity
- principle of the conservation of biological diversity and ecological integrity
- principles relating to improved valuation, pricing and incentive mechanisms
- principle of waste minimisation.

The Proponent has considered these principles in its assessment of the environmental impacts of the Proposal (Table 1).

Table 1
Principles of environmental protection

Principle	Consideration given in Proposal	Section addressed in PER
1. Precautionary Principle Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, decisions should be guided by: a) careful evaluation to avoid, where practicable, serious or irreversible damage to the environment b) an assessment of the risk-weighted consequences of various options.	The Proponent includes a risk assessment process in the development of all new projects with the intention of identifying issues early in the process to enable planning for avoidance and/or mitigation. Part of this process includes undertaking detailed site investigations of the biological and physical environs. Where these investigations identify significant conservation issues, management measures are incorporated into the project design to avoid, where practicable, and/or minimise any potential impacts.	See detailed assessment of factors in Sections 5.1–5.10 and Sections 6.2–6.8.
2. Intergenerational Equity The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.	The Proponent integrates the principles of sustainable development into all aspects of their operations to contribute to sustainable development in Australia. These principles ensure that the Proponent's operations deliver more value with less impact, where: Value = long-term financial outcomes + social outcomes + environmental outcomes Impact = financial cost + social impact + environmental impact Integration of these sustainable development principles ensures the environment in which the Proponent operates is maintained and (where possible) enhanced for future generations.	See Section 5.10 and draft Ministerial Conditions relating to conservation of biological diversity in Section 8.4.
3. Conservation of Biological Diversity and Ecological Integrity Conservation of biological diversity and ecological integrity should be a fundamental consideration.	Conservation of biological diversity and ecological integrity is fundamental to the Proponent's approach to environmental management and is a major environmental consideration for the project. This is reflected in the Proponent's well-established standard management procedures. Biological investigations are undertaken by the Proponent early in the project planning process to identify aspects of of environmental conservation significance required to be protected from disturbance. The Proponent has well-established rehabilitation guidelines for restoring disturbed environments upon decommissioning, the aim of which is to establish sustainable endemic vegetation units consistent with reconstructed landforms and surrounding vegetation. The Proponent also actively undertakes and/or contributes to biological research (for example, plant-water relationship studies) to improve the understanding and management of these biological aspects.	See references in No. 1 above, (Precautionary Principle); rehabilitation and closure section in Section 5.10; and Proponent commitments to conservation of biological diversity in Section 8.
4. Improved Valuation, Pricing and Incentive Mechanisms a) Environmental factors should be included in the valuation of assets and services. b) The polluter pays principle - those who generate pollution and waste should bear the cost of containment, avoidance or abatement. c) The users of goods and services should pay prices based on the full life cycle costs of providing goods and services, including the use of natural resources and assets and the ultimate disposal of any wastes. d) Environmental goals, having been established, should be pursued in the most cost-effective way, by establishing incentives structures, including market mechanisms, which enable those best placed to maximise benefits and/or minimise costs to develop their own solutions and responses to environmental problems.	The Proponent acknowledges the need for improved valuation, pricing and incentive mechanisms and endeavours to pursue these principles when and wherever possible. For example: • environmental factors have played a major role in determining preferred operational options • the Proponent has designed the project to ensure that pollution-type impacts are minimised as far as practicable • environmental goals will be pursued to the most cost-effective way • costs are provided for over the life of each operation on a unit of production basis.	See Section 1.5 and Section 5.10.

Principle	Consideration given in Proposal	Section addressed in PER
5. Waste Minimisation All reasonable and practicable measures should be taken to minimise the generation of waste and its discharge into the environment.	The Proponent's approach to waste management is to, in order of priority: • avoid and reduce at source • reuse and recycle • treat and/or dispose. The Proponent operates appropriately licensed landfills for the disposal of general domestic solid wastes and recycles scrap metal, rubber, waste oil and batteries. The Proponent continues to investigate other waste management opportunities with the aim of minimising waste generation and disposal requirements.	See Section 6.3.

1.9.2 Sustainability

Sustainable development can be defined as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED 1987). In the mining and minerals sector, this means that investments should be financially profitable, technically appropriate, environmentally sound and socially responsible (WCED 1987).

In September 2003, the Western Australian government released the State Sustainability Strategy (Government of Western Australia 2003a). The strategy establishes a high level approach to applying sustainability principles across government operations, including expectations for, and regulation of the mining industry. The strategy recognises that 'the international minerals sector has been one of the most pro-active industries in embracing sustainable development'.

The strategy also recognises that a number of key sustainability innovations have been developed in the Western Australian resources sector, including land and water rehabilitation, eco-efficiency in mineral processing and, more recently, a range of social innovations. The training and employment of Aboriginal people is a recent example.

The Proponent undertakes all operations in accordance with the Rio Tinto 'The Way We Work' sustainable development policy:

Rio Tinto businesses, projects, operations and products should contribute constructively to the global transition to sustainable development.

We contribute to sustainable development by helping to satisfy global and community needs and aspirations, whether economic, social or environmental. This means making sustainable development considerations an integral part of our business plans and decision-making processes.

By focusing on people, the environment, resource stewardship and management systems, we can better manage risk, create business options, reduce costs, attract the best employees, gain access to new markets and resources and deliver a better product to our customers.

In practice, this depends on the active awareness of, and support for Rio Tinto's principles and policies by each of us as individuals.

The Proponent also applies sustainable development principles in the development (planning and decision-making) of all major projects.

Sustainable development principles

Environment
- reduce water use
- reduce net land disturbances and disruption of natural water bodies
- reduce net biodiversity loss
- reduce net emissions, particularly dust and greenhouse gases.

Social
- reduce injury and illness incidents
- improve equal employment opportunities
- improve contribution to community capacity building
- reduce impact to heritage.

Economic
- optimise long-term economic value.

Through the application of these principles, the Proponent is confident that, as far as practicable, the Proposal is consistent with the sustainability principles of the Western Australia State Sustainability Strategy and the Rio Tinto 'The Way We Work' sustainable development policy.

Keeping stakeholders informed

Since mining at Marandoo commenced in 1994, the Proponent has sought to keep relevant stakeholders up to date with studies in relation to any potential future below watertable mining at Marandoo. A number of discussions and meetings have been held with relevant government agencies, non-government organisations and traditional owners specifically in relation to this Proposal.

2.1 Stakeholder engagement process

Since mining at Marandoo commenced in 1994, the Proponent has sought to keep relevant stakeholders up to date with studies in relation to any potential future below watertable mining at Marandoo.

A number of discussions and meetings have been held with relevant government agencies, non-government organisations and traditional owners specifically in relation to this Proposal.

Key stakeholders were identified through the Proponent's ongoing experience at Marandoo and other mining projects in the region, as well as through discussion with the Environmental Protection Authority Service Unit (EPASU). Those consulted during the preparation of the PER were:

Government agencies

- Commonwealth Department of the Environment, Water, Heritage and the Arts (DEWHA)
- Environmental Protection Authority Service Unit (EPASU)
- Department of Environment and Conservation (DEC) - Pilbara regional office (Karratha) and Perth office
- Department of Industry and Resources (DoIR)
- Department of Indigenous Affairs (DIA)
- Department of Water (DoW) - Pilbara regional office (Karratha) and Perth office
- Shire of Ashburton.

Non-government organisations

- Conservation Council of Western Australia
- Conservation Commission.

Community

- Eastern Guruma people
- Gumala Aboriginal people
- Tom Price and Paraburdoo communities
- Pilbara Gorge Tours.

The timing of the consultation program has enabled the topics raised to be taken into account during the design of the Proposal, determination of management measures and preparation of the PER (Table 2).

2.2 Stakeholder comments and Proponent responses

The main issues raised by stakeholders related to impacts to Aboriginal heritage, the *Eucalyptus victrix* (Coolibah) woodland to the north of Marandoo, visual amenity, Karijini National Park, fauna, as well as the disposal strategy for surplus dewatering water and closure (Table 3). The topics raised by stakeholders have been addressed in this PER.

Table 2
Summary of consultation undertaken to date

Date	Stakeholder	Purpose
7 February 2007	DEC (Karratha)	Overview of the Proposal and discussion regarding timing for referral of Proposal and studies being carried out for the Pre-Feasibility Study (PFS)
15 February 2007	DEC (Karratha)	Overview of the Proposal and discussion regarding timing for referral of Proposal and studies being carried out for the PFS
27 February 2007	DEC (Karratha)	Overview of the Proposal and discussion regarding timing for referral of Proposal and studies being carried out for the PFS
10 April 2007	EPASU DEC (Perth)	Overview of the Proposal and discussion regarding timing for referral of Proposal and studies being carried out for the PFS
22 May 2007	DoIR	Overview of the Proposal and discussion regarding timing for referral of Proposal and studies being carried out for the PFS
20 June 2007	Eastern Guruma people	To discuss referral of the Proposal
26 June 2007	EPASU	To discuss referral of the Proposal
6 August 2007	Eastern Guruma people	To explain the Proposal
30 August 2007	EPASU DEC (Perth)	To explain the Proposal, proposed studies and consultation strategy, and to identify any gaps in the project scope
12 September 2007	DoW	To explain the Proposal and proposed studies (especially those relevant to water), and to identify any gaps in the project scope
17 September 2007	DEWHA	To review the potential for Rio Tinto projects (including this Proposal) to trigger the EPBC Act
18 September 2007	Shire of Ashburton	To review proposed projects affecting the Shire of Ashburton (including this Proposal)

Date	Stakeholder	Purpose
15 October 2007	Eastern Guruma people	To review proposed projects in Eastern Guruma country (including this Proposal) and to visit the Marandoo mine site
25 October 2007	DEC (Karratha)	To explain the Proposal and scoping phase
12 November 2007	DEC (Perth)	To explain the Proposal and proposed studies
23 November 2007	DEC (Perth)	To explain the Proposal and proposed studies
30 November 2007	DEC (Pilbara)	To explain the Proposal and proposed studies
5 December 2007	Conservation Council	To explain the Proposal and proposed studies
13 February 2008	DEC (Statement of Mutual Understanding (SMU) meeting	To explain the Proposal and proposed studies
28 February 2008	Community	Shopping centre display
5 March 2008	Shire of Ashburton	Overview of the Proposal and discussion regarding timing and studies being undertaken for the PFS and discussion on how the Proposal may affect Tom Price town
13 March 2008	Eastern Guruma people	To review proposed projects in Eastern Guruma country (including this Proposal)
26 March 2008	Gumala Aboriginal people	To review proposed projects potentially in Gumula country (including this Proposal)
27 March 2008	Pilbara Gorge Tours	To explain the Proposal
4 April 2008	DEC (Perth)	Discussion of Southern Fortescue borefield and tenure
9 April 2008	Eastern Guruma people	To discuss the Proposal and consultation process in detail
6 May 2008	DEC	Site visit and presentation of information in relation to research and monitoring being undertaken on the Coolibah woodland
9 July 2008	DoW	Discuss the Proposal and provide an overview of hydrogeology and hydrology information and environmental approvals
18 July 2008	DEC (Perth)	Update on project progress
27 July 2008	Eastern Guruma people	Update on project progress
20 August 2008	Shire of Ashburton	Update on project progress and discussion of consultation process
22 August 2008	Eastern Guruma people	Visit to the MMP2 Proposal area and 'Country'
10 September 2008	Eastern Guruma people	Detailed technical briefing on the Proposal
24 September 2008	DEC (SMU meeting)	Update on project progress and studies
26 September 2008	Shire of Ashburton	Detailed technical briefing on the Proposal
Quarter 4 2008	Martu Idja Banyjima (MIB)	Detailed technical briefing on the Proposal (pending confirmation)

Table 3
Key topics raised during stakeholder consultation regarding the Proposal

Stakeholder	Topics raised	Proponent response
Government agencies		
DEC (Karratha)	The DEC would like regular meetings on the Proposal once the Pre-Feasibility Study (PFS) has progressed	The Proponent will continue to liaise with the DEC as required.
	The DEC would like to discuss proposed baseline biological studies and would like to be kept informed during the development of the project	The Proponent will continue to liaise with the DEC as required.
	Backfilling pits post-mining below the watertable	Mine pits are currently planned to be backfilled to at least 1 m above the pre-mining watertable but this is subject to the results of groundwater modelling, or requirements of other interested stakeholders (Section 5.10).
	Current water levels at Marandoo	Current water levels at Marandoo are approximately 680–686 mAHD (Section 5.2).
	A large volume of water will require disposal, which will be a key issue if surface water discharge is considered	The Proponent has considered a range of options for the management of excess water in line with the DoW hierarchy of water management methods (Section 4.6.1). Management of excess dewatering water is addressed in Section 5.3.
	The hydrogeology model needs to be robust	The hydrogeological model has incorporated results from a number of dewatering and re-injection trials conducted at Marandoo (Section 5.2).
	The PER needs to ensure cultural values are addressed	Aboriginal heritage values are addressed in Section 5.8.
	Need to understand the connectivity of various aquifers and dependence of significant vegetation on them	The connectivity of the various aquifers in the vicinity of the Proposal area has been determined through hydrogeological investigations and is described in Section 5.2. The water-use strategies for significant vegetation are discussed in Section 5.5.
	Short-range endemic (SRE) invertebrates	Invertebrate groups supporting potential SRE taxa have been surveyed (Section 5.6).
	Residue Storage Facility (RSF) details	The RSF is described in Section 4.6.3. Water management aspects associated with the RSF are addressed in Section 5.3.
	Camp locations	Options to accommodate the Marandoo workforce were investigated in an order of magnitude comparative assessment (Section 1.5.3).
	Dewatering pipeline route	A Multi-Criteria Analysis considering 12 parameters for each of three alternative dewatering pipeline routes was conducted (Section 1.5.3).
	Contingency plans important for dewatering (including engineering)	Contingency plans have been developed as part of an adaptive management approach to mine dewatering (Section 5.3 and Appendix 2).
	Feasibility of releasing surface water during peak flows	Surface water management is addressed in Section 5.3.
	Closure plans should include surface habitat complexity (for example, caves providing bat habitat)	Final rehabilitation works will include a range of habitats to encourage the return of flora and fauna to the rehabilitated areas where practicable. Detailed design will be discussed with key stakeholders during future closure planning (Section 5.10).

Stakeholder	Topics raised	Proponent response
	Workforce and camps - consider both negative and positive impacts of development near Karijini National Park	The potential impacts of development near Karijini National Park are addressed in Sections 5.1 and 6.7.
DEC (Perth)	Closure of pits and impacts to groundwater quality based on backfilling procedure (sink vs. throughflow)	Potential impacts to groundwater quality based on backfilling procedure (sink vs. throughflow) have been considered in preliminary closure planning (Section 5.10).
	Groundwater impacts to vegetation	Potential impacts to vegetation as a result of groundwater drawdown are addressed in Sections 5.4 and 5.5.
	Impacts to stygofauna, troglofauna and SRE invertebrates	Impacts to stygofauna and troglofauna are addressed in Section 5.7. Impacts to SRE invertebrates are addressed in Section 5.6.
	Impacts to visual amenity, landscape and geodiversity values especially with regard to the operations camp	Impacts to visual amenity and landscape values are addressed in Section 5.9. Impacts to geodiversity values are addressed in Section 6.2.
	Need to understand the connectivity of various aquifers and dependence of significant vegetation on them	The connectivity of the various aquifers in the vicinity of the Proposal area has been determined through hydrogeological investigations and is described in Section 5.2. The water-use strategies for significant vegetation are discussed in Section 5.5.
	Significance value of Coolibah woodland due to its unique species assemblage	The potential effects of the Proposal on the Coolibah woodland north of Marandoo are described in Section 5.5.
	Extent of groundwater drawdown to the south and impacts to Minthicoondunna Spring and Turee Creek	The potential impact of the Proposal to Minthicoondunna Spring and Turee Creek is addressed in Section 5.1 and 5.2.
	Impacts to subterranean fauna at the mine site and the Southern Fortescue borefield	Impacts to subterranean fauna are addressed in Section 5.7.
	Fire has had a significant effect on the Mulga, so fire management (for example, resourcing, equipment and training) is important	The Proponent will implement a fire management strategy, in consultation with the DEC (Section 5.1).
	Management of weeds during construction and continuity into operations	Weed occurrences within the Proposal area have been identified and weed management will be conducted during construction and operation (Section 5.4 and Appendix 2).
	Seed collection and rehabilitation	Rehabilitation, including the use of seed of local species is addressed in Section 5.10.
	Involvement of traditional owners in management	Eastern Guruma contracting companies will be given opportunities to tender for all projects in accordance with existing arrangements.
	Visual impacts - open water bodies result in different habitat types to surrounding area	Mine pits are currently planned to be backfilled to at least 1 m above the pre-mining watertable but this is subject to the results of groundwater modelling, or requirements of other interested stakeholders (Section 5.10). Ephemeral pools will form in the post-closure pit void following rain; however, the occurrence and duration of these pools will be similar to those in the surrounding landscape (Section 5.10).
	Preferable that operations camps not be selected within the area to be returned to DEC under Section 16A of *Conservation and Land Management Act 1984* (WA)	The operations camp is located outside the area to be returned to the Karijini Natinal Park under the *Conservation and Land Management Act 1984* (WA).
	Workforce management within the Park	Management of the Marandoo workforce within Karijini National Park has been addressed through commitment to a comprehensive induction program (Appendix 2).

Stakeholder	Topics raised	Proponent response
	Preferable if the RSF is located in the mine pit or to the south behind Marandoo Ridge so it is not visible from Mount Bruce	The RSF will be visible at Mount Bruce; however, this location poses fewer operational constraints and reduced environmental risk than potential RSF locations south of Marandoo Ridge (Section 1.5.3). Locating the RSF in-pit is not practicable as: a) the current mine schedule requires the wet processing plant and RSF to be operational before any cell of the pit would be available for construction of the RSF b) all available pit space is required for backfilling of mineral waste.
	Backfilling voids important to reduce visual impact	Mine pits are currently planned to be backfilled to at least 1 m above the pre-mining watertable but this is subject to the results of groundwater modelling, or requirements of other interested stakeholders (Section 5.10).
	Effect of surface drainage changes on the Coolibah woodland	The potential effects of the Proposal on the Coolibah woodland north of Marandoo are described in Section 5.5.
	Truncation by the mine of the surface and deeper aquifers and effect on the hydrology system (that is, draining)	Hydrogeology and hydrology are addressed in Sections 5.2 and 5.3.
	Monitoring and contingency plans for groundwater	Contingency plans have been developed as part of an adaptive management approach to mine dewatering (Section 5.2 and Section 5.5).
	Effect on groundwater quality at closure	Potential impacts to groundwater quality have been considered in preliminary closure planning (Section 5.10).
	Recommendation that stygofauna survey methodology submitted to Environmental Management Branch for review	Scope of work was discussed with Bill Humphreys (WA Museum) prior to mobilisation. Risk assessment approach to troglofauna assessment discussed with the Environmental Management Branch of the DEC. Stygofauna surveys were undertaken in accordance with EPA Guidance Statement No. 54 (EPA 2003) and EPA Draft Guidance Statement No. 54a (EPA 2007c) (Section 5.7).
	Undertake a pilot study for troglofauna to confirm there are no risks	A troglofauna assessment has been undertaken in accordance with EPA Guidance Statement No. 54 (EPA 2003) and EPA Draft Guidance Statement No. 54a (EPA 2007c) (Section 5.7).
	Tenure status of Southern Fortescue borefield (SFB) given return of the area to Karijini National Park in 2015	Relevant tenure applications will be made as part of a separate process to the EPA (Section 3.4.2).
EPASU	Visual amenity will be a key issue for the project	Impacts to visual amenity and landscape values are addressed in Section 5.9.
	Closure of pits and impacts to groundwater quality based on backfilling procedure (sink vs. throughflow)	Potential impacts to groundwater quality based on backfilling procedure (sink vs. throughflow) have been considered in preliminary closure planning (Section 5.10).
	Groundwater impacts to vegetation	Potential impacts to vegetation as a result of groundwater drawdown are addressed in Section 5.4 and Section 5.5.
	Impacts to stygofauna, troglofauna and SRE invertebrates	Impacts to stygofauna and troglofauna are addressed in Section 5.7. Impacts to SRE invertebrates are addressed in Section 5.6.
	Impacts to visual amenity, landscape and geodiversity values	Impacts to visual amenity and landscape values are addressed in Section 5.9. Impacts to geodiversity values are addressed in Section 6.2.
DoIR	Native Title status of Proposal area	The Proposal area is located within the Native Title claim of the Eastern Guruma people (Section 5.8).
	Aboriginal heritage	Aboriginal heritage values are addressed in Section 5.8.
	Coolibah woodland community	The potential effects of the Proposal on the Coolibah woodland north of Marandoo are described in Section 5.5.

Stakeholder	Topics raised	Proponent response
DoW	Impacts from surface disposal of water will need careful consideration and consultation	The Proponent has considered a range of options for the management of excess water in line with the DoW hierarchy of water management methods (Section 4.6.1). Management of excess dewatering water is addressed in Section 5.3.
	Any potential impact to Karijini National Park needs to be closely assessed	Potential impacts to Karijini National Park are addressed in Section 5.1.
	Sinkholes	The potential for sinkhole development as a result of the Proposal is addressed in Section 5.2.
	Clarification as to whether mine pit voids will act as sinks or throughflows	Potential impacts to groundwater (including whether mine pit voids will act as sinks or throughflows) have been considered in preliminary closure planning (Section 5.10).
	Clarification of whether the intention was to backfill the pit to above groundwater level	Mine pits are currently planned to be backfilled to at least 1 m above the pre-mining watertable but this is subject to the results of groundwater modelling, or requirements of other interested stakeholders (Section 5.10).
DEWHA	No specific issues raised with regard to the EPBC Act	The Proposal was referred to the Commonwealth DEWHA under the EPBC Act on 13 September 2007. On 19 October 2007, the DEWHA confirmed that the Proposal does not constitute a 'controlled action' as defined by the EPBC Act.
Shire of Ashburton	Shire building approvals	Quarterly meetings are held between the Proponent and the Shire to update each project as required.
	Effects of Fly in/Fly out on Tom Price community	Ongoing consultation with Shire of Ashburton.
	Job opportunities continuing with Marandoo life extension	Ongoing consultation with Shire of Ashburton.
	RSF location	The RSF is proposed to be located to the south-west of the existing Marandoo rail loop, which poses fewer operational constraints and reduced environmental risk than potential RSF locations south of Marandoo Ridge (Section 1.5.3).
	Socio-economic, particularly tourist attractiveness issues regarding camp location in proximity to Karijini National Park	The potential impacts of development near Karijini National Park are addressed in Sections 5.1 and 6.7.
	Timing of PER review periods, level of consultation and scope of PER	Review periods are set by the EPA and ongoing consultation with Shire of Ashburton will continue.
Non-government organisations		
Conservation Council of WA	Impacts from dewatering need to account for extreme climatic events, for example, droughts, when assessing impacts to Karijini National Park	The combined effect of dewatering and extreme climatic events (for example, droughts) on Karijini National Park is addressed in Section 5.5.
	Any impacts to Karijini National Park will not be acceptable	Potential impacts to Karijini National Park are addressed in Section 5.1.
	Consideration of increasing fuel costs and carbon taxes in closure costs	Closure costs are reviewed annually and closure plans are completely updated every five years. Any significant changes to closure costs (including increased fuel costs and carbon taxes) will be considered during closure reviews to ensure adequate closure provisions are in place (Section 5.10).
	Impacts to fauna	Potential impacts to fauna as a result of the Proposal are addressed in Sections 5.6 and 5.7.
	Assessment of visual impacts important	Impacts to visual amenity and landscape values are addressed in Section 5.9.

Stakeholder	Topics raised	Proponent response
Community		
Eastern Guruma people	Employment opportunities	Eastern Guruma contracting companies will be given opportunities to tender for all projects in accordance with existing arrangements.
	Protection of heritage sites	Protection of identified Aboriginal heritage sites is addressed in Section 5.8.
	Closure and rehabilitation	Closure and rehabilitation is addressed in Section 5.10.
	Impacts to springs from dewatering	The potential impact of the Proposal to springs is addressed in Section 5.1, 5.2 and 5.8.
	Impacts to known heritage sites from dewatering	Impacts to Aboriginal heritage sites from dewatering are addressed in Section 5.8.
	Monetary returns from the proposed projects	There will be significant further commercial and employment opportunities open to the Eastern Guruma people.
	Contract and tendering possibilities during construction and operations	Eastern Guruma contracting companies will be given opportunities to tender for all projects in accordance with existing arrangements.
	Surface area of any surface water/ spring investigations on the Proposal to include Hamersley Station	Impacts in the area of the Southern Fortescue borefield (located on Hamersley Station) will be assessed via a re-injection trial in 2008.
	Effects of dewatering on Karijini National Park	Potential impacts to Karijini National Park are addressed in Section 5.1.
	Information on water management including how the large volume of water will be managed and what effects that would have	The Proponent has considered a range of options for the management of excess water in line with the DoW hierarchy of water management methods (Section 4.6.1). Management of excess dewatering water is addressed in Section 5.3.
	Mining benefits	There will be significant commercial and employment opportunities for the Eastern Guruma people; however, the Hamersley Iron - Eastern Guruma Indigenous Land Use Agreement excludes benefits.
	Possibility of leaving a void for aquaculture purposes at the end of the mine life	Any potential aquaculture development would raise a number of technical, environmental and approval issues and would be addressed at a more advanced stage in the closure planning process, in consultation with stakeholders.
Gumala Aboriginal people	Noted that the Proposal area was not within their country and Eastern Guruma were key group to consult regarding surveys and other aspects of the project Appreciated being given information on the project	Noted.
Pilbara Gorge Tours	Acknowledged there was some unsocial behaviour in the Park at times but were mostly visitors to the area and not full-time mine workers	Potential impacts to Karijini National Park by the Proposal workforce are addressed through the commitment for a comprehensive induction program (Appendix 2).
	Signage at Mount Bruce warning of blasts in the area due to mining would be useful	Potential impacts and management measures as a result of blasting are considered in Section 6.6. Signage at Mount Bruce is considered as a management measure in Section 5.9.
General community - Tom Price and Paraburdoo	Possible environmental effects on the gorges and the surrounding area	Potential impacts to Karijini National Park are addressed in Section 5.1.

Undertaking baseline studies

Several studies were undertaken to describe the existing environment and assess potential impacts of the Proposal.

3.1 Studies undertaken

The following studies were undertaken to investigate the existing environment and potential impacts of the Proposal:

- desktop review and field study investigating potential impacts to the Mount Bruce Flats Coolibah woodland and Mulga (Batini 2008a, 2008b, 2008c)
- terrestrial vegetation and flora surveys and studies to assess potential impacts to the conservation status of species known, or likely to occur in the Proposal area (Biota 2008b)
- terrestrial and subterranean fauna (including Short-Range Endemic (SRE) invertebrates, troglofauna and stygofauna) surveys and studies to assess potential impacts to the conservation status of species known, or likely to occur in the Proposal area (Biota 2008c, 2008d, 2008e)
- hydrogeological and hydrological modelling and studies to investigate potential dewatering water disposal options (including re-injection and surface discharge) and the possible impacts related to the modification of surface flows and groundwater regimes (MWH 2006a, 2006b, 2006c, 2007a, 2008a)
- landscape and visual amenity modelling and studies to assess potential impacts to the Proposal area (SKM 2008)
- Aboriginal heritage surveys and studies, in consultation with the Eastern Guruma people, investigating the presence and significance of Aboriginal heritage features in the vicinity of the Proposal area (Scarp Archaeology 2008)
- desktop noise and vibration assessment to determine potential impacts from the Proposal to nearby receptors (SVT 2008)
- baseline aquatic system field studies to investigate potential impacts to aquatic ecosystems resulting from discharge of excess dewatering water (WRM 2008)
- baseline riparian vegetation field studies to investigate potential impacts to flora and vegetation resulting from discharge of excess dewatering water (Mattiske 2008).

The key studies are listed in Appendix 1 and contained on CD-ROM inside the back cover of this PER.

3.2 Physical environment

3.2.1 Climate

The Pilbara region has an arid tropical climate with two distinct seasons: a summer wet season and a winter dry season (Gentilli 1972). The region experiences very low rainfall, high evaporation and high daytime temperatures.

Summer months extend from October to April, when maximum daily temperatures can exceed 47°C. The winter months extend from May to September, with temperatures ranging from approximately 12°C to 26°C (Figure 5).

Average annual rainfall near Marandoo is approximately 415 mm and is characterised by frequent, low-intensity events related to localised thunderstorms and tropical upper air disturbances, as well as annual high-intensity events associated with tropical cyclones (Beckett 2008). These high-intensity events can result in over 100–200 mm of rain falling within a 24 hour period, often leading to large-scale sheet flooding and considerable erosion.

Average annual evaporation (from a free water surface) in the vicinity of Marandoo is approximately 1840 mm (Figure 5), which greatly exceeds average annual rainfall and contributes to the arid environment in the area

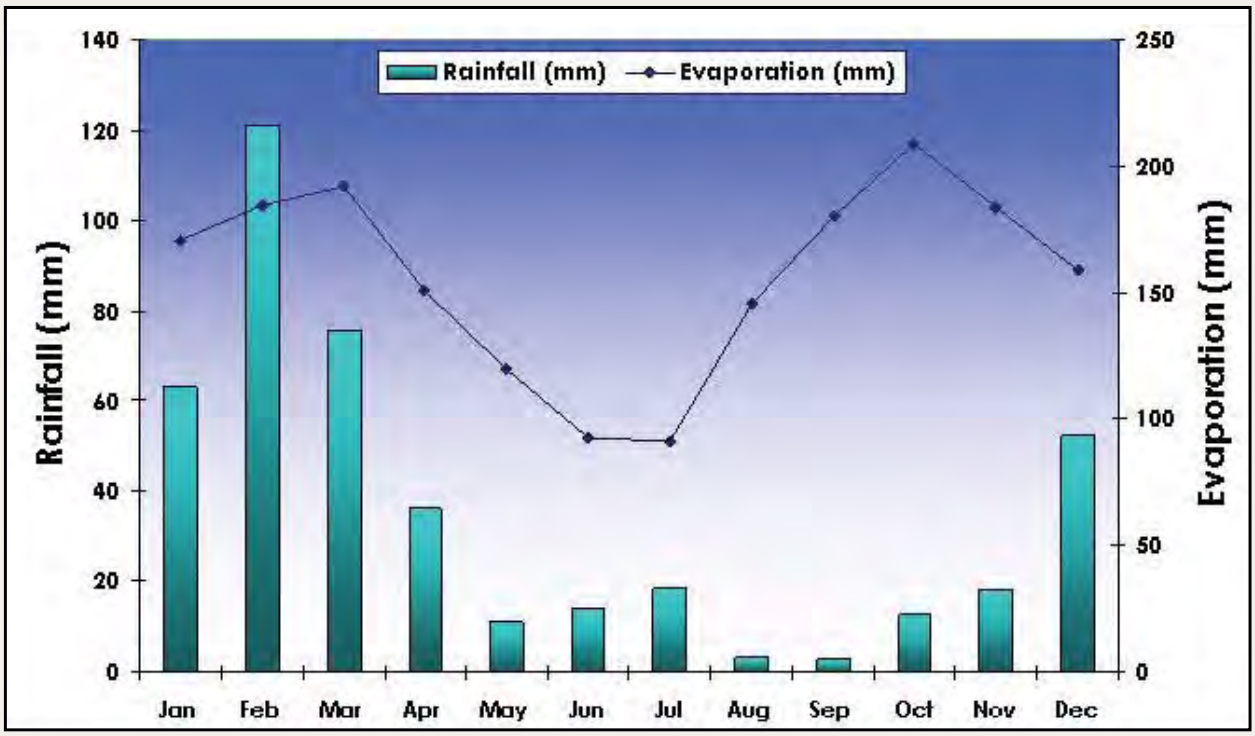
3.2.2 Landforms and soils

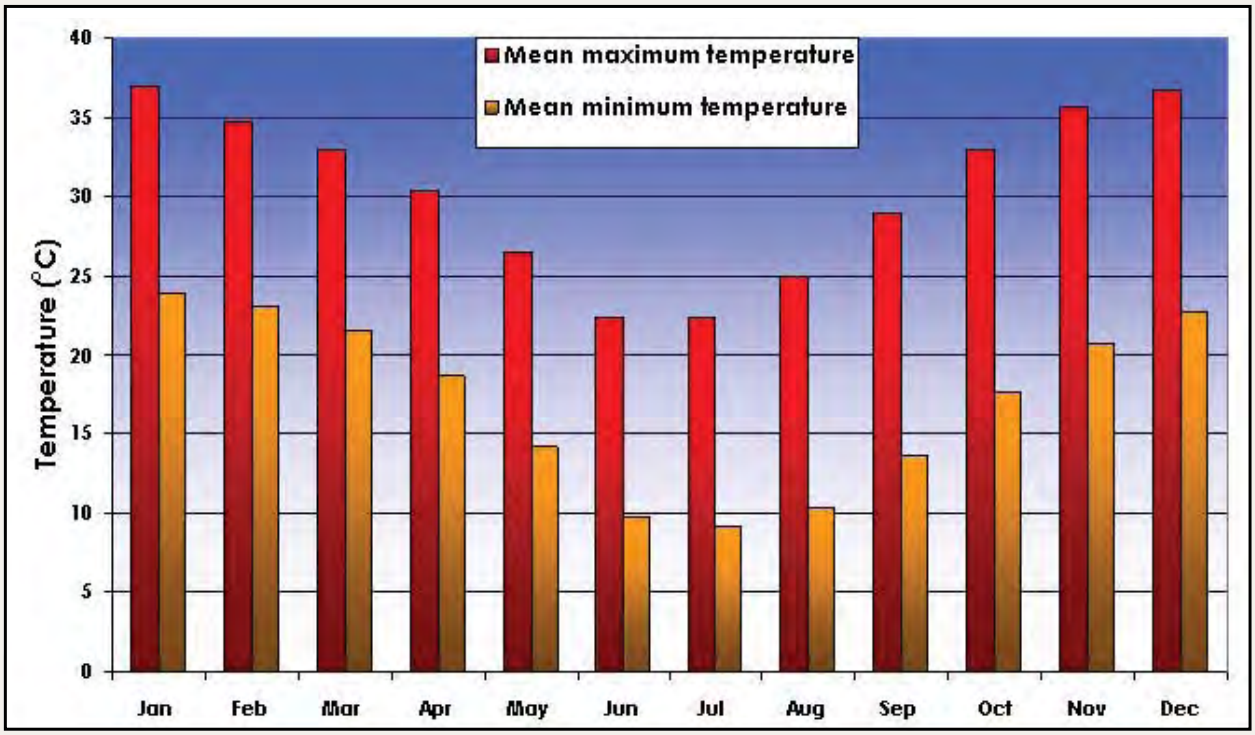
The Proposal area lies within the Hamersley Plateau as defined by Beard (1975a, 1975b). The Hamersley Plateau is characterised by rounded hills and ranges with large, expansive plains with calcrete limestone platforms or cracking clays. Wider alluvial plains occur locally, with soils (in part) deep, earthy loams, with small areas of neutral red earths and deep-cracking clays and earthy clays.

The northern edge of the Hamersley Plateau is bounded by a prominent scarp dissected by northward flowing streams and a series of spectacular gorges. The central portion of the Plateau comprises a mixture of elevated plains, valley floors and a series of hills over 1000 m high, running along a north-west/south-east axis (including Mount Bruce, which at 1235 m above sea level is the second-largest mountain in Western Australia).

The Marandoo mine site is located on the north side of a low, curvilinear outcropping of Marra Mamba iron ore (Marandoo Ridge), approximately 3 km south-south-east of Mount Bruce (Figure 6). Marandoo Ridge drains northwards towards a major, flat-lying, internally-draining basin known as the Mount Bruce Flats. The colluvium that forms the lower slopes of the Marandoo ridge is incised by a small number of drainage lines conveying runoff from the upper slopes.

Soils on the Marandoo Ridge are predominantly very thin red lithosols (weathered rock fragments), with uniform stony and skeletal loams on the lower slopes of the northern side of Marandoo Ridge. Soils become finer and soil depth increases towards the centre of the Mount Bruce Flats, where extensive areas of brown clay to depths greater than 1.5 m support a *Eucalyptus victrix* (Coolibah) open woodland, interspersed with *Acacia aneura* (Mulga) (CALM 1999).



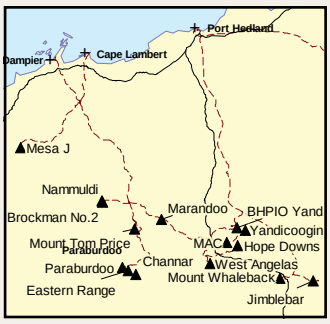


Rio Tinto

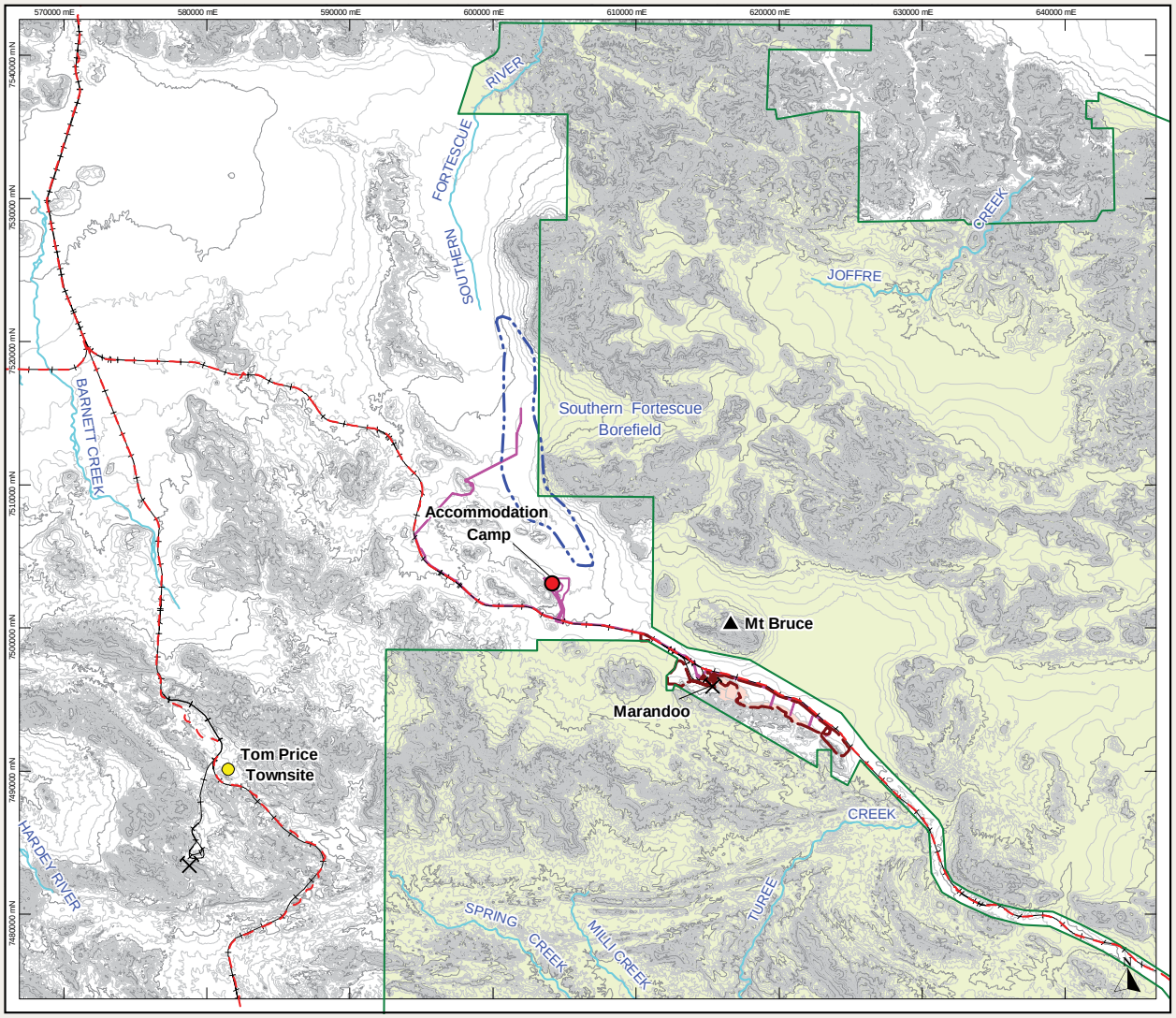
Figure 5
Marandoo Climate

Drawn:TC
Date:April 2008

Plan No:PDE0049509v1
Proj:GDA94



Source: Marandoo meteorological station data (1999-2007)



Rio Tinto

Strategic Assets - Perth

Figure 6
Marandoo Topography and Landforms

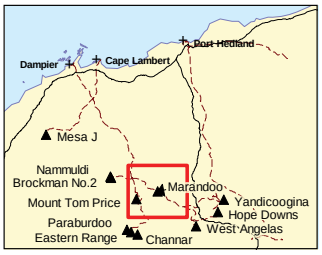
Drawn: TC
Date: Feb 2008

Plan No. PDE0049509v1
Proj: MGA94-50

LEGEND

- Railway
- Private Road
- Major River/creeks
- Contours Index
- Contours Intermediate 10m
- Mine
- Accommodation Camp
- Town
- Karijini National Park
- Current Approved Pit
- Proposed MMP2 Disturbance Footprint
- MMP2 Project Disturbance

LOCATION MAP



SCALE

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3.2.3 Land systems

The Proposal area occurs across three land systems, as mapped by van Vreeswyk et al. (2004) (Figure 7):

- Newman: rugged jaspilite plateaux, ridges and mountains supporting hard spinifex grasslands
- Boolgeeda: stony lower slopes and plains at the base of hill systems supporting hard and soft spinifex grasslands and Mulga shrublands
- Jurrawarrina: hardpan plains and alluvial tracts supporting Mulga shrublands with tussock and spinifex grasses.

3.2.4 Geology

Five geological units occur within the Proposal area (Table 4). The target geology for the Proposal is part of the Marra Mamba Iron Formation, which is the basal stratigraphic unit in the Hamersley Group. This unit is overlain by erosional remnants of the Wittenoom Formation and thick sequences of tertiary sediments (alluvials and clays) (Figure 8).

Table 4
Geological units occurring within the Proposal area

Unit	Geological Description
Qw	Undivided Quaternary deposits; includes colluvium, reworked alluvium, Aeolian sand, clay
Qa	Alluvium - unconsolidated silt, sand, and gravel; in river channels
AHm	Marra Mamba Iron Formation: chert, Banded Iron Formation, mudstone, and siltstone; metamorphosed
AFj	Jeerinah Formation: carbonaceous mudstone and siltstone, thin-bedded sandstone, chert, felsic volcaniclastic rock, basalt, and dolomite; metamorphosed
Czc	Undivided Cainozoic deposits; includes partly consolidated colluvium and alluvium, and silcrete and laterite

Source: Thorne and Trendall (2001)

The Hamersley Group is located within the Hamersley Iron Province in the Pilbara region and contains approximately 95% of the iron ore resources known to occur in Australia. The Hamersley Iron Province comprises Archaean rock sequences overlain by a thick Proterozoic volcanic and sedimentary succession known as the Mount Bruce Supergroup. This Supergroup comprises three distinct rock assemblages; the Fortescue Group, the Hamersley Group and the Turee Creek Group (CALM 1999).

Rocks of the Hamersley Group are about 2500 million years old, dating from the late Archaean and early Proterozoic time periods. The Group is approximately 2.5 km thick and comprises five major and several minor Banded Iron Formations (BIFs)[6], separated by shales and dolomites. The detrital and channel iron deposits of the Hamersley Group occur where enriched BIFs have been exposed at the ground surface and subsequently eroded and/or transported and redeposited (CALM 1999).

The surface expression of the Hamersley Group covers an area of approximately 10 000 000 ha. Within the Group, the two BIF units of economic importance are the Brockman Iron Formation (620 m thick) and the Marra Mamba Iron Formation (230 m thick).

The Marandoo deposit is described in more detail in Section 4.4.

The Southern Fortescue River Valley is located west of Marandoo with the geology consisting of outcropping Brockman Iron Formation overlying Mount McRae Shale and Wittenoom Formation (MWH 2007b). This system is regionally underlaid by the Marra Mamba Iron Formation. Alluvium and colluvium deposits overlying calcrete and goethite intercalated with sand have accumulated as a result of erosional and depositional processes (MWH 2007b; Figure 9).

3.2.5 Surface hydrology

Marandoo Ridge forms the southern boundary of the Mount Bruce Flats sub-catchment, which in turn forms the upper reaches of the Turee Creek regional catchment. The western and northern boundaries of the Mount Bruce Flats sub-catchment form the drainage divide between the Turee Creek regional catchment and the Fortescue River regional catchment (Figure 10). Like all major rivers in the Pilbara, Turee Creek, Fortescue River and their tributaries are ephemeral and flow only occasionally, generally following heavy rain (Ruprecht and Ivanescu 2000).

The natural hydrological regime of Marandoo Ridge has already been modified by the railway (Figure 2), which intercepts and re-directs surface runoff generated across the northern side of Marandoo Ridge. The majority of surface water runoff generated on Marandoo Ridge during low-intensity rainfall events infiltrates the soil and does not reach the Mount Bruce Flats. Surface runoff draining into the Mount Bruce Flats following major rainfall events flows towards a low-lying area in the centre of the basin (Liquid Earth 2005). This area may become inundated for an extended period of time (Batini 2008a). After sufficient rainfall (150 mm), water from the Mount Bruce Flats may flow south-east across the sub-catchment divide into the Turee Creek catchment (Beckett 2008).

6 Banded Iron Formations consist of alternating iron (occurring as oxides, carbonates and/or silicates) and chert (silica-rich material deposited as microcrystalline quartz). These formations occur where the rock has been locally enriched with iron in situ.

The Southern Fortescue borefield, operations campsite and the dewatering infrastructure route are located within the Southern Fortescue River Valley (containing the Southern Fortescue River sub-catchment). The borefield is located near the upper reaches of the Southern Fortescue River. The Southern Fortescue River system features perennial flow and permanent pools only in Hamersley Gorge. Small, shallow pools occur intermittently in the upper reaches of the system; however, these pools would not be expected to persist long into the dry season (WRM 2008).

The hydrology of the Proposal area is described in more detail in Section 5.3.

3.2.6 Groundwater hydrogeology

The Proposal involves interaction with groundwater resources at both Marandoo and the Southern Fortescue borefield.

The groundwater resource at Marandoo consists of two primary aquifer units:

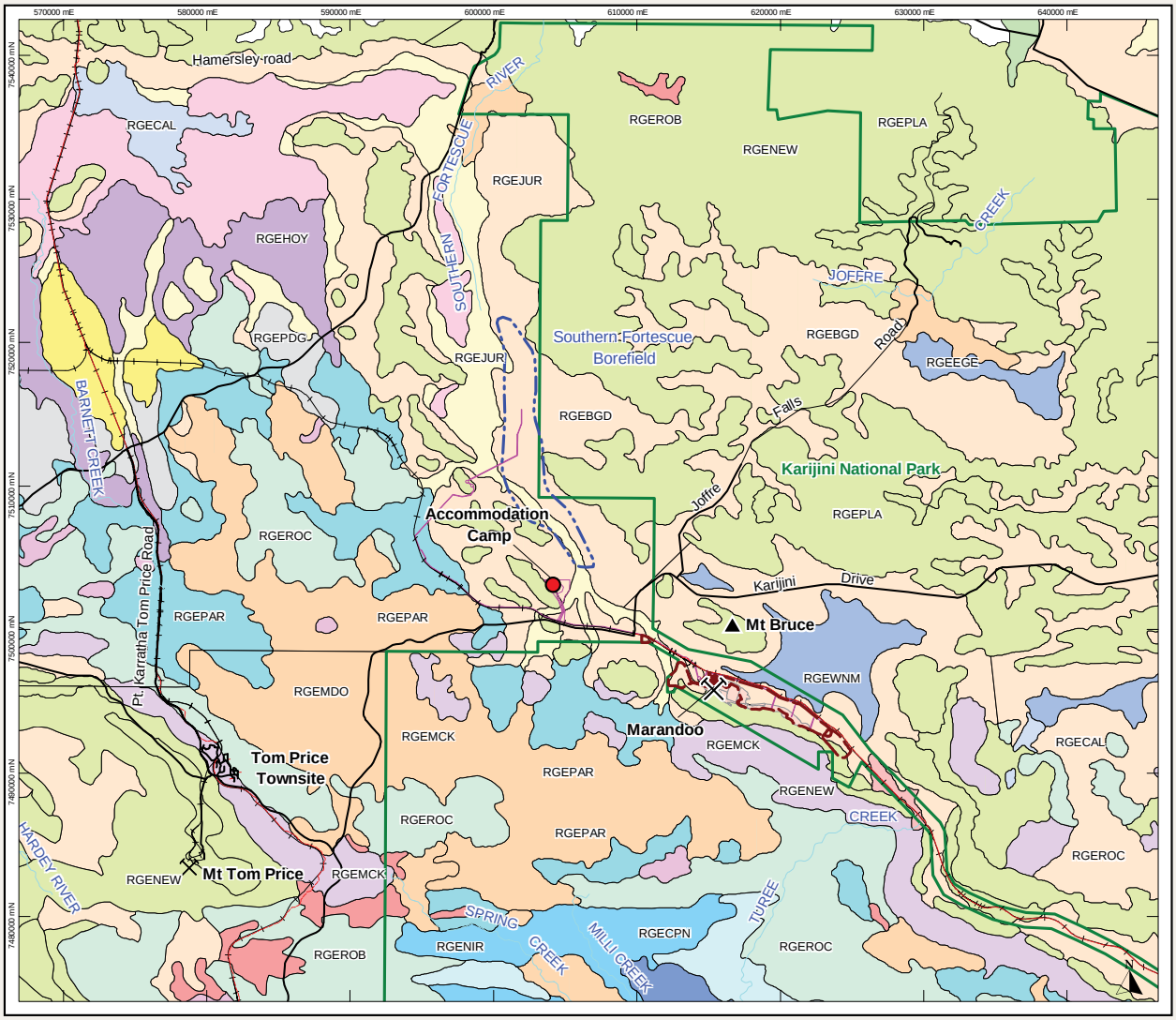
- a shallow, unconfined aquifer hosted by a calcrete horizon within a Cainozoic valley fill sequence ('unconfined aquifer')
- a deeper, lower Tertiary detrital and Proterozoic bedrock aquifer hosted by the Marra Mamba Iron Formation and the Wittenoom Formation ('confined aquifer') (Figure 11).

Groundwater within the unconfined aquifer occurs at depths below ground level of between 18 m on the Mount Bruce Flats and 50 m on the flanks of Marandoo Ridge (Liquid Earth 2005). The confined and unconfined aquifers are separated by a sequence of valley fill clays commonly up to 40 m in thickness across the Mount Bruce Flats and act as an effective aquitard between the two aquifers (Liquid Earth 2005; Youngs and Brown 2005).

The unconfined aquifer is recharged mostly in the area of the Coolibah woodlands on the Mount Bruce Flats (Figure 11). Following recharge of the unconfined aquifer, groundwater flows radially outward from the resulting groundwater mound. The confined aquifer is recharged where dolomite outcrops or sub-crops occur around the northern and eastern margins of the Mount Bruce Flats and at the base of Mount Bruce (MWH 2006c; Figure 11).

The Southern Fortescue aquifer system is located in the Southern Fortescue River Valley west of the mine and is found predominantly in the Wittenoom Formation and overlying calcrete and palaeovalley deposits (MWH 2007b). The aquifer system is bounded to the west and east by outcropping Brockman Iron and Marra Mamba Iron Formations (MWH 2007b). Water is supplied to Tom Price from this aquifer system via abstraction at the Southern Fortescue borefield. The Southern Fortescue aquifer is recharged via groundwater throughflow from the Mount Bruce Flats catchment area and infiltration through outcropping BIF rocks to the west and east of the borefield (MWH 2007b).

The hydrogeology of the Proposal area is described in more detail in Section 5.2.



RioTinto

Strategic Assets - Perth

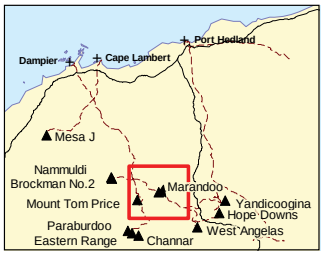
Figure 7
Marandoo
Land Systems

Drawn: TC
Date: April 2008
Plan No. PDE0049509v1
Proj: MGA94-50

LEGEND

- Railway
- Road
- Private Road
- River/creeks
- Mine
- Accommodation Camp
- Karijini National Park
- Current Approved Pit
- Proposed MMP2 Disturbance Footprint
- MMP2 Project Disturbance
- RGEBGD Boolgeeda Land System
- RGEJUR Jurrawarrina Land System
- RGENEW Newman Land System

LOCATION MAP



SCALE

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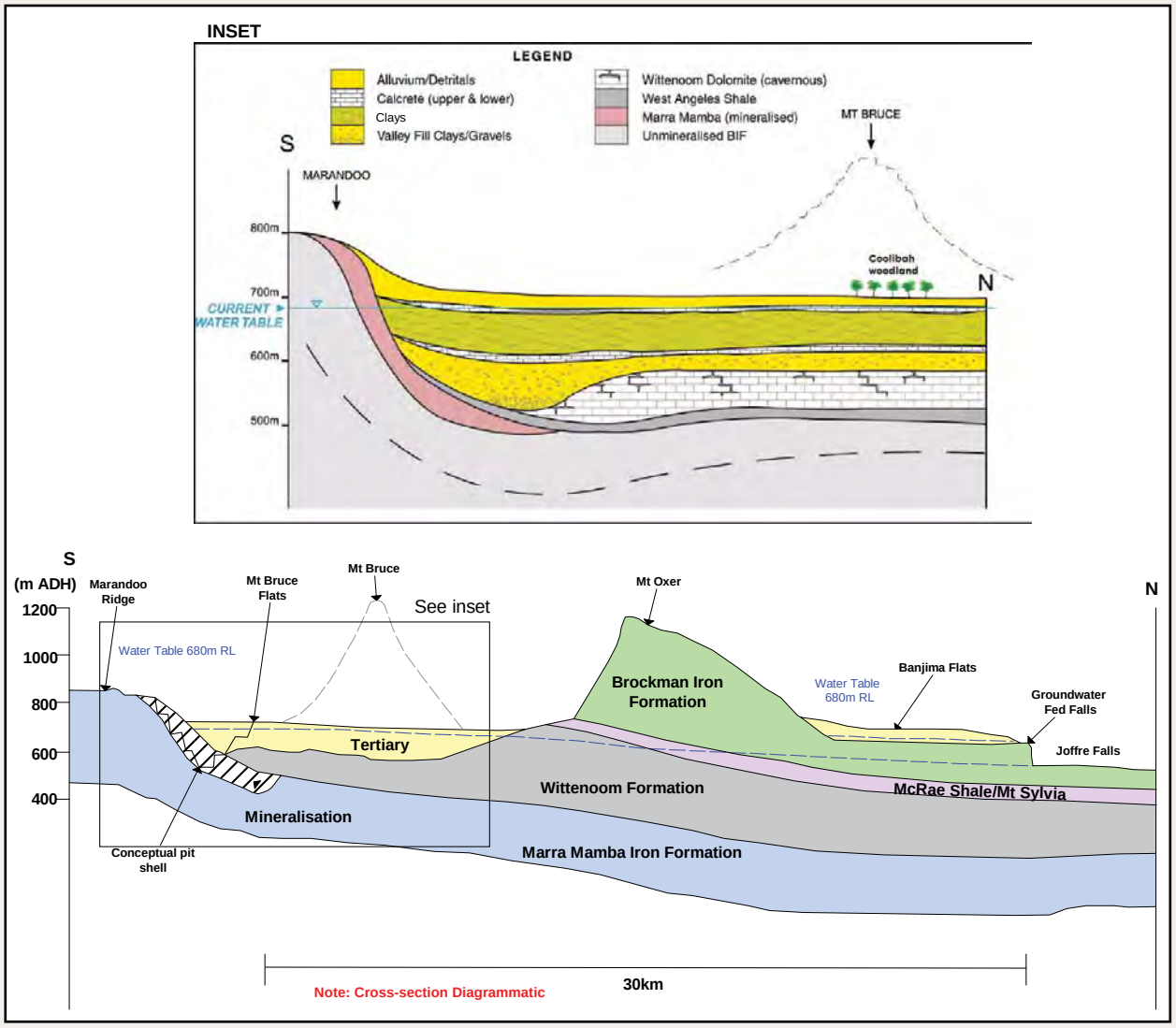
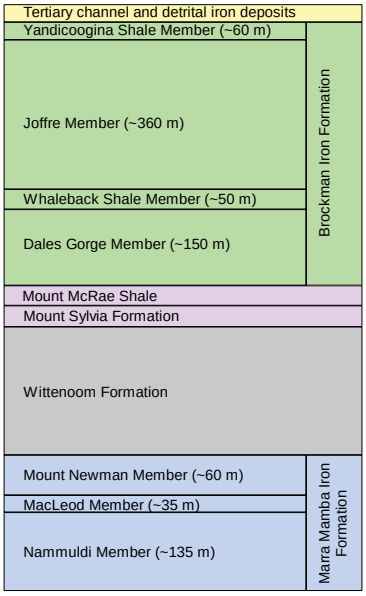


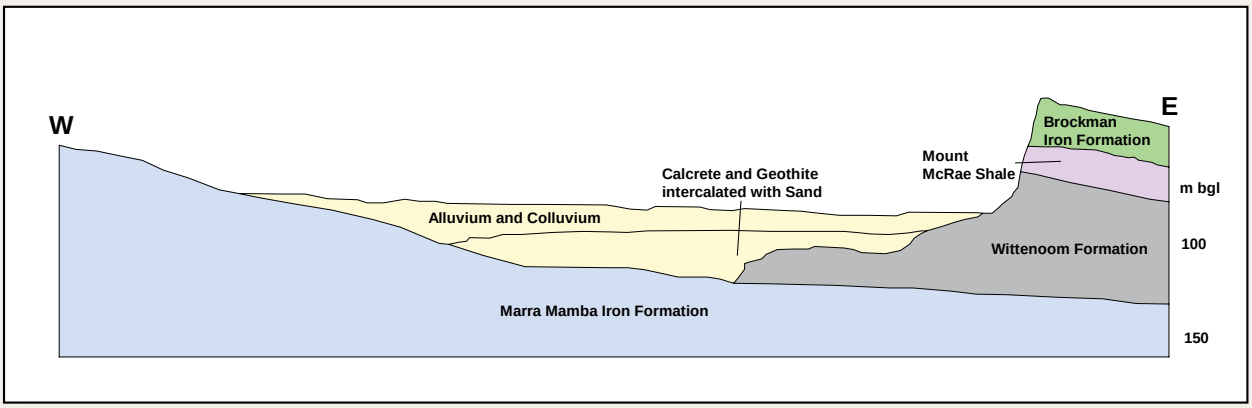
Rio Tinto

Strategic Assets - Perth

Figure 8
Schematic of Marandoo Geology

Date:June 2008 Plan No.:PDE0049509v1



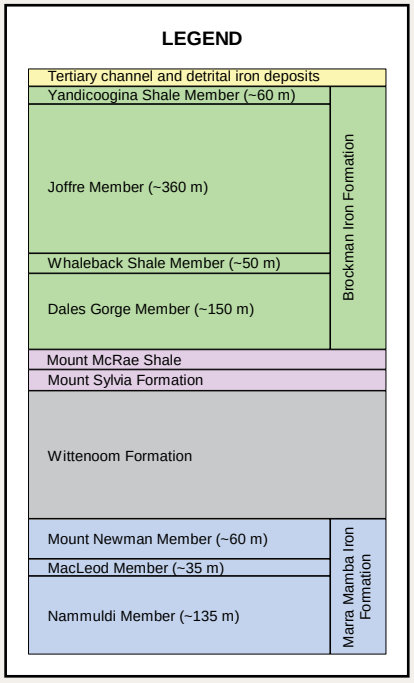


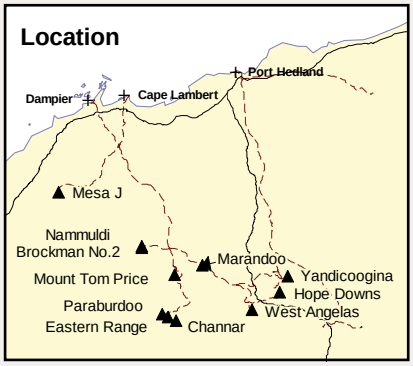
Rio Tinto

Strategic Assets - Perth

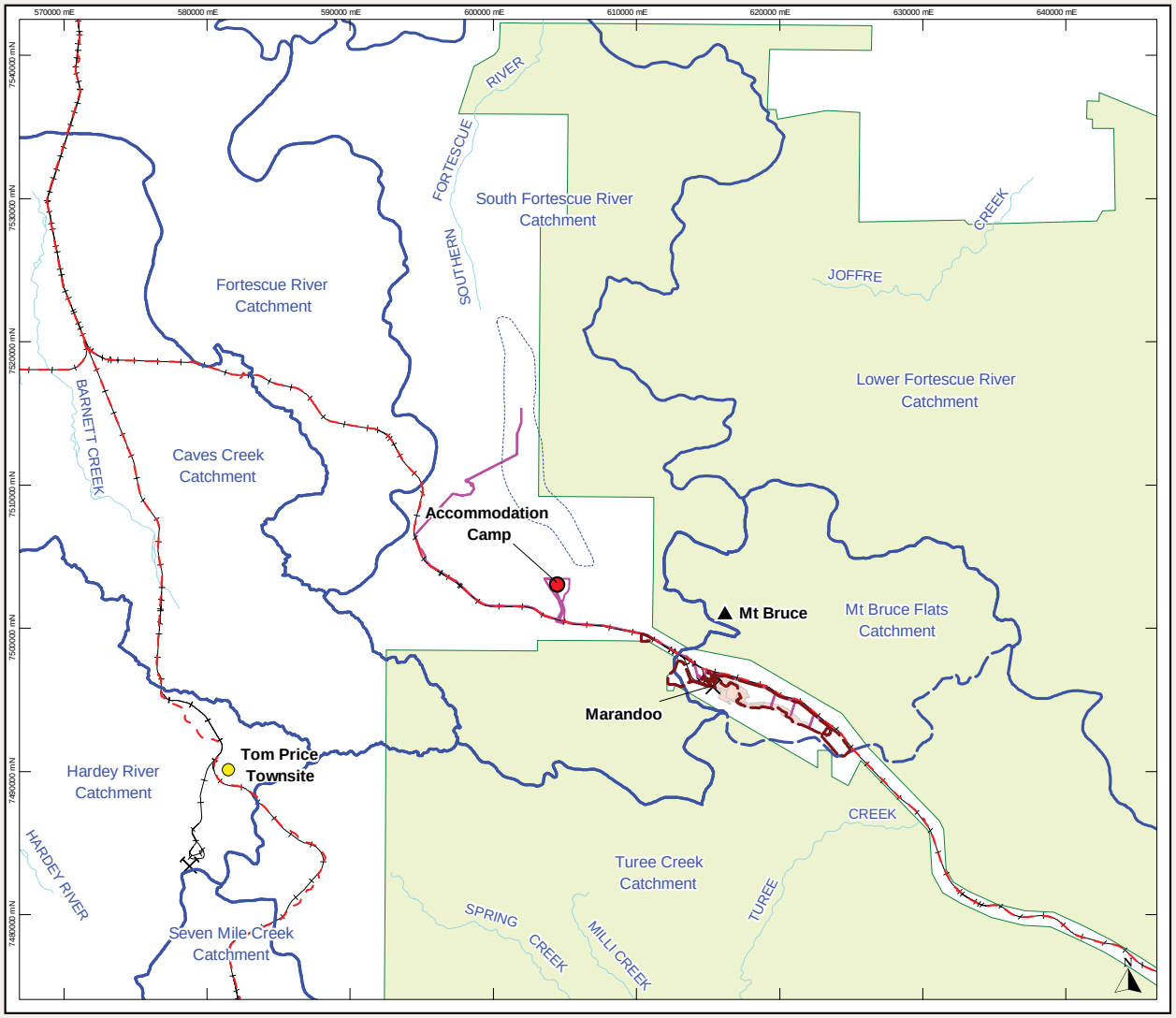
Figure 9
Schematic of Southern Fortescue Geology

PDE0049509v1





Note: Cross-section Diagrammatic



Rio Tinto

Strategic Assets - Perth

Figure 10
Marandoo Surface Water Catchments

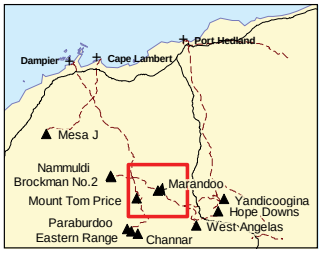
Drawn: TC
Date: Feb 2008

Plan No. PDE0049509v1
Proj: MGA94-50

LEGEND

- Railway
- Private Road
- Major River/creeks
- Surface water catchments
- Sub-catchment divide
- Southern Fortescue Borefield
- Mine
- Accommodation Camp
- Town
- Karijini National Park
- Current Approved Pit
- Proposed MMP2 Disturbance Footprint
- MMP2 Project Disturbance

LOCATION MAP



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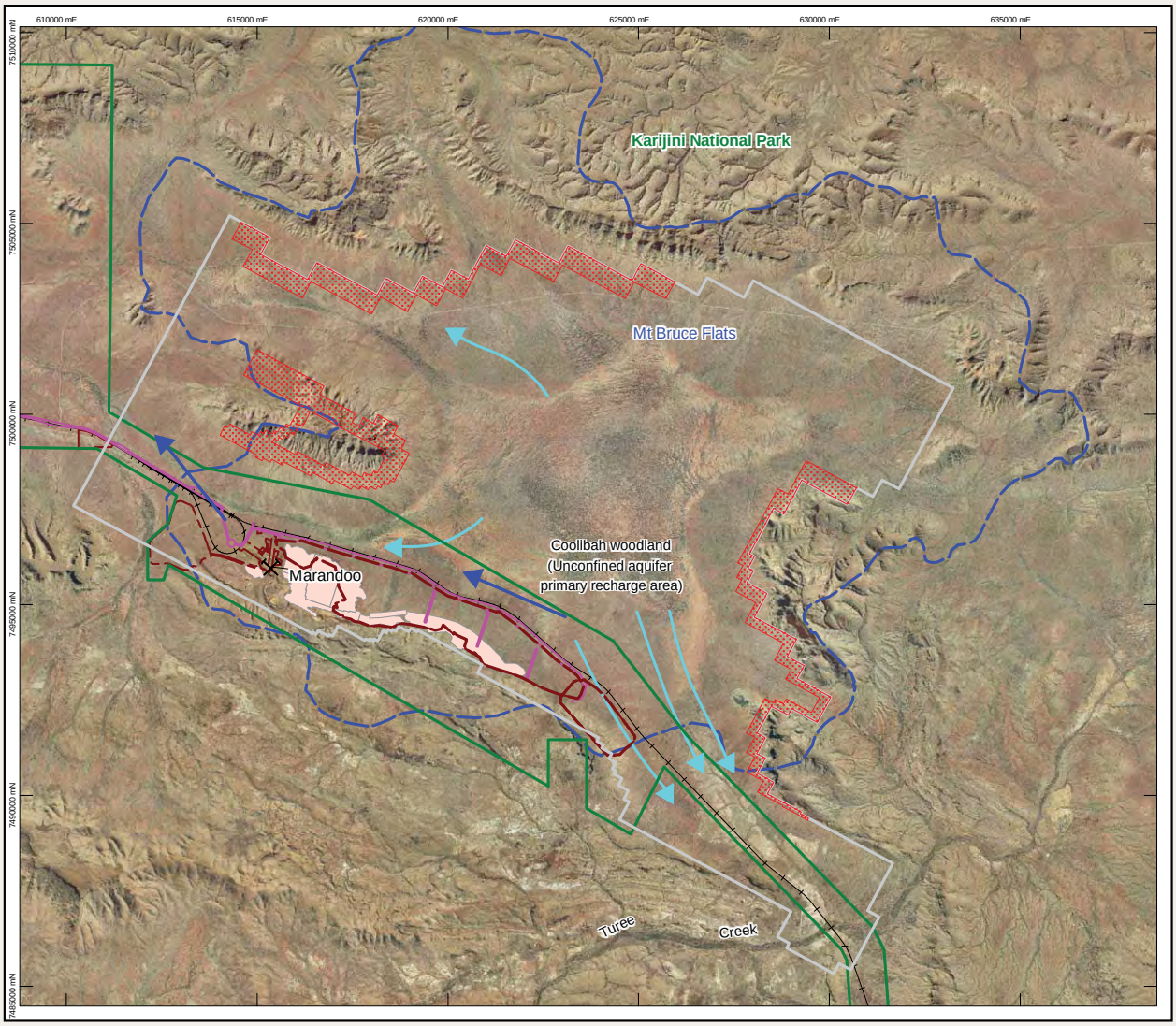


RioTinto

Strategic Assets - Perth

Figure 11
Marandoo
Hydrogeology

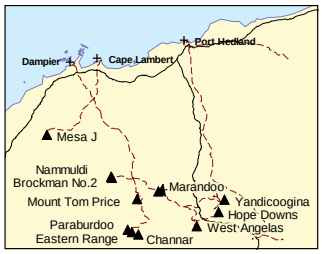
Drawn: TC
Date: Feb 2008

Plan No. PDE0049509v1
Proj: MGA94-50

LEGEND

- Railway
- Unconfined Aquifer
- Confined Aquifer
- Mine
- Surface water catchment
- Current Approved Pit
- Proposed MMP2 Disturbance Footprint
- MMP2 Project Disturbance
- Karijini National Park
- Active Model Area
- Confined aquifer recharge areas

LOCATION MAP



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3.3 Biological environment

3.3.1 Biogeographic region

The Interim Biogeographic Regionalisation for Australia divides the Australian continent into 85 bioregions, and then into 405 sub-regions according to major geomorphic features (Environment Australia 2000). The bioregions defined in the classification scheme are the largest units the EPA will consider in its assessment of impacts to biodiversity.

The Proposal area is located within the Hamersley sub-region of the Pilbara Biogeographic Region. The Hamersley sub-region is a mountainous area of Proterozoic sedimentary ranges and plateaux, dissected by basalt, shale and dolerite gorges. Ranges within the sub-region typically feature *Eucalyptus leucophloia* (snappy gum) over spinifex on skeletal soils. Valley floors within the sub-region generally comprise low Mulga woodlands over hummock grasses on fine textured soils (Kendrick 2001).

3.3.2 Vegetation and flora

The Proposal area is located within the Fortescue Botanical District of the Eremaean Botanical Province as defined by Beard (1975a, 1975b). The vegetation of this province is typically open and dominated by spinifex, acacias and occasional eucalypts. The vegetation units can be divided according to topography into six main groups as:

- broad drainage areas and basins
- major flow lines and creeks
- minor creeks
- flats
- ridges and erosional spurs
- low foothills and escarpments.

Five hundred and thirty-six (536) native vascular flora species[7] from 176 genera and 60 families have been recorded by Biota (2008b) and/or Mattiske (1992) in the vicinity of the Proposal area. Twenty (20) species of introduced flora (weeds) from 18 genera belonging to 11 families were also recorded in the area (Biota 2008b).

Declared Rare Flora and Priority Flora

No Declared Rare Flora (DRF) species have been recorded from the Proposal area (Biota 2008b) and none were recorded downstream of the preferred dewatering discharge points (Mattiske 2008). Of the two DRF species known to occur in the Pilbara region, the Proposal area contains suitable habitat for only *Lepidium catapycnon* (Hamersley Lepidium) (Biota 2008b).

Four Priority flora species have been recorded within the Proposal area, all of which have also been recorded in the Marandoo locality outside of this area (Section 5.4). This includes two Priority 1 species, *Goodenia lyrata* and *Rhagodia* sp. Hamersley (M.E. Trudgen 17794), the Priority 2 *Indigofera ixocarpa* and Priority 4 *Eremophila magnifica* subsp. *magnifica*. No Priority flora species have been recorded downstream of the preferred dewatering discharge points (Mattiske 2008).

Vegetation units of conservation significance

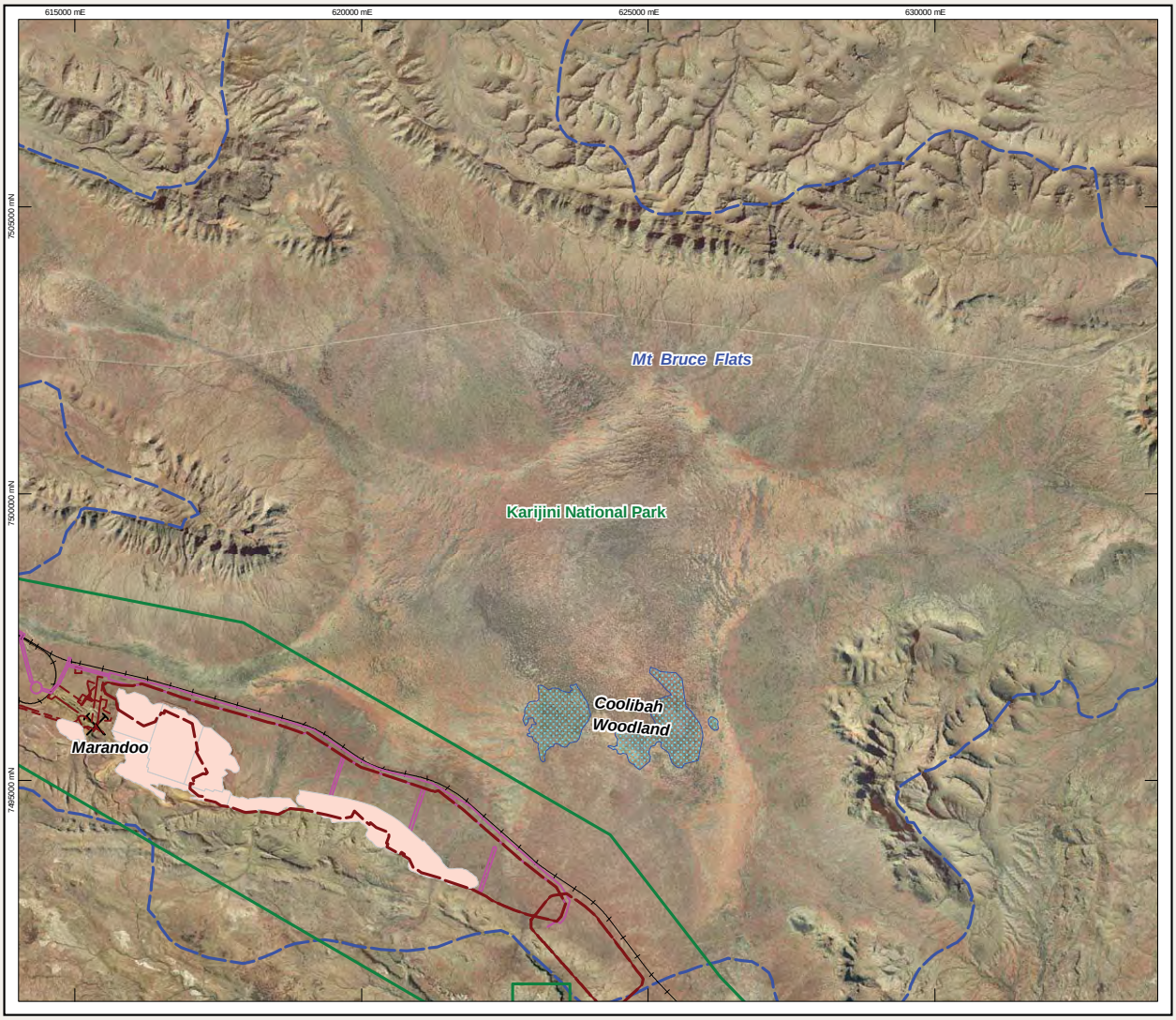
Vegetation units within Karijini National Park are of elevated conservation significance as they are representative of the vegetation of the Hamersley Range and are in relatively pristine condition compared to the highly modified ecology of surrounding pastoral stations (Australian Heritage Commission 1992; CALM 1999). Vegetation within the Park ranges from grasslands to closed forests, with the predominant vegetation type being *Acacia* shrubs and/or *Eucalyptus* trees over *Triodia* hummock grasslands.

An area of Coolibah woodland approximately 2 km north of Marandoo (Figure 12) is listed by the DEC as a Priority Ecological Community (as an example of a Coolibah woodland occurring outside riparian systems) and is considered to be a wetland of national importance (English 1999). The extensive areas of Mulga within Karijini National Park are generally recognised to be species-rich (Biota 2008b) and potentially support restricted taxa. Mulga is also considered to be close to the northern edge of its range in the Pilbara (Fortech 1999).

There are no Threatened Ecological Communities or Priority Ecological Communities in the study area, and no vegetation units of high conservation significance in the MMP2 disturbance area.

The vegetation and flora of the Proposal area is described in more detail in Section 5.4. Mulga and the Coolibah woodland on the Mount Bruce Flats are described in more detail in Section 5.5.

7 This value is likely to be an over-estimate of total native species in the lease area as it incorporates species recorded by Biota (2008b) and species designated only to genus level by Mattiske (1992).



RioTinto

Strategic Assets - Perth

Figure 12
Coolibah Woodland

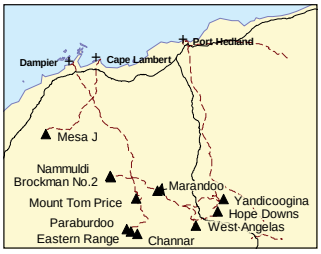
Drawn: TC
Date: May 2008

Plan No. PDE0049509v1
Proj: MGA94-50

LEGEND

- Railway
- Mine
- Surface water catchment
- Karijini National Park
- Current Approved Pit
- Proposed MMP2 Disturbance Footprint
- MMP2 Project Disturbance
- Coolibah Woodloand (Indicative 2007 Data)

LOCATION MAP



SCALE

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Scale: 1:100,000@A4

3.3.3 Terrestrial fauna

The major fauna habitats within the Hamersley Ranges are hummock grasslands, Mulga low-woodlands and fringing vegetation of pools and streams (CALM 1999). Particularly important, but less extensive habitats include:

- the gorges of the northern plateau, which provide refuge for humidophiles[8] and fire intolerant species
- the various permanent/semi-permanent pools (often associated with the gorges), which provide habitat for aquatic vertebrate and invertebrate fauna and are an important source of water to many terrestrial fauna species in an otherwise seasonally dry environment
- rock crevices, caves, hollow trees and other specialised habitats that may provide roosting sites for bats (CALM 1999; Kendrick 2001).

Broad terrestrial fauna habitat types recorded at Marandoo, the operations camp site, the Southern Fortescue borefield and along the proposed dewatering infrastructure corridor include small drainage lines, stony hill slopes, flat outwash plains and rocky gorges (Biota 2008c, 2008d).

Fauna surveys undertaken since the mid 1970s in the Marandoo mining lease and adjacent areas have recorded up to 247 fauna species (Mees 1961; Texasgulf 1979; Kitchener and Vicker 1981; National Parks Authority 1983; Ninox 1992). Recent work undertaken by Biota (2008d) recorded a total of 125 terrestrial fauna species in the mining lease, including:

- 54 avifauna species
- 51 herpetofauna species
- 20 mammal species
- three potential Short Range Endemic (SRE) invertebrate species.

Historically ten fauna species of elevated conservation significance have been recorded during the surveys of the mine lease.

Terrestrial fauna of the Proposal area are described in more detail in Section 5.6.

3.3.4 Subterranean fauna

Subterranean fauna are predominantly invertebrate animals that inhabit underground habitats. These fauna include stygofauna (obligate groundwater-dwelling aquatic fauna) and troglofauna (obligate terrestrial fauna that inhabit air chambers in underground caves or small, humid, air-filled voids) (EPA 2003).

Calcrete and alluvial aquifer systems in the Pilbara region contain stygofaunal communities that, by global standards, are very diverse (Humphreys 1999). Stygofauna are thought to perform important ecosystem functions in aquifers and in hyporheic zones (the saturated zone under rivers or streams), such as maintenance of water quality (Boulton 2000; Hancock 2002; EPA 2003).

The range of geological formations that troglofauna may inhabit has yet to be determined, but they are most commonly associated with limestone deposits, most probably due to their karstic nature (Biota 2006). Troglofauna have also been less commonly associated with lava tubes (Garth Humphries [Biota Environmental Sciences] 2007, pers. comm., 23 November), and more recently in pisolite iron formations (Biota 2006). Three of the essential characteristics for troglofauna habitat are cavities, high humidity and stable temperatures (EPA 2003; Biota 2006).

Calcrete deposits, including localised aquifers in the Hamersley Range, are considered to be important refuges and centres of endemism for troglofauna and stygofauna in the Hamersley sub-region (CALM 1999).

A total of 70 specimens of subterranean fauna were collected during sampling by Biota (2008e) at thirteen (13) impact sites (greater than 2 m predicted drawdown) and 30 reference sites in the vicinity of Marandoo mine.

The subterranean fauna in and around the Proposal area are described in more detail in Section 5.7.

3.3.5 Aquatic fauna

The aquatic macroinvertebrate assemblages of the tributaries of the Southern Fortescue River system have not been documented; however, a number of sites on the Fortescue River proper (and its tributaries) have been previously sampled as part of a wider program throughout Western Australia. The majority of aquatic macroinvertebrate families recorded at these sites are common, widely distributed and relatively ubiquitous in the Pilbara region, and would be expected to appear in pools along the Southern Fortescue River following surface flows and given sufficient time to allow fauna to colonise the system (WRM 2008).

The fish fauna of the Pilbara is characterised by low species diversity and high levels of endemism. Fish inhabiting the Pilbara are adapted to the extreme conditions that occur in the region and many have adaptations for surviving drought. Life history stages of fish in the Fortescue River system vary between 'opportunistic' and 'periodic', reflecting the seasonal, yet unpredictable nature of rainfall in the region. No introduced fish species have been recorded from the Fortescue River system (WRM 2008).

3.3.6 Weeds and introduced animals

Introduced cattle, goats, horses and donkeys, as well as particularly invasive weed species such as *Cenchrus ciliaris* (buffel grass) and *Acetosa vesicaria* (ruby dock) are listed among the key threatening processes to ecosystems in the Pilbara (Commonwealth of Australia 2007a). Introduced cats are among the most commonly listed threatening processes to native species at risk in the Pilbara (Commonwealth of Australia 2007b).

8 Humidophiles are plant or animal species that prefer and/or have a strong affinity for humid environments.

Weeds can spread into natural environments by many agents, including wind, water, people, vehicles, machinery and both native and introduced animals. Weeds are often able to rapidly invade locations subject to disturbance, land clearing and/or altered fire regimes. Weeds can smother and replace native plants and have the potential to dominate and simplify natural ecosystems. They may also lead to significant changes to ecosystems and fire regimes (EPA 2008b).

Introduced animals can have detrimental effects on native animals through competition for food or habitat, destruction or degradation of habitat, predation and the introduction of diseases or parasites (EPA 2008c).

Twenty (20) weed species have been recorded within the Proposal area, generally occurring as scattered individuals and predominantly associated with Mulga (Biota 2008b). Almost half the weed species recorded within the Proposal area belong to two families: the Asteraceae (daisies) and Poaceae (grasses). Introduced animals recorded at Marandoo include donkeys, cats and house mice (Biota 2008d).

3.3.7 Fire

Fire is an important natural feature of the Western Australian landscape and many native plant species have adaptations and/or life-cycle characteristics directly linked to fire, heat, ash or smoke (Hopper 2003; EPA 2008d). Traditional Aboriginal practices involved using fire in hunting, cultural activities and land management which combined with fires ignited by natural causes (generally due to lightning strikes), resulted in a mosaic of vegetation units at various stages of succession (CALM 1999). Since European settlement, these mosaic patterns have changed in many areas such that there is now a more even distribution of fuel load (Dixon and Barrett 2003).

Altered fire regimes (both too much and too little fire) have the potential to result in loss of biodiversity through changes in species composition within ecosystems, as well as inadequate recovery times for fire-sensitive species and inadequate reproduction times for species that rely on heat, ash and/or smoke for germination, regeneration and/or seedling nutrition. The ultimate effect of a fire regime will depend on numerous factors, including fire frequency, seasonality, intensity and extent (EPA 2008d).

Mulga, a fire-sensitive species, is often found growing in the Pilbara in association with vigorous and dense stands of highly-flammable, fire tolerant spinifex (*Triodia* sp.). The frequency of fire-related deaths in Mulga communities in the Pilbara is very high compared to communities elsewhere that occur in association with shrubby or short-grass species (Fortech 1999). Frequent and/or intense fires have the potential to eliminate Mulga communities, particularly if fires are followed by prolonged dry periods (Fortech 1999).

3.4 Social environment

3.4.1 Socio-economic setting

The Proposal is located within the Shire of Ashburton (Pilbara region), approximately 37 km east of Tom Price and 77 km north-east of Paraburdoo. The Shire of Ashburton covers an area of over 100 000 km^2 and has an economy based on mining, pastoral operations and commercial fishing operations (Shire of Ashburton 2008).

The continuing activities of various Rio Tinto subsidiaries in the area contribute significantly to the economy and employment in the Shire. Both the Tom Price and Paraburdoo townships were originally built by the Proponent to service nearby mine sites and are currently largely sustained by ongoing mining activities in the region.

3.4.2 Land use and tenure

Land use and tenure in and around the Proposal area (Figure 13) comprises:

- mining on AML70/272 (Marandoo mining lease) in accordance with the *Iron Ore (Hamersley Range) Agreement Act 1963* (WA)
- conservation of flora and fauna within Karijini National Park
- pastoral activities on Hamersley Station (predominantly cattle grazing)
- Southern Fortescue borefield infrastructure on special leases L3116/6045 and L3116/6044
- Rosella Siding to Homestead Junction mainline rail (operated by the Proponent)
- access roads (Karijini Drive and Hamersley-Mount Bruce Road) and infrastructure corridor (Reserve 41696)
- proposed operations camp (L47/234)
- mineral exploration.

In accordance with existing arrangements, two areas of the Hamersley Station pastoral lease (totalling approximately 31 953 ha) will be excluded from the lease and incorporated into Karijini National Park when the lease is renewed under the *Land Administration Act 1997* (WA) in 2015 (Figure 13). This will include the area surrounding the Southern Fortescue borefield infrastructure and the proposed switchyard. In recognition of resource development potential in the area and existing tenements granted to the Proponent, appropriate land tenure may be granted to allow the Proponent ongoing access to allow for resource development or management of infrastructure in this area.

A management agreement under Section 16A of the *Conservation and Land Management Act 1984* (WA) is also planned between the Proponent and the DEC for a portion of Hamersley Station (Figure 13). However, the MMP2 Proposal does not infringe on this area. Under this agreement, the land will be retained within the pastoral lease, but will be managed cooperatively by the Proponent and the DEC, with the Proponent retaining access to mining leases within this area. This management agreement will include assistance by the Proponent with aspects such as fence construction and maintenance, fire management planning, introduced species control and management of native *Themeda* grasslands, including research and monitoring.

3.4.3 Karijini National Park

The Marandoo mine lease and rail corridor were excised from the A-Class Karijini National Park in 1991. The Park provides for the conservation of approximately 10% (greater than 600 000 ha) of the Hamersley sub-region and contains a representative sample of many of the landscapes, geological types, and flora and fauna communities of this area (CALM 1999).

The value of the Park as a representative example of the Hamersley Range is increased by its relatively pristine condition compared to the highly modified ecology of surrounding pastoral stations (Australian Heritage Commission 1992). The Park and surrounding areas are also of significance to contemporary Panyjima, Yinhawangka and Kurrama Aboriginal people (CALM 1999).

Karijini National Park is renowned for its biological and geological diversity, as well as its scenic values. The Park is one of the primary tourist attractions in the Pilbara region and attracts over 100 000 visitors each year. The most popular locations within the Park are the northern gorges and their associated waterfalls and pools, along with Mount Meharry and Mount Bruce (the highest points in the state) (CALM 1999).

The existing values of Karijini National Park and the potential effects of the Proposal on these values are described in more detail in Section 5.1.

3.4.4 Aboriginal heritage, culture and Native Title

Archaeological investigations provide evidence that Aboriginal people have occupied the Pilbara region for at least 30 000 years. More than 30 distinct socio-linguistic groups occupied the region, living off, and managing the natural resources according to their law (Pilbara Development Commission 2008).

The Pilbara region has cultural value and includes many Aboriginal sites of significance (Australian Natural Resources Atlas 2007). Archaeological and ethnographic surveys in the vicinity of Marandoo have identified many heritage sites along Marandoo Ridge, or closely associated with water sources, ranging from low to high significance (Scarp Archaeology 2008).

Aboriginal heritage sites within the Marandoo mining lease consist of rock shelters, camps, stone artefact scatters, tree scars, grinding patches, mythological and ceremonial sites, and a quarry. Most of the highly significant Aboriginal heritage sites occur outside the Proposal area on the upper slopes of the surrounding escarpments. Numerous sites of scatters and artefacts of low to moderate significance are located within the Proposal area.

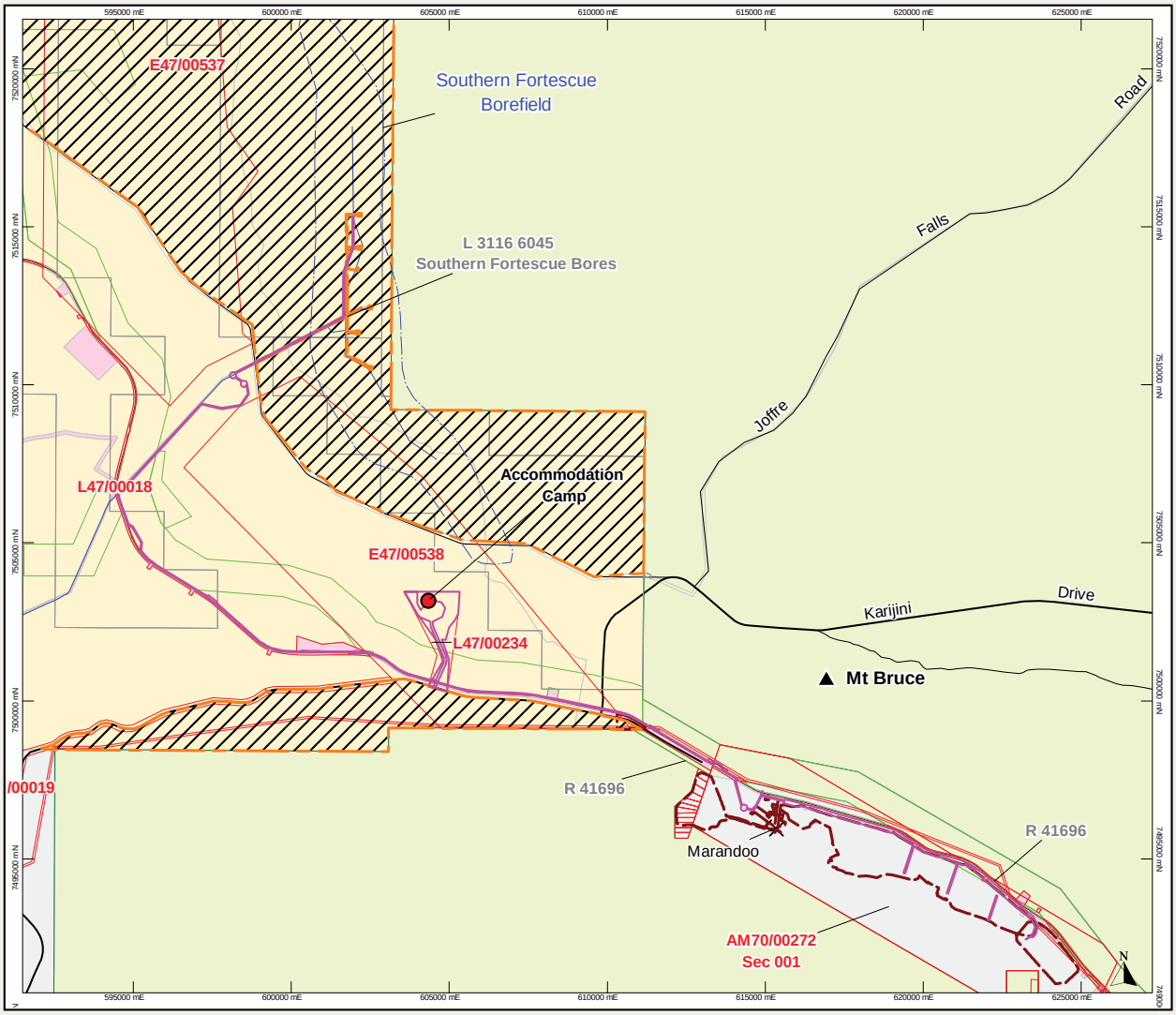
A number of pools and springs in the vicinity of Marandoo also have Aboringal heritage and ethnographic value.

Aboriginal heritage values in, and around the Proposal area are described in more detail in Section 5.8.

3.4.5 European heritage and culture

The Marandoo mine lease is adjacent to Karijini National Park, which is listed in the Commonwealth Register of the National Estate. The Park is recognised for its biological and geological diversity, scenic and scientific value, and its value as a representative example of the Hamersley Range. The Wittenoom Gorge Geological Area and the Woongarra Gorge Area are also listed in the Register of the National Estate. Much of the area of the Wittenoom Gorge Geological Area is within the northern area of the Park, south of Wittenoom. The Woongarra Gorge Area is outside Karijini National Park, approximately 70 km north-west of Paraburdoo.

Numerous places within the nearby towns of Tom Price and Paraburdoo are listed on the Heritage Council of Western Australia Database including police stations, fire stations, schools and war memorials.



RioTinto

Strategic Assets - Perth

Figure 13
Marandoo land use and tenure

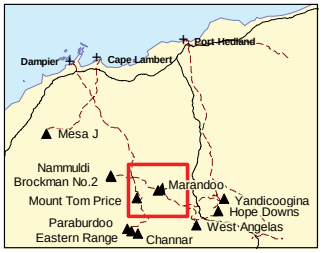
Drawn: TC
Date: Feb 2008

Plan No. PDE0049509v1a
Proj: MGA94-50

LEGEND

- Railway
- Road
- Private Road
- River/creeks
- Water Pipeline
- Mine
- Accommodation Camp
- Southern Fortescue Borefield
- Proposed MMP2 Disturbance Footprint
- MMP2 Project Disturbance
- Proposed Exclusion Area
- Hamersley Iron Tenements Live
- Robe Tenements Live
- Hancock Tenements Live
- Other Tenements Live
- National Park
- Pastoral Lease
- Special Lease
- Reserve

LOCATION MAP



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How Marandoo will expand

The Proponent proposes to expand mining operations at Marandoo by mining below the watertable, which will entail significant expansion of the existing mine pit and development of new waste dumps.

4.1 Development overview

Authorisation to implement the original Proposal for the Marandoo mine was granted through Ministerial Statement No. 286 (issued in 1994) and subsequent approvals under Section 45C of the EP Act.

This authorisation is confined to the extraction of ore above the watertable. The Proponent currently produces approximately 15 Mtpa of high grade iron ore from the mine, which is railed to Dampier and/or Cape Lambert for blending with ore from the Proponent's other operations. At current production rates, active mining would cease at Marandoo by the end of 2012, as above watertable resources are exhausted.

The MMP2 Proposal will allow continued production from Marandoo for 15–20 years[9]. The mining component of the Proposal will remain within State Agreement lease AML 70/272.

The Proponent proposes to expand mining operations at Marandoo by mining below the watertable, which will entail significant expansion of the existing mine pit and development of new waste dumps. While accessing the below watertable ore, some remnant above watertable ore may also be recovered. The Proposal will utilise existing infrastructure and services associated with the existing Marandoo mine operations; however, new infrastructure to service the expanded operations will also need to be constructed (Figure 14 and Figure 15).

In relation to this PER, the 'proposed area' comprises areas to be cleared for the MMP2 Proposal, whilst the 'project area' comprises areas to be cleared for construction of dewatering infrastructure and the accommodation camp, which is not part of the MMP2 Proposal and will be subject to a separate environmental approvals process under the EP Act (Figure 14 and Figure 15).

The key components of the Proposal are:

- expansion and deepening of the existing open cut pit below the watertable (up to 150 m below ground level)
- utilisation, expansion and modification of the existing 'run of mine' ore stockpile, waste dumps, product, topsoil and subsoil stockpiles, and drainage management structures at Marandoo
- conventional drill and blast using standard 'truck and shovel' mining methods
- modification and extension of the existing dry processing plant to accommodate wet processing
- construction and operation of a Residue Storage Facility (RSF)
- expansion of existing unsealed haul roads for transport of ore from the mine pit
- operation of a dewatering borefield and associated infrastructure to allow dewatering of the confined bedrock aquifer
- operation of a dewatering pipeline from Marandoo to the Southern Fortescue borefield to allow for a conjunctive disposal strategy for excess dewatering water
- adaptation of existing Southern Fortescue borefield production bores and associated pipelines for re-injection, and development of new re-injection bores and associated infrastructure such as intrafield pipelines to allow for disposal of excess dewatering water
- disposal of dewatering water in accordance with the following hierarchy:
  a) re-use on-site
  b) supply to Tom Price
  c) re-injection into the depleted Southern Fortescue borefield
  d) controlled discharge to natural drainage lines
- development of sewage treatment facilities and establishment of a spray irrigation area at Marandoo mine
- construction of additional buildings and infrastructure within the existing disturbed Marandoo operations area
- construction of a new switchyard to connect to the existing 220 kV powerline
- construction of a below-ground 33 kV powerline from the new switchyard to the operations camp infrastructure corridor
- removal of the existing 33 kV powerline between Marandoo and Tom Price
- upgrading or duplication (above or below-ground) of the existing 33 kV powerline from the proposed switchyard to the plant, and operation of an extension of this powerline to the borefield
- construction and use of an operations camp.

The key characteristics of the Proposal are presented in Schedule 1 (Section 8).

9 There are currently insufficient Ore Reserves to supply the forecast/estimated production for this Project. Accordingly, such production is subject to defining satisfactory Ore Reserves for the Project from the current and any further identified mineralisation.

4.2 Exclusions from the Proposal

Aspects excluded from the MMP2 Proposal include:

- the provision of a construction camp
- construction of the dewatering infrastructure
- construction and operation of a pipeline from the existing rail corridor (south of the Southern Fortescue borefield) to Tom Price.

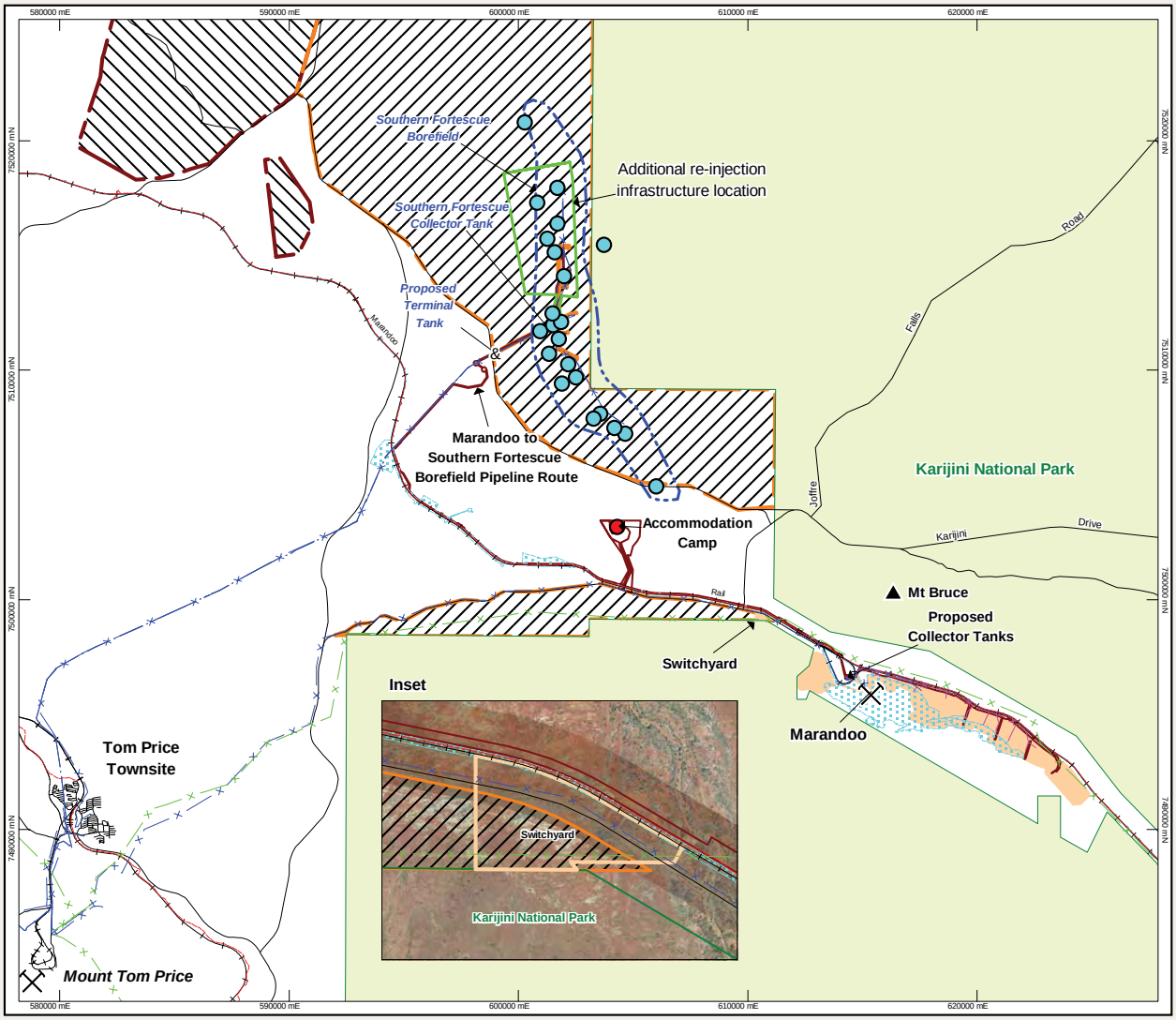
These aspects will be subject to separate environmental approvals processes under the provisions of the EP Act and in accordance with other statutes.

The provision of a construction camp is not included in the MMP2 Proposal as the Marandoo workforce will utilise the same accommodation as that provided for the 320 Rail Project[10] construction workforce. This accommodation will be upgraded and expanded to cater for the operations workforce; however, this will not require additional clearing of vegetation.

The dewatering infrastructure includes that associated with mine dewatering (bores, intrafield pipelines and 33 kV power supply etc) and the dewatering system (pipeline, laydown areas etc) from the mine to the Southern Fortescue borefield. These aspects will be predominantly constructed within already disturbed areas.

The pipeline from the rail corridor (south of Southern Fortescue borefield) to Tom Price was not referred as part of the MMP2 Proposal.

10 The 320 Rail Project is a large-scale construction project involving duplication of the existing rail network servicing the Proponent's operations throughout the Pilbara region.



Strategic Assets - Perth

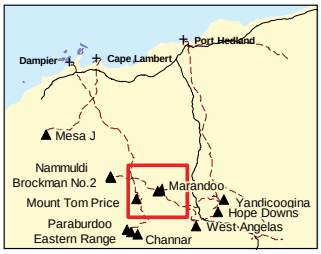
Figure 14
Conceptual Project Area and Infrastructure

Drawn: TC
Date: April 2008
Plan No. PDE0049509v1
Proj: MGA94-50

LEGEND

- Railway
- Road
- Private Road
- 33kV Power Line (Existing)
- 33kV Power Line to Borefield
- 220kV Power Line (Existing)
- Mine
- Karijini National Park
- Proposed Exclusion Area
- Proposed Management Agreement Area
- Existing Disturbance as at 2012
- Proposed MMP2 Disturbance Footprint
- MMP2 Project Disturbance
- Southern Fortescue Borefield
- Observation/Production Bores
- Existing Water Pipeline to Tom Price

LOCATION MAP



SCALE

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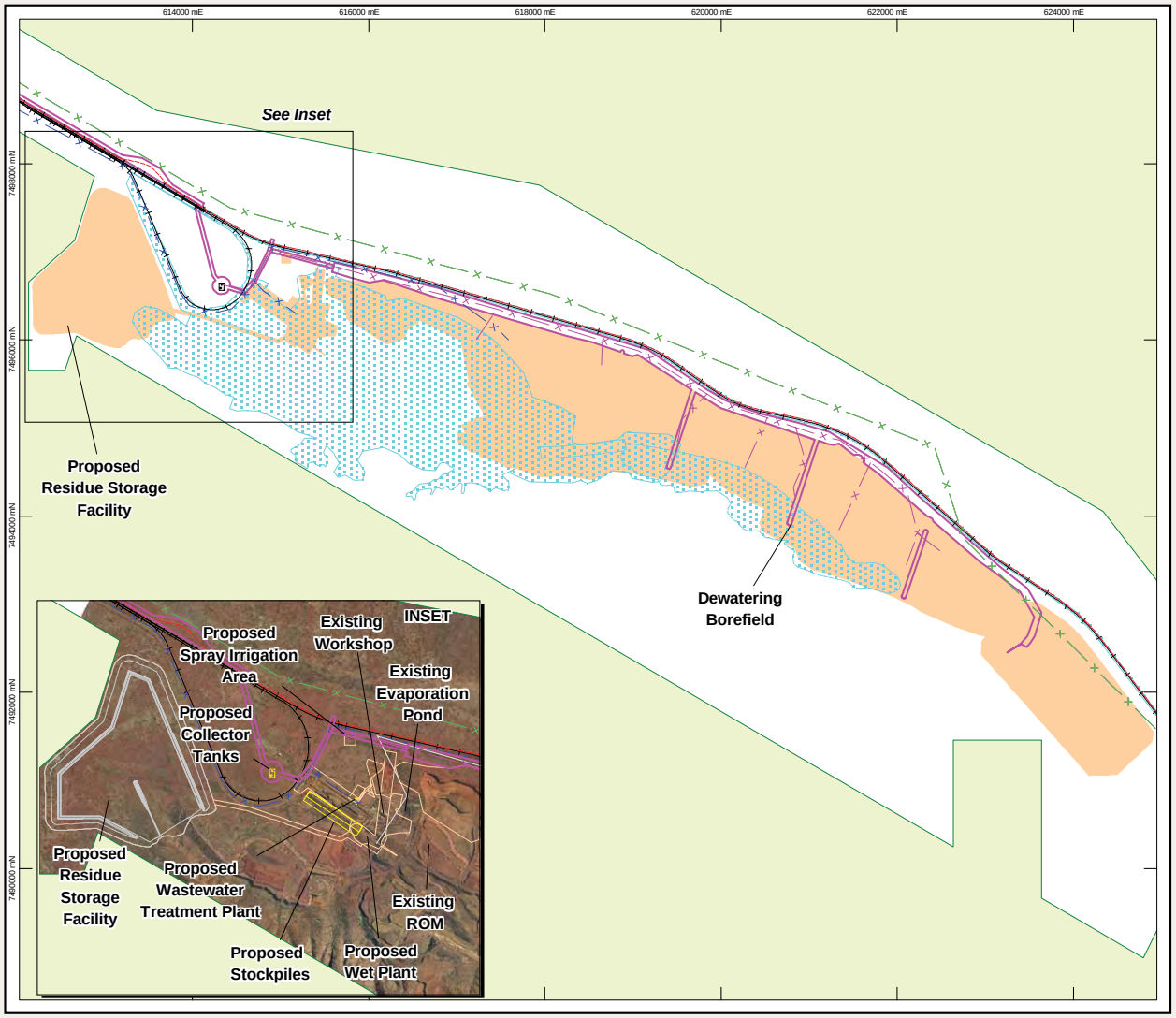

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Strategic Assets - Perth

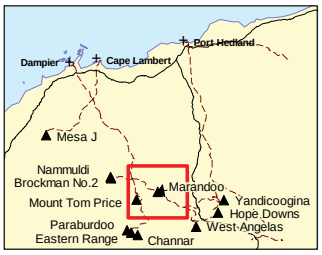
Figure 15
Conceptual Mine Site Layout and Associated Infrastructure

Drawn: TC
Date: May 2008
Plan No. PDE0049509v3
Proj: MGA94-50

LEGEND

- Railway
- Private Road
- 33kV Power Line (Existing)
- 33kV Power Line to Borefield
- 220kV Power Line (Existing)
- Karijini National Park
- Existing Disturbance as at 2012
- Proposed MMP2 Disturbance Footprint
- MMP2 Project Disturbance

LOCATION MAP



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4.3 Development schedule

Dewatering is expected to commence in Quarter 1 of 2010 while pre-stripping is expected to commence in the second half of 2011. Based on this construction start date, initial throughput of ore is expected to commence in Quarter 3 of 2012.

The Proposal is expected to operate for approximately 15–20 years, although this is dependent on a number of factors including defining sufficient Ore Reserves for the Proposal, production rates being achieved, and market conditions.

4.4 Description of resource

To access the ore the proposed mine pit will intersect the upper tertiary clay unit, which is characterised by homogenous high plasticity, stiff to hard, inorganic clay composed predominantly of kaolinite.

The deposit to be mined is part of the Marra Mamba Iron Formation (Figure 8); which is a BIF deposit occurring with minor shale. The deposit consists of alternating iron (occurring as oxides, carbonates and/or silicates) and chert (silica-rich material deposited as microcrystalline quartz).

Approximately 220 Mt of high grade iron ore within the Marra Mamba Iron Formation is expected to be mined, generating an average of 74 Mt of waste per year[11]. The stripping ratio of waste and low grade ore to high grade ore is expected to be approximately 4.5:1.

The Marra Mamba Iron Formation is regionally overlain by the Mount McRae Shale (Figure 8), which can contain pyrite-bearing black shale that poses both a self-heating and Acid Rock Drainage (ARD) risk. However, drilling and geotechnical investigations at the site have indicated negligible amounts of Mount McRae Shale within the proposed mine pit shell and, therefore, ARD is not considered a significant risk at Marandoo.

Furthermore, mineralised Marra Mamba Iron Formation is usually considered to pose an ARD risk only where total sulphur exceeds 0.3%. Interpolated resource model blocks at Marandoo have been generated based on approximately 25 000 samples from the deposit. As all resource model blocks are below 0.3% sulphur, the risk of ARD at Marandoo is considered minimal. Sulphur assays will continue to be monitored throughout the Proposal. Any ARD risk material intersected will be managed in accordance with the Proponent's Mineral Waste Management Plan.

The proposed mine pit shell will also intersect minor amounts of the unmineralised BIF (waste), which contains naturally-occurring crocodilite/asbestos (Section 6.3). However, the surrounding and underlying mineralised Marra Mamba Iron Formation (ore) does not contain asbestiform material.

11 There are currently insufficient Ore Reserves to supply the forecast/estimated production for this Project. Accordingly, such production is subject to defining satisfactory Ore Reserves for the Project from the current and any further identified mineralisation.

4.5 Pit configuration

Two mine pit options were assessed throughout the design, feasibility and planning phases of the Proposal. The 'Economic Pit' being the extent of an expanded pit that maximises economic return, and the 'Limiting Strip Ratio Pit' which represents the pit that minimises the strip ratio (that is the ratio of waste to ore) and, therefore, the volume of mineral waste produced, whilst maintaining an economically-viable operation. The option of developing a pit that falls between these two scenarios is also being considered.

All options are still under consideration; however, this PER focuses on the impacts of the Economic Pit as it represents the largest footprint and the greatest environmental impact.

4.6 Site preparation

4.6.1 Removal of overburden

Overburden will be removed to allow access to the ore as part of the initial stages of pit development. Overburden includes soils and sub-surface material, which may be sub-grade ore or waste.

Soils are an important resource for use in rehabilitation, as they contain a natural seed bank and generally have a substantial amount of organic material and nutrients. Topsoil layers in the Pilbara region are highly variable in thickness, ranging from very little soil development on rocky hillslopes to approximately 300 mm in more densely vegetated valley areas. Subsoil lies directly below the topsoil zone and is not as biologically active as topsoil. Stripped topsoil and subsoil will be stored in separate surface stockpiles located within the Proposal disturbance footprint, for later placement onto areas undergoing rehabilitation.

Any remaining overburden will be removed and transferred to above-ground dumps following the removal of soils. Clayey material will be managed as per strategies provided in Section 6.3.

4.6.2 Site water management

The proposed Marandoo mine pit is located on the north side of Marandoo Ridge and intersects three ephemeral drainage lines that flow northwards towards the Mount Bruce Flats. Sheet flow generated on the ridge is currently intercepted by either the existing mine pit or the existing railway embankment. With the development of the proposed mine pit, runoff generated on Marandoo Ridge will be intercepted only by the proposed mine pit.

An existing diversion drain along the eastern section of the proposed mine pit will channel water from the eastern catchments flowing off Marandoo Ridge around the northern pit wall, along the top of several pit benches (Figure 16 and Figure 17). Local drainage structures will be constructed during pit development to control surface water runoff within the mining area.

Flows entering the mine pit that exceed the capacity of the eastern diversion drain, as well as flows reaching the western sections of the mine pit and incident rainfall within the pit, will be managed to minimise erosion. This will include use of existing engineered erosion control structures to divert water across benches to reduce flow velocity.

Excess water collected within mine pits will be diverted to sumps located as close as practicable to the pit wall, at the base of either the flow entry point, or the bench diversion discharge point. Where water can not be sumped adjacent to the pit wall due to mine sequencing constraints, drainage channels will be constructed along the pit floor to convey flow to the sump area. Sumped water will be monitored and redirected for treatment if required and clean water discharged to culverts through the railway embankment (Figure 17). Existing spreader structures downstream of the culvert outlets will disperse the concentrated surface water flows before the flows reach the Mount Bruce Flats.

The western edge of the proposed RSF intercepts the 100 year floodplain of an ephemeral creek that drains to the north towards the Southern Fortescue River. Diversion bunds and channels will be constructed where required to direct surface flows around the perimeter of the RSF and into the downstream catchment.

Water generated from areas where hydrocarbon use is high (including the processing plant, bulk fuel facility, workshop and washdown facilities) will be directed to a concrete sump prior to discharge into an evaporation pond. Sumped water will be treated to minimise any potential impact to water quality. Once treated, this water may be re-used on-site for dust suppression.

Drainage management is discussed in detail in Section 5.3.5.

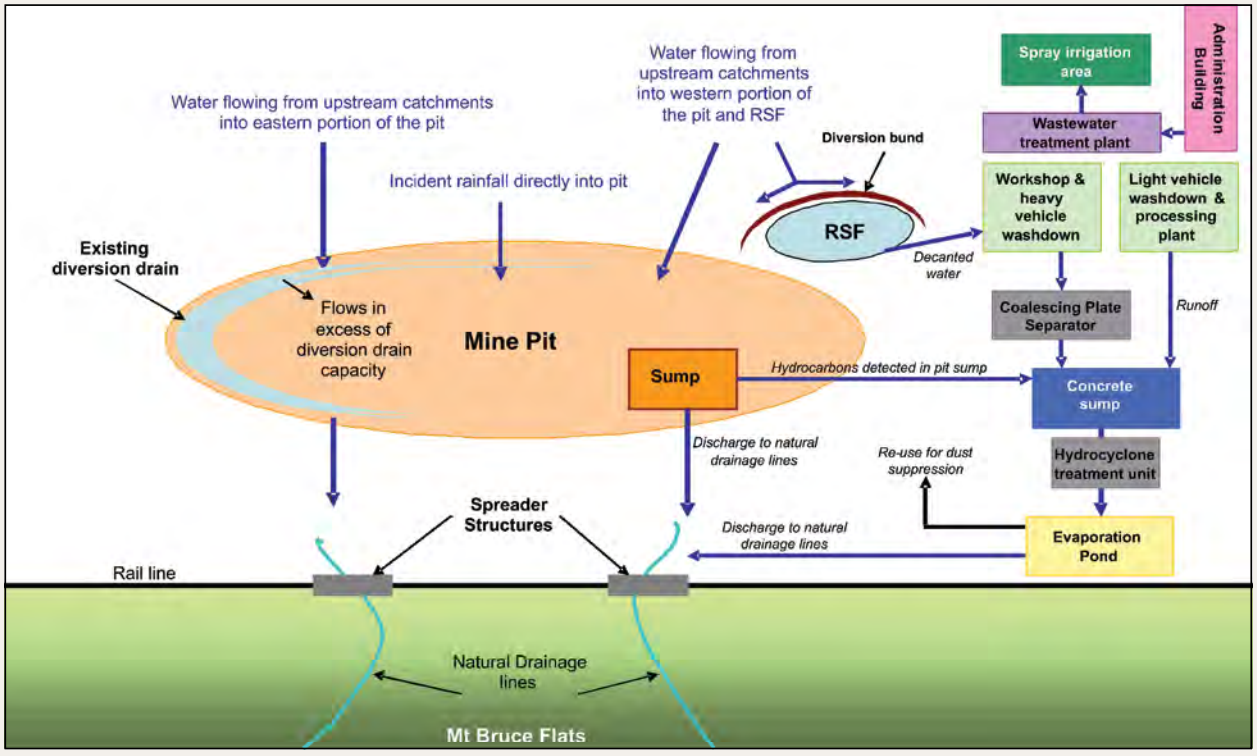
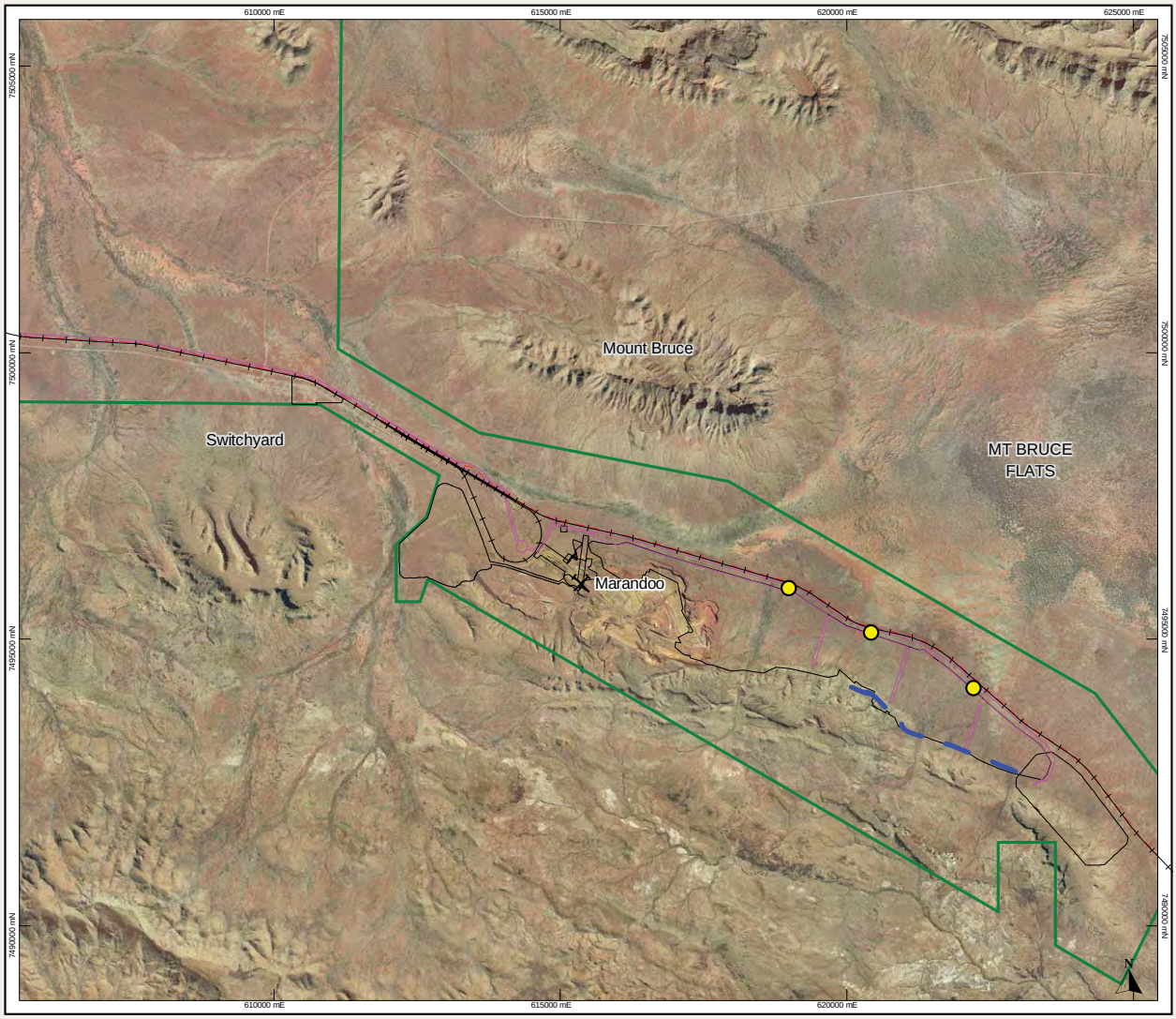


Figure 16
Minesite Water Management



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Strategic Assets - Perth

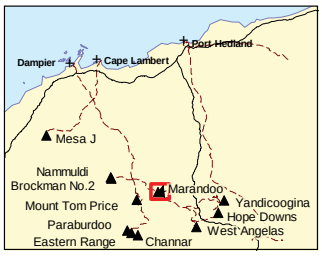
Figure 17
Drainage and Stormwater Management Infrastructure

Drawn: B Jackson
Date: August 2008
Plan No. PDE0049509v1
Proj: MGA94-50

LEGEND

- Operating Mine
- Stormwater Water Discharge Point
- Railway
- Private Road
- Existing Diversion Drain
- Karijini National Park
- Proposed MMP2 Disturbance footprint
- MMP2 Project Disturbance

LOCATION MAP



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4.7 Mining and processing operations

4.7.1 Dewatering and disposal of excess water

Based on the current mine plan, construction schedules and understanding of the hydrogeological system at Marandoo (including considerations for climate variability), the Proponent estimates a peak mean abstraction rate of approximately 65 ML/day, which is expected to reduce after the first three years to 50 ML/day. Given the uncertainty in mine planning needs, spatial and temporal hydraulic parameter variability, potential for scheduling issues to arise during construction and climate variability, the ultimate peak abstraction rate may be greater or less than the above prediction. To provide flexibility in mine planning, the planned peak design dewatering rate was conservatively set at 75 ML/day. Up to 32 dewatering bores are estimated to be required to achieve this dewatering rate for the duration of the Proposal.

The Proponent has considered a range of options for the management of excess water in line with the DoW hierarchy of water management methods (Bessen Consulting Services 2007). This hierarchy outlines the preferred sequence of surplus water management options as:

- use at source
- transfer
- re-injection
- controlled discharge.

The final surplus management strategy developed for the Proposal is an integrated scheme consisting of a combination of the above options, with an emphasis on 'use at source' and 'transfer' to maximise opportunities for environmental improvement.

Use at source

Water from dewatering will be pumped to collector tanks located within the existing Marandoo rail loop (Figure 15). A portion of this water will be retained for use at Marandoo (approximately 5 ML/day (0.06 m^3/s)) for wet processing of ore, dust suppression and use in crib rooms and ablutions. However, depending on climatic conditions, at times up to 15 ML/day (0.17 m^3/s) may possibly be used on site.

Transfer

Approximately 30 ML/day (0.35 m^3/s) of excess dewatering water will be transferred from Marandoo to the Tom Price mine and town throughout the duration of the Proposal (except during periodic maintenance and emergency shutdown events at Tom Price). The current water demand at Tom Price is around 24 ML/day (0.28 m^3/s), but due to projected increases in water required for dust suppression, low grade processing and domestic use as the town expands, demand is predicted to increase to approximately 28 ML/day (0.32 m^3/s) by 2012, with instantaneous peaks of up to 45 ML/day (0.52 m^3/s).

Existing sources that supply the Tom Price mine and town (the Mount Lionel, Hardey River and Southern Fortescue borefields, as well as dewatering operations at Tom Price mine) are currently running at, or close to capacity and do not provide security of supply for the long-term. Excess dewatering water from the Proposal has the capacity to meet the entire Tom Price mine and town demand for the life of the Proposal. Transfer of this water from Marandoo will enable existing sources to recover or be artificially recharged.

Re-injection

Any dewatering water not utilised in the 'use at source' or 'transfer' strategies is proposed to be re-injected at the Southern Fortescue borefield in the first instance.

Based on an estimated 5 ML/day used at Marandoo and 30 ML/day transferred to Tom Price, there will be an excess of approximately 30 ML/day of dewatering water during the first three years of the Proposal, and approximately 15 ML/day thereafter. Based on the Proponent's current understanding of the hydrogeological system at Southern Fortescue borefield, the aquifer is anticipated to have capacity to conservatively accept at least 15 ML/day and possibly up to 30 ML/day subject to further analysis.

Modelling of re-injection scenarios has been undertaken by MWH (2008b). Two scenarios were modelled to assess the groundwater level response to re-injection at the existing Southern Fortescue borefield and into a hypothetical borefield to the north containing an additional five bores spaced 2 km apart. Preliminary modelling results indicate that, after re-injection of 15 ML/day into the existing Southern Fortescue borefield for 16 years, groundwater levels are likely to be no higher than 10 m below ground level. There is potential for optimisation during operation to spread the groundwater level rise more evenly across the borefield (MWH 2008b). Modelling of the capacity of the Southern Fortescue aquifer system to accept required volumes and the refinement of the proposed re-injection infrastructure is ongoing. A detailed balance of surplus water to be managed and optimum injection system capacity will be resolved as project details are confirmed.

The installation of approximately four new re-injection bores and associated infrastructure such as intrafield pipelines is included as part of the MMP2 Proposal.

Table 5
Alternative discharge scenarios

Assumptions	Approximate best-case	Approximate worst-case
Proposal life	20 years	20 years
Dewatering schedule	65 ML/day for the first three years 50 ML/day thereafter	65 ML/day for the first three years 50 ML/day thereafter
Use at source volume	5 ML/day (up to 15 ML/day)	5 ML/day
Transfer volume to Tom Price	30 ML/day 0 ML/day during Tom Price shutdown	30 ML/day 0 ML/day during Tom Price shutdown
Re-injection volume	30 ML/day for the first three years 15 ML/day thereafter	15 ML/day throughout the duration of the Proposal 0 ML/day during temporary borefield shutdown
Controlled discharge volume	30 ML/day (intermittent) during Tom Price shutdown or temporary borefield shutdown	15 ML/day continuous discharge for the first three years, with intermittent peaks of 60 ML/day should Tom Price shutdown and temporary borefield failure occur concurrently No continuous discharge after the first three years, but with intermittent discharges of 45 ML/day should Tom Price shutdown and temporary borefield failure occur concurrently

Controlled discharge

Any dewatering water not utilised in the 'use at source', 'transfer', or 're-injection' strategies is proposed to be discharged into ephemeral tributaries of the Southern Fortescue River (Figure 18). This discharge will comprise intermittent, high-volume discharge during shutdown events at Tom Price (which generally last for no longer than two weeks), and if required a continuous, low-volume (15 ML/day) discharge of any excess water that exceeds the re-injection capacity of the Southern Fortescue borefield.

Dewatering discharge points will be designed to accommodate the maximum hydraulic capacity of the dewatering infrastructure and will operate alternately, allowing the discharge to be varied at each point to manage the saturation of each watercourse. Each discharge point will consist of multiple discharge pipes and energy dissipation infrastructure to minimise washout from high flow events. Preferred locations (Figure 19) for the release of water into the environment were selected based on proximity to the dewatering pipeline, existing disturbance, known heritage and environmentally sensitive areas, and current vegetation condition.

As the specific volume of water to be re-injected into the Southern Fortescue borefield is yet to be confirmed, a number of alternative scenarios for controlled discharge are possible. Both the realistic 'best-case' and 'worst-case' scenario (Table 5) are considered in this PER (Figure 20).

Water management infrastructure

Following a separate environmental approvals process under the EP Act, an above- or below-ground dewatering pipeline will be constructed from the Marandoo collector tanks to the Southern Fortescue borefield.

This dewatering infrastructure (pipeline, bores, collector tanks, power) will be commissioned around Quarter 1, 2010. The pipeline will require periodic maintenance and inspection during operations. The development of approximately four new re-injection bores and associated infrastructure such as intrafield pipelines at Southern Fortescue borefield has been considered as part of this assessment. Each bore will require clearing of vegetation within an area of approximately 40 x 40 m. The bores will be connected through a series of intrafield pipelines diverted off the main pipeline. The exact location of this infrastructure will be determined following further hydrogeological investigations. Approximately 12 existing bores and associated pipelines at the borefield will also be upgraded for the re-injection scheme.

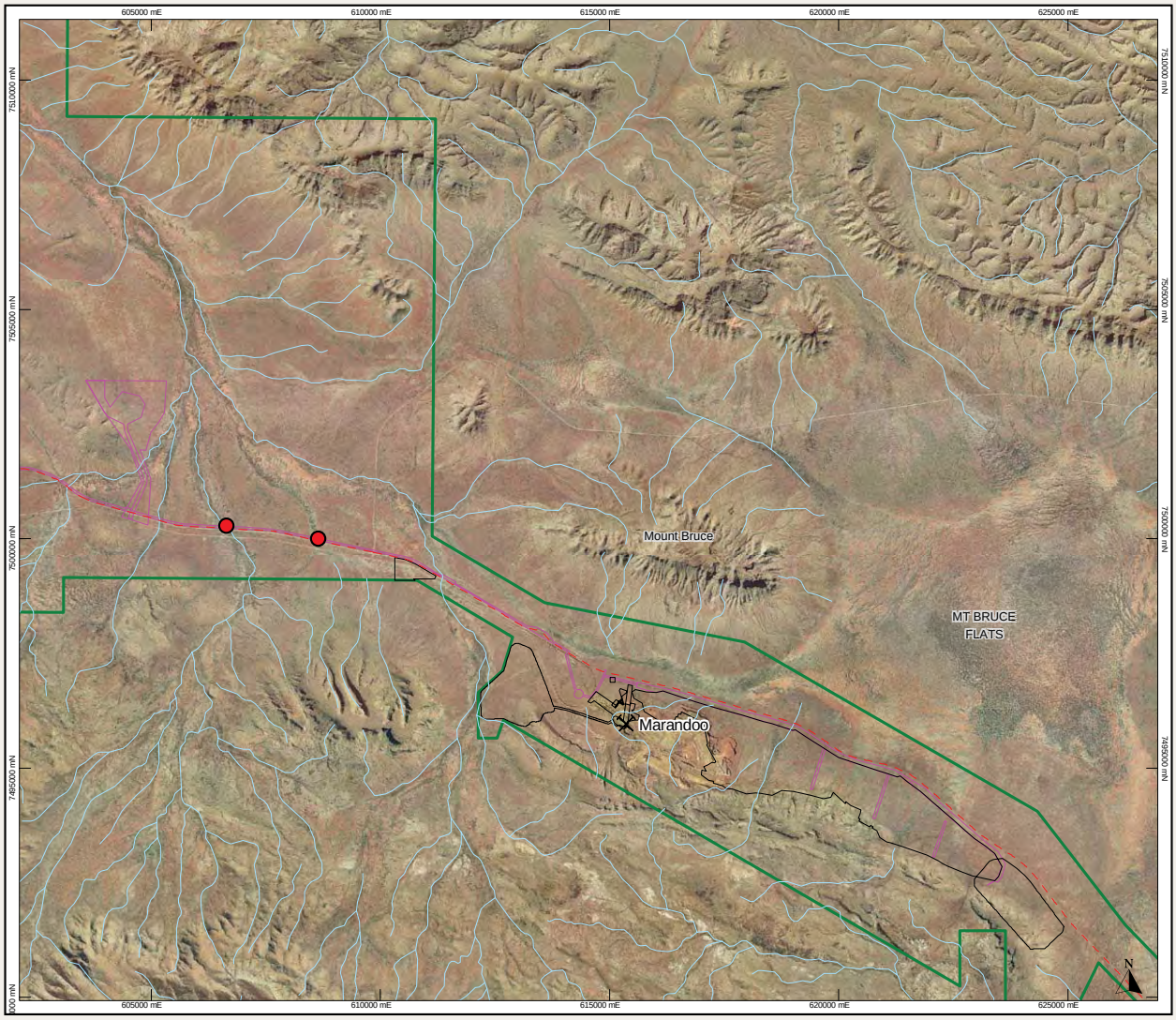

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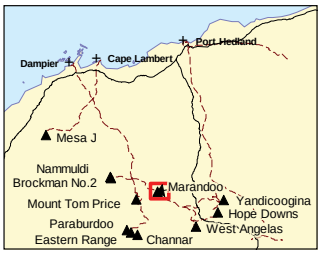
Figure 18
Proposed Excess Dewatering Water Discharge Locations

Drawn: B Jackson
Date: June 2008
Plan No. PDE0049509v1
Proj: MGA94-50

LEGEND

- Operating Mine
- Dewatering Water Discharge Point
- Railway
- Private Road
- Watercourse
- Karijini National Park
- Proposed MMP2 Disturbance Footprint
- MMP2 Project Disturbance

LOCATION MAP



SCALE

0 1 2 3 4 5km

1:100,000 @ A4

Proposed Discharge Point No. 1

Proposed Discharge Point No. 2

Figure 19
Site Photos of Proposed Dewatering Water Discharge Locations

4.7.2 Mining operations

The current rate of mining (15 Mtpa) and ore transport to Cape Lambert and/or Dampier port is not expected to change as operations move from above watertable to below watertable. The Proponent is expected to mine approximately 220 Mt of high grade iron ore from the Marandoo deposit over approximately 15–20 years.

Preliminary mine designs indicate that several pit faces will be active at any one time to achieve the required grades. Vertical batters will be at heights of approximately 15 m for overburden and 10 m for ore, with bench widths broadly matching the geometry of the deposit. The maximum depth of the mine pit will be about 150 m below ground level.

Mining method

Ore will be mined using conventional drill and blast methods. Conventional truck and shovel operations will be used for both ore and waste handling (Figure 21). Blasted material will be excavated, loaded into haul trucks and then trucked from the pit to either the existing crusher for processing (ore) or to the waste dumps (waste). Up to 45 trucks are anticipated to be required, along with an internal haul road up to 11 km in length.

The proposed mine pit outline (Figure 14; Figure 15) may be subject to some re-design as mining progresses, depending on ore quality, access, safety and geotechnical requirements.

Mineral waste dumps

Grade variation within the ore body will require that sub-grade ore and waste rock be placed in above-ground dumps at Marandoo (Figure 14). Waste rock will then be used to progressively backfill sections of the pit without sterilising the resource.

4.7.3 Ore beneficiation and residue storage

The Proposal involves the mining, sizing and transportation of ore and will require upgrading the existing dry plant to allow for wet processing of ore. Crushing will be carried out by sizer rather than the existing gyratory crusher, and wet screening will be introduced to improve screening efficiency. In addition to crushing and screening, wet processing will involve de-sliming of ore (washing out ultra-fine material below the product size range specification). Wet processing will generate a benign[12] residue consisting of a fine slurry (slimes). Minor amounts of flocculent will be added to the residue to help the material settle in a thickener, thereby conserving water and reducing the volume of the final waste product. There will be no chemical treatment of the residue.

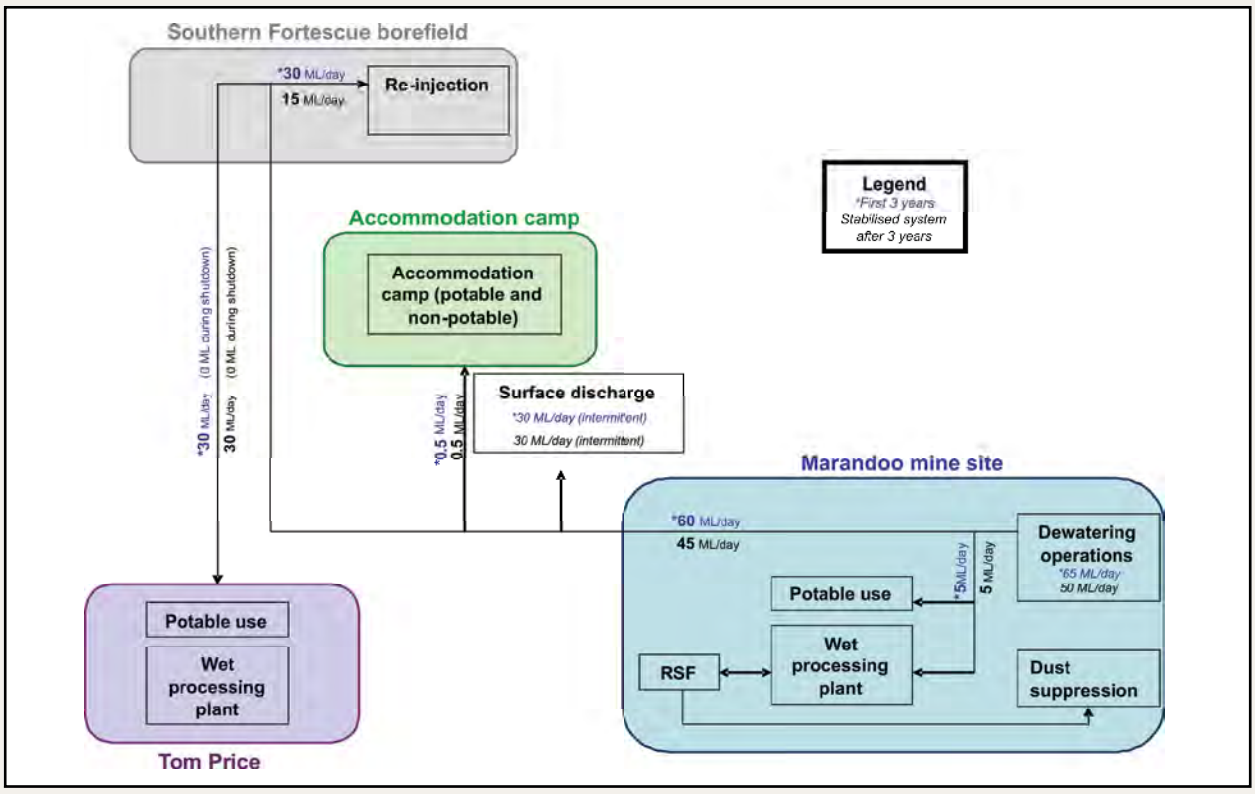
The waste slurry produced from wet processing will be pumped to an RSF which is to be constructed near the existing rail loop (Figure 15). The RSF will be a 'side-valley storage' design, whereby an existing waste dump and a hill to the south-east of the proposed RSF will confine the facility and retain residue on the south-east side. The face of the dump will be trimmed and faced with suitable material to minimise ingress of waste fines and water. This site was chosen as it is closest to the existing Marandoo plant area and will reduce the costs and energy required to transport the materials to the RSF. It will also consolidate ground disturbance within the mine area (Section 1.5.3). An existing above watertable waste dump would also be utilised as a source of fill for construction of the remainder of the RSF. The RSF will incorporate a decant tower to return supernatant water and incident rainfall to the plant site for re-use in ore processing. Water management aspects associated with the RSF are addressed in Section 5.3.

4.8 Ore transport

Following processing, ore will be loaded from the product stockpiles onto rail cars and transported via rail to Dampier and/or Cape Lambert. The Proposal will not increase rail traffic to Dampier or Cape Lambert as there will be no change to production rates compared to the existing operation at Marandoo.

12 As the mineralised Marra Mamba Iron Formation does not contain asbestiform material, there is no potential for this material to enter the processing circuit, including the RSF, at Marandoo. Asbestiform material at Marandoo is contained only within waste rock, which will not be sent to processing facilities.

Best Case



Worst Case

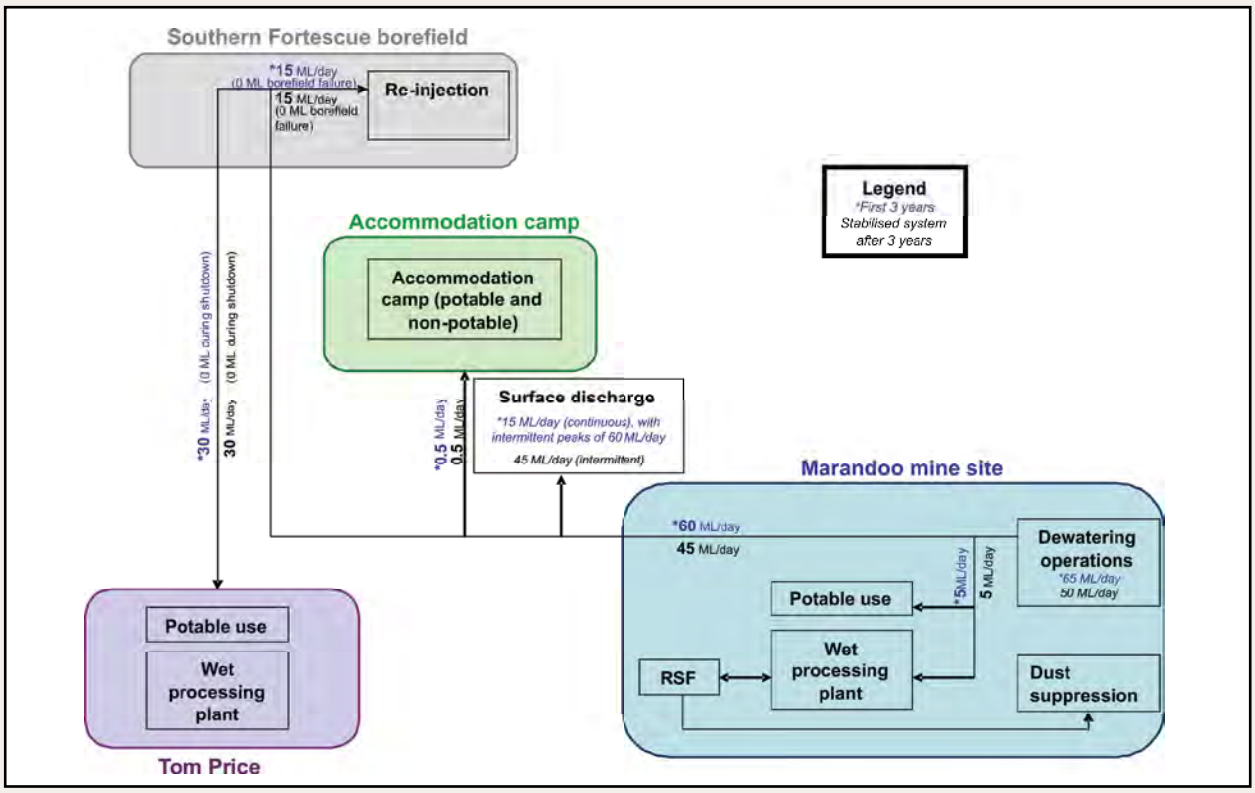


Figure 20
Indicative Water Balance

Figure 21
Conventional Truck and Shovel Mining at Marandoo

Figure 22
Existing Marandoo Infrastructure

4.9 Support infrastructure and consumables

The Proposal will require a number of support facilities and the provision of a variety of consumables during the life of the mine. Where possible, existing facilities and services at Marandoo (Figure 22) will be modified or extended to accommodate the requirements of the new operations; however, new facilities will also be required. Existing facilities at Marandoo that will be utilised include administration buildings, mine operations centre, workshop buildings, rail loop, ore loading facilities and service and access roads. A new sampling station/laboratory will be required, but will be located in proximity to existing facilities and will not require any new clearing. The proposed arrangements for support services, facilities and provision of consumables are described below.

Water supply and use

Water for use during construction will be supplied from the existing licensed production bores at Marandoo.

During operations, water will be supplied from the proposed dewatering infrastructure at the mine site and will also be recycled from water decanted from the RSF (Figure 21).

Water use at the mine site has been calculated to have a minimum requirement of 5 ML/day, but could potentially be up to 15 ML/day. Approximately 2 ML/day will be required for potable use on-site and for dust suppression across the proposed mining area, with an additional 3 ML/day required for wet processing of ore. Approximately 0.5 ML/day will also be supplied to the operations camp.

Water will be transported to the proposed operations camp via the dewatering infrastructure. Pumps, tanks and water treatment facilities will be required at both the mine site and the proposed operations camp.

Consumables

Wet processing of ore is not expected to require large-scale usage of reagents. Electrical energy, diesel and explosives will be the major consumables (Table 6).

Table 6
Estimated major consumable requirements for the Proposal

Consumable	Quantity	Source
Electrical energy	100 000 MWh/a	Existing 220 kV powerline infrastructure
Diesel for mining	25 000 000 kL/a	Transported to site via road
Explosives	7800 t/a	Transported to site via road

Abbreviations
MWh/a - megawatt hours per annum, kL/a - kilolitres per annum
t/a - tonnes per annum

Power supply
The annual power requirement for the Proposal is estimated to be approximately 100 000 megawatt hours per annum (MWh/a). Power will be required primarily for material transport and processing, but also to supply the support facilities (for example, offices and workshops). Of this annual power requirement, the operations camp is expected to require approximately 8500 MWh/a. Power will be sourced from the existing coastal power stations. During the life of the Proposal, these power stations will be converted to gas-fired operations.

Two existing above-ground powerlines (33 kV and 220 kV) traverse the Marandoo mining lease and run alongside the Marandoo access road and/or rail line to the west (Figure 14; Figure 15). Power is currently supplied to the Marandoo operation by the 33 kV powerline (Figure 15). Due to a committment to remove the existing 33 kV above-ground powerline between Marandoo and Tom Price, a new below-ground 33 kV powerline will be installed along the infrastructure corridor to the operations camp. A switchyard will be constructed adjacent to the existing Marandoo access road to facilitate the new connection to the existing 220 kV line (Figure 14) and power will be supplied to the mine and dewatering borefield through a potential upgrade/duplication and extension of the above-ground 33 kV line.

Fuel storage
Fuel will be supplied by road to the Marandoo operation. Deliveries will be made to an existing bulk fuel storage facility at Marandoo, which will be upgraded in line with the latest industry standards as part of the Proposal. This facility will be used to supply diesel to the mining fleet. Fuel will be stored and handled in accordance with Australian Standards and relevant legislation. In-pit facilities will be provided for refuelling of track-mounted equipment (for example, excavators, dozers and drill rigs).

Explosives transport and storage
The projected annual usage of bulk explosives is approximately 7800 tonnes (t) which will be transported by licensed vehicles in accordance with existing practices and the Dangerous Goods (Transport) (Explosives by Road and Rail) Regulations 1999 (WA).

The Proposal will utilise existing explosive storage facilities at Marandoo. These facilities comply with the Explosives and Dangerous Goods (Dangerous Goods Handling and Storage) Regulations 1992 (WA).

Non-mineral waste
A new sewage treatment plant will be developed at Marandoo and the existing facility at the camp will be upgraded to accommodate the additional operations workforce. Treated wastewater from the mine site will be discharged at a spray irrigation area to be established near the Marandoo rail loop (Figure 15). Sewage treatment facilities will be registered or licensed as required under the EP Act. Treated sewage will be discharged to a sprayfield that will be established as part of the Proposal. The exact location of the sprayfield (Figure 15) has yet to be determined; however, the sprayfield will be at least 500 m from administration facilities at Marandoo in accordance with health and safety requirements.

Putrescible and inert wastes from the mine site and operations camp will be deposited in the existing Marandoo landfill.

Workforce and accommodation
The operations workforce will comprise approximately 500 personnel, with an additional 200 personnel required during shutdown and maintenance periods. Existing wastewater facilities, power, water supply and common crib facilities will be used.

Up to about 800 people will be accommodated in the camp during peak periods when construction and operations personnel will coincide.

Assessing the impacts on the environment

Key environmental factors requiring detailed assessment and management were identified during the scoping and PER process.

5.1 Karijini National Park

5.1.1 Description of factor

Karijini National Park encompasses approximately 10% (greater than 600 000 ha) of the Hamersley sub-region (Section 3.3.1) and provides for the conservation of flora and fauna within the Pilbara region of Western Australia (Figure 1; Figure 23). The Park is located in the central portion of the Hamersley Range and contains a representative sample of many of the landscapes, geological types, and flora and fauna communities of this area (CALM 1999).

The value of the Park as a representative example of the Hamersley Range is increased by its relatively pristine condition compared to the highly modified ecology of surrounding pastoral stations (Australian Heritage Commission 1992). Karijini National Park incorporates a large section of the Hamersley Plateau, which is the most extensive elevated area of land in Western Australia and is traversed by a series of hills running along a north-west/south-east axis. The old plateau surface has been incised by numerous ephemeral streams, which have cut down to new base levels, creating deep gorges and waterfalls. Plunge pools occur at the foot of many of the waterfalls and many streams have permanent pools supplemented by groundwater seepages (CALM 1999).

The landscape diversity within Karijini National Park has contributed to the maintenance of equally diverse flora and fauna communities. The Park encompasses the bioclimatic transition zone between the Torresian and central Eyrean zones, as well as the phytogeographic transition zone between the Fortescue and Ashburton Botanical Provinces, and, thus, contains a more diverse species composition than adjacent areas (CALM 1999).

Vegetation within Karijini National Park ranges from grasslands to closed forests, with the predominant vegetation type being *Acacia* shrubs and/or *Eucalyptus* trees over *Triodia* hummock grasslands. There is particular diversity in *Acacia* species, with 46 of the 54 *Acacia* species that occur in the Pilbara occurring within the Park (CALM 1999). The Park supports numerous species of native mammals, birds and fish, and has particularly rich assemblages of reptiles and amphibians (CALM 1999).

Karijini National Park is relatively free from serious weed infestations, although a few weed species have become established in some areas. A number of feral animals occur throughout the Park, including cattle, horses, cats, foxes and mice, and these animals are frequently agents of disturbance and vectors for weed seeds. Human visitation to the Park is a less significant agent of weed infestation (CALM 1999).

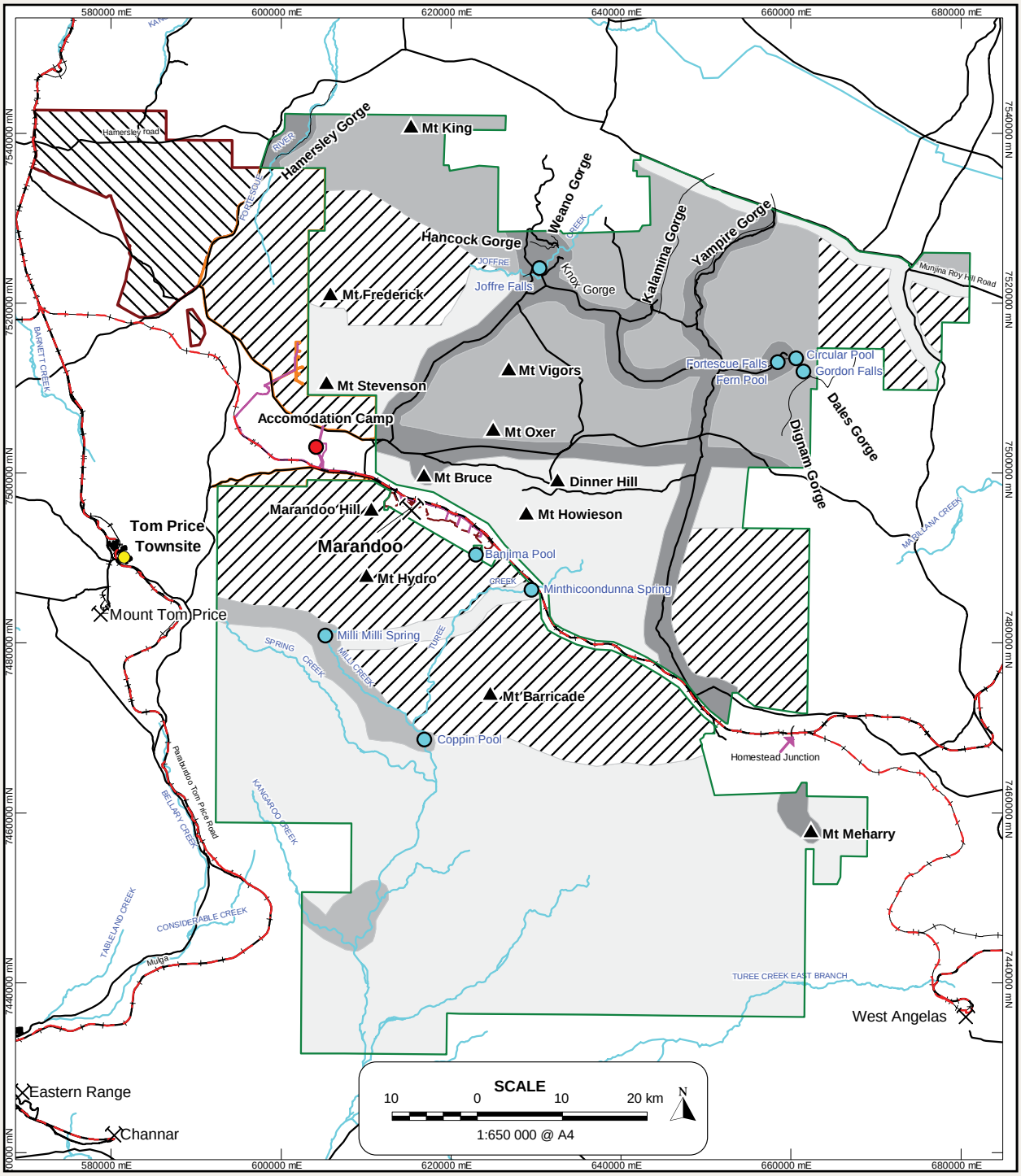


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Figure 23
Karijini National Park Management Zones and Key Locations of Interest

Drawn: B Jackson
Date: May 2008

Plan No. PDE0049509v1
Proj: MGA94 Zone 50

LEGEND

- Natural Environment Zone
- Intensive Recreation Zone
- Wilderness Zone
- Intermediate Recreation Zone
- Proposed Exclusion Area
- Proposed Management Agreement Area
- Karijini National Park
- Mine
- Town
- Accommodation Camp
- Private Road
- Major River/creeks
- Railway
- MMP2 Project disturbance
- Proposed MMP2 disturbance footprint

Key values of Karijini National Park

The gorges of the northern portion of Karijini National Park are among the most frequently visited landscape features of the Park (CALM 1999; Figure 23). Other landscape features include the highest points in the state (Mount Meharry and Mount Bruce) and various waterfalls and pools associated with the gorges. These features possess great scenic value and provide the greatest potential for recreation and tourism development (CALM 1999). The Park is one of the primary tourist attractions in the Pilbara region, with more than 100 000 visitors each year. Recreational and social values of Karijini National Park are further described in Section 6.7.

The gorges within the Park perform an important ecological function within the Hamersley Range, providing permanent water sources for many fauna species occurring in the area, as well as refuge for humidophiles[13] and fire intolerant species (Kendrick 2001). The gorges display greater species-richness than many other areas of the Park, as well as containing a high proportion of the restricted flora species that occur in the Park (CALM 1999).

The series of streams, waterfalls and pools associated with the gorges in the north of the Park provide important habitat for many species of flora and fauna in the area. Similarly, in the southern areas of the Park, a number of permanent pools associated with groundwater springs along the upper reaches of Turee Creek (Milli Milli Spring, Minthicoondunna Spring and Coppin Pool) provide equally important habitat (Figure 23). Some of these pools and springs may be more important for some species than the isolated pools associated with the northern gorges, as they provide a greater variation of habitats and support a greater diversity of fish species (CALM 1999). Many of these pools and springs also have cultural significance (Section 5.8).

Turee Creek forms on the south-east boundary of a low-lying area known as the Mount Bruce Flats, which is immediately to the north of Marandoo (Figure 10). The Mount Bruce Flats supports extensive stands of Mulga and a Coolibah open woodland (Figure 12). Mulga in the Pilbara is close to the edge of its range and considered to be at risk (Fortech 1999). The extensive stands of Mulga on the Mount Bruce Flats are important to the ongoing representation and conservation of Mulga in the region. The Coolibah woodland on the Mount Bruce Flats is an example of a vegetation type that is both in good condition and uncommon in the Pilbara region (Batini 2008b). The woodland is subject to seasonal inundation by surface water and is considered a wetland of national importance (English 1999).

Management of Karijini National Park

All National Parks in Western Australia, including Karijini National Park, are vested in the National Parks and Nature Conservation Authority. Day-to-day management of these Parks is carried out by the DEC in accordance with the *Conservation and Land Management Act 1984* (WA). Management of Karijini National Park is in accordance with the *Karijini National Park Management Plan 1999–2009* (CALM 1999; Section 5.1.3).

The Karijini Park Council and the Karijini National Park Advisory Committee were established in the early 1990s to provide input into management of Karijini National Park. The Karijini Park Council and the Karijini National Advisory Committee represent the interests of the traditional owners of the lands within the Park and the general community respectively.

The Karijini Park Council was established to facilitate direct input from the Aboriginal traditional owners into management of Karijini National Park and development of policy in relation to the Park. The Karijini Park Council is the primary agent for Aboriginal participation in Park management and consists of equal representation from the DEC and the Karijini Aboriginal Corporation[14], as well as tribal elders of the Panyjima, Yinhawangka and Kurrama people (CALM 1999). The Karijini Aboriginal Heritage Committee functions as an advisory committee to the Karijini Park Council on the effects of management and policy matters in relation to Aboriginal cultural heritage within the Park.

The purpose of the Karijini National Park Advisory Committee is to reflect the interests of the wider community and operates as a forum for public opinion and to provide an avenue to exchange advice and information on management and planning issues in relation to the Park.

The key statutory requirements, environmental policy and guidance used for managing Karijini National Park are outlined in Section 5.1.3.

13 Humidophiles are plant and animal species that prefer and/or have a strong affinity for humid environments.

14 The Karijini Aboriginal Corporation is the representative body for the traditional owners of the lands within the Karijini National Park and was incorporated pursuant to the *Aboriginal Councils and Associations Act 1976* (Cwth) in January 1991.

5.1.2 Potential sources of impact

Potential impacts to the ecological, physical, cultural and/or landscape values of Karijini National Park arising as a result of the implementation of the Proposal include:

- dewatering of the confined aquifer and/or intersection of the unconfined aquifer which may potentially result in:
  a) declining health and extent of the Coolibah woodland on the Mount Bruce Flats
  b) altered groundwater discharge to springs and water levels in groundwater-fed pools in the Park
  c) decreased discharge from the Mount Bruce Flats to Turee Creek
  d) modification to subterranean fauna habitat
  e) sinkhole formation (Section 5.2.4).
- interception of surface water flows from the mining area which may reduce flows to Coolibah and Mulga on the Mount Bruce Flats and decrease discharge from the Flats to Turee Creek
- access to the Park by the Proposal workforce which may decrease amenity and increase traffic and associated public safety risks within the Park
- mining operations may introduce and/or spread weeds and feral animals into adjoining areas of the Park
- ignition sources on the mine site may result in fire events resulting in the loss of fire-sensitive vegetation (particularly Mulga)
- hydrocarbon spills at the mine site may contaminate groundwater and/or surface water runoff in adjoining areas of the Park
- dust emissions, mine site infrastructure and altered landforms may affect visual amenity at Mount Bruce
- general mine operations and blasting may increase noise levels and vibration at Mount Bruce.

5.1.3 Key statutory requirements, environmental policy and guidance

EPA objective

In most circumstances, including this assessment, the EPA applies the following objective in its assessment of Proposals that may affect conservation areas:

To protect the environmental values of areas identified as having significant environmental attributes.

Karijini National Park Management Plan

The *Conservation and Land Management Act 1984* (WA) and the *Wildlife Conservation Act 1950* (WA) provide the legislative base for the management of National Parks in Western Australia. These Acts include a number of statutory requirements for the management of land and wildlife, including:

- 'for National Parks where there is a management plan, management must be in accordance with that published plan'
- 'National Parks must be managed to provide public recreation consistent with the conservation of flora, fauna, landscape and other values'.

The latest draft management plan for Karijini National Park was released in 1999 (CALM 1999). The plan describes in detail the environmental, cultural and social values of the Park, as well as management objectives, strategies and responsibilities.

The primary goal for management of Karijini National Park is to conserve the biological, physical, cultural and landscape values of the Park. Where consistent with conservation of these values, management also aims to facilitate recreation, tourism and scientific research within the Park (CALM 1999).

Areas within Karijini National Park are managed differently according to the specific Park values to be protected and the capacity of a given area to withstand visitor and management pressure. The Karijini National Park Management Plan (CALM 1999) specifies four general management zones for the Park (Figure 23):

- Wilderness Zones are maintained as near as possible in their natural condition, with access to these zones being restricted to minimise disturbance
- Natural Environment Zones are managed to preserve the abundance and diversity of native flora and fauna, although access is generally not restricted
- Intensive and Intermediate Recreation Zones are managed for appropriate recreation and the conservation of native flora and fauna
- Park Services Zones are set aside for Park administration, visitor services and temporary off-limits areas.

The Marandoo mining tenement and railway corridor are bordered to the south and west by two large Wilderness Zones, intersected by a Tourism and Recreation Zone along Turee Creek, and to the north by a Natural Environment Zone (Figure 23; CALM 1999).

Statement of Mutual Understanding (SMU)

The Proponent and the DEC have agreed in principle on a consultative process to address issues of potential environmental impact arising from the approved Marandoo above watertable operation by way of a Statement of Mutual Understanding (SMU). The SMU combines the objectives of operating an economically-viable mining operation and preventing environmental impacts to the Park by allowing for co-operative management of the effects of the operation on conservation values of the Park.

Matters addressed in the SMU include:

- consultation on conservation and environmental research programs, with a view to improving their value and effectiveness
- development of a co-operative program of fire management and a regime for controlled burning at Marandoo
- facilitation by the DEC of the Proponent's engineering and scientific research studies within the Park to assist in understanding matters of mutual interest, such as the hydrogeological characteristics of the underground aquifers
- consultation regarding an appropriate final landform at Marandoo following detailed hydrology and engineering studies
- development of a protocol for the handling of infringements of Park regulations.

Memorandum of Understanding

A Memorandum of Understanding (MOU) exists between the Proponent and the DEC, which covers consultative land management of the pastoral leases (Juna Downs and Hamersley Station) adjoining Karijini National Park. The MOU was developed in 1997 to formally recognise the cooperation between the Proponent and the DEC to maintain the core of the region (the Park itself) and buffer areas (the adjoining pastoral leases).

Matters addressed in the MOU include:

- Common goals: Management will support multiple uses, including conservation, pastoral production, mineral production, tourism, recreation and cultural activities. The priority of each use will vary, depending on its location in the management zone.
- Management plans: Plans will be drawn up for all components of the agreement, with input from both parties, to facilitate compatible management practices of the issues relating to cross-boundary effects, such as fire management, weed and introduced species control, and tourism.
- Research: Research directed at understanding how the region's ecosystems function and respond to disturbance will be coordinated to maximise the benefits of resources expended by the DEC and the Proponent. Research into the effectiveness of management techniques will be a priority.
- Education: The lessons learned by integrating conservation with a range of development and production activities will be of a wider interest and will be disseminated to a broad audience.

5.1.4 Assessment of potential impact

Dewatering - groundwater drawdown

Coolibah woodland

Intersection of the unconfined aquifer by the proposed mine pit is predicted to result in groundwater drawdown after eight years of approximately 0–2.5 m at the Coolibah woodland on the Mount Bruce Flats. However, a large proportion of the Coolibah woodland will only experience drawdown of less than 1.0 m.

Groundwater levels in the unconfined aquifer can naturally fluctuate by up to 9.5 m in the vicinity of the Coolibah woodland (Batini 2008a). The magnitude of the predicted drawdown is not anticipated to affect the Coolibah woodland. The estimated maximum rate at which this drawdown would occur is approximately 0.3 m/year, based on the total drawdown occurring during the initial eight years of dewatering (as a result of rapid pit advancement during this period). This is a significantly slower rate than the observed natural rises and falls in groundwater levels on the Mount Bruce Flats. This drawdown would be gradual taking at least eight years or more to occur. This should allow natural root growth to keep up with the predicted rate of dewatering. Furthermore, it is quite likely that at least one, large natural recharge event would occur during this period (Batini 2008a).

The potential impact of the Proposal to the Coolibah woodland is addressed in more detail in Section 5.5.

Subterranean fauna

Subterranean fauna surveys undertaken by Biota (2008e) have indicated the presence of troglofauna and stygofauna communities in the unconfined aquifer across the Mount Bruce Flats within Karijini National Park. Dewatering is considered unlikely to significantly affect subterranean habitat or subterranean fauna communities across the Mount Bruce Flats due to the limited drawdown predicted in the unconfined aquifer. In addition, none of the subterranean fauna species recorded in the Proposal impact area are restricted to this area (Biota 2008e).

The confined aquifer is not considered to provide suitable subterranean fauna habitat (Biota 2008e).

The potential impact of the Proposal to subterranean fauna is addressed in more detail in Section 5.7.

Springs

The Proponent has developed conceptual models for several springs, gorges and pools in Karijini National Park, based on visual observations, water chemistry data, surface flow measurements, geological information and/or physiographical catchment information (Table 7; Dodson 2008).

There is negligible risk that any gorge, spring or pool in northern Karijini National Park will be affected by the Proposal, as these systems are located at considerable distances from the Proposal area (Table 7; Figure 23) and geological information indicates they are effectively disconnected from the confined aquifer to be dewatered as part of this Proposal. The confined aquifer is associated with basement rocks that are overlain by several hundred metres of low permeability material (shale, Brockman Iron Formation and chert) with a relatively gentle lying dip to the north. Thus, if the confined aquifer extended to the gorges, it would lie several hundred metres below the bottom of the gorges (with the exception of Hamersley Gorge, which is discussed separately below). The Tertiary sediments that overlie the Brockman Iron Formation and discharge to a number of pools in northern Karijini National Park are separated from the Tertiary sediments that support the unconfined aquifer of the Mount Bruce Flats by elevated areas of basement rock, which are of low permeability (Dodson 2008).

Table 7
Springs, gorges and pools in Karijini National Park investigated by the Proponent

Site	Approximate distance from Marandoo	Mode of occurrence
Banjima Pool	2 km south of the eastern end of the proposed mine pit	Not fed by groundwater; formed downstream of a resistant band of cemented Tertiary laterite south of Marandoo Ridge
Minthicoondunna Spring	10 km south-east of the eastern end of the proposed mine pit	Fed by groundwater discharging from Tertiary detritals of alluvium, colluvium and calcrete
Dales Gorge and Circular Pool	45 km north-east	Fed by groundwater discharging from the Brockman Iron Formation
Weano Gorge	34 km north-east	Fed by groundwater discharging from the Brockman Iron Formation
Joffre Falls	30 km north-east	Fed from groundwater discharging from Tertiary sediments that overlie the Brockman Iron Formation
Fortescue Falls and Fern Pool	43 km north-east	Fed from groundwater discharging from Tertiary sediments that overlie the Brockman Iron Formation
Kalamina Gorge	34 km north-east	Fed by groundwater discharging from the Brockman Iron Formation and overlying Tertiary colluvium
Hancock Gorge	37 km north-east	Fed by groundwater discharging from the Brockman Iron Formation and overlying Tertiary colluvium
Hamersley Gorge	44 km north-west	Fed by groundwater discharging from the Tertiary sediments and the Wittenoom Formation basement of the Southern Fortescue aquifer system

Source: Dodson (2008)

Additional observations by Dodson (2008) further suggest the systems in northern Karijini National Park will not be affected by the Proposal. Key observations are listed below:

- Circular Pool (Figure 23) is fed from groundwater flowing from the north, whereas Marandoo lies to the south.
- The water chemistry of Hancock Gorge and Weano Gorge (Figure 23) is considerably fresher than Marandoo groundwater, which indicates the water in these gorges is derived from an alternative source.
- The water chemistry of Tertiary sediments overlying the Brockman Iron Formation in northern Karijini National Park is saturated in calcite and unrelated to groundwater occurring near Marandoo.

Hamersley Gorge (Figure 23) is fed by groundwater discharging from the Southern Fortescue aquifer system and, due largely to its significant distance from Marandoo, should not be affected by groundwater abstraction within the Marandoo aquifer system. Re-injection at the Southern Fortescue borefield may potentially result in increased discharge to Hamersley Gorge. There is insufficient information to determine whether historical groundwater drawdown caused by abstraction at the Southern Fortescue borefield since 1972 (unrelated to Marandoo) has resulted in reduced groundwater discharge to Hamersley Gorge (Dodson 2008).

Sites in the vicinity of Marandoo (within 10 km) investigated by Dodson (2008) were Banjima Pool and Minthicoondunna Spring. Banjima Pool is located approximately 2 km south of the eastern end of the proposed mine pit at Marandoo, on a small ephemeral tributary of Turee Creek (Figure 23). Minthicoondunna Spring is located approximately 10 km south-east of the eastern end of the proposed mine pit at Marandoo (Figure 23).

Banjima Pool is located in a Wilderness Zone within Karijini National Park and is formed downstream of a resistant band of cemented Tertiary laterite that has been ground out by large boulders during high rainfall events. As Banjima Pool occurs at approximately 705 mRL (approximately 25 m above the regional groundwater table), it is unlikely to be fed by groundwater and therefore will not be affected by groundwater drawdown resulting from the Proposal (Dodson 2008). Water chemistry data collected in July 2008 by Dodson (2008) support this, with low electrical conductivity and relatively low temperatures in Banjima Pool both indicative of an origin other than groundwater.

Minthicoondunna Spring is located in a Natural Environment Zone within Karijini National Park (Figure 23) and is believed to be supported by groundwater discharge from a near surface calcrete aquifer that has been eroded along the bank of a tributary of Turee Creek (Dodson 2008).

Water chemistry data collected in July 2008 by Dodson (2008) support this, with high electrical conductivity and relatively high temperatures indicative of a groundwater origin. The western limit of the calcrete aquifer thought to support the spring is roughly 3 km from the eastern end of the proposed mine pit at Marandoo. Although dewatering will not target the calcrete aquifer, there is a possibility of a hydraulic connection between the surficial calcrete aquifer and the deeper confined aquifer that will be be dewatered. Towards the end of the mine life, this could potentially result in a reversal in the direction of groundwater flow, such that groundwater that would normally flow to the south-east and discharge at Minthicoondunna Spring would instead be directed back into the open mine pit.

The extent to which groundwater flow to Minthicoondunna Spring may be redirected to the proposed mine pit will largely be dependent on the hydraulic properties of the upper Tertiary sediments and the degree of hydraulic connection with the lower confined aquifer. The absence of the clay layer (yet to be determined) in the vicinity of Minthicoondunna Spring (which is known to occur between the confined and unconfined aquifer across the Mount Bruce Flats) would increase the risk of impacts occurring at the spring (Dodson 2008). Any potential impact to Minthicoondunna Spring would occur only towards the end of the mine life, when the cone of groundwater drawdown is predicted to extend in a south-easterly direction.

The vegetation in this area could be described as of moderate conservation significance (2d; Eucalyptus *camaldulensis var obtusa* woodland) and the spring itself is surrounded by *Phoenix dactylifera* (date palm) and several other introduced flora species.

Minthicoondunna Spring is a listed on the Permanent Register of Aboriginal Sites (Site ID 8296/P04348). The cultural heritage values of Minthicoondunna Spring are protected under the provisions of the *Aboriginal Heritage Act 1972* (WA). Consent in accordance to the requirements of the Act would be required to be gained prior to any impact on the cultural heritage values of the spring.

Sinkholes

There is a risk of sinkhole formation in the vicinity Marandoo and the Southern Fortescue borefield as a result of the Proposal (Section 5.2).

Additional alteration to surface hydrology

The natural hydrological regime of Marandoo Ridge has already been modified as a result of the construction of the railway from Rosella Siding to Homestead Junction. The Proponent will continue to implement existing surface water management practices at Marandoo to ensure there is no further change to the hydrological regime of Marandoo Ridge or the adjacent Mount Bruce Flats. The Proposal is not expected to significantly alter flows to the Mount Bruce Flats beyond that which has already occurred as a result of existing development at the site.

Excess water that collects within the proposed mine pit during major rainfall events will be pumped out of the pit and discharged to culverts through the railway embankment. An existing diversion drain along the eastern section of the proposed mine pit will convey flows of at least 5 m^3/s (approximately the peak volume generated by a 40–50 mm rainfall event) around the pit.

Further detail on site water management is provided in Section 4.6.2. Potential impacts to the Mount Bruce Flats Coolibah woodland and Mulga communities are addressed in detail in Section 5.5.

Workforce

The proximity of the Proposal to Karijini National Park will not affect the existing social, recreational and tourist values of the Park, as the fly-in/fly-out roster type, combined with the length of working days (12 hours) will limit the time available to personnel to undertake recreational pursuits. The operations camp is not located adjacent to Karijini National Park and does not require access through the Park.

Potential effects of the Marandoo workforce on the values of Karijini National Park are addressed in more detail in Section 6.7.

Introduction of weeds and feral animals

Although additional areas of disturbance will be created during the construction of the Proposal, the potential for mine site activities to lead to the introduction and/or spread of weeds and feral animals in adjacent areas of Karijini National Park will be managed through implementation of weed control and hygiene measures in accordance with the Vegetation and Flora Management Plan (Appendix 2), as well as feral animal control programs consistent with corporate standards. The risk of weed or feral animal encroachment as a result of the operational phase of the Proposal is expected to be similar to that of the existing Marandoo operation.

The Proponent will maintain liaison with, and provide assistance to the DEC and other Karijini National Park management bodies with regard to weed management practices across the Mount Bruce Flats.

Altered fire regime

Fire is a natural and important component of ecosystems in the Pilbara. Historically, burning by Aboriginal people consisted of frequent smaller fires, which resulted in mosaic patterns of vegetation at differing stages of succession (CALM 1999). The patch burning of spinifex around Mulga by Aboriginal people probably helped slow down or stop bushfires when they occurred, protecting Mulga from being burnt (Williams 2002). Alteration of the landscape due to pastoral activities means that fires in areas surrounding Karijini National Park are now usually fuelled by a uniform fuel load, which can result in both more intense and more extensive fires (CALM 1999). Surrounding pastoralists also generally burn in summer to maximise regrowth during winter rains; however, this may exacerbate fire in surrounding areas. An example of this occurred in 1986, when a fire on a nearby pastoral lease burnt approximately 25% of Karijini National Park (CALM 1999).

In addition to accidental bushfires, the years that follow above average rainfall have the potential for bushfire to carry into the Mulga shrublands due to an increase in fuel load. Mulga are susceptible to increased frequency of burning, which can cause a shift in vegetation type to a more spinifex-dominated community (Russell-Smith 2005). Over time this can lead to a decrease in occurrence and long-term viability of Mulga and other fire-sensitive species (CALM 1999). Natural fire frequency in arid zone *Acacia* shrublands is estimated to be in the order of every 5–50 years (Williams 2002).

Hydrocarbon spills

Surface water

The existing hydrocarbon management facilities at Marandoo will be upgraded prior to the Proposal and therefore it is expected that there will be no increase in the contamination risk to Karijini National Park compared to the existing Proposal.

Groundwater

Diesel and other hydrocarbons will be used routinely at Marandoo during mining. This presents minor operational risks of spillage, such as during re-fuelling of trucks and other machinery. Groundwater quality could potentially be affected by spills of hydrocarbons; however, these risks will be managed through the application of established design, infrastructure and operational procedures (Section 5.2.5). Appropriate operational controls and clean-up procedures will be implemented to ensure any minor spills have minimal effect on groundwater quality.

Groundwater and surface water contamination are addressed in detail in Sections 5.2 and 5.3, respectively. Potential impacts to subterranean fauna within Karijini National Park as a result of surface water and/or groundwater contamination are addressed in Section 5.7.

Visual impact

The existing Marandoo mine site is already visible from Mount Bruce (located to the north of the mine within the adjacent Karijini National Park), including at the summit and the lowest public viewpoint. The Proposal will therefore result in additional modification of an already highly-modified landscape. The proposed operations camp and dewatering infrastructure (assuming the dewatering pipeline will be installed above-ground) have been evaluated as having a minor perceivable change to the landscape. Areas of significant perceived change as a result of the Proposal are restricted to public viewing locations that are not frequently used, for example, the Mount Bruce eastern summit lookout (SKM 2008).

Dust generated from the Proposal is not expected to differ significantly from dust generated from existing operations.

The effect of the Proposal on visual amenity is addressed in detail in Section 5.9.

Noise and vibration

The proposed mining operations are remote from any noise-sensitive receptors, although Mount Bruce (to the north of the mine) is frequented by visitors to Karijini National Park. The most significant noise emissions that could be audible at Mount Bruce are likely to be caused by blasting and mobile mining equipment such as haul trucks, dozers, excavators and graders. In particular, reversing beepers on this equipment have the potential to be audible at the lookout on Mount Bruce.

The Proposal is not expected to result in unacceptable vibration levels in Karijini National Park. Blast sizes are not expected to increase beyond that for the existing operation and the majority of blasting activity will occur further away from areas commonly accessed by the public in Karijini National Park (SVT 2008). There are no criteria for acceptable levels of vibration in recreational areas, although risk exclusion zones (which are set to ensure the safety and comfort of those in nearby buildings) will ensure that no adverse effects are felt beyond this, including within Karijini National Park.

Potential impacts of noise and vibration generated as a result of the Proposal are addressed in detail in Section 6.6.

5.1.5 Proposed mitigation and management measures

The existing ecological, physical, cultural and landscape values of Karijini National Park will be maintained during construction and operation primarily through the implementation of Environmental Management Plans (EMPs) (Appendix 2). Key measures within the EMPs that relate to protection and/or enhancement of existing Karijini National Park values include:

- implementing a comprehensive monitoring program and adaptive management plan to protect the Coolibah woodland on the Mount Bruce Flats
- gathering information to further develop the conceptual models for springs and pools in Karijini National Park, with the aim of determining flow and transport mechanisms of individual systems through characterisation of water sources using hydrochemistry and environmental isotopes of surface water and groundwater
- undertaking further hydrogeological investigation between Marandoo and Minthicoondunna spring to determine the hydraulic parameters of the Upper Tertiary sediments, and any hydraulic connection between the superficial calcrete aquifer and the confined aquifer
- monitoring the water level at Minthicoondunna Spring, and groundwater levels between Marandoo and Minthicoondunna Spring
- continuing consultation with the Eastern Guruma people and other relevant stakeholders
- optimising the location of the re-injection bores within the Southern Fortescue borefield to spread the rise in groundwater level across the borefield
- monitoring observation bores within Southern Fortescue borefield to ensure groundwater levels do not rise more than 5 m above historical (pre-abstraction) groundwater levels as a result of re-injection
- consulting with Karijini National Park management bodies in accordance with existing arrangements under the SMU and MOU (regular SMU meetings will continue to be held and will include discussion of the Proposal)
- continuing to assist with fire and weed management across the Mount Bruce Flats in collaboration with the DEC and other Karijini National Park management bodies, including on-site fire-fighting capability to support DEC/indigenous prescribed burning in the area
- diverting any water from the mine pit detected as potentially contaminated with hydrocarbons to the on-site hydrocarbon treatment facilities
- ensuring any water discharged to the natural environment does not cause the quality of receiving surface or groundwater systems to exceed the ANZECC Water Quality Guidelines (ANZECC/ARMCANZ 2000)
- educating mine staff and contractors as to appropriate, low-impact behaviour at popular visitor nodes within Karijini National Park (particularly the northern gorges) and informing mine staff and contractors of relevant National Park policies and requirements
- undertaking a visual assessment of the Proposal in relation to Marandoo ridgeline from Mount Bruce visitor car park lookout at finalisation of the mine plan and every five years thereafter during operations and at closure
- re-establishing disturbed landforms that are consistent with local landscape values and resemble the local environment as closely as possible
- incorporating the Coolibah woodland into a regional study by the University of New South Wales (UNSW) to provide input into the monitoring and adaptive management plan
- undertaking studies to monitor sinkholes in the vicinity of Marandoo and the Southern Fortescue borefield, including investigating the number and size of existing sinkholes to provide a baseline for future monitoring in the, this may include:
  a) visual monitoring
  b) differential photogrammetry with respect to a baseline image
- managing sinkhole risk through early detection of the onset of surface deformation and/or reactivation of existing features
- fencing sinkholes and implementing other measures to reduce any potential risk to public safety
- applying controls to hydrocarbon transport, handling and disposal in accordance with the Proponent's corporate standard
- setting blast exclusion zones to eliminate risks to public safety, including vibration-related impacts such as rock falls
- restricting public access within blast exclusion zones and enacting procedures for evacuating these areas
- publishing typical blast times at the Mount Bruce lookout visitor car park to manage recreational concerns, in consultation with DEC.

5.1.6 Predicted outcome

After mitigation and management measures have been applied, the Proposal is expected to result in the following outcomes in relation to Karijini National Park:

- Areas of significant perceived change to the landscape will be restricted to public viewing locations that are not frequently used (such as the Mount Bruce eastern summit lookout).
- The predicted magnitude and rate of groundwater drawdown within the unconfined aquifer is not anticipated to significantly affect either the Coolibah woodland or subterranean fauna communities across the Mount Bruce Flats. Application of an adaptive management condition will further reduce risk to the Coolibah woodland.
- There is a possibility of affecting water levels at Minthicoondunna Spring near the end of the mine life; further investigations are planned to determine the level of risk, if any.
- There will be no significant additional modification of the Marandoo Ridge hydrological regime as a result of the Proposal.
- There is a risk of sinkhole formation in the vicinity of Marandoo and the Southern Fortescue borefield.
- The proximity of the Proposal to Karijini National Park will not affect the existing social, recreational and tourist values of the Park, as the fly-in/fly-out roster type, combined with the length of working days (12 hours) will limit the time available to personnel to undertake recreational pursuits.
- Noise from the Proposal will not perceptively increase above existing operation, and vibration will not increase as a result of the Proposal.

The Proposal is consistent with EPA objectives, as the significant environmental values of Karijini National Park will be maintained through implementation of mitigation and management measures to maintain recreational and social values in the locality and preserve the abundance and diversity of native flora and fauna, consistent with Karijini National Park Management Plan objectives.

5.2 Groundwater quantity and quality

5.2.1 Description of factor

The Proposal area is situated across two hydrogeological systems: one at Marandoo and the other in the Southern Fortescue area, approximately 30 km to the north-west of Marandoo (Figure 2). The hydrogeological system at Marandoo is a focus for the Proposal because of the requirement to dewater the ore body to allow mining below the watertable and the potential impacts that may subsequently arise. The Southern Fortescue aquifer system has been identified as having potential to receive some of the excess dewatering water, via re-injection at the Southern Fortescue borefield.

Marandoo hydrogeological setting

The two primary aquifer units at Marandoo are:

- a shallow, unconfined aquifer hosted by a calcrete horizon within a Cainozoic valley fill sequence ('unconfined aquifer')
- a deeper, confined lower Tertiary detrital and Proterozoic bedrock aquifer hosted by the Marra Mamba Iron Formation and the Wittenoom Formation ('confined aquifer').

The confined and unconfined aquifers are separated by a sequence of valley fill clays commonly up to 40 m in thickness which act as an effective aquitard between the two aquifers (Liquid Earth 2005; Youngs and Brown 2005; Figure 8).

Permeability in the Marra Mamba Iron Formation derives from jointing and from the mineralisation process in which silicates are stripped from BIFs and vugs develop. Water yields in the Marra Mamba Iron Formation are highly variable (from low to moderately high). The Wittenoom Formation is recognised as a major aquifer in the Pilbara region, although high yields are dependent on the presence of karstic zones (MWH 2006a).

Groundwater occurs within the unconfined aquifer at depths below ground level of between 18 m across the Mount Bruce Flats and 50 m on the flanks of Marandoo Ridge (Liquid Earth 2005). The primary recharge area for the unconfined aquifer is in the vicinity of the Coolibah woodland on the Mount Bruce Flats (Figure 11) where calcrete 'crabholes' present at the surface are believed to form pathways for rapid infiltration, which is enhanced by ponding in the low-lying Coolibah woodland. In other areas, several metres of lateritic hardcap or silty sediment overlie the unconfined aquifer and restrict recharge (Liquid Earth 2005). Following recharge, groundwater within the unconfined aquifer flows radially outward from the resulting groundwater mound.

Discharge from the unconfined aquifer is through evapotranspiration and minor flow to Turee Creek in the south-east (Figure 10). Evapotranspiration is likely to be most significant to the south-east of the Proposal area, where depth to groundwater is much less. Discharge to Turee Creek is demonstrated by seepage from scoured calcrete in the banks of Turee Creek at Minthicoondunna Spring (approximately 10 km to the east; Figure 23). Available groundwater level information confirms a south-east gradient between Marandoo and Minthicoondunna Spring (Liquid Earth 2005).

The confined aquifer is recharged primarily where dolomite outcrops or sub-crops occur around the northern and eastern margins of the Mount Bruce Flats and, to a lesser degree, at the base of Mount Bruce (Figure 11). Recharge occurs to a lesser extent on the southern side of the Flats through outcropping of mineralised Marra Mamba Iron Formation. Throughflow in the confined aquifer is estimated at 1.57 GL/year (4.3 ML/day) and is to the west, following the Southern Fortescue River catchment (ultimately reaching the Southern Fortescue borefield). A lesser component of basal flow is to the south-east towards Turee Creek (Liquid Earth 2005; Figure 11).

Groundwater in the unconfined aquifer is characterised by slightly elevated salinity and appears to respond relatively quickly to rainfall recharge events in the catchment. Groundwater in the confined aquifer is relatively fresh and has a reduced and delayed response to rainfall events (MWH 2006b; Table 8).

Table 8
Groundwater quality in representative samples from the Marandoo confined aquifer and Southern Fortescue borefield

Parameter	Marandoo confined aquifer representative sample	Southern Fortescue borefield representative sample
pH	7.22	6.87
Total dissolved solids (mg/L)	619.90	633.70
Iron (Fe; soluble) (mg/L)	0.025	0.03
Sodium (Na) (mg/L)	38.64	45.06
Potassium (K) (mg/L)	12.37	10.29
Calcium (Ca) (mg/L)	60.52	56.58
Magnesium (Mg) (mg/L)	48.41	41.62
Chloride (Cl) (mg/L)	91.77	90.06
Carbonate (CO_3) (mg/L)	0.03	0.11
Bicarbonate (HCO_3) (mg/L)	264.74	250.71
Hardness (equivalent $CaCO_3$) (mg/L)	350.49	317.62
Sulphate (SO_4) (mg/L)	64.20	64.06
Nitrate (NO_3) (mg/L)	38.98	73.16
Manganese (Mn) (mg/L)	0.03	0.06
Sum of ions (mg/L)	17.90	17.74
Cation/anion balance (%)	0.56	-3.37

Source: MWH (2008b)

Marandoo groundwater trials

Extensive hydrogeological investigations have been undertaken at Marandoo since 1978, including drilling, pump testing, geophysical surveys and development and calibration of a groundwater model. Two dewatering and re-injection trials conducted at Marandoo since 2004 have 'stressed' the groundwater system over a sufficient period to provide suitable monitoring data to calibrate a predictive numerical model of the Marandoo groundwater system. These trials were:

- the 'Below Water Table Trial' (Liquid Earth 2005; Youngs and Brown 2005)
- the 'Marra Mamba Below Water Table Trial' (Evans 2006; MWH 2006b).

Below Water Table Trial

The Below Water Table Trial was run for 44 consecutive days during October and November 2004. The primary purpose of the trial was to evaluate potential dewatering requirements of the Proposal and to assess potential impacts to the surrounding environment as a result of this dewatering.

Following initial pump testing of eight bores (which provided hydraulic properties for the confined aquifer), two high-yielding bores drawing water from the confined aquifer on the mine lease were linked and pumped simultaneously at a maximum combined rate of 3.7 ML/day (Liquid Earth 2005). The combined discharge was piped approximately 2 km north and re-injected into the confined aquifer via a single bore in the vicinity of the Coolibah woodland on the Mount Bruce Flats.

Groundwater levels were monitored in both the unconfined and confined aquifer via an extensive network of monitoring bores fitted with multi-aquifer piezometers. Monitoring bores were located in the mining area, Karijini National Park and in the Marandoo transport corridor (the area between the rail line and the mining lease/National Park boundary) (Figure 24).

The key outcomes of the Below Water Table Trial were (Liquid Earth 2005; Youngs and Brown 2005):

- there was no effect on groundwater levels in the unconfined aquifer as a result of dewatering and re-injection in the confined aquifer
- there is significant connection between the Wittenoom Formation and the Marra Mamba Iron Formation within the confined aquifer
- there may be throughflow into the Wittenoom Formation (Figure 8) from outside the Mount Bruce Flats catchment (Figure 10)
- the derived aquifer transmissivities of the mineralised Marra Mamba Iron Formation at Marandoo were highly variable (50–1800 m^2/d).

Marra Mamba Below Water Table Trial

The Marra Mamba Below Water Table Trial involved mining a 60 kt sample of dewatered Marra Mamba ore at Marandoo from September to December 2005. The overall objective of the trial was to determine the dewatering requirements of the Proposal.

Following installation and pump testing of eight production bores within the mining lease, five bores drawing water from the confined aquifer were pumped at a combined average rate of approximately 6.4 ML/day for a total of 72 days. This volume was delivered back into the confined aquifer via five re-injection bores within the mining lease at a suitable distance to prevent recirculation. Groundwater levels were monitored during the trial in both the unconfined and confined aquifer at 17 monitoring bores located throughout the mining area (MWH 2006b) (Figure 24).

Data collected during the Marra Mamba Below Water Table Trial were combined with existing data to recalibrate the Marandoo groundwater model and improve understanding of specific aspects, such as aquifer recharge. During the trial, drawdown of 0.27 m in one monitoring bore indicated a limited connection between the unconfined and confined aquifers (Evans 2006). This suggests there may be a hydraulic connection between the unconfined and confined aquifers within approximately 500 m of the existing Marandoo mine pit; however, no measurable effect on water levels was observed elsewhere in the unconfined aquifer, including within the vicinity of the Coolibah woodland, some 5 km away from the dewatering site (MWH 2006b).

Marandoo groundwater model development

The Marandoo groundwater model was initially constructed by Liquid Earth (now MWH Australia Pty Ltd (MWH)) and Cymod Systems in 2004. MWH (2006c) calibrated the model against groundwater level records from 1994–2004 and the results of the Below Water Table Trial (Liquid Earth 2005; Youngs and Brown 2005). MWH (2006a) then re-calibrated the model against groundwater level records from 1992–2006 and the results of the Marra Mamba Below Water Table Trial (MWH 2006b).

The Marandoo groundwater model was validated for the confined aquifer during the Marra Mamba Below Water Table Trial, in which the predictions of groundwater level responses to the dewatering and re-injection proved to be accurate (MWH 2006b). The calcrete hydraulic parameters used in calibrating the unconfined aquifer are based on the steady state calibration of the model against observed changes in water levels during natural recharge events. The hydraulic parameters will be refined further; however, the ability to obtain field data is restricted as drilling and extensive disturbance would be required within Karijini National Park.

An internal review of the model has been undertaken by the Proponent in accordance with the Murray-Darling Groundwater Model Guidelines (Aquaterra 2001), in the context of verifying the predicted dewatering volumes.

The calibration of the Marandoo groundwater model has resulted in an average calibration error of 0.36 m based on drawdown (3% of the total difference in head across the model domain) and 0.82 m based on measured heads (5% of the total difference). An error of less than 5% is typically indicative of an acceptable calibration. Given the number of calibration bores, and the vertical and horizontal distribution in the aquifer system, the model calibration is considered comprehensive and consistent with the Marandoo aquifer system (MWH 2006a).

615000 mE
620000 mE
625000 mE
630000 mE
7500000 mN
7495000 mN
7490000 mN
Mt Bruce
Marandoo
Rail
Plant
Train loadout
Product stockpile
Marandoo Mine Layout
See inset A
See inset B
See inset C
Coolibah woodland
Rail Access Road
INSET A
INSET B
INSET C
LEGEND
Water bores
Rail access road
Railway
Tracks
Approved Disturbance
Proposed MMP2 Disturbance Footprint
MMP2 Project Disturbance
SCALE
1km
0
1
N
Figure 24
Location of bores used during groundwater trials at Marandoo
RioTinto
Drawn:TC
Date:April 2008
Plan No:PD0080/9509-1
Proj:MGA94 Zone50

Southern Fortescue borefield hydrogeological setting

The Southern Fortescue borefield is located within the Southern Fortescue River Valley, which is bounded to the west and east by outcropping Marra Mamba Iron Formation and Brockman Iron Formation respectively (Figure 9). The Southern Fortescue aquifer system has developed in a broad drainage channel incised in the Proterozoic rocks of the Hamersley Group and subsequently in-filled by alluvial, colluvial and chemical sediments (AGC 1990).

The general lithology of the area from top to bottom is as follows (Figure 9):

- palaeovalley deposits up to 88 m thick (sand, silt, gravel and clay)
- calcrete up to 40 m thick
- goethite (ferricrete)
- palaeovalley deposits up to 50 m thick (shaly, cavernous in parts)
- Wittenoom Formation up to 90 m thick (shaly, cavernous in parts)
- Wittenoom Formation up to 150 m thick (massive)
- Marra Mamba Iron Formation up to 180 m thick.

The units that function as aquifers are the palaeovalley deposits, calcrete, goethite and the Wittenoom Formation (MWH 2007b). The principle aquifer is the Wittenoom Formation. Cainozoic terrestrial regolith materials (gravel/sand alluvium and calcrete layers) overlying the Wittenoom Formation provide localised aquifers. Marra Mamba Iron Formation outcropping on the western side of the Southern Fortescue River Valley may be permeable where mineralised (MWH 2007a) (Figure 9). The Wittenoom Formation in the area has a high transmissivity, but may also have limited storage (MWH 2007a).

The Southern Fortescue aquifer system is recharged via groundwater throughflow from the Mount Bruce Flats catchment area and infiltration through outcropping BIF rocks to the west and east of the borefield. Discharge is directed north via a base flow towards the Fortescue River, following the streamline of the Southern Fortescue River (MWH 2007a; Figure 10). Groundwater discharge from the upper aquifers downstream of the Southern Fortescue borefield supports perennial surface flow in Hamersley Gorge (Dodson 2008).

Natural groundwater levels measured at the commencement of abstraction from the Southern Fortescue borefield varied between 25 m and 45 m below ground level (Wade Dodson, Principal Hydrogeologist [Rio Tinto] 2008 pers. comm., 8 September). Water has been supplied to Tom Price from the Southern Fortescue aquifer system via abstraction at the Southern Fortescue borefield at a rate of approximately 3.66 GL/year (10 ML/day) since 1972. Abstraction at this rate was initially concentrated over fewer bores than the borefield currently operates and, as a result, local groundwater levels were drawn down by approximately 20–30 m (to approximately 60 m below ground level) (MWH 2006b; MWH 2007a). Recent expansion of the borefield has distributed abstraction over a greater area and groundwater levels near the borefield have not significantly altered over the last 10 years (Wade Dodson, Principal Hydrogeologist [Rio Tinto] 2008 pers. comm., 16 June).

Southern Fortescue borefield re-injection trial

The Proponent commenced a re-injection trial at the Southern Fortescue borefield in August 2008 to refine estimates of the storage available for long-term injection and determine likely constraints to re-injection in terms of bore efficiency and the hydraulic properties of the aquifer, such as transmissivity (which determines the rate at which groundwater will move away from an injection point) and specific yield (which determines how much the aquifer can ultimately receive over time). During the re-injection trial, approximately 2.3 ML/day was continuously injected at a single bore at the Southern Fortescue borefield over 20 days.

Sinkhole formation

Six sinkholes have been identified to date within the Southern Fortescue borefield, oriented on an east-west line within approximately 650 m of each other.

Sinkholes are landform features that form predominantly in upland zones and to a lesser extent in discharge areas of carbonate aquifers, although similar morphological features have been described in non-carbonated settings (MWH 2007a).

Sinkholes are basin-like, funnel-shaped or vertical-sided surface expressions of groundwater flow conduits, which may form due to a variety of natural processes, including (MWH 2007a):

- dissolution of bedrock by percolating rainwater
- instant or progressive collapse of bedrock into underlying voids
- hydraulic compaction
- settling as materials are removed by groundwater flow
- gradual physical and chemical washing down of the sediments into stable fissures and caves of the underlying bedrock.

Sinkhole formation may also be caused or accelerated by (MWH 2007a):

- groundwater drawdown
- re-injection and discharge into wells/bores
- ground vibrations (for example, caused by blasting or heavy traffic)
- drilling-induced erosion
- artificial ponding of surface water
- enhanced groundwater recharge resulting from removal of vegetation.

Sinkholes have been reported to occur around the world as a result of dewatering, whereby lowering of water levels drains voids, which increases hydraulic gradients and removes the buoyant support of water. Soil present at the top of drained voids may then collapse or subside as a result of increased effective stress, particularly when the soil becomes wet. The rate of sinkhole formation caused by groundwater drawdown is generally related to the rate of drawdown (MWH 2007a).

Re-injection of water could also potentially lead to sinkhole development. Adding water to the system will provide physical support to karst systems; however, if the dissolved CO_2 levels, pH and level of calcite saturation are different, re-injection may result in either precipitation of $CaCO_3$ (and clogging of screens) or dissolution of $CaCO_3$ (and more karst development) (Wade Dodson, Principal Hydrogeologist [Rio Tinto], 2008, pers. comm., 8 August).

Key indicators of potential sinkhole formation include depressions or low-lying areas (particularly if circular), strain lines directed toward depressions and areas along structural lineaments (for example, marked by drainage channels and breaks in adjacent ridges) (MWH 2007a).

Sinkhole formation has been closely associated with mining of iron ore, coal, lead and zinc deposits in a number of locations throughout the world (MWH 2007a). Sinkholes present a significant risk to mining infrastructure and safety; however, risks to the environment may be less significant.

5.2.2 Potential sources of impact

Activities or aspects of the Proposal that may affect groundwater values include:

- ore body dewatering near the mine pit will lead to drawdown of groundwater levels in the confined aquifer, reduce throughflow west of Marandoo and may result in the formation of sinkholes throughout the cone of depressurisation (which may in turn harm native fauna and alter surface flows or groundwater recharge rates)
- intersection of the unconfined aquifer by the proposed mine pit will cause seepage and subsequent groundwater drawdown in the unconfined aquifer
- hydrocarbon spills may lead to groundwater contamination
- re-injection of dewatering water at the Southern Fortescue borefield will lead to an increase in groundwater levels (to previous 'natural' levels) and may:
  a) cause or enhance sinkhole formation (which may in turn harm native fauna and alter surface flows or groundwater recharge rates)
  b) increase water levels in streams, pools and springs fed by the Southern Fortescue aquifer system
- dewatering and reinjection may result in groundwater drawdown and increased groundwater levels at springs and pools in Karijini National Park (addressed in Section 5.1.4).

Potential effects of groundwater drawdown and/or increased groundwater levels on the Coolibah woodland and subterranean fauna are addressed in Section 5.5 and Section 5.7, respectively.

Activities or aspects of the Proposal that may affect groundwater values following completion of mining activities and closure of the Marandoo mine site are addressed in Section 5.10.

5.2.3 Key statutory requirements, environmental policy and guidance

EPA objective

In most circumstances, including this assessment, the EPA applies the following objective in its assessment of Proposals that may affect groundwater:

To ensure that alterations to groundwater flows or quality do not have an adverse impact on beneficial or environmental uses of the water and that the integrity, functions, and environmental values of watercourses are maintained.

Regulatory framework

Dewatering of groundwater will be subject to a licence issued by the Department of Water (DoW) under the *Rights in Water and Irrigation Act 1914* (WA) that specifies the maximum dewatering rate and includes conditions for monitoring.

Potentially polluting activities at the mine site are managed under a licence issued under the Part V of the EP Act.

Water resource strategies

The Government of Western Australia (2001) developed the State Water Quality Management Strategy in 2001 with the objective 'to achieve sustainable use of the Nation's water resources by protecting and enhancing their quality while maintaining economic and social development'.

The Strategy requires that a Water Conservation Plan be developed before a water allocation licence is issued or renewed. The Water Conservation Plan must outline water efficiency objectives and timeframes. Licence conditions require implementation of the Water Conservation Plan to an agreed schedule.

5.2.4 Assessment of potential impact

Predicted groundwater drawdown from dewatering

A total of approximately 200 GL will be extracted from the confined aquifer at Marandoo over the life of the Proposal (approximately 13 GL/year). Based on the current mine plan, construction schedules and understanding of the hydrogeological system at Marandoo (including considerations for climate variability), the Proponent estimates a peak mean abstraction rate of approximately 65 ML/day, which would reduce after three years to 50 ML/day as dewatering of the mine pit is achieved. Given the uncertainty in mine planning needs, spatial and temporal hydraulic parameter variability, potential for scheduling issues to arise during construction and climate variability, the ultimate peak abstraction rate may be greater or less than the above prediction. To provide flexibility in mine planning, the planned peak design dewatering rate was conservatively set at 75 ML/day.

Some pit sumping (or local dewatering bores) may be required during phases of rapid pit advancement and/or towards the end of the mine life, with potential sumping volumes predicted to be up to 8 ML/day (MWH 2006c). The Proponent will develop and implement a rotational bore maintenance schedule such that at no time would the entire dewatering borefield be shut down for maintenance. This will ensure groundwater levels do not recover during planned operational maintenance such that no seepage through the pit floor occurs. Groundwater levels may recover in the event of an emergency shutdown or power outage, although the degree of recovery would be dependent on the duration of shutdown and at what point in the dewatering life the event occurred. Should groundwater levels recover such that water seeps through the pit floor, the water will be removed via sump pumps and discharged to culverts through the railway embankment.

Dewatering over the life of the Proposal will result in a reduction in pressure (drawdown) within the confined aquifer of approximately 120 m at the mine site and 43 m at the far northern margins of the Mount Bruce Flats (MWH 2006c; Figure 25). Seepage and drawdown in the unconfined aquifer is expected adjacent to the mine pit due to intersection of the aquifer by the pit. Drawdown within the unconfined aquifer as a result of dewatering in the confined aquifer is expected to be negligible across the Mount Bruce Flats due to the intervening clay layer (MWH 2006c). There is the potential for a pocket of higher drawdown at an area of higher permeability between the confined and unconfined aquifers that occurs at a dolomitic outcrop near Mount Bruce (Figure 25).

Where the northern margin of the proposed mine pit intersects the unconfined aquifer, seepage of groundwater into the pit will peak after eight years and will result in a drawdown of approximately 10–20 m at the pit margin (MWH 2006c; Figure 26). Drawdown is predicted to be approximately 0–2.5 m at the Coolibah woodland (MWH 2006c); however, most parts of the Coolibah woodland will only experience drawdown of less than 1 m (Figure 26).

The rate of drawdown in the aquifers is sensitive to the mine plan finally adopted. A worst-case scenario has been established, whereby total predicted drawdown occurs in the initial eight years of dewatering as a result of rapid phases of pit advancement during this period. Dewatering subsequent to this period will not involve rapid removal of groundwater storage and will not result in additional groundwater drawdown.

Assuming a linear rate of drawdown during the initial eight years of dewatering, the estimated worst-case rate of groundwater drawdown in the confined aquifer is approximately 15 m/year at the mine site and 5.5 m/year at the far margin of the Mount Bruce Flats. The estimated worst-case rate of drawdown in the unconfined aquifer is approximately 0.3 m/year over the initial eight years at the Coolibah woodland. The scenarios modelled for drawdown within the unconfined aquifer have been based on hydraulic parameters generated from observed recharge events.

Towards the end of mine life, groundwater that would normally flow to the south-east and discharge at Minthicoondunna Spring, may instead be directed back into the open mine pit. The extent to which groundwater flow to Minthicoondunna Spring may be redirected to the proposed mine pit will largely be dependent on the hydraulic properties of the upper Tertiary sediments and the degree of hydraulic connection with the lower confined aquifer. The potential impact to Minthicoondunna Spring is discussed in Section 5.1.4.

Rebound of groundwater levels in the Marandoo aquifer system following closure is discussed in Section 5.10.

Southern Fortescue borefield re-injection

Based on an estimated 5 ML/day used at Marandoo and 30 ML/day transferred to Tom Price, there will be an excess of approximately 30 ML/day of dewatering water during the first three years of the Proposal, and approximately 15 ML/day thereafter (Figure 20). This excess is proposed to be re-injected at approximately 12 existing bores, and if required, approximately four new bores at the Southern Fortescue borefield. Approximately 2.3 ML/day has been successfully injected at a single bore at the Southern Fortescue borefield over 20 days during the August 2008 re-injection trial. The specific volume able to be received by the Southern Fortescue borefield on a daily or annual basis is still to be confirmed pending further hydrogeological trials and studies to confirm the aquifer capacity.

The mixed aquifer system at the Southern Fortescue borefield is believed to have suitable properties for sustained aquifer injection (Section 3.2.6; MWH 2006c). The 2004 re-injection trial conducted at Marandoo was in similar stratigraphy with similar chemistry to the Southern Fortescue aquifer system, providing data on the system. Based on the Proponent's current understanding of the hydrogeological system at Southern Fortescue borefield, the aquifer is anticipated to have the capacity to conservatively accept at least 15 ML/day and possibly up to 30 ML/day, subject to further analysis. Modelling of re-injection scenarios has been undertaken by MWH (2008). Two scenarios were modelled to assess the groundwater level response to injection into the existing Southern Fortescue borefield and into a hypothetical borefield to the north containing an additional five bores spaced 2 km apart. Preliminary modelling results indicate that, after injection of 15 ML/day into the existing Southern Fortescue borefield for 16 years, groundwater levels are likely to be no higher than 10 m below ground level. Natural groundwater levels measured at the commencement of abstraction from the Southern Fortescue borefield varied between 25 m and 45 m below ground level (Wade Dodson, Principal Hydrogeologist [Rio Tinto] 2008 pers. comm., 8 September). There is potential for optimisation of re-injection bore locations during operation to spread the groundwater level rise more evenly across the borefield (MWH 2008). Modelling of the capacity of the Southern Fortescue aquifer system to accept required volumes and the refinement of the proposed re-injection infrastructure is ongoing.

Excess dewatering water from the Proposal has the capacity to meet the entire Tom Price mine and town demand for the life of the Proposal. Transfer of this water from Marandoo will allow existing sources (the Southern Fortescue, Mount Lionel and Hardey River borefields) to be rested or artificially recharged to enable recovery in groundwater levels.

Sinkhole formation

There is a risk of sinkhole formation in the vicinity of Marandoo and the Southern Fortescue borefield as a result of the Proposal.

Sinkholes may form near Marandoo within the cone of aquifer depressurisation. Sinkhole formation at the Southern Fortescue borefield may be caused or enhanced by re-injection into the mixed aquifer system (MWH 2007a). The potential for further development of sinkholes will be dependent on the chemistry of Marandoo groundwater compared to that at the Southern Fortescue borefield, particularly the level of calcite saturation. Existing data indicate the chemistry of groundwater at Marandoo is similar to that at the Southern Fortescue borefield (Table 8).

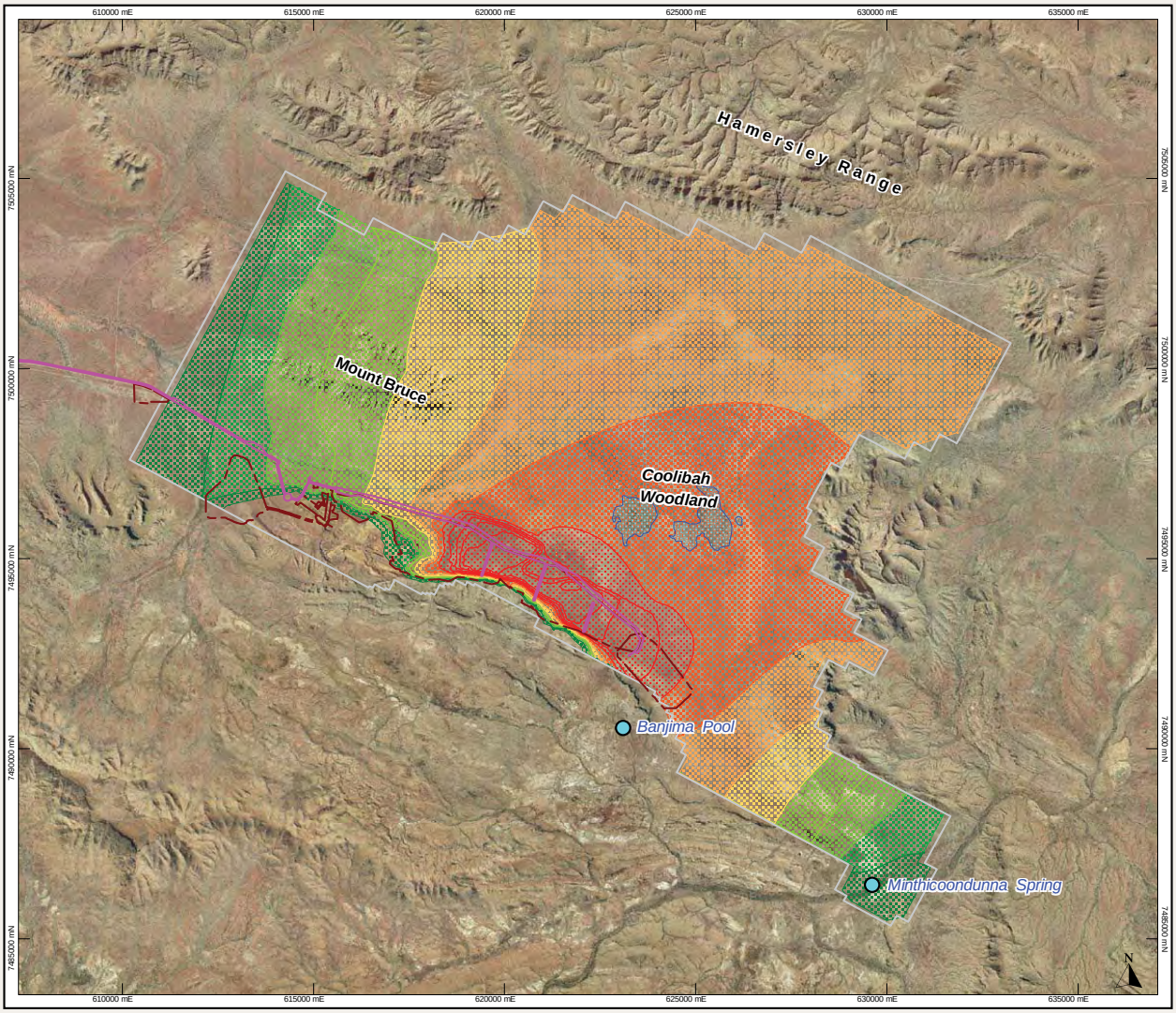
Sinkhole formation is often associated with material containing carbonate, but the active process of dissolution of carbonate material and erosion and subsidence of overlying materials is difficult to control. Therefore, sinkhole management generally focuses on monitoring and early identification of the onset of surface deformation and the subsequent development of appropriate measures to mitigate the risk to people, infrastructure and the environment. Further understanding of the mechanism of existing sinkhole formation at the Southern Fortescue borefield is being undertaken through a geotechnical drilling program to assess the potential risk of new sinkhole formation at both the Southern Fortescue borefield and Marandoo.

Physical disturbance that results from sinkhole development is very limited in area, with the depressions generally only 20–30 m in diameter. The potential environmental impact to flora and fauna values is therefore considered to be minimal. Surveys to determine whether sites of heritage significance occur in the Southern Fortescue borefield area will be undertaken in Quarter 4, 2008.

Hydrocarbon spills and re-injection - effect on groundwater quality

Diesel and other hydrocarbons will be used routinely at Marandoo during mining. Spillages of hydrocarbons are most likely to occur during re-fuelling of trucks and other machinery. Groundwater quality could potentially be affected by spills of hydrocarbons; however, these risks will be managed through the application of existing design, infrastructure and operational procedures (Section 5.2.5).

There is a potential for nitrate residues from blasting agents at Marandoo to enter groundwater, however, this is not considered a significant risk to groundwater quality given the small quantities of blasting agents involved. The water chemistry at Marandoo is very similar to the water chemistry at the Southern Fortescue borefield (Table 8), with a natural connection and water flow existing between the two systems. Therefore, the proposed re-injection is not expected to affect the chemistry of groundwater at the Southern Fortescue borefield.



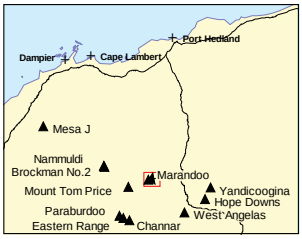
RioTinto

Strategic Assets - Perth

Figure 25
Predicted groundwater drawdown in the confined aquifer

Drawn: TC
Date: May 2008
Plan No. PDE0049509v1
Proj: MGA94-50

LOCATION MAP



SCALE

0 2 4 6 8km

1:150,000 @ A4

LEGEND

Predicted groundwater drawdown (m)

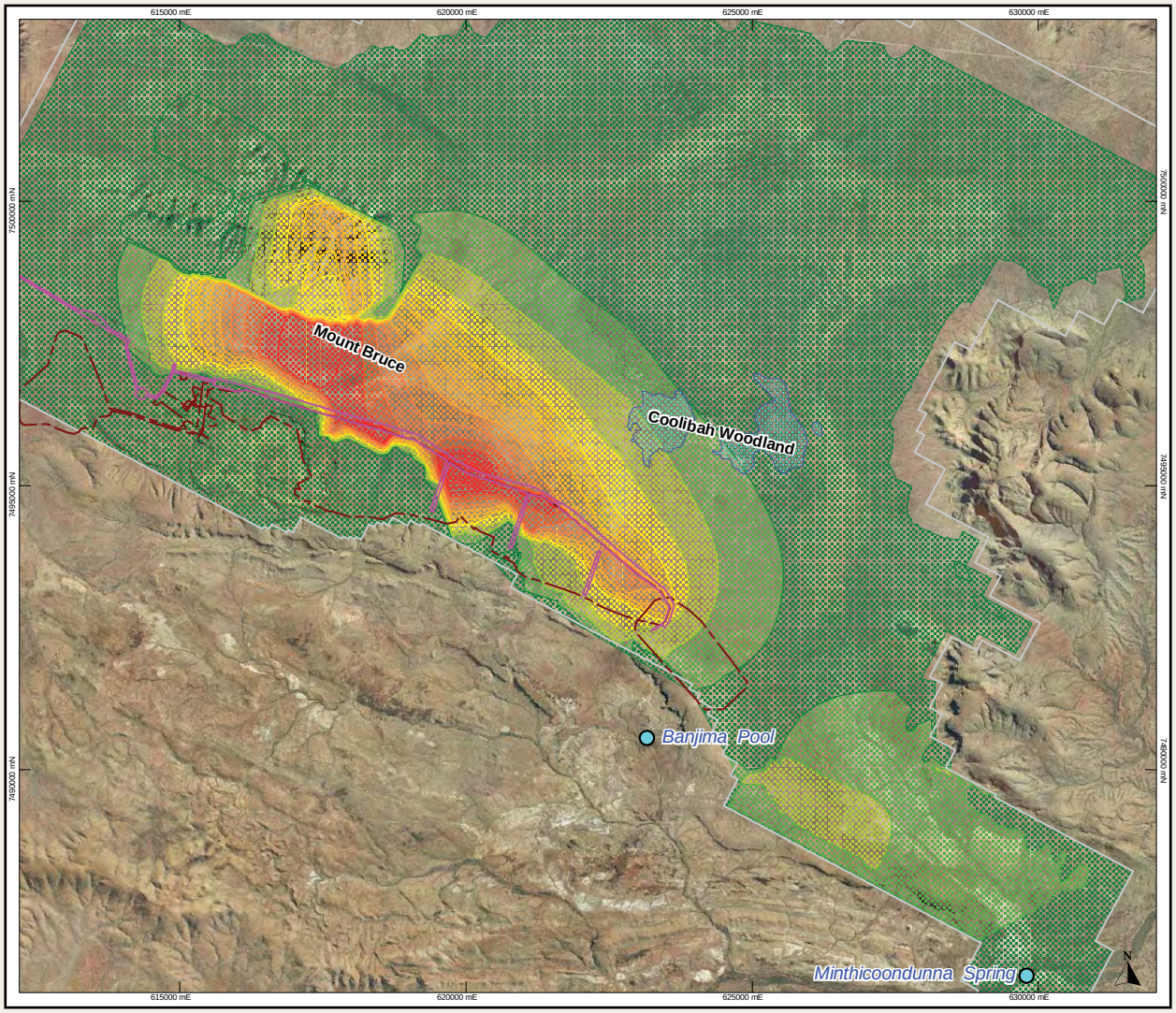
- 70 to 110
- 60 to 70
- 50 to 60
- 40 to 50
- 30 to 40
- 20 to 30
- 10 to 20
- 0 to 10

Active Model Area

MMP2 Project disturbance

Proposed MMP2 disturbance footprint

Coolibah Woodland
(Indicative 2007 Data)



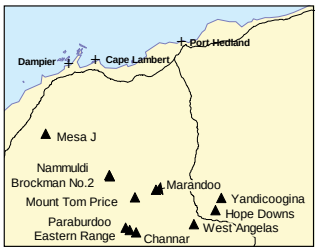
Rio Tinto

Strategic Assets - Perth

Figure 26
Predicted groundwater drawdown in the unconfined aquifer

Drawn: TC
Date: May 2008
Plan No. PDE0049509v1
Proj: MGA94-50

LOCATION MAP



SCALE

1 0 1 2km

1:75 000 @ A4

LEGEND

Predicted groundwater drawdown (m)

- 10 to 20
- 9 to 10
- 8 to 9
- 7 to 8
- 6 to 7
- 5 to 6
- 4 to 5
- 3 to 4
- 2 to 3
- 1 to 2
- 0 to 1

Active Model Area

MMP2 Project Disturbance

Proposed MMP2 disturbance footprint

Coolibah Woodland
(Indicative 2007 Data)

5.2.5 Proposed mitigation and management measures

Potential impacts to groundwater quantity and quality at Marandoo and the Southern Fortescue borefield will be addressed through the implementation of measures outlined in the Groundwater Management Plan (Appendix 2). Key measures include:

- using the results of the Southern Fortescue borefield re-injection trial to more accurately characterise the Southern Fortescue hydrogeological system to allow for the incorporation of updated information into the Southern Fortescue and Marandoo groundwater models
- developing and implementing a rotational bore maintenance schedule to minimise potential for water to seep into the mine pit
- optimising the location of the re-injection bores within the Southern Fortescue borefield to spread the rise in groundwater level across the borefield
- monitoring observation bores within Southern Fortescue borefield to ensure groundwater levels do not rise more than 5 m above historical (pre-abstraction) groundwater levels as a result of re-injection
- undertaking further hydrogeological investigations between Marandoo and Minthicoondunna spring to determine the hydraulic parameters of the Upper Tertiary sediments, and any hydraulic connection between the superficial calcrete aquifer and the confined aquifer
- monitoring the water level at Minthicoondunna Spring, and groundwater levels between Marandoo and Minthicoondunna Spring
- continuing consultation with the Eastern Guruma people and other relevant stakeholders
- investigating the chemistry of groundwater at Marandoo and the Southern Fortescue borefield to understand the carbonate chemistry and any potential implications for clogging or dissolution of the formation matrix
- conducting an investigation into the mechanism of sinkhole formation at the Southern Fortescue borefield and completing an assessment of high risk areas at the Southern Fortescue borefield, Marandoo and surrounding areas
- undertaking studies to monitor sinkholes in the vicinity of Marandoo and the Southern Fortescue borefield, including investigating the number and size of existing sinkholes to provide a baseline for future monitoring, this may include:
  a) visual monitoring
  b) differential photogrammetry with respect to a baseline image
- managing sinkhole risk through early detection of the onset of surface deformation and/or reactivation of existing features
- fencing sinkholes and implementing other measures to reduce any potential risk to public safety
- applying controls to hydrocarbon transport, handling and disposal in accordance with the Proponent's corporate standards
- applying existing hydrocarbon clean-up procedures
- safe storage, handling and disposal of ablution effluent.

5.2.6 Predicted outcome

After mitigation and management measures have been applied, the Proposal is expected to result in the following outcomes in relation to groundwater quantity and quality:

- Dewatering at Marandoo will result in a reduction in pressure (drawdown) in the confined aquifer of approximately 120 m at Marandoo, which will reduce to 43 m at the far margins of the Mount Bruce Flats. Based on the current proposed mine plan, which indicates peak dewatering during the first eight years, the estimated maximum rate of drawdown in the confined aquifer is approximately 15 m/year at the mine site and 5.5 m/year at the far margin of the Mount Bruce Flats.
- Dewatering of the confined aquifer is not expected to result in groundwater drawdown within the unconfined aquifer due to the intervening clay layer.
- Intersection of the unconfined aquifer by the northern margin of the proposed mine pit is predicted to result in a groundwater drawdown within the unconfined aquifer due to seepage into the mine pit of approximately 10–20 m at the pit margin to approximately 0–2.5 m at the Coolibah woodland. The estimated rate at which this drawdown would occur is approximately 0.3 m/year at the Coolibah woodland, based on the total drawdown occurring during the initial eight years or more of dewatering (as a result of rapid pit advancement during this period).
- Re-injection of water into the Southern Fortescue borefield will allow the active recharge and recovery of the aquifer system, which has been significantly drawn down since the commencement of operations at Tom Price. This will allow water levels to return to pre-production levels. The supply of excess dewatering water to Tom Price will also allow the passive recovery of the Mount Lionel and Hardey River borefields, which would no longer be drawn upon to supply Tom Price.
- There is a risk of sinkhole formation being caused or accelerated by the Proposal in the vicinity of Marandoo and the Southern Fortescue borefield.
- There is the possibility of affecting water levels at Minthicoondunna Spring near the end of the mine life as the groundwater cone of depression extends in a south-easterly direction. However, further hydrogeological investigations are planned to determine the level of risk, if any (Section 5.1.4).

The EPA objective for this factor will be met.

5.3 Watercourses and surface water quality

5.3.1 Description of factor

Marandoo Ridge hydrological regime

The Marandoo mine site is located on the north side of a curvilinear outcropping of Marra Mamba iron ore known as Marandoo Ridge, which forms the southern boundary of the Mount Bruce Flats sub-catchment (Figure 10). The Mount Bruce Flats sub-catchment constitutes a major, flat-lying, internally draining basin and forms the upper reaches of the Turee Creek regional catchment. The western and northern boundaries of the Mount Bruce Flats sub-catchment form the drainage divide between the Turee Creek regional catchment and the Fortescue River regional catchment (Figure 10). Like all major rivers in the Pilbara, Turee Creek, Fortescue River and their tributaries are ephemeral and generally flow only following significant rainfall events (Ruprecht and Ivanescu 2000).

The majority of surface water runoff generated on Marandoo Ridge during low-intensity rainfall events infiltrates the soil and does not reach the Mount Bruce Flats. Infiltration rates in the order of 5–10 mm/hr reduce surface runoff flow distances such that small rainfall events (less than 40–50 mm) are unlikely to result in surface water runoff in the area below the ridge. Generally, a rainfall event in excess of around 80 mm is required to generate significant runoff from Marandoo Ridge (Beckett 2008). Following large rainfall events, surface water runoff across the mine site is characterised by overland ('sheet') flow and shallow, low velocity (less than 1 m/s) flow in a small number of ephemeral drainage lines.

The Mount Bruce Flats is subject to inundation following significant rainfall events. Drainage within the Flats is mostly internal, towards topographic lows in the centre of the basin (Liquid Earth 2005). The low-lying nature of the Flats, roughly coincident with the Coolibah woodland (Section 5.5), may become flooded for an extended period of time following sufficient rainfall. The Mount Bruce Flats is capable of holding approximately 100 GL of flood water. After rainfall of more than 150 mm, the volume of water within the Flats is likely to exceed the internal holding capacity and water will begin to flow south-east across the sub-catchment divide into the Turee Creek catchment (Beckett 2008; Figure 10).

The natural surface water regime of Marandoo Ridge has already been modified as a result of the construction of the railway from Rosella Siding to Homestead Junction. The railway runs roughly east-west and is located to the north of Marandoo (Figure 10). Sheet flow generated to the south of the railway on Marandoo Ridge is intercepted by the railway embankment and subsequently directed down-slope along the base of the embankment. Water then flows towards the Mount Bruce Flats via culverts placed at regular and strategic intervals through the embankment. Spreader structures at culvert outlets disperse the concentrated flows.

Southern Fortescue River Valley hydrological regime

The Southern Fortescue borefield, operations camp, dewatering infrastructure and dewatering water discharge points are located within the upper reaches of the Southern Fortescue River Valley, adjacent to the Southern Fortescue River in the Fortescue River regional catchment (Figure 10). The Southern Fortescue River Valley is approximately 40 km long and is bounded to the east and west by rugged hills of outcropping Brockman Iron Formation and Marra Mamba Iron Formation. The Southern Fortescue River flows northwards to the wide, flat Southern Fortescue River Valley floor, before exiting the Valley via Hamersley Gorge or Weelumurra Creek, depending on flood conditions. The river then continues northwards and eventually discharges into the Fortescue River proper.

The Southern Fortescue River is fed by surface water runoff from the 570 km^2 upper catchment of the Southern Fortescue River Valley. Groundwater-fed base flow is evident downstream of the Proposal area, where the Southern Fortescue River cuts through the Hamersley Range (Figure 6). Surface water flows through the Southern Fortescue River Valley are larger when the unconfined alluvial aquifers are saturated. No hydrograph is available for this system (WRM 2008).

Excess dewatering water is proposed to be discharged throughout the life of the Proposal into tributaries of the Southern Fortescue River. The two discharge points (Figure 18) are in areas of existing disturbance associated with culverts through the railway embankment.

The area downstream of Discharge Point No. 1 (Figure 18) is weakly defined, suggesting runoff is dominated by overland flow conditions. Natural peak flow volumes at this location for 2–100 year Annual Recurrence Interval (ARI) flood events are estimated to be approximately 7–70 m^3/s (Kirsty Beckett, Hydrologist [Rio Tinto], 2008, pers. comm., 8 August).

The area downstream of Discharge Point No. 2 (Figure 18) is well-defined, with dense vegetation on the banks of the creek. Vegetation away from the creek line is less dense, forming grove-intergrove communities indicative of overland flow conditions, possibly associated with overbank flow during extreme flood events. Natural peak flow volumes at this location for 2–100 year ARI flood events are estimated to be approximately 16–226 m^3/s (Kirsty Beckett, Hydrologist [Rio Tinto], 2008, pers. comm., 8 August).

Southern Fortescue River aquatic fauna baseline assessment

A baseline aquatic fauna assessment of the Southern Fortescue River and its tributaries was undertaken by WRM (2008) to enable an evaluation of the potential impacts of discharging excess dewatering water into this system. The assessment involved a review of relevant literature and a site visit to identify the range of baseline aquatic ecosystem values and select future sampling locations for an aquatic systems monitoring program. Seventeen (17) sites along the Southern Fortescue River system were visited by WRM (2008) in June 2008 (Figure 27).

Flowing water and permanent pools were recorded by WRM (2008) only in Hamersley Gorge. A few small, remnant pools were recorded along the upper reaches of the Southern Fortescue River system approximately 500 m upstream of the Hamersley-Mount Bruce Road and downstream of the confluence of the two drainage lines on which the Discharge Points lie. These were generally small (less than 10 m long by 5 m wide), shallow (less than 30 cm deep) and appeared to be receding at the time of the site visit. These pools would not be expected to persist long into the dry season (WRM 2008).

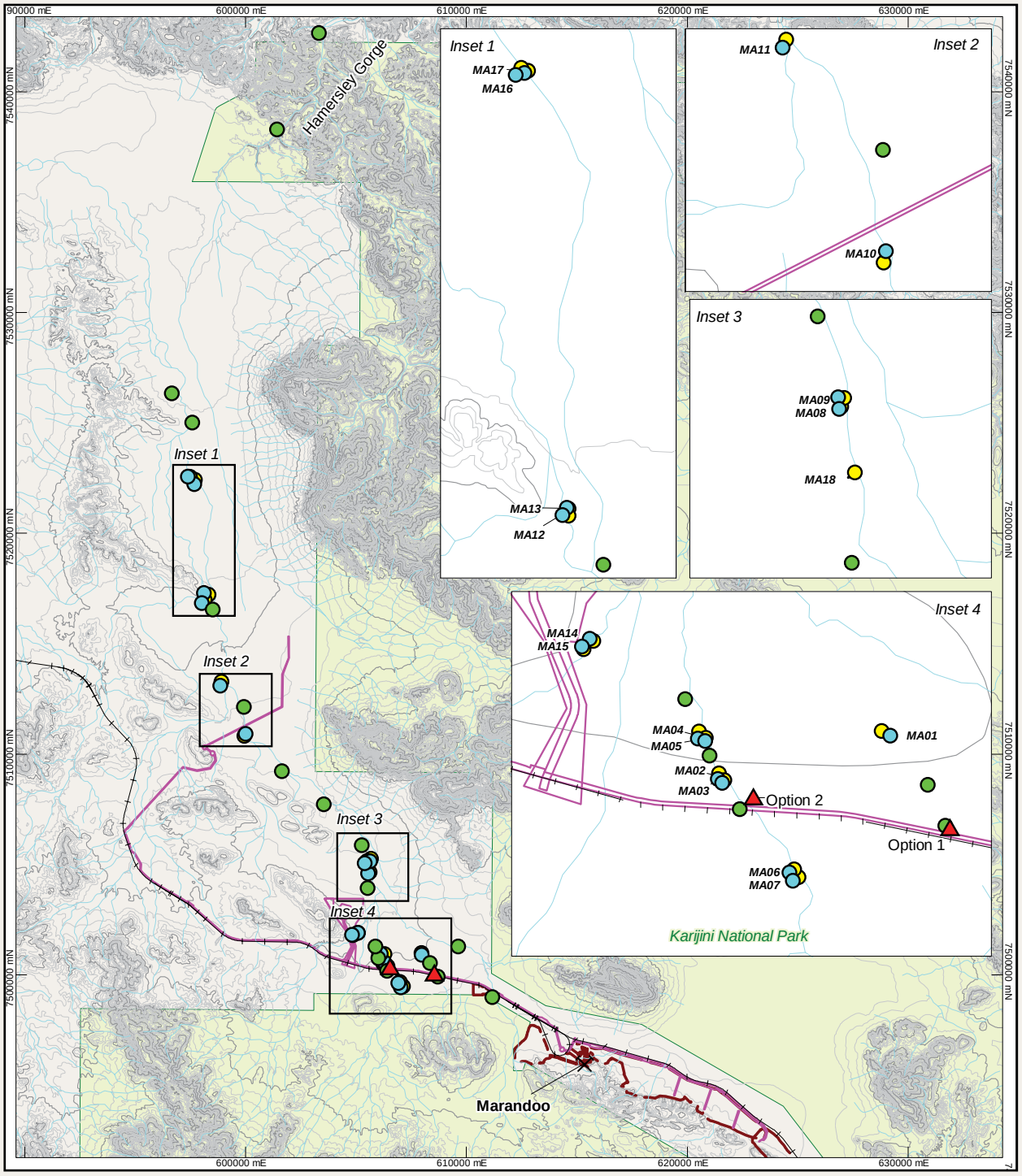
The aquatic macroinvertebrate assemblages of the Southern Fortescue River system have not been documented; however, a number of sites on the Fortescue River proper (and its tributaries) have been previously sampled as part of a wider program throughout Western Australia. The majority of aquatic macroinvertebrate families recorded at these sites are common, widely distributed and relatively ubiquitous in the Pilbara region, and would be expected to appear in pools along the Southern Fortescue River following surface flows and sufficient time to allow fauna to colonise the system (WRM 2008).

Aquatic macroinvertebrates and tadpoles were observed by WRM (2008) in most pools, and a single, unidentified adult tortoise was recorded in a pool close to the Hamersley Gorge-Mount Bruce Road.

The fish fauna of the Pilbara is characterised by low species diversity and high levels of endemicity (WRM 2008). Fish inhabiting the Pilbara are adapted to the extreme conditions that occur in the region and many have adaptations for surviving drought. No introduced fish species have been recorded from the Fortescue River system (WRM 2008).

Many large fish were observed by WRM (2008) in Hamersley Gorge pools; however, no fish were observed in the smaller pools in the upper reaches of the system, and there was no evidence (for example, bones/skeletons) of fish having been present at these locations.

No existing water quality data for the Southern Fortescue River system were located by WRM (2008).



RioTinto

Figure 27
Aquatic Survey Sites and Vegetation Condition Transects Downstream to Preferred Discharge Points

Drawn: B Jackson
Date: August 2008

Plan No: PDE0049509v1
Proj: MGA94 Zone50

LEGEND

- Aquatic Survey Sites
- Vegetation Condition Transect Start
- Vegetation Condition Transect End
- Dewatering Water Discharge Points
- Vegetation Condition Transects
- Roads
- Rail Access Road
- Railway
- Watercourse
- Contours
- Karijini National Park
- Proposed MMP2 Disturbance Footprint
- MMP2 Project Disturbance

SCALE

5 0 5km

1:250 000 @ A4

5.3.2 Potential sources of impact

Activities or aspects of the Proposal that may potentially affect surface water include:

- discharge of excess dewatering water will alter local hydrological regimes and may potentially:
  a) affect aquatic fauna
  b) cause riparian vegetation to become dependent on the artificial flow
  c) increase prevalence of weeds
  d) increase erosion and sedimentation along discharge pathways
- physical presence of mine pit and infrastructure will alter surface water flow paths
- discharge of stormwater has the potential to affect surface water quality through sediment and hydrocarbon contamination
- final landforms will lead to permanent changes to natural surface water flows.

Potential impacts to vegetation from alterations to local hydrological regimes are addressed in Section 5.4.4 (vegetation within the mining lease) and Section 5.5.4 (Coolibah and Mulga communities on the Mount Bruce Flats).

The potential effect of altered landforms on surface water values following closure of the Marandoo mine site is addressed in Section 5.10.

5.3.3 Key statutory requirements, environmental policy and guidance

EPA objectives

In most circumstances, including this assessment, the EPA applies the following objectives in its assessment of Proposals that may affect surface water and water quality:

To maintain the quantity of water so that existing and potential environmental values, including ecosystem maintenance, are protected.

To ensure that emissions do not adversely affect environmental values or the health, welfare or amenity of people and land uses by meeting statutory requirements and acceptable standards.

Water resource strategies and guidelines

The Government of Western Australia (2001) developed the State Water Quality Management Strategy in 2001 with the objective 'to achieve sustainable use of the Nation's water resource by protecting and enhancing their quality while maintaining economic and social development'.

In 2000, the Water and Rivers Commission (now DoW) and Department of Minerals and Energy (now DoIR) developed a series of Water Quality Protection Guidelines for mining and mineral processing. These guidelines address a range of issues including installation of mine site groundwater monitoring wells, mine site water quality monitoring and mine site stormwater.

ANZECC/ARMCANZ Guidelines

In 1996, the Australian and New Zealand Environment and Conservation Council (ANZECC) together with the Agricultural and Resource Management Council of Australia and New Zealand (ARMCANZ) developed the National Principles for the Provision of Water for Ecosystems (ANZECC/ARMCANZ 1996). These national principles aim to improve the approach to water resource allocation and management, and to incorporate the water requirements of the environment in the water allocation process. The overriding goal of the principles is to provide water for the environment to sustain and, where necessary, restore the ecological processes and biodiversity of water-dependent ecosystems.

A set of water quality guidelines for the protection of marine and freshwater ecosystems has also been released (ANZECC/ARMCANZ 2000). The guidelines provide a comprehensive list of recommended low-risk trigger values for physical and chemical stressors in water bodies, broken down into five geographical regions across Australia and New Zealand. The guidelines and their application to mining are discussed in Batley et al. (2003).

5.3.4 Assessment of potential impact

Dewatering discharge

The volume of excess dewatering water that may be discharged to the environment has been minimised through application of the DoW hierarchy of water management options (Section 4.7.1). Any dewatering water not utilised in the proposed 'use at source', 'transfer', or 're-injection' strategies (Figure 20) is proposed to be discharged into ephemeral tributaries of the Southern Fortescue River system (Figure 18). This discharge is likely to comprise an intermittent discharge of around 30 ML/day for approximately two weeks at a time, a few times a year (during periodic maintenance and emergency shutdown events at the Tom Price mine) throughout the duration of the proposed dewatering. As a worst-case scenario, a continuous baseflow of approximately 15 ML/day, with intermittent (approximately two weeks at a time, during periodic maintenance and emergency shutdown events at the Tom Price mine) peaks of up to 60 ML/day, may be required during the first three years of dewatering. After this time, the peak volume required to be intermittently discharged will reduce to 45 ML/day and there will be no requirement for continuous discharge, as the dewatering volume will reduce from 65 ML/day to 50 ML/day.

Any dewatering discharge points will be designed to accommodate the maximum hydraulic capacity of the water transfer system and to operate alternately, allowing the discharge to be varied at each point to manage the saturation of each watercourse. Each discharge point will consist of multiple discharge pipes and energy dissipation infrastructure to minimise washout from high flow events.

The two locations for the discharge of excess dewatering water have different flow characteristics (Section 5.3.1); one is a floodplain and the other is a distinct creek bed. Discharge infrastructure will be designed at each discharge point to mimic as closely as possible the natural flow characteristics of each of these locations. The discharge outlet at Discharge Point No. 1 will be designed to distribute flow over a wide area; the discharge outlet at Discharge Point No. 2 (Figure 18) will be designed to mimic natural creek flow.

Effect on water quantity and quality
Water quality within the Southern Fortescue River system will not be affected by the proposed discharge of excess dewatering water, due to the high quality of groundwater in the confined aquifer (WRM 2008; Table 8).

The extent of downstream groundwater and surface water influence resulting from the discharge of excess dewatering water will depend on the discharge scenario (Table 5), geological characteristics along discharge pathways (for example, depth and extent of alluvial layers, presence of clay lenses) and preceding flows/rainfall (WRM 2008). Continuous discharge of up to 15 ML/day during the first three years of the Proposal (if required) is expected to result in perennial surface flows for some distance along the Southern Fortescue River system. The potential ecological impacts of this perennial flow have been assessed by WRM (2008) and Mattiske (2008) under the conservative assumption that the flow will extend along the entire length of channel surveyed (approximately 20 km).

Unless the creek line is already saturated, the proposed intermittent discharge of larger volumes of water is less likely than continuous discharge to result in extensive surface flows, but will create pools that will remain for several weeks or months, depending on local rains, temperature and evaporation. Intermittent discharge, resulting in intermittent flows and drying pools, is similar to the natural conditions in the Southern Fortescue River system, except that the timing of surface water expression may be unseasonal relative to the natural hydrology (WRM 2008).

Effect on aquatic fauna
Alteration of the hydrological regime of the Southern Fortescue River system from episodically-flowing to continuously-flowing is likely to result in the loss of permanent aquatic fauna residents adapted to intermittent flow and colonisation by species adapted to perennial flow ('temporary residents'). Permanent aquatic fauna residents of episodically-flowing aquatic systems have a number of adaptations to survive drying out, which often include life cycle stages that tolerate and/or require periods of desiccation. These permanent aquatic fauna residents include both invertebrates (typically micro-invertebrates, such as copepods, ostracods and cladocerans) and vertebrates (including tortoises and frogs). Any permanent aquatic fauna residents lost from affected areas of the Southern Fortescue River system are likely to be present in unaffected areas upstream and downstream of the discharge point, and would re-colonise the affected areas during and following mine closure (WRM 2008).

Perennial flows downstream of discharge points will provide suitable habitat for colonisation by fish should the affected reaches become connected with source areas in Hamersley Gorge; however, establishment of large populations of native fish species in the upper reaches of the Southern Fortescue River system is not considered an adverse ecological impact in itself. Populations that colonise these reaches would be lost following mine closure as the system returns to a natural pattern of intermittent flow (WRM 2008).

Effect on vegetation
Vegetation along creek systems downstream of the dewatering discharge points is determined by surface, sub-surface, groundwater and soil conditions (Mattiske 2008). Therefore, if these local hydrological conditions change rapidly, or are modified for any length of time, then the vegetation would be expected to be influenced by the changing local hydrological conditions (Mattiske 2008).

Substantial and prolonged discharges that result in saturation of the soil profile may lead to the increase of some plant species (those that are favoured by increased soil moisture levels) and the loss of some plant species (those that cannot tolerate waterlogging). There is also a risk that there may be an increased distribution and abundance of some plant species (including weed species) in other areas due to continual water security (Adams et al. 2005; WRM 2007). Further problems may arise if the discharge is suddenly discontinued (even at the rate that normally accompanies the aftermath of floods) for plant species that may have altered their root distribution and are unable to withstand the withdrawal of water (Adams et al. 2005).

The expected impact to vegetation along the affected reach of the Southern Fortescue River system is an increase in localised physiological stress, with localised deaths in areas of prolonged saturation of the soil profile (Dr Libby Mattiske [Mattiske Consulting Pty Ltd], 2008, pers. comm., 19 August). The creek systems and plains in the vicinity of the proposed discharge are dominated *by Acacia citrinoviridis*, with localised patches of *Eucalyptus victrix*, which are fairly tolerant of waterlogging. The creek lines near the discharge areas are largely dominated by alluvial and sandy flats supporting *Acacia citrinoviridis*. The creek line ecosystems in the area of the proposed discharge are considered sufficiently resilient to recover from any temporary impact resulting from the discharge, and would be expected to return to an ecosystem with a similar community structure and composition to the existing system within a matter of decades after the cessation of discharge (Dr Libby Mattiske [Mattiske Consulting Pty Ltd], 2008, pers. comm., 19 August).

Mine pit and infrastructure effects on surface drainage

The proposed mine pit intersects three ephemeral drainage lines that drain towards the Mount Bruce Flats and intercepts sheet flow generated upslope of the mining area (Figure 18).

An existing diversion drain along the eastern section of the proposed mine pit will convey runoff around the northern pit wall along the top of several pit benches. Whilst the width of the drain is limited due to the rugged terrain, the drain is anticipated to be capable of conveying flows of at least 5 m^3/s, which is approximately the peak volume of surface water runoff generated by a 40–50 mm rainfall event (98% of rainfall events at Marandoo during the last 10 years were less than 50 mm; Beckett 2008). Local drainage structures will be constructed during pit development to control surface water runoff within the mining area.

As the proposed RSF is located across the drainage divide between the Mount Bruce Flats sub-catchment and the Southern Fortescue River regional catchment, it is not expected to intercept significant volumes of surface water flow. The proposed RSF intercepts the 100 year floodplain of an ephemeral creek that drains to the north towards the Southern Fortescue River. Diversion bunds and channels will be constructed, if required, to direct surface flows around the perimeter of the RSF and into the downstream catchment. The volume of flow and the stream-flow regime downstream will, therefore, not be significantly affected.

Several potential locations for an RSF were assessed by the Proponent and ranked according to their suitability for storage of waste residue (Section 1.5.3). This assessment included consideration of hydrology, catchment area and flood control requirements. The location selected (Figure 15) was determined to present minimal surface water management issues as it has a relatively small catchment area and does not intersect any significant drainage lines.

The operations camp is located on the flank of a small hill outside the local floodplain. The camp will intercept a minor volume of overland flow generated within the small (less than 1 km^2) upslope catchment. This water will be diverted around the camp to ensure the volume of runoff contributing to the Southern Fortescue River system is not reduced.

During operations, the dewatering pipeline will traverse multiple tributaries of the Southern Fortescue River system but will be aligned with existing rail, road and access infrastructure where natural surface water flow patterns have already been modified. As such, the dewatering pipeline is not anticipated to further modify surface flow patterns or alter the volume of runoff reaching the Southern Fortescue River system during operations.

Potential impacts to Mulga as a result of altered surface water regimes are addressed in Section 5.5.4.

Stormwater discharge

As the Proposal will not substantially alter the southern pit wall locations, there will be no significant increase in the volume of surface runoff intercepted by the proposed mine pit compared to that intercepted by the existing and approved pits; however, there will be an increase in the volume of incident rainfall into the mine pit due to an increase in pit surface area (Beckett 2008). The volume of stormwater reporting to sump locations within the proposed mine pit is expected to more than double due to the increased volume of incident rainfall capture (Beckett 2008).

Excess water collected within mine pits will be diverted to in-pit sumps and then discharged to culverts through the railway embankment (Figure 17). Spreader structures downstream of the culvert outlets will disperse the concentrated surface water flows before the flows reach the Mount Bruce Flats. In the event of a hydrocarbon spill, or if visual and/or odour observations indicate hydrocarbon contamination, water from the mine pit will be diverted to hydrocarbon treatment facilities prior to discharge.

The Mount Bruce Flats has a total catchment area of approximately 284 km^2. The Proposal will increase the proportion of the Mount Bruce catchment intersected compared to the existing mine operation (from 19 km^2 (6.7% of the Mount Bruce Flats catchment) to 24 km^2 (8.5%)) (Beckett 2008). However, the existing diversion drain and the discharge of excess water collected within mine pits will ensure surface water flows to the Mount Bruce Flats are not significantly affected.

5.3.5 Proposed mitigation and management measures

Management of heavy rainfall is governed by the Mine Site Hydrology Report in accordance with the Proponent's Pilbara Surface Water Management Strategy. The Mine Site Hydrology Report reviews historical rainfall and describes inherent flood risks associated with active mine pits and haul roads, including runoff flow directions, flow volumes and recommended sump capacities, based on the existing mine layout. The Mine Site Hydrology Report is revised prior to the wet season each year.

Outcomes from the Mine Site Hydrology Report are implemented at the mine site through wet season management plans. These plans describe local flood protection required for the coming wet season, management to be undertaken and responsibilities for their implementation.

Surface water flows in, and around the Proposal area will be managed through implementation of measures outlined in the Surface Water Management Plan (Appendix 2). Key measures include:

- installing diversion drains around the RSF if required
- stabilising diversion structures and drains to reduce erosion and water quality impacts
- designing erosion protection at discharge outlets
- ensuring any water discharged to the natural environment does not cause the quality of receiving surface or groundwater systems to exceed the ANZECC Water Quality Guidelines (ANZECC/ARMCANZ 2000)
- monitoring dewatering water quality at the water collector tanks
- regularly monitoring channel morphology, riparian vegetation condition, erosion and pool water quality if pools are present along natural drainage lines downstream of proposed discharge outlet(s)
- developing and refining a discharge hydrograph to minimise erosion, prevent overtopping of drainage lines and where practicable, match the pattern of the natural hydrograph downstream of proposed discharge outlet(s)
- investigating alternative discharge regimes should surface flow extend beyond the length of channel (20 km) surveyed
- designing waste dumps to incorporate water management features to reduce the potential for sediment-laden surface water runoff
- installing sediment traps/basins where appropriate to reduce sediment loads in runoff from the mine area
- treating surface runoff from the workshop, vehicle washdown and processing plant areas for sediment and hydrocarbons prior to re-use on site or for discharge to the natural environment
- diverting any water from the mine pit detected as being potentially contaminated with hydrocarbons to the on-site hydrocarbon treatment facilities
- ensuring that drainage channels do not cross areas of active mining, or any locations where there is potential for hydrocarbon contamination
- designing all sumps to fully contain the likely maximum volume of a one year ARI rainfall event, with an annual revision to ensure sump capacity increases in accordance with increasing catchment and pit area
- inspecting sedimentation basins and drainage structures regularly and undertaking cleaning prior to the onset of the wet season each year
- protecting the pit crest from erosion through provision of large boulders, rock armour and/or vegetation
- undertaking progressive backfill of pits.

5.3.6 Predicted outcome

After mitigation and management measures have been applied, the Proposal is expected to result in the following outcomes in relation to surface water quantity and quality:

- Approximately 30–60 ML/day of excess dewatering water may be discharged intermittently to natural drainage lines throughout the Proposal. Approximately 15 ML/day may be discharged continuously to natural drainage lines during the first three years of the Proposal.
- Continuous discharge of up to 15 ML/day during the first three years of the Proposal (if required) is expected to result in perennial surface flows for some distance along the Southern Fortescue River system. Unless the creek line is already saturated, the proposed intermittent discharge of larger volumes of water is less likely than continuous discharge to result in extensive surface flows, but will create pools that will remain for several weeks or months, depending on local rains, temperature and evaporation.
- Alteration of the hydrological regime of the Southern Fortescue River system from episodically-flowing to continuously-flowing may result in the loss of aquatic fauna adapted to intermittent flow and colonisation by aquatic fauna adapted to perennial flow. Any permanent residents lost from affected areas of the Southern Fortescue River system would re-colonise these areas during and following mine closure.
- Alteration of the hydrological regime of the Southern Fortescue River system may result in an increase in localised physiological stress in vegetation along tributaries downstream of the proposed discharge, with localised deaths in areas of prolonged saturation of the soil profile.
- Water quality within the Southern Fortescue River system will not be affected by the proposed discharge of excess dewatering water, due to the high quality of groundwater in the confined aquifer. Discharge of water to the natural environment will not cause the quality of receiving surface or groundwater systems to exceed the ANZECC Water Quality Guidelines (ANZECC/ARMCANZ 2000).
- Flows within the mining area will be locally concentrated by diversion structures, which will result in localised increases in flow velocity and potentially soil erosion; however, the installation of sediment traps will reduce sediment load in surface water runoff.
- The operations camp will not significantly affect surface water quantity or quality in the area.

The general integrity, function and environmental values of surface flow from the Proposal area will be sustained by maintaining natural drainage flows as far as practicable, minimising erosion and preventing ponding of water, thus ensuring that the EPA objective for this factor is met.

5.4 Flora and vegetation

5.4.1 Description of factor

The proposed disturbance footprint (Proposal area) is located within the Fortescue Botanical District of the Eremaean Botanical Province as defined by Beard (1975a, 1975b). The vegetation of this province is typically open and dominated by spinifex, wattles and occasional eucalypts.

Beard (1975a, 1975b) broadly mapped the Proposal area as:

- scattered *Eucalyptus leucophloia* (snappy gum) over *Triodia wiseana* (hard spinifex) hummock grassland
- *Acacia aneura* (Mulga) continuous low woodland
- Mulga sparse low woodland
- *Astrebla pectinata* and *Aristida latifolia* open tussock grassland
- scattered shrubs of Mulga and *Acacia pyrifolia* over a *Triodia pungens* and *T. basedowii*[15] hummock grassland.

Given the broad nature of Beard's (1975a, 1975b) vegetation mapping (mapped at a scale of 1:1 000 000), these units are only broadly applicable to the vegetation occurring in the Proposal area.

Extensive flora and vegetation sampling and survey work has been undertaken in the Marandoo mining lease and surrounding areas since the 1970s (Trudgen 1975, 1977a, 1977b, 1978; Weston 1977; CRA Services Ltd 1982), the results of which were incorporated into the Mattiske (1992) report prepared for the Marandoo Iron Ore Mine and Central Pilbara Railway Environmental Review and Management Program (O'Brien 1992).

Mattiske (1992) mapped the vegetation of the Marandoo mine lease and railway corridor at a scale of 1:10 000. More recent flora and vegetation survey work undertaken by Biota Environmental Sciences (Biota) involved updating the description of the existing Mattiske (1992) vegetation mapping units within the Marandoo mining lease. Vegetation and flora mapping was also undertaken by Biota (2008b) within the Southern Fortescue borefield.

An assessment of the condition of flora and vegetation downstream of the dewatering water discharge locations was undertaken in July 2008 by Mattiske (2008). The assessment comprised collection and identification of vascular plant species along 18 transects, as well as a visual evaluation of the physiological stress in vegetation along these transects (Figure 18).

Clearing of vegetation for the operations camp and dewatering infrastructure does not form part of this Proposal and will be subject to a separate environmental approvals process under the EP Act. However, baseline information for these areas is included in this PER where relevant to potential operational and cumulative impacts, as well as ongoing management.

The Biota (2008b) survey was undertaken in accordance with the methodology and approaches of EPA Position Statement No. 3 (EPA 2002a) and EPA Guidance Statement No. 51 (EPA 2004c). The Biota (2008b) report is included in Appendix 1.

Vegetation

Vegetation units

Twenty-seven (27) vegetation units were recorded within the area surveyed by Biota (2008b) (Figure 28; Figure 29; Figure 30; Figure 31; Figure 32). This total includes vegetation units for the MMP2 Proposal and not that to be cleared for construction of dewatering infrastructure and the operations camp. The vegetation units can be divided into six main groups according to topography (Table 9).

The vegetation units mapped by Mattiske (1992) are considered to be at, or somewhat below, the broad floristic formation level. There were no new vegetation units recorded in the Biota (2008b) survey; all had been identified either within the area or within nearby areas during other recent studies.

In addition to the vegetation described in Table 9, the creek systems and plains in the vicinity of the dewatering water discharge points are dominated by woodlands of *Acacia citrinoviridis*, with occasional patches of *Eucalyptus victrix* and *Eucalyptus xerothermica* (Mattiske 2008).

Vegetation condition

Vegetation condition across the proposal area varies from Poor to Excellent (as per the rating scale defined by Trudgen (1988)). Parts of the mining lease especially along Marandoo Ridge and to the south are rated as Excellent whereas much of the area in the immediate vicinity of the current mining operations and to the north of the Marandoo Ridge is considered Poor to Very Good. Weeds are common except in the area to the south of Marandoo Ridge (Biota 2008b).

The proposed RSF location is considerably disturbed as a result of historic earthworks for infrastructure including an airstrip, waste dump and various access tracks. This area had also been recently burnt at the time of the Biota (2008b) survey. The condition of the vegetation at this location is considered to range from Poor (on the flats) to Very Good (on the hills and within the drainage area) (Biota 2008b).

15 **Likely to be** *Triodia* **sp. Shovelanna Hill (S. van Leeuwen 3835) (Biota 2008a).**

Table 9
Description of vegetation groups recorded in the vicinity of the Proposal area#

Vegetation Code*	Description
Broad drainage areas and basins	
1a	*Acacia aneura* woodland on broad flat alluvial and colluvial areas
1b	Open grassland
1c	*Triodia melvillei* hummock grassland
Major flow lines and creeks	
2a	*Acacia aneura - A. pruinocarpa* woodland in major flow lines
2b	*Eucalyptus xerothermica - Acacia aneura* woodland in major flow lines
2c	*Eucalyptus xerothermica - Acacia aneura* woodland over *Acacia citrinoviridis* tall shrubland in major flow lines
2e	*Eucalyptus victrix* woodland in secondary creeklines
Minor creeks	
3a	*Acacia* species shrubland in minor flow lines
Flats	
4a	*Acacia aneura - A. pruinocarpa* woodland
4b	*Acacia synchronicia - Vachellia farnesiana* tall shrubland
4c	*Acacia aneura* scattered low trees over open grassland
4d	*Acacia xiphophylla* low woodland
4e	*Triodia wiseana*, *T. pungens* hummock grassland
4f	*Triodia wiseana*, *T.* sp. Shovelanna Hill, *T. angusta* hummock grassland
4g	*Triodia angusta*, *T. longiceps* hummock grassland
Ridges and erosional spurs	
5a	*Eucalyptus leucophloia* scattered low trees over *Acacia* spp. scattered shrubs over *Triodia brizoides*, *T. wiseana* hummock grassland
5b	*Eucalyptus leucophloia* scattered low trees over *Acacia* spp. scattered shrubs over *Triodia wiseana* (*T. brizoides*, *T.* sp. Shovelanna Hill) hummock grassland
5c	*Eucalyptus leucophloia* scattered low trees over *Acacia* spp. scattered shrubs over *Triodia* sp. Shovelanna Hill (*T. wiseana*) hummock grassland
5d	*Eucalyptus gamophylla* scattered low mallees over *Acacia* spp. scattered tall shrubs over *Triodia* sp. Shovelanna Hill (*T. wiseana*) hummock grassland
5e	Mixed community supporting a range of structural formations from *Acacia aneura* low woodlands to sheer rock faces with *Astrotricha hamptonii* scattered shrubs to *Eriachne mucronata* open grasslands
5f	*Acacia aneura* low woodland to woodland on rocky ledges and upper slopes of ranges
5g	*Eucalyptus gamophylla* scattered low mallees over *Triodia wiseana* hummock grassland
5h	*Triodia wiseana* hummock grassland with mixed *Acacia* spp. emergent shrubs
Low foothills and escarpments	
6a	*Mixed Triodia* spp. hummock grassland on upper slopes and ridges of small foothills and escarpments
6b	Mixed *Acacia aneura*, *Acacia* spp. low woodland to woodland on upper slopes of low foothills
6c	*Acacia aneura* low woodland to woodland on breakaways of low foothills
6d	*Eucalyptus trivalva*, *E. socialis* low mallee woodland with pockets of *Triodia angusta*, *T. wiseana* hummock grassland on shallow calcrete soils

***Vegetation originally mapped as unit 2d has subsequently been more accurately identified as unit 2e**
 # The 'proposal area' comprises areas to be cleared for the MMP2 Proposal, whilst the 'project disturbance area' comprises areas to be cleared for construction of dewatering infrastructure and the operations camp, which is not part of the MMP2 Proposal and will be subject to a separate environmental approvals process under the EP Act. Refer to Figure 14 for a description of Proposal area.
Source: Biota (2008b)

Given the Southern Fortescue borefield is contained within Hamersley Station it has been subject to extensive grazing especially within the low-lying areas. The flowlines and the Mulga vegetation are in relatively poor condition; the flowlines show signs of erosion and small patches of Mulga have died with no regeneration occurring. Weeds are abundant throughout the flowlines and Mulga vegetation. Overall the condition can be described as Good to Poor, although some vegetation particularly on higher ground can be considered Very Good (Biota 2008b).

The majority of *Eucalyptus* species along tributaries of the Southern Fortescue River downstream of the dewatering discharge points are stressed or slightly stressed, and there are some scattered very stressed trees. The majority of *Acacia citrinoviridis* trees downstream of the dewatering discharge points are healthy or slightly stressed, and there are some scattered very stressed trees (Mattiske 2008). The majority of dead trees appear to be as a result of recent fires.

Regional representation of vegetation units
All of the vegetation units recorded from the Proposal area occur more broadly in the Marandoo locality and none are expected to be restricted to the locality, given the landforms and dominant species (Biota 2008b).

Conservation significance of vegetation units
All of the vegetation units recorded by Biota (2008b) are considered to have conservation value as relatively intact examples of native vegetation for the area. However, no vegetation of high conservation significance was recorded. Vegetation units of moderate conservation significance comprise:

- vegetation units 1a, 2a, 2b, 2c and 4a (Table 9) are considered to be of moderate conservation significance as they are species-rich and support some restricted taxa (including Priority flora species)
- vegetation type 2e (Table 9) is considered to be of moderate conservation significance as it occurs along the major drainage system feature for the area, is species-rich and potentially supports restricted taxa
- vegetation units 4f, 5e, 5f, 6c and 6d (Table 9) are considered to be of moderate conservation significance as they have small areas of representation and potentially support habitat-restricted taxa.

The remainder of the mapping units are considered to be of Low conservation significance, representing units which are likely to be widespread and well-represented in the locality and more broadly through the Hamersley subregion.

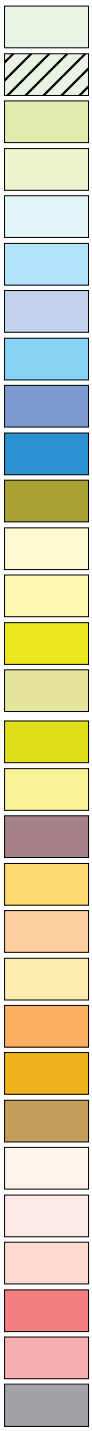
None of the vegetation units recorded by Biota (2008b) represent Threatened Ecological Communities (TECs) as listed under the EPBC Act, or as listed by the DEC. The Mount Bruce Flats Coolibah woodland (located approximately 2 km outside the proposed disturbance footprint) is listed by the DEC as a Priority Ecological Community (Biota 2008b).

LEGEND
Railway
Road
Private Road
Mine
Existing Approved AWT Disturbance as at 2012
MMP2 Project disturbance
Proposed MMP2 disturbance footprint
Southern Fortescue Borefield
Priority Flora
Eremophila magnifica subsp. magnifica
Goodenia lyrata
Calotis latiuscula
Cynanchum sp. Hamersley
Eremophila magnifica subsp. magnifica
Indigofera axocarpa
Josephinia sp. Marandoo
Lobelia heterophylla subsp. Pilbara
Triumfetta leptacantha
LOCATION MAP
Port Hedland
Newman
Nammuldi
Brockman No.2
Marandoo
Mount Tom Price
Paraburdoo
Channar
Eastern Range
Wheelarra Hill
Mount Whaleback
Jimblebar
0.5 0 0.5 1 1.5km
N
Strategic Assets - Perth
Figure 28
Vegetation mapping at Marandoo
Map 1 of 4
RioTinto
Drawn:TC
Date:June 2008
Plan No:PDE/00459/v1
Proj:GDA 95 zone50
LOCATION
MAP 1
MAP 2
MAP 3
MAP 4
Marandoo
Tom Price
596000 mE
598000 mE
600000 mE
602000 mE
604000 mE
606000 mE
7520000 mN
7518000 mN
7516000 mN
7514000 mN
7512000 mN
7510000 mN
Southern Fortescue Borefield
Southern Fortescue Collector Tank
Proposed Terminal Tank
Road
Mt Bruce
Hamersley
1c
1a/1b
1a
4c
2a
Dist
4a
4e
5d
5b

LEGEND
Railway
Road
Private Road
Mine
Existing Approved AWT Disturbance as at 2012
MMP2 Project disturbance
Proposed MMP2 disturbance footprint
Southern Fortescue Borefield
Indicative Camp Disturbance
Priority Flora
Eremophila magnifica subsp. magnifica
Goodenia lyrata
Calotis latiuscula
Cyanicchum sp. Hamersley
Eremophila magnifica subsp. magnifica
Indigofera axocarpa
Josephinia sp. Marandoo
Lobelia heteriophylla subsp. Pilbara
Triumfetta leptacantha
LOCATION MAP
Perth
Karratha
Tom Price
Newman
Nammuldi
Mesa J
Brockman No.2
Marandoo
BHPO Yandi
Whaleback
Mount Tom Price
Paraburdoo
Hope Downs
Mount Dolgellau
Channar
Mount Whaleback
Jimblebar
Eastern Ridge
0.5 0 0.5 1 1.5km
N
Strategic Assets - Perth
Figure 29
Vegetation mapping
at Marandoo
Map 2 of 4
RioTinto
Drawn:TC
Date:June 2008
Plan No:PGE00495/09-1
Proj:GDA 95 Zone50
LOCATION
MAP 1
MAP 2
MAP 3
MAP 4
Marandoo
Tom Price
Hamersley
Mt Bruce
Road
Marandoo to
Southern Fortescue
Borefield Pipeline Route
594000 mE
596000 mE
598000 mE
600000 mE
602000 mE
604000 mE
7502000 mN
7504000 mN
7506000 mN
7508000 mN
7510000 mN

LEGEND
Railway
Road
Private Road
Mine
Existing Approved AWT Disturbance as at 2012
MMP2 Project disturbance
Proposed MMP2 disturbance footprint
Southern Fortescue Borefield
Indicative Camp Disturbance
Priority Flora
Eremophila magnifica subsp. magnifica
Goodenia lyrata
Calotis latiuscula
Cynanchum sp. Hamersley
Eremophila magnifica subsp. magnifica
Indigofera ixocarpa
Josephinia sp. Marandoo
Lobelia heterophylla subsp. Pilbara
Triumfetta leptacantha
LOCATION MAP
Strategic Assets - Perth
Figure 30
Vegetation mapping at Marandoo
Map 3 of 4
RioTinto
Drawn:TC
Date:June 2008
Plan No:PGE00405/09-1
Proj:GDA 95 Zone50
LOCATION
MAP 1
MAP 2
MAP 3
MAP 4
Marandoo
Tom Price
Switchyard
Orebody
Northern Haul Road
604000 mE
606000 mE
608000 mE
610000 mE
612000 mE
614000 mE
7504000 mN
7502000 mN
7500000 mN
7498000 mN
7496000 mN
7494000 mN

LEGEND
Railway
Road
Private Road
Mine
Existing Approved AWT Disturbance as at 2012
MMP2 Project disturbance
Proposed MMP2 disturbance footprint
Southern Fortescue Borefield
Priority Flora
Eremophila magnifica subsp. magnifica
Goodenia lyrata
Calotis latiuscula
Cyanicthum sp. Hamersley
Eremophila magnifica subsp. magnifica
Indigofera ixocarpa
Josephinia sp. Marandoo
Lobelia heterophylla subsp. Pilbara
Triumfetta leptacantha
LOCATION MAP
Port Hedland
Roy Hill
Newman
Tom Price
Marandoo
Yandicoogina
Nammuldi
Brockman No.2
Mesa J
Mount Tom Price
Paraburdoo
Channar
Eastern Ridge
Mount Whaleback
Jimblebar
0.5 0 0.5 1 1.5km
N
Strategic Assets - Perth
Figure 31
Vegetation mapping at Marandoo
Map 4 of 4
RioTinto
Drawn:TC
Date:June 2008
Plan No:PD8004/M/P9-1
Proj:GDA-95 Zone50
LOCATION
MAP 1
MAP 2
MAP 3
MAP 4
Marandoo
Tom Price
618000 mE
620000 mE
622000 mE
624000 mE
626000 mE
7498000 mN
7496000 mN
7494000 mN
7492000 mN
7490000 mN
7488000 mN



1a	*Acacia aneura* woodland on broad flat alluvial and colluvial areas
1a/1b	*Acacia aneura* woodland on broad flat alluvial and colluvial areas Open grassland
1b	Open grassland
1c	*Triodia melvillei* hummock grassland
2a	*Acacia aneura* - A. *pruinocarpa* woodland in major flow lines
2b	*Eucalyptus xerothermica - Acacia aneura* woodland in major flow lines
2c	*Eucalyptus xerothermica - Acacia aneura* woodland over Acacia citrinoviridis tall shrubland in major flow lines
2e	*Eucalyptus victrix* woodland in secondary creeklines
3a	*Acacia* species shrubland in minor flow lines
3b	Low Woodland of mixed mallee Eucalyptus species (for example, *Eucalyptus trivalvis*, *Eucalyptus striaticalyx* and *Eucalyptus socialis*) on shallow calcrete soils
4a	*Acacia aneura* - A. *pruinocarpa* woodland
4b	*Acacia synchronicia - Vachellia farnesiana* tall shrubland
4c	*Acacia aneura* scattered low trees over open grassland
4d	*Acacia xiphophylla* low woodland
4e	*Triodia wiseana*, *T. pungens* hummock grassland
4f	*Triodia wiseana, T.* sp. Shovelanna Hill, *T. angusta* hummock grassland
4g	*Triodia angusta, T. longiceps* hummock grassland
5a	*Eucalyptus leucophloia* scattered low trees over *Acacia* spp. scattered shrubs over *Triodia brizoides, T. wiseana* hummock grassland
5b	*Eucalyptus leucophloia* scattered low trees over *Acacia* spp. scattered shrubs over *Triodia wiseana* (*T. brizoides, T.* sp. Shovelanna Hill) hummock grassland
5c	*Eucalyptus leucophloia* scattered low trees over *Acacia* spp. scattered shrubs over *Triodia* sp. Shovelanna Hill (*T. wiseana*) hummock grassland
5d	*Eucalyptus gamophylla* scattered low mallees over *Acacia* spp. scattered tall shrubs over *Triodia* sp. Shovelanna Hill (*T. wiseana*) hummock grassland
5e	Mixed community supporting a range of structural formations from *Acacia aneura* low woodlands to sheer rock faces with *Astrotricha hamptonii* scattered shrubs to *Eriachne mucronata* open grasslands
5f	*Acacia aneura* low woodland to woodland on rocky ledges and upper slopes of ranges
5g	*Eucalyptus gamophylla* scattered low mallees over *Triodia wiseana* hummock grassland
5h	*Triodia wiseana* hummock grassland with mixed *Acacia* spp. emergent shrubs
6a	*Mixed Triodia* spp. hummock grassland on upper slopes and ridges of small foothills and escarpments
6b	Mixed *Acacia aneura*, *Acacia* spp. low woodland to woodland on upper slopes of low foothills
6c	*Acacia aneura* low woodland to woodland on breakaways of low foothills
6d	*Eucalyptus trivalva*, *E. socialis* low mallee woodland with pockets of *Triodia angusta, T. wiseana* hummock grassland on shallow calcrete soils
	Disturbed

Rio Tinto

Strategic Assets - Perth

Figure 32
Legend for vegetation mapping at Marandoo

FDMS No: PDE0049509v1 Date: June 2008

Flora

Five hundred and thirty-seven (537) taxa of native vascular flora from 176 genera belonging to 60 families have been recorded by Biota (2008b) and Mattiske (1992) in the vicinity of the Proposal area. Twenty (20) species of introduced flora (weeds) from 18 genera belonging to 11 families have also been recorded in the area (Biota 2008b).

The total number of native taxa reported for the Proposal area may be a slight over-estimate as there is likely to be some overlap between species recorded by Biota (2008b) and taxa designated only to species or genus level by Mattiske (1992). Notwithstanding this, the number of species recorded is still considered to be higher than would be expected for a study area of this size in this locality. This is likely to reflect the variety of habitats encompassed by the survey area, including extensive areas of Mulga on clayey substrates, which are generally recognised to be species-rich (Biota 2008b).

The dominant families recorded by Biota (2008b) were Poaceae (grass family), Malvaceae (hibiscus family), Mimosaceae (wattle family), Asteraceae (daisy family), Papilionaceae (pea family), Amaranthaceae (mulla-mulla family) and Caesalpiniaceae (cassia family). The most species-rich genera recorded by Biota (2008b) were *Acacia* (wattles), *Cassia* (cassias), *Sida* (sidas), *Ptilotus* (mulla-mullas), *Abutilon* (lantern-flowers), *Eremophila* (emu-flowers, poverty bushes), *Goodenia* (goodenias), *Hibiscus* (hibiscus) and *Triodia* (spinifex).

These taxa are all typical dominant plant groups for the locality due to their prominence in the Eremaean flora. Relatively large numbers of grass (Poaceae) and daisy (Asteraceae) taxa were recorded for the size of the survey area, which is likely to reflect the presence of substantial areas of clayey plains supporting Mulga, which typically contain abundant species from these families.

The record of *Amaranthus* sp. A Kimberley flora (C.A. Gardner s.n. PERTH 00326518) represents a range extension from the Kimberley bioregion for this species (Biota 2008b).

Declared Rare Flora (DRF)

No Declared Rare Flora (DRF) species have been recorded within the area surveyed by Biota (2008b) or Mattiske (2008).

Thryptomene wittweri (Mountain Thryptomene) and *Lepidium catapycnon* (Hamersley Lepidium) are the only two DRF listed for the Pilbara. *Thryptomene wittweri* (Mountain Thryptomene) would not be expected to occur within the proposed disturbance area due to a lack of suitable habitat (Biota 2008b). Suitable habitat for *Lepidium catapycnon* (Hamersley Lepidium) occurs throughout the proposed disturbance area; however, this species has not been recorded from the Marandoo locality to date, despite relatively intensive sampling both at Marandoo and in the surrounding Karijini National Park (Biota 2008b).

Priority Flora

Seven Priority flora species have been recorded in the Marandoo locality either during the Biota (2008b) survey, or during previous survey work in the area (Figure 28; Figure 29; Figure 30; Figure 31; Figure 32; Table 10). Four Priority flora species were recorded within the Proposal area (Table 10).

For a number of reasons, accurate numbers of individuals of some Priority flora species were not recorded by Biota (2008b). The exception to this was *Eremophila magnifica* subsp. *magnifica*, where estimates of density could be made due to the high abundance of this species at the site. Where Priority flora species occur as small herbs, they can be very difficult to locate in the field, making it difficult to accurately map all individuals within an area. In other instances (for example, *Calotis latiuscula*) specimens can not always be identified to species level in the field and must be analysed in a laboratory. Finally, some species (for example, *Rhagodia* sp. Hamersley [M.E. Trudgen 17794]) were listed as Priority species only after the Biota (2008b) survey work and, therefore, were not targeted during field surveys.

No Priority flora species were recorded by Mattiske (2008) downstream of the dewatering discharge points.

Introduced flora

Twenty (20) introduced species of introduced flora have been recorded in the proposed disturbance area. Of these, 13 were recorded in the proposed disturbance area by Biota (2008b) and seven were recorded previously by Mattiske (1992), but were not recorded in the proposed disturbance area by Biota (2008b). The majority of weeds typically occurred as scattered individuals. The most common habitats in which weeds were recorded were Mulga communities on clayey plains and in drainage areas (Table 11).

Three of the weed species recorded by Biota (2008b) were also recorded downstream of the dewatering discharge points by Mattiske (2008) (Table 11).

None of the species recorded comprise Declared Plants under the *Agriculture and Related Resources Protection Act 1976* (WA), although *Cenchrus* species and *Acetosa vesicaria* are considered to be serious environmental weeds (Biota 2008b).

Table 10
Priority flora species recorded in the vicinity of the Proposal area

Species	Priority	Marandoo locality*			Regional distribution**
		Proposed disturbance area*	Project disturbance area*	Undisturbed locations	
Goodenia lyrata	Priority 1	Three locations on the northern side of Marandoo Ridge (scattered individuals at each location) within the proposed pit	–	One location on the northern side of Marandoo Ridge (scattered individuals) north of the pit close to the rail line	This species extends over a range of >250 km within the Hamersley sub-region of the Pilbara, and also occurs >400 km east in the Gibson Desert bioregion and 600 km south in the Murchison bioregion
Rhagodia sp. Hamersley (M.E. Trudgen 17794)	Priority 1	One location within the proposed mining area (MAR30 - scattered individuals)	One location within the dewatering infrastructure corridor (MARA04 - scattered individuals) One location in the dewatering borefield area (within rail loop - scattered individuals)	Two locations within the Marandoo mine lease (one location just outside the rail loop - scattered individuals; MAR24 - scattered individuals)	This species has a relatively broad distribution through the Pilbara and is not uncommon in Mulga and *Acacia xiphophylla* vegetation; it has been recorded numerous times in the vicinity of Tom Price to Newman
Indigofera ixocarpa	Priority 2	One location associated with a rocky hill (opportunistic record - scattered individuals)	–	Two locations associated with rocky hills (MAR28 - scattered individuals; MAR29 - scattered individuals)	This species extends over a range of >250 km across the Pilbara bioregion, including locations within both the Hamersley and Chichester sub-regions
Eremophila magnifica subsp. *magnifica*	Priority 4	16 locations associated with rocky hillslopes (comprising mostly scattered individuals)	53 locations associated with rocky hillslopes (comprising mostly scattered individuals)	–	This species extends over a range of >150 km within the Hamersley sub-region of the Pilbara, including numerous records from the Tom Price locality
Calotis latiuscula	Priority 1	–	One location within the dewatering infrastructure corridor (MARA04 - scattered individuals) One location within the access road corridor to the operations camp (MARA07 - scattered individuals)	–	This species extends over a range of >150 km within the Hamersley sub-region of the Pilbara, and also occurs >900 km east in the Central Ranges bioregion
Josephinia sp. Marandoo (M.E. Trudgen 1554)	Priority 1	–	One location within the access road corridor to the operations camp (MARA07 - scattered individuals)	–	This species extends over a range of >150 km across the Pilbara bioregion, including locations within both the Hamersley and Chichester sub-regions
Lobelia heterophylla subsp. *Pilbara* (R. Meissner and Y. Caruso 1)	Priority 1	–	–	One location 800 m south of the existing Marandoo mine pits - abundance not known; record is from a single vouchered specimen	This species extends over a range of >250 km across the Hamersley sub-region of the Pilbara, and extends >300 km south into the Murchison bioregion

*** The 'proposed disturbance area' comprises areas to be cleared for the MMP2 Proposal, whilst the 'project disturbance area' comprises areas to be cleared for construction of dewatering infrastructure and the construction camp, which is not part of the MMP2 Proposal and will be subject to a separate environmental approvals process under the EP Act.**
**** Michi Maier (Biota Environmental Sciences) 2008 pers. comm., 19 August**

Table 11
Weeds recorded in the vicinity of the Proposal area

Species	Location	
	Proposal disturbance area*	**Project disturbance area***
Bidens bipinnata (beggars ticks)	Scattered individuals recorded from numerous locations, including downstream of the dewatering discharge points	Scattered individuals recorded from numerous locations
Sigesbeckia orientalis (indian weed)	Recorded at Marandoo by Mattiske (1992)	–
Sonchus oleraceus (common sowthistle)	Recorded at a single site at Marandoo and downstream of the dewatering discharge points	–
Bassia scoparia	Recorded at Marandoo by Mattiske (1992)	–
Cucumis melo subsp. *agrestis* (ulcardo melon)	Recorded at Marandoo by Mattiske (1992)	Recorded at the accommodation camp by Biota (2008b)
Euphorbia hirta (asthma plant)	Recorded at Marandoo by Mattiske (1992)	–
Euphorbia peplus (petty spurge)	Recorded at Marandoo by Mattiske (1992)	–
Malvastrum americanum (spiked malvastrum)	Numerous records at Marandoo and the Southern Fortescue borefield	Numerous records at the accommodation camp and throughout the dewatering infrastructure areas
Vachellia farnesiana (mimosa bush)	Numerous records at Marandoo and the Southern Fortescue borefield	Numerous records at the accommodation camp and throughout the dewatering infrastructure areas
Bougainvillea sp. (bougainvillea) (planted)	Planted within the Marandoo rail loop	–
Cenchrus ciliaris (buffel grass)	Recorded at Marandoo by Mattiske (1992); widespread within the Marandoo rail loop and throughout the Southern Fortescue borefield during the Biota (2008b) survey; recorded downstream of the dewatering discharge points	Widespread at the accommodation camp and throughout the dewatering infrastructure areas
Cenchrus setiger (birdwood grass)	Scattered locations at the Southern Fortescue borefield	Scattered locations at the accommodation camp and throughout the dewatering infrastructure areas
Chloris virgata (feathertop rhodes grass)	Recorded at Marandoo by Mattiske (1992) and at the Southern Fortescue borefield by Biota (2008b)	–
Cynodon dactylon (couch)	Recorded at Marandoo	Recorded from a single location within the dewatering infrastructure area
Echinochloa colona (awnless barnyard grass)	Scattered locations at the Southern Fortescue borefield	Scattered locations at the accommodation camp and throughout the dewatering infrastructure areas
Setaria verticillata (whorled pigeon grass)	Recorded within the Southern Fortescue borefield and at a single location at Marandoo	–
Acetosa vesicaria (ruby dock)	Recorded twice at Marandoo	–
Portulaca oleracea (purslane)	Several sites at Marandoo and the Southern Fortescue borefield	Several sites throughout the dewatering infrastructure areas
Datura leichhardtii (native thornapple)	Recorded at Marandoo by Mattiske (1992)	Recorded at two locations at the accomodation camp
Solanum nigrum (black berry nightshade)	Recorded at Marandoo by Mattiske (1992)	Recorded at a single location within the dewatering infrastructure area

Survey limitations

The limitations of the Biota (2008b) survey were:

- The vegetation sampled within some quadrats and at some point locations was found not to correlate with the mapping unit for that location presented in Mattiske (1992)[16]. Sampling points were therefore matched with the mapping unit of best fit and used to refine these descriptions. No changes were made to the Mattiske (1992) mapping unit boundaries.
- Systematic searches for rare flora have not been conducted throughout all sections of the Proposal area.
- While the nomenclature in the species list provided in Mattiske (1992) was updated as far as possible, some taxa (for example, those designated simply as 'sp.') could not be determined. The species list presented in Biota (2008b) should therefore be taken as indicative, rather than exhaustive.

5.4.2 Potential sources of impact

Activities or aspects of the Proposal that may potentially affect flora and vegetation values include:

- vegetation clearing will directly disturb vegetation units and Priority flora species
- alteration of surface water flows through construction of mine pits, waste dumps and infrastructure may affect local water availability for some plant species
- vehicle and earth movements could potentially introduce and/or spread weed species
- groundwater drawdown within the unconfined aquifer (due to seepage) into the mine pit may reduce water availability for some plant species
- discharge of excess dewatering water may affect vegetation health and composition, and favour the establishment of weeds along discharge pathways
- re-injection of excess dewatering water at the Southern Fortescue borefield may affect vegetation health as a result of saturation of the soil profile
- ignition sources resulting in increased fire frequency/intensity may favour the establishment of weeds and prevent the regeneration of native vegetation, particularly fire-sensitive species such as Mulga.

Dust may have physical effects on plants, although this is likely to be restricted to immediate peripheral vegetation and will be mitigated by periodic high rainfall events, which would remove built-up material on leaves.

Potential impacts to vegetation along tributaries of the Southern Fortescue River system resulting from the proposed discharge of dewatering water are addressed in Section 5.3.4. Potential impacts to Mulga and Coolibah communities on the Mount Bruce Flats are addressed in Section 5.5.

16 **To some extent mapping is always a representation of the vegetation occurring at a site as subjective decisions have to constantly be made to determine units and assign boundaries between these. This can be complicated by additional factors, such as poor quality or unrectified aerial photography, vegetation units that do not have distinct photographic signatures, condition of the vegetation (for example, extent of physical disturbance and fire history) and a limited amount of time to survey an area (Biota 2008b).**

5.4.3 Key statutory requirements, environmental policy and guidance

EPA objectives

In most circumstances, including this assessment, the EPA applies the following objective to the assessment of Proposals that may affect vegetation and flora:

To maintain the abundance, species diversity, geographic distribution and productivity of flora and fauna at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge.

The following EPA objective addressing biodiversity is also relevant to this factor:

To maintain biological diversity that represents the different plants, animals and micro-organisms, the genes they contain and the ecosystems they form, at the levels of genetic diversity, species diversity and ecosystem diversity.

National Strategies

The state and Commonwealth governments have endorsed the National Strategy for the Conservation of Australia's Biological Diversity (Commonwealth of Australia 1996) and the National Strategy for Ecologically Sustainable Development (Commonwealth of Australia 1992). The strategies address the conservation of Australia's biological diversity by defining several guiding principles.

National Strategy for the Conservation of Australia's Biological Diversity

The principles of this Strategy are:

- biological diversity is best conserved in situ
- although all levels of government have clear responsibility, the cooperation of conservation groups, resource users, indigenous peoples, and the community in general is critical to the conservation of biological diversity
- it is vital to anticipate, prevent and attack at source, the causes of significant reduction or loss of biological diversity
- processes for, and decisions about, the allocation and use of Australia's resources should be efficient, equitable and transparent
- lack of full knowledge should not be an excuse for postponing action to conserve biological diversity
- the conservation of Australia's biological diversity is affected by international activities and requires actions extending beyond Australia's national jurisdiction

- Australians operating beyond our national jurisdiction should respect the principles of conservation and ecologically sustainable use of biological diversity and act in accordance with any relevant national or international laws
- central to the conservation of Australia's biological diversity is the establishment of a comprehensive, representative and adequate system of ecologically viable protected areas integrated with the sympathetic management of all other areas, including agricultural and other resource production systems
- the close, traditional association of Australia's indigenous peoples with components of biological diversity should be recognised, as should the desirability of sharing equitably, benefits arising from the innovative use of traditional knowledge of biological diversity.

National Strategy for Ecologically Sustainable Development

The principles of this Strategy are:

- decision-making processes should effectively integrate both short-term and long-term economic, environmental, social and equity considerations
- where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation
- the global dimension of environmental impacts of actions and policies should be recognised and considered
- the need to develop a strong, growing and diversified economy which can enhance the capacity for environmental protection should be recognised
- the need to maintain and enhance international competitiveness in an environmentally-sound manner should be recognised
- cost-effective and flexible policy instruments should be adopted, such as improved valuation, pricing and incentive mechanisms
- decisions and actions should provide for broad community involvement on issues which affect them.

EPA Position Statement No. 2

EPA Position Statement No. 2 (EPA 2000) provides an overview of the EPA position on the clearing of native vegetation in Western Australia. Principles and related objectives and actions have been adopted from the above-mentioned national strategies in the development of this Position Statement. In assessing a Proposal, the EPA will include the following basic elements in consideration of biological diversity:

- comparison of development scenarios, or options, to evaluate protection of biodiversity at the species and ecosystems levels, and demonstration that all reasonable steps have been taken to avoid disturbing native vegetation
- no known species of plant or animal is caused to become extinct as a consequence of the development and the risks to threatened species are considered to be acceptable
- no association or community of indigenous plants or animals ceases to exist as a result of the Proposal
- there is a comprehensive, adequate and secure representation of scarce or endangered habitats within and/or in areas biologically comparable to the Proposal area, protected in secure reserves
- if the Proposal is large (in the order of 10–100 ha or more, depending on where in the State) the Proposal area itself should include a comprehensive and adequate network of conservation areas and linking corridors whose integrity and biodiversity are secure and protected
- the on-site and off-site impacts of the Proposal are identified and the Proponent demonstrates that these impacts can be managed.

EPA Position Statement No. 3

EPA Position Statement No. 3 (EPA 2002a) discusses the principles the EPA would apply when assessing Proposals that may have an effect on biodiversity values in Western Australia. The outcomes sought by this Position Statement are intended to:

- promote and encourage all Proponents and their consultants to focus their attention on the significance of biodiversity and, therefore, the need to develop and implement best practice in terrestrial biological surveys
- enable greater certainty for Proponents in the Environmental Impact Assessment process by defining the principles the EPA will use when assessing Proposals that may have an effect on biodiversity values.

EPA Position Statement No. 9

EPA Position Statement No. 9 (EPA 2006a) recognises environmental offsets as one tool that can provide alternative beneficial environmental outcomes in situations where social and economic growth is sought at some detriment to the environment. The EPA stresses, that offsets are not intended to make otherwise 'unacceptable' environmental impacts 'acceptable' but rather to achieve a 'net environmental benefit' to counterbalance 'acceptable' environmental impacts only. The EPA position is that environmental offsets represent a 'last line of defence' for the environment and should only be used when all other options to avoid and mitigate environmental impacts have been considered and exhausted.

The EPA does not consider it appropriate to validate or endorse the use of environmental offsets where Proposals are predicted to have significant adverse impacts to critical assets[17]. The Position Statement recognises native vegetation (with some further clarification) as a critical asset and usually considers adverse impacts to this asset to be 'significant' where:

- they are seriously at variance to the principles to protect native vegetation listed under Schedule 5 of the EP Act or associated Regulations
- they would result in a 30% or less representation of the pre-clearing extent of that vegetation complex in a bioregion, or 10% or less where the vegetation complex occurs in constrained areas on the Swan Coastal Plain
- the affected vegetation is part of a Bush Forever reserve.

The EPA also recognises aspects of biodiversity as critical assets and, in relation to this, will have regard to the significance of any potential impacts to Priority flora and DRF. Karijini National Park is considered a critical asset relevant to this Proposal.

EPA Guidance Statement No. 51

EPA Guidance Statement No. 51 (EPA 2004c) provides guidance on standards and protocols for terrestrial flora and vegetation surveys, particularly those undertaken for the EIA of Proposals.

5.4.4 Assessment of potential impact

Vegetation clearing

New disturbance will comprise approximately 940 ha including clearing for mine pits, waste dumps and infrastructure (Figure 30; Figure 31; Figure 32). No vegetation of High conservation significance will be cleared. Approximately 90% of the proposed disturbance will be to vegetation of low conservation significance (Table 12). Based on the current disturbance footprint disturbance to vegetation of moderate conservation significance will be approximately 85 ha (Table 12), summarised as follows::

- units 2e, 4f, 5e, 6c and 6d will not be cleared as they fall outside the Proposal area
- units 1a and 4a will be cleared by less than 10% of the total mapped extent for the Proposal area (both units also extend more widely through the locality (including in the adjacent Karijini National Park) and in the broader Hamersley subregion)
- units 2a and 5f will be cleared by less than 30% of the total mapped extent for the Proposal area (again, both units extend more widely through the locality and subregion)
- units 2b and 2c will be cleared by >35% of the total mapped extent for the Proposal area (again, all units extend more widely through the locality and subregion).

The remainder of the mapping units are considered to be of Low conservation significance, representing units which are likely to be widespread and well-represented in the locality and more broadly through the Hamersley subregion.

The total area of vegetation clearing required for re-injection infrastructure at the Southern Fortescue borefield is approximately 3 ha based on construction of four re-injection bores (yet to be confimed) and associated water pipelines with dimensions as outlined in Section 4.7.1. This area is included in the above total of 940 ha.

Four Priority flora species have been recorded as scattered individuals in the Proposal area, including the Priority 1 species *Goodenia lyrata* and *Rhagodia* sp. Hamersley (M.E. Trudgen 17794)[18] (Table 10). Several Priority flora species recorded in the vicinity of the Proposal will not be disturbed by the Proposal, including the Priority 1 species *Calotis latiuscula*, *Josephinia* sp. Marandoo and *Lobelia heterophylla* subsp. Pilbara (R. Meissner and Y. Caruso 1). Priority flora species that will be disturbed by the Proposal occur relatively broadly throughout the Pilbara and are not restricted to the Marandoo locality (Michi Maier [Biota Environmental Sciences] 2008 pers. comm., 19 August; Table 10).

Cumulative impact

Disturbance associated with construction of the dewatering system (including the Marandoo dewatering borefield and the dewatering pipeline from Marandoo to the Southern Fortescue borefield) and the accommodation camp will comprise approximately 260 ha (Figure 28, Figure 29, Figure 30, Figure 31 and Figure 32). This disturbance does not form part of the MMP2 Proposal and will be subject to a separate environmental approvals process under the EP Act. This would result in cumulative vegetation loss of approximately 1200 ha.

17 Critical assets represent the most important environmental assets in the State that must be fully protected and conserved.

18 *Rhagodia* sp. Hamersley is not considered to warrant listing as a Priority 1 flora species, as it is poorly vouchered rather than uncommon (Michi Maier [Biota Environmental Sciences] 2008 pers. comm., 28 August).

Table 12
Area of vegetation units to be cleared within the proposal disturbance footprint and the total project area

Vegetation Code	Description	Conservation significance	Proposed disturbance (ha)*	Project disturbance (ha)*
Broad drainage areas and basins				
1a	*Acacia aneura* woodland on broad flat alluvial and colluvial areas	Moderate	26	< 1
1a/1b	Mosaic of unit 1a (*Acacia aneura* woodland on broad flat alluvial and colluvial areas) and 1b (Open grassland)	Moderate/Low	–	9
1c	*Triodia melvillei* hummock grassland	Low	637	78
Major flow lines and creeks				
2a	*Acacia aneura - A. pruinocarpa* woodland in major flow lines	Moderate	8	5
2b	*Eucalyptus xerothermica - Acacia aneura* woodland in major flow lines	Moderate	38	3
2c	*Eucalyptus xerothermica - Acacia aneura* woodland over *Acacia citrinoviridis* tall shrubland in major flow lines	Moderate	5	1
2e	*Eucalyptus victrix* woodland in secondary creeklines	Moderate	–	3
Minor creeks				
3a	*Acacia* species shrubland in minor flow lines	Low	26	3
Flats				
4a	*Acacia aneura - A. pruinocarpa* woodland	Moderate	< 1	11
4b	*Acacia synchronicia - Vachellia farnesiana* tall shrubland	Low	–	4
4c	*Acacia aneura* scattered low trees over open grassland	Low	–	14
4d	*Acacia xiphophylla* low woodland	Low	–	4
4e	*Triodia wiseana*, *T. pungens* hummock grassland	Low	–	28
4f	*Triodia wiseana*, *T.* sp. Shovelanna Hill, *T. angusta* hummock grassland	Moderate	–	3
4g	*Triodia angusta*, *T. longiceps* hummock grassland	Low	–	17
Ridges and erosional spurs				
5b	*Eucalyptus leucophloia* scattered low trees over *Acacia* spp. scattered shrubs over *Triodia wiseana* (*T. brizoides*, *T.* sp. Shovelanna Hill) hummock grassland	Low	29	6
5c	*Eucalyptus leucophloia* scattered low trees over *Acacia* spp. scattered shrubs over *Triodia* sp. Shovelanna Hill (*T. wiseana*) hummock grassland	Low	52	–
5d	*Eucalyptus gamophylla* scattered low mallees over *Acacia* spp. scattered tall shrubs over *Triodia* sp. Shovelanna Hill (*T. wiseana*) hummock grassland	Low	46	8

	Representation in Karijini National Park**	Representation in the Pilbara region or Hamersley sub-region**
	Extends further into the Park in the valley north and east of the mine; likely to be more widespread in the Park, but restricted to valley areas	Widespread in the Hamersley sub-region, but not abundant
	1a - addressed above 1b - extends further into the Park in the valley north of the mine; likely to be more widespread in the Park, but restricted to valley areas	1a - widespread in the Hamersley sub-region, but not abundant 1b - widespread in the Hamersley sub-region, but not abundant
	Extends further into the Park in the valley north of the mine; likely to be more widespread in the Park, but restricted to valley areas	Widespread in the Hamersley sub-region, but not abundant
	Extends north into the Park, in flow lines north of the mine; likely to be more widespread in the Park	Widespread throughout the Hamersley sub-region[1]
	Occurs relatively broadly throughout the Park, but restricted to moderate-sized flow lines (so would not encompass a large area)	Occurs more widely in the Hamersley sub-region (certainly across to the Hope Downs area)[1]
	Occurs relatively broadly throughout the Park, but restricted to moderate-sized flow lines (so would not encompass a large area)	Occurs more widely in the Hamersley sub-region[1]
	Widespread throughout the Park, but restricted to moderate to large creek lines	Widespread through the Hamersley sub-region
	Widespread throughout the Park	Widespread and abundant in the Pilbara region
	Widespread throughout the Park	Widespread throughout the Hamersley sub-region[1]
	Likely to be additional small stands within the Park	Widespread through the Pilbara region
	Widespread throughout the Park	Widespread through the Hamersley sub-region[1]
	Widespread throughout the Park	Widespread through the western and central Pilbara region
	Occurs broadly throughout the Park on stony flats	Occurs broadly through the Pilbara region
	Widespread throughout the Park to the south of Marandoo, but restricted to calcrete substrates	Widespread through the Hamersley sub-region, but restricted to areas of calcrete substrate
	Would probably occur within the Park, but would not be abundant	Widespread through the Hamersley sub-region, but not abundant; typically on low-lying habitats and/or calcareous substrates
	Occurs relatively broadly throughout the Park	Occurs relatively broadly through the Hamersley sub-region
	Occurs relatively broadly throughout the Park	Occurs relatively broadly through the Hamersley sub-region
	Occurs relatively broadly throughout the Park	Occurs relatively broadly through the Hamersley sub-region

Vegetation Code	Description	Conservation significance	Proposed disturbance (ha)*	Project disturbance (ha)*
5f	*Acacia aneura* low woodland to woodland on rocky ledges and upper slopes of ranges	Moderate	8	–
5h	*Triodia wiseana* hummock grassland with mixed *Acacia* spp. emergent shrubs	Low	46	5
Low foothills and escarpments				
6a	Mixed *Triodia* spp. hummock grassland on upper slopes and ridges of small foothills and escarpments	Low	–	5

*** 'Proposed disturbance' comprises the total area of vegetation clearing required for the MMP2 Proposal, whilst 'project disturbance' comprises disturbance associated with the dewatering system, which is not part of the MMP2 Proposal and will be subject to a separate environmental approvals process under the EP Act. Disturbance associated with the accommodation camp will comprise approximately 55 ha and will be mainly within vegetation units of Low conservation significance.**
**** Michi Maier [Biota Environmental Sciences] 2008 pers. comm., 8 June.**
[1]Some forms of Mulga are likely to be restricted in distribution (Michi Maier [Biota Environmental Sciences] 2008 pers. comm., 8 June).

Alteration of surface water flows

There will be some reduction in surface water runoff reaching vegetation units downstream of the proposed mine pit, as incident rainfall will be captured by the pit. Beckett (2008) estimates there will be a reduction in surface water runoff reaching vegetation within 200 m of the northern pit face; surface water runoff beyond 200 m from the northern pit face is unlikely to be affected by the proposed mine pit, as small rainfall events (40 to 50 mm) are unlikely to produce any surface water runoff in the area below the ridge

The small drainage lines that flow from Marandoo Ridge to the Mount Bruce Flats support woodlands of *Eucalyptus xerothermica - Acacia aneura* (Table 9). A significant reduction in flow along these drainage lines is not anticipated as it will be diverted around the pit or collected within the mine pit and discharged back to the Mount Bruce flats (Section 4.6.2). Therefore, vegetation along these drainage lines should not be significantly affected by the Proposal. Any effect on vegetation along these drainage lines would not be anticipated to affect its local or regional distribution, as it occurs relatively broadly throughout Karijini National Park (albeit restricted to moderate-sized flow lines), as well as more widely throughout the Hamersley sub-region (Table 12). The effect of alterations of surface water flows on Mulga is discussed in Section 5.5.4.

An ephemeral drainage line will be crossed to enable access to the operations camp, this will not be impacted through operations.

Weeds

Weed occurrences (20 species) in the vicinity of the Proposal area were identified during the Biota (2008b) survey. All weeds recorded are commonly found in the Marandoo area (Table 11). Vehicle or earth movements could potentially spread existing weeds or introduce new species to the area if equipment is not appropriately inspected and cleaned prior to arrival on site. Activities that disturb native vegetation create suitable conditions for weeds to rapidly establish and develop into infestations that are then difficult to manage and compete with native vegetation.

Groundwater drawdown

Intersection of the unconfined aquifer by the proposed mine pit will result in drawdown of groundwater levels of approximately 10–20 m at the northern pit margin. Groundwater drawdown is predicted to extend several kilometres from the northern pit margin, but will decrease rapidly with increasing distance from the pit (Figure 26).

Vegetation immediately north of the proposed mine pit within the mine lease (Figure 28) does not comprise strongly phreatophytic species[19] (such as *Melaleuca argentea* or *Eucalyptus camaldulensis*) and, therefore, would be unlikely to be affected by the predicted groundwater drawdown resulting from intersection of the unconfined aquifer. In addition, depth to the watertable in this area is approximately 50 m (Section 5.2.1), suggesting overlying vegetation would not be strongly groundwater-dependent. The potential impact of groundwater drawdown to the Coolibah woodland on the Mount Bruce Flats is discussed in Section 5.5.4.

19 Phreatophytes: species that rely on consistent access to the watertable, or a ready supply of surface water.

	Representation in Karijini National Park**	Representation in the Pilbara region or Hamersley sub-region**
	Occurs relatively broadly throughout the Park The breakaways and rocky slope areas that support units 5e and 5f would have a relatively small area of representation in the Park compared to habitats supporting the other vegetation units of ridges and erosional spurs	Occurs relatively broadly through the Hamersley sub-region The breakaways and rocky slope areas that support units 5e and 5f would have a relatively small area of representation in the sub-region compared to habitats supporting the other vegetation units of ridges and erosional spurs
	Occurs broadly throughout the Park	Occurs broadly through the Pilbara region
	Occurs relatively broadly throughout the Park, although generally restricted to upper slopes	Occurs broadly through the Pilbara region

Re-injection

Vegetation within the Southern Fortescue borefield area comprises units 1a, 1b, 1c and 4c (Figure 28; Figure 32)

Vegetation units 1b (open grassland) and 1c (*Triodia melvillei* hummock grassland) are dominated by xerophytic[20] species with shallow root zones, which would not be expected to be affected by changes in groundwater levels occurring 5 m or more below the ground surface (Michi Maier [Biota Environmental Sciences], 2008, pers. comm., 19 August).

Vegetation units 1a (*Acacia aneura* woodland on broad flat alluvial and colluvial areas) and 4c (*Acacia aneura* scattered low trees over open grassland) both contain Mulga as a dominant species. These low trees are not deep-rooted, but rather have a proliferation of shallow roots in the upper soil profile. Provided that the groundwater does not approach within 5 m of the ground surface, it is not deemed likely that waterlogging would affect the Mulga component of these vegetation units (Michi Maier [Biota Environmental Sciences], 2008, pers. comm., 19 August).

Other species in these vegetation units are xerophytic species with shallow root zones, which should not be affected by the proposed re-injection, given the measures proposed to limit the rise in groundwater levels (Michi Maier [Biota Environmental Sciences], 2008, pers. comm., 19 August).

Fire

Increased vehicular traffic and personnel movement during the construction and operational phases of the Proposal will increase the risk of accidental outbreaks of fire in adjacent areas. This may lead to an increase in fire frequency and/or intensity in these areas, which can favour the establishment of weeds and prevent the regeneration of (or destroy) native vegetation, particularly fire-sensitive species such as Mulga.

5.4.5 Proposed mitigation and management measures

Vegetation and flora values in and around the Proposal area will be protected through implementation of measures outlined in the Vegetation Management Plan (Appendix 2).

Key measures include:

- obtaining an Approvals Permit for all areas to be cleared in accordance with the Proponent's Approvals Request System
- preventing unnecessary clearing of vegetation through locating infrastructure such as the wet processing plant and RSF within, or adjacent to already disturbed areas
- undertaking progressive rehabilitation of disturbed areas with local native flora species
- identifying and mapping the extent and distribution of target weed species occurring within and adjacent to the Proposal area and eradicating weed occurrences on an ongoing basis
- implementing weed hygiene procedures for mining machinery entering and leaving the Proposal area

20 Xerophytic species are adapted to arid conditions and utilise the xeric (dry) zone, which contains moisture only as water vapour or films surrounding the soil granules.

- surveying the Southern Fortescue borefield prior to any ground disturbance to ensure protection and avoidance of areas containing vegetation of high conservation significance and/or populations of significant flora where possible
- optimising the location of the re-injection bores within the Southern Fortescue borefield to spread the rise in groundwater level across the borefield
- monitoring observation bores within Southern Fortescue borefield to ensure groundwater levels do not rise more than 5 m above historical (pre-abstraction) groundwater levels as a result of re-injection
- undertaking basic fire awareness and fire fighting training for all personnel (including contractors) prior to commencing work on-site
- maintaining adequate fire breaks across the mine site and around working areas where required
- ensuring a fire spotter is present when clearing vegetation near sensitive environmental areas.

5.4.6 Predicted outcome

After mitigation and management measures have been applied, the Proposal is expected to result in the following outcomes to flora and vegetation:

- The progressive removal and rehabilitation of approximately 940 ha of native vegetation over the life of the Proposal.
- No significant effect on regional flora and vegetation values, as the vegetation units recorded from the Proposal area occur more broadly in the Marandoo locality and are not expected to be restricted to the locality.
- No TECs, DRF species or vegetation of High conservation significance will be affected by the Proposal.
- Some locations of Priority flora species, including scattered individuals of the Priority 1 species *Goodenia lyrata* and *Rhagodia* sp. Hamersley (M.E. Trudgen 17794) will be disturbed by the Proposal. However, these species are not restricted to the Marandoo locality and occur relatively broadly throughout the Pilbara, hence, the Proposal will not affect the conservation status of these species.

The Proposal will not contravene EPA Position Statement No. 2, as all potential on-site and off-site impacts have been identified and management measures proposed. No species of flora or vegetation association will cease to exist as a result of the Proposal. Consistent with EPA objectives, the abundance, species diversity, geographic distribution and productivity of flora at species and ecosystem levels will be maintained, thereby conserving regional biological diversity.

5.5 Coolibah woodland and Mulga communities

5.5.1 Description of factor

The Mount Bruce Flats is located north of Marandoo within Karijini National Park and supports a *Eucalyptus victrix* (Coolibah) open woodland (Figure 12) and extensive stands of Mulga[21].

The Coolibah woodland on the Mount Bruce Flats is an example of a vegetation type that is both in good condition and uncommon in the Pilbara region (English 1999; Batini 2008b). The woodland is seasonally inundated and is considered a wetland of national importance (English 1999; Environment Australia 2001). The Coolibah woodland is listed by the DEC as a Priority Ecological Community (PEC) and is not commonly found in the Pilbara.

Mulga in the Pilbara is close to the northern edge of its range and considered to be at risk primarily from fire damage, from grazing and from climate change (Fortech 1999). The stands on the Mount Bruce Flats are particularly important to the ongoing representation and conservation of Mulga in the region.

At a species level, three main groups of vegetation can be described based on plant water use strategies:

- Phreatophytes: species that rely on consistent access to the watertable, or a ready supply of surface water.
- Vadophytes: species that primarily utilise water held in the vadose zone (the unsaturated zone above the watertable) and are not necessarily dependent on the watertable.
- Xerophytes: species adapted to arid conditions that utilise the xeric (dry) zone, which contains moisture only as water vapour or films surrounding the soil granules. These species are drought-adapted, non-groundwater-dependent and should not be affected by lowering groundwater levels.

Plants subject to water deficits that are neither too severe nor prolonged can, upon subsidence of the stress, resume growth rates similar to those in non-stressed plants (Chisholm 2002). Some plants, including those in the Pilbara, have various strategies to deal with drought conditions, including defoliation and stomatal closure. Variations in rainfall can result in significant and rapid changes to crown condition.

21 Throughout the PER, Mulga (capital 'M') is defined as 'any of the taxa previously or currently included in *Acacia aneura* (F Muell. ex Benth)' and Mulga (lower-case 'm') is defined as 'a community containing and frequently dominated by Mulga' (after Fortech (1999)).

Coolibah physiology

Coolibah is considered a vadophyte, a species that primarily utilises water held in the vadose zone (the unsaturated zone above the watertable) and is not necessarily dependent on the watertable. Coolibah is considered tolerant to long periods without flooding or ready availability of water (Muir Environmental 1995) and has a dimorphic root system, with extensive, dense, superficial lateral roots that spread beyond the width of the canopy and one or several long tap roots (Florentine 1999; Adams et al. 2005).

Coolibah seedlings are able to produce a long tap root during early development, which may represent an adaptive advantage in persisting through the first dry spring/early summer period (Florentine 1999). Provided sufficient carbon (or time to acquire new carbon via photosynthesis) is available, *E. victrix* is able to develop new roots (both deep tap roots and shallow roots) in response to a wide range of changing conditions, enabling it to switch its water supply from one source to another (Adams et al. 2005).

Results from excavations of the root systems of Coolibah within riparian environments in the Pilbara indicate that root structure is closely linked to the specific hydrological conditions at a site (Pauline Grierson [UWA] 2008 pers. comm., 19 August), although the structure of Coolibah root systems within the Mount Bruce Flats woodland is unknown. Excavation of Coolibah in conjunction with isotope and sap-flow studies within the Mount Bruce Flats woodland could assist in confirming their root structure, the source of water and the ability to adapt to fluctuations in the water table. Studies of isotope and sap-flow have commenced, and depending on the results of these studies, root excavation may/may not be required to confirm the depth of the root systems at this site.

Temporary flood events (usually associated with cyclones or other major rainfall events) are considered critical to stimulate germination, regeneration and seedling growth in Coolibah, and this species has morphological, physiological and anatomical adaptations that enable them to survive such periodic and prolonged waterlogging (Florentine 1999; Adams et al. 2005). The anoxic soil environment that results from prolonged waterlogging can often cause plant roots to decay and eventually die; however, some plant species are able to produce adventitious[22] roots and survive waterlogging (Hook 1984; Florentine 1999). Both seedlings and established plants of *E. victrix* are extremely tolerant of waterlogging, producing large number of adventitious roots, as well as lenticels[23] on the submerged portion of the stem (Florentine 1999).

Waterlogging of low-lying areas after cyclonic rainfall is a common natural occurrence in the Pilbara and is generally followed by a gradual drawdown of soil water. The adaptations described above more than likely enable the Coolibah to out-compete most (if not all) other species in areas exposed to extremely long periods of waterlogging and the gradual lowering of soil water levels on the Mount Bruce Flats.

The Proponent has established a monitoring program within the Coolibah woodland on the Mount Bruce Flats. The monitoring program includes 40 vertical photos of 20 Coolibah crowns (foliage cover) taken at regular intervals, analysis of remote sensing imagery and transect-style ground surveys of tree health by species and size class. Survey results from 2008 indicate the Coolibah were mostly healthy, whereas there was extensive crown decline and deaths of Mulga in and around the woodland. This appears to be related to an extended period of waterlogging that occurred in 2006 (Batini 2008b).

Foliage cover has been identified by plant ecophysiologist Professor Mark Adams (UNSW) as the most suitable parameter to measure tree health and to use as a trigger for instigation of corrective management. Eucalypts are particularly well-adapted to regeneration of crown cover with a well-developed system of 'dormant buds' in the outer wood, just below the cambial layer (Frank Batini 2008 pers. comm., 12 August). When triggered, these buds will sprout through the bark and develop a new epicormic crown. Observations of Coolibah communities in the Pilbara that are similar to the Mount Bruce Flats woodland indicate that Coolibahs are able to recover from almost 100% foliage loss from fire (Sally Madden, Specialist Advisor - Ecology, [Rio Tinto] 2008 pers. comm., 19 August). Losses and/or gains of up to 10–15% in foliage cover have been observed to occur in response to natural, seasonal fluctuations (Adams 2005, 2006, 2007).

The extent of the Coolibah woodland has remained stable over some decades (Gaia Resources 2008). At an individual tree level however, foliage cover measurements have varied significantly during this period. Data collected by Mattiske (1991, 1993 and 1995) show a high level of stress in 1991 and 1993 and some recovery between 1993 and 1995. A 16% reduction in foliage cover between 2007 and 2008 was observed by the Proponent which could be attributable to a reduction in the annual rainfall from 700 mm in 2007 to 350 mm in 2008 (Batini 2008b).

22 Adventitious roots develop from the stem following death of the original root system and are generally morphologically distinct.

23 Lenticels are small corky-celled structures produced on the surface of plant stems that permit the transport of gases to, and from the inner tissues.

Mulga physiology

Mulga does not produce deep tap roots and depends instead on incident rainfall and surface runoff that collects in shallow depressions, rock fissures and creek lines around the root zone of the plant (Kinhill 1996). Mulga can persist in areas where water is nearly always limiting for plant growth, but is confined to areas where there is an acceptable chance of useful rainfall in both summer and winter (Fortech 1999). Where Mulga does occur, localised overland flow is considered critical in sustaining individuals and communities (Fortech 1999).

Mulga has a number of adaptations at the plant and community level that maximise available water within the root zone and increase water extraction from the soil profile. These adaptations include (Fortech 1999):

- interception and subsequent channelling down the stem to the plant base of up to 40% of incident rainfall
- high levels of stomatal control resulting in altered water potential in phyllode tissues, which can double the amount of water that plants can extract from the soil
- root proliferation within the upper 30 cm of the soil profile to permit rapid water sourcing during episodic rainfall events
- formation of well-vegetated groves and sparse intergroves at the community level to maximise water harvesting within the grove.

Mulga recruitment in the Pilbara is thought to be continuous in grove communities and run-on areas where favourable moisture conditions are common. Underlying sustained recruitment is accompanied by mass recruitment following above average rainfall events (Fortech 1999).

Flowering in Mulga occurs in response to both summer and winter rains, although mature fruit is produced only after summer rains. Seed set is considered to be dependent on rain being received in both seasons of a year (Fortech 1999). Seeds are produced in hard pods that result in the seeds having variable lengths of dormancy. Pods are shed mainly during summer and seed dormancy breaks with a combination of fluctuating temperatures, wetting and drying cycles, fire and smoke. Few germinants survive when soil moisture is relatively low and/or when fires occur during early growth (Fortech 1999).

Mulga is a fire-sensitive species and, in the Pilbara, is often found growing in association with vigorous and dense stands of spinifex, a highly-flammable and fire-tolerant plant. Frequent burning of Mulga has the potential to eliminate entire stands, as trees take a long time to reach seed-bearing maturity, adult trees are often killed by fire and the effects of fire can be magnified when fires are followed by prolonged dry periods (Fortech 1999).

The Proponent established a monitoring program in 2000 to assess the health of Mulga adjacent to the Marandoo railway. Monitoring has been ongoing since 2000, with the most recent measurements occurring in 2007. Data to date indicate the major negative influence on the health of Mulga is wildfire (Batini 2008c).

5.5.2 Potential sources of impact

Potential impacts to the Coolibah woodland and Mulga on the Mount Bruce Flats as a result of the Proposal include:

- dewatering of the confined aquifer may lead to drawdown of groundwater levels in the unconfined aquifer, which may reduce groundwater availability for the Coolibah woodland
- intersection of the unconfined aquifer by the proposed mine pit will cause seepage and subsequent drawdown in the unconfined aquifer, which may reduce groundwater availability for the Coolibah woodland
- physical presence of mine pit and infrastructure will alter surface water flow paths and may reduce the volume of mine site runoff reaching Coolibah and Mulga on the Mount Bruce Flats
- ignition sources at Marandoo may increase the frequency and/or intensity of fire events, which may result in the loss of fire-sensitive Mulga communities
- vehicle and earth movements could potentially introduce and/or spread weed species across the mine site and adjacent areas of Karijini National Park.

5.5.3 Key statutory requirements, environmental policy and guidance

The key statutory requirements, environmental policies and guidance applicable to the Coolibah woodland and Mulga communities on the Mount Bruce Flats are those that apply to vegetation and flora (Section 5.4) and to National Parks (Section 5.1).

5.5.4 Assessment of potential impact

Groundwater drawdown

Groundwater drawdown within the unconfined aquifer due to dewatering of the confined aquifer is expected to be negligible across the Mount Bruce Flats as a result of the thick, intervening clay layer, which acts as an effective aquitard between the two aquifers (Section 5.2.4). There may be some drawdown within the unconfined aquifer near Mount Bruce where a zone of higher connectivity between the two aquifers occurs; however, this drawdown would not be expected to extend to the Coolibah woodland.

Intersection of the unconfined aquifer by the proposed mine pit is predicted to result in drawdown of groundwater levels of approximately 0–2.5 m at the Coolibah woodland on the Mount Bruce Flats (MWH 2006c). However, for the most part drawdown will be less than 1 m. The estimated maximum rate at which this drawdown would occur is approximately 0.3 m/year, due to rapid phases of pit advancement during the initial eight years or more of dewatering.

The magnitude of the predicted groundwater drawdown in the unconfined aquifer is not anticipated to affect the Coolibah woodland and is within the known magnitude of natural groundwater fluctuations. Figure 33 shows the response in groundwater levels of the confined and unconfined aquifer after a rainfall event in early 2006. Following an extended dry period, groundwater levels in the unconfined aquifer were approximately 20 m below ground level in the vicinity of the Coolibah woodland,

with a saturated zone of approximately 8–10 m above this. Following substantial rain in early 2006, flooding and subsequent rapid infiltration at the Coolibah woodland (Section 5.3.1) led to a large (approximately 10 m) and rapid (approximately three months) rise in groundwater levels under the woodland, followed by a more gradual (over approximately nine months) decline to base levels (Batini 2008a; Figure 33).

Difficulties may arise for Coolibah when conditions change too quickly compared to natural patterns of changes in water availability (Adams et al. 2005); however, the predicted maximum rate of drawdown of approximately 0.3 m/year is significantly lower than the rapid rise and fall in groundwater levels (up to 10 m over three months) across the Mount Bruce Flats noted in Batini (2008a). These trees should therefore be able to cope with fluctuations in the watertable caused by mining operations, especially if they are gradual and relatively small in comparison to natural events. Furthermore, it is quite likely that at least one, large, natural recharge event would occur during this period.

Coolibah can or is currently accessing water from the saturated zone/capillary fringe above the watertable. Consequently, even in a worst case scenario, assuming a maximum drawdown of 2.5 m (0.3 m/year) below the lowest recorded groundwater levels, and in the absence of rainfall inputs, it is anticipated that the root growth of Coolibah will continue to have access to adequate water.

Surface flow alterations

The natural hydrological regime of Marandoo Ridge has already been modified for over 10 years as a result of the construction of the railway from Rosella Siding to Homestead Junction (Section 5.3.1). Surface runoff from Marandoo Ridge that would have previously reached the Mount Bruce Flats as sheet flow is now redirected by the railway embankment through culverts placed at regular and strategic intervals through the embankment. Spreader structures at culvert outlets disperse the concentrated flows. Monitoring by the Proponent has investigated the effect of the railway on Mulga, which has not shown any substantial negative effects of the railway line construction on survival of Mulga (Hick et. al. 1997, Muller 2005, Nicholls 2006 and Batini 2008c). The Proposal is not expected to exacerbate any drainage shadow impacts that may have arisen from the construction of the railway.

The majority of surface water runoff generated on Marandoo Ridge during low-intensity rainfall events infiltrates the soil and does not reach the Mount Bruce Flats. Surface water runoff from the ridge is significant only after major rainfall events. Generally, a rainfall event in excess of 80 mm would be required to generate localised runoff on the Marandoo Ridge; a rainfall event in excess of 240 mm would be required to generate runoff from local sub-catchments up-slope of the mine pit that reaches the Mount Bruce Flats (Beckett 2008).

Excess water collected within mine pits will be diverted to in-pit sumps and then discharged to culverts through the railway embankment (Figure 17). Spreader structures downstream of the culvert outlets will disperse the concentrated surface water flows before the flows reach the Mount Bruce Flats.

Fire

There is clear evidence that fire can (and does) have a devastating effect on Mulga across the Mount Bruce Flats (for example, Batini 2008c). Alteration of the landscape due to pastoral activities means that fires in areas surrounding Karijini National Park are now usually fuelled by a uniform fuel load, which can result in both more intense and more extensive fires (CALM 1999). Surrounding pastoralists also generally burn in summer to maximise regrowth during winter rains; however, this may increase the fire frequency in surrounding areas. A major bushfire ignited on a nearby pastoral lease in 2000 resulted in the loss of nearly two-thirds of adult Mulga plants and 60% of Mulga recruits in monitoring plots near the Marandoo railway (Nicholls 2006).

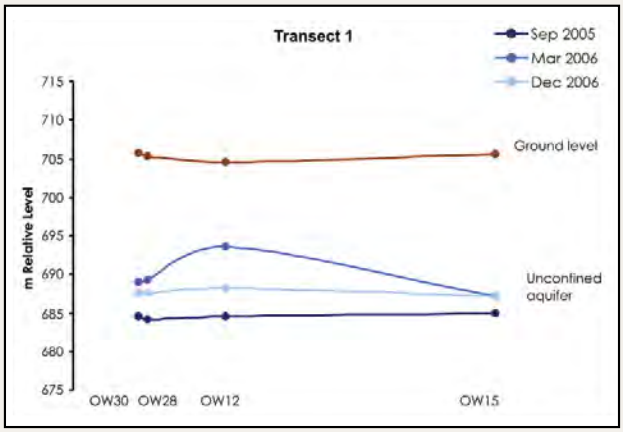
The existing Marandoo mine does not appear to have altered the fire regime in the locality, and the Proposal is not expected to pose a significantly increased risk of ignition.

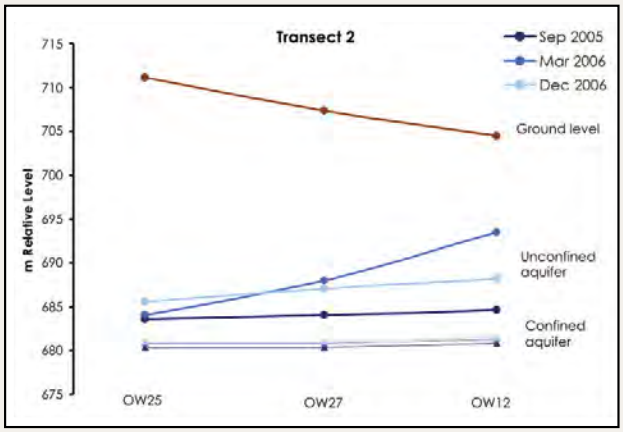
Weeds

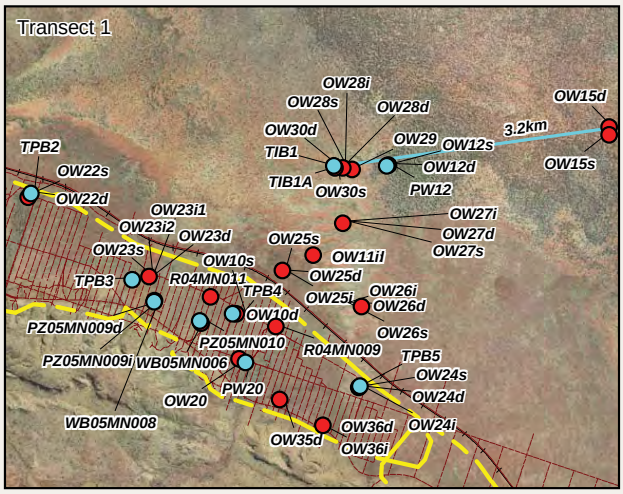
Karijini National Park is relatively free from serious weed infestations, although a few weed species have become established in some areas. Weeds that represent major threats to the natural values of the Park and that are known to occur across the Mount Bruce Flats include (CALM 1999):

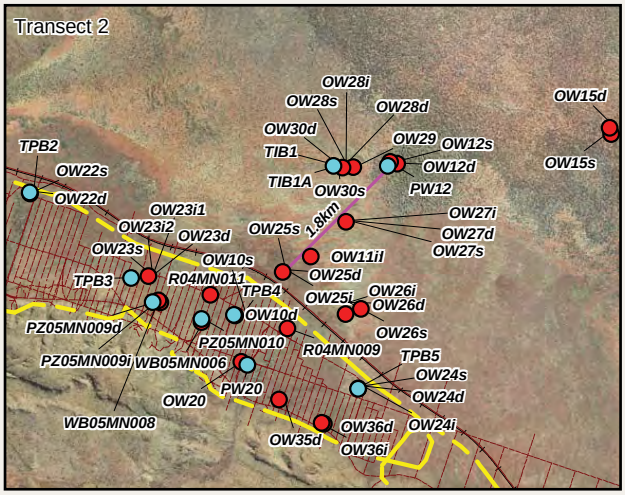
- *Bidens bipinnata* (beggars ticks) - common on alluvial flats and in Mulga areas; common on the Mount Bruce Flats
- *Acetosa vesicaria* (ruby dock) - widely spread within Karijini National Park; particularly prevalent at Marandoo and on the Mount Bruce Flats (amongst other areas).

Feral livestock are frequently vectors of weed seeds and agents of disturbance that create favourable conditions for establishment of weed species (CALM 1999).









RioTinto

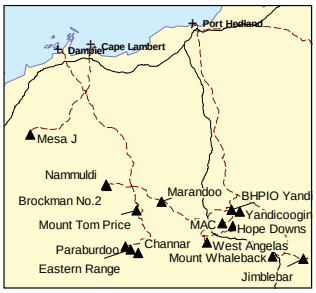
Strategic Assets - Perth

Figure 33
Rainfall Response of the Confined and Unconfined Aquifer at Marandoo

Drawn: B Jackson
Date: August 2008

Plan No. PDE0049509v1
Proj: MGA94 Zone50

LOCATION MAP



SCALE

1 0 1km

LEGEND

- Piezometer
- Water Bore
- Rail Access Road
- Railway
- Tracks
- NE Transect
- EW Transect
- Proposed MMP2 disturbance footprint

5.5.5 Proposed mitigation and management measures

The Coolibah woodland on the Mount Bruce Flats will be maintained through implementation of a comprehensive monitoring and adaptive management plan detailed in the Coolibah Management Plan (Appendix 2). Key elements of the Management Plan include:

- monitoring of the Coolibah woodland (impact site) and a control site for tree health
- development and continual refinement of appropriate trigger values for each aspect monitored/measured
- implementation of remedial contingency actions in liaison with the DEC in the event that trigger values are approached or exceeded.

Additionally, the Mount Bruce Flats Coolibah woodland has been incorporated into a Pilbara-wide study currently being undertaken by the University of New South Wales (UNSW). The study is investigating the hydrological and carbon balance of a number of riparian ecosystems to facilitate an understanding of ecosystem response to climate variability and dewatering/water abstraction in the Pilbara. Data from the study will be incorporated into an adaptive management plan to ensure potential impacts to the Mount Bruce Flats Coolibah woodland are detected and mitigated as soon as possible. Contingency measures are proposed in the adaptive management plan (Appendix 2).

Existing values of Mulga communities on the Mount Bruce Flats will be maintained through implementation of surface water and fire management measures outlined in the Surface Water Management Plan and Fire Management Plan (Appendix 2). Key elements of the Management Plans relevant to the protection of Mulga communities include:

- discharging stormwater collected within mine pits to culverts through the railway embankment
- ensuring any water discharged to the natural environment does not cause the quality of receiving surface or groundwater systems to exceed the ANZECC Water Quality Guidelines (ANZECC/ARMCANZ 2000)
- providing basic fire awareness and fire fighting training to all site personnel and ensuring appropriate fire fighting equipment is available on-site at all times
- maintaining adequate fire breaks across the mine site and around working areas where required
- ensuring ongoing consultation and provision of assistance to the DEC and other Karijini National Park management bodies with regard to fire management practices/buffers in adjoining pastoral leases, as well as mosaic burning
- continuing to assist with fire and weed management across the Mount Bruce Flats in collaboration with the DEC and other Karijini National Park management bodies including improving the on-site fire-fighting capability to support DEC/indigenous prescribed burning in the area
- implementing feral animal control measures across the Marandoo mine site to reduce the potential for proliferation of introduced species across the adjacent Mount Bruce Flats
- implementing weed control and vehicle hygiene procedures.

5.5.6 Predicted outcome

After mitigation and management measures have been applied, the Proposal is expected to result in the following outcomes in relation to the Coolibah woodland and Mulga:

- The Coolibah woodland is not anticipated to be affected by the Proposal, as the estimated magnitude and rate of groundwater drawdown in the unconfined aquifer are much lower than the magnitude and rate of natural groundwater level fluctuations across the Mount Bruce Flats. An adaptive management plan will be implemented with the objective of protecting the Coolibah woodland should there be any variation from the predicted impact to the woodland resulting from the Proposal.
- There will be no further significant change to the already modified hydrological regime of Marandoo Ridge and the Mount Bruce Flats and hence no indirect impacts to Mulga or Coolibah.
- There will be no further impact to Mulga due to implementation of fire and weed management across the Mount Bruce flats.

5.6 Terrestrial fauna

5.6.1 Description of factor

The habitats within the Proposal area support a range of fauna species, including several that are endemic to the region and/or listed for protection under state and Commonwealth conservation legislation.

Biota (2008d) conducted a review of previous fauna studies focussed on the locality of the Proposal area, including Muir (1980), Ninox (1992), Kendrick (2001) and Biota (2001), and conducted systematic terrestrial fauna survey work at the Marandoo mine lease during March/April and November 2007. The RSF location has already been extensively disturbed and was considered of little value as a potential habitat for fauna species of significance and was therefore not surveyed (Phil Runham [Biota Environmental Sciences] 2008 pers. comm., 13 May). The EPA Position Statement No. 3 (EPA 2002a) and Guidance Statement No. 56 (EPA 2004d) were utilised as a basis for the design of the fauna surveys (Biota 2008d). A desktop assessment of the Southern Fortescue borefield was undertaken.

A desktop assessment of the operations camp site was also completed, as well as targeted searches for SRE invertebrate groups at the operations camp site (Biota 2008f). The dewatering pipeline route was evaluated through a desktop assessment to identify potential habitat types and the likelihood of occurrence of terrestrial vertebrates of elevated conservation significance (Biota 2008c). Clearing of fauna habitat for dewatering infrastructure and the operations camp does not form part of this Proposal and will be subject to a separate environmental approvals process under the EP Act. Where relevant to operational impacts and ongoing management, baseline information is included below.

The following description of the fauna of the Proposal area is adapted from Biota (2008d), unless otherwise stated. The full Biota (2008d) report is included in Appendix 1.

Fauna habitat

Four primary habitat types were identified at the Marandoo mine site, which were largely based on vegetation structure and landforms. These habitats were:

- small drainage lines: **vegetated with Mulga and** occasional scatters of *Corymbia* over generally mid to dense tussock grasses with occasional patches of *Triodia* (spinifex) on loamy substrates
- stony hill slopes: **vegetated with** *Acacia* shrubs over spinifex on stony loam substrates
- flat outwash plains: **vegetated with** *Acacia* shrubs on loamy substrates
- rocky gorges: **stony surfaces with scattered** *Acacia* shrubs and spinifex.

The Southern Fortescue borefield comprised one broad fauna habitat:

- Mulga on stony plains with a clay to clay-loam substrate: vegetation within this habitat ranged from Mulga woodlands over dense tussock grasses to scattered tall shrubs of Mulga over scattered tussock and hummock grasses.

The dewatering infrastructure corridor incorporates two primary habitat types; *Acacia* on stony plains and rises with clay to clay-loam substrates and *Acacia* or *Corymbia* spp. over tussock and hummock grasses in drainage lines with stony to loamy substrates. The portion of the dewatering pipeline between the Southern Fortescue borefield and the existing rail corridor extends along a corridor, approximately 15 m in width, containing a powerline and associated access track, as well as a disused pipeline and associated access track. While four vegetation types have been described for the camp footprint these constitute two broad terrestrial fauna habitat types: scattered *Corymbia* and *Acacia* spp. over tussock and hummock grasslands on loam; and drainage line with occasional *Eucalyptus* spp. over tussock grasses with loamy banks.

Vegetation units and land systems on which the habitat classifications are based are described in Sections 5.4.1 and 3.2.3, respectively.

Fauna survey

Systematic terrestrial fauna surveys were conducted within each habitat type in the Marandoo mine lease at 16 sites (Figure 34). This sampling comprised:

- 10 trapping grids of 10 pit-traps each (MAR01, MAR02, MAR03, MAR04, MAR05, MAR06, MAR07, MAR08, MAR09, MAR10; Figure 34)
- three transects of Elliott traps (MARE01, MARE02, MARE03; Figure 34)
- avifauna censusing at each of the 13 sites and at one opportunistic site (MARSWAMP; Figure 34)
- sampling of bats at two sites using harp traps (MARHARP01, MARHARP02; Figure 34) and at two sites using Anabat echolocation call detectors (MARE02, MARE03; Figure 34).

Non-systematic searches were also conducted at the Marandoo mine lease for SRE invertebrate groups in a variety of microhabitats including:

- *Triodia* on loam (targeting terrestrial snails, mygalomorphs and scorpions at MARSN01; Figure 34)
- under flaking bark of *Corymbia* spp. (targeting pseudoscorpions at PSEUD1, PSEUD2, PSEUD3 and PSEUD4; Figure 34).

Results of fauna survey

A total of 125 vertebrate species was recorded in the area surveyed by Biota (2008d), comprising 54 avifauna species, 20 mammal species and 51 herpetofauna species (Table 13). Three groups of invertebrate fauna (potentially containing SREs) were also recorded during the Biota (2008d) survey.

Table 13
Number of vertebrate fauna species recorded at Marandoo

Fauna group	Number of species		
	Phase 1 (Autumn)	Phase 2 (Spring)	Total
Avifauna	47	39	54
Ground mammals (native)	9	6	10
Ground mammals (introduced)	2	2	3
Bats	1	7	7
Herpetofauna	31	42	51
Total	90	96	125

LEGEND
Mine location
Roads
Railway
Karijini National Park
MMP2 Project disturbance
Proposed MMP2 disturbance footprint
Fauna trapping sites
1km
Karijini National Park
Marandoo
Rail
MAR01
MAR02
MAR03
MAR04
MAR05
MAR06
MAR07
MAR08
MAR09
MAR10
MARSWAMP
MARSWAMP2
MARSWAMP3
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Figure 34
Location of Marandoo
fauna survey sites
RioTinto
Drawn:TC
Date:April 2008
Plan No:PDE00408609v1
Proj:MGA94 Zone50

Ground mammals

A total of 10 native ground mammal species was recorded during the Biota (2008d) survey, comprising four dasyurids (carnivorous marsupials), one macropod (kangaroos and wallabies), four native murid rodents (native mice) and one species from the family Canidae. The vast majority (73%) of ground mammals recorded belong to the Family Muridae (native mice), including *Zyzomys argurus* (common rock-rat), which accounted for approximately 56% of all ground mammals recorded.

Three introduced ground mammal species were recorded: these were *Equus asinus* (donkey), *Felis catus* (cat) and *Mus musculus* (house mouse).

Species of conservation significance

One individual each of *Dasyurus hallucatus* (northern quoll) and *Pseudomys chapmani* (western pebble-mound mouse) was recorded at Marandoo. These species were previously recorded at Marandoo during the Ninox (1992) survey.

The northern quoll was recorded by Biota (2008d) in the rocky gorges habitat type on Marandoo Ridge outside the area of proposed disturbance (MARE02; Figure 34). The northern quoll is listed as Endangered under the EPBC Act and as 'rare and likely to become extinct' under Schedule 1 of the *Wildlife Conservation Act 1950* (WA).

The western pebble-mound mouse was recorded in the stony hill slopes habitat type, just outside of the area of proposed disturbance (MAR06 Figure 34). The western pebble-mound mouse is listed as Priority 4 in the DEC Priority Fauna List.

The Biota (2008c) desktop study indicated that, on the basis of the known distributions of species and the available habitat types, six fauna species of elevated conservation significance may potentially occur at the Southern Fortescue borefield. These included *Dasyurus hallucatus* (northern quoll), *Rhinonicteris aurantius* (Pilbara orange leaf-nosed bat), *Liasis olivaceus barroni* (Pilbara olive python), *Falco peregrinus* (peregrine falcon), *Leggadina lakedownensis* (short-tailed mouse), and *Ardeotis Australia* (Australian bustard) (Biota 2008c).

Bats

Four species of bat from the Family Vespertilionidae, two from the Family Emballuronidae and one from the Family Megadermatidae were recorded at Marandoo during the Biota (2008d) survey.

Species of conservation significance

Macroderma gigas (ghost bat) was recorded at one site during the Biota (2008d) survey (MARE03; Figure 34). This species has been previously recorded at Marandoo by Ninox (1992). The ghost bat is listed as Priority 4 in the DEC Priority Fauna List.

Mormopterus loriae cobourgiana (little north-western mastiff bat) has been previously recorded at Marandoo by Ninox (1992); however, records of this species at Marandoo are considered to represent misidentifications, as this species is restricted to mangrove forest and adjacent areas (Biota 2008d). The little north-western mastiff bat is listed as Priority 1 in the DEC Priority Fauna List.

Birds

A total of 54 bird species was recorded during the Biota (2008d) survey, comprising 30 passerine (perching) and 24 non-passerine species. *Taeniopygia guttata* (zebra finch) and *Cacatua sanguinea* (little corella) were the two most common species recorded, together accounting for approximately 63% of all avifauna recorded. Waterfowl belonging to two Families (Anatidae and Charadriidae) were recorded from a shallow, ephemeral waterbody in the northern portion of the survey area (MARSWAMP; Figure 34).

Species of conservation significance

Sixteen (16) individuals of *Merops ornatus* (rainbow bee-eater) were recorded from four sites during the Biota (2008d) survey (MAR04, MAR10, MARE01, MARE02; Figure 34). The rainbow bee-eater has been previously recorded at Marandoo during the Ninox (1992) survey. The rainbow bee-eater is listed as Migratory under the EPBC Act.

Apus pacificus (fork-tailed swift) has been previously recorded at Marandoo by Ninox (1992). This species is listed as Migratory under the EPBC Act.

Ardeotis australis (Australian bustard) and *Burhinus grallarius* (bush stone-curlew) have been previously recorded at Marandoo by Ninox (1992). These species are listed as Priority 4 in the DEC Priority Fauna List.

Herpetofauna

A total of 51 herpetofauna species were recorded during the Biota (2008d) survey, comprising one myobatrachid (ground) and two hylid (tree) frogs, six agamids (dragons), seven gekkonids (geckos), six pygopodids (legless lizards), 13 scincids (skinks), six varanids (goannas), two typhlopids (blind snakes) and eight elapids (front-fanged snakes). The skinks were both the most abundant Family (accounting for approximately 32% of all herpetofauna records) and the most speciose group (13 species).

Species of conservation significance

No herpetofauna species of conservation significance were recorded during the survey; however, *Liasis olivaceus barroni* (Pilbara olive python) has been previously recorded at Marandoo during the Ninox (1992) survey. The Pilbara olive python is listed as Vulnerable under the EPBC Act and as 'rare and likely to become extinct' under Schedule 1 of the *Wildlife Conservation Act 1950* (WA).

Short-Range Endemic (SRE) invertebrates

Three groups of invertebrate fauna potentially harbouring SRE species were recorded at Marandoo during the Biota (2008d) survey. These groups were Pulmonata (terrestrial snails), Scorpionida (scorpions) and Pseudoscorpionida (pseudoscorpions).

Terrestrial snails were recorded at a single site within the proposed disturbance footprint (MARSN01; Figure 34). Molecular studies have shown that all individuals belong to a single *Bothriembryon* species that occurs throughout the Pilbara region (Biota 2008d).

Pseudoscorpions were recorded within the Proposal area and in similar adjacent habitat (PSEUD1, PSEUD2, PSEUD3, PSEUD4; Figure 34). All individuals have been identified as a single species of *Synsphyronus* by Dr Mark Harvey of the WA Museum (Biota 2008d).

Scorpions were recorded at four sites both inside and outside the proposed area (MAR05, MAR08, MAR02, MAR10; Figure 34). Scorpion identifications have not yet been finalised; however, all individuals appear to belong to a single species (Biota 2008d).

No SRE invertebrate groups were recorded during targeted searches at the operations camp site (Biota 2008f).

Introduced animals

Mus musculus (house mouse), *Felis catus* (cat) and donkeys have been previously recorded at Marandoo (Biota 2008d).

Survey limitations

The main limitations of the Biota (2008d) survey were:

- Funnel traps were not deployed during the survey due to high temperatures and the consequent high likelihood of individual animal death.
- Sampling for bats was carried out using harp traps, as this method provides voucher specimens that can be definitively identified; however, harp traps limit sampling to specific roost sites or flyways and do not exhaustively sample all bat species that may be present, such as high-flying taxa.
- The WA Museum curatorial staff indicated that only key specimens would be accepted for vouchering. As a consequence, terrestrial invertebrate sampling was targeted at specific groups and voucher specimens were not provided for all invertebrate species collected opportunistically during the survey.

5.6.2 Potential sources of impact

Activities or aspects of the Proposal that may affect terrestrial fauna values include:

- vegetation clearing for mine pit, waste dumps and associated infrastructure, will directly disturb terrestrial fauna habitat and may result in the loss of individual terrestrial fauna
- groundwater drawdown may affect vegetation and consequently reduce the area of fauna habitat available
- alterations to surface hydrology may affect habitats and result in the loss of individual terrestrial fauna through ponding
- vehicle movements in mining areas and on mine access roads could potentially result in the loss of individual terrestrial fauna, especially less-mobile species.

Minor potential sources of impact include noise emissions from the mining operations, which may cause nearby habitats to become unsuitable for foraging and general habitation. These aspects are not anticipated to result in a significant impact (Section 6.6). Dust emissions (Section 6.5) and the introduction and/or spread of weed species and feral animals are also not anticipated to significantly affect terrestrial fauna as a result of the proposed operations.

5.6.3 Key statutory requirements, environmental policy and guidance

EPA objective

In most circumstances, including this assessment, the EPA applies the following objective in its assessment of Proposals that may affect fauna:

To maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystem levels through the avoidance or management of adverse impacts and improvement of knowledge.

EPA Position Statement No. 3

EPA Position Statement No. 3 (EPA 2002a) discusses the principles the EPA would apply when assessing Proposals that may have an effect on biodiversity values in Western Australia. The Position Statement intends to provide the following outcomes:

- promote and encourage all Proponents and their consultants to focus their attention on the significance of biodiversity and, therefore, the need to develop and implement best practice in terrestrial biological surveys
- enable greater certainty for Proponents in the Environmental Impact Assessment process by defining the principles the EPA will use when assessing Proposals that may have an effect on biodiversity values.

EPA Guidance Statement No. 56

As described in EPA Position Statement No. 3, the EPA determined that a series of guidance statements were warranted to provide an easy-to-use decision-making guide to the level of biological survey required. EPA Guidance Statement No. 56 (EPA 2004d), provides guidance on standards and protocols for terrestrial fauna surveys, particularly those undertaken for the Environmental Impact Assessment of Proposals.

State protection

In a legislative context, the preservation and conservation of fauna is covered primarily by the following Western Australian legislation:

- *Wildlife Conservation Act 1950* (WA)
- *Conservation and Land Management Act 1984* (WA).

In Western Australia, rare or endangered species are protected by the Wildlife Conservation (Specially Protected Fauna) Notice 2005, under the *Wildlife Conservation Act 1950* (WA). Schedules 1 and 4 in this notice are relevant to this assessment, providing a listing of those species protected by this Notice.

The DEC (Nature Conservation Division) Priority Fauna List also nominates conservation species from Priority One to Five. It is expected that the potential impacts of a Proposal to these Priority listed species should be managed such that the species do not meet the IUCN criteria for threatened species.

Commonwealth protection

The Commonwealth EPBC Act protects species listed under Schedule 1 of the Act. In 1974, Australia became a signatory to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). As a result, an official list of endangered species was prepared and is regularly updated. This listing is administered through the EPBC Act. The current list differs from the various State lists; however, some species are common to both.

International agreements

Australia is party to the Japan-Australia (JAMBA), China-Australia (CAMBA) and Republic of Korea-Australia (ROKAMBA) Migratory Bird Agreements. Most of the birds listed in these agreements are associated with saline wetlands or coastal shorelines and have little relevance to the proposed area; however, some migratory birds not associated with water are also listed on these international treaties.

5.6.4 Assessment of potential impact, mitigation and residual impact

Vegetation clearing

Almost all native fauna species rely on native vegetation to provide food, shelter and breeding sites. The loss or degradation of native vegetation may reduce the capacity of the habitat to support the range of species that it would have done in an undisturbed state.

The fauna habitat types identified by Biota (2008d) support a range of fauna species, including conservation significant species. While it is not possible to rank some habitats as being more important than others, the four fauna habitats types within the Marandoo mine lease appear typical of the surrounding area and are well represented throughout the Pilbara. Similarly, the fauna assemblages documented during the Biota (2008d) survey are comparable to those recorded during earlier work and seem typical of assemblages occurring where similar habitats are found elsewhere in the Pilbara (Biota 2008d). The invertebrate groups recorded inside the Proposal area and in adjacent areas are not considered to be SRE species, primarily due to the extensive distributions of their preferred habitats outside the proposed disturbance area.

Vegetation will be progressively removed from sections of the Proposal area, during construction of mining infrastructure and during mining. Approximately 940 ha of vegetation will be disturbed for the Proposal. Vegetation units recorded in the Proposal area do not appear to be restricted in distribution within the locality, suggesting that the fauna habitats are likewise probably more widely distributed (Table 9).

Groundwater drawdown

Drawdown within the unconfined aquifer is predicted to be well within the ranges of natural seasonal fluctuations (Batini 2008a) and is therefore not anticipated to affect vegetation (Section 5.4.4), or associated fauna communities.

Alterations to surface hydrology

There will be a slight reduction in surface water runoff reaching fauna habitat downstream of the proposed mine pit as incident rainfall will be captured by the pit. Beckett (2008) estimates there will be a reduction in surface water runoff reaching vegetation within 200 m of the northern pit face; however, surface water runoff beyond 200 m from the northern pit face is unlikely to be affected by the proposed mine pit.

Vehicle movement

The site preparation process and vehicle movements around the mine site have the potential to cause the loss of some individuals of terrestrial fauna. Less-mobile species, such as reptiles, are most likely to be affected.

The conservation status and distribution of any fauna species is unlikely to be affected by the degree of impact associated with vehicle movement at Marandoo.

Impacts to fauna of conservation significance

The Proposal is considered unlikely to affect the conservation status of any fauna species of elevated conservation significance (Biota 2008d). Species that have been recorded, or were identified from database searches as potentially occurring in the Proposal area are considered either unlikely to inhabit the area due to a lack of suitable habitat, or unlikely to exclusively utilise the area to the extent that they would be significantly affected by the Proposal (Biota 2008d).

The likelihood of impacts to species of conservation significance recorded by Biota (2008d) is discussed below:

- *Dasyurus hallucatus* (northern quoll) was recorded in the rocky gorges habitat type on Marandoo Ridge outside the area of proposed disturbance (MARE02; Figure 34). Typical habitat for the northern quoll (rocky gullies and breakaways) is extremely limited in the Proposal area and the Proposal is not expected to significantly affect this species (Biota 2008d).
- *Pseudomys chapmani* (western pebble-mound mouse) was recorded in the stony hill slopes habitat type, just outside of the area of proposed disturbance (MAR06 Figure 34). The western pebble-mound mouse is common to very common in suitable habitat within the Hamersley and Chichester sub-regions of the Pilbara region and the Proposal is considered unlikely to affect the conservation status of this species (Biota 2008d).

- *Macroderma gigas* (ghost bat) was recorded at one site (MARE03; Figure 34). The ghost bat occurs in a broad range of habitats, with their distribution being influenced by the availability of suitable caves and mines for roost sites and the Proposal is considered unlikely to affect the conservation status of this species (Biota 2008d).
- *Merops ornatus* (rainbow bee-eater) was recorded from four sites (MAR04, MAR10, MARE01, MARE02; Figure 34). The rainbow bee-eater could utilise the Proposal area seasonally; however, the Proposal is unlikely to significantly affect the conservation status of this species (Biota 2008d).

5.6.5 Proposed mitigation and management measures

Terrestrial fauna within, and adjacent to the Proposal area will be protected through the implementation of measures outlined in the Fauna Management Plan (Appendix 2). Key measures include:

- undertaking feral animal control
- keeping vegetation clearing within designated areas based on the minimum necessary for safe construction and operation of the Proposal, particularly in areas adjacent to habitat of higher conservation significance
- maintaining natural drainage flows wherever practicable and preventing ponding of water
- implementing standard dust suppression measures across the Proposal area during construction and operation to mitigate effects on surrounding fauna habitat
- undertaking progressive rehabilitation to re-establish fauna habitat
- including fauna protection specifications in all construction-related contracts and subcontracts
- implementing and sign-posting appropriate speed limits for both mining equipment and light vehicles on the Marandoo access road
- providing reflectors on all barbed wire fencing to deter bats
- providing workforce environmental education programs and training.

5.6.6 Predicted outcome

After mitigation and management measures have been applied, the Proposal is expected to result in the following outcomes in relation to terrestrial fauna:

- The Proposal will result in the progressive loss and subsequent revegetation of approximately 940 ha of terrestrial fauna habitat over the life of the Proposal. Disturbed areas will be progressively rehabilitated to restore original fauna habitat values.
- No fauna habitat of high conservation significance will be affected by the Proposal and significant impacts to fauna of conservation significance at a regional, state, national or international level are highly unlikely.
- The Proposal will not conflict with the *Wildlife Conservation Act 1950* (WA), as no terrestrial vertebrate or invertebrate fauna species will cease to exist as a result of the Proposal.

Consistent with EPA objectives, the abundance, species diversity, geographic distribution and productivity of terrestrial fauna at species and ecosystem levels will be maintained, thereby conserving regional biological diversity. The zoological studies undertaken by the Proponent and implementation of the proposed management measures will ensure that direct disturbance to important fauna habitat is kept to that which is necessary and that fauna and fauna habitat are protected from indirect disturbance as far as practicable.

5.7 Subterranean fauna

5.7.1 Description of factor

Subterranean fauna are animals that inhabit underground habitats, and include stygofauna and troglofauna. Stygofauna are obligate groundwater-dwelling aquatic fauna that inhabit a range of groundwater systems. Troglofauna are obligate terrestrial fauna that inhabit air chambers in underground caves or small, humid air-filled voids.

Most subterranean fauna in Western Australia are invertebrates, the most common stygofauna being crustaceans. Common examples of troglofauna include spiders, scorpions and millipedes (EPA 2003).

Research by the WA Museum has shown that calcrete and alluvial aquifers the Pilbara and Yilgarn regions of Western Australia contain diverse stygofaunal communities (Humphreys 1999). Subterranean fauna are also found in palaeodrainage channels in inland deserts of Western Australia (Watt and Humphreys 2001). In the arid zone, troglofauna are generally considered to be relictual rainforest litter fauna, having arisen from tropical fauna lineages that descended into subterranean environments during the aridification of Australia (Humphreys 1993).

Western Australian stygofauna and troglofauna exhibit high levels of endemism (EPA 2003). Many species have restricted ranges, which is a characteristic of subterranean fauna worldwide (Strayer 1994). For example, short-range endemism is common in troglofauna, with some species only known from single cave systems (for example, the millipede *Stygiochiropus peculiaris* from Cameron's Cave at Cape Range; Humphreys and Shear 1993).

Western Australian stygofauna and troglofauna have conservation significance, as they appear to be linked to the time when Australia was part of Gondwanaland (Humphreys 1999). Some species of stygofauna have extremely localised patterns of distribution, and this has been linked to a lack of connectivity between aquifers (Watt and Humphreys 2001).

Stygofauna

Previous stygofauna sampling

Stygofauna have previously been sampled at Marandoo over six phases: September 1999, November 2000, June 2001, April 2002, July 2002 and May 2003 (Biota 2008e). A combined total of 51 bore holes were sampled across the six phases.

Historically, stygofauna were collected from only eight of the 51 bores sampled, primarily from the Mount Bruce Flats to the north of the Proposal area. In all cases, no stygofauna were collected from the confined aquifer and, therefore, stygofauna appear to be associated only with the unconfined aquifer (Biota 2008e).

Stygofauna sampling program

Further sampling of stygofauna was undertaken in 2008 by Biota (2008e) in accordance with EPA Guidance Statement No. 54 (EPA 2003) and Draft EPA Guidance Statement No. 54a (EPA 2007c).

The sampling objectives were to ensure:

- adequate spatial spread of sampling points across the Proposal area
- adequate coverage across the anticipated extent of the groundwater drawdown impact area (the groundwater drawdown impact area was defined as the area in which groundwater drawdown was predicted to be 2 m or more[24] as this is within normal seasonal groundwater level fluctuations; Biota 2008e)
- sampling within potential re-injection areas at the Southern Fortescue borefield (as these areas had not previously been sampled)
- collection of more data to validate the vertical distribution of the fauna from earlier sampling (that is, to confirm stygofauna are associated only with the unconfined aquifer and do not occur in the confined aquifer)
- re-sampling of bores that had previously yielded stygofauna (to build upon information on individual species distributions).

Forty-three (43) bores were sampled for stygofauna by Biota (2008e) to meet the above objectives. Thirty (30) bores were located inside the predicted 2 m drawdown contour ('impact area') and 13 were located outside this area.

Stygofauna were collected from just eight (12.5%) of the 64 bores sampled in total during both the historical studies and most recent field study by Biota (2008e) (Figure 35). Two troglobites were opportunistically collected at one of the bores which yielded stygofauna and also at an additional bore well outside the Proposal area.

Sampling results

No subterranean fauna were collected from the Southern Fortescue borefield during the 2008 sampling phase (Biota 2008e). Stresses placed on this aquifer as a result of long-term abstraction for water supply are likely to have already affected any stygofauna that may have been present, or compromised opportunities to collect them from the available bores (Biota 2008e). Should a stygofauna community have persisted in the area, the key potential impact of the Proposal would be changes in water chemistry resulting from re-injection of water from Marandoo (Biota 2008e) (Section 5.7.4)

Sixty-eight (68) stygal individuals from four orders were recorded during the multiple phase sampling program (Table 14). These specimens were recorded from eight of the 64 bores sampled. Fauna collections were generally limited to the area extending north-east from the existing Marandoo mine into the Mount Bruce Flats (Figure 35). All records of stygofauna were associated with the unconfined aquifer; no individuals were recorded from the confined aquifer (Biota 2008e).

Amphipods were the most abundant group recorded, accounting for 47 of the 68 specimens (69%) collected during the sampling program (Table 14). Amphipods were collected from six of the nine bores that yielded subterranean fauna. All amphipods recorded belong to the family Paramelitidae but many of the specimens were not either sufficiently mature or physically intact to allow further identification.

A selection of amphipod specimens were subject to genetic analysis as part of a regional study being undertaken by Dr Terrie Finston at the University of Western Australia. This analysis confirmed amphipods collected from both OW11S and OW28S (a distance of approximately 3 km; Figure 35) were the same species. This is consistent with both the morphological identifications that could be completed for this study and the outcomes of current and ongoing research indicating that most stygal amphipod species in the Pilbara are distributed across (at least) local surface water catchments (Biota 2008e).

Phylogenetic comparison of the Marandoo specimens with those collected from bores elsewhere in the Pilbara indicated that Marandoo amphipods are distinct from those collected elsewhere in the region and should be viewed as a separate genetic type, probably corresponding to a single species (Biota 2008e).

At least two species of copepod (*Diacyclops humphreysi humphreysi* and *Microcyclops varicans*) were collected during the Marandoo sampling program, with a further specimen that could not be determined beyond genus level (Table 14). Both *D. humphreysi humphreysi* and *M. varicans* have also been collected during the DEC Pilbara Biological Survey (which included the wider Marandoo area) and from further afield in the Pilbara region (Biota 2008e).

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24 The 2 m drawdown contour has been accepted in previous assessments as a reasonable, risk-based delineation of where significant impacts to stygal communities could be expected to begin, and the fact that the fauna across the Mount Bruce Flats has routinely had to accommodate natural fluctuations in the watertable of three or four times this magnitude, even in recent times, presumably through mobility to deeper strata (Garth Humphries [Biota Environmental Sciences] 2008 pers. comm., 19 August).

Twelve (12) bathynellaceans were collected from four bores during the multiple phase sampling program, all of which belonged to the genus *Notobathynella* (Table 14). All were preliminarily assigned to the same taxon (*Notobathynella* sp.) as limited knowledge on the taxonomy of this group prevents further identification (Garth Humphries [Biota Environmental Sciences] 2008 pers. comm., 19 August). Taxonomic work is currently continuing on this order (Syncarida). Several other *Notobathynella* individuals were collected from the wider Marandoo locality during the DEC Pilbara Biological Survey; however, it is unclear whether these individuals represent the same species as individuals collected during the multiple phase Marandoo sampling program.

Oligochaete worms were collected from bores OW12S and OW15S (Figure 35), but have not yet been determined to species level. Previous studies suggest the risk of any oligochaete species being restricted to an area the size of the current study is low (Biota 2008e).

With the exception of bore OW3 (where a single platyhelminth worm was collected; Table 14), stygofauna were reliably collected along a gradient north-east from the proposed mine pit area to the Mount Bruce Flats (Figure 35). None of the bores sampled in the core impact area for the project yielded any subterranean fauna (Biota 2008e).

Table 14
Subterranean fauna collected from Marandoo locality

Bore	Phylum	Class	Order	Family	Taxon	Individuals
OW10S	Crustacea	Malacostraca	Amphipoda	Paramelitidae	Genetic sp. A	1
	Crustacea	Malacostraca	Amphipoda	Paramelitidae	Amphipoda indef.	5
	Crustacea	Malacostraca	Amphipoda	Paramelitidae	Paramelitidae sp. 2	1
	Crustacea	Malacostraca	Syncarida	Parabathynelidae	*Notobathynella* sp.	1
OW11I	Crustacea	Malacostraca	Amphipoda	Paramelitidae	Amphipoda indef.	1
OW11M	Crustacea	Malacostraca	Syncarida	Parabathynelidae	*Notobathynella* sp.	1
OW12S	Crustacea	Malacostraca	Amphipoda	Paramelitidae	Amphipoda indef.	4
	Crustacea	Malacostraca	Amphipoda	Paramelitidae	Paramelitidae sp. 2	1
	Annelida	Clitellata	Haplotaxida	Tubificidae	Tubificidae sp.	1
	Crustacea	Copepoda	Cyclopoida	Cyclopidae	*Diacyclops humphreysi humphreysi*	2
	Crustacea	Copepoda	Cyclopoida	Cyclopidae	*Diacyclops* sp.	1
	Crustacea	Copepoda	Cyclopoida	Cyclopidae	*Microcyclops varicans*	1
	Crustacea	Malacostraca	Syncarida	Parabathynelidae	*Notobathynella* sp.	7
OW15S	Uniramia	Symphyla	Symphyla		*Symphyla* sp.*	1
	Crustacea	Malacostraca	Syncarida	Paramelitidae	*Notobathynella* sp.	3
	Annelida	Clitellata	Haplotaxida	Tubificidae	Tubificidae sp.	2
	Crustacea	Malacostraca	Amphipoda	Paramelitidae	Amphipoda indef.	5
OW28S	Crustacea	Malacostraca	Amphipoda	Paramelitidae	Genetic sp. A	5
	Crustacea	Malacostraca	Amphipoda	Paramelitidae	Paramelitidae sp. 2	2
	Crustacea	Malacostraca	Amphipoda	Paramelitidae	Amphipoda indef.	13
OW3	Platyhelminthes	–	–	–	Platyhelminthes sp.	2
OW30S	Crustacea	Malacostraca	Amphipoda	Paramelitidae	Amphipoda indef.	9
OW8S	Uniramia	Diplura	Diplura	Japygidae	*?Japyx* sp.*	1

'Indef.' refers to juvenile and/or damaged specimens unable to be morphologically determined
*** troglobitic species**

Stategic Assets - Perth
Figure 35
Location of Subterranean
Fauna Sampling Sites
RioTinto
LEGEND
Mine location
Roads
Railway
Karijini National Park
Proposed MMP2 disturbance footprint
MMP2 Project disturbance
Bores containing subterranean fauna
Bores not containing subterranean fauna
Bores containing troglofauna
INSET
SEE INSET
Marandoo
Karijini National Park
7510000 mN
7500000 mN
7490000 mN
600000 mE
610000 mE
620000 mE
630000 mE
640000 mE
Kilometers
GEOLOGY LEGEND
Cainozoic
Quaternary alluvium
Robe Pisolite
Cainozoic colluvium and alluvial sheet wash
Cainozoic calcrete & lacustrine limestone
Cainozoic laterite
Channel Iron Deposit
Proterozoic
HAMERSLEY GROUP
BROCKMAN IRON FORMATION
Archaean
MOUNT McRAE SHALE
MOUNT SYLVIA FORMATION
WITTENOOM FORMATION
MARRA MAMBA IRON FORMATION, undifferentiated
Hematite deposits
FORTESCUE GROUP
JEERINAH FORMATION, undifferentiated
Dolerites and Volcanics
BUNJINAH FORMATION

Troglofauna

No sampling for troglofauna has been previously undertaken in the Proposal area. Biota (2008e) conducted a detailed desktop review and risk assessment to determine:

- the likelihood that troglofauna occur in the Proposal area
- the potential impacts to troglofauna (if present) that may arise as a result of the Proposal.

Given the outcomes of the risk assessment (presented in the following section), a dedicated troglofauna sampling program was not undertaken. Two troglobitic individuals were collected ad-hoc during stygofauna sampling from two bores well outside the Proposal area across the Mount Bruce Flats (OW8S, OW15S; Figure 35). These records indicate that a troglobitic fauna community is probably more widespread across the Mount Bruce Flats (Biota 2008e). The two troglobites (a symphylan and a dipluran) have been submitted to the WA Museum to assist with ongoing taxonomic efforts on this fauna.

Likelihood of troglofauna occurrence

The likelihood of troglofauna occurring in the Proposal area was assessed by Biota (2008e) using a combination of regional information and site-specific habitat data. This included:

- definition of the likely area that may be affected by the Proposal (the mining area)
- regional geology mapping
- geotechnical, hydrological and hydrogeological information from other technical studies completed for the Proposal (refer to Section 5.2 and 5.3 for details)
- geological information from holes drilled in the Proposal area as part of resource assessment
- previous sampling efforts in the area and the results of published and unpublished studies on subterranean fauna from the region
- qualitative results from down-hole video camera work at Marandoo and Mesa A[25]
- locations of other troglofauna records from the Biota database and the DEC Pilbara Biological Survey.

Based on the results of this process, the Proposal was assigned a level of likelihood to support troglofauna of either 'Low', 'Moderate' or 'High/Definite' (Table 15).

Table 15
Framework for the likelihood of troglofauna occurrence within the Proposal area

Likelihood	Description
Low	No records of troglobitic fauna within 5 km radius (giving consideration to sampling effort); affected geological units unlikely to represent core subterranean fauna habitat
Moderate	Records of troglobitic fauna within 5 km radius (giving consideration to sampling effort) and/or affected geological units may represent core subterranean fauna habitat
High/Definite	Known records of troglobitic fauna within 1 km radius (giving consideration to sampling effort) and/or affected geological units likely to represent core subterranean fauna habitat

Source: Biota (2008e)

Troglobitic fauna records for the Proposal area

A review of the literature, previous formal assessments and consultation with DEC and WA Museum staff was completed to identify any previous work done in the locality. No sampling specifically targeting troglobitic fauna has previously been completed in the Marandoo project area. Previous stygofauna work at Marandoo did collect troglobitic fauna from two locations. Both of these records were from outside the proposed MMP2 footprint however, and are associated with alluvial material overlying dolomite (geologically distinct from the quarternary deposits overlying the Marra Mamba ore of the planned pit area).

Geological review

Several geological units are described for the Marandoo area in Section 3.2.4. The proposed mining area comprises Marra Mamba Iron Formation (AHm; Figure 35) overlain by quaternary alluvium (Qw; Figure 35) and Cainozoic colluvium and alluvium sheet wash (Czc; Figure 35), which have not been demonstrated to represent significant habitat for troglofauna (Biota 2008e).

Diamond drilling was completed at 24 locations across the Proposal area. This drilling method provides the most complete information on subterranean habitat, through visual inspection of the core and logging of more detailed geological and geotechnical data (Biota 2008e).

25 Mesa A is located in the Robe Valley in the Pilbara region and is known to support a diverse troglofauna community (Biota 2006).

The diamond drill core and logs did not generally indicate a cavernous or vuggy profile, with most of the major rock strata generally solid in nature (Figure 36). The units considered to have the highest potential to provide suitable troglofauna habitat (the upper and lower calcrete sequences), had minimal evidence of cavities (Figure 36). Fracturing was evident in some units (particularly mineralised BIF), but this was often at depth and beneath the widespread tertiary clay layer. Compared to diamond drill core from other locations with known troglobitic communities (that is, Mesa A; Biota 2006), there was no strong evidence of habitat likely to be suitable for troglofauna within the proposed mining area (Figure 36)

Down-hole video camera investigation

A down-hole camera system was used to profile a selection of six drill holes across the proposed mining area by Biota (2008e). This method enabled a qualitative and direct assessment of the extent of subterranean fracturing and cavities, as well as providing an opportunity to detect both troglofauna and stygofauna (if present).

Down-hole camera sites were selected to provide a representative spatial spread across the Marandoo deposit, and to target the hydrated portion of the Marra Mamba ore body (the unit most likely to host cavities and fractures in the proposed mining area). Previous employment of this method at Mesa A in the Robe Valley has demonstrated that troglofauna are reliably observed if present (Biota 2008e). No troglofauna were observed in any of the drill holes profiled at Marandoo (Biota 2008e).

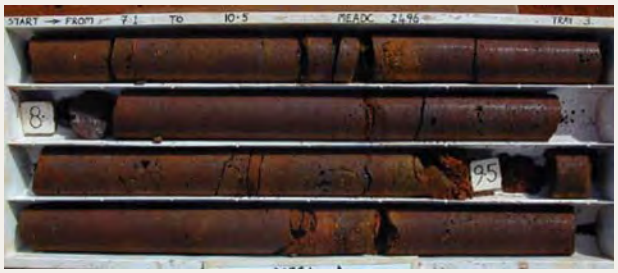
The physical nature of the stratigraphy, being dominated by clays or otherwise solid geology, did not appear suitable as troglofauna habitat, with few cavities or other openings present. This was consistent with information obtained from the drill logs and diamond drill cores (see above), and with previous geological assessments of the area. Known troglofauna habitat at Mesa A is considerably more fractured and vuggy by comparison (Biota 2008e; Figure 37).

Likelihood assessment

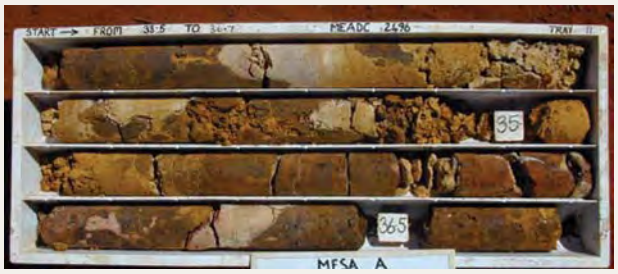
Biota (2008e) determined there is a Low likelihood (Table 15) of troglofauna occurring in the Proposal area, as:

- geological mapping does not indicate any units representing known troglofauna habitat in the proposed mining area
- drill logs and diamond cores did not show evidence of widespread cavities, vugs or thick karstic sequences in the top 100 m of the sequence
- down-hole video profiling did not show any fauna to be present (including at the base of drill holes, where experience at Mesa A indicates troglofauna naturally accrue through pitfall effects when present; Biota 2006)
- direct observation of subterranean habitat with down-hole video did not indicate any significant cavities or fractures, showing a relatively solid, clay dominated profile, unlike that of known troglofauna habitat elsewhere.

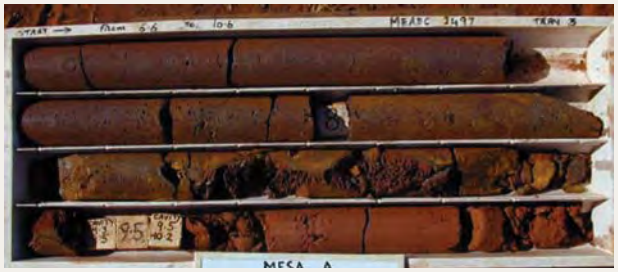
Drill Cores from Mesa A



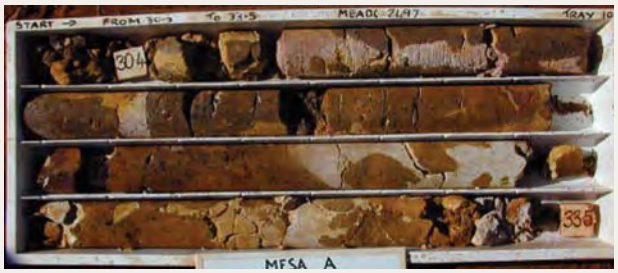
Representative Mesa A Pisolite (7 – 11m)



Representative Mesa A Pisolite (33 – 37m)



Representative Mesa A Pisolite (7– 11m)



Representative Mesa A Pisolite (30 – 33m)

RioTinto
Strategic Assets - Perth

Figure 36
Marandoo and Mesa A Drill Cores

Drawn: H Weiter
Date: May 2008
Plan No. PDE0049509v1
Proj: GDA94

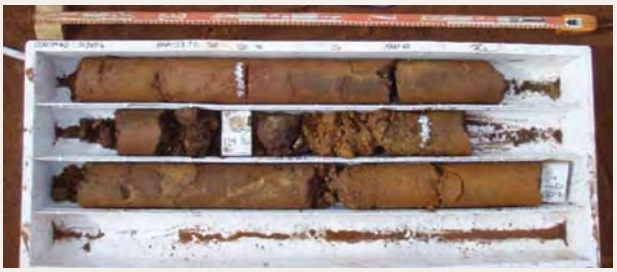
Drill Cores from Marandoo

Representative Marandoo quarternary detrital deposits (26 –29m)

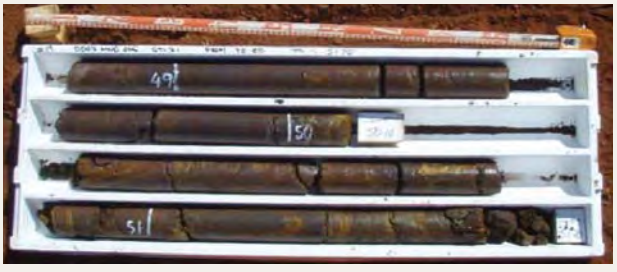
Representative Marandoo upper calcrete (39 – 42m)

Representative Marandoo tertiary clay (56 –59m)

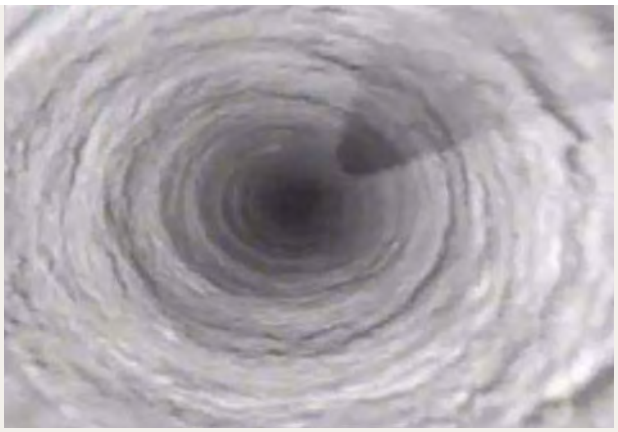
Representative Marandoo lower calcrete (86 –89m)



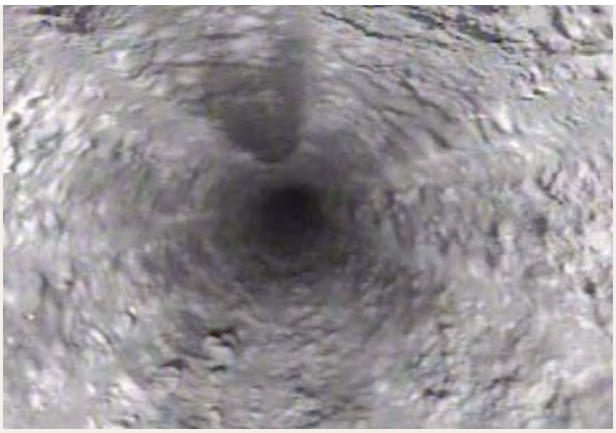
Representative Marandoo shale (128 – 131m)



Representative Marandoo mineralised BIF (48 –51m)

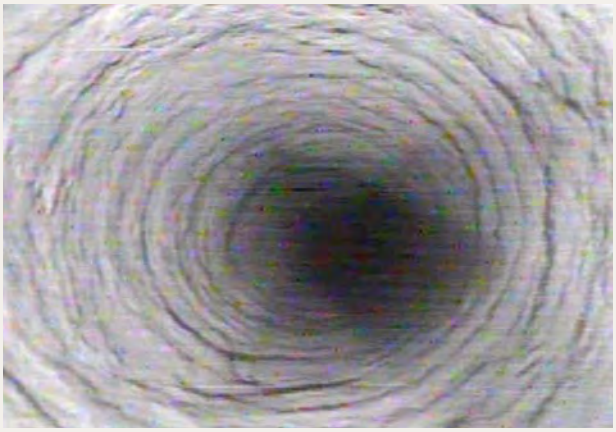


Still from down-hole video of drill hole RC07MN0430 at Marandoo.



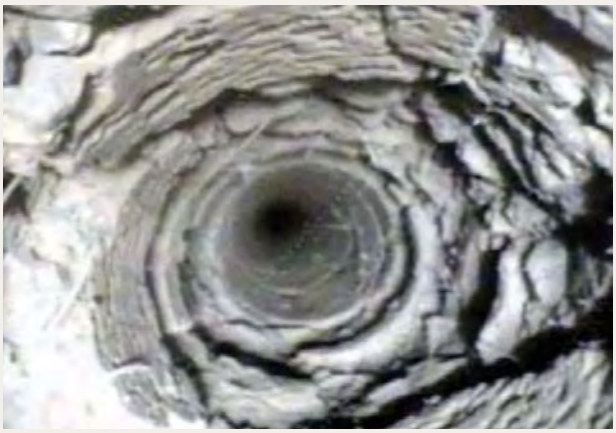
Still from down-hole video of drill hole RC07MN0551 at Marandoo.

Still from down-hole video of drill hole RC07MN0557 at Marandoo.



Still from down-hole video of drill hole RC07MN0659 at Marandoo.

Representative still from down-hole video of known troglofauna habitat at Mesa A (note extensive fracturing, cavities and vugs).



Representative still from down-hole video of known troglofauna habitat at Mesa A (note extensive fracturing, cavities and vugs).

Figure 37
Marandoo and Mesa A
down-hole video camera stills

Evaluation framework for potential impacts to troglofauna

Potential impacts to troglofauna (if present) identified by Biota (2008e) and listed in typical ascending order of likely impact to troglobitic ecosystems were:

- increased sediment loads and reduced habitat space in karstic or fracture strata above the watertable due to vegetation clearing
- reduction in organic inputs to subterranean ecosystems due to vegetation clearing
- changes to groundwater recharge or discharge areas due to sealing of surface areas, with increase in runoff and reduction in recharge
- shock and vibration effects on subterranean habitats from blasting activities
- pollution (for example, chemical pollutant spills, unlined landfills and direct discharge of waste or different water quality)
- direct excavation or mining resulting in removal and destruction of karstic strata.

Dewatering, groundwater abstraction and other aquifer impacts are of more direct relevance to stygal ecosystems rather than troglobitic systems and were, therefore, not considered by Biota (2008e) in the troglofauna risk assessment.

In evaluating the relevance of these factors to the Proposal, Biota (2008e) considered the magnitude, duration and spatial extent of the potential impacts (Table 16). The overall impact score was the sum of all potential impact scores and was assigned to either Low (overall impact score 0–5), Moderate (overall impact score 6–10) or High (overall impact score 11–15).

Table 16
Framework for potential impacts to troglofauna as a result of the Proposal

Impact mechanism	Magnitude*	Typical duration**	Spatial extent***	Potential impact score
Ground clearing/sedimentation	Small – Moderate	Moderate – Long	Localised – Wider	1–2
Vegetation clearing/nutrient removal	Small – Moderate	Moderate – Long	Localised – Wider	1–2
Changes to surface hydrology	Small – Moderate	Moderate – Long	Localised – Wider	1–2
Shock and vibration from blasting	Moderate	Short – Moderate	Localised – Wider	1–2
Pollution	Moderate	Moderate	Localised – Wider	1–2
Excavation/mining of habitat strata	High	Permanent	Localised – Wider	2–3

*** In the context of effects on troglobitic ecosystems**
**** Short - weeks to months, Moderate - less than one year, Long - greater than one year**
***** Immediate area - within 0.5 km radius of the central impact point, Localised - within 1 km radius of the central impact point, Wider - greater than 1 km radius from the central impact point**
Source: Biota (2008e)

Risk assessment

Based on available information, the risk assessment for troglobites considered:

- the types of impacts to local troglobitic ecosystems that may arise as a result of the Proposal
- the likelihood that troglofauna occur in subterranean habitats present in the Proposal area.

Potential impacts to troglofauna (if present) as a result of the Proposal were quantified by Biota (2008e) for the Proposal area according to the scale defined in Table 16. Without considering the likelihood of troglogauna occurring in the Proposal area, the overall potential impact score within the Proposal area was High (11) (Table 17) given the activities proposed.

However, as the likelihood of troglofauna occurring in the proposed mining area is low based on the outcomes of the detailed desktop assessment, it is considered unlikely that any species of stygofauna would be placed at risk as a result of the project, or that widespread affects on stygofauna habitats and populations in the locality will result from the planned dewatering. Given these outcomes, a dedicated troglofauna sampling program is not considered warranted for the Proposal (Biota 2008e).

5.7.2 Potential sources of impact

The following aspects of the Proposal have the potential to affect subterranean fauna values in, and around the Proposal area (including mining pits, stockpiles and infrastructure):

- groundwater drawdown from groundwater abstraction may lower the watertable sufficiently to dry the zone that stygofauna inhabit
- mining will result in direct habitat loss and potentially the loss of some individual subterranean fauna
- mining and infrastructure development may result in changes to surface hydrology
- spills of hydrocarbons may degrade the subterranean environment by contaminating surface water and groundwater
- vibration from blasting activities has the potential to cause changes to geological formations and may decrease the habitat available to troglofauna
- re-injection of dewatering water may affect subterranean fauna habitat through introduction of contaminants and/or altered water chemistry.

Table 17
Summary of troglofauna potential impact scores

Impact mechanism	Relevant	Proposal element / relevant management measures	Proposal area potential impact score
Ground clearing/sedimentation	Yes	Surface stabilisation; revegetation of temporarily cleared areas	2
Vegetation clearing/nutrient removal	Yes	Clearing controls during construction and operation; revegetation of temporarily cleared areas	2
Changes to surface hydrology	Yes	Drainage management to re-establish larger-scale surface drainage patterns	2
Shock and vibration from blasting	Yes	Equipment maintenance; storage and handling controls	2
Pollution	No	Workshops and primary fuel storage will remain at the existing Marandoo mine facilities	–
Excavation/mining of habitat strata	Yes	Excavation of the mine pit	3
		TOTAL	11

Source: Biota (2008e)

5.7.3 Key statutory requirements, environmental policy and guidance

EPA objective

In most circumstances, including this assessment, the EPA applies the following objective in its assessment of Proposals that may affect subterranean fauna:

To maintain the abundance, diversity, geographic distribution and productivity of fauna species and ecosystems levels through the avoidance or management of adverse impacts and improvements in knowledge.

EPA Guidance Statement No. 54 and Draft Guidance Statement No. 54a

EPA Guidance Statement No. 54 (EPA 2003) provides guidance on the information the EPA will consider when assessing Proposals where subterranean fauna is a relevant factor.

The draft EPA Guidance Statement No. 54a (EPA 2007c) has been developed as a technical appendix to EPA Guidance Statement No. 54 and provides guidance on sampling for subterranean fauna, including sampling effort, sampling design and ongoing monitoring.

State protection

In a legislative context, the preservation and conservation of fauna is covered primarily by the following Western Australian legislation:

- *Wildlife Conservation Act 1950* (WA)
- *Conservation and Land Management Act 1984* (WA).

In Western Australia, rare or endangered species are protected by the Wildlife Conservation (Specifically Protected Fauna) Notice 2003, under the *Wildlife Conservation Act 1950* (WA). Schedules 1 and 4 in this notice are relevant to this assessment, providing a listing of those species protected by this Notice.

The DEC (Nature Conservation Division) Priority Fauna List also nominates conservation species from Priority one to five. It is expected that the potential impacts from a Proposal on these Priority listed species should be managed such that the species do not meet the International Union for Conservation of Nature and Natural Resources criteria for threatened species.

5.7.4 Assessment of potential impact

Groundwater drawdown

The potential for subterranean fauna (especially stygofauna) to be affected by groundwater drawdown as a result of the Proposal is expected to be minimal as subterranean fauna do not occur in the confined aquifer and drawdown in the unconfined aquifer is predicted to be minimal across the majority of the Mount Bruce Flats (Section 5.2). While some localised reduction in groundwater levels in the unconfined aquifer is expected as a result of seepage into the pit ranging from 10–20 m at the northern pit margin to approximately 0–2.5 m at the Coolibah woodland on Mount Bruce Flats, the latter is well within, or similar to the range of natural seasonal fluctuations (Figure 26).

Stygofauna have been recorded only in areas predicted to experience 4 m or less drawdown as a result of the Proposal (Figure 26; Table 18). None of the species sampled are considered to be restricted to the drawdown area. Therefore, it is unlikely that any species of stygofauna would be placed at risk as a result of the implementation of the Proposal, or that widespread effects on stygofauna habitats and populations in the locality will result from the proposed dewatering.

Habitat removal

The risk to stygofauna populations as a result of habitat removal is minimal as it appears that no stygofauna taxa are restricted specifically to the proposed mining area or the dewatering impact area (Biota 2008e). Sampling conducted to date suggests a diverse stygofauna community extends beyond the Proposal area into the Mount Bruce Flats.

There is a low risk to troglofauna as a result of habitat removal as it is unlikely that troglofauna occur in the proposed mining area (Biota 2008e).

Table 18
Summary of stygal taxa collected from the study area

Taxon	No. individuals recorded	Site	Drawdown	Comments
Paramelitidae sp.	4	OW10S	3 m	Equivalent to specimens collected from the wider Marandoo locality during the DEC Pilbara Biological Survey; not restricted to the drawdown impact area
		OW12S	2–3 m	
		OW28S	2–3 m	
Paramelitidae sp.	6	OW15S	<1 m	DNA analysis indicates that the same species occurs at these sites, but that amphipods from the Marandoo locality are distinct from those elsewhere in the Pilbara; represented inside and outside the drawdown impact area
		OW28S	2–3 m	
Amphipoda indet.	37	OW10S	3 m	Can not be determined in any further detail due to the condition of the specimens; unlikely to be restricted to the drawdown impact area (based on the amphipod specimens that could be identified)
		OW11I	4 m	
		OW12S	2–3 m	
		OW15S	<1 m	
		OW28S	2–3 m	
		OW30S	2–3 m	
Notobathynella sp.	13	OW10S	3 m	Can not be determined in any further detail; represented inside and outside the drawdown impact area
		OW11M	4 m	
		OW15S	<1 m	
Tubificidae sp.	3	OW12S	2–3 m	Can not be determined in any further detail; unlikely to be restricted to the drawdown impact area
		OW15S	<1 m	
Diacyclops humphreysi humphreysi	2	OW12S	2–3 m	Described from elsewhere and collected from the wider Marandoo locality during the DEC Pilbara Biological Survey; not restricted to the drawdown impact area
Microcyclops varicans	1	OW12S	2–3 m	Described from elsewhere and collected from the wider Marandoo locality during the DEC Pilbara Biological Survey; not restricted to the drawdown impact area
Platyhelminthes sp.	2	OW3	<2 m	Can not be determined in any further detail; unlikely to be restricted to the drawdown impact area

Source: Biota (2008e)

Surface and groundwater contamination

There is a low risk of degradation of the subterranean environment from surface water contamination as a result of the Proposal. The level of risk is relatively similar to the existing Marandoo operation and will continue to be managed through established project and infrastructure design and operational procedures.

The potential exists for the subterranean environment to be degraded by spills of hydrocarbons. Diesel and other hydrocarbons will be routinely used during mining, presenting both operational (for example, refuelling) and storage risks.

As the chemistry of groundwater within the confined aquifer at Marandoo is similar to that naturally occurring at the Southern Fortescue borefield (Table 8), there is negligible risk of altering the water chemistry in the Southern Fortescue aquifer system as a result of the proposed re-injection of dewatering water. Therefore, although existing data suggest the Southern Fortescue borefield area does not support a stygofauna community, any stygofauna that may potentially occur at the Southern Fortescue borefield would not be affected by the proposed re-injection.

Vibration
The potential impact to subterranean fauna habitat as a result of vibrations caused by blasting is expected to be minimal. Vibration from mining activities has the potential to collapse cavity features within geological formations (Biota 2008e). This impact is difficult to quantify; however, the qualities of the material to be mined for the Proposal means that blasting frequency and levels should be lower than the existing Marandoo operation.

5.7.5 Proposed mitigation and management measures

Subterranean fauna within, and adjacent to the Proposal area will be protected through the implementation of the following management measures:

- implementing a groundwater level monitoring program across the Mount Bruce Flats (Section 5.2)
- implementing controls to reduce the occurrence and effect of hydrocarbon spills.

5.7.6 Predicted outcome

After mitigation and management measures have been applied, the Proposal is expected to result in the following outcomes in relation to subterranean fauna:

- The Proposal is unlikely to have a significant effect on stygofauna, as the estimated drawdown in the unconfined aquifer, which supports stygofauna, is within, or similar to the range of natural fluctuations. Furthermore, all species recorded in the Proposal impact zone are also represented outside this zone.
- Troglofauna should not be directly disturbed by the Proposal as there is an absence of suitable habitat in the proposed mining area.
- Existing data suggest the Southern Fortescue borefield area does not support a stygofauna community. Re-injection of dewatering water would not affect any stygofauna that may potentially occur in this area, as there is little difference in water chemistry between the dewatering water from Marandoo and the groundwater in the Southern Fortescue aquifer system.

The subterranean fauna studies indicate that disturbance to subterranean fauna and their associated habitat will be minimal. Implementation of the proposed management measures will further protect subterranean fauna and their habitat and will ensure the EPA objective is fulfilled.

5.8 Aboriginal heritage

5.8.1 Description of factor

The Proponent and the Eastern Guruma people have a comprehensive relationship which is documented in a commercial agreement and Indigenous Land Use Agreement (ILUA). The state of Western Australia is also a party to the ILUA. The agreement between the parties is one of the most comprehensive of its kind in Australia. It covers the determined area of the Eastern Guruma Native Title claim including the Tom Price mine site, the Brockman No 2 mine site, the Marandoo mine site and part of the railway between Tom Price and Dampier.

Numerous archaeological and ethnographic surveys have been carried out in and around the Marandoo mine lease, including recent surveys undertaken for the Proposal by Scarp Archaeology (2008) in consultation with the Eastern Guruma people. The Scarp Archaeology (2008) surveys were undertaken in the area of the proposed mine pit and waste dumps. This survey represents stage one of a three stage survey program to be undertaken for the Proposal. Stage two of the program involved surveys in the area of the operations camp and along the dewatering infrastructure corrridor. Stage three will include survey work along the Southern Fortescue River system, as well as additional detailed work in areas surveyed during stages one and two. A search of the Department of Indigenous Affairs (DIA) Aboriginal Heritage Inquiry System (accessed 19 May 2008) identified approximately 60 registered sites listed in proximity to the Proposal area.

Results of surveys undertaken to date indicate that 14 previously unrecorded sites have been located in the vicinity of Marandoo. Aboriginal heritage sites within the Marandoo mine lease area consist of rock shelters, stone artefact scatters, scarred trees, grinding patches, mythological and ceremonial sites, and a quarry. One rock shelter has been recorded along the escarpment to the south of the Proposal area. The open ground artefact scatters occur close to the ephemeral stream to the south of the Marandoo mine, and the main Marandoo Creek and associated floodplains (Scarp Archaeology 2008).

Minthicoondunna Spring and Banjima Pool, both with cultural significance, are located in proximity to Marandoo (Figure 23). Minthicoondunna Spring (Minthikutunha (Minthayi/Minthi for short)) located 10 km east of the Proposal, is a registered Aboriginal site and is protected by law. The Spring, according to Eastern Guruma sources, lies on the boundary between the Eastern Guruma or Muntalgura Guruma and the neighbouring Panyjima language group (Brehaut and Vitenbergs 2001). The area is an important ethnographic site for Eastern Guruma people, as well as other Aboriginal people in the Pilbara (Bunjima, Innawonga). The natural environment of Minthicoondunna Spring is equally important to Aboriginal people being interchangeable with the cultural significance of the area (McDonald & Coldrick 2008). In addition to being an important permanent water source, Minthicoondunna Spring has mythological associations with the Water Snake [thuru or karukaru] and consequently is considered to be 'living water'. There are also, as would be expected for a permanent water source, a number of archaeological sites on the Register associated with the Spring. Banjima Pool is located outside the south-eastern boundary of the mining lease and is also a culturally significant site.

5.8.2 Potential sources of impact

Activities or aspects of the Proposal that may potentially affect cultural heritage values include:

- clearing for the construction and operation of the mine and associated infrastructure
- ore body dewatering near the mine pit will lead to drawdown of groundwater levels in the confined aquifer and may result in the formation of sinkholes throughout the cone of depressurisation which may in turn affect sites of cultural significance
- re-injection of dewatering water at the Southern Fortescue borefield will lead to an increase in groundwater levels which may affect sites of cultural significance
- dewatering will result in groundwater drawdown with potential impact to springs within Karijini National Park.

5.8.3 Key statutory requirements, environmental policy and guidance

EPA objectives

In most circumstances, including this assessment, the EPA applies the following objective to the assessment of Proposals that may affect Aboriginal heritage:

To ensure that changes to the biophysical environment do not adversely affect historical and cultural associations and comply with relevant heritage legislation.

Aboriginal Heritage Act 1972 (WA)

The Minister for Indigenous Affairs is responsible for the administration of the *Aboriginal Heritage Act 1972* (WA). The Minister's responsibility is to ensure that all places that are of traditional or current sacred, ritual or ceremonial significance to Aboriginal people should be recorded and their importance evaluated on behalf of the community. Normally, consent from the Minister is required under Section 18 of the *Aboriginal Heritage Act 1972* (WA) for disturbing Aboriginal sites; however, the Marandoo mine lease is exempt from the conditions of the *Aboriginal Heritage Act 1972* (WA) under the *Aboriginal Heritage (Marandoo) Act 1992* (WA). Despite this, the Proponent still fulfils all requirements of the *Aboriginal Heritage Act 1972* (WA).

EPA Guidance Statement No. 41

EPA Guidance Statement No. 41 (EPA 2004b) provides guidance on the process for the assessment of Aboriginal heritage as an environmental factor.

In its assessment of Proposals, the EPA will expect Proponents to:

- report on the likelihood of the presence of matters of heritage significance to Aboriginal people
- determine whether the proposed changes to the biophysical environment will result in an impact to these matters of heritage significance to Aboriginal people.

The EPA will, based on this information, make a determination whether Aboriginal heritage is a relevant environmental factor to the Proposal. Where Aboriginal heritage is determined to be a relevant factor, the EPA will expect the Proponent to properly consider how to minimise any impact to heritage values resulting from the Proposal.

EPA Guidance Statement No. 41 (EPA 2004b) details actions that may be pertinent to the factor of Aboriginal heritage, including:

- consulting with DIA staff and undertaking desktop review of sites
- undertaking an Aboriginal heritage and/or archaeological survey in consultation with relevant Aboriginal representatives
- informing relevant Aboriginal people of the Proposal and conduct appropriate consultation
- demonstrating that any concerns raised by the Aboriginal people have been considered in the environmental management of the factor and that this is made known to the relevant Aboriginal people.

5.8.4 Assessment of potential impact

Clearing/site works

Ground disturbance within the Proposal area will affect some recorded archaeological sites and subsequently affect any associated ethnographic values. As some sites are located on the periphery of disturbance areas in the gullies of Marandoo Ridge, the extent and nature of the impact, particularly in terms of access, will not be determined until final planning for mine development is complete.

Most of the archaeological sites that can not be avoided are expected to consist of items of low archaeological and ethnographic significance (for example, artefact scatters). Where possible, infrastructure will be designed to avoid significant heritage sites. Where the impact to sites is unavoidable, the Proponent will consult with the DIA prior to any ground-disturbing activities.

Dewatering

Banjima Pool is located in a Wilderness Zone within Karijini National Park and is formed downstream of a resistant band of cemented Tertiary laterite that has been ground out by large boulders during high rainfall events. As Banjima Pool occurs at approximately 705 mRL (approximately 25 m above the regional groundwater table), it is unlikely to be fed by groundwater and therefore will not be affected by groundwater drawdown resulting from the Proposal (Dodson 2008). Water chemistry data collected in July 2008 by Dodson (2008) support this, with low electrical conductivity and relatively low temperatures in Banjima Pool both indicative of an origin other than groundwater.

Minthicoondunna Spring is located in a Natural Environment Zone within Karijini National Park (Figure 23) and is believed to be supported by groundwater discharge from a near surface calcrete aquifer that has been eroded along the bank of a tributary of Turee Creek. Water chemistry data collected in July 2008 by Dodson (2008) support this, with high electrical conductivity and relatively high temperatures indicative of a groundwater origin. The western limit of the calcrete aquifer thought to support the spring is roughly 3 km from the eastern end of the proposed mine pit at Marandoo. Although dewatering will not target the calcrete aquifer, there is a possibility of a hydraulic connection between the surficial calcrete aquifer and the deeper confined aquifer that will be be dewatered. Towards the end of the mine life, this could potentially result in a reversal in the direction of groundwater flow, such that groundwater that would normally flow to the south-east and discharge at Minthicoondunna Spring would instead be directed back into the open mine pit.

The extent to which groundwater flow to Minthicoondunna Spring may be redirected to the proposed mine pit will largely be dependent on the hydraulic properties of the upper Tertiary sediments and the degree of hydraulic connection with the lower confined aquifer. The absence of the clay layer in the vicinity of Minthicoondunna Spring (which is known to occur between the confined and unconfined aquifer across the Mount Bruce Flats) would increase the risk of impacts occurring at the spring (Dodson 2008). Any impact to Minthicoondunna Spring from the Proposal would occur only towards the end of the mine life, when the cone of groundwater drawdown is predicted to extend in a south-easterly direction. Further detail is provided in Section 5.1.4 and 5.2.

Surveys to determine whether sites of heritage significance occur in the Southern Fortescue borefield area (which may be potentially affected by sinkhole formation) will be undertaken in Quarter 4, 2008.

Minthicoondunna Spring is a listed on the Permanent Register of Aboriginal Sites (Site ID 8296/P04348). The cultural heritage values of Minthicoondunna Spring are protected under the provisions of the *Aboriginal Heritage Act 1972* (WA). Consent in accordance to the requirements of the Act would be required to be gained prior to any impact on the cultural heritage values of the spring.

5.8.5 Proposed mitigation and management measures

Aboriginal heritage aspects at Marandoo will be addressed by the following proposed management measures:

- avoiding disturbance to heritage sites where possible
- undertaking additional survey work and ethnographic studies within the Proposal area to identify heritage and ethnographic sites
- preventing unauthorised ground disturbance activities through implementation of the Proponent's Approvals Permit system for all areas to be disturbed
- including education regarding Aboriginal sites in inductions for contractors and personnel working on the development
- stopping work and contacting the DIA where human remains or archaeological material is uncovered during the clearing process; then assessing the site using a heritage consultant and managing the site in accordance with the Proponent's Cultural Heritage Management Plan (Appendix 2)
- marking the location of known Aboriginal heritage sites on site plans
- ensuring a fire spotter is present when clearing vegetation near sensitive heritage areas
- undertaking further hydrogeological investigations between Marandoo and Minthicoondunna Spring to determine the hydraulic parameters of the upper Tertiary sediments, and any hydraulic connection between the surficial calcrete aquifer and the confined aquifer
- monitoring the water level at Minthicoondunna Spring, and groundwater levels between Marandoo and Minthicoondunna Spring
- continuing consultation with the Eastern Guruma people and other relevant stakeholders.

5.8.6 Predicted outcome

The Proposal is unlikely to directly affect any Aboriginal heritage sites of high significance, but may affect sites of low significance. Most of the highly significant Aboriginal heritage sites occur on the upper slopes of the surrounding escarpments, which are outside the Proposal area. The Proposal is likely to avoid all highly significant sites in the valley and floodplain areas.

The Proposal will not affect Banjima Pool, as it is not groundwater-fed. There is the possibility of affecting water levels at Minthicoondunna Spring near the end of the mine life as the groundwater cone of depression extends in a south-easterly direction. However, further hydrogeological investigations are planned to determine the level of risk, if any.

5.9 Visual amenity and landscape character

5.9.1 Description of factor

Visual amenity relates to the visual quality of a site or area as experienced by visitors, and incorporates the collective impact of visual components that contribute to the visual pleasantness and character of localities. Landscape values include a wide range of human-related values that stem from relationships between people and places.

A landscape and visual assessment of the Proposal was undertaken by Sinclair Knight Merz (SKM) in 2008. A summary of the SKM (2008) report is provided below and a full copy is contained in Appendix 1. The SKM (2008) assessment focused on the operational aspects of the MMP2 Proposal and, therefore, included an assessment of the visual impacts of the operations camp and dewatering infrastructure. The visual impact assessment of the operations camp was based on the full extent of the camp and included both the construction camp (which is not part of the MMP2 Proposal) and the operations camp. The visual impact assessment of the dewatering infrastructure was based on an above ground dewatering pipeline between Marandoo and the Southern Fortescue borefield; however, the dewatering pipeline may be installed below ground, which would result in a significantly reduced visual impact.

The SKM (2008) assessment was undertaken in accordance with the methodology and guidelines of:

- Guidelines for Landscape and Visual Impact Assessment (Landscape Institute and the Institute of Environmental Management and Assessment 2002)
- Visual Landscape Planning in Western Australia - a manual for evaluation, assessment, siting and design (DPI 2007).

These guidelines identify the key visual values of a site as relating to landscape character, community use, or community perceptions and landscape values.

Landscape character

Landscape character is classified and described in terms of broad patterns of environmental characteristics according to their relevance to human interaction. Typically, this classification focuses on natural and land use character.

Marandoo is located on an area of flats surrounded by several escarpments, including Mount Bruce, Marandoo Hills, Marra Mamba Ridges, the Prider Hills and Eastern Uplands (Figure 38). These surrounding gorges, cliffs and mountain ranges are mostly located within the boundary of Karijini National Park and are largely natural and undisturbed.

SKM (2008) identified and described seven landscape types based on the characteristics within and surrounding the Proposal area (Figure 38):

- Disturbed ground: includes the existing mine pit, haul roads, stockpiles and benches at Marandoo (largely cleared)
- Escarpments: includes extensively elevated areas dominated by vegetation, exposed rock and naturally eroded ridgelines (for example, Mount Bruce, north of the Proposal area and the Prider Hills and Eastern Uplands, east of the Proposal area)
- Flat/drainage basins: includes areas near the rail line that are topographically flat and dominated by low shrubs, grassland and large areas of bare sheet-washed ground (for example, the Mount Bruce Flats north of Marandoo)
- Flats (disturbed grounds): includes the cleared flat area east of the existing Marandoo mine pit, associated with the tail pit extension disturbance area (Ministerial Statement No. 286, as amended 15 April 2008)
- Low foothills: provide a distinct transition area between the flats and the escarpments; dominated by low vegetation and very spare trees (except where watercourses are present)
- Major flow lines/creeks: includes flow lines that discharge from the surrounding ridgelines and spurs, consisting of woodland vegetation greater than 2 m in height
- Ridges, erosional spurs and plateaus: includes elevated areas dominated by vegetation, exposed rock and prominent eroded ridgelines (for example, the Marra Mamba formation south of the Proposal area).

Community use

An assessment of community use provides an indication of how people use an area and the likely importance of landscape values to their use. The main users affected by the visual amenity of the existing Proposal are people visiting Mount Bruce within Karijini National Park and people using Karijini Road (a sealed road) to access Karijini National Park, Tom Price, Paraburdoo, or mines to the west of Marandoo. Over 100 000 people visit Karijini National Park each year. Mount Bruce is frequently visited as it provides lookout points from the car park and along the walking tracks to the summit.

Viewpoints can be assessed in the following order of sensitivity (adapted from LI and IEMA 2002):

- high sensitivity: private dwellings and gardens where viewers are familiar with the overall scene and are likely to experience the views frequently
- medium to high sensitivity: footpaths and rights of way, picnic areas, lookout points, recreational or National Parks and other informal recreational facilities where viewers obtain a sustained view due to a slower speed of passage and where the quality of view is part of the purpose of the visit
- medium to low sensitivity: commercial premises, public facilities and schools where the viewer may be familiar with the scene but holds it in lower regard than viewers from residential properties and the surroundings are secondary to the purpose of the visit
- low sensitivity: surrounding road and rail networks where the viewer gains brief, transient glimpses of the view at speed.

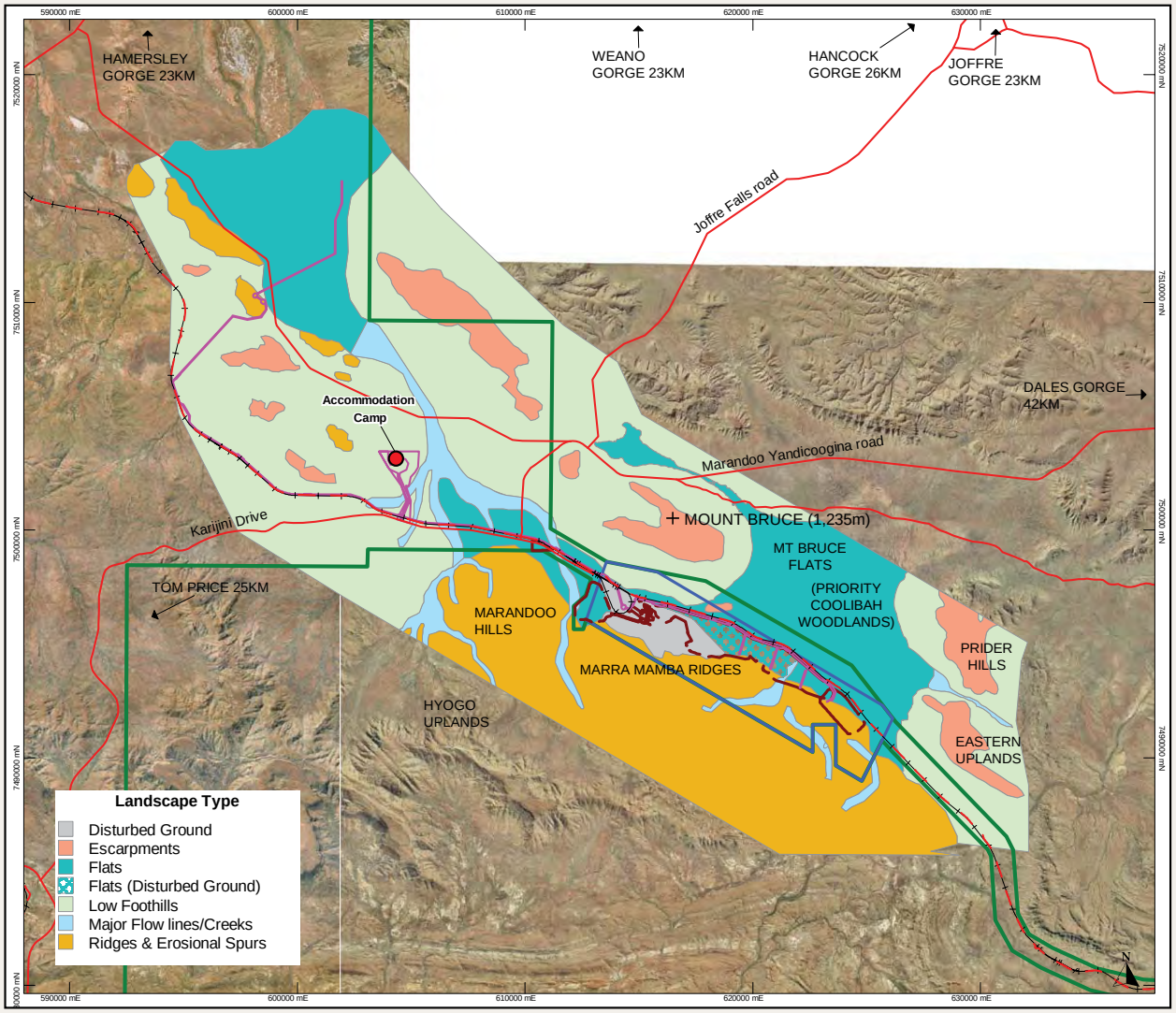


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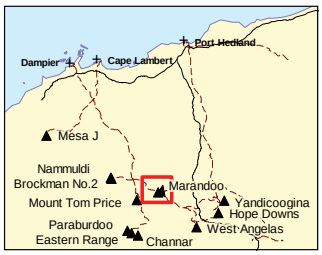
Figure 38 Marandoo Broad Landscape Character Areas

Drawn: B Jackson Plan No. PDE0049509v1
Date: June 2008 Proj: MGA94-50

LOCATION MAP



SCALE

5 0 5km

1:250,000 @ A4

LEGEND

- Mountain Summit
- Railway
- Road
- Private Road
- Current Marandoo Mine Lease
- MMP2 Project Disturbance
- Proposed MMP2 disturbance footprint
- Karijini National Park

Community perceptions and landscape values

Many of Western Australia's most highly valued natural landscapes are protected in conservation estates such as Karijini National Park (DPI 2007). Areas of high scenic amenity are those highly regarded by the community and have good views compared with other parts of the region.

The area within and surrounding the Proposal area can be considered a 'valued' landscape as it contains a number of landscapes and features that are highly valued by the community (EPA 2008a). People generally prefer areas of high scenic amenity including (DPI 2007):

- natural landscapes
- expansive landforms
- major rock outcroppings
- dramatic topography (relief, ruggedness, rocky outcrops)
- ephemeral water features (flooding, creeks) and associated riparian vegetation
- panoramic views
- areas of diverse patterns of vegetation
- recreation use associated with Karijini National Park (including access roads, four-wheel drive tracks, and panoramic views from the Mount Bruce walk track and summit lookout).

Some areas within and surrounding the Proposal area also contain landscapes that are not potentially valued by the community, such as the features of the existing Marandoo mine, railway and infrastructure corridor.

Visual impact assessment methodology

The landscape and visual impact assessment undertaken by SKM (2008) included assessment of the existing visual amenity of the Marandoo mine site and surrounding areas, taking into account current land use patterns and assessing the likely visual impacts of the Proposal. SKM (2008) identified a number of sensitive view points and utilised computer graphics to simulate images using photographs of existing views overlayed with the predicted future landscape.

The SKM (2008) assessment focused on publicly accessible areas near the Proposal area, including main access roads, Mount Bruce and four-wheel drive tracks within Karijini National Park. The assessment compared the visual impact of the existing Proposal with the predicted visual impact of this modified Proposal (based on the expected 'worst-case' visual landform; predicted to occur in 2026, when the mine will be at its most prominent extent).

The SKM (2008) assessment did not consider visual amenity at:

- any residential properties - the closest residence (at Tom Price, 37 km away) provides no views of the existing or proposed mine
- any business and industrial premises - the closest business or industrial premise (at Tom Price, 37 km away) has no views of the existing or proposed mine
- Karijini National Park gorges - the gorges are 30–60 km from the Proposal area and intervening topography obstructs any views of the existing or proposed mine
- areas not publicly accessible - including the Marandoo mine site and mine access road (Marandoo Road).

The existing mine site is already visible from Mount Bruce within the adjacent Karijini National Park, including at the lowest public viewpoint, the summit and along the walking track to the summit. The existing mine site is also intermittently visible to people driving along Karijini Road. The Proposal will therefore result in additional modification of an already highly modified landscape. The operations camp and dewatering infrastructure will be additional features affecting visual amenity from viewing locations at Mount Bruce.

Eight potential visual receptors (Receptors I–VIII; Figure 39) were identified by SKM (2008) as suitable for the visual assessment for one or more of the following reasons:

- the location is:
  a) situated in an area likely to be visually affected due to its proximity to the Proposal area
  b) a frequently visited site with recreational value in Karijini National Park
  c) a road utilised by tourists and visitors
- the Proposal area is highly visible from the location, based on:
  a) a review of topography in the area
  b) a field verification exercise.

In addition, SKM (2008) assessed the potential impact of the Proposal to the landscape character types identified in, and around the Proposal area (Figure 38).

The existing 33 kV above-ground powerline between Marandoo and Tom Price will be replaced as part of the MMP2 Proposal (except for the section between Marandoo and the proposed switchyard), which will improve visual amenity in the locality. Removal of this powerline was not considered in the SKM (2008) assessment.

Significance of visual impact

The significance of the visual impact of the Proposal at each visual receptor and to each landscape type was rated by SKM (2008) on a scale from 'Major Beneficial' to 'Severe Adverse' (Table 19).

The significance of the visual effect of the proposals is assessed on a scale of severe adverse to neutral according the *Guidance on the New Approach to Appraisal* (Department for Transport 1998). The significance rating applies to the overall impact of the proposed development for each receptor, rather than an evaluation of the potential visual impacts of an individual component of a project. For this reason the anticipated visual impact significance of the operations camp (although located 13 km north west of the mine area) has been grouped in with an assessment of the other components of the mine expansion from each receptor, not reported separately.

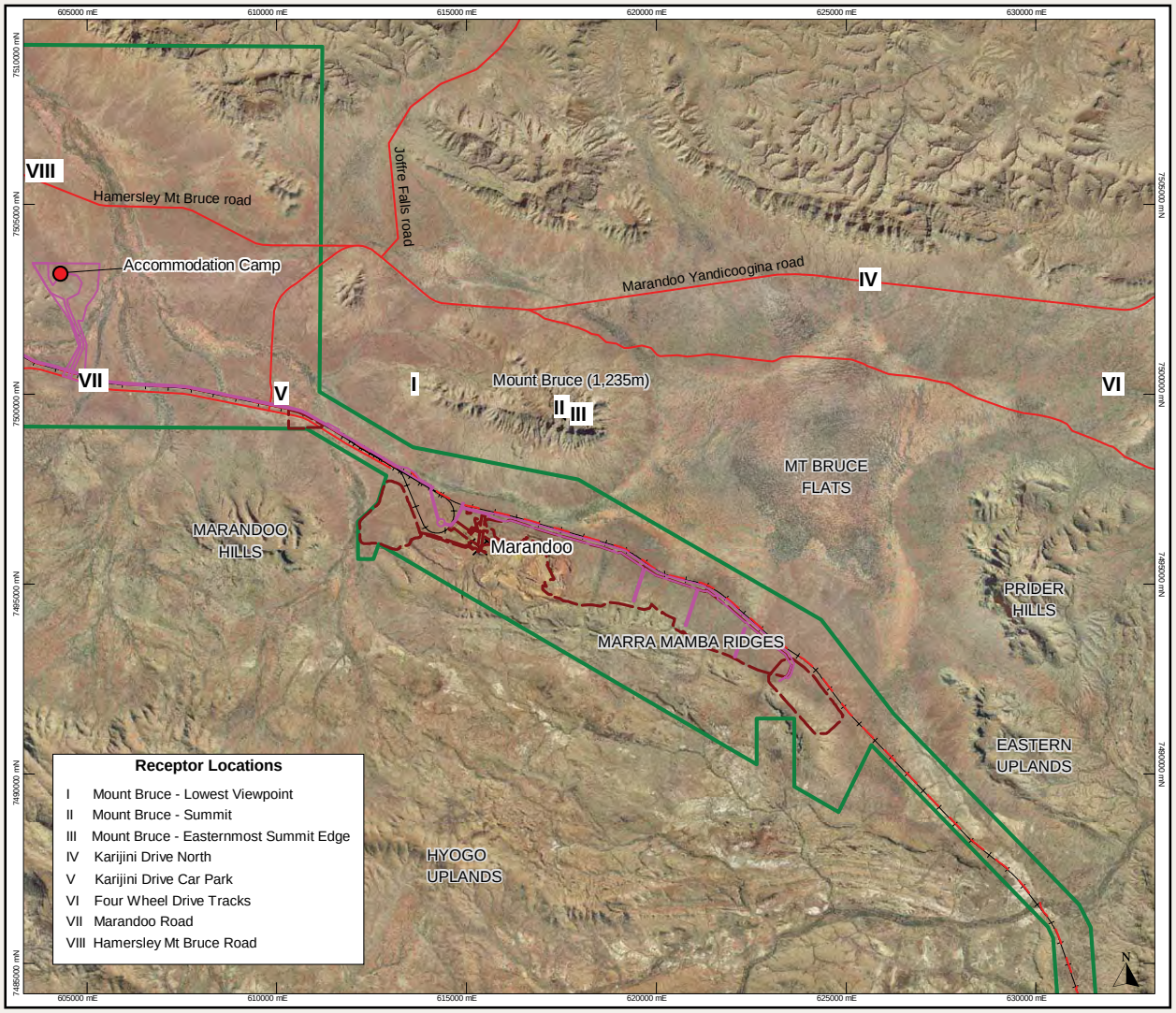


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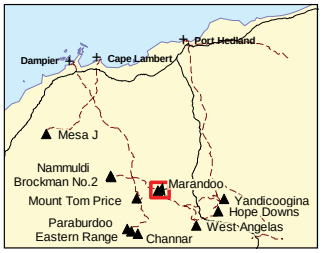
Figure 39
Marandoo Sensitive Receptor Locations

Drawn: B Jackson
Date: June 2008
Plan No. PDE0049509v1
Proj: MGA94-50

LOCATION MAP



SCALE

3 0 3km

1:150,000 @ A4

LEGEND

- Operating Mine
- Accommodation Camp
- Railway
- Road
- Private Road
- Proposed MMP2 Disturbance Footprint
- MMP2 Project Disturbance
- Karijini National Park

Table 19
Scale for describing the significance of the visual impact of the Proposal

Significance of impact	Description
Severe Adverse	The Proposal would result in impacts that are at a complete variance with the landform, scale and pattern of the landscape; would permanently degrade, diminish or destroy the integrity of valued characteristic features, elements and/or their setting; and/or would cause a very high quality landscape to be permanently changed and its quality diminished
Major Adverse	The Proposal would result in effects that cannot be fully mitigated and may cumulatively amount to a severe adverse effect; are at a considerable variance to the landscape and degrade the integrity of the landscape; and/or will be substantially damaging to a high quality landscape
Moderate Adverse	The Proposal would be out of scale with the landscape or at odds with the local pattern and landform; and/or will leave an adverse impact on a landscape of recognised quality
Minor Adverse	The Proposal would not quite fit into the landform and scale of the landscape; and/or affect an area of recognised landscape character
Neutral	The Proposal would complement the scale, landform and pattern of the landscape; and/or maintain existing landscape quality
Minor Beneficial	The Proposal has the potential to improve the landscape quality and character with enhancement or improvement of landscape elements or characteristics considered to be medium-low value. Introduction of elements considered to be unobtrusive and a noticeable feature of the view
Moderate Beneficial	The Proposal would have the potential to fit with the landscape character; and/or improve the quality of the landscape through the restoration of valued characteristic features partially lost through other land uses
Major Beneficial	The Proposal would have the potential to fit very well with the landscape character; and/or improve the quality of the landscape through removal of damage caused by existing land uses

Source: SKM (2008)

5.9.2 Potential sources of impact

Activities or aspects of the Proposal that may potentially affect landscape values and visual amenity include:

- landform modification may reduce the aesthetic value and visual quality of the area (for example, removal of native vegetation, excavation of mine pits, creation of waste dumps and loss of rural character)
- dust emissions may detract from the visual quality of the area
- physical presence of mine pits and infrastructure may detract from the visual quality of the area.

5.9.3 Key statutory requirements, environmental policy and guidance

EPA objectives

In most circumstances, including this assessment, the EPA applies the following objective in its assessment of Proposals that may affect visual amenity, landscape and landforms:

To ensure that aesthetic values are considered and measures are adopted to reduce visual impacts on the landscape as low as reasonably practicable.

To maintain the integrity, ecological functions and environmental values of landscapes and landforms.

Conditions of existing Statement

Environmental conditions for the existing Proposal (Marandoo Iron Ore Mine and Central Pilbara Railway ERMP; O'Brien 1992) are contained within Statement No. 286.

Condition No. 11 prescribes requirements for rehabilitation, including:

- ensuring rehabilitation across the mine site is consistent with local landscape values
- enabling the area to be reinstated to Karijini National Park (if appropriate)
- developing and implementing a rehabilitation plan to the satisfaction of the DEC and DoIR
- utilising local endemic plant species for rehabilitation.

Condition No. 12 requires the visual impact of the development to be minimised and mitigated where possible, in consultation with the DEC. Consideration of the surrounding landscape is required for choosing the location, design and colour of mine facilities.

EPA Guidance Statement No. 33

EPA Guidance Statement No. 33 (EPA 2008a) provides guidance on land use planning and development processes to achieve environmentally sound outcomes. Part B of the Guidance Statement ('*Biophysical factors*') provides advice in relation to 'landscape and landforms' and Part D ('*Social surrounds*') provides advice in relation to 'visual amenity'. The Guidance Statement provides checklists for considering both of these factors during local area planning. Checklist criteria relevant to the Proposal are as follows:

Landscape and landforms

- consider any guidance and principles that have been developed for the broader area
- carry out studies to describe and evaluate the existing landscape, landforms and visual resource
- describe the potential impacts that a proposed development may have with respect to landscape and landforms and their associated values
- consult with stakeholders and demonstrate how this has been incorporated into the project
- employ sound design measures and propose management measures that mitigate as far as possible the potential adverse impacts of the development on the landscape
- consider whether the location, design and management measures proposed are consistent with relevant objectives and pursue improvements where possible
- ensure implementation of approved design and management measures.

Visual amenity

- retain natural landforms and vegetation in visually prominent places, as well as other parts of a site, in order to maintain local landscape character
- avoid locating development where it would be visually obtrusive
- adopt appropriate building design
- rehabilitate disturbed natural areas
- carry out landscaping works to meet completion criteria.

Visual Landscape Planning in Western Australia

The Visual Landscape Planning in Western Australia guidance document (DPI 2007) provides guidance on land use planning, visual impact assessment and management.

The broad management objectives for visual amenity are to protect and maintain visual landscape character, restore and enhance degraded visual landscape character and undertake best practice for siting and design.

Karijini National Park Management Plan

The Karijini National Park Management Plan (1999–2009) (CALM 1999) provides strategic direction for the management of the National Park. The Plan recognises that exploration mining activities and their associated infrastructure (including the Marandoo lease and possible future mine sites and corridors) have the potential to significantly alter the character and appearance of the landscape, particularly in natural areas where there has previously been only minimal human activity or disturbance.

The objectives of the Management Plan include:

- minimising impacts of mining and infrastructure developments on the Park and the natural environment
- minimising impacts of construction and associated activities
- ensuring rehabilitation is consistent with EPA standards.

Shire of Ashburton Town Planning Scheme

An objective of the Shire of Ashburton Town Planning Scheme (DPI 2005) is to facilitate development that responds to the character and amenity, geographical context and environmental constraints of the Shire and its urban and rural areas.

For all proposed developments, the Shire of Ashburton requires that all planning approvals consider:

- impact of the development on the amenity of the locality
- any social issues that have an affect on the amenity of the locality.

The proposed area for the expansion of mine pits, waste dumps, stockpiles, processing area and haul roads are all located on local scheme reserves zoned 'Other Purposes - Industrial'. When considering planning applications for 'Infrastructure' reservation zones, the Shire of Ashburton has a number of criteria under the scheme, which consider:

- compatibility of the proposed use with other surrounding uses
- the Western Australia Planning Commission Industrial Buffer Policy (WAPC 2004) - buffers to minimise off-site impacts
- amenity for the proposed use with other surrounding uses
- landscaping and screening.

The areas for the proposed dewatering infrastructure and operations camp are zoned 'Rural' under the Shire of Ashburton Town Planning Scheme (DPI 2005). Proposals for temporary workforce accommodation are assessed by the Shire of Ashburton and require information on indicative life of the development and proposed site rehabilitation, or other intended use for the site. Rural zones require that Proposals will not impinge on the strategic development of the area.

The Shire of Ashburton has produced a Local Planning Policy in the context of transient workforce accommodation. The policy states that the Shire does not support transient workforce operations camps that are located:

- in a position or area that would adversely affect residential, rural residential or rural smallholdings uses or lifestyles or that would detract from any particular scenic or visual attraction
- adjacent to recognised tourist routes, unless suitably screened or designed for permanent use.

5.9.4 Assessment of potential impact

Impacts at key visual receptors

A series of baseline photographs facing the Proposal area were taken at each identified receptor. Computer graphic simulations of predicted future landscapes were produced for only the most significant receptors (Receptors I, II, III, IV and VIII; Figure 39). Simulations were constructed for the mine in year 2026, when the proposed disturbance footprint will be at its largest extent.

Marandoo Ridge is visible from all of the publicly accessible sensitive receptors and is unlikely to be significantly obscured by the Proposal, with only limited sections of the proposed waste dumps obscuring a small part of the ridgeline. Only limited blending of the proposed mine into the existing landscape will be possible due to the inability to screen or hide the mine and associated infrastructure from key visual receptors. Vegetation screening near the mine is considered inadequate given the relative absence of local endemic vegetation of sufficient height and general sparseness of vegetation in the region.

The greatest changes to existing views are expected to occur at locations that provide views of the proposed extensions to the mine pit and waste dumps. These proposed areas of disturbance are mainly at the eastern end of the Proposal area and hence a long way from frequently visited tourist locations or receptors.

A summary of visual impacts to key visual receptors is provided in Table 20 and described in the following sections.

Table 20
Summary of sensitive receptor locations and sensitivity levels

Receptor	Description	Level of use	Potential views	Perceivable change	Potential sensitivity	Significance
I	Mount Bruce visitor car park lookout - lowest lookout point, 12 m east of the visitor car park	High	Clear views of the Proposal to the south and east. Westward views of the operations camp are unlikely given the presence of high screening vegetation.	Minor	Medium to high	Moderate - Severe Adverse
II	Mount Bruce summit main lookout - denoted by a large beacon and open ground	Medium	Clear view south. Views of proposed pits and waste dumps significantly obscured. No views of the operations camp.	Minor	Medium to high	Moderate Adverse
III	Mount Bruce eastern summit lookout - eastern most point of the summit ridge	Very low	Extensive panoramic views south and east. No westerly views. Views of the operations camp not likely to be evident from this location as the Mount Bruce Ridge blocks any views.	Significant	Medium to high	Moderate - Severe Adverse
IV	Karijini Drive - north of the mine	High	Road is raised to avoid flooding. Contains unobscured views of the Proposal area (between Mount Bruce and the Prider Hills) and east/west (driver's view). No views of the operations camp.	Significant	Low	Moderate - Severe Adverse
V	Car Park - junction of Karijini Drive and Marandoo Road	Medium to low	Unobscured views of the escarpments and ridgelines. Views to Proposal area are diminished by vegetation. Views of the operations camp likely to be obscured.	Minor	Medium to high	Moderate Adverse
VI	Four-wheel drive tracks - across the Mount Bruce Flats (east of Mount Bruce)	Very low	Prominent views to escarpments and ridgelines. Views to Proposal area are diminished by vegetation. No views of the operations camp.	Minor	Low	Minor Adverse to Moderate Adverse
VII	Karijini Drive - west of the mine	High	Some views of the dewatering infrastructure (assuming the dewatering pipeline will be above ground). Views to the operations camp and mine site largely obscured.	Minor	Low	Moderate Adverse
VIII	Hamersley Gorge-Mount Bruce Road	Medium to high	Some views of the Proposal area are possible on higher stretches of road or where scrub is less dense. Views to the operations camp and mine site largely obscured.	Minor	Low	Moderate Adverse

Source: SKM (2008)

Receptor I – Mount Bruce visitor car park lookout
Views of the Proposal area from Receptor I (Mount Bruce visitor car park lookout) are presented in Figure 40, Figure 41, Figure 42 and Figure 43. Existing views from Receptor I are illustrated in Figure 40 and Figure 42 and can be compared with simulated (year 2026) views in Figure 41 and Figure 43.

The existing mine pit and waste dumps are largely visible to the left of the viewer's field of view. There is no prominent existing infrastructure located at the eastern end of the mine. The existing rail/transmission line corridor alongside Marandoo Road is only marginally evident.

Proposed additional infrastructure will be extended westward of the existing infrastructure and will be located south of Receptor I. The additional infrastructure includes the RSF, dewatering infrastructure parallel to the rail line and a water collector tank adjacent to the existing communications tower. All infrastructure will be sited adjacent to, or in proximity to existing infrastructure. The sides of the RSF will appear human-made in form and their colour is expected to blend to a certain extent with surrounding features as they become covered with dust. The southward views from Receptor I will be dominated by the RSF.

A minor change to the visibility of the Marandoo ridgeline on the Marra Mamba escarpment will be detected at Receptor I. Whilst the Proposal will not exceed the top of the ridgeline, the western-most waste dump will be prominent against the ridge.

In view of the scale of the mine and its prominent visibility at Receptor I, the impact is likely to be Severe Adverse (Table 19); however, the perceivable change to the view of the mine is minor given the presence of existing mine pits and infrastructure.

The proposed operations camp will be visible to visitors descending the summit walk track back to the car park but westward views of the camp from Receptor I are unlikely given the presence of high screening vegetation.

Receptor II – Mount Bruce summit main lookout
Existing views of the Proposal from Receptor II (Mount Bruce summit main lookout) are illustrated in Figure 44 and can be compared with simulated (year 2026) views in Figure 45.

Existing views of the existing mine are obscured from Receptor II. The proposed expansion of mine pits and waste dumps will be significantly screened by the Mount Bruce summit ridgeline and scrub growing on the top of the mountain. Proposed infrastructure located to the west of the existing mine pit (near the existing rail loop) is likely to be visible. This includes the RSF, collector tank and dewatering infrastructure. The switchyard is unlikely to be visible from this location given it is obscured by the Mount Bruce ridge. Perceived changes to the visibility of the Marandoo ridgeline will be minor.

Given that only a small amount of additional infrastructure, pits and waste dumps are visible from this location, the impact is likely to be Moderate Adverse (Table 19).

Receptor III – Mount Bruce eastern summit lookout
Existing views of the Proposal from Receptor III (Mount Bruce eastern summit lookout) are illustrated in Figure 46 and can be compared with simulated (year 2026) views in Figure 47.

The Proposal will be highly prominent from this elevated location. Views to the east will include existing/expanded mine pit and waste dumps. Views to the west will encompass the existing mine processing infrastructure alongside new infrastructure such as the RSF, switchyard, collector tanks and dewatering pipeline.

Rehabilitating the final landform is likely to significantly reduce the visual impacts of the Proposal following cessation of mining activity.

Whilst the visual impacts of the Proposal are pronounced from this viewpoint, this location is not frequently used by tourists. Nonetheless, the scale of the Proposal means that the impacts are likely to be Substantial Adverse (Table 19).

Views of the proposed camp are not likely to be evident from this location, as the Mount Bruce ridge blocks views to the camp location.

Receptor IV – Karijini Drive north of the mine
Views of the Proposal area from Receptor IV (Karijini Drive north of the Mount Bruce Flats) are presented in Figure 48 and Figure 49. Existing views are illustrated in Figure 48 and can be compared with simulated (year 2026) views in Figure 49.

Receptor IV and adjacent sections of Karijini Drive (north of the mine) are on a raised bitumen road. This stretch of road provides unobstructed views of the existing mine site. The height of the proposed waste dumps will not exceed Marandoo Ridge when viewed from this location. The amount of Marandoo ridgeline visible from sections of Karijini Drive will decrease moderately.

People travelling eastwards along Karijini Drive will able to view the western extent of the mine; however, views will be limited to infrastructure set against a background of the existing mine and the pit and waste dumps will be hidden by these structures. People travelling in a westerly direction along Karijini Drive are unlikely to view the mine (unless they look backwards).

The impact from this viewpoint is judged to be Moderate to Severe Adverse given the distance between this receptor and the operations it is not likely that the camp will be visible (Table 19).

Figure 40 - Receptor I – Mount Bruce visitor car park lookout, existing view looking south-east towards the proposal area

Figure 41 - Receptor I – Mount Bruce visitor car park lookout, year 2026 simulated view looking south-east towards the proposal area

Figure 42 - Receptor I – Mount Bruce visitor car park lookout, existing view looking south towards the proposal area

Figure 43 - Receptor I – Mount Bruce visitor car park lookout, year 2026 simulated view looking south towards the proposal area

Figure 44 - Receptor II – Mount Bruce summit main lookout, existing view looking south towards the proposal area

Figure 45 - Receptor II – Mount Bruce summit main lookout, year 2026 simulated view looking south towards the proposal area

Figure 46 - Receptor III – Mount Bruce summit eastern lookout, existing view looking south towards the proposal area

Figure 47 - Receptor III – Mount Bruce summit eastern lookout, year 2026 simulated view looking south towards the proposal area

Figure 48 - Receptor IV – Karijini Drive, existing view southwards from road towards the proposal area

Figure 49 - Receptor IV – Karijini Drive, year 2026 simulated view southwards from road towards the proposal area

Figure 50 - Receptor VIII – Hamersley Gorge-Mount Bruce Road, existing view from road looking north-east towards the accommodation camp

Figure 51 - Receptor VIII – Hamersley Gorge-Mount Bruce Road, year 2026 simulated view from road looking north-east towards the accommodation camp

Impacts to minor visual receptors

The existing Marandoo mine site is not visible from any widely used camping facilities or gorges in Karijini National Park. Visibility of the Proposal area from the Park is obstructed by the Vigors uplands and the Stevenson uplands located to the north along Karijini Drive. The Proposal will not be visible from camping facilities or gorges in the Park.

Receptor V – Karijini Drive and Marandoo Road junction car park

The operations camp (when viewed from Receptor V; Karijini Drive and Marandoo Road junction car park) is likely to be hidden from the stretch of Karijini Drive to the north of the Marandoo Road junction, as the road is not raised in this section and the significant distance and intervening vegetation will substantially curtail distant westward views. The height of the proposed waste dumps will not exceed Marandoo Ridge when viewed from this location (SKM 2008).

The proposed switchyard station (Figure 14) may be visible from Receptor V.

From Receptor V, the views are considered to be Moderate Adverse, given the acute angle that the mine would be viewed from and the distance between the mine and the car park/road.

Receptor VI – Mount Bruce Flats four-wheel drive tracks

Several four-wheel drive tracks are located in public areas within the Mount Bruce Flats, many of which are either difficult to access or are inaccessible. These were considered as Receptor VI. Most of these tracks are located within wetlands dominated by Coolibah trees and Mulga. Views from the tracks are dominated by the surrounding high ridges and peaks. Views of the existing mine are impeded by the surrounding vegetation.

The proposed pit and waste dumps at the eastern extent of the mine are likely to be visible intermittently, but not clearly, as the tall scrub and trees across the Mount Bruce Flats significantly diminish the degree of visibility of the mine and the ridgeline.

The Proposal would be more visible if a bush fire were to affect vegetation across the Mount Bruce Flats; however, under typical conditions, this vegetation provides a considerable screen for long range views along, or just above the horizon. The proposed waste dump at the eastern extent of the mine may be evident in 2026 in areas of sparse canopy cover.

Views of the proposed infrastructure at the western extent of the mine will be largely obscured or indiscernible from Receptor VI, given the distance between the tracks and this part of the mine and due to the fact that the infrastructure will be viewed against a backdrop of existing infrastructure.

The visual impacts are assessed to be Slight to Moderate Adverse at this location (Table 19).

The operations camp would not be visible from these locations.

Receptor VII – Karijini Drive west of the mine

The operations camp will be largely obscured from Receptor VII (Karijini Drive west of the mine) for nearly all sections of the road. Users of the road driving eastwards may experience transient glimpses of the tops of the camp buildings. These views are only likely to be evident when road users travel on the high ground of Karijini Drive, approximately 15 km west of the junction of Karijini Drive and Marandoo Road (Figure 39).

Receptor VIII – Hamersley Gorge-Mount Bruce Road

The camp may be visible to people travelling to Hamersley Gorge along the unsealed Hamersley Gorge-Mount Bruce Road to the north of the proposed operations camp. Whilst the number of users of this unsealed road will be much less than for Marandoo Road, the camp may be more visible given the absence of prominent topography between the road and the camp. However, the significant distance between the proposed camp and the road, coupled with the presence of 1.5–2 m high scrub/low woodland will significantly lessen the degree of visibility of the camp. Existing views are illustrated in Figure 50 and can be compared with simulated views on Figure 51.

Given the passing glimpses of the proposed camp that viewers would experience and the limited number of people using the unsealed road, the impact is judged to be Moderate Adverse (Table 19).

Landscape impacts

The seven landscape types identified by SKM (2008) (Section 5.9.1) were amalgamated into four groups for the purposes of impact assessment. These groups were:

- flats, broad drainage areas and basins
- major flow lines and creeks
- disturbed ground
- ridges, erosional spurs, low foothills and escarpments.

The potential impact of the Proposal to each landscape group is addressed below.

Flats, broad drainage areas and basins

Flats, broad drainage areas and basins will be affected by the Proposal as a result of extensions to the mine pit and waste dumps. The waste dumps will introduce uncharacteristically high features into a topographically flat landscape; however, the impact of such features will be reduced due to the presence of the existing mine pit and waste dumps, as well as natural ridges to the south of the mine site (SKM 2008). The proposed dewatering infrastructure may affect this landscape group (if it is located above ground), but will largely parallel existing rail and power infrastructure that has already affected flats and broad drainage areas to a large extent (SKM 2008).

In recognition of the degree to which this landscape group is already affected, the impacts of the Proposal are judged to be Moderate Adverse (Table 19).

Major flow lines and creeks
The landscape character of major flow lines and creeks in the vicinity of the Proposal area is likely to be affected by the Proposal (SKM 2008). In addition to ephemeral creeks and flow lines being removed to accommodate the mine pit and waste dumps, the landscape features upstream and downstream may be affected if hydrological characteristics are altered (SKM 2008). Flow lines are unlikely to be significantly affected as a result of the Proposal, as their courses will not be diverted and existing mine infrastructure in the vicinity already partially affects their character (SKM 2008).

The significance of the loss or deviation of flow lines and creeks as a result of the Proposal is considered Minor Adverse (Table 19).

Disturbed ground
The existing disturbed ground in the vicinity of the existing Proposal would be extended eastwards as the proposed mine pits and waste dumps are developed.

Given that the disturbed ground landscape type is not considered a positive landscape type in the local area, the impacts are judged to be Neutral (Table 19).

Ridges, erosional spurs, low foothills and escarpments
The most notable impact to ridges, erosional spurs, low foothills and escarpments as a result of the Proposal will be along Marandoo Ridge to the south of the proposed mine pit (SKM 2008). During the course of the Proposal, the mine pit and waste dumps (which will differ in topography from the more natural landform) will be sited adjacent to the ridge, thereby affecting the surrounding landscape. To a limited extent, this landscape group may be affected by the proposed mine site infrastructure; however, the presence of existing infrastructure and disturbance in these landscape types will significantly reduce the severity of this impact (SKM 2008). Impacts to this landscape group are judged to be Moderate Adverse (Table 19).

5.9.5 Proposed mitigation and management measures

Existing visual amenity values within, and surrounding the Proposal area will be maintained as far as practicable through the implementation of the following measures:

- undertaking a visual assessment of the Proposal in relation to visibility of the Marandoo ridgeline from the Mount Bruce visitor carpark lookout at finalisation of the mine plan and every five years thereafter during operations and at closure
- rehabilitating disturbed areas with the aim of achieving safe, stable and self-sustaining landforms
- progressively rehabilitating the Proposal area to come as close as possible to local landscape values and surrounding environment
- utilising local provenance species and matching local relative plant densities in rehabilitation areas
- preventing unnecessary clearing of vegetation
- locating infrastructure in, or near previously disturbed areas where possible
- selecting colour schemes for buildings and infrastructure that blend in with the surrounding landscape
- erecting informational signage about the Proposal at the Mount Bruce car park lookout.

5.9.6 Predicted outcome

After mitigation and management measures have been applied, the Proposal is expected to result in the following outcomes in relation to visual amenity and landscape character:

- The Proposal will result in additional modification of an already highly modified landscape.
- Likely impacts relate largely to the proposed mine pit, waste dumps and RSF, with the potential visual effects of the proposed development varying spatially between visual receptors near the Proposal area.
- Visitors to Mount Bruce will experience significant impacts to visual amenity, particularly from the visitor car park lookout at the western extent of the mountain (Receptor I). The most significant impact will be experienced at the Mount Bruce eastern summit lookout; however, this location is not frequently used.
- The impact of the proposed waste dumps on the visibility of the Marandoo ridgeline is not expected to be significant and will be largely indiscernible from a visual perspective.
- Final landforms will stive to be consistent with local landscape values and the surrounding environment.
- Views of the proposed operations camp are likely to be restricted to limited, transient views from roads in the vicinity of the infrastructure, including Karijini Drive and Hamersley Gorge-Mount Bruce Road.
- Replacement of the existing above-ground 33 kV power line between the proposed Marandoo switchyard and Tom Price with a new below-ground power line will improve visual amenity.

The Proposal is consistent with EPA objectives for visual amenity and landscape and landforms, given existing effects on visual amenity in the area and proposed management measures that will be implemented throughout the Proposal.

5.10 Closure

5.10.1 Description of factor

Mining and the establishment of associated infrastructure will require clearing of vegetation and disturbance to soil profiles and landforms. Due to the sensitive location of Marandoo adjacent to Karijini National Park, closure management is particularly important to ensure that the area disturbed is suitable for the long-term end land use that is determined in consultation with relevant stakeholders and the community.

General objectives for mine closure are to prevent adverse environmental impacts and to create self-sustaining natural ecosystems, or an alternative land use based on an agreed set of end land use objectives (ANZMEC and MCA 2000). Closure planning is a dynamic process that requires regular review and development to take into account changes in legal obligations, corporate requirements, community expectations and changes in technical knowledge.

5.10.2 Key statutory requirements, environmental policy and guidance

EPA objective

In most circumstances, including this assessment, the EPA applies the following objective in its assessment of Proposals that have a rehabilitation and closure component:

To ensure, as far as practicable, that rehabilitation achieves a stable and functioning landform that is consistent with the surrounding landscape and other environmental values.

EPA Guidance Statement No. 6

EPA Guidance Statement No. 6 (EPA 2006b) provides guidance on the rehabilitation of terrestrial ecosystems following disturbance. The Guidance Statement states that the key aims of rehabilitation are to:

- ensure the long-term stability of soils, landforms and hydrology required for the sustainability of sites
- partially or fully repair the capacity of ecosystems to provide habitats for biota and services for people.

Actions relevant to rehabilitation planning and design include the identification of relevant rehabilitation objectives (in consultation with key stakeholders), as well as the development of clear targets for rehabilitation that can be effectively monitored and audited to confirm objectives are achieved. Rehabilitated sites should (EPA 2006b):

- include safe, stable and resilient landforms and soils
- include appropriate hydrology
- provide visual amenity
- retain heritage values
- be suitable for agreed land uses
- include resilient and self-sustaining vegetation comprised of local provenance species
- reach agreed numeric targets for vegetation recovery
- comprise habitats capable of supporting all types of biodiversity.

Government and industry guidelines

Regulatory agencies and industry bodies have established guidelines (industry best-practice) to assist mining companies achieve acceptable standards of mine closure and rehabilitation. While there are no legislative requirements to adhere to these guidelines, the Proponent subscribes to the intent and advice of such guidelines.

The Department of Industry and Resources (DoIR) is the regulatory agency of mining in Western Australia. The Department has developed a number of guidelines and environmental notes in relation to mining and rehabilitation, including:

- Guidelines for Mining in Arid Environments (DME 1996)
- Environmental Notes on Mining, Waste Rock Dumps (DME 2001)
- Mine Void Water Resource Issues in Western Australia (Johnson and Wright 2003).

Other key government and industry guidelines relevant to mine closure and rehabilitation include:

- Strategic Framework for Mine Closure (ANZMEC and MCA 2000)
- Mine Closure Guidelines for Mineral Operations in Western Australia (Chamber of Minerals and Energy 2000)
- Enduring Value - The Australian Minerals Industry Framework for Sustainable Development (Minerals Council of Australia 2004)
- Best Practice Environmental Management in Mining Series (EPA 1995; Environment Australia 1998).

Corporate requirements

The Proponent has established policies and standards, some of which may go beyond legislative and statutory requirements, and to which all operations must adhere.

Rio Tinto Environment Standards

The Rio Tinto Closure Standard is the key document in directing the development and implementation of closure activities at Rio Tinto operations. Through the implementation of this standard, Rio Tinto seeks to influence the design, development, operation and closure of all its operations to ensure optimisation of post-closure outcomes in terms of social, environmental and economic development needs and expectations.

In addition to the Closure Standard, there are a number of environmental standards that have direct or indirect implications for closure. These standards outline the minimum level of compliance for all operations and are regularly audited for compliance.

Proponent's Environmental Policy

The Corporate Environmental Policy outlines specific directions and management commitments for environmental management. The Policy incorporates the aim of leaving areas in as close as practicable to their original condition and preventing pollution. To fulfil these aims, it is necessary to minimise land disturbance and waste generation, continually update disturbance and closure plans and undertake progressive rehabilitation.

5.10.3 Closure strategy

The closure vision for the Proposal is:

To create a positive legacy by remediating the effects of mining to:

- *maximise potential productive, community and/or natural land uses*
- *achieve end states that are safe and stable, and enable effective stewardship for the future and minimising the company's post-closure impact on the natural environment, returning the land to a state compatible with the agreed land-use and contribute to the biodiversity of the area.*

The post-closure land use option for the Proposal area takes into consideration the specific values and constraints of the surrounding physical and biological environment, as well as the socio-economic aspects of the Proposal. The proposed post-closure land use option for the Proposal area is to be consistent with Karijini National Park objectives. The post-closure land use option will be reviewed throughout the life of the Proposal. The final land use option will be developed in consultation with key stakeholders and will be incorporated into the final Decommissioning Closure Plan, at least five years prior to planned closure.

These objectives are conceptual only and will evolve throughout the life of the Proposal, subject to review by key stakeholders. These conceptual objectives will continue to be revised and made more specific, with measurable targets developed and agreed with key stakeholders. Final objectives and targets will be developed in consultation with key stakeholders at least five years prior to planned closure, as part of the final Decommissioning Closure Plan. These agreed objectives and targets will become the 'completion criteria' upon which the success of closure activities will be measured.

Table 21
Closure objectives

Decommissioning
• relinquish the site in a condition that minimises risks to human health or safety and to the natural environment • prioritise sustainable economic returns from decommissioning to offset aspects of financial closure costs.
Decontamination
• ensure no ongoing contaminated site management is required beyond five years post-closure.
Rehabilitation
• have a positive net impact to biodiversity • relinquish a safe, stable and uncontaminated site, where the majority of the site is aesthetically compatible with the surrounding landscape and is suitable for the agreed land use • construct post-mining landforms that are non-polluting • establish sustainable endemic vegetation units consistent with surrounding undisturbed vegetation and suitable for the support of the future land use option • ensure water quality is suitable for the proposed land use.
Human Resources
• ensure there are no unacceptable impacts to Rio Tinto business from closure • ensure employees have the opportunity to choose/elect/determine their own quality of life outcomes resulting from mining cessation and closure (including redeployment, or retirement) • transfer appropriate skilled and experienced personnel within Rio Tinto • retain human resources to implement closure plans • maintain a safe and healthy working environment throughout the closure process.
Communication and consultation
• maintain and document a comprehensive stakeholder information, communication and consultation program through closure • identify and manage indigenous concerns • maintain indigenous heritage values in the Proposal area.

5.10.4 Closure Plan

Whilst the Proposal has an estimated life of 15–20 years, planning for closure has already begun to ensure closure objectives and obligations are met and that adequate financial provisions are made for closure in accordance with accounting standards. It is a specific requirement of the Rio Tinto Closure Standard that a Closure Plan for each operation is developed, implemented and reviewed on a regular basis (fully updated at least every five years). The update must identify the adequacy and performance of the Closure Plan. In years when the Closure Plan does not undergo a full review, the closure cost estimate must be updated to reflect known developments, scope changes, inflation, changes to exchange rates, new regulatory requirements and other material developments.

One of the keys to achieving acceptable closure outcomes and reducing the cost of closure without compromising outcomes is the successful integration of closure concepts into ongoing short and long-term mine planning activities. A Conceptual Closure Plan for the Proposal (Rio Tinto 2008) has been developed to identify key aspects of closure that will require further investigation throughout the life of the Proposal and to identify high risk considerations associated with the eventual closure of the proposed operation (full copy of the report provided in Appendix 1).

Key risks related to closure that were identified by Rio Tinto (2008) included:

- visual impact
- re-establishment of surface water flows
- impacts to groundwater
- future land use
- rehabilitation.

One of the key risks to address in closure is the potential impact to groundwater quality from backfilling of mine pit voids. Defining the potential beneficial use of the local and regional groundwater resources is therefore an important consideration in establishing the appropriate management objectives during project planning (Johnson and Wright 2003).

The beneficial use of the unconfined aquifer is primarily in the maintenance of ecological processes and any groundwater dependent ecosystems. The impact of groundwater drawdown (0–2.5 m over eight years) in the unconfined aquifer to the Coolibah woodland is not considered significant when compared to natural fluctuations (Section 5.5.4).

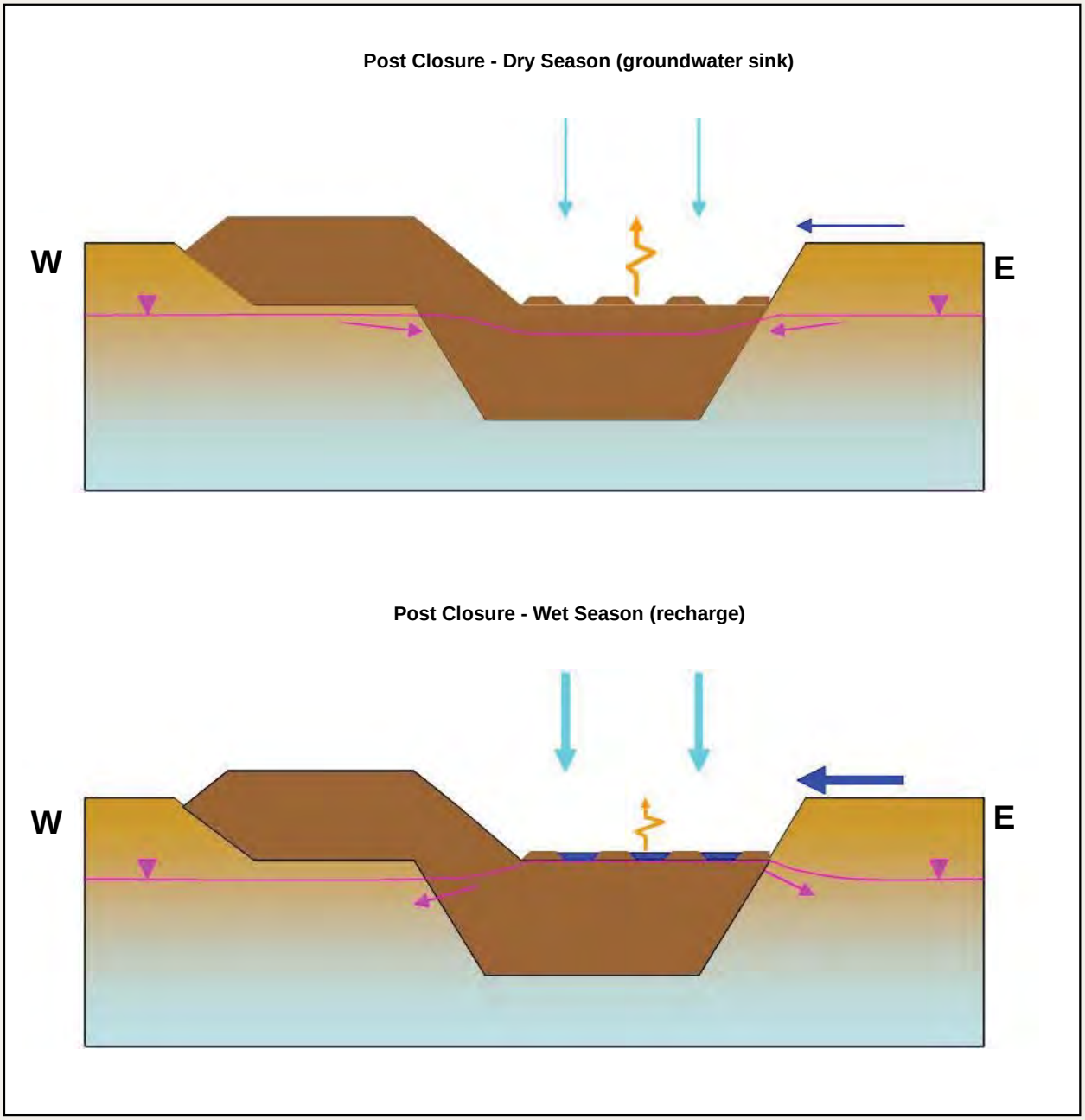
Although of potable quality, groundwater in the confined aquifer has less obvious beneficial uses in the vicinity of Marandoo. The confined aquifer is not considered to play a significant role in maintaining ecological processes within the vicinity of Marandoo. The nearest potential user of the water (other than the existing use for mining purposes at Marandoo) is the water drawn from the Southern Fortescue borefield for supply of potable water to the Tom Price town and mining operation (Section 5.2.1). At the closest point, the Southern Fortescue borefield is over 10 km from the Proposal area and only a proportion of the recharge of the aquifer is from the Marandoo system.

The development of pit lakes after closure and the potential impacts of this to groundwater quality at Marandoo are subject to ongoing numerical modelling by the University of Western Australia (UWA). Modelling is likely to be finalised following commencement of the proposed operations, when aquifer characteristics are more fully understood, and the study assumes that pits will require backfilling to at least 1 m above the watertable. The decision to backfill the pit to above the watertable will not be solely based on protection of groundwater water quality, but will also include aesthetic and stakeholder considerations.

A conceptual model of the potential hydrogeological conditions at Marandoo is shown in Figure 52. This model reflects the hydrogeological conditions expected at closure. The model describes the planned closure scenario of backfilling the void to a nominal 1 m above the pre-mining watertable.

During dry conditions (that is, when evaporation exceeds rainfall and surface inflows) the mine pit is expected to act as a 'groundwater sink'. Water levels are expected to slowly recover and stabilise at a level lower than that of the pre-mining watertable. Continued evaporation with no outflow will lead to a progressive salinity increase (Johnson and Wright 2003). This is expected to be off-set during periods of heavy rain, when groundwater recharge will occur as surface water inflows and direct precipitation form ephemeral pools in the pit (Rio Tinto 2008). This will cause a groundwater mound to form, thus reversing the groundwater flow and potentially lowering salinity levels.

Depending on the size and frequency of rainfall events, pools in the mine pit may remain for several months. As part of the final closure design, the backfill surface is likely to be designed to incorporate topographical low points to create areas for water to pool to reduce the surface area for evaporation. Revegetation of these areas will include species that will cope with inundation.



Rio Tinto

Figure 52
Conceptual Closure Hydrogeology

Drawn: B Jackson
Date: August 2008

Plan No: PDE0049509v1

LEGEND

- Precipitation
- Groundwater
- Surface Water
- Evaporation
- Mine Backfill

5.10.5 Rehabilitation Plan

A Rehabilitation Plan has been developed for Marandoo as part of the Conceptual Closure Plan. The Rehabilitation Plan will be incorporated into the site rehabilitation plan upon commencement of the proposed operations and will be regularly reviewed and finalised at least five years prior to closure as part of the Closure Plan.

The rehabilitation process undertaken by the Proponent involves five general phases:

- Recovery and stockpiling of cleared vegetation and topsoil in advance of mining for use on rehabilitation areas. Management of topsoil is an important factor in successful rehabilitation, particularly in arid environments such as the Pilbara. Topsoil is valuable as it has a high nutrient content relative to other sections of the soil profile; has a higher water holding capacity; has suitable structural properties; contains most of the viable seed and vegetative material; and, contains mycorrhizal fungi that facilitate plant growth.
- Battering slopes to an angle ≤ 20º (angle depends on the nature of the material being shaped). Battering slopes reduces the risk of erosion and creates a more stable landform. Deep ripping of soil surfaces reduces the risk of erosion and enhances water harvesting capabilities of the rehabilitated landform. Surface ripping creates a typical bank and trough system and is undertaken prior to seeding to control runoff and create favourable microsites for seeds.
- Re-spreading of topsoil and deep ripping of soil surfaces.
- Seeding using local provenance seed where possible. Seed used in current rehabilitation areas at Marandoo consists of a range of local provenance species, including *Acacia aneura, A. atkinsiana, A. bivenosa, A. colei, A. dictyophleba, A. maitlandii, A. monticola, A. pachyacra, A. pruinocarpa, A. tumida, Aristida latifolia, Codonocarpus cotinifolius, Corymbia deserticola, C. hamersleyana, Dodonaea pachyneura, Eremophila latrobei, Gompholobium polyzygum, Hakea lorea, Hibiscus sturtii, Indigofera monophylla, Keraudrenia integrifolia, Maireana villosa, Paraneurachne muelleri, Porana commixta, Ptilotus calostachyus, P. exaltatus, Santalum lanceolatum, Senna artemisioides* subsp. *oligophylla, Senna glutinosa* subsp. *glutinosa, Sida* sp., *Solanum ferocissimum, S. lasiophyllum, Themeda triandra and Triodia* sp. The above list of species is expected to form the basis for the species used during progressive rehabilitation works for the Proposal. The species list will be refined based on rehabilitation monitoring results and stakeholder consultation. Particular species used may be further targeted to specific rehabilitation landforms, for example rocky slopes, flat plains and low lying areas.
- Monitoring establishment of plants and development of ecosystem processes. Monitoring is necessary to clearly demonstrate successful closure has been achieved, or to provide an early indication of when problems may arise and management intervention is required. Progressive rehabilitation has been undertaken at a number of sites in, and around the existing Marandoo operations. Rehabilitation-sites have been regularly monitored to assess their progress and evaluate the successional development of the rehabilitation (Figure 53). In many cases, post-closure monitoring will be a continuation of monitoring programs established during operations, appropriately adjusted to reflect the closed status of the mine. Specific closure measures and schedules will be determined during the development of the Decommissioning Closure Plan. Monitoring is expected to include programs for:
  a) landform stability and erosion monitoring of reconstructed landforms in relation to surface hydrology, erosion gullying, rilling, loss of surface material and factors affecting surface stability and revegetation
  b) revegetation monitoring of specific factors to gauge success and identify required remedial actions to establish sustainable native vegetation units
  c) water monitoring of surface and groundwater against closure targets and modelling expectations.

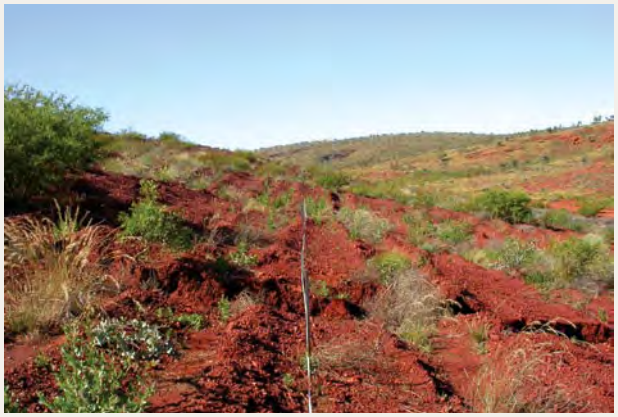
Revegetation monitoring will be undertaken to ensure that vegetation units are approaching the planned land use values for the area. In general, vegetation is monitored to assess and compare composition, structure and function of the revegetated area to an adjacent control area.

WD1B Bottom Start 2004

WD1B Bottom Start 2006

WD1B Bottom End 2004

WD1B Bottom End 2006



WD1C Start 2004

WD1C Start 2006

WD1C End 2004

WD1C End 2006

Figure 53
Rehabilitation Monitoring at Marandoo

5.10.6 Proposed mitigation and management measures

The Proponent has developed a Conceptual Closure Plan for the Proposal (which includes a Rehabilitation Plan) in accordance with EPA Guidance Statement No. 6 (EPA 2006b). As part of the plan, the Proponent has committed to developing and implementing a final Closure Plan at least five years prior to planned final closure of the mine (Table 22). The Closure Plan will be regularly updated (as required throughout the life of the Proposal) and will address:

- suitable end land uses and objectives for closure, in consultation with relevant stakeholders and the community
- identification and evaluation of closure options and determination of preferred options
- establishment of completion criteria
- closure monitoring requirements
- cost estimates and fund allocation for future closure
- management measures to facilitate future closure.

A detailed inventory of the existing facilities (decommissioning units) at Marandoo required to be decommissioned has been prepared as part of previous closure planning studies. The general aims for decommissioning of infrastructure are:

- demolition/removal of all infrastructure
- removal of services (including water lines, power lines and communications-services more than 1 m below final ground level may be left in situ if they pose no long-term threat to the environment)
- removal/burial of all concrete slabs, footings and retaining walls
- removal of all services and infrastructure associated with the rail loop
- removal of all bitumen surfaces within the site (the main access road up to the main gate will remain)
- provision for backfilling of the mine pit void to achieve acceptable post-mining landforms and groundwater quality
- location and design of infrastructure (including camps, dewatering infrastructure and processing facilities) to minimise potential post-closure impacts
- strategic placement of temporary spoil heaps during operations to minimise visual impacts from public roads and viewing points throughout Karijini National Park
- design of water diversion structures to minimise impacts to downstream flows.

Any areas of contaminated land within the Proposal area will be identified, remediated and managed by the Proponent leading up to, and following closure (as necessary) to ensure that the land is left in a condition that does not present a risk for the identified future land use.

Specific rehabilitation measures

Specific rehabilitation measures to be applied at Marandoo have been developed for each general category of disturbance, as outlined in the following section. The rehabilitation measures will be regularly reviewed based on knowledge obtained from trials, monitoring performance of existing rehabilitation and site-specific information on material characterisation and performance.

Mine pit

Under the current closure plan the mine pit is to be backfilled to at least 1 m above the pre-mining watertable level. This will be subject to the results of long-term hydrogeological modelling and stakeholder consultation. Modelling is likely to be finalised following commencement of the proposed operations, when aquifer characteristics are more fully understood (Section 5.10.4).

Pit backfilling is planned to occur progressively throughout the life of the Proposal, with waste being directly placed into mined-out sections of the pit, where practicable. Depending on scheduling and availability of in-pit areas,

Table 22
Closure plan development schedule

Stage of closure planning	Project stage/year of operation													
	PFS	FS	Ops	1–5	+5	6–9	+10	11–14	+15	16	17	18	19	Closure
Development of Conceptual Closure Plan	*													
Full review of Closure Plan					*		*							
Cost estimate update														
Final Closure Plan									*					
Implementation of Closure Plan														*

*** - Consultation with key regulatory stakeholders on relevant aspects relating to closure**
PFS - Pre-feasibility study
FS - Feasibility study, Ops - Post commissioning of the Proposal

temporary surface dumps may be required. These dumps will be progressively backfilled into the pit.

Topsoil and mulch will be spread over backfill to a minimum depth of 200 mm and then deep ripped (0.5–1.0 m) and seeded, with the spacing of rip lines at no greater than 1.5 m apart.

An abandonment bund will be constructed around the perimeter of the pit outside of the zone of geotechnical instability. The bund will be constructed of competent waste rock material and will be at least 2 m high and 5 m wide (at the base) consistent with statutory requirements (DoIR 1997). At the point where the existing diversion drain and the abandonment bund meet, provisions will be made to allow the passage of water to continue to flow to the diversion drain while still meeting DoIR (1997) requirements.

Residue storage facility (RSF)
The outer walls of the RSF are planned to be rehabilitated throughout the Proposal, with walls battered back to an angle of ≤ 20° (subject to characterisation of wall material), topsoil re-spread over the surface to a nominal depth of 100 mm and the surface ripped and seeded with local provenance seed.

Upon completion of processing operations and the achievement of suitable density of the residue material, the surface of the facility is planned to be capped with a 2 m layer of inert waste material, then spread with topsoil to a nominal depth of 100 mm and the surface ripped and seeded with local provenance seed.

Inert waste rock dumps
Some waste dumps will not be completely utilised in the backfill of the void and will remain as raised landforms. These will be designed in accordance with the Proponent Landform Design Guidelines. The design incorporates features to minimise waste re-handling and optimise the configuration and stability of waste dumps to facilitate successful rehabilitation. Final design of landforms will be determined by the results of characterisation of waste material.

Surface water runoff from adjoining landforms will be directed away from waste dumps, such that the top surface of waste dumps will receive only incident rainfall. The top surface will be sloped towards the centre (concave) to allow the formation of one or more pools. Pools will be a minimum of 20 m from the edge of the waste dump.

Final waste landforms may consist of variable waste rock types in terms of their susceptibility to erosion. The maximum slope and length of each waste dump will be dependent on the erodibility of the waste material. The Proponent's existing guidelines stipulate berms 5–10 m wide must be constructed at 10 m vertical intervals along each waste dump slope and be back-sloped into the dump to direct water to a predetermined discharge point. Steep slopes at either side of waste dump haul roads will be pushed down to form maximum gradients of 20°, with berms at 10 m vertical intervals. Cross bunds will be incorporated along the gradient of the road at approximately 50 m intervals. Slopes of the haul road will be deep ripped along the contour and seeded as per the remainder of the waste dump.

Topsoil and mulch (where available) will be spread over the waste dump surface to a minimum depth of 100 mm. Dump slopes will then be deep ripped (1.0–2.0 m) and seeded, with the spacing of rip lines at no greater than 1.5 m apart.

Landfill
The Marandoo landfill will be capped with at least 2 m of competent inert material. The area will then be spread with topsoil and stockpiled vegetation, before being deep ripped and seeded on the contour to a depth of 800 mm.

The Proponent maintains a contaminated sites register for the existing Marandoo operation, as required by the *Contaminated Sites Act 2003* (WA) and the corporate Environmental Management System, and will continue to operate in accordance with this legislation.

Miscellaneous disturbed areas
Rehabilitation of disturbed areas will be determined according to the level of disturbance, primarily the degree of modification from the original relief. Areas of low disturbance (including unsealed roads, tracks and laydown areas) are likely to require deep ripping and revegetation only. Areas of moderate disturbance (including rail formations) may require minor earthworks to either return the area to natural relief, or to create a landform compatible with the surrounding natural relief and landforms. Areas of high disturbance are likely to require extensive earthworks to either return the area to natural relief, or to create a landform compatible with the surrounding natural relief and landforms. These areas typically contain concrete footings that require cracking and covering with fill, capping or filling with waste rock, and significant reshaping and contouring creating the required relief.

Re-contouring of disturbed areas typically involves battering of any steep slopes to less then 20° and/or rock armouring to prevent erosion. Windrows will be constructed (at approximately 50 m intervals) to prevent sheet flows over large areas with low slopes.

Following re-contouring, disturbed areas will be deep ripped, spread with topsoil and seeded as per waste rock dumps. Tracks may be left to rehabilitate naturally where topsoil has not been removed and compaction is limited to two wheel tracks. Natural drainage lines will be re-established where practicable, or otherwise redirected into the natural drainage system downstream of any obstacles.

5.10.7 Predicted outcome

The early consideration of closure in the development of the Proposal is expected to ensure closure concepts are fully integrated into short and long-term mine planning activities and that acceptable and cost-effective closure outcomes are achieved. The proposed mitigation and management strategies will ensure that closure is consistent with the EPA objective.

All relevant factors considered

There are a number of factors relevant to the Proposal requiring less detailed assessment than other factors, as they are either subject to controls imposed under other legislation, subject to routine environmental management procedures and plans, or the Proposal poses low risk to them.

6. Other management considerations

6.1 Overview

There are a number of factors relevant to the Proposal requiring less detailed assessment than other factors, as they are either subject to controls imposed under other legislation, subject to routine environmental management procedures and plans, or the Proposal poses low risk to them.

These factors are addressed below and include:
- geodiversity
- waste
- greenhouse gas emissions
- dust emissions
- noise and vibration
- recreation and tourism
- public risk and safety.

6.2 Geodiversity

6.2.1 Geodiversity values

Geodiversity refers to the range of geological, geomorphological and soil features, systems and processes that exist in an area (John Cleary Planning 2005). Geodiversity includes intrinsic values, ecological values and scientific values.

Landscape values for the Proposal are addressed separately in Section 5.9 as these relate to human values attached to a place based on a person's perception of that place.

6.2.2 Intrinsic values

Intrinsic geodiversity recognises the value of the area regardless of the human-related rating of importance and relates to the range of geological, geomorphological and soil features, systems and processes (John Cleary Planning 2005).

The Proposal area occurs across three land systems, as mapped by van Vreeswyk et al. (2004) (Section 3.2.3). The Proposal will not significantly affect the regional condition of any of these land systems, as disturbance will be less than 0.2% for each (Table 23). Features of particular intrinsic significance in the Hamersley sub-region (including gorges and mountain tops of the Hamersley Range, calcrete aquifers and permanent spring systems (Kendrick 2001, CALM 2002)) will not be significantly affected by the Proposal.

Table 23
Land systems occurring in the MMP2 Proposal areas

Land system	Area within Pilbara region (ha)	Area within Proposal area (ha)	Percentage disturbance of landsystems
Newman	1 458 000	96	0.007 %
Boolgeeda	774 800	827	0.107 %
Jurrawarrina	66 400	12	0.018 %

*** The 'proposed disturbance area' comprises areas to be cleared for the MMP2 Proposal, whilst the 'project disturbance area' comprises areas to be cleared for construction of dewatering infrastructure and the operations camp, which is not part of the MMP2 Proposal and will be subject to a separate environmental approvals process under the EP Act.**

6.2.3 Ecological values

Ecological values are typically determined in relation to the biodiversity of flora and fauna (John Cleary Planning 2005), although consideration of the ecological function of an area is also important (EPA 2002a). Ecological geodiversity can be affected when the intrinsic vales of an area (the geological, geomorphological and soil features, systems and processes) are affected, which, in turn affect biotic components of ecosystems. Ecological function refers to the ecological processes and interactions that occur within an ecological community. Scientific values focus on formations that demonstrate particular aspects of geological and geomorphic processes (John Cleary Planning 2005).

Biodiversity conservation

The Mount Bruce Flats north of Marandoo supports a nationally significant Coolibah woodland and extensive stands of Mulga. These will not be significantly disturbed by the Proposal (Section 5.5).

Approximately 90% of the proposed disturbance from the Proposal will be to vegetation of low conservation significance (Table 12). The Proposal will disturb some locations of Priority flora species; however, as these species are not restricted to the Marandoo locality and occur relatively broadly throughout the Pilbara, the Proposal will not affect their conservation status (Biota 2008b).

Fauna habitats occurring across the Proposal area are typical of the surrounding area and are well represented across the Pilbara region (Section 5.6).

Ecological function

The major Proposal activities with the potential to impact ecological function in, and around the Proposal area are:
- Mining at Marandoo - however, this will not significantly affect the hydrological regime of Marandoo Ridge or the Mount Bruce Flats (Section 5.3.4).
- Dewatering of the confined aquifer and/or intersection of the unconfined aquifer by the proposed mine pit - this will result in groundwater drawdown well within the magnitude of natural fluctuations and is not expected to affect the Mount Bruce Flats Coolibah woodland (Section 5.5.4).

- Re-injection of dewatering water at the Southern Fortescue borefield - this is not anticipated to significantly alter the hydrological or hydrogeological regime of the area (Section 5.2.4).
- Surface discharge of stormwater and excess dewatering water - this is not anticipated to significantly alter the ecological function of the receiving environment (Section 5.3.4).

Scientific values

The deposits of the Marra Mamba Iron Formation (including the Marandoo deposit) occur extensively throughout the Hamersley Province, which dominates the geology of the Pilbara region. These deposits have scientific value due to what they reveal about the evolution of the area (and the origin of the ores); however, the Marandoo deposit has no additional scientific value that is unique from other deposits. The Proposal is not expected to affect the scientific values of the region.

Proposed mitigation and management measures

The potential impact to geodiversity from the Proposal will be controlled through implementation of the following management measures:

- progressively rehabilitating the Proposal area to a standard compatible with local landscape values and surrounding environment
- keeping vegetation clearing within designated areas based on the minimum necessary for safe construction and operation of the Proposal, particularly in areas adjacent to habitat of higher conservation significance
- regularly updating (as required throughout the life of the Proposal) and developing a final Closure Plan at least five years prior to closure of the mine.

6.3 Waste

Waste generated by the Proposal will be similar in composition to that already generated at the existing Marandoo mine and will include:

- domestic solid and liquid wastes (including food scraps and ablution effluent)
- mineral waste
- washdown water
- general office waste
- waste oils and lubricants.

A new sewage treatment plant will be developed at Marandoo and the existing facility at the camp will be upgraded to accommodate the additional operations workforce. Treated wastewater from the mine site will be discharged at a spray irrigation area to be established near the Marandoo rail loop (Figure 15). Treated wastewater from the operations camp will be discharged at a spray irrigation area near the camp.

Putrescible and inert wastes from the Proposal will be disposed of at the existing Marandoo mine site landfill. Wastes will be segregated to facilitate recycling and appropriate disposal.

Wet processing of ore at Marandoo will produce a benign residue that will be stored safely at the site in the proposed RSF. The RSF will be designed to discharge to a central decant where the available stormwater capacity is significantly greater than a 1 in 100 year ARI rainfall event (capacity available is equivalent to approximately 2 m of rainfall) (Knight Piésold 2007).

Seepage into the groundwater system from the RSF should be limited to approximately 2–5% of the water pumped into the RSF due to features such as underdrainage blankets and toe drains (Knight Piésold 2007). As the water seeps into the ground, it is envisaged that a water mound would develop beneath the RSF, which would tend to push the seepage plume northwards. Seepage from the RSF would be relatively high quality and would not be expected to affect vegetation in the vicinity (Knight Piésold 2007). Water reclaimable back to the plant site is expected to be 25–35% of the water pumped to the RSF.

Drilling and geotechnical investigations at the site have indicated negligible amounts of Mount McRae Shale within the proposed mine pit shell and, therefore, ARD is not considered a significant risk at Marandoo (Section 4.4).

The proposed mine pit shell intersects minor amounts of the unmineralised BIF (waste) which contains naturally-occurring crocodilite/asbestos (Section 4.4); however, this does not enter the processing system. As the mineralised Marra Mamba Iron Formation does not contain asbestiform material, there is no potential for this material to enter the processing circuit at Marandoo. There are several systems in place (including grade control) to prevent asbestos being fed into the plant.

Following clearing of vegetation and stripping of topsoil, waste rock material (overburden) will be removed from the surface to allow for the excavation of ore. This material will initially be directed to surface waste dumps and, thereafter, will be used in progressive backfilling of the mine pit where possible.

Clayey material will be managed through selective handling and dumping strategies to maintain dump stability. The design of waste dumps will take into account the need to either encapsulate these weak erodible materials and/or restrict dump height. The Proponent's Final Waste Dump Landform Guidelines take into account the erosion potential of the waste material. Opportunities to utilise clay material to line surface water control channels will be investigated (in which case adequate compaction and erosion control measures will be implemented to mitigate the erosion potential of these materials). The indicative volume of waste clay material anticipated from the Proposal is in the order of 10–100 Mm^3, depending on the final mine pit layout.

Proposed mitigation and management measures

The storage and disposal of wastes generated by the Proposal will be controlled through implementation of a Waste Management Plan (Appendix 2) which includes the following management measures:

- maintaining and servicing equipment regularly
- maintaining and operating workshop and liquid effluent control systems in accordance with existing practices
- disposing of domestic waste at the existing approved landfill facility at Marandoo
- collecting and treating ablution effluent in a licensed sewage treatment facility
- maintaining sediment control structures at washdown facilities
- maintaining existing management practices employed by the Proponent if any ARD-generating or asbestiform material is encountered
- maintaining hydrocarbon treatment facilities at the workshop and washdown facilities
- disposing of treated wastewater at spray irrigation areas at both the operations camp and Marandoo
- re-using treated water from the workshop and washdown facilities for dust suppression on non-pit roads where possible
- strict grade control procedures to ensure asbestiform material does not enter the processing circuit.

6.4 Greenhouse Gases

The greenhouse effect is a natural phenomenon caused by atmospheric (primarily carbon-based) gases, where heat radiating off the Earth's surface is trapped within the atmosphere. Greenhouse gases in the atmosphere include carbon dioxide (CO_2), water vapour, methane, nitrous oxide, non-methane volatile organic compounds, halocarbons, carbon monoxide and sulphur hexafluoride. The main anthropogenic greenhouse gas emission is CO_2, which has increased in concentration in the atmosphere by about 31% over the last 200 years (EPA 2002b).

The warmth experienced through the greenhouse effect is essential to support life on Earth; however, there is a general consensus that warming over the last century has been exacerbated due to increased emissions of greenhouse gases from anthropogenic sources. This 'global warming' is believed to be a major factor in altering the climate of the Earth ('climate change').

In most circumstances, including this assessment, the EPA applies the following objective to the assessment of Proposals where greenhouse gas emissions are a relevant factor:

To minimise emissions to levels as low as practicable on an ongoing basis and consider offsets to further reduce cumulative emissions.

The *National Greenhouse and Energy Reporting Act 2007* (Cwth) (NGER Act) establishes a single, national system for reporting greenhouse gas emissions, abatement actions, and energy consumption and production by corporations. The NGER Act requires controlling corporations to register and report to the Greenhouse and Energy Data Officer if they emit greenhouse gases, produce energy, or consume energy at or above specified quantities per financial year.

From 1 July 2008[26], corporations will be required to register and report if:

- they control facilities that emit 25 kt or more CO_2 equivalents (CO_2-e), or produce/consume 100 terajoules (TJ) or more of energy per financial year
- their corporate group emits 125 kt or more CO_2-e, or produces/consumes 500 TJ or more of energy.

In October 2002, the EPA released Guidance Statement No. 12, 'Guidance Statement for Reducing Greenhouse Gas Emissions' (EPA 2002b). The statement sets out objectives regarding the minimisation of greenhouse gas emissions from new or expanding operations.

Carbon rights legislation was passed by the Western Australian Parliament in 2003. The purpose of the Bill is to provide for the registration a 'carbon right' and accompanying 'carbon covenant' on land titles. The Bill provides certainty to those wanting to trade in carbon rights and gain the credits or emission offsets which arise from sequestration.

The Western Australia Greenhouse Strategy was released in 2004 and sets out the state government's response to climate change. The state recognises the weaknesses and limitations of the Kyoto Protocol, but believes the Protocol represents an essential step towards dealing with climate change. Key components of the Strategy include government leadership, reducing emissions, local government and community involvement, and national and international representation.

Activities or aspects of the Proposal that will emit greenhouse gases include:

- fuel usage by mobile plant and equipment
- energy usage by processing plant and conveyors
- explosives used for blasting
- land clearing and revegetation.

Greenhouse gas emissions from the Proposal will be approximately 190 000 t CO_2-e per year (Table 24), with a carbon intensity of approximately 15.3 t CO_2-e/kt of ore produced. Greenhouse gas emissions from the existing Marandoo mining operation are approximately 50 000 t CO_2-e per year, with a carbon intensity of approximately 4.6 CO_2-e/kt of ore produced. Sequestration of CO_2-e by rehabilitation is also not included in the peak emission calculation.

26 Lower thresholds for corporate groups will be phased in by 2010–2011. The final thresholds will be 50 kt CO_2-e or 200 TJ of energy.

Emissions as a result of vegetation clearing are once off and will not contribute to the peak annual emissions shown in Table 24. Based on the estimated clearing footprint required for the Proposal (940 ha), a once-off emission of 50 000 t CO_2-e is expected over the period of construction and ground preparation.

Table 24
Estimated peak annual greenhouse gas emissions from the Proposal

Emission source	Predicted emissions (t CO_2-e/yr)
Mobile mine site (diesel)	98 000
Conveyor/plant infrastructure	88 000
Explosives	4000
Total peak annual emissions	190 000

The Proposal will result in an increase in peak annual greenhouse emissions compared to existing Marandoo operation. A number of factors will contribute to this increase, including the significant increase in the stripping ratio (from 1:1 to 4.5:1 waste:ore) and the large percentage of the waste likely to be rehandled back into the pit void during mining. The elongated shape of the ore body dictates that a haul road in excess of 11 km must be built, as the below watertable operations will extend further east than existing operations.

The shift from crushing to wet processing is also a significant source of additional energy use; however, the use of this method is essential due to the geotechnical qualities of the ore.

Proposed mitigation and management measures

The Proponent has been formally involved in climate change matters going back more than a decade. All existing operations have targets for increasing efficiency and for reducing energy consumption and the emission of greenhouse gases. These targets are set to be formalised during 2009. At Marandoo, these targets will be revised to reflect the change from above to below watertable operations. The Proposal has been designed in light of the current state of knowledge and potential future commitments, such as emissions trading schemes, which may be introduced during the life of the Proposal. Implementation of greenhouse gas and energy conservation measures will enable the company to minimise emissions and provide a mechanism for continuous improvement in greenhouse gas emissions resulting from the Proposal.

Greenhouse gas emissions at Marandoo will be reduced through implementation of the following management measures:

- conducting an energy efficiency audit
- maintaining membership of the Australian Greenhouse Challenge Plus program
- preventing over-clearing of vegetation
- utilising existing infrastructure at Marandoo and reducing the need for additional infrastructure
- increasing the efficiency of the operation through scheduling and prevention of rehandling
- increasing the efficiency of waste and ore haulage
- regularly maintaining and servicing equipment
- evaluating and adopting appropriate technology during the detailed design phase to improve greenhouse efficiency.

An energy efficiency audit will be conducted once sufficient information becomes available.

In accordance with the requirements under the NGER Act, the Proponent will report annually on:

- production of energy
- consumption of energy
- Scope 1 (direct) emissions
- Scope 2 (indirect) emissions.

Implementation of greenhouse gas and energy conservation measures will enable the company to minimise emissions and provide a mechanism for continuous improvement in greenhouse gas emissions resulting from the Proposal.

6.5 Dust emissions

Dust is generated during mining mainly by mechanical disturbances such as blasting, earthmoving and road traffic on unsealed surfaces. In dry, windy conditions, particles can be lifted from open or disturbed areas, resulting in visible dust emissions. In the assessment of environmental impacts, dust is more conventionally referred to as 'particulates' or 'airborne particulates'.

Most airborne particulates likely to originate from the proposed operations are larger than PM_{10} and are more associated with nuisance than public health problems[27]. The larger particles tend to settle back to the ground within a short range (less than 300 m) from the source.

Dust may have physical effects on plants, although this is likely to be restricted to immediate peripheral vegetation and will be mitigated by periodic high rainfall events, which would remove built-up material on leaves. Dust can also adversely affect health where there are nearby residences; however, due to the remoteness of the mine from any residential areas, there will be no air quality impact to any residents as a result of the Proposal.

27 **PM_{10} refers to particulate matter with an equivalent aerodynamic diameter of 10 µm or less.**

The generation of dust from mining and ore handling operations will depend on:
- the frequency at which a dust generating activity takes place
- meteorological conditions such as wind speed
- composition of dust including particle size distribution, particle density and moisture content
- the condition of the dust source.

Activities or aspects of the Proposal that will result in dust emissions include:
- physical disturbance to the land surface during construction of infrastructure and mining (removal of vegetation, blasting and excavations)
- ore handling and processing at plant sites and between stockpile areas
- haulage and light traffic on unsealed roads
- wind episodes over dry, open mine areas, stockpiles and unsealed roads.

The predicted Run of Mine moisture from the dewatered ore body is above the dust extinction moisture values for typical Marandoo ore. Therefore, handling and processing of below watertable ore during the Proposal will potentially create less dust than is currently produced from above watertable ore.

The potential for dust generation as a result of the Proposal will be limited by:
- undertaking secondary crushing, wet processing and rail loadout in enclosed facilities
- the coarse and wet nature of the mined material
- backfilling of waste and stockpiling of low grade ore in mine pit voids which reduces exposure to wind
- progressive rehabilitation of disturbed areas.

Proposed mitigation and management measures

The generation of dust within the Proposal area will be controlled through the implementation of the Dust Management Plan (Appendix 2) including the following management measures:
- application of water to haul roads, working surfaces and stockpiles as required
- ore moisture content control and operation of dust extraction systems at processing and rail loadout facilities
- clearing work areas only as they are required
- operation of primary and secondary scrapers to remove excess material from plant conveyor belts
- progressive rehabilitation of disturbed areas to minimise total exposed area.

Dust emissions from the Proposal will be subject to controls imposed through a licence issued under the EP Act.

Through implementation of the above existing and proposed control measures, dust emissions are not expected to be a significant impact of the Proposal.

6.6 Noise and vibration

The existing and proposed mining operations are remote from any noise-sensitive receptors, although Mount Bruce (approximately 2 km north of the mine) is visited by tourists.

The Environmental Protection (Noise) Regulations 1997 (WA) set noise limits (assigned levels) for various types of receiving premises and buildings associated with noise-sensitive uses. The regulations are not applicable to Mount Bruce (as there are no noise-sensitive premises at Mount Bruce).

The most significant noise emission sources that could affect receptors at Mount Bruce are likely to be mobile mining equipment items such as haul trucks, dozers, excavators and graders (SVT 2008). In particular, reversing beepers on this equipment have the potential to be audible at the lookout on Mount Bruce.

It is unlikely the proposed wet processing plant will have any additional noise impact at Mount Bruce compared to the existing dry processing plant because:
- noise from the new wet processing plant is unlikely to be any higher than for the dry plant, and the existing dry plant has not been identified as a source of noise impacts
- the wet plant is to be located south of the existing dry plant further away from Mount Bruce
- wet and dry plants will not be operated simultaneously.

Blast sizes are not expected to be any greater than existing blasts at Marandoo. For the life of the mine, the frequency of blasting is likely to be low because most of the material to be moved is not expected to require blasting. As the expansion develops, the operational pits will move to the east, further away from Mount Bruce and hence blast noise will be further attenuated due to increased distance. Furthermore, the majority of blasting activity will occur further away from areas commonly accessed by the public in Karijini National Park. Therefore, noise and vibration from blasting would not be expected to affect recreational values in the locality.

EPA Draft Guidance Statement No. 8 (EPA 2007a) for assessment of environmental noise from new Proposals recommends that camps for operational personnel should be located and designed 'so as to achieve compliance with the assigned noise levels and acceptable standards'. The proposed operations camp will be located approximately 13 km to the north-west of Marandoo and will not be affected by noise from the existing or proposed mining operations (SVT 2008). Although noise from the Proposal is not expected to exceed any legislative criteria, the following noise mitigation measures should assist in reducing any potential noise impacts:
- use of 'smart reversing alarms'
- selection and location of conveyor start-up alarms to reduce noise impacts
- posting of typical blasting times at the Mount Bruce lookout.

Although any vibration impact that results from blasting is expected to be reduced compared to the existing Marandoo operation, the following mitigation measures should assist in managing any recreational or public safety concerns:

- setting blast exclusion zones to eliminate risks to public safety, including vibration-related impacts such as rock falls
- restricting public access within blast exclusion zones and putting procedures in place for evacuating these areas
- publishing typical blast times at the Mount Bruce lookout car park to manage recreational concerns, in consultation with DEC.

The Proposal will be subject to a licence under the EP Act that may potentially control noise emissions and vibration. Noise from the Proposal will not perceptively increase above existing operations. Vibration will not increase as a result of the Proposal.

6.7 Recreation and tourism

The Marandoo mine lease and rail corridor were excised from Karijini National Park in 1991. The Park is the second-largest National Park in Western Australia and attracts over 100 000 visitors each year. Visitor numbers to other major National Parks in the Pilbara are much lower and do not show the same steadily increasing trend as observed at Karijini National Park (Table 25).

Table 25
Karijini National Park visitor numbers

National Park	2002/2003	2003/2004	2004/2005
Karijini	88 284	104 098	114 110
Millstream Chichester	27 540	14 916	20 895
Rudall River	4000	5000	5000
Collier Range	300	500	Data not available

Data sourced from the Department of Environment and Conservation (March 2008). Note figures are estimates only for financial years determined or extrapolated from metrocount vehicle classifiers, traffic counters, ticket sales and entry/camping fees.

Whilst Karijini National Park is the principal recreational destination in the vicinity of the Proposal, other nearby tourist locations include:

- Mount Nameless (adjacent to the Tom Price township)
- Kings Lake (approximately 5 km from the Tom Price township)
- Mount Sheila Lookout (approximately 35 km north of the Tom Price township).

Karijini National Park is best known for the spectacular gorges in its northern sections, which are the focus for most visitors to the Park (CALM 1999). Each year many visitors climb Mount Bruce (Figure 23), which offers exceptional views of the Hamersley Ranges and interceding valleys. Mount Bruce, Mount Meharry and the more remote areas in the south of the Park are attracting more visitors as these areas become better known (CALM 1999).

Camping is a popular activity in Karijini National Park, with facilities and services provided at two main locations: Dales Recreation Area and Savannah Camp. Camping outside designated camping areas is prohibited, except under permission of the ranger in charge (CALM 1999). Most visitors enter the Park via Karijini Drive, whilst smaller numbers enter from the west along Mount Bruce Road and from the south-east along Juna Downs Road (CALM 1999).

The Proposal requires approximately 500 personnel during operations, plus an additional 200 personnel during shutdown maintenance periods. The size of the Proposal workforce and the proximity of both the mine site and operations camp to Karijini National Park (and other tourist locations) may potentially affect the existing social, recreational and tourist values in the area; however, the fly-in/fly-out roster type, combined with the length of working days (12 hours) will limit the time available to personnel to undertake recreational pursuits.

Proposed mitigation and management measures

Recreational and tourism values in the vicinity of the Proposal area will be maintained through the implementation of a comprehensive induction program (Appendix 2). Key measures include:

- informing mine staff and contractors of the requirement to remain on established walking and vehicle tracks wherever possible
- educating mine staff and contractors as to appropriate, low-impact behaviour within Karijini National Park
- educating mine staff and contractors on the potential for off-road access to result in increased erosion and weed dispersal
- informing mine staff and contractors of relevant National Park policies and requirements, including in relation to entrance fees, campfires and firewood collection
- emphasising prohibition of alcohol consumption in National Parks, except in areas as permitted by the DEC.

6.8 Public risk and safety

The Proposal is expected to increase traffic volumes in the vicinity of the Proposal area. Traffic may increase from roads connecting the mine especially during peak travel times to/from work, including Karijini Drive, which services the operations camp and connects the mine to Tom Price and Paraburdoo.

Ammonium nitrate will be used for blasting at Marandoo. Ammonium nitrate is classified as a dangerous good and poses a threat to public safety due to associated fire and explosive hazards.

Proposed mitigation and management measures

Measures are already in place at Marandoo to minimise potential risks to public safety. These measures will be continued through the implementation of management strategies that include:

- installing signage around the work site warning of public risk
- restricting speed limits within the vicinity of the work site to 40 km/h
- including public safety aspects in induction training such as requirements to obey road laws to reduce the risk of injury, death and damage to the environment
- transporting ammonium nitrate by licensed vehicles in accordance with existing practices and the Dangerous Goods (Transport) (Explosives by Road and Rail) Regulations 1999 (WA)
- ensuring people are at a safe distance from the site during blasting activities
- ensuring blasting will not take place near public roads or the proposed dewatering infrastructure
- applying water to the work site and detours as required to reduce dust generation as far as practicable
- transporting and storing goods in accordance with appropriate regulations and guidelines.

Minimising our impact on the environment

The Proponent will minimise environmental impacts through the implementation of mitigation and management measures.

7. Environmental management framework

7.1 Overview

The Proponent will minimise environmental impacts through the implementation of ongoing management measures, which include:

- maintaining an Environmental Management System (EMS) and business systems
- implementing an Environmental Management Plan (EMP) for the Proposal (Appendix 2)
- developing environmental improvement plans each year for priorities identified in reviews of systems and performance
- improving mechanisms to measure water and energy use, and greenhouse gas emissions
- improving the efficiency of natural resource use
- updating plans for disturbance and closure, progressively rehabilitating and measuring success
- training staff and contractors in environmental requirements of their work
- ensuring that community views are sought, respected and considered
- reporting regularly to stakeholders on performance
- aligning with the Rio Tinto Health, Safety and Environmental Policy.

The Proponent acknowledges the environmental protection principles listed in Section 4a of the EP Act through its strong commitment to sustainable development and environmental management at its operations (Section 1.9). These principles are clearly reflected in the Proponent's Environmental Policy (Section 7.2) and the Rio Tinto corporate environmental standards that are being implemented across the Rio Tinto Group.

The Proponent maintains membership of the Australian Greenhouse Challenge Plus program and continues to evaluate and adopt appropriate technology to improve greenhouse efficiency wherever possible (Section 6.4).

7.2 Proponent's environmental policy

The Proponent aims to conduct business in an efficient and environmentally responsible manner that is compatible with the expectations of shareholders, the government and the community. The Proponent also recognises that environmental responsibilities go beyond those required under statutory regulations to encompass social obligations, leadership in sustainable development and minimising environmental impacts.

Marandoo operates under the Proponent's Environmental Policy, which was signed in February 2006 by the company's executive management. The Policy is the guiding document for environmental management and provides context and specific direction for continuous improvement.

The Proponent also operates under an ISO14001 framework through the Iron Environmental Management System (IEMS). ISO14001 is an internationally recognised continuous improvement model, the key elements of which include assessing environmental risk and legal requirements, developing objectives and targets for improvement, training, operational control, communication, emergency response, corrective actions, audits and review.

The Proponent's sites were certified to ISO14001 in 2003. To maintain ISO14001 certification, these sites are required to successfully complete regular external independent surveillance audits. Successful demonstration of commitment to continual improvement resulted in re-certification of the Proponent's sites to ISO14001 in 2006.

7.3 Environmental risks and manageability

The approach taken in this environmental review has been based on a risk assessment approach to characterise environmental factors, determine potential impacts and develop mitigation and management measures.

The Proponent has extensive experience in managing the development, operation and environmental compliance of similar projects (including the existing Marandoo operation) and this experience is anticipated to lead to a greater certainty in achieving desirable environmental outcomes.

The environmental aspects of the Proposal will be primarily managed through the EMP and Conceptual Closure Plan, existing environmental policy, relevant licences and the implementation of the proposed Environmental Conditions for the Proposal. The Proponent will also ensure an acceptable closure outcome through ongoing revision of the Conceptual Closure Plan for the Marandoo operation, which will include development of closure completion criteria, in consultation with relevant stakeholders.

The Proponent has consulted with stakeholders (including government agencies, non-government organisations, traditional owners, community groups and neighbours/residents) to scope the potential impacts of the Proposal and to determine the significance of environmental issues and the acceptability of mitigation and management. This process substantially improves the likelihood that all significant environmental issues have been identified, investigated and mitigated as far as practicable.

7.4 Environmental Management Plan (EMP)

The environmental aspects of the Proposal will be primarily managed through the EMP for the Proposal. This has been prepared and will be implemented to manage specific environmental issues arising from the Proposal (Appendix 2). The purpose of the EMP is to document environmental management objectives and strategies in relation to the Proposal, including:

- environmental factors potentially affected by the construction and operational phases of the Proposal
- measures to prevent, minimise, mitigate and manage any potential environmental impacts of the Proposal
- monitoring and reporting procedures.

The Proponent has comprehensive standard corporate practices in place to manage potential environmental impacts at all operations, including the existing Marandoo above watertable operation. These standard procedures address in detail all management measures required to mitigate potential risks resulting from the implementation of the Proposal.

The following management plans have been developed as part of the EMP:

- Groundwater Management Plan
- Surface Water Management Plan
- Vegetation and Flora Management Plan
- Coolibah Management Plan
- Terrestrial Fauna Management Plan
- Fire Management Plan
- Waste Management Plan
- Dust Management Plan
- Cultural Heritage Management Plan.

The majority of the management plans represent a summary of the relevant existing corporate procedures; however, the Groundwater, Surface Water and Coolibah Management Plans have been developed to a higher detailed standard than other management plans, to address uncertainties in predicted impacts, or to provide additional protection to areas of high conservation significance. This has been achieved through the incorporation of an adaptive management plan and/or additional site-specific management strategies.

The Cultural Heritage Management Plan represents a summary of the site-specific Cultural Heritage Management Plan that has already been developed for Marandoo. This Cultural Heritage Management Plan will be further refined as results of ongoing surveys become available.

The adaptive management approach utilises the following three trigger levels:

- Level 1 trigger: Focus - establish a watching brief. Identification of the cause of trigger level exceedence is required, to determine whether the trigger event is the effect of mining activities or as a result of natural changes. This level 1 'focus' trigger will ensure appropriate monitoring and management attention is given to the event or issue. No significant or irreversible environmental impacts are expected at this trigger level.
- Level 2 trigger: Investigate - detailed investigation required. Causal investigations will be undertaken, with an emphasis on increased monitoring. Remedial actions may be taken where necessary. This level 2 'investigate' trigger will ensure the event or issue is understood and appropriate response measures are developed. No significant or irreversible environmental impacts are expected at this trigger level.
- Level 3 trigger: Action - highest investigation level with advisory notification of event or issue to relevant stakeholders, including the DEC and DoW. Active intervention/contingency measures will be implemented as required. This level 3 'action' trigger will ensure appropriate counter-measures are deployed.

Rehabilitation is addressed in the Closure Plan (Section 5.10). The EMP includes details of monitoring that will be undertaken, and will be regularly reviewed and revised where relevant.

Applying Conditions to the Proposal

The Proponent has developed proposed Environmental Conditions to address the key environmental aspects of the Proposal that are not capably managed under other existing regulatory controls such as a DEC Licence for prescribed premises. These Environmental Conditions are proposed to apply to the whole operation (original Proposal and this Proposal) and to replace the existing Conditions and Proponent commitments of Statement No. 286 that applies to the above watertable original Proposal.

8.1 Overview

The Proponent has developed proposed Environmental Conditions (Section 8.4) to address the key environmental aspects of the Proposal that are not capably managed under other existing regulatory controls such as a DEC Licence for prescribed premises. These Environment conditions are proposed to apply to the whole operation (original Proposal and this Proposal) and to replace the existing Conditions and Proponent commitments of Statement No. 286 that applies to the above watertable original Proposal.

In addition to controls under Part IV of the EP Act, other approvals will also be required for the operation that will impose further controls on the Proposal (Section 8.2).

The Proponent has also proposed environmental offsets (Section 8.3).

8.2 Summary of likely environmental control instruments

Table 26 outlines the controls that either currently exist or will be put in place to ensure appropriate management of the Proposal for each key environmental factor. The controls include:

- implementation conditions as per any Statement issued by the Minister for the Environment
- conditions of the DEC (Environmental Management Division) Works Approval (under Part V of the EP Act) for construction of works on prescribed premises
- conditions of the DEC (Environmental Management Division) Licence (under Part V of the EP Act) for the operation of activities on prescribed premises (ore processing, landfill and sewage facility)
- conditions of the Licences to 'Take Water' and disturbance to bed and banks (under *Rights in Water and Irrigation Act 1914* (WA)).
- relevant Rio Tinto Environmental Standards and guidelines.

Proponent management controls that will be regularly reviewed and that will apply to the Proposal include measures and/or actions contained within the following documents:

- Construction Environmental Management Plan (CEMP)
- Operation Environmental Management Plan (OEMP)
- Annual Environmental Report
- Annual Aquifer Review
- Conceptual Closure Plan.

Table 26
Statutory and environmental management controls for the Proposal

	Topic	Environmental Conditions*	EMP	Other relevant legislation and regulations**
Key environmental factors				
Vegetation and flora	Protection of areas not approved to be cleared under Part IV of the EP Act		✔	✔ NVCP
	Protection of significant vegetation	✔	✔	
	Protection of Declared Rare Flora and Priority flora		✔	✔ Wildlife Conservation Act
	Weed management		✔	
	Fire Management		✔	
	Pre-ground disturbance flora surveys		✔	✔ Wildlife Conservation Act
Fauna	Protection of areas not approved to be cleared under Part IV of the EP Act		✔	✔ NVCP
	Protection of significant habitat	✔	✔	
	Protection of rare and endangered fauna species		✔	✔ Wildlife Conservation Act
	Feral fauna management		✔	
Groundwater	Prevention of groundwater contamination		✔	✔ Works Approval/Licence under the EP Act
Coolibah	Protection against impacts from groundwater drawdown	✔	✔	✔ Licence under the RIWI Act
	Protection against altered surface water regime (not watercourses)		✔	
	Ongoing knowledge development (for example, Coolibah research)		✔	
Mulga	Protection against altered surface water regime (not watercourses)		✔	
	Fire management		✔	
Surface water and water quality	Drainage management		✔	
	Discharge of excess water from dewatering	✔	✔	✔ Works Approval/Licence under the EP Act
	Prevent surface water contamination		✔	✔ Works Approval/Licence under the EP Act
Visual amenity and landscape values	Undertaking a visual assessment of the Proposal in relation to visibility of the Marandoo ridgeline from the Mount Bruce visitor carpark lookout at finalisation of the mine plan and every five years thereafter during operations and at closure	✔		
Closure	Closure and rehabilitation	✔	✔	✔ Agreement Act ✔ Mining Act
	Collection of provenance seed		✔	
	Develop rehabilitation completion criteria	✔	✔	✔ Agreement Act ✔ Mining Act
	Undertake closure to meet pre-determined targets	✔	✔	✔ Agreement Act ✔ Mining Act
Other management considerations				
Noise and vibration	Noise and vibration management			✔ Works Approval/ Licence under the EP Act ✔ Environmental Protection (Noise) Regulations 1997

	Topic	Environmental Conditions*	EMP	Other relevant legislation and regulations**
Dust	Dust management		✔	✔ Works Approval/ Licence under the EP Act
Aboriginal heritage	Protection of Cultural heritage sites		✔	✔ Aboriginal Heritage Act
Waste	Mineral (including asbestos)		✔	✔ Health Act/Licence
	Liquid waste (including sewage)		✔	✔ Works approval under the EP Act ✔ Health Act
	Solid waste disposal		✔	✔ Works Approval/Licence under the EP Act
Greenhouse gases	Reporting			✔ NGERA
Recreation and tourism	Workforce management		✔	

*** Environmental Conditions proposed by the Proponent (Section 8.4)**
**** Other relevant legislation and regulations (Section 8.2)**

Abbreviations
NVCP - Native Vegetation Clearing Permit, Wildlife Conservation Act - *Wildlife Conservation Act 1950* (WA),
EP Act - *Environmental Protection Act 1986* (WA), RIWI Act - *Rights in Water and Irrigation Act 1914* (WA)
Agreement Act - *Iron Ore (Hamersley Range) Agreement Act 1963* (WA), Mining Act - *Mining Act 1978* (WA)
Aboriginal Heritage Act - *Aboriginal Heritage Act 1972* (WA), Health Act - *Health Act 1911* (WA)
NGERA - *National Greenhouse and Energy Reporting Act* (Cwth)

8.3 Summary of proposed environmental offsets

The environmental offsets proposed by the Proponent have been developed in accordance with EPA Position Statement No. 9 (EPA 2006a) and EPA Draft Guidance Statement No. 19 (EPA 2007a) (Table 27).

Environmental assets were classified in terms of their relative value to allow application of the decision-making matrix presented in Environmental Position Statement No. 9 (EPA 2006a). Each asset has been assessed in terms of the ability to mitigate the potential on-site impacts to the asset and the significance of any residual impact after mitigation and management measures are applied. Where there are residual impacts to potential critical or high-value environmental assets, environmental offsets are proposed.

Native vegetation/habitat and flora may be classified as a critical asset, high-value asset, or a medium to low-value asset, depending on its condition and/or its perceived value to the Community (EPA 2007a, 2008a). In accordance with EPA Guidance Statement No. 9 (EPA 2007a) and EPA Guidance Statement No. 33 (EPA 2008a), vegetation within Karijini National Park is likely to be considered a critical asset. Native vegetation within the Proposal area could range from low to high value depending on its conservation significance, condition and proximity to existing disturbance (Section 5.4.1).

Complete avoidance of vegetation/habitat and flora within the proposed development area is not possible, and therefore an offset is proposed (Table 27). Both direct and contributing offsets have been proposed.

Table 27
Assessment of proposed environmental offsets against EPA Position Statement No. 9

Environmental assets	Asset value	Potential inherent impacts
Coolibah woodland	Priority Ecological Community. High value asset.	Dewatering of the confined aquifer may lead to drawdown of groundwater levels in the unconfined aquifer, which may reduce groundwater availability for the Coolibah woodland. Intersection of the unconfined aquifer by the proposed mine pit will cause seepage and subsequent drawdown in the unconfined aquifer, which may reduce groundwater availability for the Coolibah woodland. Vehicle and earth movements could potentially introduce and/or spread weed species across the mine site and adjacent areas of Karijini National Park. Alterations to the local hydrology at the mine site may impede surface water flow to the Coolibah woodland.
Mulga	Stands on the Mount Bruce Flats are particularly important to the ongoing representation and conservation of Mulga in the Pilbara region. High value asset.	Physical presence of mine pit and infrastructure has already altered surface water flow paths of mine site runoff on the Mount Bruce Flats since 1994. Ignition sources at Marandoo may increase the frequency and/or intensity of fire events, which may result in the loss of fire sensitive Mulga communities. However, there is no evidence of this since the Marandoo mine commenced operations, Vehicle and earth movements could potentially introduce and/or spread weed species across the mine site and adjacent areas of Karijini National Park.
Vegetation disturbance (including riparian vegetation)	The Pilbara region is considered a biodiversity hotspot. Riparian vegetation units (Table 9) that occur within the Proposal footprint include: 2a, 2b, 2c, 2e and 4a (moderate conservation significance). High value asset.	Vegetation clearing within the mining lease and at the Southern Fortescue borefield will directly disturb riparian vegetation units. Alteration of surface water flows through development of mine pits, waste dumps and infrastructure may affect local water availability for some riparian species. Surface discharge of excess water into the Southern Fortescue River tributaries will result in temporary alteration to the ecology of the system.

	Mitigation and management measures	Predicted residual impact	Proposed offsets
	The Coolibah woodland on the Mount Bruce Flats will be maintained through implementation of a comprehensive monitoring and adaptive management plan detailed in the Coolibah Management Plan (Appendix 2). Key elements of the Management Plan include: • monitoring of the Mount Bruce Flats Coolibah woodland (impact site) and a reference site for foliage cover and visual inspection including ratio of healthy crowns to poorer crowns by diameter size classes • development and continual refinement of appropriate trigger values for each monitored/measured parameter • implementation of remedial contingency actions, in liaison with the DEC, in the event that trigger values are approached or exceeded.	The estimated magnitude and rate of groundwater drawdown in the unconfined aquifer are much lower than the magnitude and rate of natural groundwater level fluctuations across the Mount Bruce Flats and, as such, are not anticipated to affect the Coolibah woodland. However, as a contingency, an adaptive management plan will be applied with the objective of protecting the Coolibah woodland (Appendix 2). The residual risk to the Coolibah woodland is low.	**Direct** The Proponent will rehabilitate and manage a defined area within Coondawanna Flats, which is located within Juna Downs pastoral station and due to be relinquished to Karijini National Park in 2015. This location has similar vegetation assemblage to the Mount Bruce Flats Coolibah woodland. **Contributing** Undertake investigations and research to address Coolibah water use requirements.
	Existing values of Mulga communities on the Mount Bruce Flats will be maintained through implementation of surface water and fire management measures outlined in the Surface Water Management Plan and Fire Management Plan (Appendix 2). Key elements of the Management Plans relevant to protection of Mulga communities include: • discharging stormwater collected within mine pits along a drain to culverts through the railway embankment • ensuring any water discharged to the natural environment complies with the ANZECC Water Quality Guidelines (ANZECC/ARMCANZ 2000) • providing basic fire awareness and fire fighting training to all site personnel and ensuring appropriate fire fighting equipment is available on-site at all times • maintenance of adequate fire breaks across the mine site and around working areas where required • appropriate fire-fighting capability at the mine which would benefit suppression • weed control as required.	No further significant change to the modified hydrological regime of Marandoo Ridge and the Mount Bruce Flats is expected.	**Contributing** Undertake investigations and research to address: • threats to Mulga communities such as fire and climate change • improve on-site fire-fighting capability to assist with fires in the Park and the support of DEC/indigenous prescribed burning in the area.
	Volume of excess dewatering water that may be required to be discharged to the environment has been minimised through application of the DoW hierarchy of water management options.	It is anticipated that natural surface water flows will be maintained onto Mount Bruce Flats. The discharge of excess dewatering water is expected to result in only temporary modification to the riparian system and is not expected to create a significant impact. Approximately 940 ha will be cleared for infrastructure development.	**Contributing** Provision of support for investigations and research to address: • fire management • weed management.

Environmental assets	Asset value	Potential inherent impacts
Karijini National Park	Critical environmental asset.	Dewatering of confined aquifer and/or intersection of the unconfined aquifer may potentially affect National Park values through decreased health and extent of the Coolibah woodland on the Mount Bruce Flats; altered groundwater discharge to springs and water levels in groundwater-fed pools in the Park; decreased discharge from the Mount Bruce Flats to Turee Creek. Interception of surface water flows from the mining area may reduce flows to Mulga on the Mount Bruce Flats and decrease discharge from the Flats to Turee Creek. Access to the Park by the Proposal workforce may decrease amenity and increase traffic and associated public safety risks within the Park. Mining operations may introduce and/or spread weeds and feral animals into adjoining areas of the Park. Ignition sources on the mine site may result in increased frequency and/or intensity of fire events resulting in the loss of fire sensitive vegetation (particularly Mulga). Hydrocarbon spills on the mine site may contaminate groundwater and/or surface runoff to adjoining areas of the Park. Dust emissions, mine site infrastructure and altered landforms may affect visual amenity at Mount Bruce. Noise emissions from general mine operations and blasting may increase noise levels at Mount Bruce.

8.4 Proposed environmental conditions

The Proponent proposes the Environmental Conditions for the Proposal presented in Table 28 for incorporation into any Statement issued to apply to the original Proposal and this Proposal. The implementation of the Proposal will be in line with the impacts assessed in the PER, and a summarised environmental footprint (Table 29) is proposed to form Schedule 1 of any Ministerial Statement issued by the Minister. Trigger values proposed to form Schedule 2 have been specified (Table 30).

These conditions have been proposed so as not to duplicate other regulatory controls that are capably and likely to be applied under other existing legislation. The Proponent has developed these conditions having given consideration to the existing above watertable conditions and Proponent commitments detailed in Statement No. 286 (Table 31). The proposed conditions replace the conditions and commitments in the existing Statement. The Proponent considers there are a number of conditions and Proponent commitments in the existing Statement that are either not auditable or no longer relevant (that is fulfilled).

	Mitigation and management measures	Predicted residual impact	Proposed offsets
	Implementing a comprehensive monitoring and adaptive management program to protect the Coolibah woodland on the Mount Bruce Flats. Continuing to assist with fire and weed management across the Mount Bruce Flats, in collaboration with the DEC and other Karijini National Park management bodies. Ensuring any water discharged to the natural environment complies with the ANZECC Water Quality Guidelines (ANZECC/ ARMCANZ 2000) Educating mine staff and contractors as to appropriate, low-impact behaviour at popular visitor nodes within Karijini National Park (particularly the northern gorges) and informing mine staff and contractors of relevant National Park policies and requirements. Rehabilitation of disturbed areas shall aim to achieve safe, stable and self -ustaining landforms which are compatible with surrounding areas. Incorporating the Mount Bruce Flats Coolibah woodland into a regional study currently being undertaken by UNSW to provide input into the comprehensive monitoring and adaptive management plan proposed to be implemented. Consulting with Karijini National Park management bodies in accordance with existing arrangements under the SMU and MOU (regular SMU meetings which will include discussion of the Proposal).	No significant impacts to the Karijini National Park are predicted.	**Direct** By rehabilitating a defined area of Coondawanna Flats, this will help to create habitat linkages into Karijini National Park. This could include stock exclusion and weed management. **Contributing** The Proponent will: • assist with fire management undertaken by DEC in adjacent Karijini National Park • assist with weed and feral animal control within Karijini National Park • contribute funding to assist with the management of recreation within Karijini National Park.

A condition has not been proposed if the environmental impact can, or is adequately addressed by other environmental control instruments (Section 8.2), the proposed EMP (Appendix 2) or the proposed Closure Management Plan (Section 5.10 and Appendix 1). The proposed conditions are outcome-based and are thus auditable. To provide additional protection for the Coolibah woodland and tributaries of the Southern Fortescue River, adaptive management plans have been prepared and an adaptive management condition proposed in Table 28. Any breach of these values will require a response involving investigation of potential impacts and implementation of mitigation and management measures and stakeholder consultation, as required.

Table 28
Proposed MMP2 environmental conditions

Condition No.	Proposed Condition
Proposal Implementation	
1-1	The Proponent shall implement the Proposal subject to the conditions of this statement and within the footprint defined in Schedule 1 of this Statement.
Proponent Nomination and Contact Details	
2-1	The Proponent nominated by the Minister for the Environment under section 38(6) or 38(7) of the *Environmental Protection Act 1986* (WA) is responsible for the implementation of the Proposal.
2-2	The Proponent shall notify the Chief Executive Officer (CEO) of the Department of Environment and Conservation (DEC) of any change of the name and address of the Proponent for the serving of notices or other correspondence within 30 days of such change.
Time Limit of Authorisation	
3-1	The authorisation to implement the Proposal provided for in this statement shall lapse and be void within five years after the date of this statement if the Proposal to which this statement relates is not substantially commenced.
3-2	The Proponent shall provide the CEO of the DEC with written evidence which demonstrates that the Proposal has substantially commenced, on or before the expiration of five years from the date of this statement.
Compliance Reporting	
4-1	The Proponent shall prepare and maintain a compliance assessment plan.
4-2	The Proponent shall submit to the CEO of the DEC, the compliance assessment plan required by condition 4-1 at least six months prior to the first compliance report required by condition 4-6. The compliance assessment plan shall indicate: • frequency of compliance reporting • approach and timing of compliance assessments • retention of compliance assessments • reporting of potential non-compliances and corrective actions taken • table of contents of compliance reports • public availability of compliance reports.
4-3	The Proponent shall assess compliance with conditions in accordance with the compliance assessment plan required by condition 4-1.
4-4	The Proponent shall retain reports of all compliance assessments described in the compliance assessment plan required by condition 4-1 and shall make those reports available when requested by the CEO of the DEC.
4-5	The Proponent shall advise the CEO of the DEC of any potential non-compliance as soon as practicable.
4-6	The Proponent shall submit a compliance assessment report annually from the date of issue of this statement addressing the previous 12 month period or as agreed by the CEO of the DEC. The compliance assessment report shall: • be endorsed by the Proponent's Managing Director or a person, approved in writing by the DEC, elegated to sign on the Managing Director's behalf • include a statement as to whether the Proponent has complied with the conditions • identify all potential non-compliances and describe corrective and preventative actions taken • be made publicly available in accordance with the approved compliance assessment plan • indicate any proposed changes to the compliance assessment plan required by condition 4-1.
Performance Review, Monitoring and Reporting	
5-1	The Proponent shall prepare and maintain a Performance Review Program.

Condition No.	Proposed Condition

5-2	The Proponent shall submit to the CEO of the DEC, the Performance Review Program required by condition 5-1 at least 12 months prior to the first Performance Review Program report required by condition 5-3. The Performance Review Program shall include:
	• key performance indicators and targets for the following key environmental factors:
	  • Karijini National Park
	  • groundwater and water supply
	  • watercourses and surface water quality
	  • flora and vegetation units
	  • Coolibah woodland and Mulga communities
	  • terrestrial fauna
	  • subterranean fauna
	  • Aboriginal heritage
	  • visual amenity and landscape character
	  • closure
	• monitoring programs to assess outcomes for those key environmental factors
	• monitoring program to assess the effectiveness of weed control measures
	• fire and weed management and feral animal eradication programs in areas of Karijini National Park adjacent to Marandoo mine site, facilitated through the existing SMU between the DEC and the Proponent as well as in an area within Coondawanna Flats to be returned to Karijini National Park in 2015
	• rehabilitation monitoring program
	• surface water quality monitoring program
	• research and investigation programs including:
	  • threats to Mulga communities such as fire and climate change
	  • Coolibah water use requirements.

5-3	The Proponent shall submit to the CEO of the DEC a report on the Performance Review Program within 2 years of the date of issue of this statement and then every three years thereafter, which addresses: • results and trends of monitoring programs described in the Performance Review Program required by condition 5-2 • achievement (or otherwise) of predicted outcomes, the success (or otherwise) of mitigation and management measures in achieving these predicted outcomes and rehabilitation criteria • proposed or implemented changes to mitigation and management measures to ensure predicted outcomes are achieved • progress, results and modification to the research and investigation programs described in the Performance Review Program.
Karijini National Park/Significant Vegetation units	
6-1	If any Level 1 or 2 Coolibah management trigger criterion prescribed in schedule 2 is exceeded, within four weeks following the detection of the exceedence the Proponent shall: • notify the CEO of the DEC • provide details of the actions proposed to mitigate and manage activities which are affecting the site • undertake an assessment of the residual risk to the Coolibah woodland as a result of these proposed actions.
6-2	If any Level 3 Coolibah management trigger criterion prescribed in schedule 2 is exceeded, the Proponent shall supply the woodlands with water using a method agreed with the DEC.

6-3	If any Level 3 Coolibah management trigger criterion prescribed in schedule 2 is exceeded for the Coolibah woodland within Karijini National Partk, the Proponent shall:
	• within one week following the detection of the exceedence notify the CEO of the DEC:
	• within twelve weeks following the detection of the exceedence provide to the CEO of the DEC a report including:
	  • details of any new actions that will be taken to reduce impacts groundwater drawdown at the affected site;
	  • an assessment of risk to the environment accounting for any new mitigation and management measures proposed; and
	  • an independent expert peer review of these matters.

6-4	At least six months prior to commencement of dewatering activities, the Proponent shall prepare and submit, a Coolibah Baseline Survey and Monitoring Program to the DEC for review. This program shall address the following: • survey methods for baseline surveys and subsequent monitoring following commencement of dewatering • location and establishment of survey sites • timing of surveys • parameters • analysis and assessment of survey data.
6-5	The Proponent shall amend the Coolibah Baseline Survey and Monitoring Program in accordance with the DEC review of the program under condition 6-4.

Condition No.	Proposed Condition
6-6	The Proponent shall undertake the initial baseline survey in accordance with the Coolibah Baseline Survey and Monitoring Program as required by conditions 6-4 and 6-5 and provide a report on the initial baseline survey at least two months prior to the commencement of dewatering activities. This report shall contain: • coolibah health and groundwater levels across the Mount Bruce Flats • evaluation of tree health through vegetation stress measures including water use requirements and foliage cover • any available results from the UNSW study.
6-7	Every 6 months during dewatering activities, the Proponent shall repeat the monitoring required by the Coolibah Baseline Survey and Monitoring Program required by conditions 6-4 and 6-5.
6-8	Within six months following completion of the dewatering activities, the Proponent shall repeat the monitoring required by the Coolibah Baseline Survey and Monitoring Program required by conditions 6-4 and 6-5.
6-9	The Proponent shall repeat the monitoring required by the Coolibah Baseline Survey and Monitoring Program required by conditions 6-4 and 6-5 at the same time of the year annually for three years following the cessation of dewatering.
6-10	Within three months following completion of the monitoring required by Conditions 6-7, 6-8 and 6-9, the Proponent shall report the findings of the monitoring to the DEC.
Groundwater re-injection	
7-1	If the groundwater re-injection trigger criterion prescribed in schedule 2 is exceeded, within four weeks following the detection of the exceedence the Proponent shall: • notify the CEO of the DEC • provide details of the actions proposed to mitigate and manage activities which are affecting the site • undertake an assessment of the residual risk to the Southern Fortescue aquifer system as a result of these proposed actions.
Surface Water Drainage	
8-1	The Proponent shall ensure that surface water discharges (including runoff, seepage from the waste dumps and the residue storage facility, and the disposal of dewatering water) do not cause the quality of surface or groundwater systems to exceed ANZECC* criteria, taking into consideration natural background water quality and environmental values of the receiving environment. * Australian Water Quality Guidelines for Fresh and Marine Waters, ANZECC (November 1992, and its updates)
8-2	The Proponent shall provide a report to the DEC on any exceedence of the criteria prescribed in Condition 8-1.
Discharge of excess dewatering water to watercourses	
9-1	The Proponent shall implement the Proposal so surface water or sub-surface water flow resulting from the discharge of excess dewatering water alone does not reach Hamersley Gorge.
9-2	If any Level 1 or 2 surface discharge management trigger criterion prescribed in schedule 2 is exceeded, within four weeks following the detection of the exceedence the Proponent shall: • notify the CEO of the DEC • commence more frequent (3 monthly) monitoring for water quality, vegetation and aquatic health and recalibrate hydrological calculations, if required • based on revised hydrological and monitoring results, review and revise the impact assessment and management plan • undertake appropriate remedial action as required • revise procedures as required to prevent recurrence.
9-3	If any Level 3 surface discharge management trigger criterion prescribed in schedule 2 is exceeded, the Proponent shall: • notify the CEO of DEC immediately • investigate cause/s and provide the CEO of DEC with details of mitigation and management to be undertaken and an assessment of residual risk to the Karijini National Park within twelve weeks following the detection of the exceedence • undertake appropriate remedial action and reporting as required to the satisfaction of the CEO of the DEC • revise procedures as required to prevent recurrence.
9-4	The Proponent shall notify the Minister for the Environment on any exceedence of a Level 3 trigger within one week following the detection of the exceedence.
9-5	Within sixteen weeks following the detection of an exceedence of any Level 3 trigger, the Proponent shall provide details of any new actions proposed to prevent surface water or sub-surface water flow from reaching Hamersley Gorge and provide an assessment of the residual risk to the environment accounting for any new management measures that are to be implemented in a report to the Minister for the Environment.
9-6	The Proponent shall provide an independent expert peer review of the risk assessment and proposed management measures in the report required by Condition 9-5.

Condition No.	Proposed Condition
9-7	At least six months prior to commencement of excess dewatering water discharge to watercourses, the Proponent shall prepare and submit a Dewatering Discharge Baseline Survey and Monitoring Program to the DEC for review. This program shall address the following: • excess water discharge strategy • in-stream/riparian environmental targets to be met by the discharge of excess water • excess water discharge points • morphology of the watercourses in the area of discharge • establishment of a hydrograph for the watercourses to which discharges may occur • survey methods for baseline and subsequent monitoring following each surface discharge event • location of survey sites • timing and frequency of surveys • vegetation condition, vegetation composition, weed infestation and erosion classification schemes • analysis of survey data.
9-8	The Proponent shall amend the Dewatering Discharge Baseline Survey and Monitoring Program: • in accordance with the DEC's review of the Program under condition 9-7; or • at anytime prior to the completion of excess dewatering water discharge to watercourses , if required, as a result of a significant change in biodiversity or stream values of the affected area resulting from the implementation of the Proposal.
9-9	The Proponent shall discharge excess dewatering water in accordance with the Dewatering Discharge Baseline Survey and Monitoring Program as required by Conditions 9-7 and 9-28
9-10	At least 6 months prior to the commencement of excess dewatering water discharge to watercourses, the Proponent shall provide to the DEC a report on the detailed surveys (required by the Baseline Survey and Monitoring Program) of aquatic systems and vegetation and flora within, or adjacent to, the area of excess dewatering water discharge. This report shall contain: • a record of the vegetation composition and indicator tree species health • visual assessment and foliage cover • a record of channel morphological assessment, including sites of erosion • an evaluation of the aquatic health of permanent pools • data included in an appropriate Geographic Information System data set format.
9-11	If excess dewatering discharge has commenced the Proponent shall annually provide to the DEC a report, by the date of the issue of this statement in each year following the year in which the report required by condition 9-10 was provided to the DEC, on the detailed surveys (required by the Baseline Survey and Monitoring Program) of aquatic systems and riparian vegetation and flora within, or adjacent to the area of excess dewatering water discharge.
9-12	The Proponent shall continue to submit the report described in 9-11 until three years following the cessation of excess dewatering water discharge to watercourses.
Visual Amenity	
10-1	The Proponent shall ensure waste dumps, the residue storage facility, and stockpiles do not exceed the height of the Marandoo ridgeline, as viewed from the Mount Bruce car park visitor lookout.
Rehabilitation	
11-1	The Proponent shall conduct rehabilitation progressively as areas become available.
11-2	The Proponent shall submit a Rehabilitation Plan as part of the final closure plan to the CEO of the DEC. The Rehabilitation Plan shall address: • the sequence and timing for areas to be rehabilitated • conceptual rehabilitation objectives and targets for each area with the aim of achieving safe, stable and self-sustaining landforms that are compatible with surrounding areas.
11-3	The Proponent shall monitor the performance of rehabilitation against rehabilitation targets required by Condition 11-2 based on annual monitoring at the same time each year and report results in the Proponent's Annual Environmental Report.
Closure	
12-1	A final closure plan will be developed in consultation with the DEC and Department of Industry and Resources and submitted to the CEO of the DEC at least five years prior to the planned date of closure for review. The Final Closure Plan shall address: • detailed measures to be implemented for closure • the schedule and timing of final closure activities • agreed completion criteria for closure • closure monitoring requirements • management measures to facilitate closure.
12-2	The Proponent shall review the closure plan taking into account comments from the DEC's review of the Plan developed under Condition 12-1.

Table 29
Schedule 1 - Environmental footprint

Proposal characteristic	Detail
Total area of vegetation disturbance	Clearing of approximately 940 ha within the area shown in Figures 28–31. Localised impact to riparian vegetation along drainage lines shown in Figure 18.
Ore location	Above and below the water table.
Waste rock disposal	Waste rock disposed of in surface dumps and/or progressive backfilling of mine pits within the area shown in Figure 15.
Water disposal	Re-injection in the vicinity of the Southern Fortescue borefield shown in Figure 14.
	Discharge to drainage lines shown in Figure 18.
	Off-site discharge of stormwater from the mine pit at locations shown in Figure 17.
Slurry from wet processing of ore	Residue Storage Facility (RSF) as shown in Figure 15.
Greenhouse Gases	Greenhouse gas emissions of approximately 15.3 CO_2-e/kt of ore.

Table 30
Proposed Schedule 2 - Management criteria

Coolibah triggers	
Level 1	Loss of 15% mean foliage cover not able to be explained by natural events such as drought and fire, and not seen at reference site. or Decrease in groundwater level in the unconfined aquifer to greater than 2.5 m below the lowest recorded groundwater level in bores OW28s, OW12s & OW30s. or After groundwater levels fall below the lowest groundwater level recorded (prior to the commencement of dewatering activities) in any of the observation bores OW28s, OW27s and OW30s, or any decrease in groundwater level greater than 0.35 m within any twelve month period or part thereof in any of the observation bores OW28s, OW27s and OW30s.
Level 2	Loss of 25% mean foliage cover not able to be explained by natural events such as drought and fire, and not seen at reference site.
Level 3	Loss of 40% mean foliage cover not able to be explained by natural events such as drought and fire, and not seen at reference site.
Surface Discharge triggers	
Level 1	Development of permanent surface flow in excess of 20 km.
Level 2	Introduced fish species observed or Water quality in permanent/semi-permanent pools along discharge pathways outside ANZECC* criteria, taking into consideration natural background water quality and environmental values of the receiving environment.
Level 3	Surface water or sub-surface water flow resulting from the discharge of excess dewatering water alone reaches within 5 km of Hamersley Gorge.
Groundwater re-injection trigger	
	Groundwater levels rise as a result of re-injection into the Southern Fortescue aquifer system to more than 5 m above historical (prior to abstraction at Southern Fortescue borefield) water levels within observation bores.

Table 31
Consideration of existing environmental conditions for the original Proposal

No.	Ministerial Statement 286 Condition	Consideration
1	The Proponent has made a number of environmental management commitments in order to protect the environment.	No longer applicable as the EPA no longer proposed Proponent commitments.
1-2	In implementing the project, the Proponent shall fulfil the commitments (which are not inconsistent with the conditions or procedures contained in this statement) made in the Environmental Review and Management Programme which are listed in Environmental Protection Authority Bulletin 643 as Appendix 1 and in its Statement of Mutual Understanding entered into with the Department of Conservation and Land Management. (A copy of the commitments is attached).	No longer applicable as the EPA no longer proposed Proponent commitments.
	Commitments	
1	Educational and environmental induction courses for Marandoo personnel will be instigated, prior to the construction phase, to address the broad issues of conservation of flora and fauna. As a condition of employment, employees will attend an induction programme designed to create an environmental awareness. CALM will be consulted during the development of the courses.	Addressed through comprehensive induction program.
2	The expertise and knowledge gained from the Channar construction camp will be applied in minimising environmental impacts of construction workers at Marandoo during their leisure hours.	Addressed through comprehensive induction program.
3	Part of the induction course (see No. 1) will address Aboriginal heritage issues to increase awareness of Aboriginal cultural heritage.	Addressed through EMP (Aboriginal Heritage Management Plan).
4	The views of Aboriginal people in Onslow and Roebourne who claim traditional affiliation with the Project Areas will be sought by Hamersley's Aboriginal Liaison Officer who will: • assist in preparation of inductions (see above) • advise Hamersley on any Aboriginal cultural matters.	Addressed through the ILUA.
5	Employees and contractors at Marandoo will be made familiar with any applicable requirements of the *Aboriginal Heritage Act 1972* (WA)	Addressed through EMP (Aboriginal Heritage Management Plan).
6	Tom Price needs in terms of housing, services and facilities are already considered adequate. Any additional needs identified during the project feasibility study stage will be minimal and will be addressed at that time.	Not an environmental issue.
7	Hamersley will assist protection of the Park values by encouraging amongst its local employees an understanding and awareness of the importance of the Park.	Addressed through EMP comprehensive induction program.
8	Hamersley will continue to give careful consideration to the employment needs of women, Aboriginal people and young people.	Not an environmental issue.
9	Hamersley will continue to support opportunities for Aboriginal employment through its Ieramugadu programme.	Not an environmental issue.
10	Hamersley will develop a programme through its Aboriginal Liaison Officer presently stationed at Onslow, to explore, trial and implement practicable and effective training and employment projects, in close co-operation with responsive individuals and groups of Aboriginal people.	Addressed through the ILUA.
11	Hamersley will support research with CALM on the range, distribution and taxonomy of the pebble-mound mouse, as outlined in the ERMP.	No longer applicable; completed and signed off by the DEC.
12	Special attention will be given to the occurrence of any Bilby habitats in future fauna surveys.	Subsequent survey results support the conclusion that the area is not a bilby habitat.
13	Hamersley will include in its induction programme (see No. 1), information to assist in protection of rare and significant species of fauna and flora.	Addressed through EMP.
14	Hamersley will continue to progress its regional land-unit work, and to continue to research its environmental predictive capabilities for future mines.	Addressed through EMP.

No.	Ministerial Statement 286 Condition	Consideration
15	Hamersley will, as far as practicable, avoid damage to significant vegetation units in the Project Area and where appropriate will consult with experienced botanists to achieve this aim. Where mining operations will remove a particular community locally, Hamersley will consult with CALM prior to taking appropriate action.	Addressed through IEMS and EMP.
16	Construction activities will be conducted so as to minimise any necessary disturbance to the environment. Areas disturbed for construction purposes will be rehabilitated as soon as practicable after they are no longer required for the project.	Addressed through new proposed Condition 11, IEMS and EMP.
17	Rehabilitation of disturbed areas will be undertaken in accordance with the guidelines set out in the ERMP. Monitoring of rehabilitated areas will be undertaken and the findings reported. Remedial work will be undertaken if required.	Addressed through new proposed Condition 11.
18	Final landforms will be designed to be safe and stable.	Addressed through new proposed Conditions 11 and 12.
19	At the end of the construction period, the construction camp will be removed and the servicing areas and evaporation ponds will be ripped and revegetated.	Construction camp from original construction of the Marandoo mine has been removed. New construction camp addressed through new proposed Condition 11.
20	A fire management policy for the Marandoo Project Area which is compatible with the management objectives for the Park will be developed in consultation with CALM.	Completed for current mine operations. Ongoing management addressed through new proposed Condition 5 and EMP.
21	Hamersley will wherever possible use seed derived from local sources during rehabilitation works. If local seed is not available Hamersley will consult with CALM prior to determining alternatives.	Addressed through new proposed Condition 11.
22	Measures to prevent and restrict the introduction and spread of weeds will be investigated and managed after consultation with CALM.	Addressed through new proposed Condition 5 and EMP (Vegetation and Flora Management Plan and Fauna Management Plan).
23	Possession of pets and firearms by project personnel will not be permitted in the Project Area. The induction courses will provide information on the conservation of fauna and their habitats.	Addressed through comprehensive induction program.
24	Appropriate dust suppression measures, including water sprays and dust collector systems will be implemented to ensure that acceptable ambient and occupational dust levels are achieved, as required by the *Mines Regulation Act Regulation 1976* (WA).	Addressed through EMP and EP Act Part V environmental licence.
25	Dust monitoring programmes will be established to assess ambient dust levels for environmental purposes and respirable dust levels and fibre sampling for occupational health and safety purposes. The monitoring programmes will be developed and conducted in accordance with the *Mines Regulation Act Regulation 1976* (WA).	Addressed through EP Act Part V environmental licence.
26	Monitoring of occupational noise levels will be undertaken in accordance with the *Mines Regulation Act Regulations 1976* (WA).	Addressed through EP Act Part V environmental licence.
27	Hamersley will develop a 'closed' system for the treatment of contaminated waters from service areas.	Addressed through EP Act Part V environmental licence and EMP.
28	Toxic wastes will be removed from Marandoo and disposed of at existing approved sites.	Addressed through EP Act Part V environmental licence.
29	Used oil will be collected, stored in bunded above-ground tanks and transported to Dampier for use in the power station.	Addressed through EP Act Part V environmental licence.
30	Sewage effluent will be dealt with in accordance with the requirements of the *Health Act 1911* (WA).	Addressed through EP Act Part V licence or other legislation (Health Act).
31	Licences will be obtained under the *Poisons Act 1964* (WA) for relevant material.	Addressed through other legislation (*Poisons Act 1964* (WA)).
32	Waste disposal will be in accordance with an EPA licence.	Addressed through EP Act Part V environmental licence.

No.	Ministerial Statement 286 Condition	Consideration
33	Hamersley will undertake further detailed hydrological, geological and mining engineering studies during 1992–1993 to provide inputs into the study of end-use options.	Addressed through new proposed Condition 12.
34	Hamersley will continue to refine computer simulation of the groundwater systems.	Addressed through EMP and new proposed Condition 6.
35	Hamersley in conjunction with CALM will monitor Bandjima Pool and Minthicoondunna Spring to develop a more complete understanding of their hydrology.	Addressed through EMP and new proposed Conditions 5 and 6.
36	Selected monitoring bores will be established to assess groundwater levels and quality on a routine basis.	Completed, and for ongoing management addressed through new proposed Conditions 5 and 6.
37	Where practicable and as appropriate, surface water samples will be collected from major discharge points of the open water system to test for contamination.	Completed, and for ongoing management addressed through new proposed Conditions 8 and 9.
38	Hamersley will continue its weather observations at Marandoo, to maintain a regional meteorological data base.	Addressed through EMP.
39	Design and location of the borefield for the long-term operation will take into account the need to limit vegetation impacts to an acceptable level. Monitoring of groundwater and vegetation will be undertaken and appropriate remedial action taken as required.	Addressed through new proposed Conditions 5 and 6.
40	Under the Statement of Mutual Understanding, Hamersley will work with CALM to refine and implement an agreed end-use plan for the mine site after decommissioning.	MOU and SMU ongoing and addressed through EMP.
41	The location, design and colour of surface facilities will be chosen as far as practicable in sympathy with the landscapes.	Addressed through EMP.
42	Hamersley will sign its roads as far as practicable with CALM's management practices.	No longer applicable as signs have been installed.
2	The implementation of the Marandoo Project will proceed under the provisions of the *Environmental Protection Act 1986* (WA) and in accordance with the *Iron Ore (Hamersley Range) Agreement Act 1963* (WA) as amended, hereafter called 'the Agreement'. Reporting requirements or compliance with these environmental conditions shall be achieved through the requirements for environmental management Proposals or reports under the Agreement by the Minister for State Development referring such Proposals and reports to the Minister for the Environment.	Separately regulated by the Agreement Act. Addressed through new proposed Conditions 4 and 5 and specific reporting under Conditions 6, 7, 8 and 9.
2-1	Subject to these conditions, the manner of detailed implementation of the Proposal shall conform in substance with that set out in any designs, specifications, plans or other technical material submitted by the Proponent in project Proposals pursuant to the Agreement ('the Proposals'). Where, in the course of that detailed implementation, the Proponent seeks to change those designs, specifications, plans or other technical material in any way that in the opinion of the Minister for State Development with the concurrence of the Minister for Environment on the advice of the Environmental Protection Authority is not significant, those changes may be affected.	Addressed through new proposed Condition 1 and the EP Act Part IV.
3	An overall Environmental Management Programme shall be submitted, describing in sufficient detail all aspects of the Central Pilbara Railway and Marandoo Iron Ore Mine and the integration of the Proponent's commitments and the requirements of the conditions in this statement.	Addressed through EMP.
3-1	The Proponent shall submit the Environmental Management Programme in accordance with the Agreement to the Minister for State Development and to the Minister for the Environment for their approval prior to the commencement of construction.	No longer applicable.

No.	Ministerial Statement 286 Condition	Consideration
3-2	The Proponent shall prepare and submit the Environmental Management Programme required by condition 3-1 in consultation with the Department of Conservation and Land Management. This Programme shall contain, but not necessarily be limited to the following elements: • protection of significant flora and fauna (condition 4); • protection of significant flora and fauna (condition 4); • workforce management (condition 5);	No longer applicable; EMP provided with PER.
	• Central Pilbara Railway (condition 6); • drainage Management (condition 7); • management of groundwater abstraction (condition 8); • management of weeds (condition 9); • management of fire (condition 10); • rehabilitation of the project area and decommissioning (conditions 11 and 15); and • management of waste disposal sites (condition 13).	
3-3	Subsequent revisions of the Environmental Management Programme required by condition 3-1 will be prepared and submitted in consultation with the Department of Conservation and Land Management where appropriate and may form part of the annual and triennial reports pursuant to the Agreement.	No longer applicable; EMP provided with PER.
3-4	Each element of the Environmental Management Programme required by condition 3-1 shall where appropriate address: potential source of environmental impact; commitments; objectives; procedures; and reporting including monitoring.	No longer applicable; EMP provided with PER.
3-5	The Proponent shall implement the various elements of the Environmental Management Programme required by conditions 3-1 to 3-4 to the satisfaction of the Minister for State Development and the Minister for the Environment.	No longer applicable; EMP provided with PER.
3-6	In the event that monitoring shows unacceptable environmental impacts, the Proponent shall in accordance with the Agreement prepare and subsequently implement a plan to mitigate these impacts to the satisfaction of the Minister for State Development and the Minister for the Environment.	Addressed through new proposed Conditions 5, 6, 7, 8 and 9.
4	Rare, priority and geographically restricted species of flora and fauna in the project area shall be treated with special consideration.	Addressed through EMP and *Wildlife Conservation Act 1950* (WA).
4-1	The Proponent shall provide details of the results of all surveys carried out on areas likely to be disturbed through construction and operational activity, to the satisfaction of the Minister for State Development and the Minister for the Environment on the advice of the Department of Conservation and Land Management, prior to those areas being disturbed.	Addressed through EMP.
4-2	Significant species of flora and fauna found in the surveys referred to in condition 4-1, shall be managed in accordance with the Proponent's commitments and the Environmental Management Programme referred to in condition 3.	Addressed through EMP and *Wildlife Conservation Act 1950* (WA).
5	The Proponent is responsible for the management of the constructional and operational workforce to ensure that environmental impacts on the Karijini National Park are minimised.	Not auditable and addressed through EMP.
5-1	The Proponent shall manage the workforce and assist the Department of Conservation and Land Management to ensure that environmental impacts on the Karijini National Park resulting from constructional, operational and recreational activities are minimised.	Not auditable and addressed through EMP.
6	The Proponent may proceed to construct and operate the Central Pilbara Railway (from Marandoo to Homestead Junction) but shall do so in such a manner that reasonably minimises environmental impacts.	No longer relevant; railway constructed.
6-1	Prior to the construction of the Central Pilbara Railway the Proponent shall prepare and subsequently implement in consultation with the Department of Conservation and Land Management an Environmental Management Programme for this railway describing how the management measures for the railway will meet the requirements of this condition.	No longer relevant; railway constructed.

No.	Ministerial Statement 286 Condition	Consideration
7	The important vegetation units in the area, in Coolibah and Mulga woodlands, shall where possible be protected from drainage impacts associated with the development and operation of the project.	Addressed through new proposed Conditions 6 and 8.
7-1	Prior to the commencement of construction, the Proponent shall submit and subsequently implement a drainage management plan, setting out the measures to meet the requirements of this condition in consultation with the Department of Conservation and Land Management. This plan shall include a monitoring component to permit determination of its effectiveness.	Addressed through new proposed Condition 8.
8	There shall be no unacceptable impact on the conservation values of the Karijini National Park resulting from groundwater abstraction associated with the project, particularly the Coolibah woodlands to the east of Mount Bruce.	Addressed through new proposed Condition 6.
8-1	Prior to commissioning of the Marandoo borefield, the Proponent shall prepare and subsequently implement a groundwater management plan describing in sufficient detail the measures to meet the requirements of this condition in consultation with the Department of Conservation and Land Management and the Water Authority of Western Australia. This plan shall include a monitoring component to permit determination of its effectiveness.	Addressed through new proposed Condition 6 and EMP.
9	The spread of weeds resulting from the development and operation of the project shall be minimised.	Addressed through new proposed Condition 5 and EMP (Vegetation and Flora Management Plan and Fauna Management Plan).
9-1	Prior to the commencement of construction, the Proponent shall prepare and subsequently implement a weed management plan describing in sufficient detail measures to meet the requirements of this condition, in consultation with the Department of Conservation and Land Management. This plan shall prescribe monitoring and control measures and shall include a monitoring component to permit determination of its effectiveness.	Addressed through EMP (Vegetation and Flora Management Plan and Fauna Management Plan).
10	The development and operation of the project shall not lead to a significantly increased fire risk within the Karijini National Park.	Addressed through EMP (Fire Management Plan).
10-1	Prior to the commencement of construction, the Proponent shall develop and subsequently implement a fire management plan describing in sufficient detail the measures to meet the requirements of this condition, in consultation with the Department of Conservation and Land Management. This plan shall include a monitoring component to permit determination of its effectiveness.	Addressed through EMP (Fire Management Plan).
10-2	The Proponent shall develop the fire management plan required by condition 10-1 to integrate fire management in the project area with the overall fire management requirements of the Karijini National Park.	Addressed through EMP (Fire Management Plan).
11	The standard of rehabilitation of the project area shall where possible be consistent with local landscape values and if appropriate enable the return of the area to the Karijini National Park.	Addressed through new proposed Condition 11.
11-1	Prior to the commencement of construction and throughout the life of the development, the Proponent shall prepare rehabilitation plans, in consultation with the Department of Conservation and Land Management and the Department of Minerals and Energy, to the satisfaction of the Minister for State Development and the Minister for the Environment. These plans shall include a monitoring component to permit determination of their effectiveness, and shall specify the sources of seed and species proposed for planting during rehabilitation.	Addressed through new proposed Condition 11.
11-2	The Proponent shall subsequently implement the rehabilitation plans required by condition 11-1.	Addressed through new proposed Condition 11.
11-3	The Proponent shall where possible only use plant material of local provenances for rehabilitation to the requirements of the Department of Conservation and Land Management	Addressed through new proposed Condition 11.
12	The visual impact of the proposed development shall be minimised	Addressed through new proposed Condition 10.

No.	Ministerial Statement 286 Condition	Consideration
12-1	The Proponent shall where possible mitigate the visual impact of the development in consultation with the Department of Conservation and Land Management. The location, design and colour of surface facilities will be chosen as far as practicable in sympathy with the landscape.	Addressed through new proposed Condition 10.
13	Domestic and industrial waste material from the project shall be managed to prevent scavenging by animals and pollution of groundwater.	Addressed through EP Act Part V environmental licence.
13-1	Prior to the commencement of construction, the Proponent shall develop and subsequently implement a plan describing in sufficient detail measures to manage the waste disposal sites to meet the requirements of this condition, in consultation with the Department of Conservation and Land Management and the Health Department of Western Australia. This plan shall include provision for minimisation of scavenging by animals including birds, and contamination of groundwater. The plan shall also include a monitoring component to permit determination of its effectiveness.	Addressed through EP Act Part V environmental licence.
14	The Proponent shall consult with relevant community groups to minimise the impact of the project on the community.	Not an environmental issue.
14-1	The Proponent shall establish a consultative mechanism as referred to in the Proponents commitments.	Not an environmental issue.
15	The satisfactory decommissioning of the project, removal of the plant and installations and final rehabilitation of the site and its environs is the responsibility of the Proponent.	Addressed through new proposed Conditions 11 and 12.
15-1	At least six months prior to the decommissioning of the project, the Proponent shall prepare and implement a decommissioning and final rehabilitation plan, in consultation with the Department of Conservation and Land Management and the Department of Minerals and Energy.	Addressed through new proposed Conditions 11 and 12.
16	The conditions in this statement apply to the nominated Proponent	No longer applicable; new wording of condition.
16-1	No transfer of ownership, control or management of the project which would give rise to a need for the replacement of the Proponent shall take place until the Minister for State Development with the concurrence of the Minister for the Environment has advised the Proponent that approval has been given for the nomination of a replacement Proponent. Any request for the exercise of that power of the Ministers shall be accompanied by a copy of this statement endorsed with an undertaking by the proposed replacement Proponent to carry out the project in accordance with the conditions and procedures set out in the statement.	Addressed through Agreement Act and new proposed Condition 2.
17	The environmental approval for the Proposal is limited.	Addressed through new proposed Condition 3.
17-1	If the Proponent has not substantially commenced the project within five years of the date of this statement, then the approval to implement the Proposal as granted in this statement shall lapse and be void. The Minister for State Development with the concurrence of the Minister for the Environment shall determine any question as to whether the project has been substantially commenced. Any application to extend the period of five years referred to in this condition shall be made before the expiration of that period, to the Minister for the Environment by way of a request for a change in the condition under Section 46 of the *Environmental Protection Act*. (On expiration of the five year period, further consideration of the Proposal can only occur following a new referral to the Environmental Protection Authority.)	Addressed through new proposed Condition 3.
18	In order to ensure that environmental conditions and commitments are met, an audit system is required.	Addressed through new proposed Condition 4.
18-1	The Proponent shall prepare periodic 'Progress and Compliance Reports', to help verify the environmental performance of this project the requirements of the Minister for State Development and the Minister for the Environment pursuant to the Agreement.	Addressed through new proposed Condition 4.

9. Shortened forms and glossary

Marandoo Mine Phase 2

Table 32 details the short titles and acronyms used in this document.

Table 32
Short titles and acronyms

Shortened form	Full title
ARD	Acid Rock Drainage
ARI	Annual Recurrence Interval
ATAL	Aboriginal Training and Liaison
BIF	Banded Iron Formation
CAMBA	China-Australia Migratory Bird Agreement
CEMP	Construction Environmental Management Plan
CEO	Chief Executive Officer
CITES	Convention on International Trade in Endangered Species
CO_2	Carbon dioxide
CO_2-e	Carbon dioxide equivalents
DEC	Department of Environment and Conservation
DEWHA	Department of the Environment, Water, Heritage and the Arts
DIA	Department of Indigenous Affairs
DoIR	Department of Industry and Resources
DoW	Department of Water
DRF	Declared Rare Flora
EMP	Environmental Management Plan
EMS	Environmental Management System
EP Act	*Environmental Protection Act 1986* (WA)
EPA	Environmental Protection Authority
EPASU	Environmental Protection Authority Service Unit
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Cwth)
ESD	Environmental Scoping Document
GL/year	Gigalitres per year
GWh/a	Gigawatt hours per annum
Hamersley Iron	Hamersley Iron Pty Ltd
IEMS	Iron Environmental Management System
ILUA	Indigenous Land Use Agreement
IUCN	International Union for Conservation of Nature
JAMBA	Japan-Australia Migratory Bird Agreement
KNP	Karijini National Park
KNPAC	Karijini National Park Advisory Committee
KPC	Karijini Park Council
kt	Kilotonne
mg/L	Milligrams per litre
ML/day	Megalitres per day

Shortened form	Full title
Mm	Million metres
MOU	Memorandum of Understanding
m/s	Metres per second
Mt	Million tonnes
Mtpa	Million tonnes per annum
NGER Act	*National Greenhouse and Energy Reporting Act 2007* (Cwth)
OEMP	Operational Environmental Management Plan
PER	Public Environmental Review
PFS	Pre-Feasibility Study
Pilbara Iron	Pilbara Iron Company (Services) Pty Ltd
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreement
RSF	Residue Storage Facility
SMU	Statement of Mutual Understanding
SPQ	Single Persons Quarters
SRE	Short-Range Endemic
t	Tonnes
TEC	Threatened Ecological Community
TJ	Terajoule
UNSW	University of New South Wales
UWA	University of Western Australia

10. References

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Adams, M., Grierson, P. and Stoddart, J. 2005, *Proceedings of a workshop on riparian tree health and the impacts of translocation of water in the Pilbara*, University of Western Australia.

Adams, M. 2005, *Monitoring Plan for the Impacts on Tree Health in Riparian Ecosystems surrounding Pilbara Iron's Yandicoogina Operations*, University of Western Australia.

Adams, M. 2006, *Regional Plan for managing riparian zones in the Pilbara*, University of Western Australia.

Adams, M. 2007, *Monitoring Plan for the Impacts on Tree Health in Riparian Ecosystems at Hope Downs*, Advanced Ecological Consultants.

Aquaterra Consulting Pty Ltd (Aquaterra) 2001, *Murray-Darling Basin Commission Groundwater Flow Modelling Guideline, Project No. 125*, Final Guideline - Issue I, January 2001, South Perth.

Armstrong K. N., Anstee, S. D., Landman, P. A. and Teale, R. J. (in prep.), *Gilgai soils as core habitat for the mainland Pilbara population of the rodent Leggadina lakedownensis [Watts, 1976] (Muridae).*

Australasian Legal Information Institute 2008, *Case Studies under the Aboriginal and Torres Strait Islander Heritage Protection Act 1984*, http://www.austlii.edu.au/au/special/rsjproject/rsjlibrary/evatt/annexvii.html, accessed 20 May 2008.

Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC/ARMCANZ) 1996, *National Principles for the Provision of Water for Ecosystems*, Sustainable Land and Water Resources Management Committee Subcommittee on Water Resources Occasional Paper SWR No. 3.

Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC/ARMCANZ) 2000, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, National Water Strategy, Canberra.

Australian and New Zealand Minerals and Energy Council (ANZMEC) and Minerals Council of Australia (MCA) 2000, *Strategic Framework for Mine Closure*, National Library of Australia Catalogue.

Australian Groundwater Consultants (AGC) 1990, *Tom Price Water Supply Wellfield Assessment*, unpublished report, July 1989 - June 1990.

Australian Heritage Commission 1992, *Assessment statement for Karijini National Park on the Register of the National Estate*, Australian Heritage Commission, Canberra.

Australian Natural Resources Atlas 2007, *Rangelands overview, Western Australia*, http://www.aussieheritage.com.au/listings/wa/Wittenoom/HamersleyRangeNationalPark1977boundary/20406, accessed 19 May 2008.

Austroads 1994, *Waterway Design: A Guide to the Hydraulic Design of Bridges, Culverts and Floodways*, Austroads Inc., Sydney.

Batini, F. 2008a, *Marandoo Phase 2 Proposal - Mining below watertable - Assessment of Impacts from Groundwater Dewatering and Surface Water Drainage on Significant Vegetation - Coolibah and Mulga*, unpublished report prepared for Rio Tinto Iron Ore, May 2008.

Batini, F. 2008b, *Report on Coolibah survey results - April 2008*, unpublished report prepared for Rio Tinto Iron Ore, April 2008.

Batini, F. 2008c, *Marandoo Mulga monitoring - Summary of 2005 results*, unpublished report prepared for Rio Tinto Iron Ore, April 2008.

Batley, G. E., Humphrey, C. L., Apte, S. C. and Stauber, J. L. 2003, *A Guide to the Application of ANZECC/ARMCANZ Water Quality Guidelines in the Mineral Industry*, Australian Centre for Mining Environmental Research, September 2003.

Beard, J. S. 1975a, *Pilbara Explanatory Notes and Map Sheet, 1:1,000,000 Series, Vegetation Survey of Western Australia*, University of Western Australia Press, Nedlands.

Beard, J. S. 1975b, *Vegetation Survey of Western Australia, 1:100,000 Vegetation Series Mapsheet 5 - Pilbara*.

Beckett, K. 2008, *Marandoo Phase II Surface Water Management*, unpublished report prepared for Rio Tinto Iron Ore Expansion Projects, March 2008.

Bessen Consulting Services 2007, *Pilbara Regional Water Planning Forum - outcomes report*, Department of Water, Karatha.

Biota Environmental Sciences (Biota) 2001, *Southern Plains and Southern Detritals Fauna and Vegetation Monitoring 2001*, unpublished report.

Biota Environmental Sciences (Biota) 2006, *Mesa A and Robe Valley Mesas Troglobitic Fauna Survey - Subterranean Fauna Assessment*, unpublished report prepared for Robe River Iron Associates, March 2006.

Biota Environmental Sciences (Biota) 2008a, *Residue Storage Facility Option 2 - Marandoo Mine Phase 2*, letter to Una Phelan, Rio Tinto, 12 March 2008.

Biota Environmental Sciences (Biota) 2008b, *Marandoo Mine Phase 2 Project Vegetation and Flora Survey*, unpublished report prepared for Pilbara Iron, June 2008.

Biota Environmental Sciences (Biota) 2008c, *Dewatering Pipeline (Marandoo Mine to South Fortescue Borefield) and Southern Fortescue Borefield*, letter to Kerrie Gorman, Strategen, 3 June 2008.

Biota Environmental Sciences (Biota) 2008d, *Marandoo Mine Phase 2 Seasonal Fauna Survey*, unpublished report prepared for Pilbara Iron, April 2008.

Biota Environmental Sciences (Biota) 2008e, *Marandoo Mine Phase 2 Extension Subterranean Fauna Assessment*, unpublished report prepared for Pilbara Iron, May 2008.

Biota Environmental Sciences (Biota) 2008f, *Marandoo Construction Camp: Nature Vegetation Clearing Permit Report*, unpublished report prepared for Hamersley Iro, June 2008.

Boulton, A. J. 2000, 'The functional role of the hyporheos', in *Verhandlungen der Internationalen Vereinigung für Theoretische und Angewandte Limnologie*, vol. 27, pp. 51–63.

Bradshaw, E. and Thomson, J. 2004, *Cultural Heritage Management: Community Partnerships and Integrated Business Systems*, http://www.minerals.org.au/__data/assets/pdf_file/0012/6051/9B-3BradshawElizabeth.pdf, accessed 19 May 2008.

Brehaut, L. and Vitenbergs, A. (eds.) 2001, *The Guruma Story. Jukurrpa*, IAD Press, Alice Springs.

Brundtland Commission 1997, *The Brundtland Commission: The World Commission on Environment ad Development*, Chaired by Norwegian Prime Minister Gro Harlem Brundtland.

Bureau of Meteorology 2008, *Climate Statistics for Australian Locations - Pilbara rainfall displays*, http://www.bom.gov.au/hydro/flood/wa/pilbara.shtml, accessed 5 March 2008.

Chamber of Minerals and Energy of Western Australia 2000, *Mine Closure Guidelines for Mineral Operations in Western Australia*, October 2000.

Chisholm, L. A. 2002, 'Spectral Response of *E. camaldulensis* to Moisture Stress Recovery', in *Proceedings of the 11th Australasian Remote Sensing and Photogrammetry Association Conference*, September 2–6, Brisbane, Queensland, pp. 524–531.

Churchill, S. K. 1998, *Australian bats*, Reed New Holland, Frenchs Forest, New South Wales.

Commonwealth of Australia 1992. *Intergovernmental Agreement on the Environment,* Australian Government Publishing Service, Canberra

Commonwealth of Australia 1996, *The National Strategy for Conservation of Australia's Biological Diversity*, Biodiversity Group, Environment Australia, Canberra.

Commonwealth of Australia 1998, *National Greenhouse Strategy*, Australian Greenhouse Office, Canberra.

Commonwealth of Australia 2007a, *Biodiversity Assessment - Pilbara - Threatened Ecosystems*, http://www.anra.gov.au/topics/vegetation/assessment/wa/ibra-pil-ecosystem-threats.html, accessed 23 April 2008.

Commonwealth of Australia 2007b, *Biodiversity Assessment - Pilbara - Species at Risk and the Threatening Process*, http://www.anra.gov.au/topics/vegetation/assessment/wa/ibra-pil-species-threats.html, accessed 23 April 2008.

CRA Services Ltd 1982, *Marandoo Biological Report*, unpublished report prepared by the Iron Ore Division, CRA Services Ltd, Perth.

Department of Home Affairs and Environment 1983, *National Conservation Strategy for Australia*, Australian Government Publishing Service, Canberra.

Department for Planning and Infrastructure (DPI) 2005, *Shire of Ashburton Town Planning Scheme No. 7*, Government of Western Australia, Perth.

Department for Planning and Infrastructure (DPI) 2007, *Visual Landscape Planning in Western Australia: a manual for evaluation, assessment, siting and design*, Western Australian Planning Commission, November 2007.

Department of Conservation and Land Management (CALM) 1989, *Hamersley Range National Park Draft Management Plan*, Perth, Western Australia.

Department of Conservation and Land Management (CALM) 1999, *Karijini National Park Management Plan 1999–2009*, Management Plan No. 40, prepared by the Department of Conservation and Land Management for the National Parks and Nature Conservation Authority, Perth, Western Australia.

Department of Conservation and Land Management (CALM) 2002, *A Biodiversity Audit of Western Australia's 53 Biogeographic Sub-regions in 2002*, Perth.

Department of Industry and Resources (DOIR) 1997, *Safety bund walls around abandoned open pit mines*, December 1997.

Department of Industry and Resources (DoIR) 2008, *Latest Statistics Release - Department of Industry and Resources*, http://www.doir.wa.gov.au/1525.aspx, accessed 24 April 2008.

Department of Minerals and Energy Western Australia (DME) 1996, *Guidelines for Mining in Arid Environments*, June 1996.

Department of Minerals and Energy Western Australia (DME) 2001, *Environmental Notes on Mining, Waste Rock Dumps*, January 2001.

Department of the Environment and Water Resources (DEW) 2003, *Kemp Declares Biodiversity 'Hotspots' - A World First*, Media Release, 3 October 2003.

Department of the Environment, Water, Heritage and the Arts (DEWHA) 2007, *Australia's 15 National Biodiversity Hotspots*, http://www.environment.gov.au/biodiversity/hotspots/national-hotspots.html, accessed 5 March 2008.

Department of the Environment, Water, Heritage and the Arts (DEWHA) 2008, *Australian Natural Resources Atlas Biodiversity Assessment - Pilbara*, Department of the Environment, Water, Heritage and the Arts, Government of Australia, Canberra.

Dixon, K. and Barrett, R. 2003, 'Defining the role of fire in south-west West Australian plants', in *Fire in Ecosystems of South-west Western Australia: Impacts and Management*, eds. Abbott, I. and Burrows, N., Backhuys Publishing, Amsterdam.

Dodson, W, 2008, *Marandoo Phase II Spring and Gorge Water Assessment*, Unpublished report prepared for Rio Tinto, August 2008.

Ecologically Sustainable Development Steering Committee 1992, *National Strategy for Ecologically Sustainable Development*, December 1992.

English, V. 1999, *A Directory of Important Wetlands in Australia*, Australian Government, Department of the Environment and Water Resources, http://www.environment.gov.au/cgi-bin/wetlands/report.pl, accessed 12 Feb 2007.

Environment Australia 2000, *Revision of the Interim Biogeographic Regionalisation for Australia (IBRA) and Development of Version 5.1*, Summary Report, Environment Australia, November 2000.

Environment Australia 2001, *A Directory of Important Wetlands in Australia*, Third Edition, Environment Australia, Canberra.

Environmental Protection Authority (EPA) 1995, *Rehabilitation and Revegetation - One Module in a Series on Best Practice Environmental Management in Mining*, June 1995.

Environmental Protection Authority (EPA) 2000, *Environmental Protection of Native Vegetation in Western Australia*, Position Statement No. 2, December 2000.

Environmental Protection Authority (EPA) 2002a, *Terrestrial Biological Surveys as an Element of Biodiversity Protection*, Position Statement No. 3, March 2002.

Environmental Protection Authority (EPA) 2002b, *Guidance Statement for Reducing Greenhouse Gas Emissions*, Guidance Statement No. 12, October 2002.

Environmental Protection Authority (EPA) 2003, *Consideration of Subterranean Fauna in Groundwater and Caves during Environmental Impact Assessment in Western Australia*, Draft Guidance Statement No. 54, December 2003.

Environmental Protection Authority (EPA) 2004a, *Principles of Environmental Protection,* Position Statement No. 7, August 2004.

Environmental Protection Authority (EPA) 2004b, *Assessment of Aboriginal Heritage*, Guidance Statement No. 41, April 2004.

Environmental Protection Authority (EPA) 2004c, *Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia,* Guidance Statement No. 51, June 2004.

Environmental Protection Authority (EPA) 2004d, *Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia*, Guidance Statement No. 56, June 2004.

Environmental Protection Authority (EPA) 2006a, *Environmental Offsets*, Position Statement No. 9, January 2006.

Environmental Protection Authority (EPA) 2006b, *Rehabilitation of Terrestrial Ecosystems*, Guidance Statement No. 6, June 2006.

Environmental Protection Authority (EPA) 2007a, *Environmental Offsets*, Draft Guidance Statement No. 19, June 2007.

Environmental Protection Authority (EPA) 2007b, *Environmental Noise*, Draft Guidance Statement No. 8, May 2007.

Environmental Protection Authority (EPA) 2007c, *Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia*, Guidance Statement No. 54a (Technical Appendix to Guidance Statement No. 54), August 2007.

Environmental Protection Authority (EPA) 2007d, *State of the Environment*, Environmental Protection Authority, Perth.

Environmental Protection Authority (EPA) 2008a, *Environmental Guidance for Planning and Development*, Guidance Statement No. 33, May 2008.

Environmental Protection Authority (EPA) 2008b, *State of the Environment Report: Biodiversity - Weeds*, http://www.soe.wa.gov.au/report/biodiversity/weeds.html, accessed 23 April 2008.

Environmental Protection Authority (EPA) 2008c, *State of the Environment Report: Biodiversity - Introduced animals*, http://www.soe.wa.gov.au/report/biodiversity/introduced-animals-.html, accessed 23 April 2008.

Environmental Protection Authority (EPA) 2008d, *State of the Environment Report: Biodiversity - Changed fire regimes*, http://www.soe.wa.gov.au/report/biodiversity/changed-fire-regimes.html, accessed 23 April 2008.

Evans, L. 2006, *Preliminary Dewatering-Reinjection Operational Report - Marra Mamba Below Watertable Project*, unpublished report prepared for Pilbara Iron, January 2006.

Florentine, S. K. 1999, *Ecology of* Eucalyptus victrix *in grassland in the floodplain of the Fortescue River*, PhD Thesis, Curtin University of Technology, Western Australia.

Fortech 1999, *Pilbara Mulga Study Stage 1*, prepared for the Department of Resources Development, March 1999.

Froend, R.H. and Loomes, R.C. 2004a, *Approach to the Determination of Ecological Water Requirements of Groundwater Dependent Ecosystems in Western Australia*, Report No. CEM 2004-12, Centre for Ecosystem Management, Edith Cowan University, Joondalup.

Froend, R.H. and Loomes, R.C. 2004b, *South West Yarragadee - Assessment of Vegetation Susceptibility and Possible Response to Drawdown*, report prepared for Water Corporation, December 2004.

Froend, R.H. and Zencich, S. 2001, *Phreatophytic Vegetation and Groundwater Study. Phase 1 : Phreatophytic Vegetation Research Review*, Report No. CEM 2001-12, Centre for Ecosystem Management, Edith Cowan University, Joondalup.

Froend, R.H., Loomes, R.C., Horwitz, P., Bertuch, M., Storey, A. and Bamford, M. 2004, *Study of Ecological Water Requirements on the Gnangara and Jandakot Mounds under Section 46 of the Environmental PRotection Act. Task 2: Determination of Ecological Water Requirements*, Draft report prepared for the Water and Rivers Commission.

Froend, R.H., Loomes, R.C. and Zencich, S. 2002, *Drought Response Strategy - Assessment of Likely Impacts of Drawdown on Groundwater Dependent Ecosystems*, Report No. CEM 2002-09, Centre for Ecosystem Management, Edith Cowan University, Joondalup.

Gaia Resources 2008, *Marandoo Remote Sensing Acquisition and Analysis*. Unpublished report to Rio Tinto.

Gentilli, J. 1972, *Australian Climate Patterns*, Nelson.

Government of Western Australia 1975, EPA Red Book Recommendations for Conservation Reserves of Western Australia, Perth.

Government of Western Australia 1987, A Nature Conservation Strategy for Western Australia, Perth

Government of Western Australia 2001, *State Water Quality Management Strategy No. 1 Framework for Implementation*, May 2001.

Government of Western Australia 2003a, *Hope for the Future: The Western Australian State Sustainability Strategy*, Department of the Premier and Cabinet, Perth.

Government of Western Australia 2003b, *Draft Greenhouse Gas Strategy for WA*, Department of the Premier and Cabinet, Perth.

Hancock, P. 2002, 'Human impacts on the stream-groundwater exchange zone', in *Environmental Management*, vol. 29, pp. 763–781.

Hick, Caccetta and Corner, 1998. *An assessment of vegetation condition and monitoring strategy for Hamersley Iron's Central Pilbara Railway reserve (CPR) through Karijini National Park using remotely-sensed and ancillary data*, Unpublished report for Rio Tinto.

Higgins, P. J. 1999, *Handbook of Australian, New Zealand and Antarctic Birds Volume 4: Parrots to Dollarbird*, Oxford University Press, South Melbourne.

Hook, D. D. 1984, 'Adaptations to flooding with fresh water', in *Flooding and Plant Growth*, ed. Kozlowski, T. T., Academic Press, New York, pp. 265–294.

Hopper, S. 2003, 'An evolutionary perspective on south-west Western Australian landscapes, biodiversity and fire: A review of management and implications', in *Fire in Ecosystems of South-west Western Australia: Impacts and Management*, eds. Abbott, I. and Burrows, N., Backhuys Publishing, Amsterdam.

Humphreys, W. F. 1993, 'Cave Fauna in Semi-Arid Tropical Western Australia: A diverse relict wet-forest litter fauna', in *Memoires de Biospeologie*, Tome XX, pp. 105–110.

Humphreys, W. F. 1999, 'Relict stygofaunas living in sea salt, karst and calcrete habitats in arid north-western Australia contain many ancient lineages', in *The Other 99%: The Conservation Biodiversity of Invertebrates*, eds. Ponder, W. and Lunney, D., Royal Zoological Society of New South Wales, Sydney, pp. 219–227.

Humphreys, W. F. and Shear, W. A. 1993, 'Troglobitic Millipedes (Diplopoda, Paradoxosomatidae) from semi-arid Cape Range, Western Australia: systematics and biology', in *Invertebrate Taxonomy,* vol. 7, pp. 173–195.

John Cleary Planning 2005, *Mesa A - Warramboo Robe River: Landscape and Geodiversity Assessment Study*, unpublished report prepared for Robe River Iron Associates.

Johnson, S. L and Wright, A. H. 2003, *Mine void water resource issues in Western Australia*: Western Australia, Water and Rivers Commission, Hydrogeological Record Series, Report HG 9, 93p

Kendrick, P. 2001, *Pilbara 3 (PIL3 - Hamersley sub-region)* in "A Biodiversity Audit of Western Australia's 53 Biogeographical Sub-regions 2002", eds. May, J. E. and McKenzie, N. L. 2003, Department of Conservation and Land Management, Perth.

Kinhill Engineers Pty Ltd (Kinhill) 1996, *Central Pilbara Railway Rosella Siding to Homestead Junction Section: Drainage Mitigation Plan*, unpublished report prepared for Hamersley Iron, August 1996.

Kitchener, D. J. and Vicker, E. 1981, Catalogue *of Modern Mammals in the Western Australian Museum 1895–1981*, Western Australian Museum.

Knight Piésold Pty Ltd (Knight Piésold) 2007, *Rio Tinto Iron Ore Expansion Projects - Marandoo Mine Phase 2 Project - Waste Fines Storage Facility (WFSF) Preliminary Cost Study*, unpublished report prepared for Pilbara Iron, June 2007.

Landscape Institute and the Institute of Environmental Management and Assessment (LI and IEMA) 2002, *Guidelines for Landscape and Visual Impact Assessment*, Second Edition, Spon Press, 2002.

Liquid Earth 2005, *Marandoo Hydrogeological Investigation Report*, unpublished report prepared for Pilbara Iron, August 2005.

Marchant, S. and Higgins, P. J. 1993, *Handbook of Australian, New Zealand and Antarctic Birds Volume 2: Raptors to Lapwings*, Oxford University Press, South Melbourne.

Mattiske, E. M. and Associates (Mattiske) 1992, *Flora and Vegetation: Marandoo Project Area*, unpublished report prepared for Enviroscan, January 1992.

Mattiske Consulting Pty Ltd (Mattiske) 2008, *Review of flora and vegetation along creek systems near discharge points - Marandoo*, unpublished report prepared for Rio Tinto, August 2008.

McDonald, E and Coldrick, B, 2008 *Preliminary Report of a Desktop Ethnographic Assessment of Groundwater-Related Aboriginal Sites at the Marandoo Iron Ore Mine, near Tom Price, Pilbara, Western Australia*, Unpublished report prepared for the Guruma Mali Wartu Aboriginal Corporation and Pilbara Iron Pty Ltd

Mees, G. F. 1961, 'An Annotated Catalogue of a Collection of Bird-Skins from West Pilbara, Western Australia', in *Journal of the Royal Society of Western Australia*, vol. 44, pp. 97–143.

Minerals Council of Australia 2004, *Enduring Value: The Australian Minerals Industry Framework for Sustainable Development*, October 2004.

Muir, B. G. 1980, *A fauna survey of Hamersley Range National Park*, Western Australia.

Muir Environmental 1995, *Possible Long-term Impacts of the Yandicoogina Iron Ore Project on Riverine Species along Marillana Creek,* unpublished report prepared for BHP Iron Ore and AGC Woodward-Clyde Pty Ltd, November 1995.

Muller C. 2005, *Water flow in Mulga areas adjoining Fortescue Marsh.*

MWH Australia Pty Ltd (MWH) 2006a, *Marandoo Model Development 2006*, unpublished report prepared for Pilbara Iron, May 2006.

MWH Australia Pty Ltd (MWH) 2006b, *Marra Mamba BWT Project - Dewatering and Re-injection Program*, unpublished report prepared for Pilbara Iron, April 2006.

MWH Australia Pty Ltd (MWH) 2006c, *Marandoo BWT Order of Magnitude Study: Water Management Options*, unpublished report prepared for Pilbara Iron, January 2006.

MWH Australia Pty Ltd (MWH) 2007a, *Southern Fortescue Sinkholes Position Paper*, unpublished report prepared for Pilbara Iron, July 2007.

MWH Australia Pty Ltd (MWH) 2007b, *Southern Fortescue Borefield Numerical Modelling*, unpublished report prepared for Pilbara Iron, July 2007.

MWH Australia Pty Ltd (MWH) 2008a, *Marandoo and SFB Modelling Update Report*, unpublished letter report prepared for Pilbara Iron, August 2008.

MWH Australia Pty Ltd (MWH) 2008b, *Marandoo and SFB Modelling Update Report*, unpublished letter report prepared for Pilbara Iron, February 2008.

MWH Australia Pty Ltd (MWH) 2008c, 'Groundwater Management Considerations', extract from *Marandoo BWT Dewatering Discharge Management Plan*, unpublished report prepared for Pilbara Iron, June 2008.

National Parks Authority 1983, *A Fauna Survey of the Hamersley Range National Park, Western Australia 1980*, National Parks Authority of WA, Bulletin No. 1.

Nicholls, O. 2006, *Marandoo Mulga monitoring - Summary of 2005 results*.

Ninox Wildlife Consulting (Ninox) 1992, *Marandoo Project Area Vertebrate Fauna Assessments (1975–1991)*, unpublished report prepared for Enviroscan, January 1992.

O'Brien, B. J. and Associates Pty Ltd (O'Brien) 1992, *Marandoo Iron Ore Mine and Central Pilbara Railway Environmental Review and Management Program*, prepared for Hamersley Iron Pty Ltd, February 1992.

Office of Native Title 2007, *Native Title in the Pilbara, Eastern Guruma: WC97/89, WAD6208/98*, http://www.nativetitle.wa.gov.au/index.aspx?id=434 & http://www.nativetitle.wa.gov.au/agreements_All.aspx, accessed 19 May 2008.

Pilbara Development Commission 2008, *Regional History*, http://www.pdc.wa.gov.au/regional-information/history.aspx, accessed 19 May 2008.

Rio Tinto 2007, *Rio Tinto Aboriginal Policy and Programs*, Briefing Note, June 2007.

Rio Tinto. 2008, *Marandoo Mine Phase 2 Conceptual Closure Management Study*, unpublished report prepared for Rio Tinto, May 2008.

Ruprecht, J. and Ivanescu, S. 2000, *Surface Hydrology of the Pilbara Region: Summary Report*, Water and Rivers Commission Surface Water Hydrology Report Series, Report No. SWH 32.

Russell-Smith, J. 2005, *Fire in the Kimberley and Inland Regions of WA - Issues Paper,* Environmental Protection Authority, Perth.

Scarp Archaeology 2008, *Preliminary Advice of an archaeological survey at Marandoo Mine, Pilbara, Western Australia*, Stage 1, unpublished report prepared for Aboriginal Training and Liaison, Pilbara Iron and the Eastern Guruma Native Title Holders, March 2008.

Shire of Ashburton 2008, *Shire of Ashburton - Welcome to the Shire of Ashburton*, http://www.ashburton.wa.gov.au, accessed 19 February 2008.

Sinclair Knight Merz (SKM) 2008, *Marandoo Phase 2 Landscape and Visual Impact Assessment*, unpublished report prepared for Pilbara Iron, June 2008.

State Weed Plan Steering Group 2000, *A Weed Plan for Western Australia*, Draft for Public Comment, July 2000.

Strayer, D. L. 1994, 'Limits to biological distributions in groundwater', in *Groundwater Ecology*, eds. Gilbert, J., Danielopol, D. L. and Stanford, J. A., Academic Press, San Diego, pp. 287–310.

SVT Engineering Consultants (SVT) 2008, *Review of Noise Impacts Associated with the Marandoo Mine Phase 2 Project*, unpublished report prepared for Pilbara Iron, June 2008.

Texasgulf Australia Ltd (Texasgulf) 1979, *Marandoo Flora and Fauna*, unpublished report, Perth.

Thorne, A. M. and Trendall, A. F. 2001, *Geology of the Fortescue Group, Pilbara Craton, Western Australia*, Western Australia Geological Survey Bulletin No. 144.

Tongway, D. 1994, *Rangeland Soil Condition Assessment Manual*, CSIRO Division of Wildlife and Ecology, Canberra.

Trudgen, M. E. 1975, *Floristic Report on Marandoo Mining Site, May 1975*, unpublished report prepared for Texusgulf Australia Ltd.

Trudgen, M. E. 1977a, *Report on Visit to Marandoo, 7–10 October, 1977*, unpublished report prepared for Texusgulf Australia Ltd.

Trudgen, M. E. 1977b, *Report on Visit to Marandoo and Identification of Plant Specimens*, unpublished report prepared for Texusgulf Australia Ltd.

Trudgen, M. E. 1978, *Report on Visit to Marandoo and Mount Whaleback, 14–17 February 1978*, unpublished report prepared for Texusgulf Australia Ltd.

Trudgen, M. E. 1988, *A Report on the Flora and Vegetation of the Port Kennedy Area*, unpublished report prepared for Bowman Bishaw and Associates, West Perth.

van Vreeswyk, A. M. E., Payne, A. L., Leighton, K. A. and Hennig, P. 2004, *An Inventory and Condition Survey of the Pilbara Region, Western Australia*, Department of Agriculture Technical Bulletin No. 92.

Watt, C. H. S. and Humphreys, W. F. 2001, 'A new genus and six species of Dytiscidae (Coleoptera) from underground waters in the Yilgarn paleodrainage system of Western Australia', in *Records of the South Australian Museum*, vol. 34, pp. 99–114.

Western Australia Planning Commission (WAPC) 2004, *State industrial buffer statement of planning policy 4.1*, Government of Western Australia, Perth, July 2004.

Weston, A. S. 1977, *Report on Visit to Marandoo, December 17–19, 1977*, unpublished report prepared for Texusgulf Australia Ltd.

Wetland Research and Management (WRM) 2007, *Dewatering discharge: Potential impacts to aquatic biota of Weeli Wolli Creek*, unpublished report prepared for Rio Tinto Hamersley Hope Management Services, July 2007.

Wetland Research and Management (WRM) 2008, *Dewatering discharge: Potential impacts to aquatic biota of Fortescue River South*, unpublished report prepared for Rio Tinto, July 2008.

Williams, J. 2002, 'Fire Regimes and their Impacts in the Mulga (*Acacia aneura*) Landscapes of Central Australia', in *Australian Fire Regimes: Contemporary Patterns (April 1998 – March 2000) and Changes Since European Settlement*, eds. Russell-Smith, J., Craig, R., Gill, A. M., Smith, R. and Williams, J., Australia State of the Environment Second Technical Paper Series (Biodiversity), Department of the Environment and Heritage, Canberra.

Woodward-Clyde 1997, *Newman Satellite Development Mining of Orebody 23 Below the Watertable: Consultative Environmental Review*, unpublished report prepared for BHP Iron Ore, September 1997.

World Commission on Environment and Development (WCED) 1987, *Our Common Future*, Oxford University Press.

Youngs, J. and Brown, D. M. 2005, *Aquifer re-injection as a low impact groundwater investigation tool - a case study from the Pilbara region*, Western Australia, unpublished report prepared for Pilbara Iron, 2005.

Zencich, S.J., Froend, R.H., Turner, J.T. and Gailitis, V. 2002, 'Influence of Groundwater Depth on the Seasonal Sources of Water Accessed by Banksia Tree Species on a Shallow, Sandy Coastal Aquifer', *Oecologia*, vol. 131, pp 8-19.

Supporting documents

The supporting documents listed are contained on CD-ROM inside the back cover of the Public Environmental Review.

Supporting documents

The following supporting documents are contained on CD-ROM inside the back cover of the Public Environmental Review.

Batini, F. 2008a, *Marandoo Phase 2 Proposal - Mining below watertable - Assessment of Impacts from Groundwater Dewatering and Surface Water Drainage on Significant Vegetation - Coolibah and Mulga*, unpublished report prepared for Rio Tinto Iron Ore, May 2008.

Batini, F. 2008b, *Report on Coolibah survey results - April 2008*, unpublished report prepared for Rio Tinto Iron Ore, April 2008.

Batini, F. 2008c, *Marandoo Mulga monitoring - Summary of 2005 results*, unpublished report prepared for Rio Tinto Iron Ore, April 2008.

Biota Environmental Sciences (Biota) 2008a, *Residue Storage Facility Option 2 - Marandoo Mine Phase 2*, letter to Una Phelan, Rio Tinto, 12 March 2008.

Biota Environmental Sciences (Biota) 2008b, *Marandoo Mine Phase 2 Project Vegetation and Flora Survey*, unpublished report prepared for Pilbara Iron, June 2008.

Biota Environmental Sciences (Biota) 2008d, *Marandoo Mine Phase 2 Seasonal Fauna Survey*, unpublished report prepared for Pilbara Iron, April 2008.

Biota Environmental Sciences (Biota) 2008e, *Marandoo Mine Phase 2 Extension Subterranean Fauna Assessment*, unpublished report prepared for Pilbara Iron, May 2008.

Dodson, W, 2008, *Marandoo Phase II Spring and Gorge Water Assessment*, Unpublished report prepared for Rio Tinto, August 2008.

Mattiske Consulting Pty Ltd (Mattiske) 2008, *Review of flora and vegetation along creek systems near discharge points - Marandoo*, unpublished report prepared for Rio Tinto, August 2008.

MWH Australia Pty Ltd (MWH) 2008, *Southern Fortescue borefield modelling - Preliminary Results*, unpublished letter report prepared for Pilbara Iron, August 2008.

Rio Tinto 2008, *Marandoo Mine Phase 2 Conceptual Closure Management Study*, unpublished report prepared for Rio Tinto, May 2008.

Sinclair Knight Merz (SKM) 2008, *Marandoo Phase 2 Landscape and Visual Impact Assessment*, unpublished report prepared for Rio Tinto, June 2008.

Wetland Research and Management (WRM) 2008, *Dewatering discharge: Potential impacts to aquatic biota of Fortescue River South tributaries*, unpublished report prepared for Rio Tinto, July 2008.

Environmental Management Plan

The Proponent will minimise environmental impacts through the implementation of ongoing management measures.

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1. Introduction

1.1 Overview of the Environmental Management Plan

As part of Marandoo Mine Phase 2 ('the Proposal'), the Proponent has committed to the development and implementation of an Environmental Management Plan (EMP) to address potential construction and operational impacts of the Proposal. The purpose of this EMP is to document environmental management objectives and strategies in relation to the Proposal, including:

- environmental factors potentially affected by the construction and operational phases of the Proposal
- measures to prevent, minimise, mitigate and manage any potential environmental impacts of the Proposal
- monitoring and reporting procedures.

This EMP will form the basis for minimum standards that will be carried forward by the Proponent during both construction (via Engineering, Procurement and Construction Management) and operation. The EMP has been split into two parts. Part I defines the overarching environmental management procedures, processes and systems in place to ensure all management measures are adequately implemented. This includes details on statutory obligations, responsibilities, environmental awareness and inductions, document and incident management and the EMP review procedure. Part II includes the management plans that have been developed in response to the impacts identified during the environmental review process. Each plan contains detailed measures to guide the implementation of the Proposal in an environmentally acceptable manner. The Proponent has comprehensive standard corporate practices in place to manage potential environmental impacts at all operations, including the existing Marandoo above watertable operation. These standard procedures address in detail all management measures required to mitigate potential risks resulting from the implementation of the proposal.

The following management plans have been developed as part of the EMP:

- Groundwater Management Plan
- Surface Water Management Plan
- Vegetation and Flora Management Plan
- Coolibah Management Plan
- Terrestrial Fauna Management Plan
- Fire Management Plan
- Waste Management Plan
- Dust Management Plan
- Cultural Heritage Management Plan.

The majority of the management plans represent a summary of the relevant existing corporate procedures; however, the Groundwater, Surface Water and Coolibah Management Plans have been developed to a higher detailed standard than other management plans, to address uncertainties in predicted impacts, or to provide additional protection to areas of high conservation significance. This has been achieved through the incorporation of adaptive management plans (Coolibah and surface water) and/or additional site-specific management strategies.

The Coolibah and surface water adaptive management plans utilises the following three trigger levels:

- Level 1 trigger: Focus - establish a watching brief. Identification of the cause of trigger level exceedence is required, to determine whether the trigger event is the effect of mining activities or as a result of natural or other changes. This level 1'focus' trigger will ensure appropriate monitoring and management attention is given to the event or issue. No significant or irreversible environmental impacts are expected at this trigger level.
- Level 2 trigger: Investigate - detailed investigation required. Causal investigations will be undertaken, with an emphasis on increased monitoring. Remedial actions may be taken where necessary. This level 2 'investigate' trigger will ensure the event or issue is understood and appropriate response measures are developed. No significant or irreversible environmental impacts are expected at this trigger level.
- Level 3 trigger: Action - highest investigation level with advisory notification of event or issue to relevant stakeholders including the DEC and DoW. Active intervention and contingency measures will be implemented as required. This level 3 'action' trigger will ensure appropriate counter-measures are deployed.

The Cultural Heritage Management Plan represents a summary of the site-specific Cultural Heritage Management Plan that has already been developed for Marandoo. This Cultural Management Plan will be further refined as results of ongoing surveys become available.

Each individual management plan is structured in a consistent format as outlined in Table 1.

1.2 Statutory and other obligations

The Proposal will be implemented in compliance with relevant environmental laws and regulations (Table 2), legal obligations and commitments, in accordance with the Rio Tinto Legal and Other Requirements Procedure.

A Legal and Other Requirements Register will be developed and maintained throughout the Proposal in accordance with the Rio Tinto Legal and Other Requirements Register Template to ensure relevant legal and other requirements have assigned accountabilities and that a process is in place for compliance auditing.

Prior to implementation of the Proposal, a Works Approval will be obtained under Part V of the *Environmental Protection Act 1986* (WA) where required for each prescribed premise. The conditions of each Works Approval will be incorporated into the relevant management plan. Where there is conflict between the conditions of the management plan and the Works Approval, the conditions of the Works Approval will prevail.

All relevant documentation including licenses, permits and approvals applications will be available to site personnel.

Compliance auditing will be conducted on at least an annual basis to monitor ongoing compliance with all legal and other requirements.

Table 1
Management Plan framework

Management Plan Framework	
Management Issues	Outlines the anticipated construction and/or operational issues associated with the Proposal
Objectives	Establishes over-arching objectives for environmental management of the Proposal consistent with the Rio Tinto Environmental Objectives and Targets Procedure and the Rio Tinto Expansion Projects Environmental Objectives and Targets Register
Targets	Establishes specific targets for environmental management of the Proposal based on over-arching management objectives consistent with the Rio Tinto Environmental Objectives and Targets Procedure and the Rio Tinto Expansion Projects Environmental Objectives and Targets Register
Performance Indicators	Provides details on the studies and key indicators that will be used to determine the Proponent's achievement of the targets
Standard Management Strategies	Provides details of standard management measures performed to facilitate sound environmental management to all Rio Tinto projects and operations
Proposal Specific Management Strategies	Provides details of management measures developed specifically for the Proposal and not adequately addressed through implementation of standard Rio Tinto Management Strategies
Monitoring	Provides information on monitoring activities to be performed consistent with the Rio Tinto Data Quality Guidance Note, Environmental Monitoring and Measurement
Contingency Trigger and Actions	Provides details of actions to be taken in the event that specified criteria are breached

Table 2
Commonwealth and state legislation and standards relevant to environmental management of the Proposal

Legislation/Regulation	**Application**
Environmental Protection Act 1986 (WA)	Prevention, control and abatement of pollution. Conservation, protection and enhancement of the environment. Environmental Assessment, Works Approval and Pollution Prevention Licences.
Environment Protection and Biodiversity Conservation Act 1999 (Cwth)	Protects matters of National Environmental Significance.
Native Title Act 1993 (Cwth)	Recognition and protection of native title.
Conservation and Land Management Act 1984 (WA)	Preservation and conservation of flora and fauna.
Soil and Land Conservation Act 1945 (WA)	Conservation of soil and land resources and mitigation of the effects of erosion.
Aboriginal Heritage Act 1972 – 1980 (WA)	Protection of sites of Aboriginal heritage significance, both known and as yet unknown.
Australian Standard (AS1940 – 1993): The Storage and Handling of Flammable and Combustible Liquids	Design and specifications for the handling and storage of flammable and combustible liquids.
Environmental Protection (Liquid Waste) Regulations 1996 (WA)	Control and abatement of liquid waste.
Environmental Protection (Noise) Regulations 1997 (WA)	Noise limits, methods for noise assessment and control.
Explosive and Dangerous Goods (Dangerous Goods Handling and Storage) Regulations 1992 (WA)	Regulations for management and handling of dangerous goods.
Explosives and Dangerous Goods Act 1961 (WA)	Specifies storage, handling and blasting requirements.
Wildlife Conservation Act 1950 (WA)	Conservation and protection of wildlife (flora and fauna). Special provisions and schedules apply to the protection and management of gazetted rare flora and fauna.
Agriculture and Related Resources Protection Act 1976 (WA)	Obligations for control, destruction and notification of gazetted noxious plants and animals.
Australian Heritage Commission Act 1975 (WA)	Identifies areas of national heritage significance.
Bush Fires Act 1974 (WA)	Minimising dangers resulting from bush fires, and the prevention, control and extinguishment of bush fires.
Clean Air Regulations 1967 (WA)	Regulates air borne emissions.

1.3 Responsibilities, authorities and resources

This EMP is a reference document and will be made available for use by all site personnel. The EMP provides an overview of the environmental initiatives to be undertaken during the Proposal.

Implementation of the EMP management practices and procedures is the responsibility of all site personnel; however, key personnel (Project Manager, Construction Manager, Superintendents and the Site Environmental Officer) are responsible for communicating environmental matters and ensuring management practices and procedures are being implemented.

Where surveys or studies are currently conducted by third parties the Proponent commits to completing those surveys in the event that the third party is unable to for any reason.

2. Environmental awareness and inductions

2.1 Objective

All personnel will be inducted to ensure they are aware of environmental expectations, requirements of the EMP, environmental sensitivities in and around the Proposal area, and tasks and procedures to be followed and complied with to minimise environmental impacts.

The objectives of the Environmental Induction Program are:

- to ensure all personnel are aware of environmental sensitivities in and around the Proposal area, as well as the environmental issues and appropriate management measures
- to ensure all personnel are aware of their environmental responsibilities
- to ensure compliance with the Rio Tinto Health Safety and Environmental (HSE) Policy, the Proponent's Corporate Environmental Policy, regulatory requirements, legal obligations and environmental management commitments.

2.2 Components addressed

The Induction Program will cover the following (as a minimum):

- Rio Tinto HSE Policy
- Proponent's Corporate Environmental Policy
- legislative responsibilities
- duty of care
- requirements of the EMP
- rehabilitation
- hazardous materials management
- heritage.

In respect to the requirements of the EMP, the induction program will specifically address the issues set out in Table 3.

Basic fire training, conducted separately to the induction, provides instruction in relation to the following issues:

- the effects of fire on vegetation and fauna
- basic fire fighting training
- fire restrictions
- fire vehicle access and maintenance
- fire fighting equipment location and use.

Personnel will be required to sign an attendance record and a declaration that they agree to comply with tasks and procedures outlined in the EMP.

Visitors to the site will be informed of the relevant environmental policy-related and site-specific requirements. They will be advised that conformance to these requirements is a pre-condition of being allowed to enter and remain on the site.

Table 3
Induction program

Area to be covered	Induction material
Groundwater protection	• potential for fuel and chemical spillages to contaminate groundwater • consequences of groundwater contamination • proper storage and handling of fuel and chemicals • spill response procedures.
Surface water protection	• potential for drainage and stormwater management to affect vegetation, fauna and surface water values • drainage and stormwater management procedures.
Vegetation and flora	• importance of vegetation and flora protection with specific emphasis on areas of Coolibah and Mulga • existing remnant vegetation and significant flora locations and their importance • the requirement to stay within approved clearing boundaries • appropriate recreational behaviour to minimise disturbance to vegetation and flora • the importance of controlling the spread of weeds • identification and reporting of weeds • procedures to minimise the introduction and spread of weeds.
Terrestrial fauna	• potential for mine activities to affect fauna and fauna habitat • fauna encounter procedures • appropriate recreational behaviour to minimise disturbance to fauna • feral animal controls.
Waste	• recycling and housekeeping • the need for all work areas to be maintained in a neat and orderly manner.
Dust	• potential effects of dust on health and the environment • dust suppression procedures.
Workforce	The workforce will be inducted on how they will behave in Karijini National Park and will be briefed and referred to the Karijini National Park Management Plan. They will be instructed on such issues as: • the requirement to remain on established walking and vehicle tracks wherever possible • appropriate, low-impact behaviour within Karijini National Park • the potential for off-road access to result in increased erosion and weed dispersal • prohibition of consumption of alcohol in National Parks, except in areas as permitted by the DEC • relevant National Park policies and requirements, including entrance fees, campfires and firewood collection.
Aboriginal heritage	Aboriginal heritage requirements in relation to disturbance of sites.

3. Document and incident management

3.1 Document control

A document control system will be implemented to ensure that copies of the EMP are updated as revisions occur.

The system will include mechanisms to ensure the EMP reflects changes to supporting documents including the Rio Tinto HSE Policy, Proponent's Corporate Environmental Policy, all relevant legal documentation (including licences, permits and approvals applications), the Legal and Other Requirements Register and the Construction Environmental Risk Register.

The Iron Environmental Management System (IEMS) allows Rio Tinto personnel to access key environmental documents and forms.

3.2 Complaints, incidents and corrective actions

All environmental incidents and 'near misses' will be recorded on the Environmental Incident Register in accordance with the Rio Tinto Incidents and Corrective Actions Procedure. Incidents will be reported by the person who causes or identifies the incident within 24 hours of its identification. A completed Incident Form will also be submitted within seven days of the incident identification. Incidents and 'near misses' will be investigated and appropriate measures implemented to prevent recurrence. Environmental incidents considered significant will be reported to the government where required. The Site Environmental Officer is responsible for fulfilling any further reporting requirements and ensuring that the cause of the incident is determined and the appropriate remedial and/or preventative action taken.

The Incident Register will be reviewed regularly to ensure trends (if any) are identified and to assess the effectiveness of preventative measures.

All community complaints will be recorded on the complaints register and investigated to the satisfaction of the regulatory authorities. A summary of the complaint, including any monitoring results and corrective action (proposed mitigation measures) will be prepared and submitted in the annual Compliance Report.

3.3 Emergency response

Emergency response plans will be developed in accordance with the Rio Tinto Approvals Coordination Emergency Procedure to minimise environmental impacts of emergency scenarios (including hazardous materials, minerals waste and residue storage facilities, drought, flood, failure of flood retention structures and unplanned discharges).

The emergency response plan will detail:

- potential environmental emergencies
- associated measures required to mitigate environmental harm
- communication procedures and emergency contact details.

Emergency response training will be provided to all personnel and appropriate emergency response equipment will be available on-site.

3.4 Monitoring and reporting

Monitoring will be undertaken to verify compliance with environmental conditions and commitments, satisfy regulatory and reporting requirements, track environmental performance and measure the effectiveness of environmental management measures.

Monitoring will be completed in a manner consistent with the Rio Tinto Data Quality Guidance Note to ensure completeness, comparability, representativeness, accuracy and precision.

Monitoring outcomes will be submitted in the Monthly Environmental Report and contribute to the Annual Environmental Report. Reporting of monitoring will include, but not be limited to, the following:

- definition of the intent and the scope of the monitoring program
- specification of the parameters to be measured and appropriate units
- outline of monitoring methods consistent with the Rio Tinto Environmental Monitoring and Measurement Guidance Note
- specification of the frequency of the monitoring
- assumptions made
- calibration requirements and records.

3.5 Inspections and audits

3.5.1 Auditing

Auditing forms an important part of the EMP implementation. The objective of Environmental Compliance Audits is to ensure that environmental objectives and performance criteria are met, assess the effectiveness of management measures and verify environmental compliance with the EMP, environmental policies, legal requirements, conditions and commitments.

Compliance auditing will include, but not be limited to:

- disturbance beyond the approved boundary
- impacts to flora and fauna
- rehabilitation
- any aspects of the Proposal that result in pollution
- effluent or wastes
- permits/licences
- impacts to Cultural heritage
- management systems to identify, control and monitor environmental risks arising during the Proposal
- contractor compliance with all relevant environmental requirements
- reviewing the effectiveness of the EMP.

Environmental Compliance Audits will be conducted by an independent auditor on at least an annual basis in accordance with the Rio Tinto Environmental Audit Schedule and Requirements. Compliance Reports will be submitted to the Environmental Protection Authority (EPA) on an annual basis in accordance with the approved Audit Program.

Where non-conformances are identified, corrective actions will be identified and incorporated into an amended edition of the EMP. All employees will be inducted on the revised EMP as soon as practicable.

3.5.2 Reporting

Results of all monitoring and inspections will be reported consistent with regulatory, local and Proposal requirements. The EPA and/or DEC will be notified as soon as practicable of any instances of serious environmental harm.

3.6 Management Plan review

The EMP is a dynamic document that will be reviewed and revised as required, on at least an annual basis.

Through the process of audits, corrective actions and the inclusion of new initiatives in environmental management, the EMP will be reviewed and revised to ensure environmental objectives are met and management practices undertaken. Factors such as changes to the Proposal, construction experience, new initiatives for environmental management and regulatory changes will be taken into account.

Such revisions will ensure the EMP reflects current requirements of:

- the Rio Tinto HSE Policy and the Corporate Environmental Policy
- the Ministerial Statement of Approval under Part IV of the *Environmental Protection Act 1986* (WA)
- Works Approvals
- other relevant licences and statutory requirements.

Relevant government agencies will be consulted where a proposed change may relate to a particular agency's area of responsibility and approval for amendments will be sought.

4. Environmental management plans

4.1 Groundwater Management Plan

4.1.1 Background

- Based on the current mine plan, construction schedules and understanding of the hydrogeological system at Marandoo (including considerations for climate variability), the Proponent estimates a peak mean abstraction rate of approximately 65 ML/day which would reduce over the duration of the Proposal.
- Approximately 5 ML/d of dewatering water will be used at the Marandoo mine site (potable use, dust suppression and wet processing of ore) and the operation's accommodation camp.
- Preliminary assessment suggests Tom Price will be able to accept approximately 30 ML/d of excess dewatering water from the Proposal, except during periodic maintenance and emergency shutdown events (where the demand from Tom Price will be reduced to zero).
- Water not required at Tom Price will be re-injected into the Southern Fortescue aquifer system.
- Where the volume of excess water exceeds the capacity for re-injection, the remaining excess will be discharged to nearby natural drainage lines.
- Dewatering at Marandoo will result in a reduction in pressure (drawdown) in the confined aquifer. The potential for this reduction to result in groundwater drawdown within the unconfined aquifer is expected to be negligible due to the intervening clay layer.
- Intersection of the unconfined aquifer by the northern margin of the proposed mine pit is predicted to result in drawdown of the watertable due to seepage into the pit of approximately 10–20 m at the pit margin, to approximately 0–2.5 m at the Coolibah woodland on the Mount Bruce Flats.

A detailed description of groundwater aspects of the Proposal is included in Section 5.2 of the PER.

Management in relation to discharge of excess dewatering water is addressed in the Surface Water Management Plan (Table 5).

Potential groundwater impacts as a result of the Proposal will be managed through the implementation of strategies outlined in Table 4.

Table 4
Groundwater management

Groundwater Management Plan	

Management Issues	Impacts resulting in a reduction in groundwater quality may occur as a result of:
	• ore body dewatering near the mine pit will lead to drawdown of groundwater levels in the confined aquifer, reduce throughflow west of Marandoo and may result in the formation of sinkholes throughout the cone of depressurisation (which may in turn harm native fauna and alter surface flows or groundwater recharge rates)
	• intersection of the unconfined aquifer by the proposed mine pit will cause seepage and subsequent groundwater drawdown in the unconfined aquifer
	• hydrocarbon spills may lead to groundwater contamination
	• re-injection of dewatering water at the Southern Fortescue borefield will lead to an increase in groundwater levels (to previous 'natural' levels) and may:
	  • cause or enhance sinkhole formation (which may in turn harm native fauna and alter surface flows or groundwater recharge rates)
	  • increase water levels in streams, pools and springs fed by the Southern Fortescue aquifer system
	• dewatering and reinjection may result in groundwater drawdown and increased groundwater levels at springs and pools in Karijini National Park.

Objectives	To ensure efficient, safe and sustainable use and protection of existing water resources and groundwater dependent ecosystems. To maximise opportunities for re-using water in preference to sourcing new water. To maintain the existing quality of water resources. To take water only from licensed sources. To minimise the potential for groundwater contamination. Compliance with relevant legislation, including meeting ANZECC* guidelines.
Targets	Groundwater levels do not exceed 5 m of historical (prior to abstraction at Southern Fortescue borefield) groundwater levels in observation bores, as a result of re-injection into the Southern Fortescue aquifer system. Groundwater abstraction does not exceed licence limits. Groundwater quality at all monitoring locations does not exceed ANZECC* requirements, taking into consideration natural background water quality and environmental values of the receiving environment.

Groundwater Management Plan	
Performance Indicators	Groundwater monitoring results. Environmental incident reports. Hydrocarbon and chemical storage infrastructure inspection reports. Effluent treatment infrastructure inspection reports. Groundwater abstraction data.
Standard Management Strategies	Opportunities for water recycling will be evaluated and will be undertaken where practicable (e.g. reuse of water for dust suppression). An appropriate understanding of the cumulative demands and impacts being placed on water resources and dependent ecosystems will be developed and maintained. This will include an assessment of current water requirements, prediction of future water requirements and effects on key upstream and downstream users. Targets will be developed to drive continuous improvements in on-site and off-site water management. A water quality monitoring program and schedule will be established for groundwater. The monitoring program will clearly identify the applicable legal compliance limits. Equipment used to monitor groundwater quality will be calibrated and associated records maintained. Water data will be maintained and will include: • abstraction monitoring including quantity and quality • discharge monitoring including quantity and quality • quantity of water that is recycled and re-used • aquifer monitoring including levels and quality. Water will only be taken from points licensed by the DoW. Copies of all water licences, permits and operating strategies will be held on-site. The amount of groundwater extracted will be reconciled regularly against the licence limit, and will not exceed the licensed limit.
Proposal Specific Management Strategies	Using the results of the Southern Fortescue borefield re-injection trial to more accurately characterise the Southern Fortescue hydrogeological system to allow for the incorporation of updated information into the Southern Fortescue and Marandoo groundwater models. Developing and implementing a rotational bore maintenance schedule to minimise potential for water to seep into the mine pit. Monitoring observation bores within Southern Fortescue borefield to ensure groundwater levels do not exceed 5 m of the original (pre-abstraction) groundwater levels due to re-injection. Optimising the location of the re-injection bores within the Southern Fortescue borefield to spread the rise in groundwater level across the borefield. Undertaking further hydrogeological investigations between Marandoo and Minthicoondunna spring to determine the hydraulic parameters of the Upper Tertiary sediments, and any hydraulic connection between the superficial calcrete aquifer and the confined aquifer. Monitoring the water level at Minthicoondunna Spring, and groundwater levels between Marandoo and Minthicoondunna Spring. Consulting with the Eastern Guruma people and other relevant stakeholders. Investigating the chemistry of groundwater at Marandoo and the Southern Fortescue borefield to understand the carbonate chemistry and any potential implications for clogging or dissolution of the formation matrix. Conducting an investigation into the mechanism of sinkhole formation at the Southern Fortescue borefield and completing an assessment of high risk areas at the Southern Fortescue borefield, Marandoo and surrounding areas. Undertaking studies to monitor sinkholes in the vicinity of Marandoo and the Southern Fortescue borefield, including investigating the number and size of existing sinkholes to provide a baseline for future monitoring, this may include: • visual monitoring • differential photogrammetry with respect to a baseline image. Managing sinkhole risk through early detection of the onset of surface deformation and/or reactivation of existing features. Fencing sinkholes and implementing other measures to reduce any potential risk to public safety.

Groundwater Management Plan					
	Applying controls to hydrocarbon transport, handling and disposal in accordance with the Proponent's corporate standards. Applying existing hydrocarbon clean-up procedures. Safe storage, handling and disposal of ablution effluent.				
Monitoring	**Groundwater levels and quality**				
	Location	**Frequency**	**Parameters**	**Procedure**	**Purpose**
	Water collector tank (within the Marandoo rail loop)	Quarterly	EC, pH, temperature, TDS, TSS, $CaCO_3$, HCO_3, Ca, K, Mg, Na, Cl, SO_4, NO_3, NO_2, NH_3-N, F, As, Al, Ba, B, Cd, Cr, Cu, Fe, Pb, Mn, Mo, Zn, Total Hardness	Water Monitoring Procedure - Groundwater (Rio Tinto-HSE-0010726)	To closely monitor quality of dewatering water quality to ensure minimal impact on the environment.
		Continuously	Metering of dewatering volume at Marandoo rail loop water collector tanks and Southern Fortescue borefield terminal water tank		To closely monitor volume of dewatering water.
	Marandoo mine dewatering production bores	Monthly	Depth to water		To closely monitor borefield to provide information to feed into the adaptive management plan for Coolibah woodland and to ensure minimal impact on the environment.
	Marandoo mine dewatering observation bores	Monthly	Depth to water		To closely monitor borefield to provide information to feed into the adaptive management plan for Coolibah woodland and to ensure minimal impact on the environment.
	Southern Fortescue observation bores	Monthly	Depth to water		To closely monitor borefield to provide information to ensure compliance with Ministerial Conditions.
	Springs and Pools				
	Minthicoondunna Spring	Quarterly and opportunistically	pH, EC, temperature	Water Monitoring Procedure - Groundwater (Rio Tinto-HSE-0010726)	To closely monitor water levels and confirm source of water.
		Quarterly	Water level (including photographs)		
	Groundwater observation bores between Marandoo and Minthicoondunna Spring	Quarterly	Water level	Water Monitoring Procedure - Groundwater (Rio Tinto-HSE-0010726)	To closely monitor the cone of depression for early detection of any potential impact to Minthicoondunna Spring.

<table>
<tr><td colspan="6">Groundwater Management Plan</td></tr>
<tr><td rowspan="4"></td><td colspan="5">Sinkholes</td></tr>
<tr><td>Location</td><td>Frequency</td><td>Parameters</td><td>Procedure</td><td>Purpose</td></tr>
<tr><td rowspan="2">Southern Fortescue borefield</td><td>Quarterly</td><td>Visual monitoring</td><td rowspan="2">Various survey techniques are available and are currently under investigation</td><td rowspan="2">To identify depressions, low lying areas, strain lines directed towards depressions, areas along structural lineaments (e.g. marked by drainage channels and breaks in Marandoo Ridge) with high potential for sinkhole development</td></tr>
<tr><td>6 monthly (progressing to yearly)</td><td>Photogrammetry using differential photogrammetry with respect to a baseline image</td></tr>
<tr><td>In the vicinity of Marandoo minesite</td><td>To be determined</td><td>Onset of surface deformation and/ or reactivation of existing features</td><td>Various survey techniques are available and are currently under investigation</td><td>More detailed studies will be undertaken along the northern edge of the proposed development due to the risk of sinkhole development affecting key infrastructure and a detailed Trigger Action Response Plan (TARP) developed accordingly. Management of the sinkhole risk, will focus on early detection of the onset of surface deformation and/ or reactivation of existing features.</td></tr>
<tr><td></td><td colspan="5">Note water quality information collected from the dewatering infrastructure (at the water collector tanks) and the Southern Fortescue borefield baseline information will be used to investigate the chemistry of injecting waters and receiving groundwater to understand any potential implications on the carbonate chemistry for clogging or dissolution of the formation matrix.</td></tr>
<tr><td>Contingency Trigger</td><td colspan="5">Action</td></tr>
<tr><td>Water quality within Marandoo water collector tanks and/or Southern Fortescue borefield terminal tank in excess of permitted limit</td><td colspan="5">1. Investigate cause.
2. Undertake treatment as required.
3. Review the treatment schedule.</td></tr>
<tr><td>Groundwater levels within Southern Fortescue borefield observation bores exceed 5 m of the original (pre-abstraction) groundwater levels.</td><td colspan="5">1. Investigate cause of exceedence.
2. Validate measured response in groundwater model and run new predictions to determine future outcomes
3. Revise operational procedure if greater exceedence is predicted
4. Advise DoW and DEC of exceedence and undertake remedial action if required.</td></tr>
</table>

Groundwater Management Plan	
Springs and Pools	**Action**
Reduction in the water level at observation bores between Marandoo minesite and Minthicoondunna Spring as a result of the proposal	1. Investigate cause/s. 2. Commence more frequent (monthly) monitoring of water levels and validate groundwater model based on observed drawdown. 3. Based on revised groundwater model results, review and revise impact assessment and management plan. 4. Undertake appropriate remedial action as required.
Reduction in the extent or depth of Minthicoondunna Spring as a result of the proposal beyond the natural variation as measured at the site between 2002 and the start of dewatering.	1. Notify the CEO of DEC of the exceedence immediately. 2. Investigate cause/s and undertake stakeholder consultation. 3. Provide the CEO of DEC with details of mitigation and management being undertaken and an assessment of residual risk to the springs. 4. Undertake appropriate remedial action (e.g. re-injection and/or surface irrigation as required to the satisfaction of DEC and Traditional Owners.

*** Australian Water Quality Guidelines for Fresh and Marine Waters, ANZECC (November 1992, and its updates)**

4.2 Surface Water Management Plan

4.2.1 Background

- During pit development and other mining activities, local surface water drainage will be modified within the Proposal area.
- Up to approximately 60 ML/d of excess dewatering water may be required to be discharged intermittently to Southern Fortescue River tributaries when water cannot be accepted by Tom Price due to periodic maintenance events at Tom Price and/or when the Southern Fortescue borefield needs to be shutdown.
- It is anticipated that 15 ML/d of excess dewatering water way be required to be discharged continuously to natural drainage lines over an initial three year period.

A detailed description of surface water aspects of the Proposal is included in Section 5.3 of the PER.

Potential surface water quality impacts as a result of the Proposal will be managed through the implementation of strategies outlined in Table 5.

Table 5
Surface Water management

Surface Water Management Plan	

Management Issues	Impacts resulting in a reduction in surface water quality may occur as a result of:
	• discharge of excess dewatering water will alter local hydrological regimes and may potentially:
	  • affect aquatic fauna
	  • cause riparian vegetation to become dependent on the artificial flow
	  • increase prevalence of weeds
	  • increase erosion and sedimentation along discharge pathways
	• physical presence of mine pit and infrastructure will alter surface water flow paths
	• discharge of stormwater has the potential to affect surface water quality through sediment and hydrocarbon contamination
	• final landforms will lead to permanent changes to natural surface water flows.

Objectives	Ensure efficient, safe and sustainable use and protection of existing water resources and ecosystems. Maintain the existing quality of water resources. Maintain local drainage patterns where possible and minimise environmental impact of surface runoff. Minimise the potential for surface water contamination. Comply with relevant legislation including meeting ANZECC* guidelines.
Targets	No discharge from the Proposal area in exceedence of ANZECC* requirements, taking into consideration natural background water quality and environmental values of the receiving environment. No erosion or sedimentation in nearby streams from the discharge of stormwater or excess dewatering water. No hydrocarbon or chemical contamination of surface water beyond the immediate boundaries of the proposal area. No inappropriate release of effluent. No flooding or ponding as a result of project infrastructure.
Performance Indicators	Surface water monitoring results. Riparian vegetation monitoring results along surface discharge drainage lines. Erosion monitoring results. Environmental Incident Reports. Hydrocarbon and chemical storage infrastructure inspection reports. Effluent treatment infrastructure inspection reports.
Standard Management Strategies	Areas at risk of erosion will be identified. Pits, dumps and other infrastructure will be designed to reduce the potential for erosion (e.g. slopes will be contoured (gradient, length and height) to prevent erosion). Drainage, erosion and sediment control measures will be incorporated in the design of landforms. The total area to be disturbed will be limited to the minimum area required for the project. Unnecessary soil compaction and vegetation removal will be avoided to reduce surface flows from the site. Sufficient culverts will be used to minimise flow velocities when crossing drainage lines. Progressive stabilisation and revegetation of disturbed areas will be undertaken as part of the Proponent's Closure Plan. Water from the evaporation pond will be recycled for use in dust suppression around the site, where practicable.

<table>
<tr><td colspan="6">Surface Water Management Plan</td></tr>
<tr><td></td><td colspan="5">Drainage, erosion and sediment control structures and hydrocarbon treatment facilities will be routinely inspected and maintained to ensure they remain effective, including the removal of accumulated silt as required.

Effluent will be stored, transported and/or disposed of safely.

Hydrocarbons and chemicals will be stored, transported and/or disposed of safely.

Spillages of chemicals, hydrocarbons and explosives will be contained and immediately cleaned up to minimise contamination of surface waters.</td></tr>
<tr><td>Proposal Specific Management Strategies</td><td colspan="5">Excess water collected within mine pits will be diverted to sumps either on the pit floor or adjacent to the pit wall at the base of either the flow entry point or the bench diversion discharge point. The majority of sediment will have time to settle out of sumped water. Following sediment removal, water will be discharged along a drain to a culvert under the railway embankment.

Installing diversion drains around the RSF if required.

Stabilising diversion structures and drains to reduce erosion and water quality impacts.

Designing erosion protection at discharge outlets.

Ensuring any water discharged to the natural environment does not cause the quality of receiving surface or groundwater systems to exceed the ANZECC Water Quality Guidelines (ANZECC/ARMCANZ 2000).

Monitoring dewatering water quality at the water collector tanks.

Regularly monitoring channel morphology, riparian vegetation condition, erosion and pool water quality if pools are present along natural drainage lines downstream of proposed discharge outlet(s).

Developing and refining a discharge hydrograph to minimise erosion, prevent overtopping of drainage lines and where practicable, match the pattern of the natural hydrograph downstream of proposed discharge outlet(s).

Investigating alternative discharge regimes should surface flow extend beyond the length of channel (20 km) surveyed.

Designing waste dumps to incorporate water management features to reduce the potential for sediment-laden surface water runoff.

Treating surface runoff from the workshop, vehicle washdown and processing plant areas for sediment and hydrocarbons prior to re-use on site or for discharge to the natural environment.

Ensuring that drainage channels do not cross areas of active mining, or any locations where there is potential for hydrocarbon contamination.

Designing all sumps to fully contain the likely maximum volume of a one year ARI rainfall event, with an annual revision to ensure sump capacity increases in accordance with increasing catchment and pit area.

Inspecting sedimentation basins and drainage structures regularly and undertaking cleaning prior to the onset of the wet season each year.

Protecting the pit crest from erosion through provision of large boulders, rock armour and/or vegetation undertaking progressive backfill of pits.</td></tr>
<tr><td rowspan="3">Monitoring</td><td colspan="5">Minesite</td></tr>
<tr><td colspan="5">Visual inspections will be carried out during operations to determine the effectiveness of erosion control measures and stability of structures that may be prone to erosion (three monthly).</td></tr>
<tr><td>Location</td><td>Frequency</td><td>Parameters</td><td>Procedure</td><td>Purpose</td></tr>
<tr><td></td><td>Evaporation Pond</td><td>Monthly (and prior to each discharge event)</td><td>Total flow, pH, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total Residual Hydrocarbons (TRH), Chemical Oxygen Demand (COD), MBAS (Methyl Blue Active Substances), Pb, Cu, Fe, Mn, Mo, Zn, As, Hg, Cd, Cr</td><td>Water Monitoring Procedure - Surface Water (Rio Tinto-HSE 0010745)</td><td>To closely monitor the evaporation pond to ensure minimal impact on the environment and compliance with conditions.</td></tr>
</table>

Surface Water Management Plan					
	Location	**Frequency**	**Parameters**	**Procedure**	**Purpose**
	Discharge from the pit (sump)	Prior to each discharge	Visual and odour inspection for any indication of a hydrocarbon spill	To be determined	If a spill is suspected through visual and odour inspection of the sump area, water will be pumped to hydrocarbon treatment prior to discharge.
		During each discharge event	Total flow, pH, Total Disolved Solids (TDS), Total Suspended Solids (TSS), Total Recoverable Hydrocarbons (TRH), EC	Water Monitoring Procedure - Surface Water (Rio Tinto-HSE 0010745)	To contribute to future management practices.
	Residue Storage Facility	Quarterly and opportunistically during major (>50 mm rainfall events)	pH, TDS, TSS, Total Recoverable Hydrocarbons (TRH), Chemical Oxygen Demand (COD), Methyl Blue Active Substances (MBAS), Pb, Cu, Fe, Mn, Mo, Zn, As, Hg, Cd, Cr	Water Monitoring Procedure - Surface Water (Rio Tinto-HSE 0010745)	To closely monitor the residue storage facility to ensure minimal impact on the environment and compliance with conditions.
	Dewatering drainage lines, including discharge points				
	Location	**Frequency**	**Parameters**	**Procedure**	**Purpose**
	Dewatering water discharge drainage lines	3 monthly	Erosion and channel morphology	In accordance with standard Rio Tinto procedures	To closely monitor channel structure to ensure minimal impact on the environment.
		Continuous	Flow rate/water level	Water Monitoring Procedure - Surface Water (Rio Tinto-HSE 0010745)	To closely monitor water level and flow to ensure minimal impact on the environment and information to assist with management of impacts.
	Permanent/ semi-permanent pools (if present) within 20 km of discharge points, representative pools upstream of the dewatering discharge (upstream control) and in adjacent creeklines (reference sites) if present	Late wet (March/ April) and if dewatering discharge results in permanent flows or pools in the survey zone increase frequency to include late dry (Sept/Oct) also	Macroinvertebrates	250 µm mesh sweep net	To closely monitor aquatic systems to ensure minimal impact on the environment.
			Microinvertebrates	50 µm mesh sweep net	
			Fish	Seine net, gill net, fyke net, electrofisher, visual observation	
			pH, Dissolved Oxygen (DO), EC, Nephelometric Turbidity Unit (NTU), temperature, total-N, Total-P, ions, metals	Calibrated meters for field measurements and 0.45 µm filtered and unfiltered water samples for laboratory analysis	
			Incidental aquatic fauna (frogs, tortoise)	As sampled using above methods	

Surface Water Management Plan					
	Location	**Frequency**	**Parameters**	**Procedure**	**Purpose**
	Hamersley Pool (at head of Hamersley Gorge)	Late wet (March/ April) and late dry (Sept/Oct)	Macroinvertebrates	250 µm mesh sweep net	To provide baseline data for regional aquatic fauna studies and as a contingency to ensure that no environmental impact occurs as a result of this proposal
			Microinvertebrates	50 µm mesh sweep net	
			Fish	Seine net, gill net, fyke net, electrofisher, visual observation	
			pH, dissolved oxygen (DO), EC, Nephelometric Turbidity Unit (NTU), temperature, total-N, Total-P, ions, metals	Calibrated meters for field measurements and 0.45 µm filtered and unfiltered water samples for laboratory analysis	
			Incidental aquatic fauna (frogs, tortoise)	As sampled using above methods	
	Springs and pools				
	Location	**Frequency**	**Parameters**	**Procedure**	**Purpose**
	Banjima Pool	Quarterly and opportunistically during major (>50 mm) rainfall events	pH, EC, temperature.	Water Monitoring Procedure - Surface Water (Rio Tinto-HSE 0010745)	To closely monitor water levels
		Quarterly	Water level (including photographs)		
Contingency Trigger	**Action**				
Minesite					
Flooding or ponding occurring on-site	1. Investigate cause. 2. Modify the drainage system as required.				
Integrity of drainage system compromised	1. Investigate cause. 2. Modify the drainage system as required.				
Excess debris and sediment accumulation within drainage system	1. Investigate cause. 2. Undertake maintenance as required (e.g. remove accumulated material and ensure drainage system remains effective). 3. Review the drainage maintenance schedule.				
Discharge/runoff water quality does not meet relevant standards (e.g. for sediment content or hydrocarbons)	1. Immediately cease affected discharge. 2. Investigate cause. 3. Undertake treatment as required. 4. Review environmental incidents relating to water quality (e.g. hydrocarbon spills). 5. Review relevant environmental procedures (e.g. hydrocarbon spill procedures). 6. Review the need for personnel training (e.g. in spill procedures).				
Erosion of pits, dumps or other infrastructure due to surface water	1. Investigate cause. 2. Undertake maintenance as required. 3. Modify drainage infrastructure as required.				

Surface Water Management Plan	
Adaptive Management Plan	
Dewatering and discharge drainage lines	
Development of permanent surface flow in excess of 20 km as a result of the discharge of excess dewatering water	1. Investigate cause/s. 2. Commence more frequent (3 monthly) monitoring for water quality, vegetation and aquatic health and recalibrate hydrological calculations, if required. 3. Based on revised hydrological and monitoring results, review and revise impact assessment and management plan. 4. Undertake appropriate remedial action as required (may include switching to designated alternative discharge outlet). 5. Revise procedures as required to prevent recurrence.
Erosion or sedimentation along discharge pathways	1. Investigate cause. 2. Modify discharge hydrograph design and/or improve erosion protection structures as required. 3. Undertake channel excavations or increase channel stability (e.g. revegetation, fencing) as required. 4. Assess whether discharge should be directed to designated alternative discharge channel.
Increased weed abundance along discharge pathway	1. Investigate cause. 2. Undertake control measures as required. 3. Review the hygiene management as required to prevent recurrence.
Surface water or sub-surface water flow resulting from the discharge of excess dewatering water along reaches within 5 km of Hamersley Gorge	1. Notify the CEO of DEC immediately. 2. Investigate cause/s. 3. Provide the CEO of DEC with details of mitigation and management being undertaken and an assessment of residual risk to the Karijini National Park. 4. Undertake appropriate remedial action (e.g. look at alternative disposal options or alternative discharge points) as required to the satisfaction of DEC. 5. Revise procedures as required to prevent recurrence.

Australian Water Quality Guidelines for Fresh and Marine Waters, ANZECC (November 1992, and its updates)

4.3 Vegetation and Flora Management Plan

4.3.1 Background

- The Proposal will result in the progressive removal and rehabilitation of approximately 940 ha of native vegetation over the life of the Proposal.
- The Proposal is not expected to have any significant effect on regional vegetation values, as the vegetation units recorded from the Proposal area occur more broadly in the Marandoo locality, and also are not expected to be restricted to the locality. Approximately 90% of the proposed disturbance will be to vegetation of low conservation significance.
- No Threatened Ecological Communities, Declared Rare Flora species or vegetation of High conservation significance have been recorded within the Proposal area.
- Four Priority flora species have been recorded as scattered individuals in the Proposal area, including the Priority 1 species *Goodenia lyrata* and *Rhagodia* sp. Hamersley.
- Twenty (20) weed species have been recorded within the proposed disturbance area, most of which are widespread throughout the area and typically occurr as scattered plants.
- None of the weeds recorded comprise Declared Plants under the *Agriculture and Related Resources Protection Act 1976* (WA); however, *Cenchrus* species and *Acetosa vesicaria* (Ruby Dock) are considered to be serious environmental weeds (Biota 2008a).

A detailed description of vegetation and flora in and around the Proposal area is included in Section 5.4 of the PER.

Potential impacts on vegetation and flora as a result of the Proposal will be managed through the implementation of strategies outlined in Table 6.

Table 6
Vegetation and Flora management

Vegetation and Flora Management Plan	
Management Issues	Activities or aspects of the Proposal that may potentially affect flora and vegetation values include: • vegetation clearing will directly disturb vegetation units and Priority flora species • alteration of surface water flows through construction of mine pits, waste dumps and infrastructure may affect local water availability for some plant species • vehicle and earth movements could potentially introduce and/or spread weed species • groundwater drawdown within the unconfined aquifer due to seepage into the mine pit may reduce water availability for some plant species • discharge of excess dewatering water may affect vegetation health and composition, and favour the establishment of weeds along discharge pathways • re-injection of excess dewatering water at the Southern Fortescue borefield may affect vegetation health as a result of saturation of the soil profile • ignition sources resulting in increased fire frequency/intensity may favour the establishment of weeds and prevent the regeneration of native vegetation, particularly fire-sensitive species such as Mulga.
Objectives	To minimise the amount of vegetation and flora that is permanently cleared and ensure that ground disturbance does not occur outside of approved areas. To avoid significant vegetation communities and Priority Flora species as far as practicable. Identifying and mapping the extent and distribution of target weed species occurring within, and adjacent to the Proposal area (mine and SFB) and eradicating on an ongoing basis.
Targets	No clearing or disturbance outside pre-defined boundaries (as indicated in Schedule 1 of the Ministerial Statement for the Proposal) throughout the duration of the Proposal. No new weed species introduced into the Proposal area throughout the duration of the Proposal. No spread of existing target weed species into new areas throughout the duration of the Proposal.
Performance Indicators	Results of Proponent's Approvals Permits and inspection reports. Environmental Incident Reports (clearing outside approved areas). Extent and distribution of target weed species.
Standard Management Strategies	Priority flora species locations excluded from disturbance will be clearly marked and access to these areas prohibited. Maps and photographs of Priority flora will be displayed in the workplace to raise awareness and facilitate identification and on-the-ground management. The approved clearing envelope will be available to all persons involved in mine planning and relevant personnel involved in initial Proponent's Approvals Permit. Approvals Permit will be obtained in accordance with the Proponent's Approvals Permit procedure for each area to be disturbed.

Vegetation and Flora Management Plan	
	The boundaries of the working area will be verified by an environmental advisor prior to disturbance to ensure significant vegetation communities and flora are avoided as intended in the design. Established access tracks and roads will be used as far as practicable. Where new tracks are required, they will be preferentially located within previously disturbed areas. Access for vehicles and machinery will be along designated access tracks and parking areas. In accordance with Proponent's existing Approvals Permit Procedures, clearing boundaries will be defined with ground markings (e.g. flagging) or as GPS coordinates in earthmoving equipment prior to commencement of ground-disturbing activities to ensure personnel are aware of clearing limits. If DRF species are identified, they will be reported. If there is a need to disturb them, an application for a permit to take the plant/s will be lodged with the DEC, or the infrastructure will be re-located to avoid them. Approvals Permit approval request will be completed if proposed works will in any way change or disturb the ground surface. The process incorporates environmental and heritage surveys to ensure disturbance to these areas is avoidable wherever possible. Trees that overhang clearing areas will be pruned to the minimum required to ensure a safe working environment. Cleared vegetation (mulched) will be mixed with topsoil in preparation for use in rehabilitation. Temporarily disturbed sites will be rehabilitated as soon as practicable.
	Weed hygiene measures for mobilisation and demobilisation of mining equipment entering and leaving the Proposal area (i.e. between areas that are weed-infested and weed-free) will be implemented. To include: • inspecting the equipment • cleaning the equipment (including dust bowls and filters) at the nearest washdown facility, as required. An 'application to bring equipment onto site' form (or equivalent) will be completed for all earthmoving and mobile construction equipment and will include a declaration that the equipment is free from earth, weeds and weed propagules. Signage will be used where necessary to communicate weed-status of areas and hygiene requirements. Posters and other educational material relating to weed identification and control will be displayed in the workplace for weed identification and awareness.
Proposal Specific Management Strategies	Preventing unnecessary clearing of vegetation through locating infrastructure such as the wet processing plant and RSF within, or adjacent to already disturbed areas. Undertaking progressive rehabilitation of disturbed areas with local native flora species. Identifying and mapping the extent and distribution of target weed species occurring within, and adjacent to the Proposal area and eradicating weed occurrences on an ongoing basis. Surveying the Southern Fortescue borefield prior to any ground disturbance to ensure protection and avoidance of areas containing vegetation of high conservation significance and/or populations of significant flora where possible. Optimising the location of the re-injection bores within the Southern Fortescue borefield to spread the rise in groundwater level across the borefield. Monitoring observation bores within Southern Fortescue borefield to ensure groundwater levels do not exceed 5 m of the original (pre-abstraction) groundwater levels. Undertaking basic fire awareness and fire fighting training for all personnel (including contractors) prior to commencing work on-site. Maintaining adequate fire breaks across the mine site and around working areas where required. Ensuring a fire spotter is present when clearing vegetation near sensitive environmental areas.

Vegetation and Flora Management Plan					
Monitoring	**Location**	**Frequency**	**Parameters**	**Procedure**	**Purpose**
	Clearing lines, temporary fences and markings	Opportunistically and annually	Ground-truth approved clearing with actual clearing	In accordance with standard Rio Tinto procedures	To ensure clearing is in accordance with Approvals permits and the Mine Clearing Plan.
	Minesite	3 monthly	Weed species and abundance	Locations of weed infestations will be recorded by GPS and mapped	To closely monitor weed encroachment to ensure minimal impact on the environment and early management.
	Dewatering discharge drainage lines	6 monthly	Riparian and in-stream vegetation composition and indicator tree species health	To be determined	To closely monitor vegetation health to ensure minimal impact on the environment.
		6 monthly	Weed species and abundance	Locations of weed infestations will be recorded by GPS and mapped	To closely monitor weed encroachment to ensure minimal impact on the environment and early management.
Contingency Trigger	**Action**				
Marked clearing boundary is not as shown in the Mine Clearing Plan and/or Approvals Permit.	1. Stop work in area immediately adjacent to clearing boundary. 2. Complete incident report and investigations. 3. Implement corrective actions, which may include amending clearing boundaries in accordance with the Mine Clearing Plan and/or Approvals Permit.				
Breaching clearing boundary or cleared area larger than pre-defined boundaries	1. Report as Environmental Incident and initiate Incident Response Procedure including: a) stopping work in the vicinity of the clearing boundary b) investigating cause of breach. 2. Implement corrective actions, including rehabilitating the disturbed area 3. Implement measures to prevent recurrence.				
Additional population(s) of threatened flora species are found within the operational area.	1. Investigate opportunities to prevent or minimise the impact to the newly recorded flora. 2. Delineate individuals to be protected in the Geographic Information System. 3. If DRF are found and cannot be avoided, submit an application to the DEC to take DRF, for approval by the Minister for the Environment in accordance with the *Wildlife Conservation Act 1950* (WA). If Priority flora are found and cannot be avoided, liaise with DEC regarding appropriate management.				
Introduction of new weed species and/or spread of existing weed species.	1. Undertake weed control. This may need to include quarantining of areas in some cases (for example, if *Melinis repens* was identified). 2. Review relevant procedures (e.g. vehicle hygiene procedures) and modify as required. 3. Incorporate locations into Geographic Information System.				
Dewatering discharge drainage lines					
Decreased riparian vegetation health condition along discharge pathways	1. Investigate cause. 2. Cease discharge at this location and commence at an alternative approved drainage line if required. 3. Modify discharge hydrograph design as required. 4. Undertake appropriate remedial action (e.g. rehabilitation) as required. 5. Revise procedures as required to prevent reoccurrence.				
Introduction of new weed species and/or spread of existing weed species.	1. Undertake weed control. 2. Review relevant procedures and modify as required. 3. Incorporate locations into Geographic Information System.				

4.4 Coolibah Management Plan

4.4.1 Background

- An *Eucalyptus victrix* (Coolibah) woodland approximately 2 km north of the Marandoo mine site is listed as a DEC Priority Ecological Community and is considered to be a wetland of National importance.
- Intersection of the unconfined aquifer by the northern margin of the proposed mine pit is predicted to result in a drawdown of the watertable due to seepage into the pit of 0–2.5 m over the initial eight years or more of dewatering at the Coolibah woodland on the Mount Bruce Flats.

A detailed description of the Mount Bruce Flats Coolibah woodland is included in Section 5.5 of the PER.

An adaptive management plan will be implemented throughout the Proposal to determine and mitigate the effect of the Proposal on the Mount Bruce Flats Coolibah woodland (Table 7).

Table 7
Coolibah management

Coolibah Management Plan	
Management Issues	Potential impacts to the Coolibah woodland and Mulga on the Mount Bruce Flats as a result of the Proposal include: • intersection of the unconfined aquifer by the proposed mine pit will cause seepage and subsequent drawdown in the unconfined aquifer, which may reduce groundwater availability for the Coolibah woodland • physical presence of mine pit and infrastructure will alter surface water flow paths and may reduce the volume of mine site runoff reaching Coolibah and Mulga on the Mount Bruce Flats • ignition sources at Marandoo may increase the frequency and/or intensity of fire events, which may result in the loss of fire-sensitive Mulga communities • vehicle and earth movements could potentially introduce and/or spread weed species across the mine site and adjacent areas of Karijini National Park.
Objectives	To maintain the health of the Coolibah woodland. To monitor the effects of dewatering, surface water flow alterations, weeds and fire on the Mount Bruce Flats Coolibah woodland, including reference sites. To undertake monitoring to enable initiation of adaptive management contingency actions prior to significant long-term impacts to the Mount Bruce Flats Coolibah woodland.
Targets	No greater than 40% loss of mean foliage cover for the Coolibah woodland not explainable by natural events and not seen at the reference site. A specific monitoring program in place prior to commencement of dewatering to enable impacts to the Coolibah woodland to be identified and quantified. Refine trigger values for levels of acceptable change to Coolibah as data become available, in consultation with the DEC. Develop quantifiable targets for changes in health of vegetation detectable using remote sensing in consultation with DEC and other experts,
Performance Indicators	Groundwater level monitoring results. Coolibah health monitoring results. Remote sensing data. Monitoring as per the Coolibah Baseline Survey and Monitoring Program Plan (Section 8 of the PER).
Proposal Specific Management Strategies	Develop and implement a Coolibah Baseline Survey and Monitoring Program for the Coolibah woodland (Section 8 of the PER). Discharging stormwater collected within mine pits to culverts through the railway embankment. Ensuring any water discharged to the natural environment does not cause the quality of receiving surface or groundwater systems to exceed the ANZECC Water Quality Guidelines (ANZECC/ARMCANZ 2000). Providing basic fire awareness and fire fighting training to all site personnel and ensuring appropriate fire fighting equipment is available on-site at all times.

Coolibah Management Plan					
	Maintaining adequate fire breaks across the mine site and around working areas where required. Ensuring ongoing consultation and provision of assistance to the DEC and other Karijini National Park management bodies with regard to fire management practices/buffers in adjoining pastoral leases, as well as mosaic burning. Continuing to assist with fire and weed management across the Mount Bruce Flats in collaboration with the DEC and other Karijini National Park management bodies including improving the mine's fire-fighting capability to support DEC/indigenous prescribed burning in the area. Implementing feral animal control measures across the Marandoo mine site to reduce the potential for proliferation of introduced species across the adjacent Mount Bruce Flats. Implementing weed control and vehicle hygiene procedures.				
Monitoring	**Location**	**Frequency**	**Parameters**	**Procedure**	**Purpose**
	Coolibah Woodland and Coondawanna Flat (or suitable reference site)	Six monthly	Tree health monitoring for foliage cover and visual inspection including ratio of healthy crowns to poorer crowns by diameter size classes Visual observation for evidence of recent fire, storm activity and insect attack.	Using standard measurement techniques comparison of the two established monitoring sites against Coondawanna Flats	To closely monitor health of individuals of Coolibah to establish natural variation, detect any impact resulting from the Proposal and provide information for the adaptive management plan.
		Annually	Measures of crown area and tree health	Multi spectral imagery collection and interpretation of the Mount Bruce Flats Coolibah woodland and reference site	To closely monitor plant cell density of the Coolibah woodland to establish natural variation, detect any impact resulting from the Proposal and provide information for the adaptive management plan.
	Minesite and Coondawanna Flats reference site	Monthly	Rainfall	In accordance with standard Bureau of Meteorology procedures	To allow for interpretation of tree health data in relation to environmental changes.
	Coolibah woodland	Opportunistic following high rainfall event	Surface water inundation depth and extent	To be determined	To allow for interpretation of tree health information in relation to environmental changes.

Coolibah Management Plan	
Adaptive Management Plan	
Contingency Trigger[1]	**Action**
Exceedence of any of the following Level 1 Trigger Criteria at the Mount Bruce Flats Coolibah woodland compared (where applicable) to the reference site: • loss of 15% foliage cover not explainable by natural events and not seen at the reference site; or • decrease in groundwater level in the unconfined aquifer to greater than 2.5 m below the lowest recorded groundwater level in bores OW28s, OW12s and OW30s; or • after groundwater levels fall below the lowest groundwater level recorded prior to the commencement of dewatering activities in any of the observation bores OW28s, OW27s and OW30s, or any decrease in water level greater than 0.35 m within any twelve month period or part thereof in any of the observation bores OW28s, OW27s and OW30s.	1. Commence more frequent 3 monthly monitoring of vegetation health and validate groundwater model based on observed drawdown. 2. Investigate cause/s (including plant water stress using sap flow methodologies and other techniques, climate data, fire scar mapping and visual inspection). 3. Based on revised groundwater model results, review and revise impact assessment and adaptive management plan. 4. Undertake appropriate remedial action as required. 5. Revise procedures as required to prevent reoccurrence.
Exceedence of the following Level 2 Trigger Criteria at the Mount Bruce Flats Coolibah woodland compared (where applicable) to the reference site: • loss of 25% foliage cover not explainable by natural events and not seen at the reference site	1. Notify the CEO of DEC of the exceedence within two weeks following detection of the exceedence. 2. Provide the CEO of DEC with details of additional monitoring being undertaken and planned mitigation and an assessment of residual risk to the Coolibah woodland. 3. Investigate cause/s (including plant water stress using sap flow methodologies and other techniques, climate data, fire scar mapping and visual inspection). 4. Undertake appropriate remedial action as required (e.g. re-injection and/or surface irrigation). 5. Revise procedures as required to prevent reoccurrence.
Exceedence of the following Level 3 Trigger Criteria at the Mount Bruce Flats Coolibah woodland compared (where applicable) to the reference site: • loss of 40% foliage cover not explainable by natural events and not seen at the reference site	1. Notify the CEO of DEC of the exceedence immediately. 2. Provide the CEO of DEC with details of mitigation being undertaken and an assessment of residual risk to the Coolibah woodland following mitigation. 3. Investigate cause/s (including plant water stress using sap flow methodologies and other techniques, climate data, fire scar mapping and visual inspection). 4. Undertake appropriate remedial action (e.g. re-injection and/or surface irrigation, rehabilitation, weed control) as required to the satisfaction of DEC and until such time as it is demonstrated that Coolibahs are not experiencing water stress outside the range seen during baseline measurements or regionally. 5. Continue remedial action and/or monitoring until such time as agreed to by DEC. 6. Revise procedures as required to prevent reoccurrence.

1 Trigger levels are considered conservative due to observed natural losses/gains in foliage cover between monitoring events of up to 10–15% in Coolibah reference sites in response to seasonal fluctuations (Adams 2005, Adams 2006 & Adams 2007).

4.5 Terrestrial Fauna Management Plan

4.5.1 Background

- Four primary habitat types were identified at the Marandoo mine site, which were largely based on vegetation structure and landforms. These habitats were:
  - small drainage lines: vegetated with Mulga and occasional scatters of *Corymbia* over generally mid to dense tussock grasses with occasional patches of *Triodia* (spinifex) on loamy substrates
  - stony hill slopes: vegetated with *Acacia* shrubs over spinifex on stony loam substrates
  - flat outwash plains: vegetated with *Acacia* shrubs on loamy substrates
  - rocky gorges: stony surfaces with scattered *Acacia* shrubs and spinifex.
- A total of 125 vertebrate species was recorded in the area surveyed by Biota (2008d), comprising 54 avifauna species, 20 mammal species and 51 herpetofauna species.
- Listed terrestrial fauna species recorded in and around the Proposal area include
- *Dasyurus hallucatus* (northern quoll), *Liasis olivaceus barroni* (Pilbara olive python), *Pseudomys chapmani* (western pebble-mound mouse), *Macroderma gigas* (ghost bat), *Ardeotis australis* (Australian bustard), *Merops ornatus* (rainbow bee-eater) and *Apus pacificus* (fork-tailed swift).
- Feral animals considered to present the greatest threat to environmental values in the Hamersley sub-region are *Equus asinus* (donkey), *Equus caballus* (horse) and *Bos taurus* (cattle). *Mus musculus* (house mouse), *Felis catus* (cat) and donkeys have been previously recorded at Marandoo.

A detailed description of terrestrial fauna in and around the Proposal area is included in Section 5.6 of the PER.

Potential impacts to fauna as a result of the Proposal will be managed through the implementation of strategies outlined in Table 8.

Table 8
Terrestrial Fauna management

Terrestrial Fauna Management Plan	
Management Issues	Activities or aspects of the Proposal that may affect terrestrial fauna values include: • vegetation clearing for mine pit, waste dumps and associated infrastructure, will directly disturb terrestrial fauna habitat and may result in the loss of individual terrestrial fauna • groundwater drawdown may affect vegetation and consequently reduce the area of fauna habitat available • alterations to surface hydrology may affect habitats and result in the loss of individual terrestrial fauna through ponding • vehicle movements in mining areas and on mine access roads could potentially result in the loss of individual terrestrial fauna, especially less-mobile species • introduction and spread of introduced fauna.
Objectives	To minimise the direct and indirect impacts to fauna and habitats, particularly to species and habitats of conservation significance. To prevent the spread and introduction of feral animals.
Targets	No disturbance to habitats outside of the approved working areas throughout the duration of the Proposal. No increase or introduction of feral animals in the vicinity of the Proposal area throughout the duration of the Proposal.
Performance Indicators	Environmental Incident Reports (clearing outside approved areas, fauna entanglement, fauna collision). Number of feral animals recorded during trapping exercises at the commencement of the Proposal compared to the number recorded throughout and at the completion of the Proposal.
Standard Management Strategies	The requirements of the Iron Environmental Management System Wildlife Interaction Policy and the Rio Tinto Biodiversity Guidance will be communicated and implemented on-site. Maps and photographs of significant fauna will be displayed in the workplace to raise awareness and facilitate identification and on-the-ground management.
Proposal Specific Management Strategies	The boundaries of the working area will be verified by an environmental advisor prior to disturbance to ensure that sensitive fauna habitats (for example, gorge areas along Marandoo Ridge) are avoided as intended in the design. Traffic will be restricted to designated tracks and drivers will abide by the allocated speed limit to minimise fauna fatality or injury by moving vehicles. In the event an animal is crossing the road or in close proximity to a vehicle, the vehicle driver will stop or slow to 5 km/hr (if safe to do so) to allow the animal to move on. Firearms and pets will be prohibited within the Proposal area. Machines and vehicles will be inspected for fauna (excluding invertebrates) by the operator every morning to ensure no fauna has migrated to machinery.

<table>
<tr><th colspan="6">Terrestrial Fauna Management Plan</th></tr>
<tr><td></td><td colspan="5">Snakes to be relocated from work areas by appropriately trained snake-handlers. Any Pilbara olive pythons encountered during clearing to be relocated to areas of suitable habitat beyond the clearing envelope.

Lighting controls, such as minimising light broadcast and installation of sodium lights, will be implemented.

Lights used at night will be coloured yellow.

Where possible motion sensors will be used to further reduce light emissions.

Reflectors will be fitted to all barbed wire fencing to deter bats.

Feral animal control measures will be implemented, including:
• prohibiting the feeding of feral animals
• trapping and eradication programs
• effective management of waste.

Undertaking feral animal control.

Keeping vegetation clearing within designated areas based on the minimum necessary for safe construction and operation of the Proposal, particularly in areas adjacent to habitat of higher conservation significance.

Maintaining natural drainage flows wherever practicable and preventing ponding of water.

Implementing standard dust suppression measures across the Proposal area during construction and operation to mitigate effects on surrounding fauna habitat.

Undertaking progressive rehabilitation to re-establish fauna habitat.

Including fauna protection specifications in all construction-related contracts and subcontracts.

Implementing and sign-posting appropriate speed limits for both mining equipment and light vehicles on the Marandoo access road.

Providing workforce environmental education programs and training.</td></tr>
<tr><td rowspan="5">Monitoring</td><td>Location</td><td>Frequency</td><td>Parameters</td><td>Procedure</td><td>Purpose</td></tr>
<tr><td rowspan="4">Project area</td><td>Opportunistically</td><td>Sightings of threatened species</td><td>In accordance with standard Rio Tinto procedures</td><td>To monitor occurrence of threatened species.</td></tr>
<tr><td>Opportunistically and annually</td><td>Sightings of introduced animals</td><td>In accordance with standard Rio Tinto procedures</td><td>To monitor occurrence of introduced species and implement management action if required.</td></tr>
<tr><td>All events</td><td>Vehicle collision with fauna</td><td>In accordance with standard Rio Tinto procedures</td><td>To monitor occurrence of introduced species and implement management action if required.</td></tr>
<tr><td>All events</td><td>Fauna entrapment</td><td>In accordance with standard Rio Tinto procedures</td><td>To monitor occurrence of introduced species and implement management action if required.</td></tr>
</table>

Terrestrial Fauna Management Plan	
Contingency Trigger	**Action**
Vehicle collision with fauna	1. Investigate cause. 2. Undertake appropriate remedial action (e.g. contacting the nominated carer or Wildlife Hotline to assess possible rescue and rehabilitation of the animal) as required. 3. Revise procedures and education programs as required to prevent reoccurrence.
Increased feral animal abundance	1. Report as Environmental Incident and initiate Incident Response Procedure, including: a) investigating cause b) implementing corrective actions, including undertaking additional trapping and revising waste disposal procedures as required.

4.6 Fire Management Plan

4.6.1 Background

- A number of activities (ignition sources) that will be undertaken as part of the Proposal have the potential to cause fire. This may lead to an increase in fire frequency within the mine lease and within the adjacent Karijini National Park.
- Fires may severely affect fire-sensitive vegetation units, such as Mulga shrublands, which may result in an increasingly fire-adapted vegetation community.
- Increased fire frequency or intensity may favour the establishment of weeds and can also prevent the regeneration of native vegetation.

A detailed description of aspects of the Proposal relevant to fire is included in Section 5.5 of the PER.

Increased risk of fire to Karijini National Park as a result of implementation of the Proposal will be controlled through implementation of the management strategies as outlined in Table 9.

Table 9
Fire management

Fire Management Plan	
Management Issues	Uncontrolled fires have the potential to cause extensive damage to the environment. The following aspects of the Proposal have been identified as requiring management to reduce the potential for fires: • ignition of fuel or oil spills/leakages during re-fuelling of equipment • ignition of other material during welding, grinding and other activities with an ignition source, including incorrect disposal of cigarette butts • fire resulting from clearing land • blasting or incorrect storage and handling of explosives required for blasting.
Objectives	To minimise the potential for activities to result in fires. To prevent the spread of fires outside the Proposal area.
Targets	No fires during re-fuelling of equipment or as a result of blasting throughout the duration of the Proposal. No instances of fire outside the Proposal area as a result of the Proposal.
Performance Indicators	Environmental Incident Reports (occurrences of fire).
Standard Management Strategies	No burning of rubbish or open fires will be permitted anywhere in the Proposal area, except for fire training purposes and barbecues at the camp. Welding activities will be undertaken only where there is a minimum 3 m radius free of combustible material. Fire extinguishers or other control equipment will be made available in all vehicles. Fire fighting equipment will be maintained to comply with relevant fire safety standards. Appropriate fire fighting equipment is available to control localised bushfires under coordinated supervision. Site personnel will be required to complete basic fire-fighting training. Particular attention will be paid to fire risks associated with the use of earthmoving equipment that can result in sparks (metal blade on rock surface). Vehicle undersides will be checked and any material stuck around exhaust manifolds to be removed as part of normal vehicle check routines. Cigarette smoking will be restricted to designated smoking areas with appropriate cigarette butt disposal facilities. Firebreaks will be established around key facilities and will be maintained on a regular basis.
Proposal Specific Management Strategies	A fire spotter will be used when clearing undisturbed vegetation in the vicinity of sensitive environmental or heritage areas. Providing basic fire awareness and fire fighting training to all site personnel and ensuring appropriate fire fighting equipment is available on-site at all times. Maintaining adequate fire breaks across the mine site and around working areas where required. Ensuring ongoing consultation and provision of assistance to the DEC and other Karijini National Park management bodies with regard to fire management practices/buffers in adjoining pastoral leases, as well as mosaic burning.

Fire Management Plan					
	Continuing to assist with fire and weed management across the Mount Bruce Flats in collaboration with the DEC and other Karijini National Park management bodies including improving the mine's fire-fighting capability to support DEC/indigenous prescribed burning in the area.				
Monitoring	**Location**	**Frequency**	**Parameters**	**Procedure**	**Purpose**
	Minesite	Quarterly	Visual Inspection	All potential fire risks are to be recorded and action taken to prevent recurrence	Identify any potential fire risks as part of safety audits
	Proposal area	Opportunistically	Number of outbreaks of fire	All fire outbreaks are to be recorded and action taken to prevent recurrence	To allow the assessment of progress against key performance indicators.
Contingency Trigger	**Action**				
Fire incident	1. Report as an Incident and initiate incident response procedure, including as appropriate: a) immediately extinguishing the fire b) contacting Fire and Emergency Services Authority c) investigating the cause d) rehabilitating the burnt area.				

4.7 Waste Management Plan

4.7.1 Background

- Wastes generated by the Proposal will be similar in composition to that already generated at the existing Marandoo mine and will include:
  - domestic solid and liquid wastes
  - mineral waste
  - washdown water
  - general office waste
  - waste oils and lubricants.
- Wet processing of ore at Marandoo will produce a benign residue that will be stored safely at the site in a Residue Storage Facility (RSF).

A detailed description of aspects of the Proposal relevant to waste is included in Section 6.3 of the PER.

The storage and disposal of wastes generated by the Proposal will be controlled through implementation of the management strategies outlined in Table 10.

Table 10
Waste management

Waste Management Plan	
Management Issues	Waste will comprise three main streams: • solid waste including earth works, domestic and green waste • non-solid wastes (i.e. discharge of waste water may result in ecological effects including reduced water quality) • hazardous waste (used oils and greases). Waste, if inappropriately managed, has the potential to contaminate soils, groundwater and surface water and to attract feral animals.
Objectives	To minimise environmental impacts associated with waste generation. To ensure safe handling, treatment and disposal of all generated wastes in accordance with legal requirements so that no unacceptable environmental impact occurs. To prevent contamination of soils, surface water or groundwater and ensure protection of existing water resources and ecosystems. To implement the waste management hierarchy (reduction, recycling, reuse and recovery). Maximise the backfilling of pit voids with mineral waste.
Targets	No incorrect disposal of wastes throughout the duration of the Proposal. Opportunities to maximise the backfilling of pit voids with mineral waste are investigated and documented prior to implementation of the Proposal.
Performance Indicators	Number of Environmental Incident Reports (waste contamination). Waste disposal facility inspection report results. Water quality monitoring results.
Standard Management Strategies	Waste management will be in accordance with the Iron Environmental Management System Non-Mineral Waste and Waste Management Procedures, including: • waste segregation • labelling of containers • no burning of waste • waste management hierarchy (e.g. reduce at source) • sufficient number and appropriate placement of bins. Bins will not be placed in drainage lines and/or other sensitive areas. Controlled wastes will be managed in accordance with the requirements of the Environmental Protection (Controlled Waste) Regulations 2003 including obtaining tracking receipts. Environmental hazards and impacts will be evaluated for materials and chemicals during transport, storage, use and disposal. Emergency response procedures will be developed and maintained. Spill response must be in accordance with the requirements of Iron Environmental Management System Spill Response Procedure, including clear marking and ready availability of spill response equipment. Contamination will be reported immediately for further assessment and remediation. Contaminated material will be treated or disposed of appropriately. Where required, clean water diversion systems and contaminated water collection systems will be established.

<table>
<tr><td colspan="6">Waste Management Plan</td></tr>
<tr><td></td><td colspan="5">Waste water will be excluded from drainage lines as far as practicable.

All mechanical equipment washdown must occur on an impervious pad and not along drainage lines. Controls to minimise stormwater entering the washdown area will be implemented.

Water use will be in accordance with Iron Environmental Management System (IEMS) standards - Water Use and Quality Control Standard, which includes actions to minimise and re-use treated wastewater.

Wastewater treatment facility operation and maintenance will be at a minimum in accordance with Iron Environmental Management System Procedure - Waste Water Treatment Plant Operations and Maintenance Guide.

Where wastewater treatment facilities are not feasible, closed systems (with evacuation by a licensed provider) will be considered.

Waste inventory catalogue held on file documenting disposal volumes and types and disposal locations.</td></tr>
<tr><td>Proposal Specific Management Strategies</td><td colspan="5">Putrescible and inert wastes from the Proposal will be disposed of at the existing Marandoo mine site landfill. Wastes will be segregated to facilitate recycling and appropriate disposal.

Treated wastewater from the operations camp and mine site will be discharged via spray fields located within the project area at least 500 m from any administration buildings.

Maintaining and servicing equipment regularly

Maintaining sediment control structures at washdown facilities

Maintaining existing management practices employed by the Proponent if any ARD-generating or asbestiform material is encountered

Maintaining hydrocarbon treatment facilities at the workshop and washdown facilities

Re-using treated water from the workshop and washdown facilities for dust suppression on non-pit roads where possible

Strict grade control procedures to ensure asbestiform material does not enter the processing circuit.</td></tr>
<tr><td rowspan="4">Monitoring</td><td>Location</td><td>Frequency</td><td>Parameters</td><td>Procedure</td><td>Purpose</td></tr>
<tr><td>Minesite</td><td>Quarterly and opportunistically</td><td>Litter/general waste</td><td>Visual inspections</td><td>To detect any breach of the Iron Environmental Management System Non Mineral Waste and Waste Management Procedures.</td></tr>
<tr><td>Minesite and operations camp</td><td>In accordance with standard procedure</td><td>Effluent monitoring</td><td>Iron Environmental Management System Procedure - Waste Water Treatment Plant - Discharge Sampling & Monitoring</td><td>To ensure compliance with operating conditions and efficient functioning system.</td></tr>
<tr><td>Wastewater system tanks and pipelines</td><td>Six monthly</td><td>Visual inspection for any signs of leakage or damage</td><td>Visual inspections</td><td>To allow detection of any spill and leakage.</td></tr>
<tr><td>Contingency Trigger</td><td colspan="5">Action</td></tr>
<tr><td>Wastewater quality exceeds treatment specifications</td><td colspan="5">1. Report as an Environmental Incident and initiate Incident Response Procedure, including:
a) investigating cause
b) if cause is a breakdown in treatment plant, then:
i. initiate immediate repairs
ii. take action to reduce effluent quantity (e.g. by temporary storage, reduced ablutions)
c) if cause is overloading of treatment facility, then:
i. take action to reduce flow to treatment plant
ii. initiate upgrade of plant capacity if necessary.</td></tr>
</table>

Waste Management Plan	
Wastewater disposal causing significant environmental effects	1. Report as Environmental Incident and initiate Incident Response Procedure, including: a) investigating cause b) if cause is exceedence of effluent quality of quantity, then undertake actions above c) if cause is failure of disposal area to assimilate effluent, then: i. re-evaluate disposal requirements ii. vary disposal procedures in consultation with DEC.
Contamination of surface or groundwater	1. Report as Environmental Incident and initiate Incident Response Procedure. 2. Review Marandoo Local Emergency Management Plan (Doc No. 103731) and modify as necessary to avoid recurrence.

4.8 Dust management plan

4.8.1 Background

- Dust is generated during mining mainly by mechanical disturbances, such as blasting, earthmoving and road traffic on unsealed surfaces. In dry, windy conditions, particles can be lifted from open or disturbed areas, resulting in visible dust emissions.
- The predicted Run of Mine moisture is above dust extinction moisture values for typical Marandoo ore and would be expected to create less dust than the current above watertable material.
- Most airborne particulates likely to originate from the Proposal are larger than PM10 (particulate matter with an equivalent aerodynamic diameter 10 µm or less) and are more associated with nuisance than public health problems. The larger particles tend to settle back to the ground within a short range (<300 m) from the source.

A detailed description of aspects of the Proposal relevant to dust is included in Section 6.5 of the PER.

The generation of dust at Marandoo will be controlled through implementation of management strategies outlined in Table 11.

Table 11
Dust management

Dust Management Plan	
Management Issues	During construction and operation works, dust will be generated as a result of: • vehicle movements on unsealed tracks • clearing of vegetation • earthmoving activities • drilling and blasting • operation of mobile plant and equipment • general operational activities including loading, dumping and transport of ore • wind action on cleared areas and/or stockpiles. Dust emissions may adversely affect vegetation, fauna habitat and visual amenity. Erosion may increase dust generation and the impacts described above.
Objectives	To identify and minimise dust generation so that impacts to the natural environment are minimised. To comply with the Environmental Protection (Air) Policy 1997 and the National Environment Protection Measure (Ambient Air Quality) 1998. To establish an historical record of exposure levels.
Targets	No complaints lodged relating to air quality issues throughout the duration of the Proposal. No visible dust crossing site boundaries.
Performance Indicators	Dust levels at boundaries of mine site and near sensitive areas such as vegetation and operation camp. Visual monitoring of dust movement during site inspections. Dust monitoring at boundaries and/or downwind.
Standard Management Strategies	Sprinklers, water cannons, enclosed storage areas and other dust suppression devices/structures and techniques will be used where appropriate. Dust suppression equipment will be well maintained. Vehicles will be driven at the specified speeds indicated around the project area (compliance with speed restrictions is mandatory). Mobile crushing and screening facilities will be operated with suitable dust extraction systems, screens and/or sprays where practicable to minimise dust. Water trucks are to be used to minimise dust. Dust-prone areas will have sufficient water or chemical stabilisation applied to reduce dust levels. Soil stabilisation materials will be available for use within 48 hours. Vehicles are to be restricted to designated roads and existing tracks to minimise the creation of dust and the extent of clearing and exposure to soil surfaces.

<table>
<tr><td colspan="6">Dust Management Plan</td></tr>
<tr><td>Proposal Specific Management Strategies</td><td colspan="5">Area of exposed surfaces (such as stockpiles and cleared areas) and the duration of exposure will be minimised.

Application of water to haul roads, working surfaces and stockpiles as required.

Ore moisture content control and operation of dust extraction systems at processing and rail loadout facilities.

Clearing work areas only as they are required.

Operation of primary and secondary scrapers to remove excess material from plant conveyor belts.

Progressive rehabilitation of disturbed areas to minimise total exposed area.</td></tr>
<tr><td rowspan="6">Monitoring</td><td>Location</td><td>Frequency</td><td>Parameters</td><td>Procedure</td><td>Purpose</td></tr>
<tr><td>Within proposal area</td><td>Opportunistically</td><td>Visual monitoring</td><td>In accordance with standard Rio Tinto procedures</td><td rowspan="5">To ensure minimal impact on the environment and information for management.</td></tr>
<tr><td>Minesite</td><td>Daily</td><td>Meteorological monitoring, including wind speed and direction</td><td>In accordance with standard Bureau of Meteorological procedures</td></tr>
<tr><td>Stockpile</td><td>Monthly</td><td>Stockpile moisture</td><td>In accordance with standard Rio Tinto procedures</td></tr>
<tr><td>Minesite</td><td>Annually</td><td>Dust control systems (i.e. sprayers)</td><td>In accordance with standard Rio Tinto procedures</td></tr>
<tr><td>Minesite</td><td>Continuous</td><td>Dust loading (g/m^2/30 days)</td><td>Dust Monitoring Procedure-Depositional Dust (RTIO-HSE-0017585)</td></tr>
<tr><td>Contingency Trigger</td><td colspan="5">Action</td></tr>
<tr><td>Visual observations indicate dust suppression is not effective in reducing dust generated from areas of ground disturbance or non compliance of dust levels at monitors.</td><td colspan="5">1. Investigate cause.
2. Implement additional dust control measures including, as appropriate:
a) increased application of water
b) inspection of dust control equipment
c) application of dust stabilisers to vehicle loads and stockpiles.
3. Moderate activities generating dust if actions listed under (2) above are inadequate to reduce dust emissions to acceptable levels.</td></tr>
</table>

4.9 Cultural Heritage Management plan

4.9.1 Background

- The Proposal is unlikely to directly affect any Aboriginal heritage sites of high significance. Most of the highly significant Aboriginal heritage sites occur on the upper slopes of the surrounding escarpments, which are outside the Proposal area. All highly significant sites are likely to be avoided in the valley and floodplain areas through planning and design of the Proposal.
- The Proposal is likely to affect some less significant Aboriginal heritage sites.
- Minthicoondunna Spring is a registered Aboriginal site and protected by law. The area is an important ethnographic site for Eastern Guruma people, as well as other Aboriginal people in the Pilbara .

A detailed description of aspects of the Proposal relevant to Aboriginal heritage is included in Section 5.8 of the PER.

Aboriginal heritage values in the vicinity of the Proposal area will be maintained through implementation of management strategies outlined in Table 12.

Table 12
Cultural Heritage Management

Cultural Heritage Management Plan - Marandoo	
Management Issues	Activities or aspects of the Proposal that may potentially affect cultural heritage values include: • clearing for the construction and operation of the mine and associated infrastructure • dewatering near the mine pit will lead to drawdown of groundwater levels in the confined aquifer and may result in the formation of sinkholes throughout the cone of depressurisation which may affect sites of cultural significance • re-injection of dewatering water at the Southern Fortescue borefield will lead to an increase in groundwater levels and may cause or enhance sinkhole formation which may affect sites of cultural significance.
Objectives	To minimise impact to heritage sites and protect and manage existing heritage sites and the cultural landscape in partnership with the Traditional Owners. To undertake consultation with the Traditional Owners in relation to the Marandoo mine, including undertaking comprehensive archaeological and ethnographic surveys of new project areas with the Traditional Owners. To only undertake ground disturbance with the appropriate Approvals Request Permits. To minimise the potential for heritage incidents. Compliance with the *Aboriginal Heritage Act 1972* (WA) Ensure heritage risks are communicated to Project Managers. To ensure that all heritage sites are managed appropriately
Target	No heritage incidents
Performance Indicators	Heritage incidents reports. Regular inspection and on-ground management of heritage sites. Regular liaison with Traditional Owners in relation to heritage management. Heritage survey results. Relevant employees and contractors informed of sites within the project area. Guidelines for the management of Aboriginal heritage sites sent with ground disturbance permit. No unauthorised disturbance to Heritage sites.
Management Strategies	Impact to heritage sites is minimised and where possible all heritage sites are avoided. Regular ongoing involvement of the Traditional Owners in heritage management throughout the life of the Project. An appropriate understanding of the cumulative demands and impacts being placed on heritage resources and the cultural landscape will be developed. Regular heritage inspections should be conducted to ensure heritage sites are being managed. Opportunities for reducing impact to heritage sites will be considered and, wherever feasible, implemented.

<table>
<tr><td colspan="6">Cultural Heritage Management Plan - Marandoo</td></tr>
<tr><td></td><td colspan="5">Heritage sites within close proximity to work area will be fenced in consultation with Traditional Owners.

All heritage sites are to be marked with pink and black heritage flagging tape.

Undertaking additional survey work and ethnographic studies within the Proposal area to identify heritage and ethnographic sites.

Preventing unauthorised ground disturbance activities through implementation of the Proponent's Approvals Permit system for all areas to be disturbed.

Including education regarding Aboriginal sites in inductions for contractors and personnel working on the development.

Stopping work and contacting the DIA where human remains or archaeological material is uncovered during the clearing process, then assessing the site using a heritage consultant..

Marking the location of known Aboriginal heritage sites on site plans.

Ensuring a fire spotter is present when clearing vegetation near sensitive or heritage areas.

Undertaking further hydrogeological investigations between Marandoo and Minthicoondunna Spring to determine the hydraulic parameters of the upper Tertiary sediments, and any hydraulic connection between the surficial calcrete aquifer and the confined aquifer.

Monitoring the water level at Minthicoondunna Spring, and groundwater levels between Marandoo and Minthicoondunna Spring.

Consulting with the Eastern Guruma people and other relevant stakeholders.</td></tr>
<tr><td rowspan="3">Monitoring</td><td>Location</td><td>Frequency</td><td>Parameters</td><td>Procedure</td><td>Purpose</td></tr>
<tr><td>Project Area</td><td>3 monthly</td><td>Number of heritage incidents and remedial actions</td><td>Information regarding the incident will be entered into the Rio Tinto system</td><td>To enable tracking of incidents to ensure appropriate liaison with stakeholders and management can be undertaken.</td></tr>
<tr><td>Existing heritage sites</td><td>As required by audit procedures</td><td>Account for the continued and undisturbed existence of identified Aboriginal heritage site and protective signage, fencing, etc</td><td>Visual inspection</td><td>To enable tracking of incidents to ensure appropriate liaison with stakeholders and management can be undertaken.</td></tr>
<tr><td colspan="5">Monitoring and management of potential impacts on cultural values associated with Minthcoondunna Spring as a result of dewatering are detailed in the Groundwater Management Plan (Table 4)</td></tr>
<tr><td>Contingency Trigger</td><td colspan="5">Action</td></tr>
<tr><td>Heritage incident occurs</td><td colspan="5">1. Report the incident immediately.
2. Investigate cause of incident.
3. Consult Traditional Owners in relation to heritage incident.
4. Revise operational procedures to avoid future incidents and/or further impact to heritage sites.
5. Advise DIA of incident and undertake remedial action.</td></tr>
<tr><td>Suspected new heritage site</td><td colspan="5">1. Report the discovery immediately to the site manager.
2. Consult Traditional Owners in relation to heritage values.
3. If it is determined to be a potential site, revise operational procedures to avoid impact to heritage sites.
4. Advise DIA and undertake remedial action if required.</td></tr>
</table>

Acknowledgements

This PER has been prepared jointly by Rio Tinto, Strategen (Principal Consultants) and specialists consultants. The key personnel involved in preparation of this PER include:

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Public Environmental Review

Marandoo Mine Phase 2

September 2008

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INTERIM REPORT TO 17-09-2008

MARANDOO PHASE 2 PROPOSAL

ASSESSING THE IMPACTS OF GROUNDWATER DEWATERING AND SURFACE WATER DRAINAGE ON SIGNIFICANT VEGETATION- COOLIBAH AND MULGA.

SUMMARY

The potential for the Marandoo Phase 2 (mining below water table) Proposal to impact the natural values of the adjacent Karijini National Park has been assessed. It is concluded that there is a negligible risk of any additional impact to the Mulga and Coolibah communities since:

- Modelling results (Figure 26 in PER document) show that the predicted groundwater drawdown in the unconfined aquifer below the Coolibah stands which are located some 2 km away from the pit face would be between zero and 2.5 m. This drawdown would be gradual, taking at least 8 or more years to occur. This should allow natural root growth to keep up with the predicted rate of dewatering. Also, it is quite likely that at least one, large, natural recharge event would occur during this period.
- Results from existing bores in the unconfined aquifer show natural variations below the Coolibah stands of up to 9.5 m, when substantial rainfall follows a run of dry years. These trees should therefore be able to cope with fluctuations in the water table caused by mining operations, especially if they are gradual and relatively small in comparison to natural events.
- At the end of the dry period, when the water levels in the unconfined aquifer were about 20 m below ground, there was still a saturated zone of between 8 and 10 m deep. In a worst-case scenario, this would now be reduced to a saturated zone 5 to 7 m in depth.
- The major change to surface flow patters occurred after the building of the railway line in the mid 1990's when some sheet flow was intercepted and re-directed to natural drainage lines prior to reaching the Mt Bruce Flats. DEC advise that there is evidence that this has had a detrimental historical effect on some of the Mulga communities adjacent to and North of the railway embankment. However, monitoring by RT has been unable to show any substantial negative effects on Mulga. No additional impact is expected as a result of this proposal.

However it is quite possible that future events such as cyclonic storm, waterlogging, extended drought, climate change, weed invasion and wildfire will pose an ongoing threat to the sustainability of the mulga and Coolibah communities within the Mt Bruce flats. Monitoring protocols will need to be developed to try and separate any effects on the vegetation in the National Park that may be due to mining from those changes caused by "natural" events.

It may well be desirable for Rio Tinto Iron Ore to liaise with and assist DEC with management actions directed to control feral animals, weeds and wildfire in the Mt Bruce flats.

INTRODUCTION

The Marandoo Phase 2 proposal for mining below water table has the potential to detrimentally affect the natural values in the adjacent Karijini National Park in a number of ways. The extension above water table of the tail-pit will reduce the natural surface flows northwards into the Mt Bruce flats and may further affect the Mulga (*Acacia aneura*) stands in this area. Mining below water table will require dewatering on a major scale of the confined aquifers, with possible effects on a Coolibah (*Eucalyptus victrix*) open woodland, considered to be a wetland of National importance (English 1999). Also, the deeper mine pit face will now cut the unconfined aquifer on which the Coolibah may be partially dependent for survival. In addition, the presence of mining operations for an extended period of time may increase the opportunity for additional weed invasion or for wildfire to impact on the National Park.

Data collected by Rio Tinto should be able to address these key questions

- What are the possible effects of the proposed mine on the adjacent, significant vegetation in the National Park?
- What actions can be taken to avoid, reduce, monitor or make good any likely impacts?

SURFACE FLOWS

The Marandoo mine site is located on the north side of the Marandoo Ridge, adjacent to the Karijini National Park. The Ridge is wholly contained within the Mt Bruce Flats catchment and drains northwards towards the Mt Bruce Flats (Figure 1a). The colluvium that forms the lower slopes of the Ridge is incised by drainage lines conveying runoff from the upper slopes, but is reasonably permeable and the majority of surface water runoff generated during low-intensity rainfall events infiltrates the soil and does not reach the Flats. Generally, a rainfall event in excess of around 80 mm is required to generate significant runoff from the Marandoo Ridge and into the Mt Bruce flats (Beckett 2008). Rainfall is highly variable from year to year. Records at Marandoo over nine years give a range from 187 to 697 mmpa.

The Mt Bruce Flats located just to the north of the Marandoo minesite is essentially a large, internally draining basin surrounded by hills. Surface flow is towards the lowest point, a Coolibah open woodland. The watersheds of the Southern Fortescue River and Turee Creek form at the margins of the Mt. Bruce Flats (Liquid Earth, 2005). After major rainfall the central portion is flooded for some time, there is evaporation, recharge to the unconfined aquifer and eventually some surface water may drain to the south-east down Turee Creek (DEC pers com, Figure 1c). The last recorded time that the wetland flooded was in March 2006, the estimated depth of flooding was probably 0.5m as bore OW 12d was overtopped (Figure 6d) and water remained on the surface for some weeks.

It would be valuable to understand more fully the surface and near-surface hydrology of the whole of the Mt Bruce flats and a digital terrain model would assist. Rio Tinto Iron Ore has captured these data (Figure 1c). Calculations of surface hydrology suggest that the mine pit will intercept about ten percent of the total surface flows into the Mt Bruce flats catchment. A considerable proportion of this water will be

discharged by “sump and pump”, that is, captured by engineering design, diverted into a sump and then discharged and re-distributed back into the flats. There will be some difficulty with achieving an even discharge, as much of the railway line is in “cut” and even when in “fill” the embankment is fairly low in profile so that large diameter discharge structures cannot be used. However there have been recent improvements in the design of “spreader” structures below culverts (Muller pers comm) that will be considered by Rio Tinto Iron Ore for possible implementation at Marandoo.

The natural hydrological regime of the Marandoo Ridge has already been modified as a result of the construction of the railway from Rosella Siding to Homestead Junction in the mid 1990’s (Figure 1b). The railway runs east-west and is located to the north of the existing Marandoo mine site and the proposed tail pit extension. Sheet flow generated to the south of the railway on the Marandoo Ridge is intercepted by the railway embankment and subsequently directed along the base of the embankment towards natural drainage lines. Water then flows (via culverts) northwards along the drainage lines towards the Mount Bruce Flats. Surface water runoff which would have otherwise reached the Mount Bruce Flats via sheet flow, now reaches the Flats only via natural drainage lines. Monitoring of vegetation health has been implemented by RTIO and their consultants.

The existing Marandoo mine catchment of 2,350 ha, equates to approximately 8% of the Mt Bruce Flats catchment. The majority of surface water runoff generated within the mining area is directed to an evaporation pond and subsequently used for dust suppression across the mine site. Excess water collected within the existing mine pits during major rainfall events is discharged (following sediment and hydrocarbon removal) to the Mt Bruce Flats via natural drainage lines. Excess water collected within the proposed tail pit extension (an additional 1.6%) will be discharged to natural drainage lines in accordance with existing management practices. The actual reduction in surface water runoff to the Flats as a result of the mine will therefore be much less than 10%.

Effects on vegetation

The mine will intercept some drainage lines that discharge to the Mount Bruce Flats (Figure 1a). These drainage lines are dry for the majority of the year; generally flowing only after significant and intense rainfall events. Surface water flows in rivers and creeks in the Pilbara are often a major contributor to groundwater recharge. However, due to the proposed discharge of excess water collecting within the mine pit, via culverts into the Flat, a significant reduction in flow is not anticipated. The small drainage lines that flow from the Ridge to the Flats support woodlands of *Eucalyptus xerothermica* to *Acacia aneura* (mulga) over *Triodia longiceps* (grey spinifex) hummock grassland. The drainage line vegetation communities themselves do not comprise strongly phreatophytic (groundwater-dependent) species and are unlikely to be affected by dewatering or by any potential reduction in groundwater recharge.

The Mt Bruce Flats support vegetation communities comprising mainly Mulga and, to a lesser extent, *Eucalyptus victrix* (Coolibah) woodlands. The Coolibah woodlands are listed by DEC as a Priority Ecological Community and also in “A

directory of important wetlands in Australia" by Environment Australia, 2001. As a result of the railway construction, this area of the Mt Bruce Flats has already been subjected to a modified hydrological regime for over 10 years, whereby some sheet flow is intercepted and re-directed to natural drainage lines prior to reaching the Mt Bruce Flats. There is anecdotal evidence that this has had a detrimental historical effect on some of the Mulga communities adjacent to and North of the railway embankment (S van Leewen, DEC, pers.comm.). However, this view is not supported by any of the monitoring of Mulga carried out by RTIO and their consultants (Batini 2008 a). The monitoring data do however show that fire is a much greater threat to the survival of mulga than is "water shadow" effect.

Beckett (2008) estimates that only communities within 200 m downstream of the pit (2 year ARI flood) will experience some reduction in surface water runoff. Beyond 200 m, surface water runoff is unlikely to change as a result of the BWT pit.

There is also no evidence that the Coolibah woodland some 1.5 to 2.5 kms from the railway has been or will be affected by a reduction in surface sheet flow. A recent survey of the Coolibah woodland near Marandoo, in April 2008, showed that this woodland is in good condition, with a 3:1 ratio of healthy crowns to poorer crowns (Batini 2008 b).

THE UNCONFINED AQUIFER

Natural fluctuations

Rainfall data show that after a dry period of about five years, from mid 2001 to 2005 inclusive, reasonable rainfall was recorded in early 2006, then in late 2006 and early 2007 (Figure 2).

There are reasonable data for six bores into the unconfined water table, drilled to depths of 26-35 m, near the Coolibah wetland, for a period of about 33 months, February 2005 to November 2007.These bores cover two transects: the first starts just North of the railway (bore OW25s) then heads NE for about 1.8 km to the western edge of the Coolibah wetland (bore OW12s); the second starts just to the west of the wetland (bore OW30s) and traverses the wetland in an ENE direction for about 3.2 km to bore OW 15s, which is located on the eastern edge of the Coolibah (Figure 3).

Towards the end of the dry period (end of March 2006), the shallow, unconfined water table was at about the same Relative Level in all bores (683.6 to 685m), with possibly some slight drainage towards the SSW from the Coolibah. This water table was some 20 to 27.5 m below the surface of the Mt Bruce flats, with a saturated zone of some 8-10 m below the water table. After rain in early 2006, the water levels rose rapidly in all bores, the greatest rise of 9.5 m was observed at the western edge of the Coolibah flats (bore OW12s) and the least rise, of 2.0 m in bores OW25s, located near the railway line, in mulga to the SW of the Coolibah and also in bore OW 15s, located on the eastern edge of the Coolibah (Figures 4 and 5).

The water tables then fell in four bores over the next nine months (to December 2006), the greatest fall of 5.3 m being recorded at bore OW12s and the least, 0.0m at bore OW 15s. Bores OW 27s, 28s and 30s showed rises and falls that were

intermediate between these extremes. In contrast, bore OW25s rose about 1.6 m, as water drained in this direction. All graphs show only one peak in late March 2006 and show no further response to rainfall events in late 2006 and early 2007, probably because there was no report of surface flooding (Figures 4 and 5).

After rain, the observed water tables ranged between 11 m below ground level at bore OW 12s and 27 m at bore OW25s. Fifteen months later, water tables were still at least 2.0 m higher than their levels at the end of the dry period. If the Storage Coefficient of the soil is estimated as eight percent, a rise in water table of 9 m represents a storage equivalent of about 720 mm of rain and 2.0m represents a storage of 160 mm (ie eight percent of 2000 mm).

A water table between 11 and 20 metres below ground surface should still be accessible to deeper-rooted species such as Coolibah .UWA and UNSW are currently undertaking studies in the Pilbara on the rooting depths of different species. However this access to some groundwater does not necessarily mean that Coolibah is a groundwater **dependent** species, particularly as the trees also have access to soil moisture stored in about 20 metres of the unsaturated soil profile.

It appears from these data that after rain the area around bore OW12s may become flooded and is then a major intake area for the Coolibah flats. Sub-surface drainage then occurs relatively slowly and outwards from here through the soil profile. Thus the groundwater in the shallow aquifer mounds near the centre of the internally draining basin of the Mt. Bruce Flats and flow radiates outwards (Liquid Earth, 2005), an antonym of the surface water flow.

Possible effects of dewatering

The results of a dewatering trial carried out in 2005 over a period of 80 days within the deeper, confined aquifers have been reported by Evans and Youngs (2007). No measurable change to the water table levels were recorded in the shallow bores into the unconfined aquifer within the National Park (OW 22s at a distance of 1.5 km from the dewatered area and OW 12s at the edge of the Coolibah, some 5 km away). Of the four bores into the unconfined water table located closer to the dewatering trial, only one, OW 21s, located within 0.5 km, showed a draw-down of 0.27 m due to the dewatering (Figure 3, inset A).

These data confirm that the unconfined and confined aquifer systems are not well connected hydrologically. Also, the observed and modelled values are well within the “natural” fluctuations in the shallow water table at the Coolibah of about 9 metres.

Possible effects of intersecting the unconfined aquifer

If mining proceeds below the water table, the mine pit will intersect the unconfined aquifer and the implications of this action also required to be modelled. At the minepit, the unconfined aquifer is thinner, has low permeability and is therefore expected to desaturate quickly.

Extensive modelling of both systems has now been conducted. The evidence of field testing and numerical modelling indicates that dewatering required would have a

drawdown of between zero and 2.5 m on the shallow aquifer below the Coolibah, some 2 km away from the pit (MWH 2006 b, PER Figure 26). This drawdown would be gradual, taking at least 8 or more years to occur. The gradual change should allow root growth of Coolibah to keep pace with the rate of dewatering. Also, it is quite likely that at least one, large, natural recharge event would occur during this period.

Results from existing bores in the unconfined aquifer show rapid, natural variations below the Coolibah stands of up to 9.5 m, when substantial rainfall follows a run of dry years. These trees should therefore be able to cope with fluctuations in the water table caused by mining operations, especially if they are gradual and relatively small in comparison to natural events.

At the end of the dry period, when the water levels in the unconfined aquifer were about 20 m below ground, there was still a saturated zone of between 8 and 10 m deep. In a worst-case scenario, with a drawdown of say 3 m, this would now be reduced to a saturated zone that is still 5 to 7 m in depth.

Should monitoring show early warning that the unconfined water table is being impacted to a greater degree than anticipated, remedial adaptive management options that may be considered within the Mining Lease Area include:

- Establishing a grout "curtain" within the Lease to seal the surface aquifer (unlikely to succeed over the distances required)
- Reinjection into the shallow water table within the Lease, to reduce the head loss in the shallow aquifer
- Surface irrigation within the Lease to supplement the surface water table

However, the latter two options may have geotechnical implications with respect to the integrity and stability of the pit wall.

With the approval of the Conservation Commission, periodic discharges of fresh, unsilted water directly into the Coolibah stands to simulate a flood event may also be possible.

THE CONFINED AQUIFERS

Investigation of the hydrogeologic setting of the Marandoo area has been accelerated since 1992 with development of the Marandoo mine (e.g., AGC Woodward Clyde 1992; Waterhouse and Howe 1994; Youngs 2004; Liquid Earth 2005; Youngs and Brown 2005; MWH, 2006a; MWH, 2006b, Evans and Youngs 2007).

The following description is taken from Evans and Youngs 2007 paper.
"Quaternary and Tertiary sediments overlie much of the Proterozoic Hamersley Group on the Mt. Bruce Flats. In the area the Proterozoic Hamersley Groups constitutes the Brockman Iron Formation, Mt. McRae Shale, Mt. Sylvia Formation, Wittenoom Formation and Marra Mamba Iron Formation. Locally the Brockman Iron Formation, Mt McRae Shale, and Mt. Sylvia Formation are generally above water table and present on the flanks of Mt. Bruce.

The principal aquifer units, collectively referred to as the 'deep aquifer', are the karstic Wittenoom Formation and the mineralised Marra Mamba Iron Formation

(Liquid Earth, 2005). The deep aquifer is overlain by a tertiary clay and gravel layer incorporating a calcrete horizon termed the 'intermediate aquifer'. A sequence of tight reactive clays over at least 30 m deep then hydraulically isolate these aquifers from an extensive calcrete horizon, referred to as the "shallow aquifer".

Bores have been drilled to depths of 130 m into the deeper aquifer. The groundwater regime is relatively consistent between the deep and intermediate aquifers, suggesting a strong connectivity, with a general hydraulic gradient to the west (Liquid Earth, 2005). The deeper, confined aquifers are found some 75 to 200 metres below the surface, show smaller rises (about 0.7 metres) and also react more slowly to rainfall events (Figure 6), most probably because the main recharge areas are located some distance away from the bores (Figure 7). During the dewatering trial in late 2005, the confined water tables showed a maximum fall of about 9m at the dewatering site over the 80 day pumping period (Evans and Youngs 2007) and 0.2m in each of the three bores along the transect within the National Park (Figures 6b, 6c, 6d). These bores, OW25d, OW27d and OW12d are located between 1.5 and 5 km from the site of the dewatering trial and were drilled to a depth of 129-132 m. There is an unusual record from bore OW 12d in March 2006 where a very rapid rise is recorded (Figure 6d). This is probably due to inflow from surface water when overtopping of the bore casing occurred (Evans pers comm).

However, the proposed dewatering for the mine itself is expected to be at least 100 to 150 m deep and the anticipated time period for dewatering is at least 17 years. The cone of depression will be greater and it is possible that the draw-down effects in the deeper aquifers will also be much greater than was shown in this particular trial. Because of this, extensive modelling to simulate the actual mining conditions was undertaken (MWH 2006 a and b). The model is considered to be robust and modellers are confident that it simulates the hydrogeology well. The results show that " Impact on the shallow aquifer water levels beneath the Coolibah due to dewatering of the orebody aquifer is expected to be between zero and 2.5 m".

GROUNDWATER-DEPENDENT ECOSYSTEMS

A **potentially** groundwater dependent ecosystem occurs in the area of the shallow unconfined aquifer and groundwater mound. This ecosystem, referred to locally as the Coolibah open woodland is considered a wetland of National importance (English, 1999) and is incorporated within an ongoing Pilbara wide collaborative study (Grierson et al., 2007) supported in part by Rio Tinto Iron Ore.

An Australian Government publication (Land and Water Australia- A Framework for Assessing Groundwater Dependent Ecosystem Environmental Water Requirements 2005) defines a groundwater dependent ecosystem as:

- A forest, where some or all of the plant species draw water from the water table for all or some of the year is regarded as a GDE
- Aquatic vertebrates and invertebrates that rely on a consistent water temperature provided by baseflow or springs for reproduction, form part of a GDE
- A wetland that relies on a shallow water table during summer is a GDE

Whereas definitions two and three appear reasonable, since the biota is **dependent** on a continued supply of groundwater, the first definition appears to be too broad to be useful in practice. It is recommended that the first of these definitions be reviewed by the relevant State and Federal authorities.

As an example, the dry scherophyll jarrah (*E. marginata*) and wandoo (*E. wandoo*) forests near Perth contain trees that may be 200-300 years old. On upper slopes, bores drilled to 30-35 m show that there is no groundwater table. Yet, on the lower slopes shallow groundwater tables can be found between 9 and 25 metres below ground (Batini et al 1977). The trees on lower slopes are favoured by some use of this water, possibly growing for longer periods, or maintaining larger crowns. However, neither jarrah nor wandoo forests would be regarded by ecologists or foresters as a **groundwater dependent ecosystem.**

Similarly, the Coolibahs on the Mt Bruce Flats may utilise the groundwater when it is available, but the trees are not necessarily dependent on it for their survival and reproduction.

THE WOODLANDS IN THE KARIJINI NATIONAL PARK

THE MULGA WOODLAND

In March 1999, FORTECH (a Dames and Moore Company) prepared a comprehensive report for the Department of Resources Development, titled, Pilbara Mulga Study, Stage 1. This Study (which is referred to extensively here) concluded that Mulga (ie all the taxa previously or currently included in *Acacia aneura*) is in a precarious situation in the Central Pilbara. The principal environmental pressures are: over-grazing; increased fire frequency, intensity and spatial distribution; disruption of overland flow and weed ingress.

Mulga is a long-lived species (up to 250 years) and is one of the most widely distributed acacias in Australia, but only grows where both summer and winter rainfall can be expected and where water is nearly always limiting for plant growth. . One consequence is the critical importance of maintaining localised overland water flow to sustain Mulga communities. In the Pilbara, Mulga is close to the edge of its range and modest environmental/climatic changes can have a profound effect on its health and survival. A major concern is the decline in rainfall (about 120mm) observed over the past 35 years and the predicted 30percent future decrease in rainfall over the next 90 years for this part of the Pilbara. (Environmental Modelling and Predictions P/L Australia 2007)).

Recruitment probably occurs about one a decade and is closely tied to rainfall events (for germination) and possibly a run of two or three good seasons (for seedling survival). Root studies show that the majority of roots are found in the top 30cm of soil though some roots may penetrate beyond a metre. A high level of stomatal control allows water to be extracted from very dry soils. At the community level, the presence of well-vegetated groves and sparse intergroves on the contour, allows for localised overland flow in the intergrove and for water harvesting to occur within the groves. S van Leewen (pers comm) advises that the Mulga within the Mt Bruce flats

is important but that there is no evidence that they are floristically different from other similar woodlands.

Mulga is a fire sensitive species, but often occurs with spinifex, a fire-tolerant species. A sequence of two or three wildfires at short time intervals will kill not only the adult Mulga plants but also any regeneration that may have resulted after the first fire. Young Mulga is palatable to stock and grazing has had a major direct effect on the species, especially on favoured areas and near watering points. Stock pads may also alter the drainage patters within groves leading to starvation for water. Overall, the current level of weed infestation is low and the aim would be to maintain control over existing and new infestations.

THE COOLIBAH WOODLAND

"A Directory of important wetlands in Australia" Environment Australia 2001, lists the Mt Bruce coolibah-lignum flats, a wetland of about 82 ha as WA number 113, located in the Pilbara, type B6 (seasonal freshwater/floodplain lake), listed under Criterion 1 (A good example of a wetland type occurring within a Biogeographic region of Australia). A wetland is defined from Ramsar Article 1.1 as follows " Wetlands are areas of marsh, fen , peatland or water, whether natural or artificial, permanent or temporary, with water that is fresh, brackish or salt…. "

The following comments are drawn from the Directory and were prepared by DEC's Ms V English in 1999.

"The wetland is characterised by woodlands and forests of coolibah *Eucalyptus victrix* over thickets of lignum *Muehlenbeckia florentula.* The wetland type occurs on red cracking clays in run-on zones and is dependent on inundation with fresh water from episotic rainfall events. The wetlands provide seasonal surface water in an otherwise arid environment. The largest of these wetlands covers about 62 ha, the total area is approximately 82 ha. Coolibah-lignum flats are relatively uncommon in the Pilbara region and the Mt Bruce occurrences of this wetland type are in very good condition. Most of the known wetlands of this type occur on pastoral lands and are being impacted by grazing.

The management plan for Karijini National Park (1999-2009) specifies that the area of wetlands at the base of Mt Bruce is within a Natural Environment Management Zone which implies that the zone will "be managed to preserve the abundance and diversity of native plants and animal species". Feral cattle, donkeys and horses are impacting this wetland type by grazing on the *Eulalia* and *Themeda* and trampling on this and other vegetation. Impacts of changes in fire regime on the wetlands are unknown, but fire is known to significantly impact on fringing mulga woodlands. Weed encroachment (Ruby dock) is also a problem in surrounding mulga woodland and may impinge on the wetland."

The available photographs taken by Rio Tinto Iron Ore (Figure 8) show an open woodland comprising a range of age classes from younger saplings and poles to mature and overmature specimens, up to 60 cm in diameter. Presumably regeneration events occur sporadically following flooding events or runs of good seasons. Dr van Leewen of the DEC describes the species assemblages found in the Mt Bruce

coolibah woodland as “unique”, both in structure and composition. The Coolibah is listed by DEC as a Priority Ecological Community (PEC).

A survey of the Coolibah woodland near Marandoo, in April 2008, showed that this woodland is in good condition, with a 3:1 ratio of healthy crowns to poorer crowns. The survey also established a baseline for codominant height (15 metres), for crown cover (20 percent), for density (basal area and stems per hectare at nine square metres/ ha and 90 stems/ha respectively) and diameter classes. There appears to be an adequate number of trees in the smaller size classes to ensure the regeneration of this woodland. In contrast, the adjacent Mulga stands were quite unhealthy and lacked seedling regeneration (Batini 2008 b).

The Department of Environment and Conservation’s FloraBase map shows that *E. victrix* is widely distributed in Western Australia, mainly in the Murchison, Gascoyne and Pilbara Regions.

Department of Agriculture’s Technical Bulletin 92 (2004) separates the Pilbara region into various Land Systems, nine of which are found on river flood plain systems. One of these is classified as Coolibah and defined as “flood plains and minor channels with weakly gilgaid clay soils that differs from the other systems mainly in the vegetation that it supports”. The Coolibah Land System covers about 1014 km2, about 0.6% of the survey area, and is described in detail on pages 220 and 221 of the Bulletin. Site type DEGW (Drainage eucalypt and acacia grassy woodland/shrubland) is the most extensive type found on Coolibah and is common on the Fortescue Land System. The Mt Bruce Coolibah –lignum flats would be described as “low lying depression and drainage foci up to 1.5 km in extent, but usually smaller, found within other units”.

COPING WITH DROUGHT

Trees such as mulga, coolibah and river gum are very long-lived organisms (150 to 300+ years) and have therefore developed multiple strategies to cope with threatening processes such as unusual weather, fire, climatic change and attack by insects and fungi. Drought strategies include stimulating root growth, control over transpiration and stomata, thick cuticles and bark, leaf alignment, leaf fall, branch dieback and the replacement of a primary crown by epicormic growth. Attack and infection may be countered by increased leaf or root production and/or mobilisation of defence mechanisms such as gum veins, periderm formation and occlusions. These processes are dynamic; tree crowns may partially recover, and then be affected once again.

However, because of their great age, these older trees may not necessarily be in balance with the **current** environment.

Drought strategies all use less water and therefore mean that a lesser amount of photosynthetic material is produced. Active response to infection or insect attack requires mobilisation of defence mechanisms that need additional photosynthetic products. These new leaves are often much more palatable to insect grazers leading to an increase in decline and further stress on the tree. Where the negative impacts on the trees are sustained over long periods (some years or decades) by a *chronic* climatic change, drought or continuous insect or fungal attack, the availability of food

resources becomes limiting, defence mechanisms are severely stretched and may then fail.

Such a chronic situation may lead to what is referred to as *predisposition* of a tree to fungal or insect attack. For example studies of bark borers such as *Phorocantha semipunctata* show that bark conditions (such as decreased bark moisture content and increased concentration of soluble sugars) greatly affect the attractiveness of a host tree and the survival rates of borer larvae. It is also possible that environmental changes (eg temperature, soil moisture, predator numbers) may favour the build-up of fungal and insect pests. The classical "disease triangle" shows that the environment acts both on the host as well as on the pathogen/pest species, possibly favouring one and disfavouring the other.

External influences that would have been dealt with by the tree in a normal situation may now lead to severe debility and tree death.

TREE ROOTING PATTERNS AND WATER USE

Long-lived organisms like trees rely on two distinct types of root systems, each with its specific function. The surface root system that fully explores the top 1.5-2 metres of soil provides most of the water and nutrients required for growth and to maintain health. There are structural roots for stability and many fine roots to absorb water and nutrients.

The deeper root system, to a depth of up to 30 metres, is the system that supports life during periods of drought. These larger roots are usually located along old root channels and other preferred pathways and so do not fully explore all of the available soil profile. At about the water table there may be a proliferation of finer roots. Where these "tap roots" are not well developed, as for example in Mulga, the tree must rely on other mechanisms, such as stomatal closure, leaf shape and morphology, in order to reduce its water use or to extract additional water from the soil.

Current data from root excavations suggest that mulga, cajeput and coolibah do not have a well-developed sinker root systems whereas river red gum has. There are also some indications that coolibahs may be more susceptible to waterlogging than river gums (Adams pers comm.).

The water chemistry in the sub-surface and deeper groundwater systems can be quite different and may be able to be used, in addition to other "isotopes", to determine where water used for transpiration is being drawn from. Measurements of sap flow may also be used to determine where water is being drawn from, for example if rapid transpiration continues during extended periods without rain it is likely that the tree has access to the permanent water table. These physiological aspects of tree water use are being studied by a team of scientists drawn from UWA/UNSW and results are expected by the end of 2008.

NATURAL CHANGE

The climate of the Pilbara is highly variable, with cyclonic events at about 5 yearly intervals, which may dump over 400 mm of rain in just a few days, being followed by

sustained drought when no rain may fall for five to six months. A drought risk map rates the Karijini National Park area as “high to severe risk” (AGWA 2004). Data from Marandoo average 397 mmpa but show a variation in annual rainfall from 187mm to 697 mm over a period of nine years (Evans and Youngs 2007). The indications from climate change models suggest that though cyclones are likely to become more frequent, the mean annual rainfall is expected to decrease, which suggests that the climate will show increasing variability (Environmental Modelling and Predictions P/L Australia 2007)).

Trees have adapted to these conditions. As long as these changes in climatic conditions and those changes that may result from dewatering during mining operations are held “within” the observed natural range of fluctuations, the vegetation should be able to cope. It is therefore important to be able to assess the past levels of “natural” variability, particularly in the unconfined aquifer, both on a seasonal scale and preferably on a longer-term basis. Earlier, it has been shown that rapid fluctuations of about 9m can occur in the unconfined aquifer, naturally after rainfall. Data collected over the past four years have also show a “natural” change of 10 to 15 percent in leaf area from year to year from control plots, as trees adapt to seasonal conditions (Adams pers comm.).

Vegetation is regarded by most people as being “ fairly static” but in fact there are many changes in composition, density and health that can be observed if measurements are made over a longer time period. An example of this is the changes that have been recorded for the Water Corporation by Mattiske on the Swan coastal plain over the past 40 years (Mattiske pers comm). It is therefore important to try and separate changes in composition, density or health that may be due to the mining operation, from those “ natural” changes that are caused by other events, such as climate change, drought, flood and wildfire. RTIO are funding a study by UNSW titled “Climate change, management and ecosystem interactions in the Pilbara” so as to address this.

The two main environmental “drivers” in an arid environment are water (as rainfall, overland surface flows, water tables, springs, pools and streams) and nutrients. In an arid environment nutrients are often held in fertile “patches” associated with organic matter that has accumulated around shrubs and trees (eg groves) that are interspersed with less fertile, bare areas (eg intergroves). Events such as wildfire or overgrazing that may destroy or reduce the vegetation and lead to erosion can cause a significant and permanent loss in fertility. Plants such as Mulga improve their nutrient status by fixing nitrogen in association with rhizobium nodules in their roots. Eucalypts exploit mycorrhizal fungi to improve their ability to explore the soil profile for scarce nutrients.

For example the regeneration of both Coolibah and Mulga occurs in episodic events, possibly once each decade, when a whole cohort of even aged seedlings is established during favourable seasons, often following fire or flood events. However regeneration can be wiped out by a poor season following this germination, or wildfire or overgrazing and mature stands are also killed by wildfire. Landsat data may well be useful to indicate whether the extent and health of the Mulga grove-intergrove patterns and the Coolibah wetland have changed over some decades. More detailed mapping of the location of groves-intergroves from remote sensing may be desirable.

Some field data on size class distribution and location of regeneration may also give some clues as to the current health of the Coolibah woodland and whether it has been recently expanding or contracting. RTIO has engaged consultants to address these aspects. A report by Gaia Resources (2008) from data acquired between 1972 and 2008, shows a major reduction in the area of Mulga on the Mt Bruce flats (probably due to fire) and only minor changes to the area occupied by Coolibah.

There is also the need to consider other processes that may also threaten the survival of Mulga and Coolibah on the Mt Bruce flats. For Mulga, the main threats come from overgrazing by feral animals, weed invasion and wildfire. Since Mulga in the Pilbara is seen as being on the margins of its natural range, where water is almost always limiting (Fortech 1999), the projected climatic changes such as an increase in temperature and a substantial decrease in rainfall by 2060 will also play a part. Possible threats to the Coolibah are an increased threat of damage from cyclonic winds, weed invasion, wildfire and climate change, leading to excessive waterlogging or severe drought.

Ongoing monitoring by Rio Tinto will need to cover both measurements at regular intervals as well as any “unusual episodic” occurrences. The monitoring protocols will need to be developed to the satisfaction of DEC and EPA. They will need to be timely so as to give adequate advance warning and robust enough to be able to discern changes due to mining from changes due to other causes. There are a number of issues to be examined and I would suggest that a 2-3 hour workshop (that should include DEC and EPASU staff at least for the last hour) would be the best way to address these matters: eg what to monitor, how and where to monitor, by whom and how often. Also, what access protocols should be in place to minimise damage by tracks, weed introduction, accidental fire.

It may well be desirable for Rio Tinto Iron Ore to liaise with and assist DEC with management actions directed to control feral animals, weeds and wildfire in the Mt Bruce flats. This can be done as part of the Statement of Mutual Understanding (SMU) process and these activities would seem to offer a good opportunity to train and employ local Indigenous people.

FINDING SUITABLE CONTROL SITES

In most studies, the environmental effects of an activity such as mining need to be separated from other natural events that may lead to a similar environmental effect. This is normally done by the selection of representative “control” sites in the same general area that are not impacted by the mining operation. As the Coolibah stand is rather a unique feature of the Mt Bruce flats, it has been difficult to locate suitable control sites nearby. This means that there will be need to increase the level of “opportunistic” and “event” monitoring (for example, wildfire, flood, cyclone, extended drought) by Rio Tinto Iron Ore of the Mt Bruce Coolibah site. The UWA/UNSW study have selected as their “control” a site in the Coondewanna area, located some 70 kms away from the Mt Bruce flats and monitoring of this site should also assist with the interpretation of results. However, Dr van Leewen advises that these stands differ from the Mt Bruce site in their floristic composition. This may not be a serious concern as the main emphasis will be on the responses of the Coolibah trees.

CONCLUSION

At this stage in the process, (mid September 2008), there is no evidence from existing data that the mining below water table proposed by Rio Tinto Iron Ore will have a significant detrimental effect on the vegetation in the Karijini National Park.

However this statement needs to be qualified, since additional data are currently being gathered on some particular aspects of the project.

It is quite possible that future events such as cyclonic storm, extended drought, climate change, weed invasion, grazing and wildfire will pose a significant threat to the sustainability of the Mulga and Coolibah communities within the Mt Bruce flats. Action should be taken by DEC and Rio Tinto Iron Ore through the SMU and PER commitments, to ensure that these threats are reduced as far as is possible.

Monitoring protocols will need to be jointly developed to try and separate any effects on the vegetation in the National Park that may be due to mining from changes caused by “natural” events.

Frank Batini
17-09-2008

FIGURES

Figure 1a	Marandoo Surface Water Catchments
Figure 1b	Marandoo railway and sidings
Figure 1c	Marandoo hydrogeology
Figure 2	Marandoo Rainfall Data 1998 to 2008
Figure 3	Hydrology monitoring locations
Figure 4 a to e	Unconfined aquifer: Water Level Changes in Boreholes OW 12s, 15s, 28s and 30s
Figure 5 a to d	Unconfined aquifer: Water Level Changes in Boreholes OW 12s, 25s and 27s
Figure 6 a to d	Confined aquifer: Water level Changes in Boreholes OW 12d, 25d and 27d.
Figure 7	Marandoo mine, box cut dewatering, diagrammatic: Location of Recharge Areas
Figure 8	Photographs of Coolibah woodland

References

AGC Woodward Clyde (1992) Marandoo Iron Ore Project – Investigation of the Hydrogeology of the Mount Bruce Flats and Environs, unpublished consultant report.

Agriculture WA (2004) An inventory and condition survey of the Pilbara region, Western Australia. Tech Bull No 92.

Batini F E, A B Hatch and A B Selkirk (1977) Variations in the level and salinity of perched and semi-confined water tables, Hutt and Wellbucket catchments, Res Pap For Dept WA No 45.

Batini F E (2008 a) Marandoo Mulga monitoring- Summary of 2005 results. Consultants report to Rio Tinto Iron Ore.

Batini F E (2008 b) Report on Coolibah survey results- April 2008. Consultants report to Rio Tinto Iron Ore.

Beckett k (2008) Marandoo Phase II- Surface water management. RTIO- PDE-0051455. Doc.

Conservation and Land Management (1999). Management plan for the Karijini National Park.

English V, (1999) A Directory of Important Wetlands in Australia, Australian Government, Department of the Environment and Water Resources http://www.environment.gov.au/cgi-bin/wetlands/report.pl Cited 12 Feb 2007.

Environment Australia (2001) A Directory of important wetlands in Australia.

Environmental Modelling and Predictions P/L (2007) Consultants report to RTIO on climate change for the Tom Price-Paraburdoo region.

Evans and Youngs (2007) Conservation of trial dewatering discharge through re-injection in the Pilbara region, Western Australia. RTIO report.

FORTECH (1999) Pilbara Mulga Study –Stage I Consultants report for the Department of Resources Development.

Gaia resources (2008) Marandoo remote sensing acquisition and analysis. Report to RTIO.

Grierson PF, Adams MA, Madden S, White S, van Leeuwen S, Smith B, Evans LR, (2007) Dynamics of water and woody vegetation in central Pilbara –

understanding and managing for environmental change. Australian Research Council Linkage Projects, Application for funding, 88 pp.

Land and Water Australia (2005) A framework for assessing groundwater dependent ecosystem environmental water requirements

Liquid Earth (2005) Marandoo Hydrogeological Investigation Report, Pilbara Iron Pty. Limited, unpublished consultant report.

MWH (2006a) Marra Mamba BWT, Dewatering and Reinjection Program, Pilbara Iron and RTIO Expansion Projects, unpublished consultant report prepared by Youngs, J.

MWH (2006b) Marandoo Model Development 2006, Pilbara Iron, unpublished consultant report prepared by Youngs, J. and Milligan N.

Waterhouse JD, Howe PJ, (1994) An Environmental Hydrogeological Study near Mount Bruce, Pilbara Region of Western Australia, Proceedings of Water Down Under ’94, Congress of the International Association of Hydrogeologists and International Hydrology and Water Resources Symposium, Adelaide.

Youngs J, (2004) Groundwater level behaviour at a Pilbara mine. MEng., University of Technology Sydney, Australia, in press

Youngs J, Brown D, (2005) Aquifer re-injection as a low-impact groundwater investigation tool – a case study from the Pilbara Region, Western Australia. Conference Proceedings of the 5th International Symposium on Management of Aquifer Recharge, Berlin, Germany, 11-16 June 2005

APPENDIX 1 GAP ANALYSIS

The following data are required. Comments have been added as a result of the workshop held by Rio Tinto on 23rd October 2007 as to availability of data and the person responsible for collating these.

Data	Rainfall data over past decades for Marandoo
Reason	To show marked variability and vegetation adaptation to this
Need	High
Availability	Yes, from Bureau of Met, Rio Tinto
Comment	Data are available and have been collated by Ms Beckett

D	Predictions of whether and how climate may change
R	Understand likely direction and magnitude of natural changes
N	M-H
A	Yes, from Bureau of Met and CSIRO models
C	Modelling data are available and collated (Ms Beckett)

D	Seasonal and long-term changes to water tables-surface, shallow, deep
R	To show high variability in some, much less so in others
N	High
A	Yes, from Rio Tinto, from bores (mining, monitoring, pastoral?)
C	Some data are available for shallow and deep bores (Mr Dodson)

D	Description of soil profiles
R	Understanding of soils and geology, aquifers, aquicludes
N	High
A	Yes, from Rio Tinto
C	Data are available (Mr Dodson)

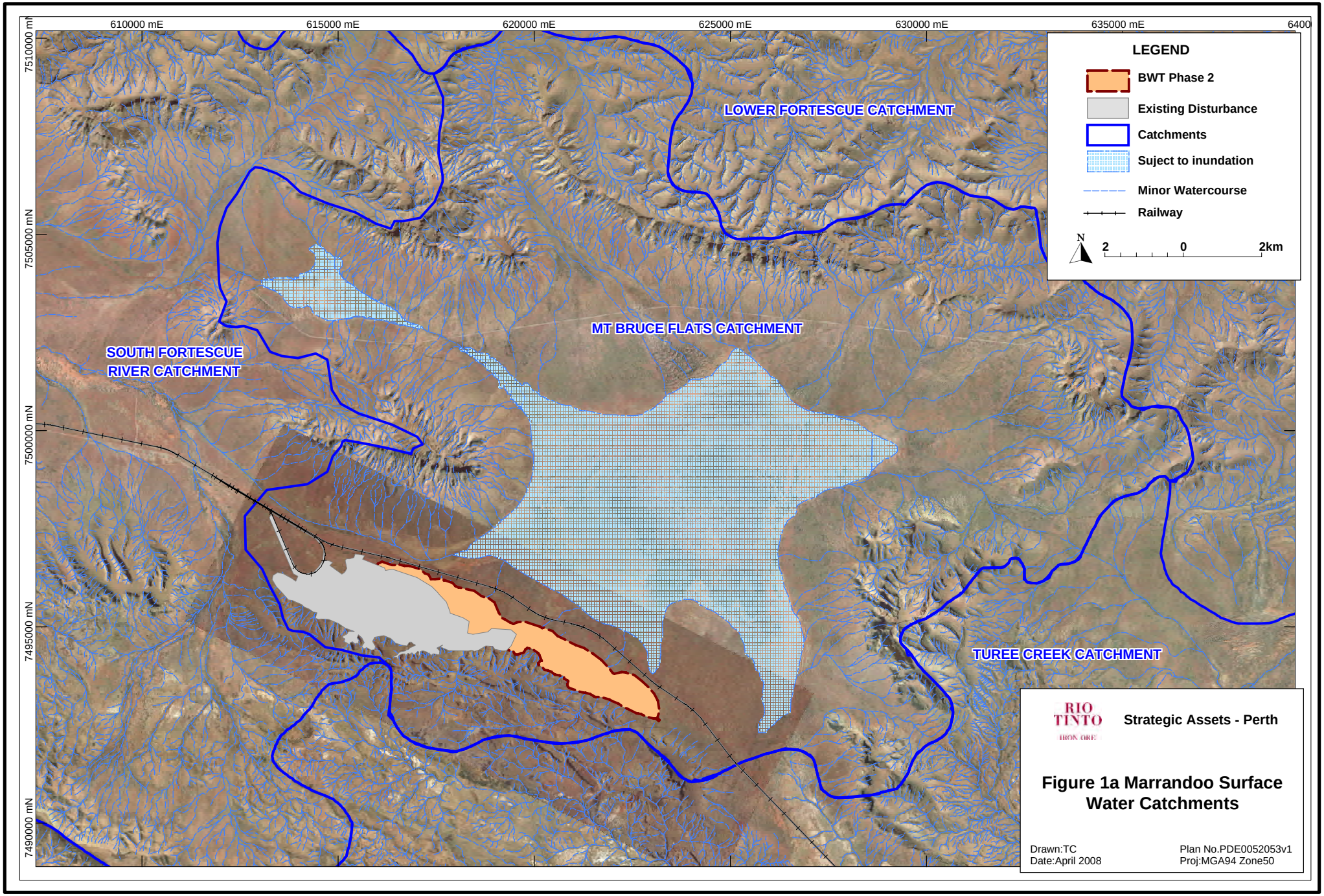
D	Results of long-term pump tests
R	Understanding of responses in different aquifers, storage coefficients
N	High
A	Rio Tinto
C	Data are available (Mr Dodson). However the modelling could be improved if some additional bores located within the National Park could be drilled. Rio Tinto (Mr Dodson, Mr Eckersley, Ms Phelan) to consider whether this avenue should be pursued with DEC.

D	Rooting patterns and depths for mulga and coolabah
R	Understanding of where water is sourced
N	M-H
A	Unsure-possibly Rio, UWA, Other studies (P Curry, J Laws)
C	Data are available from UWA (Professor Adams) and possibly from other studies (Ms Madden)

D	Tracer experiments in the wetland
R	Understanding where water is sourced
N	M-H

A	possibly UWA
C	An experiment is to commence soon (UWA and Rio Tinto staff)
D	Water use patterns by two key species
R	Understanding differences and ability to shut-off water use
N	M
A	Unsure-possibly UWA
C	Sap flow monitoring of coolabah and mulga will commence soon (UWA, funded by Rio Tinto)
D	Detailed contour data
R	To determine surface flow patterns accurately
N	H
A	Rio Tinto
C	Not yet available, but considered useful. Rio Tinto will investigate methodology and cost of capture (Ms Beckett?)
D	Likely volume of “run-on” that may be diverted by the mine-pit
R	Calculate likely flows into pit and scale of “water-shadow” effects
N	H
A	Rio Tinto-from rainfall and catchment area
C	Already completed (Ms Beckett). Improved designs for discharge areas are desirable and the recent work of C Muller for FMG may assist. It may be possible to flood irrigate some areas with dewatering surplus on a “campaign” basis. Rio Tinto to consider whether to approach EPASU and DEC (Mr Eckersley, Ms Phelan, Ms Beckett)
D	Health of vegetation over time, size of wetland over time
R	To separate mine effects from longer-term trends
N	H
A	Unsure- possibly Landsat (CSIRO), Specterra, air-photos, plots
C	Some recent data available for the wetland and Weeli Wooli (UWA and Specterra). Some further field evaluation is required for the wetland and possibly for some mulga stands (Ms Alford, Ms Madden, Professor Adams, Mr Batini?)

Frank Batini
Consultant
Revised
10/12/2007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LOWER FORTESCUE CATCHMENT
MT BRUCE FLATS CATCHMENT
SOUTH FORTESCUE RIVER CATCHMENT
TUREE CREEK CATCHMENT
LEGEND
BWT Phase 2
Existing Disturbance
Catchments
Suject to inundation
Minor Watercourse
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RIO TINTO
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Strategic Assets - Perth
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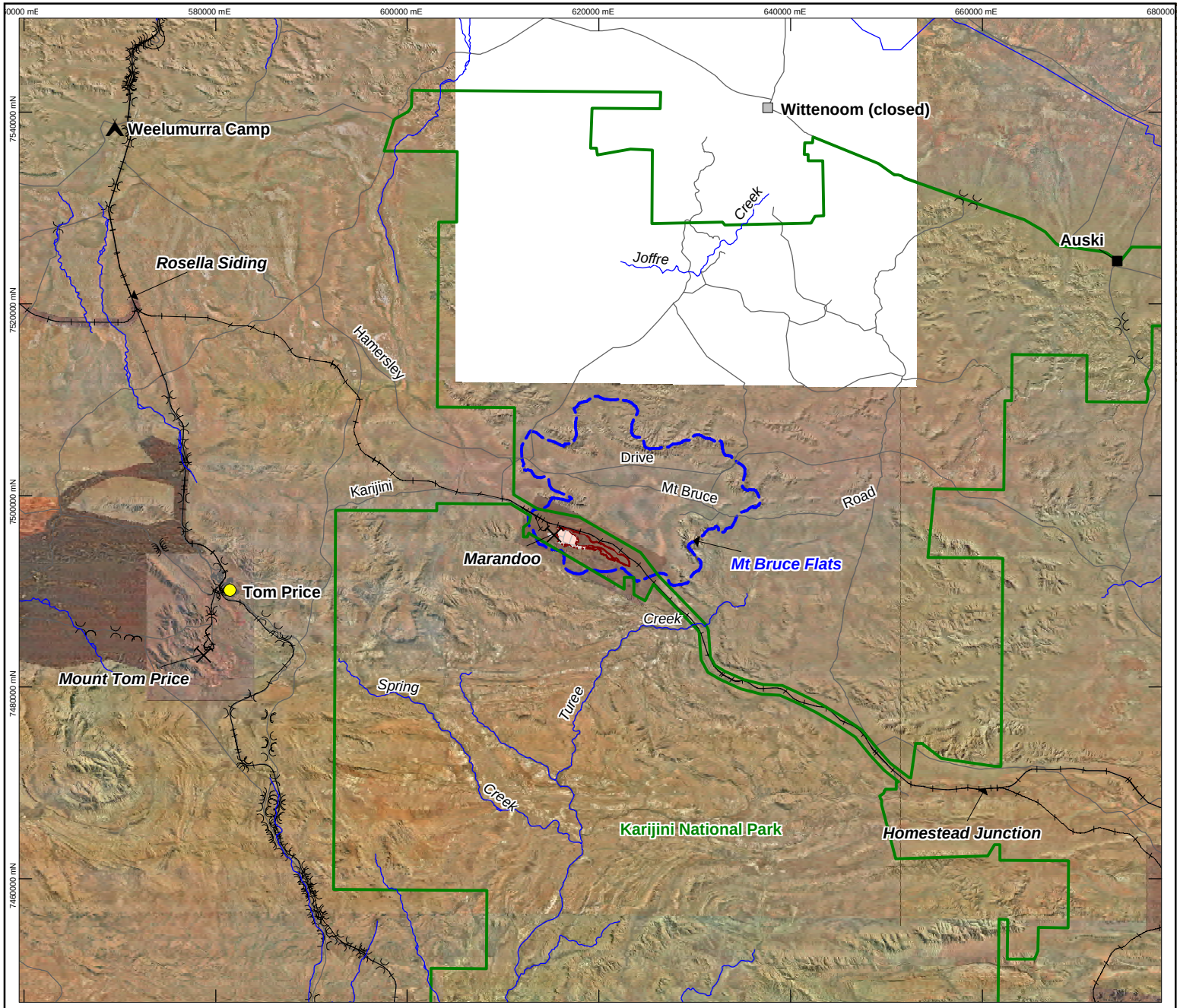
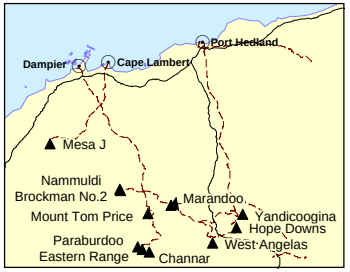


LEGEND

- Railway
- Roads
- Major Watercourse
- Culvert
- Major Town (closed)
- Roadhouse
- Major Town
- Camp
- Mine
- Surface water catchment
- Current Pit Outlines
- BWT Proposed pit outline

LOCATION MAP



SCALE

N

12 0 12km

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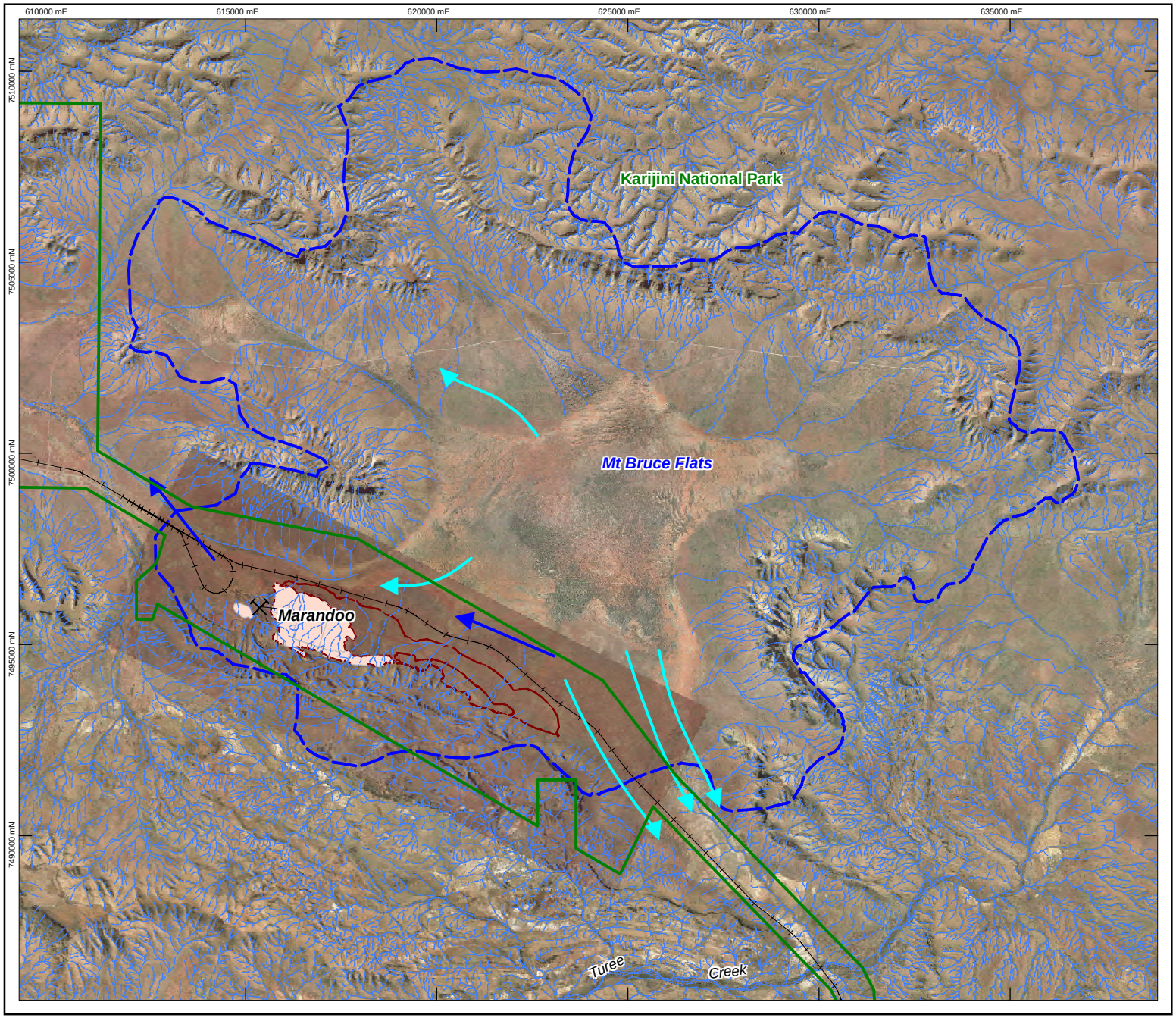
Figure 1b:
Marandoo railway and sidings

Drawn: TC
Date: April 2008

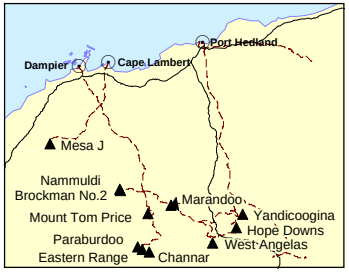
Plan No. PDE00520531v1
Proj: MGA94-50



LEGEND

- Railway
- Road
- Private Road
- Minor Watercouse (non-perennial)
- Unconfined Aquifier
- Confined Aquifier
- Mine
- Surface water catchment
- Current Pit Outlines
- BWT Proposed pit outline

LOCATION MAP



SCALE

N

3 0 3km

Scale: 1:150,000@A4

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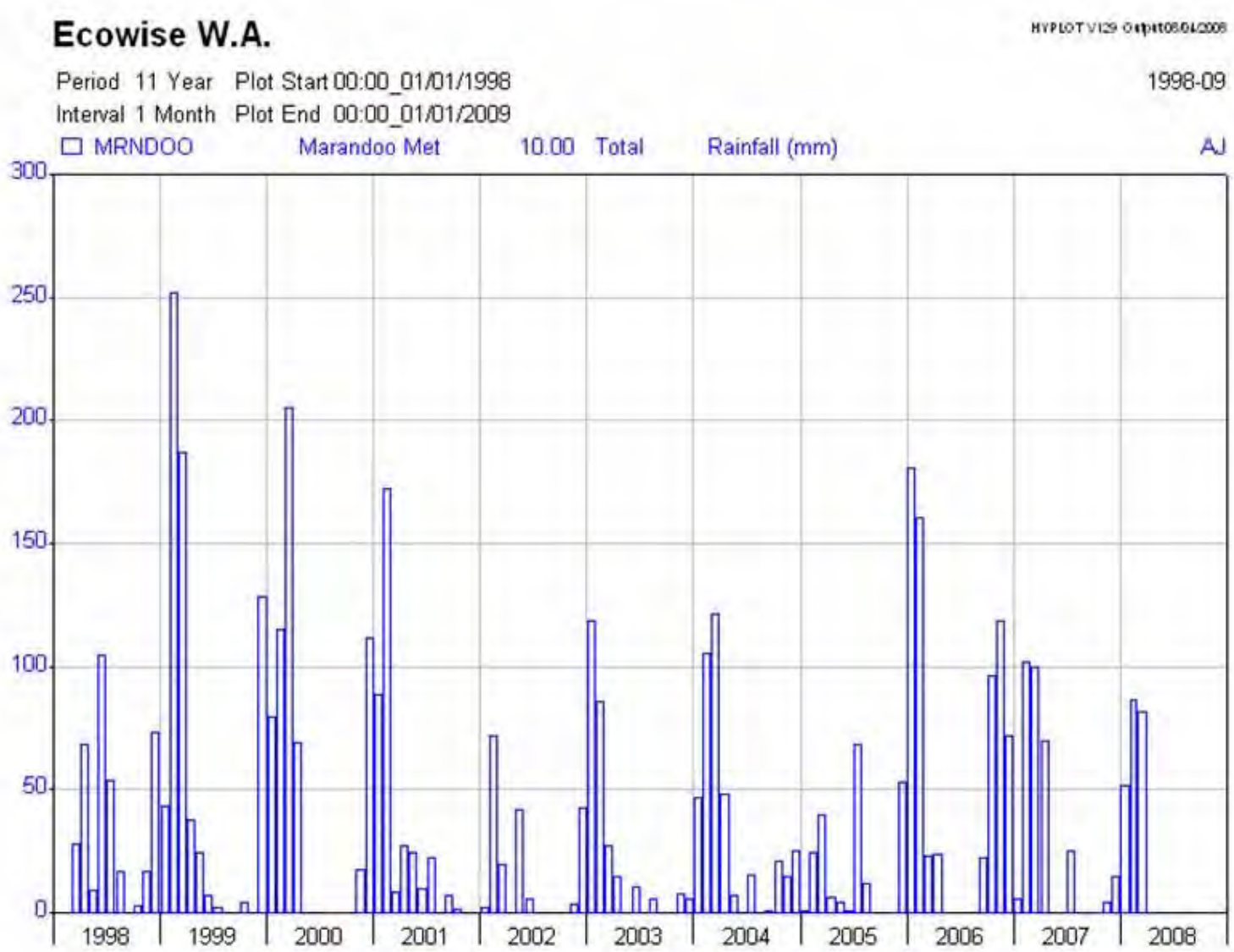
Strategic Assets - Perth

Figure 1c: Marandoo Hydrogeology

Drawn: TC
Date: Feb 2008

Plan No. PDE0052053v1
Proj: MGA94-50



RIO TINTO IRON ORE **Strategic Assets - Perth**

Figure 2: Marandoo Rainfall

Plan No.PDE0052053v1

615000 mE
620000 mE
625000 mE
630000 mE
7500000 mN
7495000 mN
7490000 mN

OW13
OW14
OW09
OW03
PZ05MN005
PZ05MN006
R04MN002
R04MN003
21
R04MN001
TPB1
PZ05MN004
PZ05MN011
TPB2
OW22d
OW22s
OW31d
OW32d
WB05MN005
PZ05MN002
WB05MN002
Marandoo
Rail
Plant
Train loadout
Product stockpile
Marandoo Mine Layout
See inset A
See inset B
See inset C

TIB1
OW15s
OW15d
OW30d
OW28s
OW28i
OW12d
TIB1A
PW12
OW12s
OW06
OW30s
OW28d
OW29
OW27i
OW27d
OW25i
OW11i
OW27s
OW11d
OW25d
TPB3
OW23s
R04MN011
OW23i2
OW25s
PZ05MN009d
TPB4
OW26i
OW26d
PZ05MN009i
OW10s
OW10d
OW26s
WB05MN008
WB05MN006
R04MN009
PZ05MN010
TPB5
OW24s
OW20
PW20
OW24d
OW35d
OW24i
OW36i
OW36d

INSET C
OW15d
OW28s
OW28i
OW28d
OW15s
OW30d
OW29
OW12s
3.2km
TIB1
OW12d
TIB1A
PW12
OW06
OW30s
1.8km
OW27s
OW25s
OW11i
OW25d
OW25i
OW26i
OW26d
OW26s
R04MN009

INSET A
OW03
R04MN002
PZ05MN005
PZ05MN006
21
R04MN003
R04MN004
OW21s
OW21d
PZ05MN001
TPB1
PZ05MN004
WB05MN001
WB05MN005
OW32d
WB05MN002
OW31d
PZ05MN002

INSET B
OW27i
OW27d
OW27s
OW25i
OW11i
OW25d
OW23s
OW23i2
OW23i1
R04MN011
TPB3
WB05MN008
OW25s
PZ05MN009d
OW10s
OW26s
TPB4
PZ05MN009i
OW10d
R04MN009
PZ05MN010
WB05MN006
OW20
PW20
TPB5
OW24d
OW35d
OW24s
OW24i
OW36i
OW36d

Rail Access Road
OW08s
OW08d
Mindthi Spring

LEGEND

- Piezo
- Water bore
- Rail access road
- Railway
- Tracks
- NE Transect
- EW Transect

SCALE

1 0 1km

Port Hedland
Cape Lambert
Dampier
Mesa J
Nammuldi
Marandoo
BHPIO Yand
Brockman No.2
Yandicoogin
MAC
Hope Downs
Mount Tom Price
Channar
West Angelas
Paraburdoo
Mount Whaleback
Eastern Range
Jimblebar

N

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Figure 3: Marandoo Project Hydrology Monitoring Locations Regional Overview

Drawn:TC
Date:April 2008

Plan No:PDE0052053v1
Proj:MGA94 Zone50

Figure 4a Groundwater levels (mRL/time)
Unconfined Aquifer

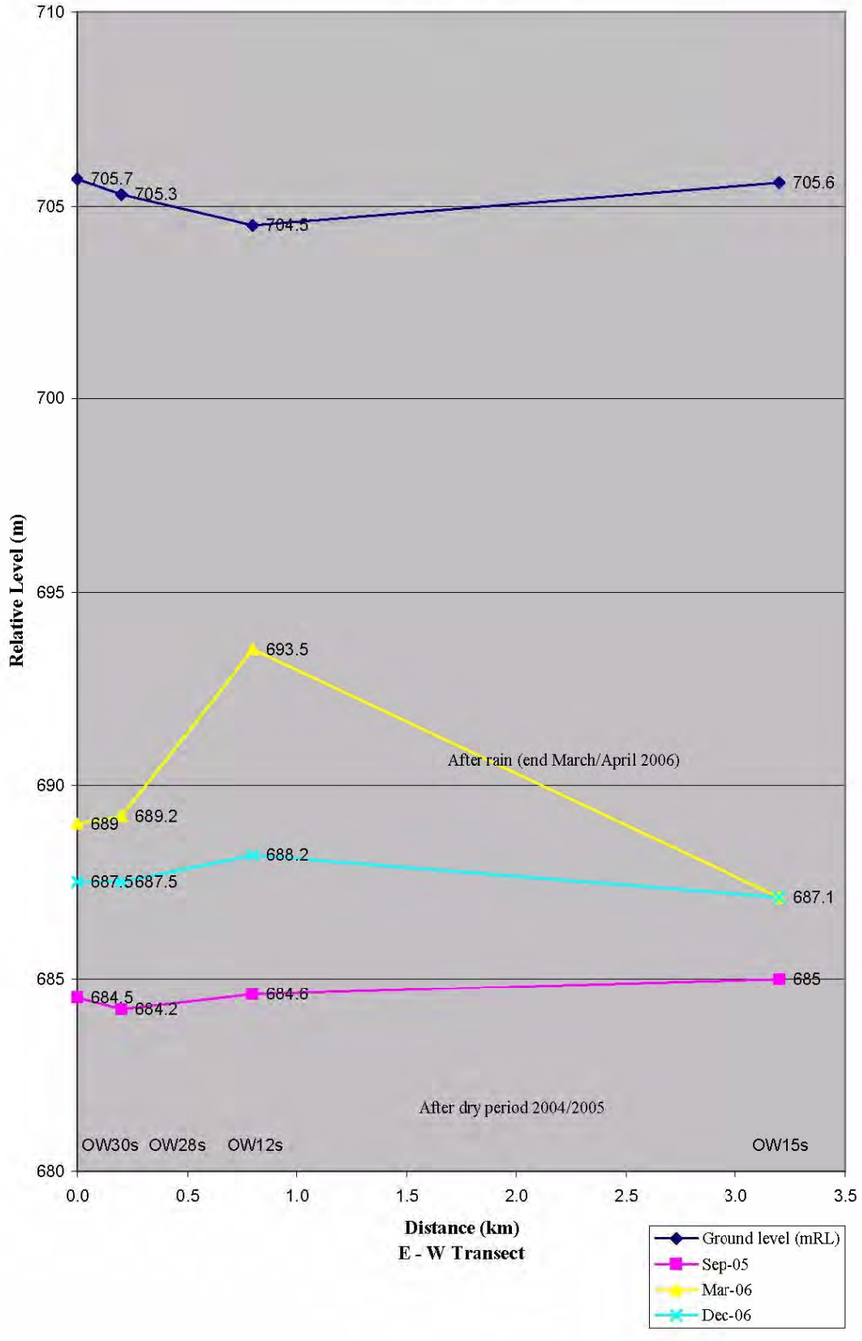

Figure 4b: OW30s

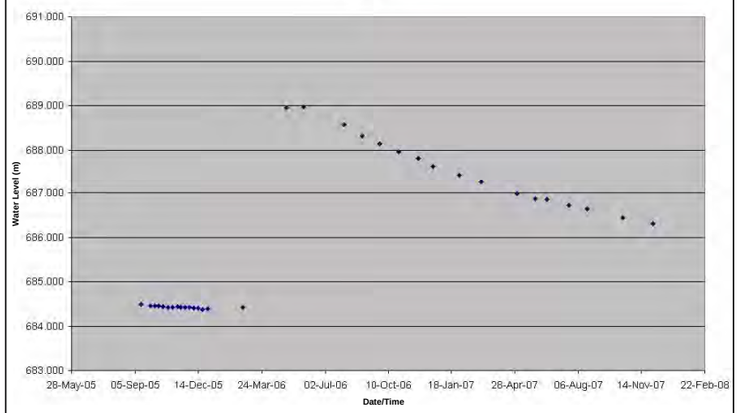

Figure 4c: OW28s

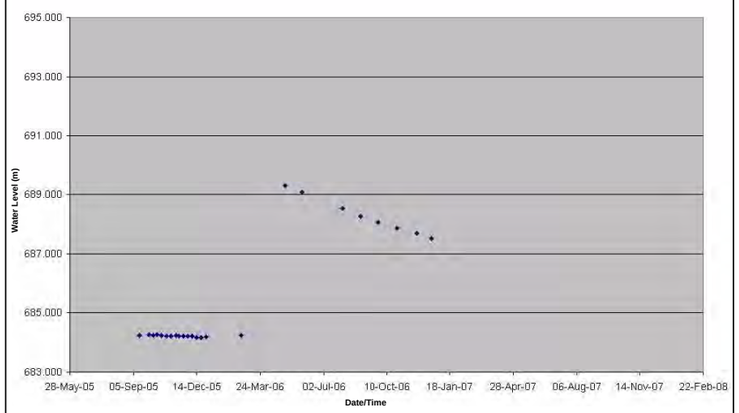

Figure 4d: OW12s

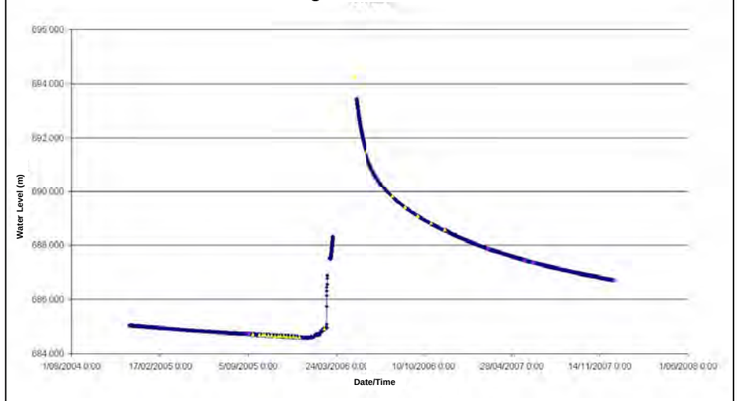

Figure 4e: OW15s

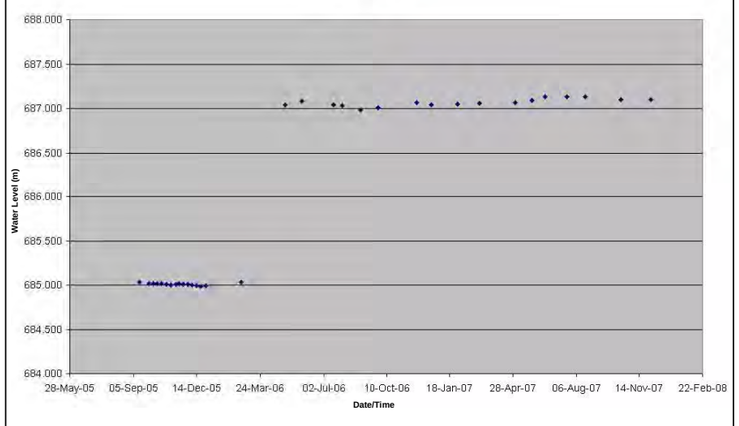

Figure 4: Unconfined Aquifer- Water level changes in Boreholes OW12s, OW15s, OW28s and OW30s

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PDE0052053v1_Fig4 Date: May 2008

Figure 5a Groundwater levels (mRL/time)
Unconfined Aquifer

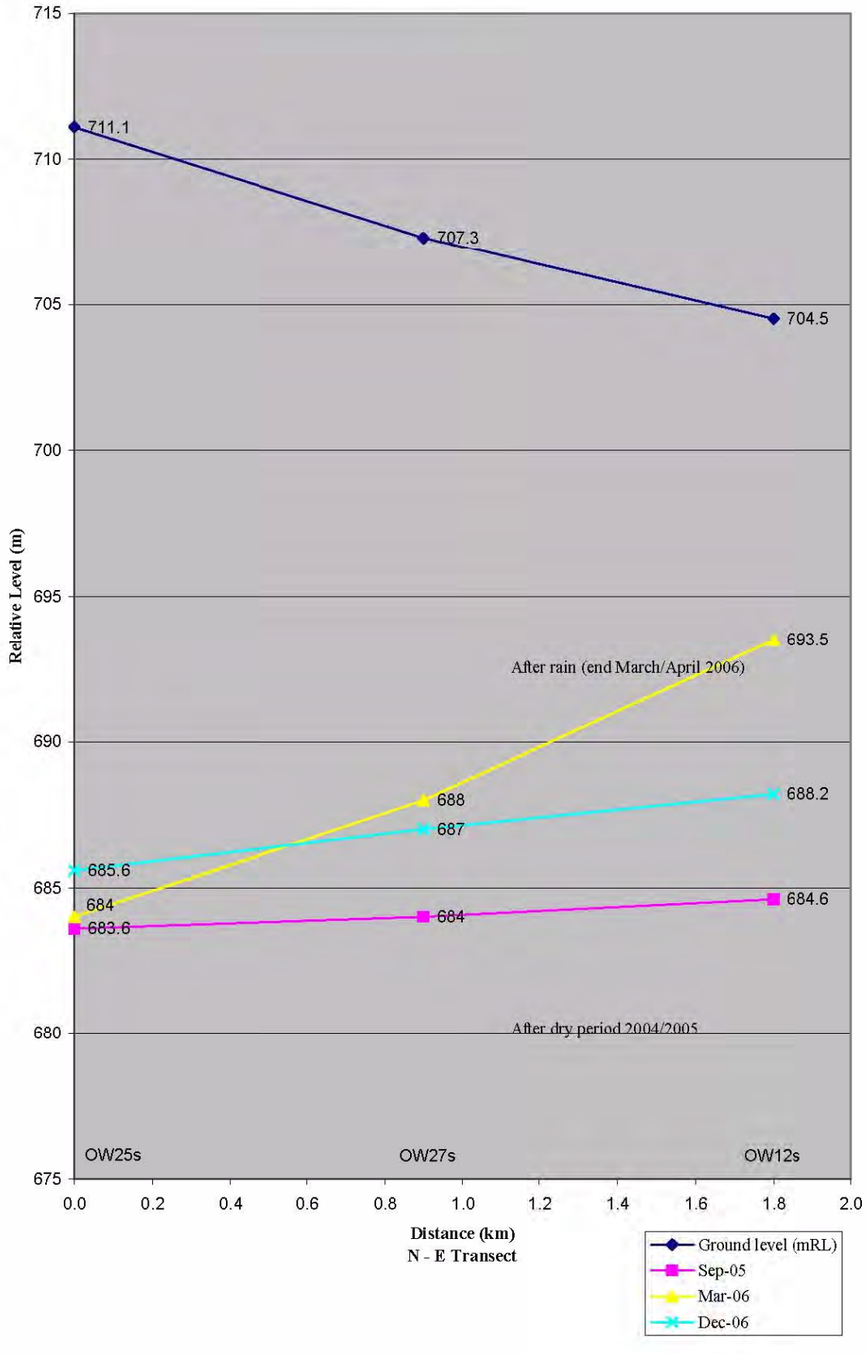

Figure 5b: OW25s

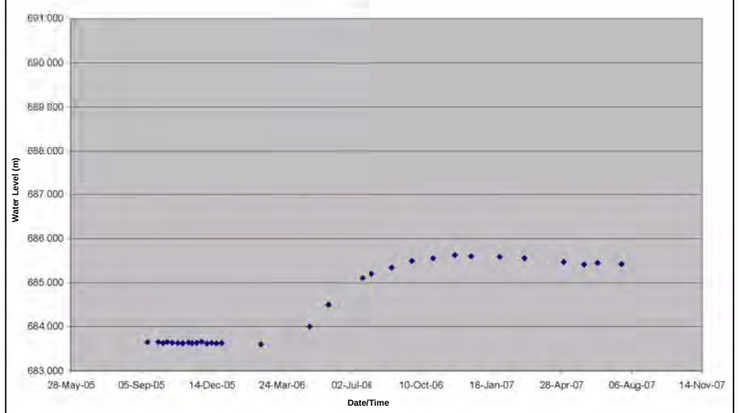

Figure 5c: OW27s

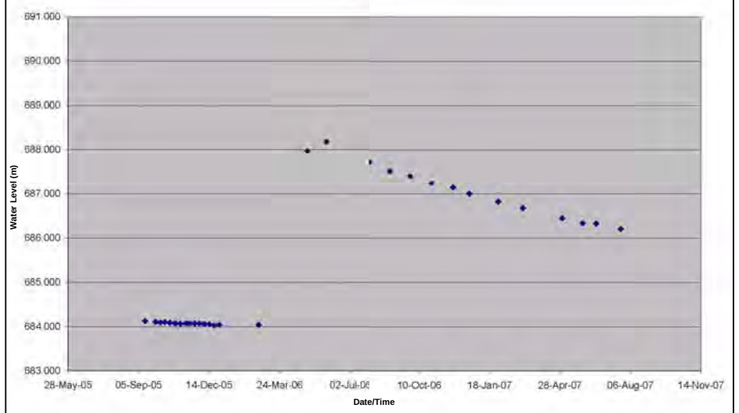

Figure 5d: OW12s

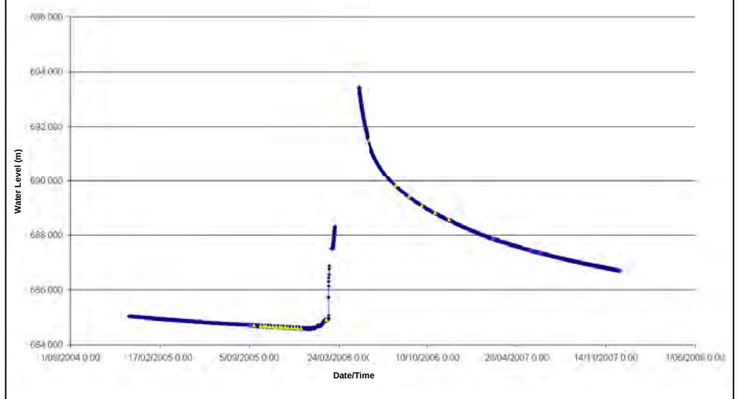

Figure 5: Unconfined Aquifer- Water level changes in Boreholes OW25s, OW27s and OW12s

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Figure 6a Groundwater levels (mRL/time)
Confined Aquifer

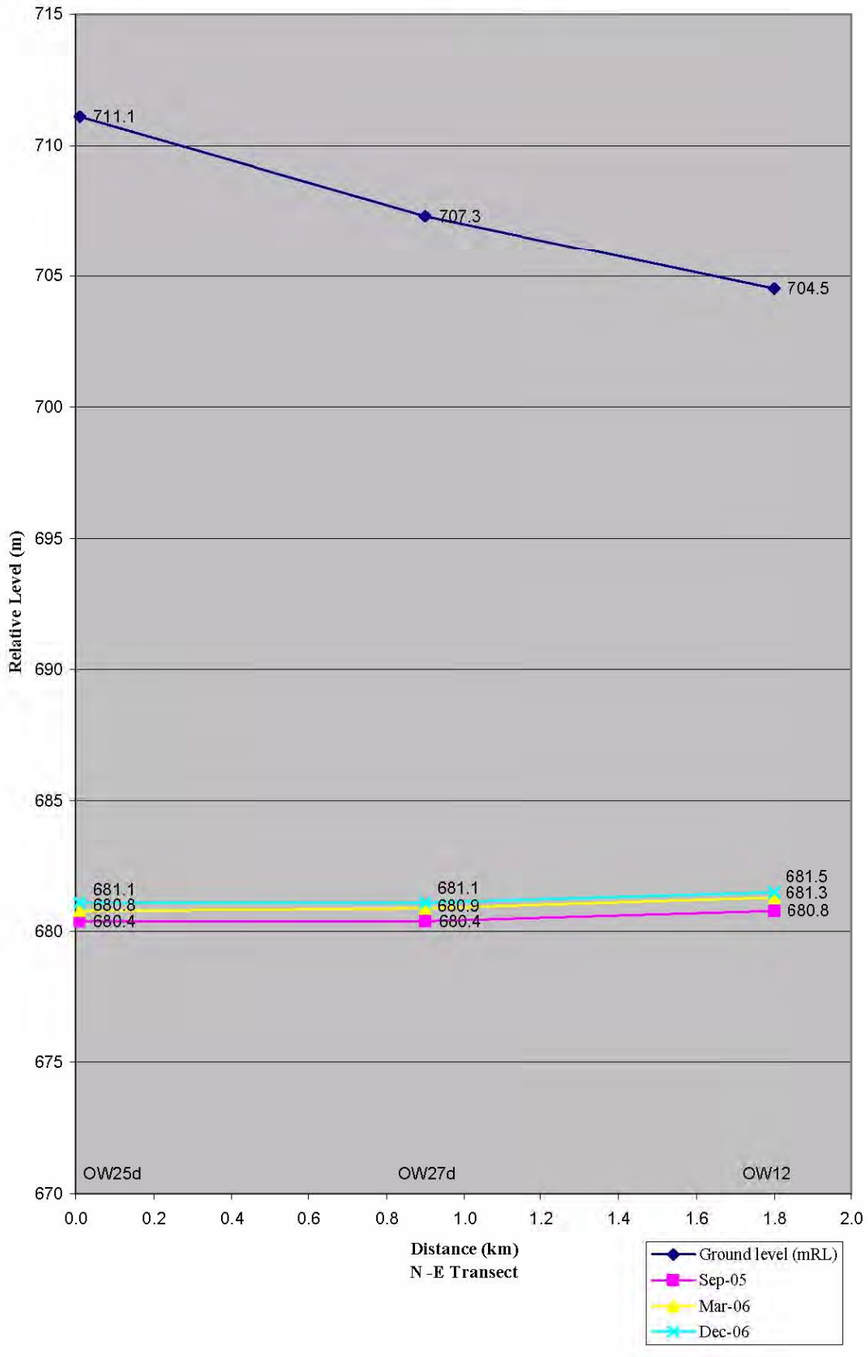

Figure 6b: OW25d

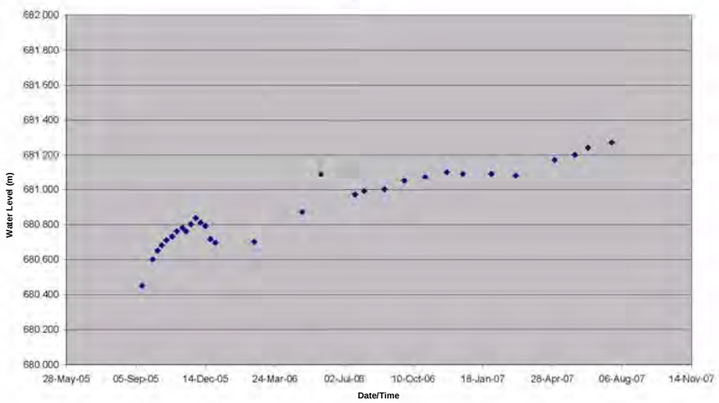

Figure 6c: OW27d

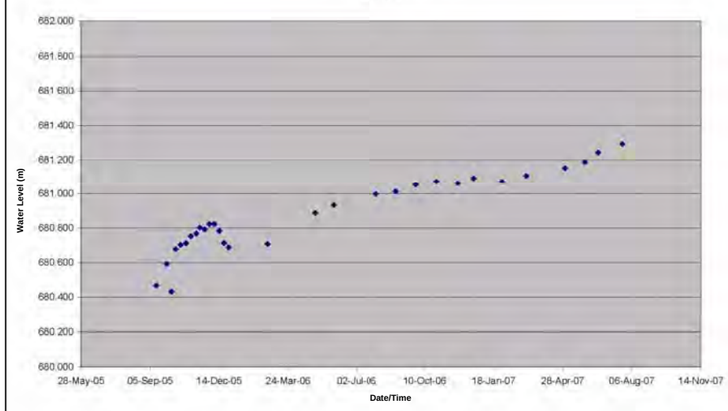

Figure 6d: OW12d

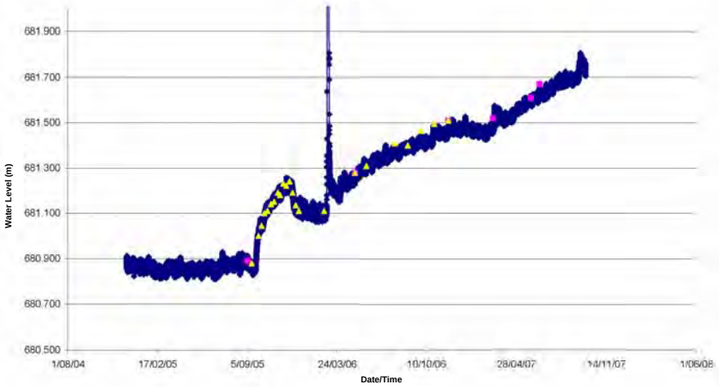

Figure 6: Confined Aquifer- Water level changes in Boreholes OW12d, OW25d and OW27d

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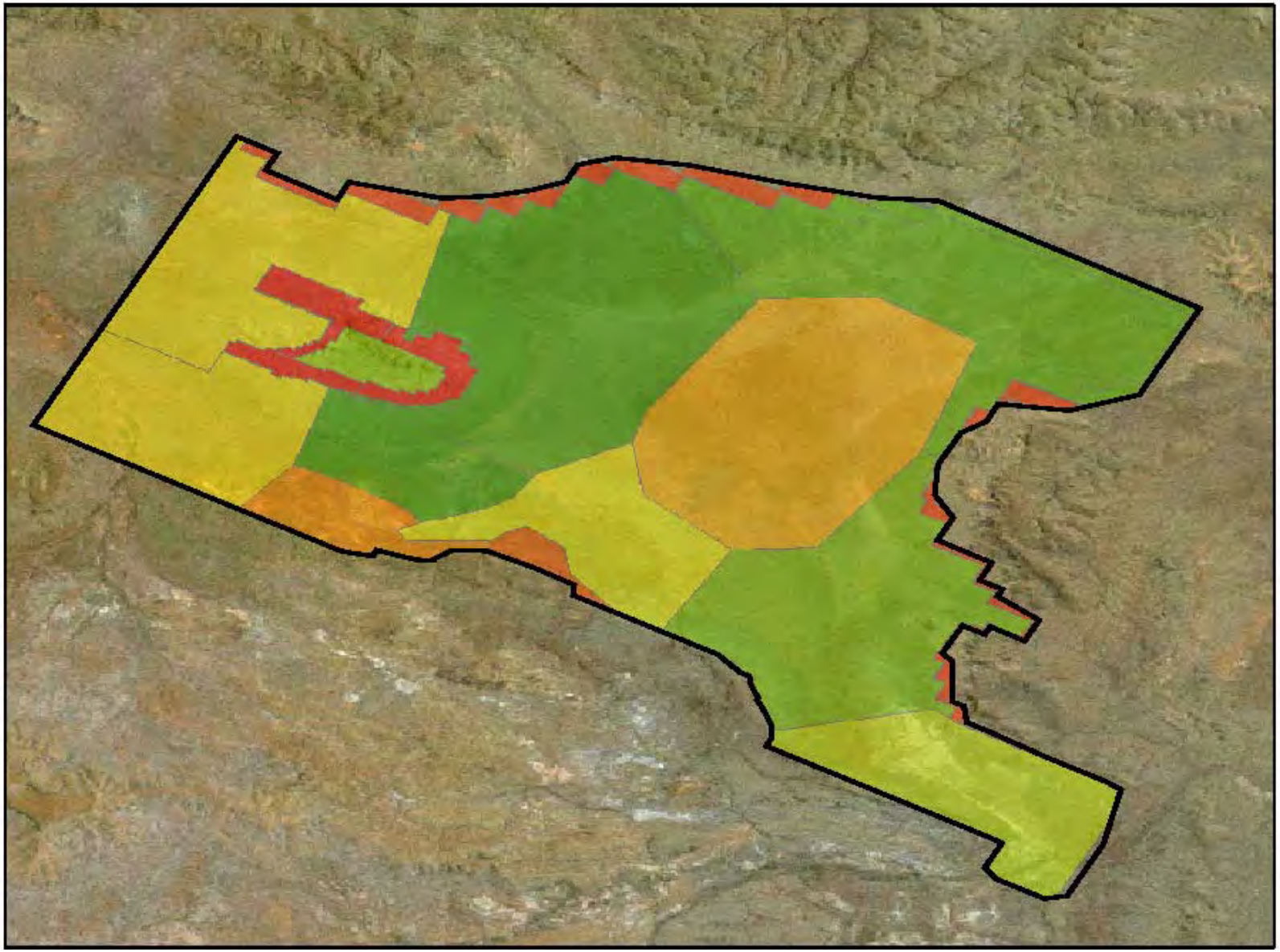
IRON ORE

PDE0052053v1_Fig6 Date: May 2008



LEGEND

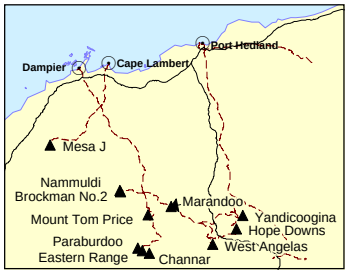
Active Model Area

Recharge, m/day

- 0.0000002
- 0.0000003
- 0.0000005
- 0.000001
- 0.000002
- 0.000005
- 0.0000055
- 0.000006
- 0.00001
- 0.0002
- 0.00025
- 0.00055

N

LOCATION MAP



RIO TINTO IRON ORE

Strategic Assets - Perth

Figure 7: Marandoo Mine Box Cut Dewatering, Diagrammatic

Drawn:TC
Date:April 2008

Plan No.PDE0052053v1

Figure 8

REPORT ON COOLIBAH SURVEY RESULTS- APRIL 2008
(Updated August 2008)

By Frank Batini

Summary

A survey of the Coolibah woodland near Marandoo, in April 2008, showed that this woodland is in good condition, with a 3:1 ratio of healthy crowns to poorer crowns. The survey also established a baseline for codominant height (15 metres), for crown cover (20 percent), for density (basal area and stems per hectare at nine square metres/ ha and 90 stems/ha respectively) and diameter classes. There was no field evidence that the extent of Coolibah distribution had changed markedly in recent years. There appears to be an adequate number of trees in the smaller size classes to ensure the regeneration of this woodland. In contrast, the adjacent Mulga stands were quite unhealthy and lacked seedling regeneration.

Introduction

Three transects each 10 metres in width and totalling 2000 metres were surveyed within the Coolibah woodland in the Karijini National Park, at Marandoo, on the 16th April 2008 by Ms Madden and Ms Scott of RTIO and Mr Batini (consultant to RTIO). There was evidence of recent good rains and some surface flows, with Spinifex and grasses in flower and germination within run-on areas. The transects were selected using aerial spectral photographs prepared by Specterra which show changes in canopy health between November 2005 and November 2007. Transects were aligned so as to cover as much of the variation as possible (Figure 1). Along these transects data were collected on crown condition of the Coolibah trees (in five Classes (Figure 2), as used by the Department of Environment and Conservation (DEC) for crown health surveys in wandoo forests), by tree size class (using eight size classes, ranging from seedlings to trees > 50 cm in diameter). These data were recorded separately for each 50 metre section along the line, measured with a tape. In addition, at regular intervals, data were collected on basal area over bark (by Factor 1 gauge), on stems per hectare (number of trees within an eight metre radius x 50), on top and codominant height (by clinometer and tape) and on crown cover (spherical densitometer). The purpose of the survey was to ascertain the current health of trees in the Coolibah woodland and to establish a baseline for these stands. The lines stopped at the next 50 m station once the transition into Mulga woodland occurred.

Results

The actual survey time was five hours (excluding travel and lunch). In the five hours, 2000 metres (2 hectares) of line were covered. A total of 448 trees were assessed for size class and crown health condition.

Coolibah

Data were originally extracted for each of the three lines separately and compared. However the differences between lines were much smaller than the

differences observed within a line and so the data were pooled and the results are shown below.

The basal area over bark of all live trees > 10 cm in diameter was calculated as nine square metres /hectare, with a range of between 4 and 18 m2/ha (n = 39). Basal area is a measure of stand density and is the estimated sum of the cross sectional areas, at breast height, of all live stems that are greater than 10 cm in diameter.

Another conventional measure of stand density is the number of live stems per hectare (sph) that are larger than 10 cm in diameter. This was estimated to average 90 stems, with a range from zero to 200 (n = 39). Another estimate was calculated by dividing the total number of live Coolibah trees > 10 cm that were assessed (205) by the area surveyed (2 hectares) giving a value of 102 sph. A further 43 sph were recorded in size classes less than 10 cm in diameter. Of these, half were less than two metres in height and the remainder were taller than two metres.

The calculated average crown cover was 20 percent, with a very wide range from zero to 80 percent (n = 39).

Top height was calculated as 21 metres (n = 4) and codominant height as 15 metres (n =14). Codominant height is the average height of the majority of the trees in the upper crown, whereas top height singles out the tallest trees.

The percentage of live stems in six size classes ranging from < 10 cm to > 50 cm were as follows: 30, 23, 19, 9, 12 and 8 percent, with the expected bias towards the smaller sizes, with half of all stems being smaller than 20 cm in size.

Overall, 328 Coolibah were recorded during the survey, of which eleven percent were dead. There were very few recent deaths in Coolibah, most were old, they were more common in the smaller trees < 20 cm in diameter and were probably associated with past wildfire events, as shown by the presence of dry-sides in some trees and dead trees coppicing from the stump. There was no evidence of recent branch dieback or “flagging”. Even where older trees showed some past damage to the crown (resulting from fire, storm or branch dieback), the crowns were healthy.

The crown health assessment showed that the Coolibah trees are currently healthy, with 53 percent of all stems being assessed in the better Classes 1 and 2 and only 18 percent in the poorer Classes 4 and 5, a ratio of about 3:1. The percentage of trees in each crown health Class 1 to 5 was as follows: 19, 34, 29, 11 and 7 percent.

As expected, the smaller trees (10-30 cm) generally had better crowns than the larger trees (>40 cm). In the former, 61 percent rated as Class 1 or 2 whereas the latter only scored 41 percent in these two Classes. The ratio of healthy : poor crowns for the smaller trees was 4:1 and for the larger trees was 2:1.

Previous surveys of crown condition were carried out in 1991, 1993 and 1995 by Mattiske and Associates on various transects within the Coolibah stands. These data show a severe level of stress in 1991 (71 percent) and 1993 (74 percent) along transect number 7, due variously to insect attack, termite damage, yellowing of leaves and past fire damage. When data from all four transects were included for 1993 (7, 8A, 8B and 9) the stress levels are still high, rating at 61 percent. Between 1993 and 1995 there was an overall improvement in canopy condition, with a marked improvement shown on two transects (7 and 9) and a slight deterioration within transect 8B. The data show that Coolibah will increase or decrease its canopy cover in response to seasonal fluctuations.

Rio Tinto Iron Ore have recently established two permanent sampling sites within the Coolibah, each with ten trees. At each tree two spots are marked with steel pegs and at each peg vertical photographs are taken annually of the tree crowns. These photographic images are then converted to foliage cover. Data provided to me

by Ms S Madden of RTIO for the 2007 and 2008 monitoring show a significant reduction in foliage cover in 2008, on both sites, of 13 and 16 percent respectively. This difference was probably due to rainfall, with 700mm recorded at Marandoo in 2007 and only 350 mm in 2008. Annual changes of this magnitude, primarily in response to rainfall, are not considered as unusual (M Adams pers. comm.).

Despite this reduction, the average foliage cover in 2008 was 40 percent, which explains why these crowns were still rated as healthy.

Most Coolibah were found within the 703-704 metre contour and the ground was flat dropping only one metre in a kilometre (Figure 3).

There was no field evidence that the extent of Coolibah distribution had changed markedly in recent years. If Coolibah were actively expanding its range, there would be many younger cohorts established on the edges, whereas if Coolibah were retreating, there would be the evidence of dead trees and stumps on the edges of the current woodland. These observations are supported by a recent study by Gaia Resources (2008) for Rio Tinto Iron Ore. Using various sets of remotely sensed data acquired between 1972 and 2008, their study concludes that " In respect of the Coolibah woodland, we find little evidence of substantial change in distribution over the period of this study".

Mulga

The data for Mulga are more limited but still show a major contrast to the data collected for Coolibah. Of the 120 mulga recorded on the lines, 70 (58%) were dead. Of the remaining 50 plants, all were classified as health Class 3 and 4, with either average or poor, thin crowns. The stands were denser recording at 450 sph, with a basal area of 21 m2/ha and a crown cover of 27 percent. Comparative data for Coolibah were 11 percent dead, an average of 102 sph, a basal area of 9 m2/ha and a crown cover of 20 percent. Some of the Mulga were clearly killed by wildfire but many others were not. The smaller trees < 10 cm had a greater proportion of dead : live stems (5:1) than the larger trees (1:1 for classes > 10 cm). Many of these retained fine branches suggesting that these deaths occurred within the last 3 to 4 years, possibly as a result of waterlogging that occurred in summer 2006. Many of the Mulga had few leaves held at the very extremity of the crown. There was no regeneration of Mulga seedlings observed on these short transects.

SpecTerra data

These data, which had been collected for RTIO, had been downloaded on to a PDA and were available in the field. The crown change condition data provided by SpecTerra showed that the health of Coolibah crowns had mostly improved between 2005 and 2007, whereas that of Mulga had deteriorated (Figure 1). This was confirmed by the field survey. Most of the Mulga deaths had occurred in the period from late 2005 to late 2006 and fewer deaths are recorded between 2006 and 2007. Some "losses" in crown health were also indicated on a few of the Coolibah and we attempted to locate some of these in the field. In one case the mature Coolibah appeared to have a thinner and "wilted" crown, in another case two large branches had recently fallen and still had leaves attached, and in the third case part of the upper crown was dying. Photos were taken of each condition (Figure 4). On these observations, the SpecTerra analysis of crown health condition appears to be very sensitive. A SpecTerra crown cover of 31 percent was calculated for the westernmost stand of Coolibah.

Discussion

The Coolibah in the Mt Bruce flats at Karijini, as surveyed in April 2008, is a healthy, open woodland of pure Coolibah, with a dense understorey dominated by native grasses with the occasional lignum (Muehlenbeckia florentula). The extent and distribution of this woodland appears to have remained quite stable over the past 36 years.

The Department of Environment and Conservation (DEC) have also established a Pilbara Biological Survey site within this woodland and have survey lists of plants, animals, birds and invertebrates. The Coolibahs are "patchily" distributed (as shown by the observed range in basal areas and stems per hectare) with some open areas and others where the trees are clumped closely together (Figure 5).

The size class distribution follows the expected negative exponential curve, with over half of all the stems being less than 20 cms in diameter, or about 25-30 years old. Of these stems, a further 50 percent (a quarter of all stems) were smaller than 10 cm and are probably younger than 12 years. Data provided by Liquid Earth (Figure 6) show a wetter period between 1994 and 1999, some 9 to 14 years ago, which could have regenerated most of this cohort of Coolibah. The more recent rains in 2006 probably regenerated those seedlings that are still less than 50 cm in height. In contrast, the older trees that are around 60 cm in diameter may well be over 150 years of age.

This woodland is located in a sump within a large drainage basin(Figure 7). Periodically this area can be inundated for several weeks, occasionally to a height of as much as 0.5 metres (Figure 8). This allows the recharge of the surface aquifer to occur and a rapid rise in water table of 9.5 metres (from 20 m to 10.5 m below ground level) was recorded at Bore OW 12 (shallow) during late March/early April 2006. Over the next nine months the water level in this bore fell 6 metres (to 16.5 m below ground) as this sub-surface mound gradually drained outwards.

In stark contrast, the adjacent Mulga stands were very dense and unhealthy, with no recent regeneration, many dead younger trees and the live trees carrying poor, sparse crowns (Figure 4). Past fire events were one obvious cause but the more recent deaths showed no evidence of fire damage. A possible explanation is that Mulga is not as tolerant to water-logging as is Coolibah and that the 2006 inundation could be the cause of these deaths and ill health. Mulga located further away from the sump area had denser, healthier crowns.

REFERENCES

Gaia Resources (2008) Marandoo Remote Sensing Acquisition and Analysis. Report to RTIO.

Mattiske and Associates (1991,1993, 1995) Marandoo Project Area. Botanical Monitoring Studies. Tree transects. Reports for Hamersley Iron Pty Ltd.

SpecTerra (2005,2006,2007) Thematic imagery acquired for RTIO.

Figure 1 Specterra data showing change in crown condition 2005-2007

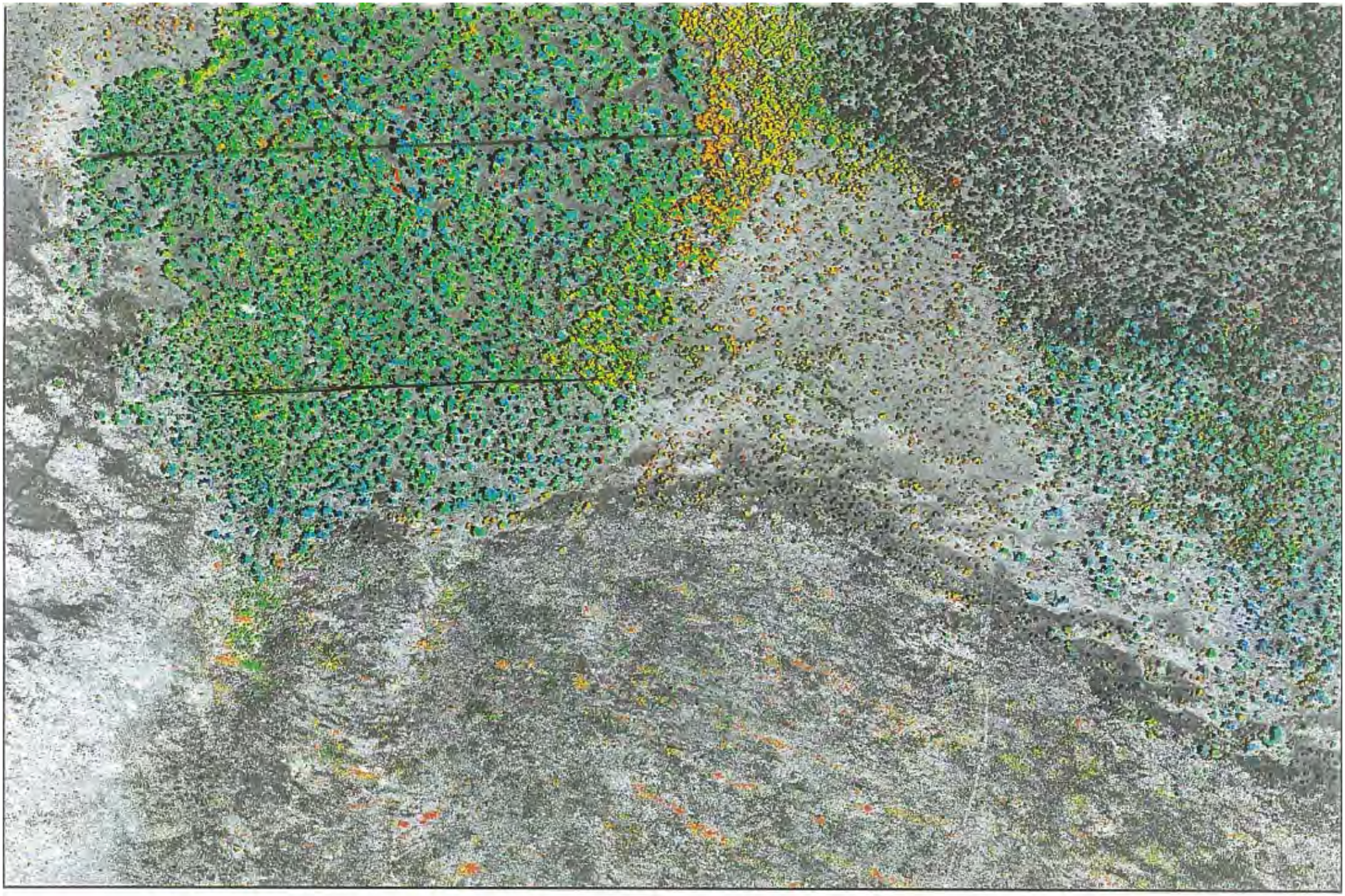
Figure 2 Classes used for determining crown decline

Figure 3 One metre contour data within Coolibah woodland

Figure 4 Photographs of Coolibah and Mulga trees showing some crown loss in 2007

Figure 5 Photographs of Coolibah woodland, two of mature stands and two of regeneration
Figure 6 Natural rainfall/recharge variation (Liquid Earth)
Figure 7 Marandoo Hydrogeology
Figure 8 Photograph of surface flooding in March 2006, following rain

10 May 2008
Updated 25 th August 2008



SpecTerra Services

Figure 1
Marandoo

2007 - 2005 Change Detection

Plant Cell Density
Change Detection

Max Loss — Max Gain

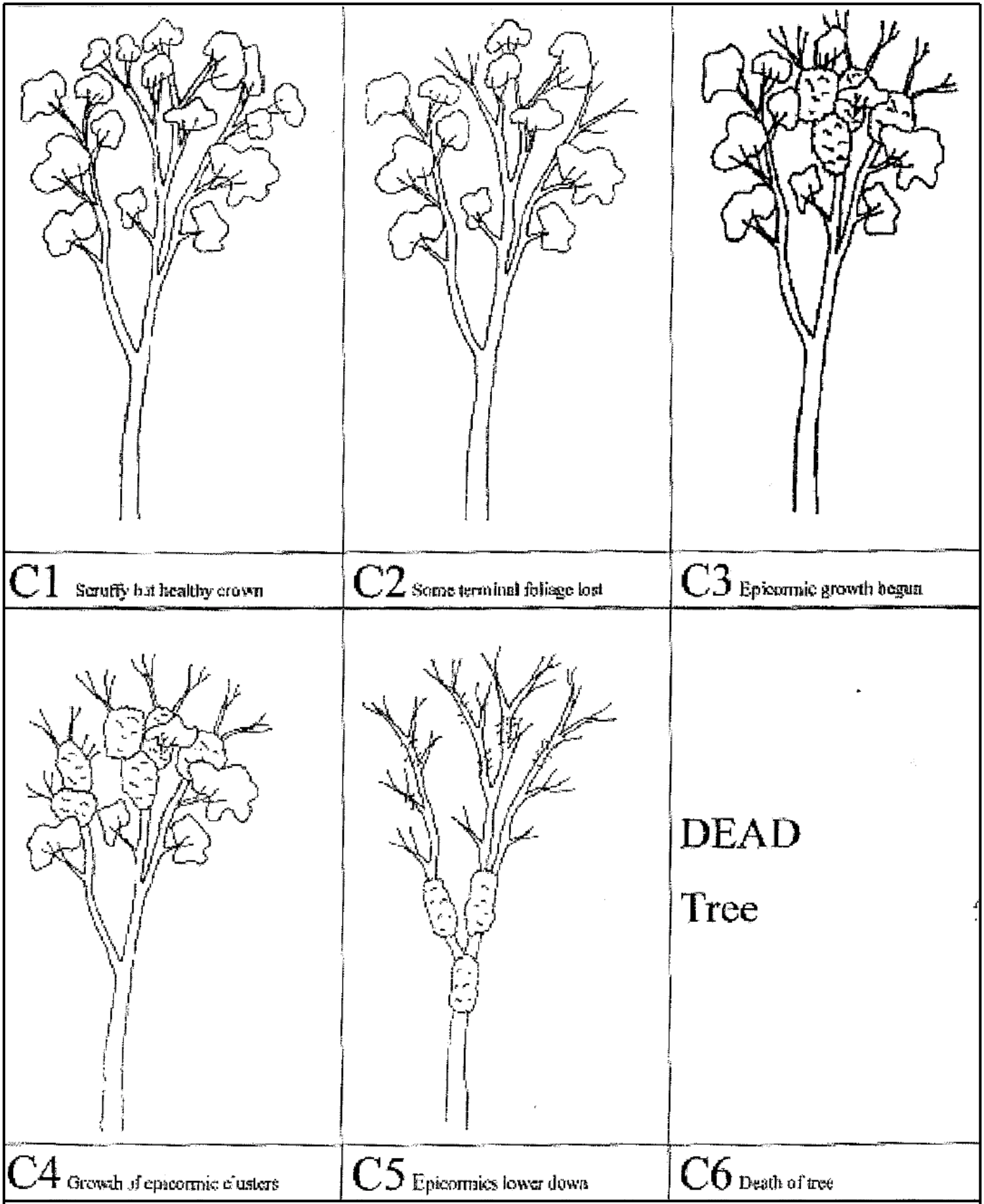


Figure 2
Crown Decline Stages

705
706
707
708
709
710
711
704
703
705
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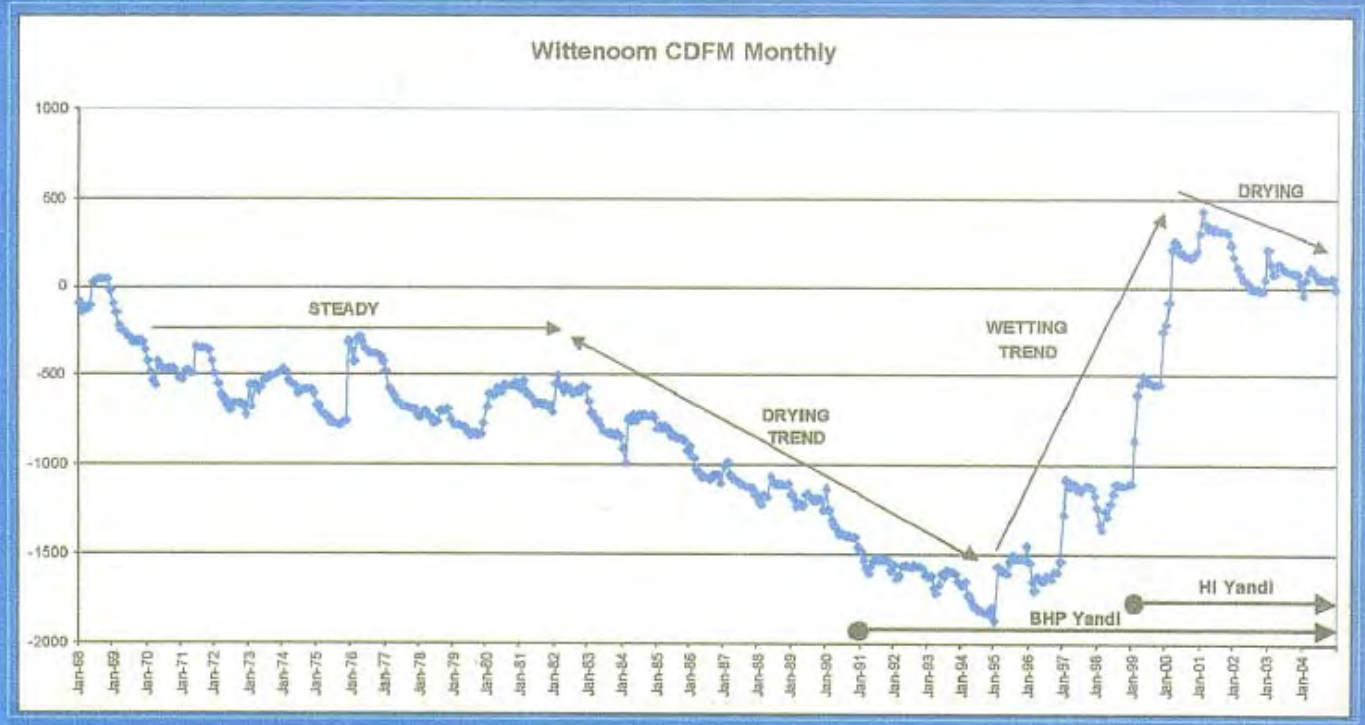
711
704
703
705
706
707
708
709
710
711
704
703

Figure 4

Figure 5

Figure 6

Natural Rainfall/Recharge Variation



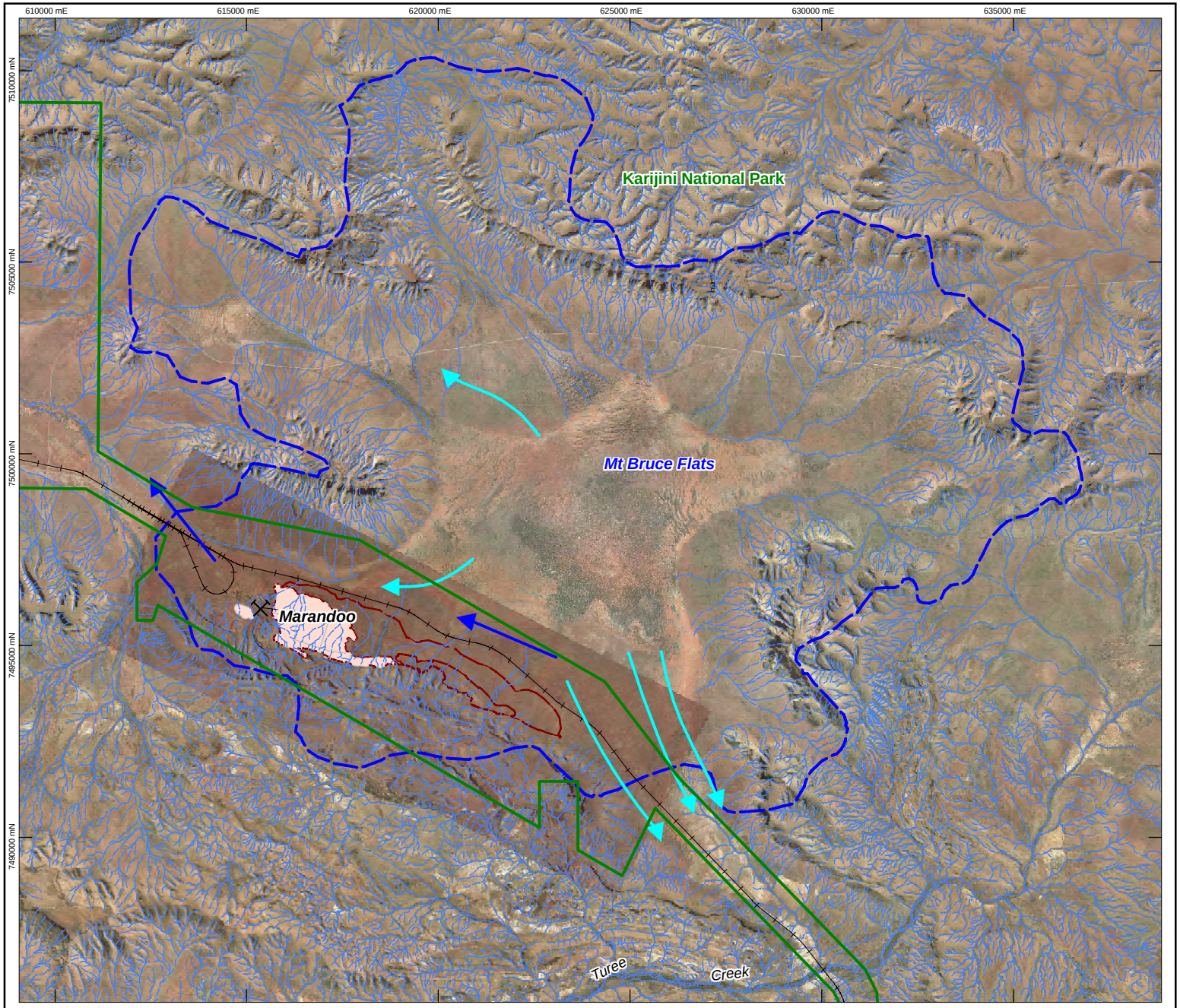
Note:

Increasingly extreme rainfall conditions

e.g. HI Yandi Planning phase – drying trend/ HI Yandi Operational phase – wetting trend

Pre-mining baseline information and ongoing "out of catchment" monitoring critical

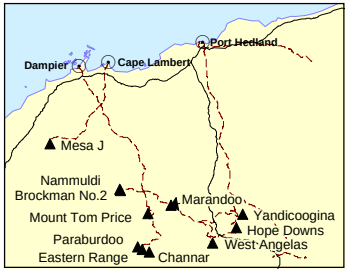
LIQUID EARTH



LEGEND

- Railway
- Road
- Private Road
- Minor Watercouse (non-perennial)
- Unconfined Aquifier
- Confined Aquifier
- Mine
- Surface water catchment
- Current Pit Outlines
- BWT Proposed pit outline

LOCATION MAP



SCALE

N

3 0 3km

Scale: 1:150,000@A4

RIO TINTO IRON ORE

Strategic Assets - Perth

Figure 7
Marandoo Hydrogeology

Drawn: TC
Date: Feb 2008

Plan No. PDE0052053v1
Proj: MGA94-50

Figure 8

MARANDOO MULGA MONITORING – 2000 to 2007

By Frank Batini

SUMMARY

Some additional analyses have been done on data contained in reports by Dr Nicholls, dated 2006 and 2008. These analyses do not show any substantial negative effects of the railway line construction at Marandoo on survival of mulga. In fact the areas below the railway had a higher initial number of mulga in 2000, a higher recruitment between 2001 and 2005 and also a higher total number of mulga in 2005. This conclusion is consistent with that reached in reports by Dr Nicholls (2006, 2008), by Hick et al, of CSIRO in 1997 and by Ms J Wilson at Curtin (undated).

The data also show that 61% of the established mulga plants over one metre in height were killed by wildfire between the 2000 and 2001 measurements. These data show that fire is a much greater threat to the survival of mulga than is "water shadow" effect. This conclusion is further supported by data collected by Gaia Resources (2008) that show a major reduction in the distribution of mulga woodlands of just over 1000 ha, or 45 percent, in the period 1972 to 2008, associated with extensive fire scars in the 2000 and 2006 imagery.

The overall number of mulga in 2007 increased to a level that is slightly higher than that recorded at the beginning of the monitoring in 2005. There are now an average of 350 mulga per hectare of which nearly 20 percent are seedlings. There are slightly fewer adult plants than in 2005, but more stems in the 1-2 m class.

INTRODUCTION

Reports prepared by Dr Owen Nicholls for Rio Tinto Iron Ore was given to me for comment, in February and August 2008, by Ms Sally Madden of Rio Tinto. The reports provided a summary of results for the 2005 and 2007 monitoring periods.

I have known Dr Nicholls for some years and acknowledge his competence as a scientist and biologist. However, while detailed results were provided for each of 12 transects, I felt the data would also benefit from some additional analyses of the overall trends. This report discusses these additional analyses. As I did not have access to the original data, I have had to estimate mulga survival from the various graphs and though my absolute numbers may not be exact, they will be close enough to analyse major trends. Before sending this document to Rio Tinto I gave Dr Nicholls the opportunity to read it and make comment. This he has done and he has no concerns with the additional analyses that were carried out or with the conclusions that I have reached.

DATA ANALYSIS

There are two sites each with three transects above the railway line and three below, a total of 12 transects. Each transect is 400m long by 10 m wide, that is 0.4 ha, for a total area of 4.8 hectares. The transects are located at distances of 25, 50 and 200 metres above and below the clearing required for the railway embankment, communications corridor and maintenance track. The location of all transects is shown in Figure 1.

The individual graphs show that a major change in mulga numbers occurred between the 2000 and 2001 measurements. I have therefore chosen to analyse data between 2000 and 2001, 2001 to 2005 and 2005 to 2007 (the latter for all plots only).

SUMMARY FOR ALL 12 PLOTS

	2000	2001	Difference	2005	Difference	2007	Difference
Seedlings	325	663	+338	685	+22	330	-355
Recruits	380	159	-221	352	+193	652	+300
Adult plants	880	332	-548	330	-2	710	+380
Totals	1585	1154	-431	1367	+213	1692	+325

Comment- Between 2000 and the 2001 measurements there was major loss of adult (>2 m) and recruiting plants (1-2 m) but a very high level of seedling recruitment. A loss of nearly two-thirds of all adult plants and of 60 percent of recruits was recorded. These data are consistent with a fire event that killed many of the established plants and promoted seedling regeneration.

Between 2001 and 2005 there was major recruitment into the 1-2 m size class, some further germination of seedlings occurred but no trees grew into the adult >2 m class. The overall number of mulgas increased by 213 plants or by 18.5 % of the 2001 number. There is now an average of 280 mulga/ha of which about half are seedlings.

Between 2005 and 2007 there was major reduction in the number of seedlings and a corresponding recruitment into the 1-2 m size class and the adult plants >2 m. The overall number of mulga increased to a level that is slightly higher than that recorded at the beginning of monitoring in 2005. There is now an average of 350 mulga per hectare, of which nearly 20 percent are seedlings. There are slightly fewer adult plants than in 2005 but more stems in the 1-2 m class.

SUMMARY COMPARING PLOTS ABOVE AND BELOW THE RAILWAY LINE

ABOVE THE LINE

	2000	2001	Difference	2005	Difference 01-05
Seedlings	120	328	+208	205	-123
Recruits	195	106	-89	195	+89
Adult plants	390	182	-208	180	-2
Totals		616	-89	580	-36

Comment- Between 2000 and the 2001 measurements there was major loss of adult (>2 m) and recruiting plants (1-2 m) but a very high level of seedling recruitment. Between 2001 and 2005 seedlings numbers fell sharply, there was no change in adults and a substantial addition to the recruit numbers.

BELOW THE LINE

	2000	2001	Difference	2005	Difference 01-05
Seedlings	205	335	+130	480	+145
Recruits	185	43	-142	157	+114
Adult plants	490	150	-340	150	Nil
Totals		528	-352	787	+259

Comment- Between 2000 and the 2001 measurements there was major loss of adult (>2 m) and recruiting plants (1-2 m) but a high level of seedling recruitment. Between 2001 and 2005 seedlings and recruit numbers rose substantially and there was no change in adult numbers.

Comparisons above and below the railway line
For 2000 to 2001 the data are consistent both above and below the line.
Some differences are observed in the period 2001-2005, especially in the major reduction in numbers of seedlings above the line and a substantial recruitment of seedlings below the line. This would be contrary to expectations that construction of the railway has had a negative effect on the mulga vegetation below the line. In 2000, there were 25% more mulga growing below the railway line than above it. Again, this would be contrary to expectations that construction of the railway has had a negative effect on the mulga vegetation below the line. Recruits increased substantially on both sides of the line and adults numbers were unchanged. Whereas total numbers fell slightly above the line, the total number of mulga below the line recorded in 2005 increased by 259 or by 49% on the numbers recorded in 2001.

SUMMARY OF COMPARISONS BETWEEN SITES 312 AND 319
Site 312

	2000	2001	Difference	2005	Difference 01-05
Seedlings	75	233	+158	260	+27
Recruits	50	29	-21	142	+113
Adult plants	240	27	-213	55	+28
Totals		289	-76	457	+168

Comment- Between 2000 and the 2001 measurements there was major loss of adult (>2 m) but a high level of seedling recruitment. Between 2001 and 2005 recruit numbers rose substantially and there was a small increase in seedling and in adult numbers. Overall there was an increase between 2001 and 2005 of 168 plants or 58% of the 2001 values.

Site 319

	2000	2001	Difference	2005	Difference 01-05
Seedlings	250	430	+180	425	-5
Recruits	330	120	-210	340	+220
Adult plants	640	305	-335	290	-15
Totals		855	-365	1055	+200

Comment- Between 2000 and the 2001 measurements there was major loss of adult (>2 m) and recruits (1-2 m) but a high level of seedling germination. Between 2001 and 2005 recruit numbers rose substantially and there was a small decrease in seedling and in adult numbers. Overall there was an increase between 2001 and 2005 of 200 plants or 23.4% of the 2001 values.

Comparison between two Sites.

For 2000 to 2001 the data are consistent between the two sites sampled. Some small differences are observed in the period 2001-2005. Overall numbers increased substantially on both sites, primarily due to a large increase in the number of recruits (1-2 m) on each site. Seedlings and adult numbers rose slightly on site 312 and fell slightly on site 319. Data and trends between sites are consistent and within the range that would be expected due to sampling. Site 312 has always had many less mulga than site 319. Possibly it is a less desirable habitat for mulga.

SUMMARY COMPARING SURVEY DATA AT DIFFERENT DISTANCES BELOW THE RAILWAY LINE

It is also desirable to analyse any effects below the railway line by comparing the data obtained at 25 metres with the data for the transects at 200 metres, on the hypothesis that the greatest effects of " water –shadow" would be expressed nearest the line. This hypothesis is based on field observations and also on experimental data by Mr Muller that show that surface flows from point sources such as culverts will gradually spread out naturally across the landscape and will eventually coalesce. The use of properly constructed culverts, levees and spreader ditches will also greatly assist with reducing the size of the area affected by "water shadow".

Dr Nicholls indicated that a comparison of "near railway" and "away from railway" could be carried out by analysing results from two transects, X, located at 25 metres and two transects, Z, located at 200 metres from the cleared areas. This analysis has now been done. The hypothesis is that the two survey lines nearer the railway -312 X and 319 X, will show greater effect of "water shadow" than the two that are further away – 312 Z and 319 Z.

BELOW AND NEAR THE RAILWAY- Lines X

	2000	2001	Difference	2005	Difference 01-05
Seedlings	105	115	+10	140	+25
Recruits	95	20	-75	85	+65
Adult plants	110	30	-80	30	nil
Totals		165	-145	255	+90

Comment- Between 2000 and the 2001 measurements there was major loss of adult (>2 m) and recruiting plants (1-2 m). Between 2001 and 2005 seedlings and recruit numbers rose, but there was no change in adult plants.

BELOW AND AWAY FROM THE RAILWAY- Lines Z

	2000	2001	Difference	2005	Difference 01-05
Seedlings	70	45	-25	100	+55
Recruits	17	4	-13	33	+29
Adult plants	145	55	-90	55	nil
Totals		104	-128	188	+84

Comment- Between 2000 and the 2001 measurements there was major loss of adult (>2 m) and some loss of seedlings and recruiting plants (1-2 m). Between 2001 and 2005 seedlings and recruit numbers rose, but there was no change in adult plants.

Comparing "near" and "away from" railway. A comparison of mulga survival between 2000 and 2005 shows minimal differences between two sites that are below and very close to the railway formation with two sites that are also below but further away from the influence of the railway line. In both sites there was a major loss of both recruit and of adult plants between the 2000 and 2001 surveys. These deaths were caused by a wildfire event. On both sites the numbers of seedlings and recruits increased between 2001 and 2005.

OVERALL COMMENTS

The data show a major loss of established plants and a substantial regeneration of seedlings between 2000 and 2001 measurements. This is consistent with a wildfire event and Dr Nicholls recorded in his report that such a fire did occur, with both sides of the railway line burnt in 2000. This conclusion is further supported by data collected by Gaia Resources (2008) that show a major reduction in the distribution of mulga woodlands of just over 1000 ha, or 45 percent of the total area, during the period 1972 to 2008, associated with extensive fires in 2000 and 2006.

There was a general improvement in the numbers of mulga between 2001 and 2005, especially in the 1-2 m recruit class. Between 2005 and 2007 many stems grew into the "recruit" and "adult" classes. The overall number of mulga in 2007 increased to a level that is slightly higher than that recorded at the beginning of the monitoring in 2005. There are now an average of 350 mulga per hectare of which nearly 20 percent are seedlings. There are slightly fewer adult plants than in 2005, but more stems in the 1-2 m class.

These available data do **not** show any substantial negative effects of the railway line construction, in fact the areas below the railway had a higher initial number of mulga in 2000, a higher recruitment between 2001 and 2005 and also a higher total number of mulga in 2005. Sites that are lower in the landscape (and below the railway formation) are often more fertile and have better water relations than those sites on higher slopes. This may explain some of the data above that show that these sites appear to be preferred by mulga.

The conclusion that there are no data to show a substantial negative effect of the railway is consistent with that reached in reports by Dr Nicholls (2006, 2008), by Hick et al, CSIRO in 1997 and by Ms J Wilson at Curtin (undated). The last two reports were based on analyses of data captured by remote sensing and compared vegetation trends above and below the railway. The report by Dr Nicholls and the Executive Summaries of the other two reports are attached as Appendices I to III.

I have no doubt that some deaths of mulga due to "water-shadow" effects do occur in the Pilbara as a result of surface water changes caused by roads, railways, powerlines and even cattle pads, having seen the evidence for myself during past field work. Where the discussion now lies is how serious a problem this is, whether other environmental variables such as fire, grazing and drought have a greater effect on

mulga survival and why, if the deaths from “water-shadow” are serious and widespread, these changes have not been captured by any of the field and remote sensing techniques that have so far been used for monitoring.

A suggestion that mulga deaths did occur as a result of “water-shadow effects” following the construction of the railway line at Marandoo has been proposed by Dr S van Leewen of the DEC. This opinion is based on visible deaths of mulga observed by Dr van Leewen after the railway line was constructed and on some field data collected but not yet analysed by DEC, nor made available to Rio Tinto Iron Ore. I recommend that it would be desirable to seek an exchange of data with DEC.

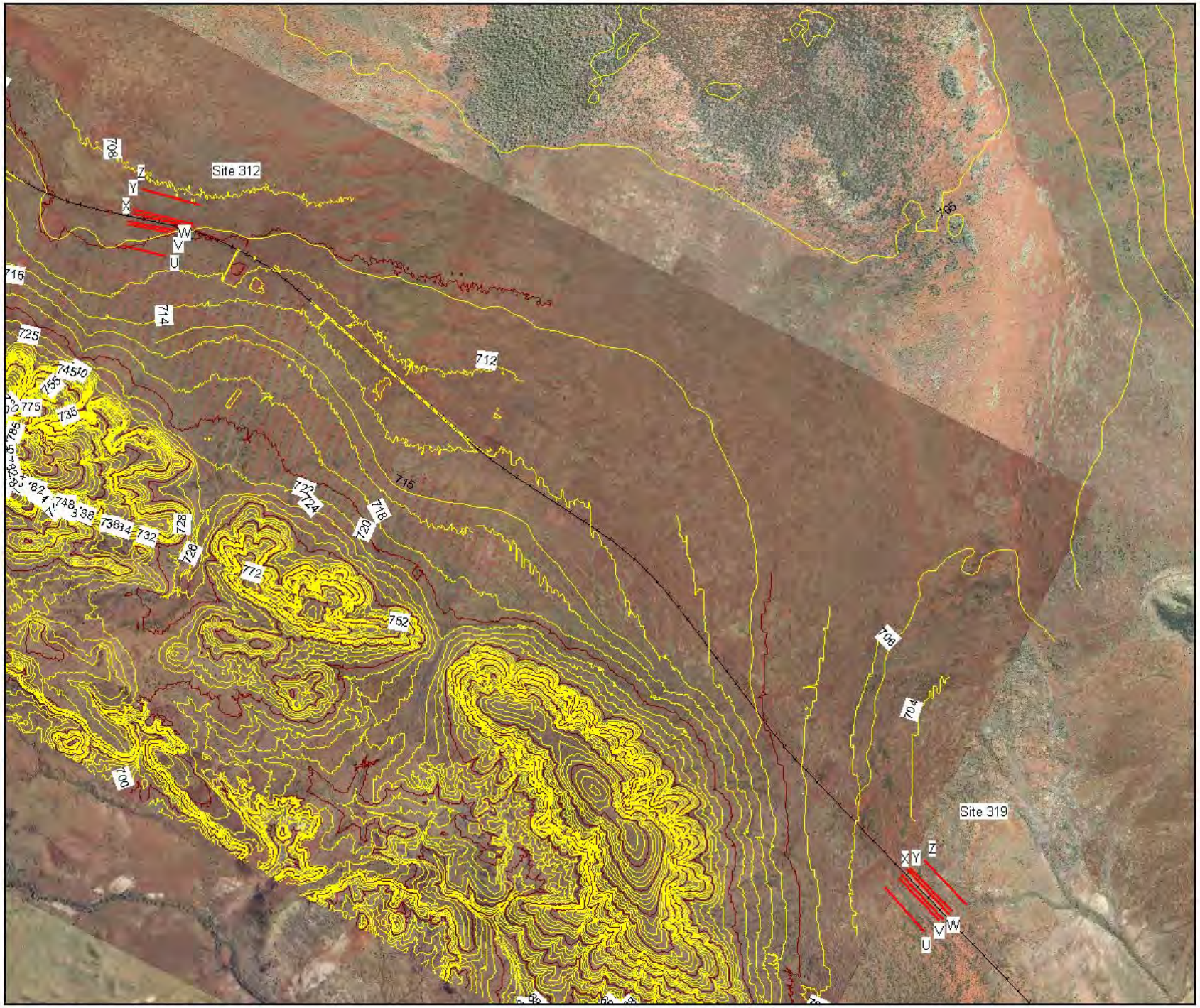
No statistical tests have been conducted on the data provided by Dr Nicholls, as they were not considered to be warranted. However this option is still open should Rio Tinto Iron Ore or DEC wish to pursue this.

It could also be argued that, as the railway construction commenced in late 1992 and the first survey discussed here was done in 2000, that mulga deaths due to “ water-shadow” would have already occurred and thus may not have been recorded. To counter this view is the fact that dead mulga trees are very durable and remain visible for many years. Also, Dr Nicholls reports that originally dead adult mulga were recorded in the original survey data but that this practice was later discontinued in 2003 as there were few new dead mulgas to record, it was difficult to be absolutely sure of the species and some of the dead plants could have been removed by fire or pushed down by stock.

REFERENCES

Gaia Resources (2008). Marandoo remote sensing acquisition and analysis.
Hick P et al (1997) An assessment of vegetation condition and monitoring strategy for Hamersley Iron’s Central Pilbara railway through Karijini National Park using remotely sensed and ancillary data. CSIRO.
Muller C (2005) Water flow in mulga areas adjoining Fortescue marsh
Nicholls O (2006) Marandoo mulga monitoring, summary of 2005 results.
Nicholls O (2008) Marandoo mulga monitoring, summary of 2007 results
Wilson J (undated) The use of remotely sensed data to assess the impact on vegetation condition of the Central Pilbara railway reserve, Karijini National Park, WA. Curtin School of Spatial Sciences

Frank Batini
25-08-2008



LOCATION MAP

RIO TINTO
IRON ORE

Marandoo mulga drainage shadow monitoring transects

Drawn: Sally Malden
Date: 10 March 2008

Plan No:
Proj: GDA 94

MARANDOO MULGA MONITORING
- summary of 2005 results

METHODS

Design of the monitoring program

Two drainage shadow monitoring sites were selected at key locations along the Marandoo railway line. At each site six permanent transects were established; three upslope (U,V,W) and three downslope (X,Y,Z) of the railway line. Each transect was divided into four 100m sections, with each section divided into five 20m replicates. Within each 20m replicate, live and dead plants were counted within 5m to either side of the transect (i.e. the effective survey area was 10m width x 20m length). Counted plants were divided into the following age classes: A1=seedlings (<1m), A2=recruitment Mulga (>1m and <2m), A3=mature Mulga (>2m).

Monitoring took place between 21 – 22 July 2005.

Analytical procedures used

Live Plants:

To obtain an idea of general trends in each of the transects, total numbers of each plant age class were graphed against time for all sites. Proportions of plants in each age class were also graphed to give an indication of variation over time.

For each transect of sites 319 and 312, the non-parametric Kruskal-Wallis Test (Zar 1984) was used to compare the five replicates in each of the four sections, to determine whether significant variation existed within the transect. Where it was clear that variation existed between the replicates, that transect was not included in the subsequent statistical comparison of transects at the site. In some cases, more than 50% of the counts were zero values and for these sites no calculations were carried out; where it was apparent that no difference existed, NAD = 'No Apparent Difference' was recorded.

At each site and for each plant age class, a similar approach was then used to compare section totals from each of the four transects. Thus, ANOVAs or Kruskal-Wallis tests were used where appropriate, or where doubt existed both were used.

The findings of these graphs and analyses were then assessed to determine whether any clear differences existed between sites located upslope and downslope of the railway line.

Dead plants:

In previous years, monitoring showed that numbers of dead Mulga in age class D1 (seedlings) and D2 (recruitment) were so low in all sites and all years that no analyses or plotting could

be conducted; it was not even possible to comment on any trends. Analyses prior to 2003 were therefore restricted to dead mature Mulga data (age class D3).

However, at a review workshop at Tom Price in February 2003, it was decided that dead Mulgas would no longer be recorded. There are several reasons for this. Firstly, numbers are usually low and it is difficult to detect trends. Secondly, with dead plants it is not always possible to accurately identify the species. Finally, dead plants can be removed by fire and disturbance by stock, affecting the ability to interpret results.

The 2003 and 2005 data therefore do not include any analysis of dead Mulga data.

DRAFT SUMMARY DOT POINTS ON ANALYSED MARANDOO MULGA MONITORING DATA

Site 312

- Both sides of the railway line were burnt in 2000; the upslope transects U-W just prior to the 2000 monitoring and the downslope transects X-Z just after the monitoring.
- Numbers of Mulga seedlings decreased in most transects apart from V and Y where they remained largely unchanged (Figure 1). Transects X, Y and Z, located downslope from the railway line, appear to support higher numbers of seedlings than all other transects. Analysis of variance (Table 1) showed that there was a significant difference between the transects; With X and Y excluded (due to large variation within different sections of both – see Table 2), Z was significantly different to U, V and W. In 2001 it was concluded that the increase at all sites may have been due to the fire, although the increase was much greater in Transects X and Y. For these two transects, it is not known whether this might be due to patchiness of the fire or their proximity to the railway line. The difference between transects upslope and downslope of the railway line has increased since 2003, suggesting that the line may have an influence on seedling numbers. However, if the railway line is causing a rain shadow effect, one might expect that seedling numbers would be lower downslope (due to lack of water) and higher upslope (where water is retained); this is not the case.
- Numbers of recruitment Mulga increased in all transects (Figure 2). In 2005, the highest numbers were at transects W, Y and Z, located upslope and downslope of the railway line, while the lowest were in transects U, V and X, also located upslope and downslope of the railway line. Statistical analysis showed no significant difference between the sites.
- Numbers of mature Mulga remained largely unchanged at all sites (Figure 3). Insufficient numbers were present at the sites to conduct statistical analyses; the two downslope sites closest to the railway line (X and Y) support the lowest mature Mulga numbers, however given the limited data, it is not possible to determine whether this is due to chance alone, or some effect of the line.
- Changes in Mulga age structure at the six sites are shown in Figure 4. The proportion of Mulga seedlings decreased at all sites apart from transect V. Proportions of recruitment Mulga increased in most sites due to the higher numbers, while any changes in mature Mulga proportions simply reflect changes in the numbers of other age classes.
- In conclusion, it can be seen that some changes in the numbers of seedlings and recruitment Mulgas have occurred, with no change in the numbers of mature Mulgas. Some differences between transects located upslope and downslope of the railway line have become more apparent, with sites located upslope of the railway having lower seedling numbers. However, the reasons for this are not clear as it does not appear to be related to any water ponding or rain shadow effect. At this stage it cannot be be determined with certainty whether the railway line is having any effect on the Mulga community.
- Further monitoring is needed to determine whether these differences between the sites remain over time, and if so, what the causes might be.

Site 319

- As at site 312, both sides of the railway line were burnt in 2000; the upslope transects U-W just prior to the 2000 monitoring and the downslope transects X-Z just after the monitoring.
- Numbers of Mulga seedlings decreased at all sites, with the highest numbers present in transect Y (Figure 5). The total number of seedlings varied significantly within the sections of transects U and X (Table 3), so for seedlings, the transects of site 319 were compared with and without these included. The resulting analyses showed that in both cases there was no statistically significant difference between any of the transects in 2005 (Table 1). Previous years results suggested that between 2001 and 2002, the *increase* in Mulga seedling numbers was greater in transects located downslope of the railway line, while from 2002-2003, seedling numbers in the upslope transects decreased more than in the downslope transects. However, this may only be a temporary effect; between 2003 and 2005, no clear differences existed in the extent of changes recorded between upslope and downslope transects.
- Numbers of recruitment Mulga increased in transects U, W, X, Y and Z, and decreased at V (Figure 6). The lowest total was recorded at transect Z. The total number of recruitment plants varied significantly within the sections of transect V (Table 4), so for this age class, the transects of site 319 were compared with and without V included. This showed that, with V excluded, the differences were not significant (Table 1). Thus, although in 2003 a difference between all transects located upslope and downslope of the railway line appeared to exist, this difference is no longer apparent in 2005.
- Numbers of mature Mulga decreased at all transects apart from W and X (Figure 7), with the highest numbers in 2005 still recorded in transect U. However, the difference between all transects was small, and not statistically significant (Table 1).
- The decline in Mulga seedlings resulted in a decrease in the proportion of this age class in all transects (Figure 8). In 2003, it was noted that the proportion of Mulga seedlings was higher in all three downslope transects compared with the upslope transects. In 2005, this was no longer the case, with the proportion in V higher than that in X.
- In conclusion, the results show no statistically significant differences between upslope and downslope transects in the total Mulga numbers of any age class. Previous differences in recruitment Mulga and in changes in numbers of seedlings were no longer apparent. This possibly means that, for some age classes, temporary differences exist between upslope and downslope sites, however these do not seem to be permanent, and may be related to rainfall patterns. Further monitoring would help confirm whether either temporary or permanent difference between the two sites exists, and if so, what the reasons for this might be. At this stage, it can be concluded that no major, permenant differences exist.

REFERENCES

Zar, J.H. (1984) Biostatistical Analysis. Prentice Hall, New Jersey

Figure 1: 312. Graph of Mulga seedlings v. time

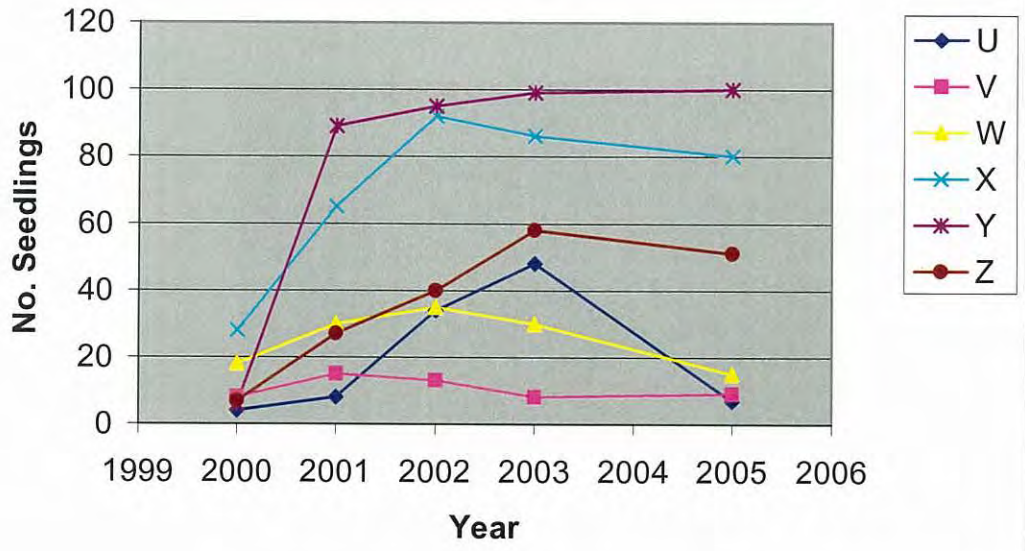


Figure 2: 312. Graph of Mulga recruitment numbers v. time

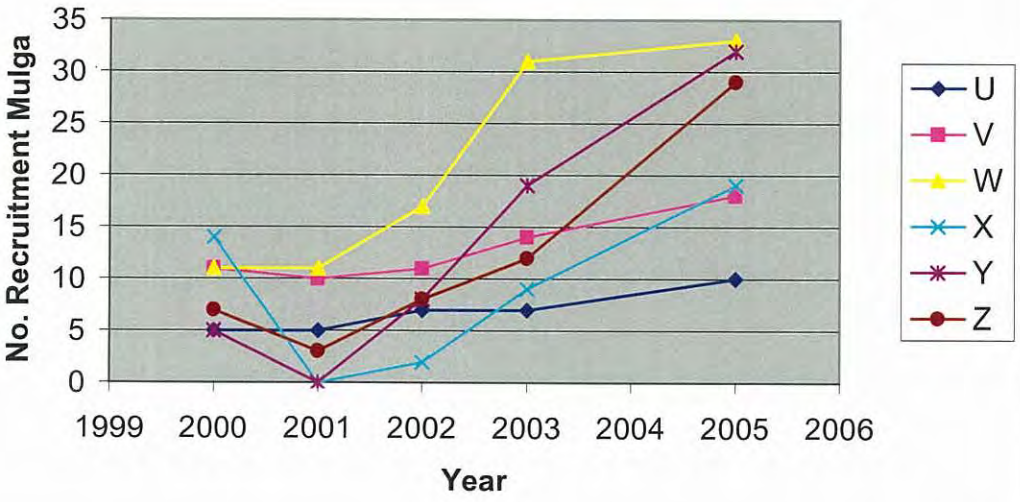
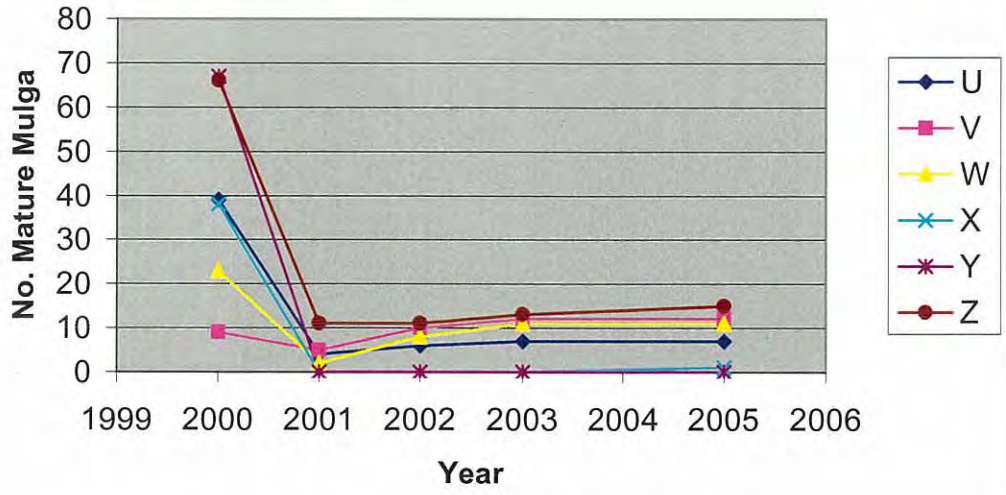


Figure 3: 312. Graph of mature Mulga numbers v. time



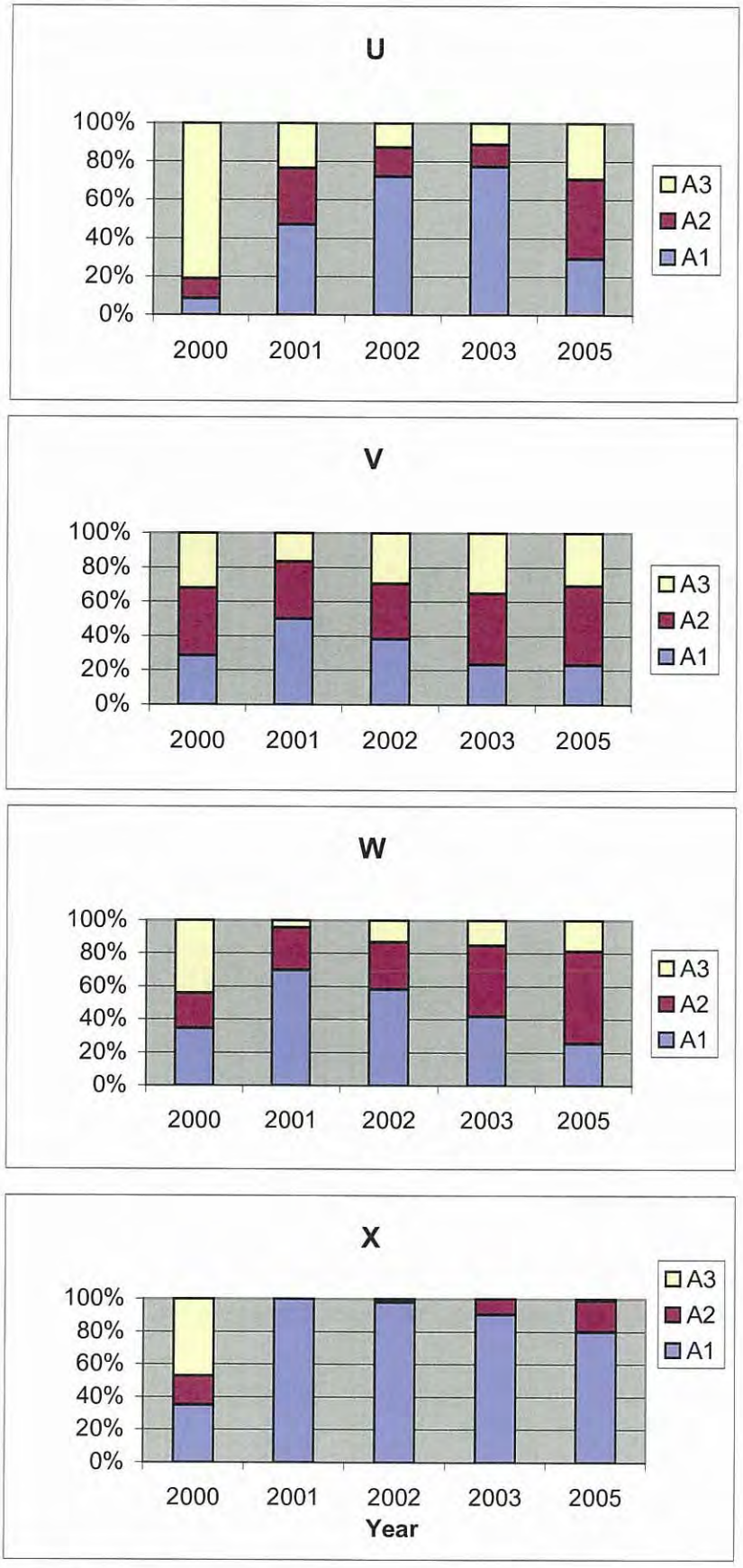


Figure 4: Percentage of Mulga in each age class v. time for the six transects U-Z at Site 312. A1=seedling, A2=recruitment (<2m), A3

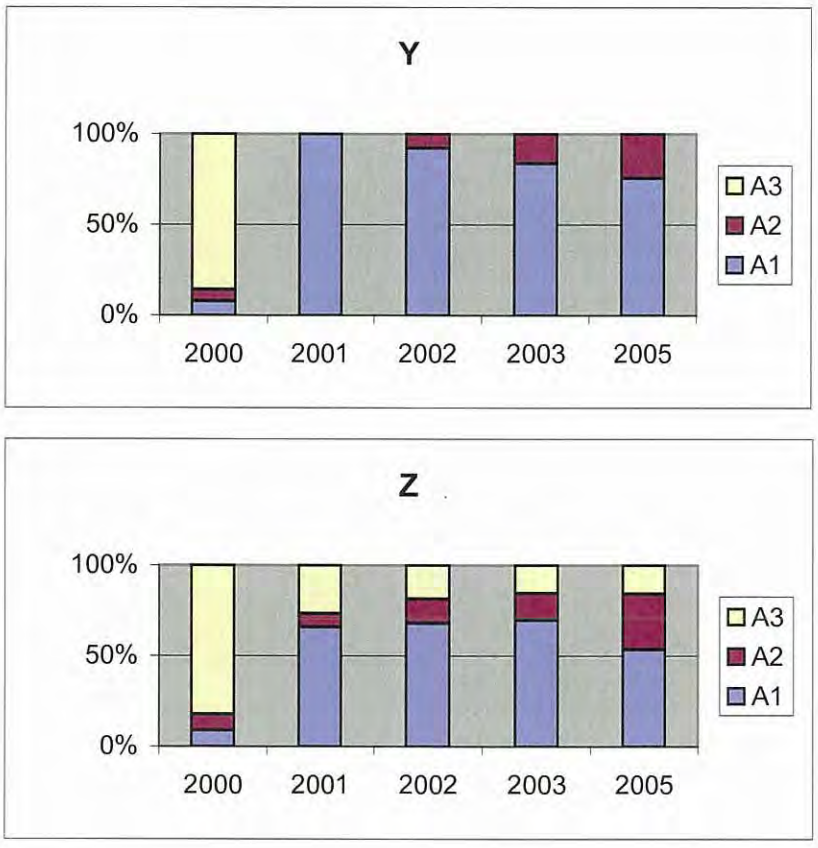


Figure 4: (..Cont.) Percentage of Mulga in each age class v. time for the six transects U-Z at Site 312. A1=seedling, A2=recruitment (<2m), A3=mature (>2m)

Figure 5: 319. Graph of Mulga seedlings v. time

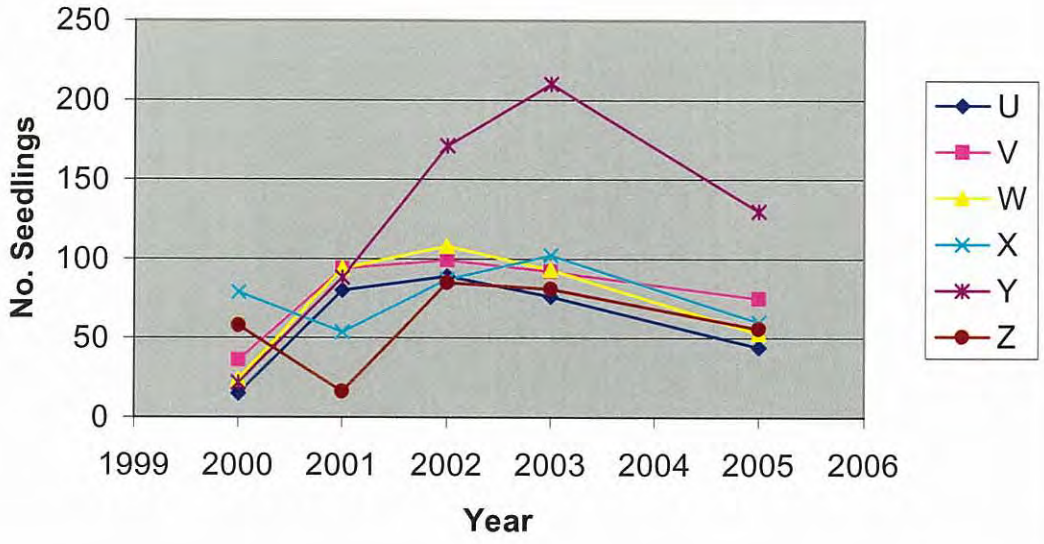


Figure 6: 319. Graph of Mulga recruitment numbers v. time

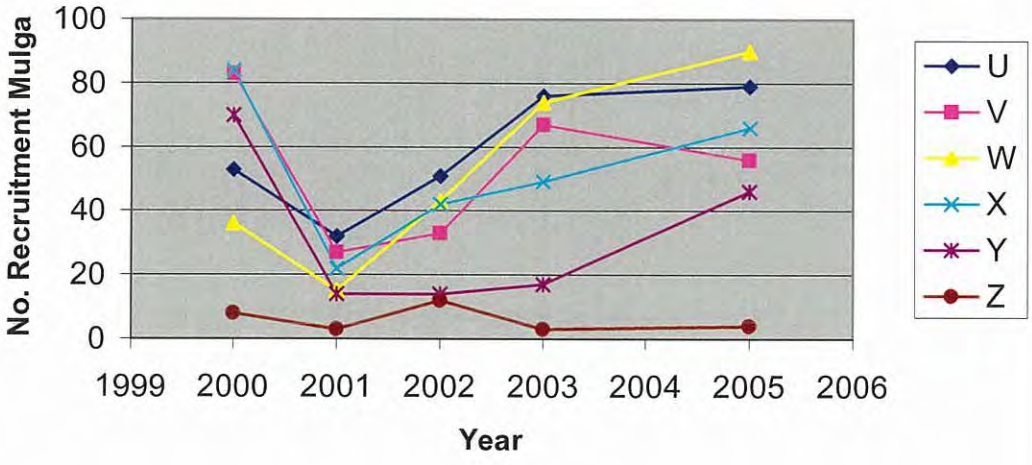
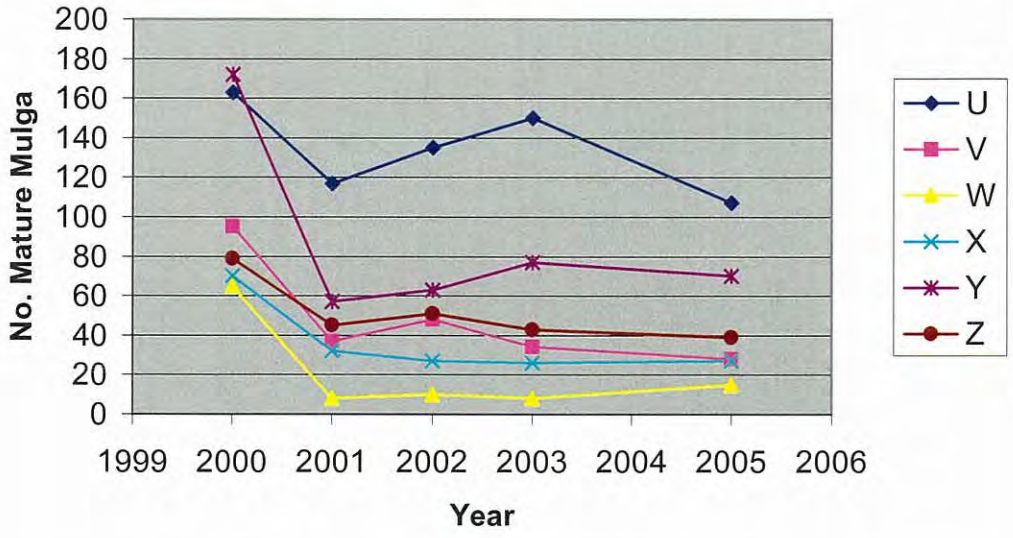


Figure 7: 319. Graph of mature Mulga numbers v. time



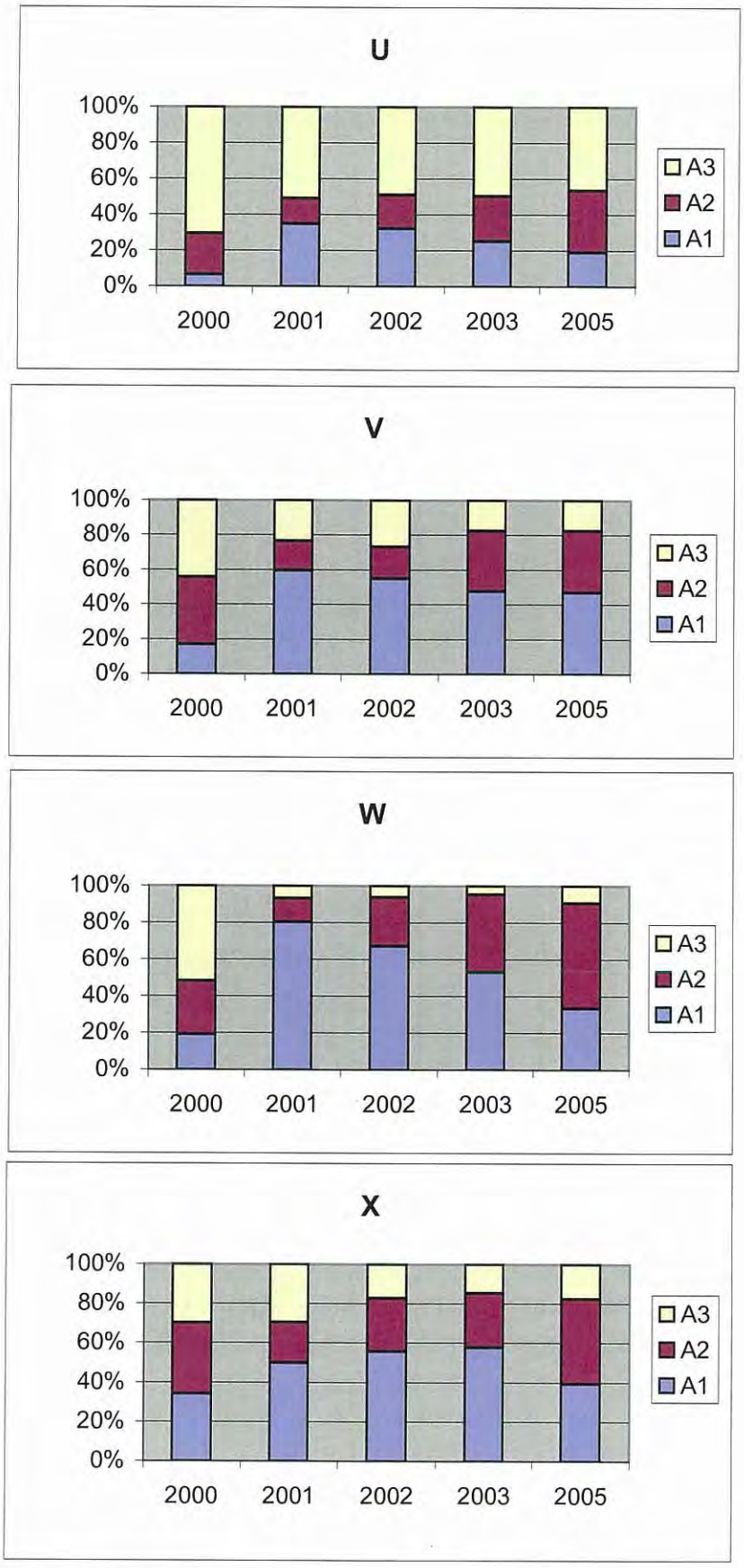


Figure 8: Percentage of Mulga in each age class v. time for the six transects U-Z at Site 319. A1=seedling, A2=recruitment (<2m), A3=mature (>2m). Continued..

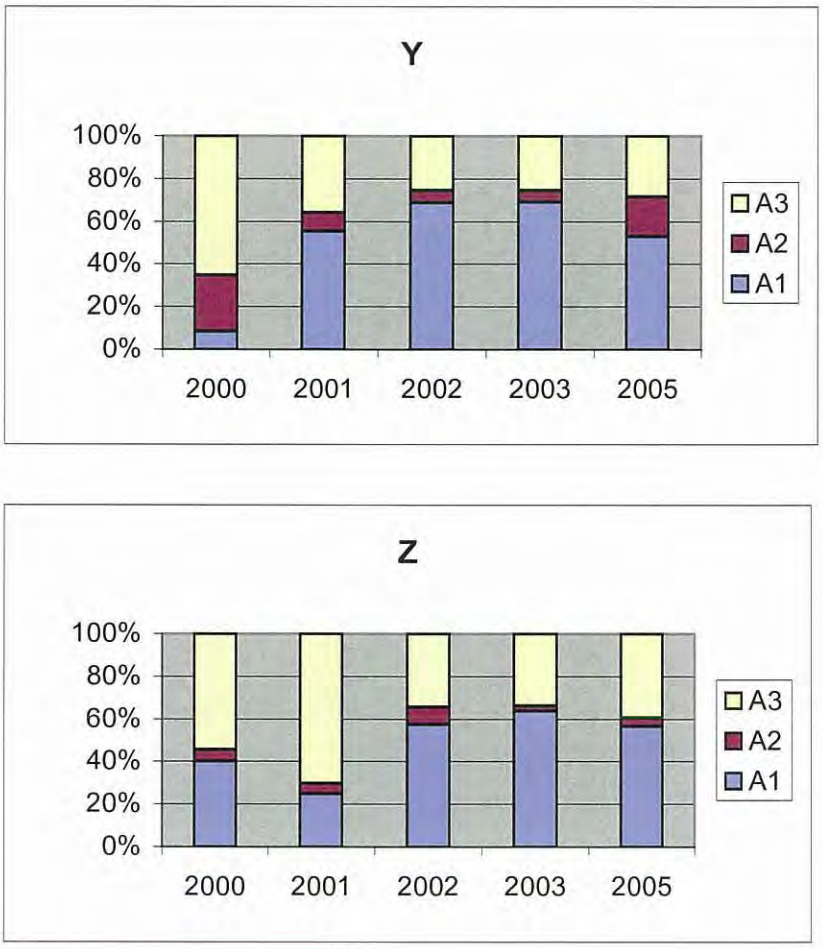


Figure 8: (..Cont.) Percentage of Mulga in each age class v. time for the six transects U-Z at Site 319. A1=seedling, A2=recruitment (<2m), A3=mature (>2m)

Minesite Rehabilitation Research Program
CSIRO Land and Water, Division of Exploration & Mining, Division of Coal & Energy Technology, Division of Wildlife & Ecology,

FINAL REPORT

An assessment of vegetation condition and monitoring strategy for Hamersley Iron's Central Pilbara Railway reserve (CPR) through Karijini National Park using remotely-sensed and ancillary data.

DATE: December 1997

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471C/3

Executive summary

- Hamersley Iron constructed a railway formation (the Central Pilbara Railway, CPR) through Karijini National Park, in 1992, to service future expansion of their iron ore mining operations. The formation was thought to be affecting the mulga woodlands, *Acacia aneura* (mulga) and *Acacia xiphophylla* (snakewood) and some tree deaths were reported.

- A sequence of 8 Landsat Thematic Mapper (TM) Satellite images, over a 10 year period, was used to determine the general status of vegetation before and after construction, based on the assumption that vegetation as a whole is closely linked to the status of mulga. From these data a monitoring strategy has been suggested to quantify the impact that may occur with the future development between Marandoo and the edge of the national park.

- This study initially established that there is a significant net difference in the spectral response of the vegetation within 250 m of the rail line compared to the whole of the available image between the Sep'90 and Dec'95. This difference persists even if those pixels known to be affected by engineering works are excluded from the analysis.

- A second iteration that combined the averaged pre- and post- construction imagery showed that this difference may have been seasonally-related although decline in condition between the meaned dates was still evident. The result of this approach, using all dates, indicated that on the 250 m wide strip on the left-hand side of the CPR (mostly up-slope) 35 sections show a decrease and 24 show an increase in green vegetation status. On the right-hand side 250 m strip from the alignment (mostly down-slope) 29 sections show a decrease and 30 show an increase.

- However, within the decrease in NDVI shown, (with known disturbed areas masked out) there is no significant evidence that the direction of cross drainage is a factor in determining which side has fared least well.

- The analysis of the gross differences between the immediate 250 m strip on either side of the formation against the adjacent an outer 250 m strip gave almost exact correspondence, and this appears to be compelling evidence that the impact of the CPR, with the areas of construction removed, is minimal on the vegetation vigour as a whole.

- Up to 60% of the area proximal to the CPR has been burnt in the study period, and since the last acquisition even more was probably burnt in the recent fires (Oct-Nov 1997). It seems that this degree of periodic burning is, and has in the recent past, been normal and is governed to a large extent by available fuel-load (or time since last fire). The impact of fire appears to be significantly more important than any anthropogenic influence.

- Analysis of the high-resolution terrain data and the susceptibility categories from the Kinhill report was done to test the sensitivity of the change and there appears to be little difference on the left to right comparison or between the categories and the impact of change is relatively uniform over the risk categories.

- With the datasets as they are now assembled, and those that may be acquired and added in the future, opportunities exist to monitor the vegetation on the basis of the topographic position occupied by the rail corridor and compare the NDVI difference in that corridor with other areas of similar topographic position. This work has also provided an objective basis for the selection of field monitoring transects and suggestions have been presented.

School of Spatial Sciences

The use of Remotely-Sensed Data to Assess the Impact on Vegetation Condition of the Central Pilbara Railway Reserve, Karijini National Park, WA.

By Jenny Wilson

Bachelor of Science (Cartography)
Project 394

ABSTRACT

In 1992, the Central Pilbara Railway (CPR) was constructed by Hamersley Iron Pty Ltd to provide a transport link between Marandoo and the proposed Yandicoogina mine in the Central Pilbara, Western Australia. A section of the railway passes through the Karijini National Park along a strip which has been excised from the park. The main area of interest in this study is the section 500 metres either side of the railway centreline through the National Park between Marandoo and the eastern boundary near Juna Downs.

This study uses multi-temporal satellite data to determine the impact on vegetation condition due to construction and operation of the CPR. This was carried out for one kilometre intervals along, and 100 metre intervals away from the line, for specific landform units; and in relation to the Kinhill susceptibility classes.

It was found that change in vegetation condition is significantly greater closer to the railway centreline than farther away. The significant decrease in vegetation condition is only in the 0 to 100 m buffer width, but not beyond and may be considered an inevitable result of the CPR.

The landform units and the Kinhill susceptibility classes showed varied NDVI differences with no relationships proven.

It seems that fire has the greatest impact on vegetation condition in this region and the impact of the CPR is minimal in comparison. It is difficult to prove that the CPR has caused any changes relating to relief, with no corresponding declines in vegetation condition on either side of the railway alignment.

Biota
Environmental
Sciences

Biota (n): The living creatures of an area; the flora and fauna together

12 Mar 2008

Una Phelan
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Dear Una

Residue Storage Facility Option 2 – Marandoo Mine Phase 2

We have undertaken a desktop review and comparison of Options 1 and 2 for the Residue Storage Facility (RSF) considering relative potential environmental impacts. Development of the RSF and associated infrastructure within the Option 1 area is likely to have the least environmental impact. A vegetation and flora survey will be carried out within the Option 1 area in April 2008 to confirm this conclusion.

This desktop comparison was based on aerial photograph interpretation, Biota's quadrat data (2007), Mattiske's (1992) vegetation mapping and report, and summary information provided by C. Nixon (2008). Biota has not established any quadrats nor conducted blanket flora surveys within the Option 1 area due to its proximity to the open cut operations and existing disturbance. Two quadrats, MAR22 and MAR23 have been established by Biota within the northern section of the Option 2 area. Both quadrats are representative of rocky hills and slopes, supporting *Eucalyptus leucophloia* subsp. *leucophloia* low open woodlands over *Acacia atkinsiana* or *Acacia bivenosa* tall shrublands over *Triodia brizoides* and *Triodia wiseana* hummock grassland. No Declared Rare or Priority flora species were recorded in these quadrats, however the vegetation was reported as in excellent condition. Mattiske (1992) mapped the areas supporting these quadrats as community's 5b and 5e respectively.

Floristic richness and vegetation types:
The topography within Option 1 is primarily lower lying broad drainage areas and basins, some minor creeklines and low foothills. The dominant vegetation community within Option 1 is mapped by Mattiske (1992) as 1c Hummock Grassland of *Triodia (Plectrachne) melvillei*, which was considered quite extensive locally but relatively restricted on a regional level. Small areas of species rich, creekline vegetation community's 2b and 2c Mattiske (1992) also occur within Option 1 area.

The Option 2 area is likely to support a greater diversity of plant species as topographically it is more diverse, less disturbed and contains large gullies, low ridges, stony rises and a profusion of minor flowlines. Gullies are considered to have an enhanced conservation value because they provide refugia for fire sensitive species and species that prefer rocky mesic habitats. In addition, larger areas of relatively intact creekline vegetation community

2b (Mattiske, 1992) occur in several locations within the Option 2 area, including one medium sized creek draining to the south.

There are a similar number of vegetation communities mapped within Option 1 and Option 2 areas however most of Option 1 area is the 1c vegetation community (Mattiske, 1992).

DRF and Priority flora:
No Declared Rare Flora or Priority Flora has been recorded within the Option 1 or Option 2 areas to date. The Priority 2 species *Indigofera ixiocarpa* was recorded in quadrats to the east (MAR28 and MAR29) of Option 2 and the Priority 4 species *Eremophila magnifica* subspecies *magnifica* was recorded in three quadrats to the north of the Option 2 area. The available habitat, based on topography and relative intactness of the Option 2 area indicates that these priority species are likely to be present. The habitat within the Option 1 area is less likely to support any Declared Rare or Priority Flora species.

Weeds and disturbance:
The Option 1 area is directly adjacent to the rail loop and open cut pit. The original airstrip also runs through this area. Several populations of Ruby Dock (*Rumex vesicarius*) have been recorded and it is likely that Beggars Ticks (*Bidens bipinnata*), Spiked Malvastrum (*Malvastrum americanum*) and other weed species are also present.

The Option 2 area is relatively inaccessible due to the terrain and is less disturbed than the Option 1 area. Beggars Ticks (*Bidens bipinnata*) and Spiked Malvastrum (*Malvastrum americanum*) have been recorded in the areas adjacent to Option 2.

Field assessment:
The indicative site for the RSF structure within the Option 1 area extends into a major flow line and associated vegetation types 2a, 2b and 2c; with *Acacia aneura, Eucalyptus xerothermica* (previously referred to as *patellaris)* and *Acacia citrinoviridis.* The field survey will focus on this area and any intact areas supporting the *Triodia melvillei* vegetation community 1c, to assess the likely impact of the RSF and infrastructure.

Based on topography, it is likely that Option 2a may support the Schedule 1 (EPBC Act) Northern Quoll (*Dasyurus hallucatus*) (which has been recorded from the mine extension area) as well as important bat roosts.

Conclusion
Option 1 is considered a better location for the RSF given it is a predominantly disturbed area close to the existing plant. One, locally extensive vegetation community is dominant and weeds are prevalent. No Declared Rare Flora or Priority Flora has been found in the area.

Option 2 lies in a previously undisturbed area where the habitat is more likely to support Priority Flora species and fewer aggressive weed species. The gullies within this area are likely to be considered to have enhanced conservation value by the DEC. EPBC listed fauna (Commonwealth protected species) may also be found in this area – the northern quoll was recorded near here in 2007 and there may also be caves supporting bat roosts.

Yours sincerely,

Biota Environmental Sciences Pty Ltd

Jeni Alford

Jeni Alford
Botanist

Biota Environmental Sciences

Rio Tinto

Marandoo Mine Phase 2 Project Vegetation and Flora Survey

Prepared for Rio Tinto

August 2008

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Marandoo Mine Phase 2 Project Vegetation and Flora Survey

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1.0 Summary

1.1 Background to the Project

Rio Tinto is currently investigating a proposal to expand mining operations below the water table at the Marandoo Iron Ore Mine (AML 70/272), located in the central Pilbara, approximately 37 km east of Tom Price. The Marandoo mine was approved by the Minister for the Environment in October 1992 under the *Iron Ore (Hamersley Range) Agreement Act 1963.*

The proposal is part of the Marandoo Mine Phase 2 (MMP2) and would require clearing to expand existing mining pits, and for new waste dumps, topsoil stockpiles and haul roads. All of the proposed developments are within the existing mining lease AML 70/272. Dewatering infrastructure, residue storage facility and an operations camp are also required.

Biota Environmental Sciences was commissioned to review existing botanical information relevant to the above project, and to conduct field work to provide supplementary data where necessary for the main Marandoo lease area (including the pit and waste dumps, Residue Storage Facility (RSF) and Dewatering Bore Drilling area), along with some additional infrastructure areas (comprising the Operations Camp, Southern Fortescue Borefield and the Dewatering Pipeline Corridor).

The study area for the purposes of this report extended beyond the Proposal Area for the MMP2 project (shown in Figure 2.1). Environmental clearing approvals are also being sought for the construction of the camp and dewatering infrastructure are being sought through a separate environmental impact assessment process. Baseline information on these additional areas is also provided here to allow for the assessment of cumulative impacts on flora and vegetation.

1.2 Study Methodology and Limitations

1.2.1 Methodology

The vegetation and flora of the Marandoo lease area and various rail corridors were assessed in 1991 for the Environmental Review and Management Programme prepared for the Marandoo Iron Ore Mine and proposed transport corridors (see Mattiske and Associates 1992). During this historic survey work, vegetation mapping was prepared for the entire area, and a list of flora species for the area (including some species of conservation significance) was collated.

Given that the species data from the Mattiske and Associates (1992) report is now over 15 years old, the current study was focussed on updating this information. This was achieved by:

- reviewing the historic list of species in Mattiske and Associates (1992) and making any changes to nomenclature as necessary;
- reviewing various targeted rare flora surveys completed in the Marandoo area by Pilbara Iron internal botanists;
- reviewing other existing data for the area (including a recent Department of Environment and Conservation rare flora database search for Marandoo);
- conducting additional survey work to increase the list of species recorded in the area (including the establishment of 44 permanently marked standard 50x50 m floristic quadrats and three relevés (unbounded flora survey sites), and targeted searches for species of conservation significance);
- reviewing the vegetation mapping prepared by Mattiske and Associates (1992) and providing a more detailed discussion of the individual units based on the recent survey work; and

- extending the vegetation mapping as necessary to cover new development areas not surveyed as part of the historic work by Mattiske and Associates (1992).

1.2.2 Limitations

While this report provides a good representation of the vegetation and flora values of the various study areas at Marandoo, the following limitations of the study and the subsequent interpretations must be considered:

- The vegetation sampled within some quadrats established during the 2007/2008 survey work was found to disagree with the mapping unit for that location presented in Mattiske and Associates (1992). To some extent, mapping is always a representation of the vegetation occurring at a site, as subjective decisions are constantly made to determine units and assign boundaries between these. This can be complicated by additional factors, such as poor quality or unrectified aerial photography, vegetation types which do not have distinct photographic signatures, and a limited amount of time to survey an area. Sampling points were therefore matched with the mapping unit of best fit and used to refine these descriptions. No changes were made to mapping unit boundaries.
- Systematic searches for rare flora have not been conducted through all sections of the project area. In addition, while the nomenclature in the species list provided in Mattiske and Associates (1992) was updated as far as possible, some taxa (eg. those designated simply as "sp") could not be determined. The species list presented should therefore be taken as indicative rather than exhaustive.
- This report contains only limited discussion of the potential impacts of clearing on significant vegetation and flora arising from the MMP2 project. A full discussion of potential project impacts is presented in the Public Environmental Review prepared for the project (see Rio Tinto 2008).

1.3 Vegetation

1.3.1 Vegetation Types

Twenty-eight broad vegetation units are mapped by Mattiske and Associates (1992) within the Marandoo study area, which broadly comprise:

- scattered to moderately dense Mulga (*Acacia aneura*) woodlands over an understorey of mixed tussock and or hummock grasses on broad drainage areas/basins and flats;
- Eucalypt and/or Mulga woodlands in major creeklines;
- mixed *Acacia* shrublands in minor flowlines;
- sparse to moderately dense mixed shrublands (mostly of Mulga or other *Acacia* species) over hummock grasslands of various *Triodia* species depending on topographic position on ridges/erosional spurs and low foothills/escarpments.

One of the vegetation units (2e) was subsequently reclassified, leaving a total of 23 vegetation from within the study area.

1.3.2 Vegetation of Conservation Significance

There are no Threatened Ecological Communities or Priority Ecological Communities within the study area, and no other vegetation units otherwise assessed as being of High conservation significance.

Several mapping units are considered to be of Moderate conservation significance:

- unit 1a, comprising Mulga and associated vegetation of broad drainage areas and basins (species rich and supporting some restricted taxa, including some Priority flora species);

- units 2a, 2b and 2c, comprising Mulga vegetation in the largest flowlines (of particular interest for the same factors mentioned above);
- unit 2e, comprising Coolibah (*Eucalyptus victrix*) woodlands in creeklines (important drainage system features for the area; species rich and potentially supporting restricted taxa);
- unit 4a, comprising dense Mulga woodland of the clayey flats (species rich and potentially supporting restricted taxa);
- units 5e, 5f and 6c, comprising vegetation of breakaways and cliff habitats (small area of representation and supporting habitat restricted taxa); and
- units 4f and 6d, comprising vegetation of calcretes (small areas of representation and potentially supporting restricted taxa).

Based on the current MMP2 development proposal:

- Units 2e, 4f, 5e, 6c and 6d will not be cleared;
- Units 1a and 4a will be cleared by less than 10% of the total mapped extent for the study area (both units also extend more widely through the locality (including in the adjacent Karijini National Park) and in the broader Hamersley subregion);
- Units 2a and 5f will be cleared by less than 30% of the total mapped extent for the study area (again, both units extend more widely through the locality and subregion); and
- Units 2b and 2c will be cleared by >35% of the total mapped extent for the study area (again, all units extend more widely through the locality and subregion).

The remainder of the mapping units are considered to be of Low conservation significance, representing units which are likely to be widespread and well-represented in the locality and more broadly through the Hamersley subregion.

1.4 Flora

Based on the work conducted to date, a total of 537 native vascular flora species from 176 genera and 60 families has been recorded from the various study areas at Marandoo. This number of species is higher than would be expected for a study area of this size in this locality. This is likely to reflect the variety of habitats encompassed by the study area, including extensive areas of Mulga vegetation on clayey substrates, which are generally recognised to be species rich.

On the whole, the species recorded were typical of this section of the Hamersley subregion, however the record of *Amaranthus* sp. A Kimberley Flora (C.A. Gardner s.n. PERTH 00326518) represents a range extension from the Kimberley bioregion, and the record of *Sporobolus blakei* is the first for the Pilbara.

1.4.1 Flora of Conservation Significance

No Declared Rare Flora have been recorded from the Marandoo study area, and none are considered likely to occur.

Five Priority flora were recorded from the study areas at Marandoo during the 2007/2008 survey work, a sixth species has been previously recorded from the flats north of the mine, and a seventh species was recorded during the 1991 survey by Mattiske and Associates from a collection locality within the lease area which remains outside of the current cleared mine areas. Of these species, four were recorded in the Proposal Area, three within the Project Area and one was outside of any proposed disturbance. A summary of the Priority taxa follows.

- *Calotis latiuscula* (Priority 1): 1 record from the Dewatering Pipeline Corridor and 1 record from the Operations Camp.

- *Goodenia lyrata* (Priority 1): 4 records from within the main Marandoo lease area, all from the flats on the northern side of the Marandoo Ridge.
- *Josephinia* sp. Marandoo (M.E. Trudgen 1554) (Priority 1): 1 record from the Operations Camp.
- *Lobelia heterophylla* subsp. Pilbara (R. Meissner & Y. Caruso 1) (Priority 1): 1 record from the main Marandoo lease area, from the southern side of the Marandoo Ridge; this location is beyond the proposed development areas.
- *Rhagodia* sp. Hamersley (M. Trudgen 17794) (Priority 1): 3 records from the main Marandoo lease (MAR24, MAR30 and within the rail loop), 1 record from the Dewatering Bore Drilling area and 1 record from the Dewatering Pipeline Corridor (MARA04); only the MAR24 location is outside the proposed development areas.
- *Indigofera ixocarpa* (Priority 2): 3 records from the main Marandoo lease, two of which are outside the current proposed development areas.
- *Eremophila magnifica* subsp. *magnifica* (Priority 4): numerous records from the northern slopes of the Marandoo Ridge within the main lease area; many of these locations (16) are within the proposed pit and waste dump expansion areas, however there are still numerous records (53) on the hillslopes to the south.

Up to four additional Priority species appear to have been recorded from locations which are apparently within existing disturbance areas in the Marandoo lease and probably no longer exist. These comprise:

- *Dicladanthera glabra* (Priority 2);
- *Cynanchum* sp. Hamersley (M. Trudgen 2302) (Priority 3);
- *Eremophila magnifica* subsp. *velutina* (Priority 3); and
- *Triumfetta leptacantha* (Priority 3).

1.4.2 Introduced Flora (Weeds)

Twenty weed species have been recorded from the Marandoo Proposal Area: **Bidens bipinnata* (Bipinnate Beggartick), **Sigesbeckia orientalis* (Indian Weed), **Sonchus oleraceus* (Common Sowthistle), **Bassia scoparia, *Cucumis melo* subsp. *agrestis* (Ulcardo Melon), **Euphorbia hirta* (Asthma Plant), **Euphorbia peplus* (Petty Spurge), **Malvastrum americanum* (Spiked Malvastrum), **Vachellia farnesiana* (Mimosa Bush), **Bougainvillea* sp. (Bougainvillea; planted), **Cenchrus ciliaris* (Buffel Grass), **Cenchrus setiger* (Birdwood Grass), **Chloris virgata* (Feathertop Rhodes Grass), **Cynodon dactylon* (Couch), **Echinochloa colona* (Awnless Barnyard Grass), **Setaria verticillata* (Whorled Pigeon Grass), **Acetosa vesicaria* (Ruby Dock), **Portulaca oleracea* (Purslane), **Datura leichhardtii* (Native Thornapple) and **Solanum nigrum* (Black Berry Nightshade).

None of the species recorded comprise Declared Plants under the *Agriculture and Related Resources Protection Act 1976,* however **Cenchrus* species and **Acetosa vesicaria* are considered to be serious environmental weeds.

2.0 Introduction

2.1 Background to the Project

The operating Marandoo Iron Ore Mine is located within lease AML 70/272, located approximately 37 km east of Tom Price in the Pilbara region of WA. The lease is surrounded on all sides by the Karijini National Park.

The Marandoo Mine has been operating since 1994 and Rio Tinto Iron Ore (Rio Tinto, the Proponent) is currently investigating the feasibility of developing mining below the water table, which may increase the mine life by 15-20 years. It is estimated that the Marandoo Mine Phase 2 (MMP2) project would require the disturbance of approximately 940 ha, which includes the following proposed developments within the mining lease:

- expansion of mine pits,
- expansion of waste dumps, and
- a residue storage facility.

Other developments under consideration for the project include:

- dewatering infrastructure to carry dewatering water from the Marandoo Mine to the Southern Fortescue Borefield (this is being assessed under a separate environmental impact assessment (EIA) process, however the baseline data for this area is included to provide contextual information and to allow the assessment of cumulative impacts); and
- an Operations Camp within the proposed Camp Site 6 (also being considered for a temporary rail duplication construction camp); as for the dewatering infrastructure, the camp proposal is being assessed under a separate EIA process, however the baseline data has been included for context.

The study area for the purposes of this report extended beyond the Proposal Area for the MMP2 project (shown in Figure 2.1). Environmental clearing approvals are also being sought for the construction of the camp and dewatering infrastructure are being sought through a separate environmental impact assessment process (components of the wider 'Project Area'). Baseline information on these additional areas is also provided here to allow for the assessment of cumulative impacts on flora and vegetation.

These areas are summarised in Table 2.1 and shown in Figure 2.1 and Figure 2.2.

Table 2.1: Areas associated with the broader MMP2 project that were surveyed as part of the current study.

	Development Area	Location
Proposal Area	Marandoo pit and waste dump expansions	Mining lease, comprising area south of rail line
	Residue Storage Facility	South-western corner of mining lease (south-west of rail loop)
	Southern Fortescue Borefield	Southern Fortescue Borefield, ~25 km north-west of the Marandoo mine
Project Area	Dewatering Bore Drilling Area	Northern section of mining lease
	Dewatering infrastructure to the Southern Fortescue Borefield ("Dewatering Infrastructure Corridor")	Extends ~24 km north-west of the Marandoo mine, ending at the "Terminal Tank" south-west of the Southern Fortescue Borefield
	Operations Camp*	~15 km west-north-west of the Marandoo mine

* Being considered for approval as part of a separate environmental impact assessment process.

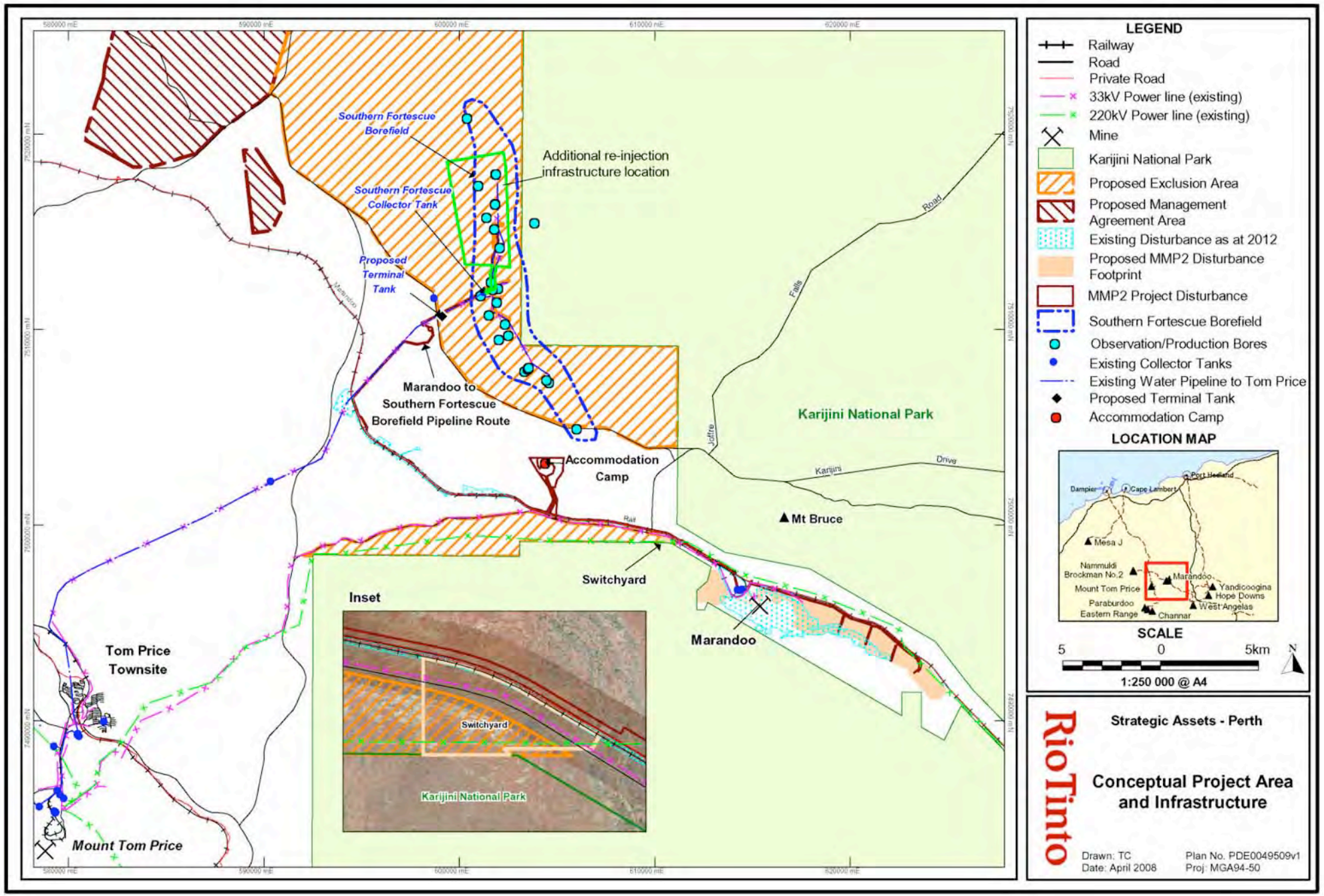

Figure 2.1: Conceptual mine site layout and associated infrastructure for the Marandoo Mine Phase 2 project.

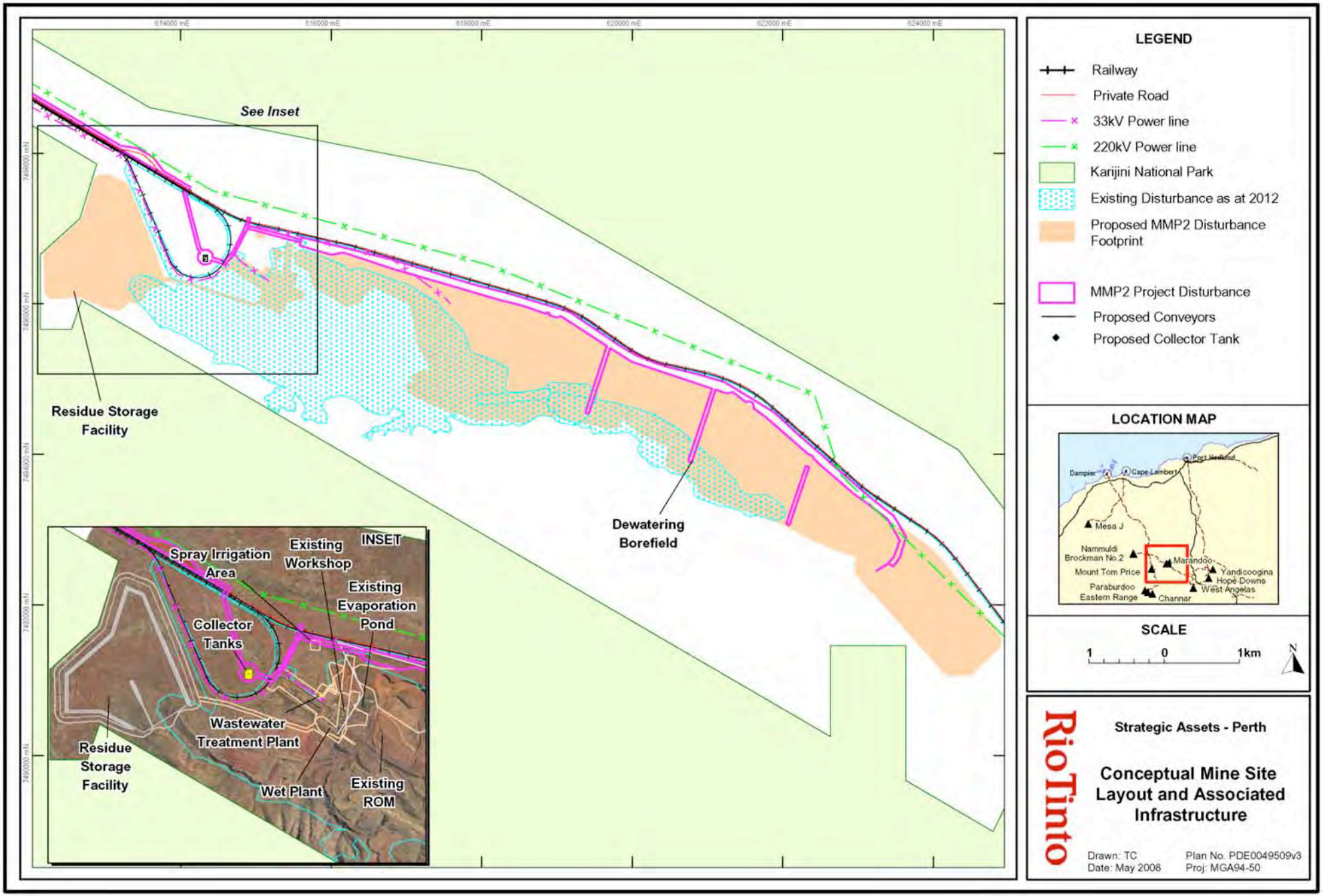

Figure 2.2: Conceptual project layout within the Marandoo Mine lease.

2.2 Approach to this Study

The vegetation and flora of the Marandoo lease area and various rail corridors were assessed in 1991 for the Environmental Review and Management Programme (ERMP) prepared for the Marandoo Iron Ore Mine and proposed transport corridors (see Mattiske and Associates 1992). During this study, vegetation mapping was prepared for the entire area, and a list of flora species for the area (including some species of conservation significance) was collated based on new field work and review of various historic reports (Trudgen 1975, 1977a, 1977b, 1978; Weston 1977; CRA Services Ltd 1982).

Given that even the most recent species data from the Mattiske and Associates (1992) report is now over 15 years old, the current study was focussed on updating this information. This was achieved by:

- reviewing the historic list of species and making any changes to nomenclature as necessary;
- conducting additional survey work in the area (including the establishment of permanently marked floristic quadrats and targeted searches for species of conservation significance);
- reviewing the vegetation mapping prepared by Mattiske and Associates (1992) and providing a more detailed discussion of the individual units based on the recent survey work; and
- extending the vegetation mapping as necessary to cover new development areas not surveyed as part of the historic work by Mattiske and Associates (1992).

This document provides a description of the methodology of the current study and a synthesis and evaluation of vegetation and flora data for the Marandoo lease area collected between the 1970s (Mattiske and Associates 1992) and 2007/2008 (Biota, this report).

3.0 Review of Existing Information

3.1 Methodology of Review

3.1.1 *EPBC Act 1999* Protected Matters Search

A search for "protected matters" relevant to the MMP2 project under the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* was conducted online in May 2008.

Protected matters include:

- Matters of National Environmental Significance:
  - World Heritage Properties
  - National Heritage Places
  - Wetlands of International Significance: (Ramsar Sites)
  - Commonwealth Marine Areas
  - Threatened Ecological Communities
  - Threatened Species
  - Migratory Species
- Other Matters Protected by the *EPBC Act*:
  - Commonwealth Lands
  - Commonwealth Heritage Places
  - Places on the Register of the National Estate
  - Listed Marine Species
  - Whales and Other Cetaceans
  - Critical Habitats
  - Commonwealth Reserves
- Extra Information:
  - State and Territory Reserves
  - Other Commonwealth Reserves
  - Regional Forest Agreements

Matters of relevance to this botanical study are reported in the appropriate sections following.

3.1.2 Rare Flora Database Searches

A search of the Department of Environment and Conservation (DEC) and WA Herbarium databases was done in March 2008 for Declared Rare Flora (DRF) and Priority Flora recorded within approximately 30 km of the study area.

The locations of the resulting records were investigated in ArcView to indicate populations in the vicinity of the study area (see Section 3.2.6).

3.1.3 Review of Other Existing Information

General environmental studies, including floristic collections, have been conducted within and adjacent to the Marandoo Mine lease area between 1974 and 1982. In 1990-1991, Mattiske and Associates (1992) surveyed the Marandoo Lease area as part of the environmental assessment for mining, and increased the number of families recorded by 11, genera by 50 and total species by 196. This document comprises the major comparative reference used for this study.

Several Declared Rare and Priority Flora surveys for ground disturbance have also been conducted in the area by Pilbara Iron botanists, including for the:

- Marandoo Crusher Access (Hamersley Iron 2003);

- Marandoo North West Area, extending between the rail loop and the mine (Hamersley Iron 2004a);
- Marandoo South West Pit, on the south-western side of the mine (Hamersley Iron 2004b);
- Marandoo Tail Pit, extending along the northern flanks of the Marandoo Ridge to the east of the mine (Pilbara Iron 2005);
- Marandoo Below Water Table Evaluation Drilling - Eastern Area, extending along the flats areas to the east of the mine (Pilbara Iron 2006a); and
- Marandoo Old Grid and Baseline Area, comprising drill lines to the east of the areas surveyed within Pilbara Iron (2005) and Pilbara Iron (2006a) (see Pilbara Iron 2006b).

These biological surveys were reviewed to indicate vegetation types and species that occur in the areas associated with the MMP2 project.

The DEC Pilbara Biological Survey will provide a broad overview of vegetation and floristic communities for the Pilbara bioregion, however this study is still in progress and data is not yet available.

3.2 Regional Context of the Study Area

3.2.1 Beard's Mapping of Botanical Provinces, Physiographic Units and Vegetation

Beard (1975) mapped the vegetation of the Pilbara at a scale of 1:1,000,000. The study area lies entirely within the Fortescue Botanical District of the Eremaean Botanical Province as defined by Beard. The vegetation of this province is typically open, and frequently dominated by spinifex, wattles and occasional Eucalypts.

Beard also identified four major physiographic units within the Fortescue District:

- Abydos Plain: extending from Cape Preston east to Pardoo Creek, and south to the Chichester Range; including alluvial plains, low stony hills and granite outcrops; comprising largely granitic soils, with alluvial sands on the coastal portion;
- Chichester Plateau: a plateau of mainly basalts, with included siltstone, mudstone, shale, dolomite and jaspilite; forming a watershed between numerous rivers flowing north through the Abydos Plain to the coast, and the Fortescue drainage on the southern side of the range;
- Fortescue Valley: occupying a trough between the Chichester and Hamersley Plateaux; the eastern portion drains into the Fortescue Marsh; and
- Hamersley Plateau: rounded hills and ranges, mainly of jaspilite and dolomite with some shale, siltstone and volcanics.

The MMP2 project area lies within the Hamersley Plateau physiographic unit.

Vegetation of the locality including the MMP2 project area was mapped by Beard as five main units (summarised in Table 3.1). Given the broad nature of Beard's mapping, these units are only broadly applicable to the vegetation occurring on site (see Section 5.1).

Table 3.1: Beard's (1975) vegetation mapping units within the current study areas at Marandoo.

	Proposal Area			Project Area		
Beard's Mapping Unit	Marandoo Lease Area (including mine pit and waste dump expansion areas)	Residue Storage Facility	Southern Fortescue Borefield	Dewatering Bore Drilling Area	Dewatering Pipeline Corridor	Operations Camp
Hamersley 18: Mulga *(Acacia aneura)* continuous low woodland	√ (north of the Marandoo Ridge)	√ (along eastern third)	√ (eastern half)	√ (entire area)	√ (western half and easternmost end)	√ (northern half)
Hamersley 29: Mulga *(Acacia aneura)* sparse low woodland		√ (western half)			√ (eastern half)	√ (southern half)
Hamersley 82: Scattered Snappy Gums *(Eucalyptus leucophloia)* over a Hard Spinifex *(Triodia wiseana)* hummock grassland	√ (Marandoo Ridge itself)	√ (hills at southern boundary)			√ (scattered hills along western half)	√ (hills along north-western edge)
Hamersley 175: *Astrebla pectinata, Aristida latifolia* open tussock grassland.			√ (western half)			
Hamersley 567: Scattered shrubs of Mulga *(Acacia aneura)* and *Acacia pyrifolia* over a *Triodia pungens, T. basedowii†* hummock grassland	√ (south of the Marandoo Ridge)					

† Probably rather *Triodia* sp. Shovelanna Hill (S. van Leeuwen 3835).

3.2.2 Hamersley IBRA Subregion

The Interim Biogeographic Regionalisation for Australia (IBRA) recognises 85 bioregions (Environment Australia 2000). The MMP2 project area lies within the Pilbara bioregion, which is divided into four subregions: Roebourne Plains, Chichester, Fortescue Plains and Hamersley. These subregions are largely equivalent to the physiographic regions of Beard (1975; see Section 3.2.1), although the coastal portion of Beard's Abydos Plain unit comprises the Roebourne Plains subregion, while the inland portion is included under the Chichester subregion. The current study area lies in the Hamersley subregion.

3.2.3 Conservation Reserves in the Locality

The Marandoo mine is located within an exclusion from the A-class Karijini National Park, which is listed on the Register of the National Estate, Place ID 10129 (21 March 1978). No other conservation reserves are located within 50 km of the study area.

The Pilbara bioregion is listed as a medium priority for funding for land purchase under the National Reserves System Co-operative Program due to the limited representation of the area in conservation reserves. Portions of various pastoral leases in the region have been nominated for exclusion for public purposes in 2015, when the leases come up for renewal. Many of the submissions are from the WA DEC, with the intention of adding these areas to the existing conservation estate in order to contribute to a comprehensive, adequate and representative reserve system. One of these exclusions comprises a 32,260 ha section of Hamersley Station, which is proposed to be added to the Karijini National Park. This area includes the Southern Fortescue Borefield, meaning that once the pastoral exclusion process is enacted in 2015, the borefield will be effectively located within the Karijini National Park. However, in recognition of existing Rio Tinto tenements in this area, appropriate land access may be granted to allow for future development and ongoing management of infrastructure.

3.2.4 Land Systems

Land Systems (Rangelands) mapping covering the study area has been prepared by the Western Australian Department of Agriculture (van Vreeswyk et al. 2004). Land Systems are comprised of repeating patterns of topography, soils, and vegetation (Christian and Stewart 1953) (ie. a series of "land units" that occur on characteristic physiographic types within the Land System).

A total of 107 Land Systems occur in the Pilbara bioregion. [This information was obtained by combining the Land System mapping for the Pilbara (van Vreeswyk et al. 2004) and Ashburton (Payne et al. 1988), and intersecting this with the Pilbara bioregion (Environment Australia 2000) in ArcView 3.2.]

The Land Systems mapped by the Department of Agriculture (van Vreeswyk et al. 2004) for the region including the MMP2 project area are shown in Figure 3.1. Seven land systems occur within the current study areas (Table 3.2). Three of these occur within the Proposal Area. The Newman Land System dominates the stony hills of the Marandoo Ridge in the main Marandoo lease, with areas of McKay Land System occurring on hills to the south. These are surrounded by plains of the Platform and Boolgeeda Land Systems, with the latter extending broadly through the other infrastructure areas to the west. Broad drainage tracts through the study areas comprise the Jurrawarrina Land System, while there is a large swathe of Paraburdoo Land System along the Dewatering Pipeline Corridor. Very small amounts of the Wannamunna Land System occur along the northern edge of the main lease. Descriptions for each Land System are provided in Table 3.2.

Most of the Land Systems occurring within the current study areas at Marandoo are widespread through at least the Hamersley subregion, however the Jurrawarrina and Wannamunna Land Systems have relatively fewer occurrences and a smaller area of representation than the other units (see Table 3.3). Most of the Land Systems occurring within the study area are also well

represented within the adjacent Karijini National Park, with the exception of the Jurrawarrina Land System, which occurs in only small areas along the western boundary of the Park.

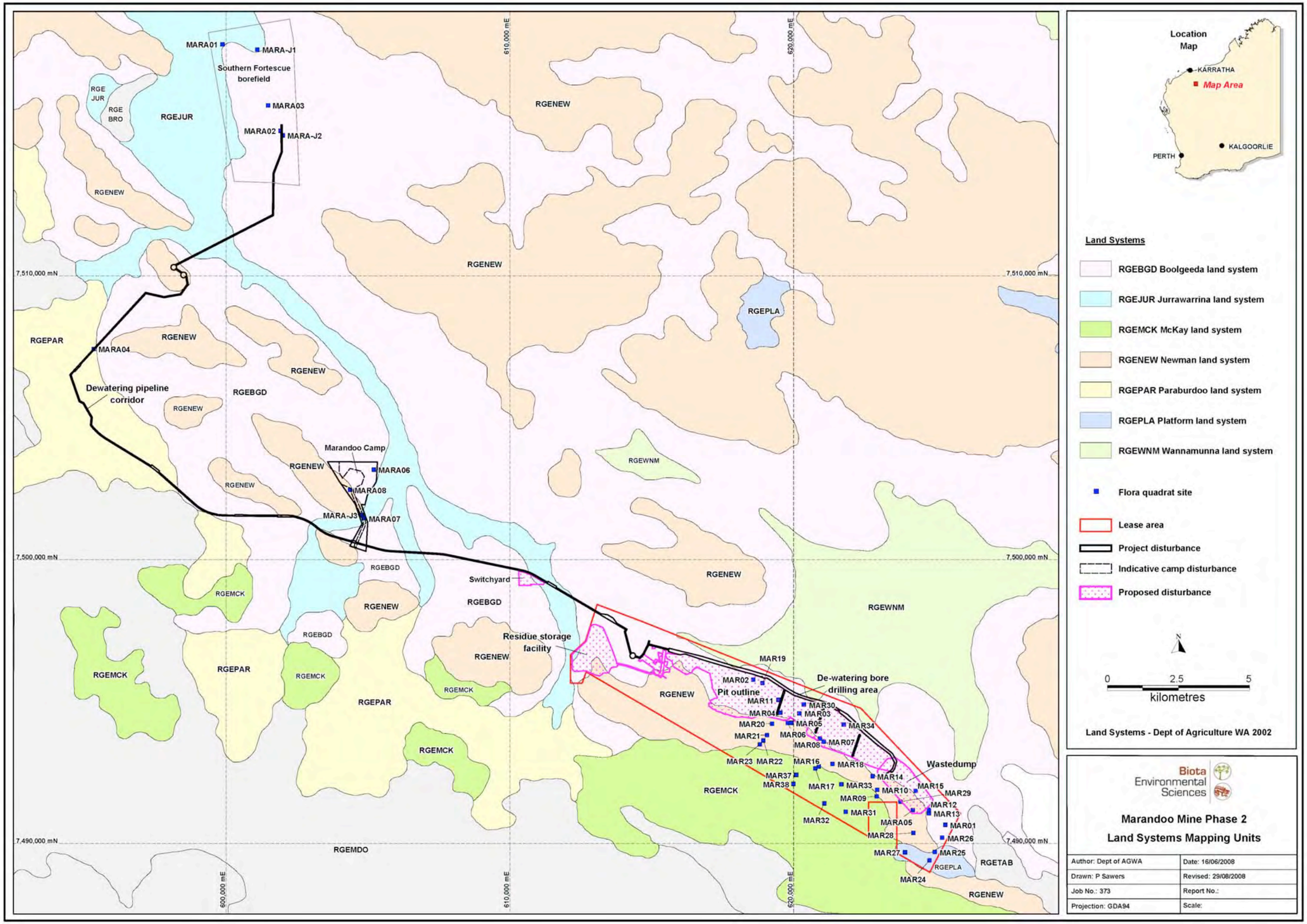

Figure 3.1: Land Systems mapping for the locality including the current study areas at Marandoo (data from van Vreeswyk et al. 2004).

Table 3.2: Land Systems of the current study areas at Marandoo (descriptions from van Vreeswyk et al. 2004).

	Proposal Area			Project Area		
Land System	Marandoo Lease Area (including mine pit and waste dump expansion areas)	Residue Storage Facility	Southern Fortescue Borefield	Dewatering Bore Drilling Area	Dewatering Pipeline Corridor	Operations Camp
Boolgeeda: Stony lower slopes and plains below hill systems supporting hard and soft spinifex grasslands and mulga shrublands; vegetation mostly in very good condition	√ (dominating the stony plains on the northern side of the Marandoo Ridge)	√ (dominating the stony plains)	√ (eastern two-thirds)	√ (virtually entire area)	√ (broad swathes)	√ (dominating the stony plains)
Jurrawarrina: Hardpan plains and alluvial tracts supporting mulga shrublands with tussock and spinifex grasses; vegetation mostly in fair to very poor condition, being preferentially grazed	√ (one tract along western boundary)	√ (one tract along western boundary)	√ (western edge)		√ (in broad tracts)	√ (one broad tract through the centre)
McKay: Hills, ridges, plateau remnants and breakaways of meta-sedimentary and sedimentary rocks supporting hard spinifex grasslands; vegetation mostly in very good condition	√ (south of the Marandoo Ridge) *					
Newman: Rugged jaspilite plateaux, ridges and mountains supporting hard spinifex grasslands; vegetation mostly in very good condition	√ (dominating the hills of the Marandoo Ridge)	√ (hills along central southern boundary)			√ (scattered hills)	√ (hills along the north-western boundary)
Paraburdoo: Basalt derived stony gilgai plains and stony plains supporting snakewood and mulga shrublands with spinifex and tussock grasses; vegetation mostly in very good to good condition					√ (broad swathe towards western end)	
Platform: Dissected slopes and raised plains supporting hard spinifex grasslands; vegetation mostly in very good condition	√ (south-east corner) *					
Wannamunna: Hardpan plains and internal drainage tracts supporting mulga shrublands and woodlands (and occasionally eucalypt woodlands); vegetation mostly in very good condition	√ (very small areas along northern edge) *			√ (very small areas along northern edge)		

* Not located within proposal disturbance footprint

Table 3.3: Distribution of Land Systems within the areas assessed for the MMP2 project and in the wider Pilbara region (data from Payne et al. 1988 and van Vreeswyk et al. 2004).

Land System	Total Area in the Pilbara Bioregion (Rank†)	Number of Mapping Polygons in the Pilbara Bioregion	General Distribution through the Pilbara Bioregion	Area within the Current Study Areas at Marandoo		Quadrats Established in Land System During Current Study
				Hectares¥	% of total in Pilbara bioregion	
Boolgeeda	961,635 ha (103rd)	588	Widespread with a large number of occurrences, particularly through the Hamersley subregion	2,814.8	0.29%	MAR01, MAR02, MAR03, MAR04, MAR11, MAR12, MAR13, MAR15, MAR19, MAR26, MAR30, MAR34, MARA02, MARA03, MARA06, MARA-J2
Jurrawarrina	66,475 (63rd)	32	Widespread through the Fortescue Plains subregion and the central Hamersley subregion, but with few occurrences	355.5	0.53%	MARA01, MARA-J1, MARA07, MARA-J3
McKay	426,142 ha (99th)	129	Widespread through the Pilbara region, concentrated in the northern Hamersley and southern Chichester subregions	618.6	0.15%	MAR09, MAR16, MAR17, MAR31, MAR32, MAR33, MAR37, MAR38
Newman	1,993,741 ha (106th)	321	Widespread and abundant through the Hamersley subregion, also occurring as a band along the Chichester Range to the north of the Fortescue Marsh; numerous occurrences	1,027.9	0.05%	MAR05, MAR06, MAR07, MAR08, MAR10, MAR14, MAR18, MAR20, MAR21, MAR22, MAR23, MAR28, MAR29, MARA05, MARA08
Paraburdoo	130,692 ha (77th)	87	Widespread through the Pilbara, but concentrated in the central Hamersley subregion	20.4	0.02%	MARA04
Platform	236,336 ha (92nd)	169	Widespread through the Pilbara with a large number of occurrences; predominantly in the Hamersley subregion, with small occurrences also in the Chichester subregion, and to a lesser extent in the Fortescue Plains subregion	80.0	0.03%	MAR24, MAR25, MAR27
Wannamunna	63,013 ha (60th)	35	Relatively uncommon and restricted to the eastern Hamersley subregion	4.4	<0.01%	–
Pilbara Total	17,800,479 ha	5,636				

† Ranking of Land System in terms of area out of the 107 Land Systems in the Pilbara bioregion; ranked from least abundant in terms of area (1) to most abundant (107).

¥ Note that these values comprise the total hectares mapped within the combined study areas, minus "areas already approved for clearing" as designated by the Proponent. These values are therefore the total mapped occurrences of each Land System for the study area, not for the MMP2 impact areas specifically; impact areas are designated in the PER for the proposal (see Rio Tinto 2008).

3.2.5 Significant Vegetation Communities Known from the Vicinity of Marandoo

The framework under which significant communities are classified is provided in Appendix 1.

3.2.5.1 Threatened Ecological Communities under the *EPBC Act 1999*

No Threatened Ecological Communities (TECs) listed under the *EPBC Act 1999* have been recorded from the study area or the locality.

3.2.5.2 Threatened Ecological Communities listed by DEC

The TEC which comprises "*Themeda* grasslands of the Pilbara region" is restricted to areas of heavy clays, and occurs ~30 km north of Tom Price over an east-west range of approximately 80 km. There are two areas of Brockman Land System within 2 km of the western boundary of the Southern Fortescue Borefield which are mapped as this TEC, however this vegetation does not appear to extend any closer to the Southern Fortescue Borefield. This TEC is considered to be at risk from grazing and trampling by stock, weed invasion, changed fire regimes and alteration of hydrology (Kendrick 2001).

3.2.5.3 Priority Ecological Communities listed by DEC

There are a number of Priority Ecological Communities (PECs) listed by the DEC for the Pilbara bioregion, however none of these are associated with habitats in the current study areas at Marandoo.

The PEC which comprises "Coolibah *(Eucalyptus victrix)* swamp" occurs on the flats east of Mt Bruce, approximately 1.5 km north of the eastern end of the main Marandoo lease. This PEC is considered to be at risk from grazing and trampling by stock and weed invasion (particularly by Ruby Dock, **Acetosa vesicaria;* see Kendrick 2001).

3.2.5.4 Other Ecosystems Considered to be At Risk by DEC

A number of ecosystems in each WA IBRA bioregion are listed as "ecosystems at risk" from various threatening processes (see May and McKenzie 2003).

Ecosystems for the Hamersley subregion which may be relevant to the current study areas include the following:

- "Lower-slope mulga", which we understand to refer to areas of Mulga (*Acacia aneura*) over spinifex hummock grasslands, is listed as being under threat from frequent fires preventing regeneration of the *Acacia* overstorey (see Kendrick 2001).
- "All major ephemeral water courses" are considered to be threatened by grazing and trampling by stock, large fires and weed invasion, particularly from Buffel Grass (**Cenchrus ciliaris*) and Ruby Dock (**Acetosa vesicaria*); Kendrick (2001).

3.2.5.5 Refugia

Gorges of the Hamersley Ranges are listed by Kendrick (2001) as being of significance as refugia, since they provide refuge sites for species requiring high humidity and those that are intolerant of fire (eg. White Cypress Pine, *Callitris columellaris*). Such areas frequently support species restricted to rocky and/or humid habitats, including Priority flora such as *Sida* sp. Barlee Range (S. van Leeuwen 1642) and *Triumfetta leptacantha*. Numerous gorges exist within the Marandoo lease area, some of which occur within the MMP2 development area.

3.2.6 Significant Flora Species Known from the Vicinity of Marandoo

The framework under which significant flora species are classified is provided in Appendix 1.

3.2.6.1 Probability of Listed Species under the *EPBC Act 1999* Occurring in the Locality

Only two plant species from the Pilbara are currently listed under the *EPBC Act 1999:*

- Mountain Thryptomene (*Thryptomene wittweri*) is only known from high-altitude mountain tops in the Pilbara, its distribution extending south into the Gascoyne and Great Victoria Desert bioregions. Given the absence of suitable habitat within the MMP2 project area, this species would not be expected to occur.
- Hamersley Lepidium (*Lepidium catapycnon*) is now known from a number of locations in the Hamersley Range, extending broadly from Tom Price across to Newman. Given that this species has been recorded from several locations around Tom Price and suitable habitat (stony hills and plains) occurs at Marandoo, there is a slight possibility that it occurs in the MMP2 project area, however it has not been recorded from the Marandoo locality to date.

3.2.6.2 Probability of Declared Rare Flora Occurring in the Locality

The two Declared Rare Flora currently listed for the Pilbara are the two species listed under the *EPBC Act 1999* (Section 3.2.6.1). As discussed, *Thryptomene wittweri* is unlikely to occur in the MMP2 project area, however there is a slight possibility that *Lepidium catapycnon* may occur given the presence of suitable habitat (Section 3.2.6.1).

3.2.6.3 Priority Flora Occurring in the Locality

The Marandoo Mine lease area and surrounding Karijini National Park have been relatively well surveyed compared to many other areas of the Pilbara, and the WA Herbarium and DEC rare flora database searches yielded numerous records of several Priority flora species from the Marandoo locality, including:

- four Priority 1 species: *Brachyscome* sp. Wanna Munna Flats (S. van Leeuwen 4662), *Calotis squamigera, Josephinia* sp. Marandoo (M. Trudgen 1554) and *Lobelia heterophylla* subsp. Pilbara (R. Meissner & Y. Caruso 1);
- six Priority 2 species: *Acacia daweana, A. effusa, Euphorbia* sp. Mt. Bruce flats (S. van Leeuwen 3861), *Indigofera ixocarpa, Scaevola* sp. Hamersley Range Basalts (S. van Leeuwen 3675) and *Spartothamnella puberula*;
- nine Priority 3 species: *Acacia bromilowiana, Cynanchum* sp. Hamersley (M. Trudgen 2302), *Dampiera anonyma, Eremophila magnifica* subsp. *velutina, Geijera salicifolia, Rostellularia adscendens* var. *latifolia, Sida* sp. Marandoo (M. Trudgen 10976), *Swainsona* sp. Hamersley Station (A. A. Mitchell 196) and *Triumfetta leptacantha*; and
- two Priority 4 species: *Eremophila magnifica* subsp. *magnifica* and *Ptilotus mollis*.

A number of additional species are listed on the most recent Declared Rare and Priority Flora List (Atkins 2008) for general locations within this search area, however no records were yielded from either database search:

- two Priority 2 species: *Dicladanthera glabra*, which is listed in Mattiske and Associates (1992), and *Olearia fluvialis*; and
- two Priority 3 species: *Dampiera metallorum* and *Polymeria* sp. Hamersley (M.E. Trudgen 11353).

Given the intensity of sampling in the locality, the zone of particular interest for flora of conservation significance was restricted to approximately 15 km of the existing mine site (and thus the MMP2 project area).

Flora of conservation significance that have been previously recorded from this area are described individually in the following:

- There is a record of the Priority 1 species, *Calotis squamigera*, from 10 km north-west of the Marandoo mine, on the southern side of the sealed Marandoo access road (40 m from the roadway). While the only lodged specimens of this species are currently from the Marandoo locality, this annual daisy has apparently also been collected from Wittenoom (Atkins 2008). Habitats from which this species has been collected include rocky hillsides, rocky creeks, riverbeds and floodplains.

- There are four records of the Priority 1 species, *Goodenia lyrata*, from the plains on the northern side of the Marandoo Ridge (see Pilbara Iron 2006a). This species is infrequently collected but has a relatively broad range, extending from Tom Price–Newman in the Pilbara through to Laverton in the Murchison bioregion and inland to the Gibson Desert bioregion.
- There are two records of the Priority 1 species, *Josephinia* sp. Marandoo (M. Trudgen 1554), from 2.5 km north and 11 km north-east of the Marandoo mine. This annual herb has a relatively broad distribution through the central Pilbara, but is infrequently recorded.
- There is a single record of the Priority 1 species *Lobelia heterophylla* subsp. Pilbara (R. Meissner & Y. Caruso 1) from the Marandoo lease, ~800 m south of the current mine pits. This herb has a distribution extending from the southern Pilbara to the northern Murchison bioregion.
- There are several records of the Priority 2 species, *Acacia daweana,* from between 4 km north (on Mt Bruce) and 8 km north-north-west of the Marandoo mine. This spreading shrub has a narrow distribution in the central Hamersley Ranges, occurring mainly on low rocky rises and along drainage lines.
- There are several records of the Priority 2 species, *Acacia effusa,* distributed over the same area as *A. daweana*. This moderate-height shrub has minniritchi bark, and is typically recorded on stony plains and scree slopes. This species has a relatively narrow distribution through the eastern Hamersley Ranges.
- There is a single record of the Priority 2 species, *Euphorbia* sp. Mt. Bruce flats (S. van Leeuwen 3861), from a cracking clay substrate some 7.5 km east of the Marandoo mine. This species is currently only known from this location.
- *Indigofera ixocarpa* (Priority 2) has been previously recorded from Marandoo Hill, ~5 km west of the Marandoo mine within Karijini National Park. This species is also known from Tom Price and Nullagine, an, a single record was made from the northern Abydos Plain during the Hope Downs Rail Corridor survey (Biota and Trudgen 2002).
- There is one record of the Priority 2 species, *Scaevola* sp. Hamersley Range basalts (S. van Leeuwen 3675), from 9 km south-west of the Marandoo mine. This species is restricted to the central southern Pilbara, typically occurring on the slopes or summits of tall hills.
- There is a single record of the Priority 2 species, *Spartothamnella puberula*, from 3 km north of the Marandoo mine. This multi-stemmed low shrub typically grows in rocky habitats, and is distinguished from the more common *Spartothamnella teucriiflora* by the dense short indumentum (covering of hairs) on the stems and leaves.
- The database search returned two records of the Priority 3 species, *Cynanchum* sp. Hamersley (M. Trudgen 2302), from the Marandoo locality. Both of these locations appear to be within the current mine pit areas and are likely to have been destroyed. This creeper has a relatively broad range through the central Pilbara, extending south into the western Gascoyne bioregion, and tends to be recorded from sheltered rocky areas or from drainage features.
- There are several records of the Priority 3 species, *Dampiera anonyma*, extending from 4 km north (on Mt Bruce) to 9 km south-west of the Marandoo mine. This low shrub is described as growing on the summits and upper slopes of tall hills (>1000 m tall), and current known locations are clustered in the central section of the Hamersley subregion.
- The Priority 3 taxon *Eremophila magnifica* subsp. *velutina* was listed by Mattiske and Associates (1992) as occurring in the Marandoo lease area, however the single record of this taxon returned by the database searches from the locality is from ~5 km west-north-west of the Marandoo mine. This perennial shrub species occurs in a band through the central Pilbara, extending into the northern Gascoyne bioregion, and is typically found on the slopes and crests of steep rocky hills.
- There is a single record of the Priority 3 species, *Geijera salicifolia*, from 14 km east of the Marandoo mine. This large shrub species is restricted to rocky habitats, particularly basalt rockpiles.
- There are two records of the Priority 3 species, *Rostellularia adscendens* var. *latifolia*, from 4 km north (on Mt Bruce) and 9 km south-west of the Marandoo mine. This species has a disjunct

distribution, with population centres in the Hamersley subregion and the far eastern Chichester subregion. It has been recorded from near creeklines and on rocky hills.

- There is a single record of the Priority 3 species, *Sida* sp. Marandoo (M. Trudgen 10976), from 2.5 km north of the Marandoo mine. This species is currently only vouchered from this location.
- There is a single record of the Priority 3 pea species, *Swainsona* sp. Hamersley Station (A.A. Mitchell 196), from 8.5 km south-west of the Marandoo mine. This annual herb is restricted to heavy clay substrates.
- There are several records of the Priority 3 species, *Triumfetta leptacantha*, from locations extending from Marandoo itself (this location appears to be within the current mine pit and has presumably been destroyed) to 3.5 km north-north-east and 5 km west-north-west of the MMP2 project area. This species has a broad distribution through the southern central Pilbara but is virtually restricted to rocky habitats (gorges, gullies and the bases of rocky breakaways).
- The database searches returned a single record of the Priority 4 taxon, *Eremophila magnifica* subsp. *magnifica*: while the location coordinates were not precise, this collection locality is almost 20 km from the Marandoo mine. This taxon was listed by Mattiske and Associates (1992) as occurring in the Marandoo lease area, and has been recorded frequently from the northern slopes of the Marandoo Ridge (see Pilbara Iron 2005, 2006a). It is also known from numerous populations around Tom Price.
- There is a single record of the Priority 4 species, *Ptilotus mollis*, from 4 km north of the Marandoo mine on Mt Bruce. This species has a broad distribution extending from the central Pilbara east to the northern Little Sandy Desert bioregion. It is typically restricted to shaly scree slopes on the sides of hills.

4.0 Field Survey Methodology

4.1 Study Team and Timing of the Field Surveys

The MMP2 study area was initially surveyed by four botanists (Michi Maier, Rachel Warner, Paul Hoffman and Jeni Alford; all of Biota) between the 6th and 9th of March 2007. This trip was planned to be of longer duration but was cut short due to heavy rainfall. A second survey was conducted between the 18th and 26th of May 2007 by Rachel Warner, Paul Hoffman and Britta Mathews (Biota). Brian Morgan (private consultant) also participated in the second survey from the 22nd to the 26th of May. A total of 48 person days was thus spent within the MMP2 project area in 2007.

The March 2007 survey followed rainfall which was well below average in January and slightly above average in February (Figure 4.1). Despite the February rain, conditions may not have been optimal for the collection of ephemeral flora or cryptic perennial species as not all of these species would have had adequate time to respond. The second survey in May 2008 followed three months of above average rainfall.

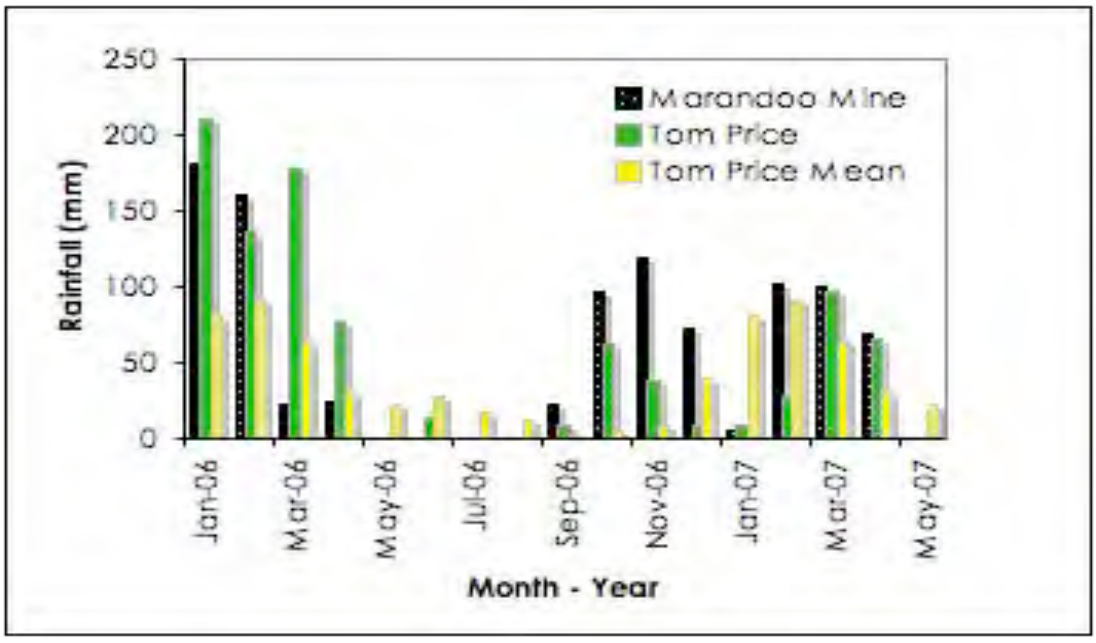

Figure 4.1: Monthly rainfall for Marandoo Mine and Tom Price from January 2006 to June 2007 compared with the monthly Tom Price mean (data supplied by Pilbara Iron and the WA Bureau of Meteorology).

Additional survey work was conducted by Jeni Alford and Justin Fairhead (Biota) between the 21st and 28th of April 2008, comprising brief site assessments of several more defined infrastructure areas (the Residue Storage Facility, Dewatering Bore Drilling area, Dewatering Pipeline Route, Southern Fortescue Borefield and Operations Camp). The survey in March followed considerable rainfall in the previous month (Figure 4.2), and was considerable favourable for the collection of annual flora species.

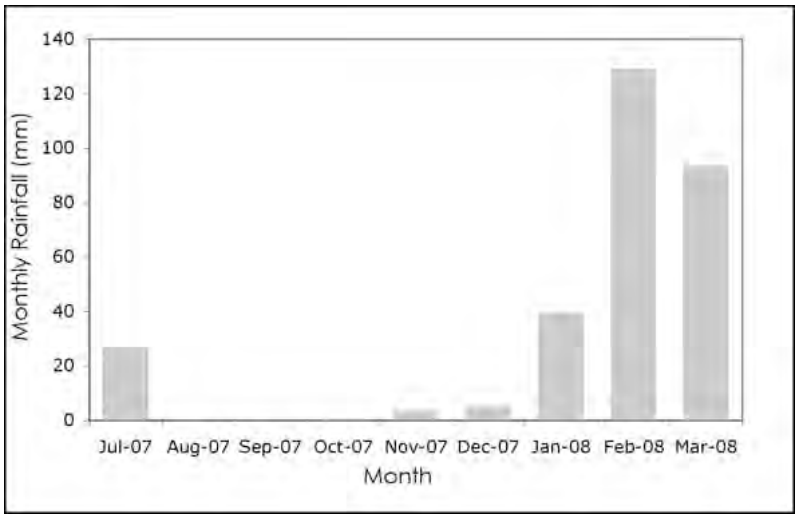

Figure 4.2: Monthly rainfall for Tom Price for the period preceding the March 2008 survey work (data supplied by the WA Bureau of Meteorology).

4.2 Survey Approach

The 2007 surveys focused on establishing 35 standard floristic survey quadrats (Section 4.2.2) in order to update the descriptions of mapping units provided by Mattiske and Associates (1992). Opportunistic collections of flora were also made to supplement the list of species recorded from the quadrats (Section 4.2.3).

The 2008 vegetation surveys of the various additional areas for the MMP2 project focussed on extending the Mattiske and Associates (1992) mapping units to cover the additional areas. Most comprised comparatively small areas, sometimes associated closely with existing infrastructure and therefore largely disturbed. Large sections of some areas were also recently burnt. These two factors reduced the area available for quadrat establishment, and a total of eight quadrats and three relevés (unbounded floristic survey sites) were assessed in 2008.

4.2.1 Location of the Quadrats

The locations of the detailed flora recording quadrats were chosen to represent the main vegetation types identified by Mattiske and Associates (1992) and as identified on aerial photography. The quadrats were uniquely numbered, using the prefix "MAR" (2007) or "MARA" (2008) followed by a number sequence. Locations of the quadrats and relevés are shown on the mapping in Appendix 2.

4.2.2 Quadrat Sampling Method

Quadrats were typically 50 m x 50 m, as this size is considered optimal to represent the floristic diversity within vegetation communities in the Pilbara. It also gives a good indication of the shrub and grass layer vegetation structure for most vegetation types that occur in 'uniform' habitats (eg. plains and hillslopes, where vegetation stands are typically greater than this quadrat size). Quadrat shape and/or size were adjusted as necessary to fit smaller or linear shaped habitats (eg. flowlines).

Most quadrats were permanently marked using a steel fence dropper at three corners of the quadrat, however some were only marked at one corner (usually the north-west corner). An optical square and measuring tapes were used to ensure that the quadrat sides were correctly positioned.

The following parameters were recorded for each quadrat:

1. Location: AMG coordinates recorded in WGS84 datum (within 1-2 m of GDA94) using a hand-held Global Positioning System (GPS), to accuracy usually within 5 m; readings were usually taken for all four corners of the quadrat.
2. Vegetation Description: Using the height and estimated cover classes of dominant species in Aplin's (1979) modification of the vegetation classification system of Specht (1970) (see Appendix 3).
3. Habitat: Description of landform and habitat.
4. Soil: Description of soil type and stony surface mantle.
5. Disturbance Details: Condition ranked according to the scale of Trudgen (1988) as shown in Appendix 3, considering evidence of grazing, weed invasion, frequent fires etc. Note that fire effects are only considered as a negative impact if they are caused by repeated burning (such as that done for pastoral purposes at higher than natural frequency). Fire is a natural and frequent process in the north of Western Australia to which the vegetation has adapted, and to class areas as being in poor condition simply because they have been recently burnt is misleading.
6. Percentage Foliar Cover: Cover was estimated visually for each species. Estimates were made to the nearest percent where possible, or a range (eg. 5-10%) was used. '+' was used where only occasional individuals were present, with a cover of less than 1%.

Colour photographs of the vegetation were taken at each site using a digital camera.

4.2.3 Foot Traverses for Rare Flora and Opportunistic Species Records

The MMP2 areas surveyed by Biota in March and May 2007 were not "blanket cleared" for rare flora as considerable survey work had been undertaken through the lease area to date:

- systematic searches for rare flora were conducted over substantial areas around the existing mine footprint by Mattiske and Associates in 1991;
- in addition, Pilbara Iron botanists have completed several ground disturbance and targeted Declared Rare and Priority Flora surveys (see Section 3.1.3).

However, limited foot traverses were conducted through the lease area in 2007, including targeted searches for rare flora in areas of suitable habitat (eg. rocky hills for *Eremophila magnifica*). Similarly, foot traverses were walked through the additional areas surveyed in 2008, although the entire areas were not systematically searched.

All flora species observed during these foot traverses were recorded in order to improve the list of species for the area above those simply recorded from the quadrats and relevés. This included a particular focus on species of management concern (ie. flora of conservation significance and weeds).

4.3 Specimen Identification, Nomenclature and Data Entry

Common species that were well known to the survey botanists were identified in the field. Voucher specimens of all other species were collected and assigned a unique number to facilitate tracking of data. These were pressed in the field and dried in a drying oven.

These vouchers were then identified by keying out, reference to appropriate publications, use of reference collections and comparison to the collections held at the Western Australian Herbarium. Rachel Butler, Paul Hoffman, Britta Matthews, Rachel Warner, Jeni Alford and Michi Maier of Biota identified most specimens. Assistance was also received from Malcolm Trudgen of M.E. Trudgen and Associates for various problematic groups. Specimens will be lodged with the Western Australian Herbarium for all taxa for which suitable material is available.

Nomenclature was checked against the current listing of scientific names recognised by the Western Australian herbarium and updated as necessary. The only outdated nomenclature retained was that relating to *Cassia*. This genus is currently recognised as *Senna* (see Randell 1989), however the older *Cassia* classification (Symon 1966) was perceived to be a more realistic level of separation of the taxa (eg. with taxa such as *'glutinosa'* and *'pruinosa'* recognised at specific rather than subspecific level). A more detailed discussion is contained in Trudgen and Casson (1998), while a comparison of the nomenclature under the two classifications is presented in Appendix 5.

4.4 Limitations of the Study

While this report provides a good representation of the vegetation and flora values of the various study areas at Marandoo, the following limitations of the study and the subsequent interpretations must be considered:

- The vegetation sampled within some quadrats established during the 2007/2008 survey work was found to disagree with the mapping unit for that location presented in Mattiske and Associates (1992). To some extent, mapping is always a representation of the vegetation occurring at a site, as subjective decisions are constantly made to determine units and assign boundaries between these. This can be complicated by additional factors, such as poor quality or unrectified aerial photography, vegetation types which do not have distinct photographic signatures, condition of the vegetation (eg. extent of physical disturbance, fire history, etc), and a limited amount of time to survey an area. Sampling points were therefore matched with the mapping unit of best fit and used to refine these descriptions. No changes were made to mapping unit boundaries.
- Systematic searches for rare flora have not been conducted through all sections of the project area. In addition, while the nomenclature in the species list provided in Mattiske and Associates (1992) was updated as far as possible, some taxa (eg. those designated simply as "sp") could not be determined. The species list presented should therefore be taken as indicative rather than exhaustive.
- This report contains only limited discussion of the potential impacts of clearing on significant vegetation and flora arising from the MMP2 project. A full discussion of potential project impacts is presented in the Public Environmental Review prepared for the project (see Rio Tinto 2008).

5.0 Vegetation of the Marandoo Study Areas

5.1 Description of the Vegetation Mapping Units

The broad vegetation mapping units recorded from the current study areas at Marandoo according to the Mattiske and Associates (1992) study and more recent extensions of the mapping by Biota are summarised in Table 5.1 and presented in Appendix 2. The units are described individually in more detail in the following sections. Area values presented below are for the total mapped area across the combined study areas, minus the "areas already approved for clearing" as designated by the Proponent (a total of 981.3 ha). A further 8.9 ha were designated as "disturbed" around the stock-yard on the access to the Southern Fortescue Borefield.

5.1.1 Vegetation of Broad Drainage Areas and Basins

1a: *Acacia aneura* woodland
This vegetation unit has been mapped in the Marandoo lease area, where it was found to occur on broad flat alluvial and colluvial areas, including in patches within the Residue Storage Facility. It was also the dominant vegetation type in the Southern Fortescue Borefield, and occurred in a small stand towards the eastern end of the Dewatering Pipeline Corridor. The total mapped area for this unit by itself comprised 112.2 ha, however it also occurred as a mosaic with unit 1b over an additional 540.7 ha. No quadrats were established in 2007 in this vegetation in the lease area as it had been recently burnt, however quadrat MARA01 and relevé MAR-J1 were established in the Southern Fortescue Borefield in 2008.

The vegetation at site MARA01 (Plate 5.1) within the Southern Fortescue Borefield was typical of this vegetation unit, comprising a low open forest of *Acacia aneura* over a tussock grassland dominated by *Chrysopogon fallax.* Various other annual and perennial grasses were present, including *Aristida ingrata, A. obscura, Dactyloctenium radulans, Digitaria brownii, D. ctenantha, Eragrostis cumingii, Eulalia aurea, Paspalidium constrictum, Perotis rara, Setaria dielsii, S. surgens, Sporobolus australasicus* and *Themeda triandra*. Herbs were also abundant and included *Alternanthera nana, Boerhavia repleta, Brachyscome ciliocarpa, Cleome viscosa, Commelina ensifolia, Euphorbia biconvexa*, *Evolvulus alsinoides* var. *villosicalyx, Goodenia muelleriana, Ipomoea muelleri, Mukia maderaspatana, Pterocaulon sphacelatum, Spermacoce brachyste*ma and *Wahlenbergia tumidifructa*. Only scattered shrubs were present, including *Ptilotus obovatus, Sida* spp. and *Solanum sturtianum*. This vegetation was typically in Very Good to Good condition, with usually scattered but occasionally dense patches of weeds (mainly **Bidens bipinnata,* although species such as **Echinochloa colona* and **Malvastrum americanum* were also recorded).

1b: Open grassland
One relatively small area (0.08 ha) of this vegetation unit is mapped on the northern boundary of the Marandoo lease and several patches occur as a mosaic with unit 1a over an area of some 540.7 ha within the Southern Fortescue Borefield area. No quadrats were established in this mapping unit during the current study. Fires and disturbance in the lease area resulted in the stand of this vegetation being in too poor condition to redescribe, however it was described in the Southern Fortescue Borefield area.

This vegetation occurs within the broad drainage areas amongst bands of dense mulga and includes most of the species described in the grass and herb component of 1a above, but at lesser densities and without a tree overstorey. In some areas, this vegetation comprises scattered patches of *Aristida contorta* and a large proportion of bare ground, probably in response to local surface drainage patterns (Plate 5.2).

Table 5.1: Descriptions of broad vegetation types occurring in the study areas at Marandoo, including both the Proposal and Project Areas (after Mattiske and Associates 1992*).

Mapping Code	Vegetation Type (after Mattiske and Associates 1992*)	Quadrats Assessed by Biota (2007/2008)	Total Area (ha) within the Marandoo Study Area
Broad Drainage Areas and Basins			
1a	*Acacia aneura* woodland on broad flat alluvial and colluvial areas	MARA01, MARA-J1	112.2 ha, plus 540.7 ha as mosaic with 1b
1b	Open grassland	No quadrats assessed; majority of vegetation recently burnt or otherwise disturbed	0.08 ha, plus 540.7 ha as mosaic with 1a
1c	*Triodia melvillei* hummock grassland	MAR01, MAR04†, MAR19, MAR26, MAR30, MARA06, MARA-J2	1501.1 ha
Major Flowlines and Creeks			
2a	*Acacia aneura – A. pruinocarpa* woodland in major flowlines	MAR02, MAR11, MAR14, MAR34, MARA04, MARA07	53.4 ha
2b	*Eucalyptus xerothermica – Acacia aneura* woodland in major flowlines	MAR17	78.3 ha
2c	*Eucalyptus xerothermica – Acacia aneura* woodland over *Acacia citrinoviridis* tall shrubland in major flowlines	MAR24	13.9 ha
2e	*Eucalyptus victrix* woodland in secondary creeklines	MARA-J3	11.7 ha¥
Minor Creeks			
3a	*Acacia* species shrubland in minor flowlines	MAR05, MAR13, MAR20	220.5 ha
Flats			
4a	*Acacia aneura – A. pruinocarpa* woodland	No quadrats assessed; majority of vegetation recently burnt or otherwise disturbed	17.2 ha
4b	*Acacia synchronicia – *Vachellia farnesiana* tall shrubland	No quadrats assessed; no sufficiently large stands found	5.8 ha
4c	*Acacia aneura* scattered low trees over open grassland	MARA02, MARA03	631.0 ha
4d	*Acacia xiphophylla* low woodland	No quadrats assessed; no pure stands found;	147.3 ha
4e	*Triodia wiseana, T. pungens* hummock grassland	No quadrats assessed; quadrat established in mapped area represents different unit	201.6 ha
4f	*Triodia wiseana, T.* sp. Shovelanna Hill, *T. angusta* hummock grassland	MAR27	104.2 ha
4g	*Triodia angusta, T. longiceps* hummock grassland	No quadrats assessed; vegetation largely recently burnt or otherwise disturbed	8.0 ha

* Species names have been updated to reflect changes in nomenclature; all references to *Triodia basedowii* are believed to correspond to *Triodia* sp. Shovelanna Hill (S. van Leeuwen 3835).

† Interzone between 1c and 5h.

¥ NB: A 1.1 ha polygon labelled as unit 2d (*Eucalyptus camaldulensis* woodland) within the study area was re-attributed as unit 2e on the basis of the current mapping notes.

Table 5.1: continued.

Mapping Code	Vegetation Type (after Mattiske and Associates 1992*)	Quadrats Assessed by Biota (2007/2008)	Total Area (ha) within the Marandoo Study Area
Ridges and Erosional Spurs			
5a	*Eucalyptus leucophloia* scattered low trees over *Acacia* spp. scattered shrubs over *Triodia brizoides, T. wiseana* hummock grassland	MAR29	118.3 ha
5b	*Eucalyptus leucophloia* scattered low trees over *Acacia* spp. scattered shrubs over *Triodia wiseana (T. brizoides, T.* sp. Shovelanna Hill) hummock grassland	MAR23, MAR28, MAR33	294.4 ha
5c	*Eucalyptus leucophloia* scattered low trees over *Acacia* spp. scattered shrubs over *Triodia* sp. Shovelanna Hill *(T. wiseana)* hummock grassland	MAR06, MAR07, MAR08, MAR12, MAR15, MAR16, MAR22, MAR25	189.2 ha
5d	*Eucalyptus gamophylla* scattered low mallees over *Acacia* spp. scattered tall shrubs over *Triodia* sp. Shovelanna Hill (*T. wiseana*) hummock grassland	MAR09, MAR21	198.6 ha
5e	Mixed community supporting a range of structural formations from *Acacia aneura* low woodlands to sheer rock faces with *Astrotricha hamptonii* scattered shrubs to *Eriachne mucronata* open grasslands	MAR10, MAR18,	68.5 ha
5f	*Acacia aneura* low woodland to woodland on rocky ledges and upper slopes of ranges	MARA05	26.7 ha
5g	*Eucalyptus gamophylla* scattered low mallees over *Triodia wiseana* hummock grassland	No quadrats assessed; unit remote from development areas and not accessed	22.7 ha
5h	*Triodia wiseana* hummock grassland with mixed *Acacia* spp. emergent shrubs	MAR03, MAR04†, MARA08	147.4 ha
Low Foothills and Escarpments			
6a	Mixed *Triodia* spp. hummock grassland on upper slopes and ridges of small foothills and escarpments	MAR37	116.3 ha
6b	Mixed *Acacia aneura, Acacia* spp. low woodland to woodland on upper slopes of low foothills	MAR32	47.2 ha
6c	*Acacia aneura* low woodland to woodland on breakaways of low foothills	MAR38	18.9 ha
6d	*Eucalyptus trivalva, E. socialis* low mallee woodland with pockets of *Triodia angusta, T. wiseana* hummock grassland on shallow calcrete soils	MAR31	18.1 ha

* Species names have been updated to reflect changes in nomenclature; all references to *Triodia basedowii* are believed to correspond to *Triodia* sp. Shovelanna Hill (S. van Leeuwen 3835).

† Interzone between 1c and 5h.

Plate 5.1: Vegetation unit 1a (MARA01; Southern Fortescue Borefield).

Plate 5.2: Vegetation unit 1b in foreground (Southern Fortescue Borefield).

1c: *Triodia melvillei* hummock grassland

This is the dominant vegetation type on the broad plains within the main Marandoo lease area (including the majority of the Residue Storage Facility and the Dewatering Bore Drilling area), and also occurs within the Operations Camp area and along the eastern end of the Dewatering Pipeline Corridor. Sites MAR01 (Plate 5.3), MAR04 (in an interzone with unit 5h), MAR19 (Plate 5.4), MAR26, MAR30, MARA06 and MARA-J2 were established in this mapping unit during the current study. Based on these sampling points, a more accurate description of the vegetation would comprise a low open woodland of *Acacia aneura* (typically var. *pilbarana*), usually with *A. pruinocarpa,* over scattered hummocks to a hummock grassland of *Triodia melvillei* or *T. schinzii*. The understorey tends to be extremely variable and species rich. Shrub species typically included *Ptilotus obovatus* and *Solanum lasiophyllum.* Other associated species included *Abutilon otocarpum* (acute leaf form), *Aristida contorta, A. holathera* var. *holathera, A. ingrata, Cheilanthes sieberi* subsp. *sieberi, Chrysopogon fallax, Cymbopogon obtectus, Digitaria brownii, Duperreya commixta, Enneapogon polyphyllus, Evolvulus alsinoides* var. *villosicalyx, Panicum effusum, Paraneurachne muelleri* and *Ptilotus exaltatus* var. *exaltatus*. This vegetation was typically in Very Good condition, with only scattered weeds (mainly **Bidens bipinnata*).

Plate 5.3: Vegetation unit 1c (MAR01).

Plate 5.4: Vegetation unit 1c (MAR19).

5.1.2 Vegetation of Major Flowlines and Creeks

2a: *Acacia aneura – A. pruinocarpa* woodland

This vegetation unit occurs in or adjacent to creek lines on floodplains, and was present within the main Marandoo lease area and all the additional areas. A number of sampling points were established within this mapping unit during the 2007 and 2008 survey work, including quadrats MAR02, MAR11, MAR14, MAR34, MARA04 and MARA07 (Plate 5.5). The vegetation typically comprised a low open forest of *Acacia aneura* (typically var. *pilbarana*), with substantial amounts of *A. pruinocarpa,* over a tussock grassland dominated by species such as *Chrysopogon fallax,*

Eulalia aurea and *Themeda triandra*. Shrub species typically included *Eremophila forrestii* subsp. *forrestii, Indigofera georgei, Ptilotus obovatus* and *Sida* sp. spiciform panicles (E. Leyland s.n. 14/8/90). Other associated species included *Abutilon otocarpum* (acute leaf form), *Alternanthera nana, Aristida contorta, A. ingrata, Dipteracanthus australasicus* subsp. *australasicus, Duperreya commixta, Enneapogon polyphyllus, Euphorbia biconvexa, Evolvulus alsinoides* var. *villosicalyx, Mukia maderaspatana, Pterocaulon sphacelatum* and *Rhynchosia minima.* This vegetation was typically in Very Good condition with only scattered weeds (most commonly **Bidens bipinnata* and **Malvastrum americanum,* although a number of other species were noted).

Plate 5.5: Vegetation unit 2a (MARA07).

2b: *Eucalyptus xerothermica – Acacia aneura* woodland

This vegetation type occurs within relatively broad loamy flowlines through the main Marandoo lease area (including within the Residue Storage Facility and the Dewatering Bore Drilling area), and also occurs along the Dewatering Pipeline Corridor. Mattiske and Associates (1992) note that the understorey species in this unit vary significantly. It is likely that this unit contains several different vegetation types, which are generally not mappable at a useful scale and are often referred to as "third order creeks". A single quadrat established within the study area was considered representative of this vegetation unit although it was not mapped as such: the vegetation in quadrat MAR17 (mapped as unit 4e) comprised *Eucalyptus xerothermica, Acacia aneura* var. *pilbarana* low open forest over *Acacia bivenosa, Santalum lanceolatum* open shrubland over *Triodia longiceps* hummock grassland and *Themeda triandra, Eulalia aurea* very open tussock grassland (Plate 5.6). In some areas the hummock grassland understorey was replaced almost completely by a tussock grassland of *Digitaria brownii*. Other associated species included *Acacia pruinocarpa, Alternanthera nana, Aristida latifolia, Capparis lasiantha, Cheilanthes sieberi* subsp. *sieberi, Dichanthium sericeum* subsp. *humilius, Dipteracanthus australasicus* subsp. *australasicus, Duperreya commixta, Enneapogon lindleyanus, E. polyphyllus, Eragrostis cumingii, E. tenellula, Eremophila longifolia, Goodenia stellata, Panicum decompositum, Phyllanthus maderaspatensis, Pterocaulon serrulatum, Ptilotus obovatus* and *Rhynchosia minima*. This vegetation was typically in Very Good condition, with only scattered weeds (mainly **Bidens bipinnata* and **Malvastrum americanum,* with occasional **Vachellia farnesiana*).

Plate 5.6: Vegetation unit 2b (MAR17).

2c: *Eucalyptus xerothermica – Acacia aneura* woodland over *Acacia citrinoviridis* tall shrubland
A very small area (13.9 ha) of this vegetation unit was mapped by Mattiske and Associates (1992) within the Marandoo Lease area (including along the western boundary of the Residue Storage Facility). This vegetation was not resampled during the recent surveys, however a site established in another mapped unit appears equivalent (MAR24, which was mapped as 3a). In addition, a vegetation type which appears similar but lacks *Eucalyptus xerothermica* was recorded opportunistically in the Operations Camp study area and along the Dewatering Pipeline Corridor (Plate 5.7). This vegetation often occurs in bands parallel to the riparian vegetation unit 2e. Occasional Coolibahs (*Eucalyptus victrix*) occur within this vegetation type and it is possible that this species was recorded as *E. xerothermica* during the previous surveys, as an unusual rough-barked form of *E. victrix* occurs occasionally in the Marandoo area. At ground level there is typically a closed grassland of perennial tussock and annual bunch grasses, including species such as *Aristida* spp., *Chrysopogon fallax, Dactyloctenium radulans, Digitaria brownii, Enneapogon polyphyllus, Eulalia aurea, Panicum effusum, Paraneurachne muelleri, Perotis rara* and *Themeda triandra*. Based on the above sampling points, other associated species include *Cleome viscosa, Dodonaea petiolaris, Eremophila forrestii* subsp. *forrestii, Euphorbia biconvexa, Ptilotus* spp., *Rhagodia eremaea, Sclerolaena cornishiana, Solanum ferocissimum* and *Vittadinia* spp. This vegetation was typically in Very Good condition, with scattered weeds being the main disturbance (mainly **Bidens bipinnata* and **Malvastrum americanum*).

2e: *Eucalyptus victrix* woodland
This vegetation unit was recorded within the access corridor to the Operations Camp, and along the Dewatering Pipeline Corridor. (Note that a creekline towards the western end of the Dewatering Pipeline Corridor which was mapped by Mattiske and Associates (1992) as unit 2d (*Eucalyptus camaldulensis* woodland) has been re-attributed as unit 2e, as the current field data identified the dominant trees species in this area as *E. victrix*. It is considered likely that this stand was originally mapped based on a vegetation description obtained further downstream, to the north of the dewatering infrastructure corridor, where this creekline is more developed.) This vegetation comprised a *Eucalyptus victrix* low open woodland over *Acacia citrinoviridis* tall open scrub over *Themeda triandra* open tussock grassland (Plate 5.8). A bunch grassland dominated by *Dichanthium sericeum* subsp. *humilius* was also present in places. Other associated species included *Acacia aneura, Achyranthes aspera, Alternanthera nana, Aristida ingrata, Chrysopogon fallax, Corchorus crozophorifolius, Crotalaria medicaginea, Cymbopogon ambiguus, Dicladanthera forrestii, Digitaria brownii, Enneapogon polyphyllus, Eulalia aurea, Evolvulus alsinoides* var. *villosicalyx, Gomphrena canescens* subsp. *canescens, Hybanthus aurantiacus, Ipomoea muelleri, Mukia maderaspatana, Phyllanthus maderaspatensis, Plumbago zeylanica, Rhynchosia minima, Rulingia luteiflora, Sporobolus australasicus, Stemodia grossa, Streptoglossa decurrens, Tephrosia rosea* var. *glabrior* and *Waltheria indica*. This vegetation was typically in Very Good to Good condition, with scattered weeds of several species recorded including **Bidens bipinnata, *Cenchrus ciliaris, *Cenchrus setiger, *Datura leichhardtii, *Echinochloa colona* and **Malvastrum americanum.*

Plate 5.7: Vegetation unit 2c (Dewatering Pipeline Corridor).

Plate 5.8: Vegetation unit 2e within the Operations Camp study area (relevé MARA-J3).

5.1.3 Vegetation of Minor Creeks

3a: *Acacia* species shrubland

A relatively large area of this minor flowline vegetation unit occurs in the numerous minor flowlines dissecting the ranges and erosional spurs, including within the main Marandoo lease and all of the additional study areas except the Southern Fortescue Borefield. Quadrats MAR05, MAR13 (Plate 5.9) and MAR20 (Plate 5.10) were established in minor flowlines, not all of which were indicated individually on the mapping (as is typical for minor habitats such as these). The overstorey composition of this unit varies greatly depending on the substrate and landform traversed by the flowline, however typical dominant shrub species include *Acacia atkinsiana* and *A. maitlandii*, and scattered low trees of *Eucalyptus leucophloia* subsp. *leucophloia* are also usually present. The composition of the hummock grassland is similarly variable, but owing to the position of these flowlines through the stony hills, the most common dominant species are *Triodia wiseana* and *T.* sp. Shovelanna Hill (S. van Leeuwen 3835). Other associated species included *Abutilon dioicum, Acacia aneura* var. *pilbarana, A. pruinocarpa, Cassia glutinosa, C. oligophylla* x *helmsii, Cymbopogon ambiguus, Duperreya commixta, Eriachne mucronata, Evolvulus alsinoides* var. *villosicalyx, Gompholobium karijini, Hibiscus sturtii* var. *campylochlamys, Keraudrenia velutina* subsp. *elliptica, Panicum effusum, Paraneurachne muelleri, Solanum sturtianum* and *Themeda triandra*. This vegetation was typically in Excellent condition.

Plate 5.9: Vegetation unit 3a (MAR13).

Plate 5.10: Vegetation unit 3a (MAR20).

5.1.4 Vegetation of Flats

4a: *Acacia aneura – A. pruinocarpa* woodland
A small area of this vegetation unit is mapped within the Marandoo lease area and along the Dewatering Pipeline Corridor. No quadrats were established during the 2007 and 2008 surveys as most of this vegetation was burnt: an access road, powerline corridors and general earthworks have also affected the condition of the vegetation along the Dewatering Pipeline Corridor. This vegetation appears relatively similar to unit 2a, and is often similarly located adjacent to a major flowline with Coolibahs (*Eucalyptus victrix*). Occasional *Acacia citrinoviridis* are also typically present. This vegetation was generally in Very Good condition within the study areas, except along the Dewatering Pipeline Corridor, where it was considered to be in Good to Poor condition.

4b: *Acacia synchronicia – *Vachellia farnesiana* tall shrubland
Only a few small stands of this vegetation unit are mapped within the Marandoo lease area and along the Dewatering Pipeline Corridor. Ground reconnaissance in 2007/2008 suggests that areas mapped as this type have either changed species composition over time or may have been mapped incorrectly from poor quality historic aerial photography. One small stand of vegetation along the Dewatering Pipeline Corridor surveyed in 2008 fitted Mattiske and Associates (1992) description in terms of species and topographic location (Plate 5.11). The vegetation in this area comprised scattered tall shrubs to a shrubland of *Acacia synchronicia* over a low open shrubland of *Eremophila forrestii* subsp. *forrestii* over a hummock grassland of *Triodia melvillei* and *T. wiseana*. Other associated species included *Acacia aneura, Eremophila latrobei* subsp. *filiformis, Cassia oligophylla* x *helmsii* and *Cassia luerssenii.* Although **Vachellia farnesiana* was not recorded within the stand sampled in 2008, this species would not be unexpected from larger areas of this vegetation from which Mattiske and Associates (1992) would probably have described the unit.

4c: *Acacia aneura* scattered low trees over open grassland
A small area of this vegetation unit was recognised and mapped by Mattiske and Associates (1992) within the Marandoo lease area and along the Dewatering Pipeline Corridor, but was not resampled during the 2007 surveys as these areas had been burnt. A large area of stony undulating plain believed to support this unit was noted in the Southern Fortescue Borefield during the 2008 survey work, and two quadrats were established (MARA02, Plate 5.12; and MARA03). The vegetation cover is patchy and variable but typically quite species rich. The overstorey stratum in the Southern Fortescue Borefield was described as scattered low trees to a low open woodland of *Corymbia deserticola, Acacia aneura* and *A. pruinocarpa*. The cover at ground level comprised scattered hummocks of *Triodia melvillei* with a very open tussock grassland of *Chrysopogon fallax* and *Digitaria brownii*. Scattered low to medium height shrubs of various species were also typically present, including *Cassia* spp., *Eremophila forrestii* subsp. *forrestii, Hibiscus burtonii, H. sturtii* var. *platychlamys, Maireana villosa, Ptilotus obovatus, Sida platycalyx* and *Solanum* spp. Other associated species included *Abutilon* spp., *Acacia ancistrocarpa, A. pachyacra, A. pyrifolia, Aristida contorta, A. ingrata, Boerhavia coccinea, Cleome viscosa, Dactyloctenium radulans, Enneapogon polyphyllus, Eriachne pulchella, Euphorbia* spp., *Glycine canescens, Gomphrena kanisii, Goodenia forrestii, Hakea lorea* subsp. *lorea, Paraneurachne muelleri, Paspalidium rarum, Pterocaulon sphacelatum, Salsola tragus, Sclerolaena cornishiana, Themeda triandra, Tribulus astrocarpus, T. macrocarpus* and *Urochloa occidentalis* var. *ciliata*. This vegetation was typically in Very Good condition, with only scattered weeds (mainly **Bidens bipinnata* and **Portulaca oleracea*).

Plate 5.11: Vegetation unit 4b (597338E, 7509326N).

Plate 5.12: Vegetation unit 4c (MARA02).

4d: *Acacia xiphophylla* low woodland

A relatively large area of this vegetation unit is mapped within the main Marandoo lease, on the southern side of the Marandoo Ridge, and small stands are also mapped within the Dewatering Pipeline Corridor. While it is acknowledged that the entire lease area was not traversed during the 2007 and 2008 field surveys, no pure stands were identified during this later field work, although stands of Mulga (*Acacia aneura*) with only occasional Snakewood (*A. xiphophylla*) were noted. It is possible that the mapping of this unit was an artefact based on poor quality historic photography, and that this unit is less well represented within the main lease area than the mapping suggests. Snakewood woodlands and tall shrublands on stony plains are generally quite species poor, supporting few understorey species with large areas of bare ground. They often occur adjacent to or as part of broader Mulga vegetation types. The areas of unit 4d mapped in the study area are likely to be in Excellent condition as a consequence of their inaccessibility, although they may have recently been burnt.

4e: *Triodia wiseana, T. pungens* hummock grassland on flatter valley floors and flats

This vegetation unit is mapped adjacent to minor flowlines in the southern half of the main Marandoo lease and is also scattered through the Dewatering Pipeline Corridor. Mattiske and Associates (1992) notes that the community also supports emergent species of *Acacia, Cassia* and *Eucalyptus*. The single quadrat (MAR16) established in an area mapped as this unit proved to be unit 5c, hence there was no more detailed sampling of this vegetation unit during the current study. The areas mapped as this unit in the southern section of the main Marandoo lease area are likely to be in Excellent condition due to their inaccessibility.

4f: *Triodia wiseana, T.* sp. Shovelanna Hill, *T. angusta* hummock grassland

This broad mapping unit covers a variety of vegetation types occurring on shallow calcareous soils, and is mapped in the south-eastern corner of the main Marandoo lease area as well as along the Dewatering Pipeline Corridor. Calcrete vegetation associations have been found to be highly variable depending on localised drainage patterns and thus the mixture of calcrete present. Mattiske and Associates (1992) described this vegetation type as also supporting emergent mallee eucalypts such as *E. trivalva.* This eucalypt species was recorded as a minor component of only two quadrats sampled as part of this study (MAR23 and MAR38), neither of which were associated with calcrete substrates. The more common species within the area appeared to be *Eucalyptus socialis* subsp. *eucentrica.* For example, as sampled at site MAR27 (Plate 5.13), this vegetation comprised a low woodland of *Eucalyptus socialis* subsp. *eucentrica* over scattered shrubs of *Acacia bivenosa* over a hummock grassland of mixed *Triodia wiseana* and *T. longiceps*. Other associated species included *Abutilon cunninghamii, Acacia bivenosa* (wispy/weeping form), *Cassia notabilis, C. oligophylla* x *helmsii, Codonocarpus cotinifolius, Eragrostis eriopoda, Goodenia muelleriana, Hakea lorea* subsp. *lorea, Heliotropium chrysocarpum, Hibiscus sturtii* var. *campylochlamys, Panicum effusum, Paraneurachne muelleri, Pterocaulon serrulatum, Ptilotus obovatus, Salsola tragus* and *Stackhousia muricata*. This vegetation was typically in Excellent condition. Mattiske and Associates describe this mapping

unit as having affinities with unit 6d, depending on location, and the two are difficult to distinguish on the basis of the information provided.

Plate 5.13: Vegetation unit 4f (MAR27).

4g: *Triodia angusta, T. longiceps* hummock grassland
This vegetation is mapped as occurring broadly over the Dewatering Pipeline Corridor. These areas were not resampled, as most were in Poor condition due to recent fires and considerable disturbance from construction of an access road, powerlines and other earthworks.

5.1.5 Vegetation of Ridges and Erosional Spurs

5a: *Eucalyptus leucophloia* scattered low trees over *Acacia* spp. scattered shrubs over *Triodia brizoides, T. wiseana* hummock grassland
This mapping unit occurred on ridges in the southern half of the main Marandoo lease and comprises vegetation types with an understorey dominated by both *Triodia brizoides* and *T. wiseana*. A single quadrat (MAR29; Plate 5.14) was established in this vegetation, which here comprised scattered trees to a low open woodland of *Eucalyptus leucophloia* subsp. *leucophloia* over scattered tall shrubs of *Acacia pruinocarpa* over an open heath of *Acacia maitlandii* over the hummock grassland of *Triodia wiseana* and *T. brizoides*. Other associated species included *Acacia aneura var. pilbarana, A. atkinsiana, A. hamersleyensis, A. marramamba, A. pyrifolia, A. sibirica, Aristida holathera* var. *holathera, Capparis lasiantha, Cassia glutinosa, Enneapogon polyphyllus, Eremophila forrestii* subsp. *forrestii, Eriachne mucronata, E. pulchella, Gompholobium karijini, Goodenia stobbsiana, Gossypium australe* (Burrup Peninsula Form), *G. robinsonii, Hakea chordophylla, Indigofera ixocarpa, I. monophylla, Keraudrenia velutina* subsp. *elliptica, Polycarpaea holtzei, Ptilotus* spp., *Schizachyrium fragile, Sida pilbarensis* (ferruginous form), *Solanum lasiophyllum* and *Trachymene oleracea* subsp. *oleracea*. This vegetation was typically in Excellent condition.

5b: *Eucalyptus leucophloia* scattered low trees over *Acacia* spp. scattered shrubs over *Triodia wiseana* (*T. brizoides, T.* sp. Shovelanna Hill) hummock grassland
This mapping unit includes those areas of ridge vegetation with an understorey dominated by *Triodia wiseana*, typically also with lesser amounts of *Triodia brizoides* and/or *T.* sp. Shovelanna Hill. It is mapped broadly through the southern half of the main Marandoo lease area, including along the southern boundary of the Residue Storage Facility. Three quadrats were established in this vegetation unit: MAR23, MAR28 (Plate 5.15) and MAR33. While *Acacia maitlandii* is often present in the shrub stratum, this typically provides little cover compared with the *Acacia maitlandii* open heath present higher on the ridges. Other wattle species typically occurring include *Acacia atkinsiana, A. pruinocarpa, A. pyrifolia, A. synchronicia* and *A. tenuissima*. Other associated species included *Capparis lasiantha, Cassia* spp., *Duperreya commixta, Enneapogon caerulescens, E. polyphyllus, Eriachne mucronata, Goodenia cusackiana, Indigofera monophylla, Panicum effusum, Ptilotus calostachyus* var. *calostachyus, P. exaltatus* var. *exaltatus, Solanum sturtianum, Themeda triandra, Trachymene oleracea* subsp. *oleracea* and *Tribulus suberosus*. This vegetation was typically in Excellent condition.

Plate 5.14: Vegetation unit 5a (MAR29).

Plate 5.15: Vegetation unit 5b (MAR28).

5c: *Eucalyptus leucophloia* scattered low trees over *Acacia* spp. scattered shrubs over *Triodia* sp. Shovelanna Hill, (*T. wiseana*) hummock grassland

This mapping unit runs parallel to and down slope of unit 5b, and is mapped broadly through the southern half of the main Marandoo lease. Comparisons of the species present in the quadrats established in this mapping unit (MAR06 (Plate 5.16), MAR07 (Plate 5.17), MAR08, MAR12, MAR15 (Plate 5.18), MAR16, MAR22 (Plate 5.19) and MAR25) with those of 5b (see above) indicate that these vegetation units are floristically very similar and in some locations indiscernible. The typical dominant shrub species included *Acacia atkinsiana, A. bivenosa, A. maitlandii* and/or *A. pruinocarpa*. Other associated species included *Aristida ingrata, Cassia glutinosa, C. luerssenii, C. pruinosa, Corchorus lasiocarpus* subsp. *lasiocarpus, Cymbopogon ambiguus, Duperreya commixta, Eriachne mucronata, Gompholobium karijini, Goodenia stobbsiana, Hibiscus sturtii* var. *campylochlamys, Indigofera monophylla, Keraudrenia velutina* subsp. *elliptica, Panicum effusum, Paraneurachne muelleri, Ptilotus calostachyus* var. *calostachyus, P. exaltatus* var. *exaltatus, Solanum lasiophyllum, S. sturtianum, Trachymene oleracea* subsp. *oleracea* and *Trichodesma zeylanicum* var. *zeylanicum*. This vegetation was typically in Excellent condition.

Plate 5.16: Vegetation unit 5c (MAR06).

Plate 5.17: Vegetation unit 5c (MAR07).

Plate 5.18: Vegetation unit 5c (MAR15).

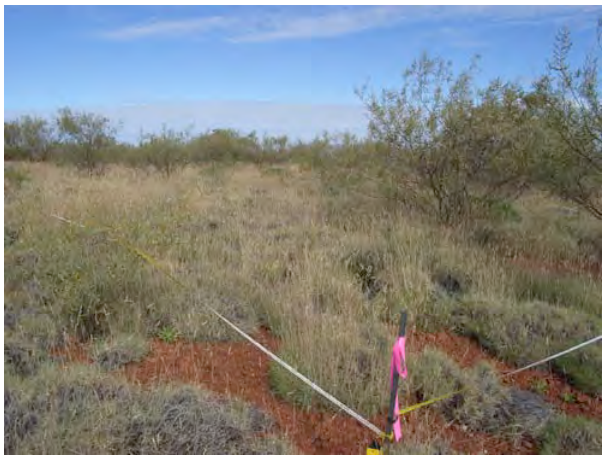

Plate 5.19: Vegetation unit 5c (MAR22).

5d: *Eucalyptus gamophylla* scattered low mallees over *Acacia* spp. scattered tall shrubs over *Triodia* sp. Shovelanna Hill, *(Triodia wiseana)* hummock grassland

This mapping unit occurred mainly on lower foothills, primarily along the southern and eastern sides of the main Marandoo lease. Site MAR09 (Plate 5.20) was established within this vegetation unit on the lower slopes, and while there were no mallee eucalypts within the quadrat itself, *E. gamophylla* was present in the surrounds. Site MAR21 (Plate 5.21) was established on the crest of a tall hill, and although it shared the dominant species characteristic of the mapping unit, it may not be typical of this broad vegetation type. Both sites had a small component of *T. wiseana* in the hummock grassland layer. Other associated species included *Acacia ancistrocarpa, A. atkinsiana, Gompholobium karijini, Goodenia stobbsiana, Keraudrenia velutina* subsp. *elliptica, Ptilotus calostachyus* var. *calostachyus* and *Solanum lasiophyllum*. This vegetation was typically in Excellent condition.

Plate 5.20: Vegetation unit 5d (MAR09).

Plate 5.21: Vegetation unit 5d (MAR21).

5e: Mixed community supporting a range of structural formations from *Acacia aneura* low woodlands to sheer rock faces with *Astrotricha hamptonii* scattered shrubs to *Eriachne mucronata* open grasslands

This vegetation unit is mapped within the southern half of the main Marandoo lease area from rocky ledges and cliff faces on the breakaways of the ranges. Two quadrats were established in this unit: MAR10 and MAR18 (Plate 5.22). The vegetation at these sites comprised a low open woodland of *Eucalyptus leucophloia* over tall shrublands dominated by species such as *Acacia hamersleyensis, A. maitlandii, A. marramamba, A. pruinocarpa* and *Gossypium robinsonii*. The ground cover comprised a hummock grassland dominated by the spinifex species present on the surrounding hillslopes, interspersed with scattered tussock grasses to an open tussock grassland of *Eriachne mucronata*. The species recorded at sites MAR10 and MAR18 were similar overall to those recorded in quadrats mapped within unit 5c (see above). The major difference between this unit and other ridge and erosional spur units was the presence of species such as *Astrotricha hamptonii, Corymbia ferriticola subsp. ferriticola, Nicotiana benthamiana* and *Rhodanthe*

margarethae, which are restricted to rocky breakaway and gully habitats. Other associated species included *Abutilon otocarpum* (acute leaf form), *Bulbostylis barbata, Capparis lasiantha, Cassia glutinosa, Cleome viscosa, Duperreya commixta, Dysphania rhadinostachya, Eremophila magnifica* subsp. *magnifica, Jasminum didymum* subsp. *lineare, Pterocaulon serrulatum, Ptilotus* spp., *Rhagodia eremaea, Themeda triandra* and *Trachymene oleracea* subsp. *oleracea.* This vegetation was typically in Excellent or Very Good condition, with the main disturbance factor comprising scattered weeds (mainly **Bidens bipinnata*).

5f: *Acacia aneura* low woodland to woodland on rocky ledges and upper slopes of ranges
Relatively small pockets of this vegetation unit are found in the southern half of the Marandoo lease area (including the Residue Storage Facility), occurring amongst the crests of gullies and rocky breakaways. This vegetation differs from the other units on the ridges and erosional spurs primarily in the dense cover of Mulga (*Acacia aneura*). Much of this vegetation unit had been burnt prior to the 2007/2008 field survey work. Site MARA05 (Plate 5.23) was located within an unburnt area in the main Marandoo lease, and comprised a low open forest of *Acacia aneura* with scattered *Eucalyptus leucophloia* subsp. *leucophloia* over an open shrubland of mixed species including *Eremophila magnifica* subsp. *magnifica, Acacia marramamba, Dodonaea pachyneura and D. petiolaris.* At ground level there was an open hummock grassland of *Triodia brizoides,* with scattered *Eriachne mucronata* tussock grasses. Other associated species included *Acacia pruinocarpa, A. rhodophloia, Aristida contorta, Astrotricha hamptonii, Capparis lasiantha, Cassia notabilis, Cheilanthes sieberi* subsp. *sieberi*, *Cymbopogon ambiguus, Digitaria ammophila, Duperreya commixta, Enneapogon caerulescens, Eremophila jucunda* subsp. *pulcherrima*, *Eremophila latrobei* subsp. *filiformis*, *E. petrophila* subsp. *petrophila, Grevillea berryana, Mukia maderaspatana, Perotis rara, Psydrax suaveolens*, *Sida* spp., *Solanum ferocissimum, S. phlomoides, Spartothamnella teucriiflora* and *Tribulus suberosus.* This vegetation was typically in Excellent or Very Good condition, with the main disturbance factor comprising scattered weeds (mainly **Bidens bipinnata*).

Plate 5.22: Vegetation unit 5e (MAR18).

Plate 5.23: Vegetation unit 5f (MARA05).

5g: *Eucalyptus gamophylla* scattered low mallees over *Triodia wiseana* hummock grassland
There is a single small area of this vegetation mapped near the southern boundary of the main Marandoo lease area. This vegetation was not resampled during the 2007/2008 field work due to its remoteness from the main mine area, but is considered likely to be in Excellent condition due to its inaccessibility.

5h: *Triodia wiseana* hummock grassland with mixed *Acacia* spp. emergent shrubs
This well represented vegetation unit is scattered throughout the main Marandoo lease (including within the Residue Storage Facility), and also occurs on the low stony hills in the western section of the Operations Camp. Sites MAR03 (Plate 5.24) and MARA08 were established within this vegetation unit, while site MAR04 represents an interzone between units 5h and 1c. The dominant overstorey shrub species vary with location (eg. *Acacia ancistrocarpa* at MAR03 versus *A. maitlandii* at MARA08), however the hummock grassland is consistently dominated by *Triodia wiseana*. Scattered low trees of *Eucalyptus leucophloia* subsp. *leucophloia* are often present.

Other associated species include *Acacia bivenosa, A. pruinocarpa, A. tenuissima, Amphipogon sericeus, Aristida holathera* var. *holathera, Cassia* spp., *Cymbopogon ambiguus, Eremophila latrobei* subsp. *filiformis, Eriachne mucronata, Gomphrena kanisii, Paraneurachne muelleri, Ptilotus* spp. and *Solanum sturtianum*. This vegetation was typically in Excellent condition.

Plate 5.24: Vegetation unit 5h (MARA03).

5.1.6 Vegetation of Low Foothills and Escarpments

6a: Mixed *Triodia* spp. hummock grassland on upper slopes and ridges of small foothills and escarpments

This mapping unit is very broadly described and could cover a variety of vegetation types. Stands are mapped through the southern half of the main Marandoo lease, including an area surrounding the Collector Tanks within the rail loop (at the western end of the Dewatering Bore Drilling area; Map 3, Appendix 2). A single quadrat (site MAR37; Plate 5.25) was located within the area mapped as 6a. The vegetation at this site on a ridge crest comprised a low woodland of *Acacia aneura* var. *pilbarana* with *Eucalyptus leucophloia* subsp. *leucophloia* over an open shrubland dominated by *Petalostylis labicheoides* and *Acacia maitlandii* over a closed hummock grassland of *Triodia brizoides* and *T. wiseana*. This is not dissimilar to vegetation unit 5a. Other associated species include *Acacia tenuissima, A. xiphophylla, Anthobolus leptomerioides, Aristida contorta, Bulbostylis barbata, Capparis lasiantha, Cassia* spp., *Cymbopogon ambiguus, Dodonaea pachyneura, D. petiolaris, Dysphania rhadinostachya, Enneapogon caerulescens, E. polyphyllus, Eremophila cuneifolia, E. latrobei* subsp. *filiformis, Eriachne mucronata, Gompholobium karijini, Grevillea wickhamii* subsp. *hispidula, Indigofera monophylla, Keraudrenia velutina* subsp. *elliptica, Mukia maderaspatana, Panicum effusum, Paraneurachne muelleri, Perotis rara, Polycarpaea holtzei, P. longiflora, Psydrax suaveolens, Ptilotus* spp., *Rhagodia eremaea, Sida* spp., *Solanum ferocissimum, S. lasiophyllum* and *Trichodesma zeylanicum* var. *zeylanicum.* This vegetation was typically in Excellent condition.

6b: Mixed *Acacia aneura, Acacia* spp. low woodland to woodland on upper slopes of low foothills

This vegetation unit is limited within the study area to the crests of low foothills towards the southern boundary of the main Marandoo lease area. Mattiske and Associates (1992) noted that this unit is strongly influenced by local site conditions and there is often overlap with 5f. Site MAR32 (Plate 5.26) was established on a hill crest and comprised a low woodland of *Acacia aneura* var. *aneura* with scattered *Eucalyptus leucophloia* subsp. *leucophloia* over a shrubland of *Petalostylis labicheoides* over an open hummock grassland of *Triodia wiseana*. Other associated species include *Acacia atkinsiana, A. bivenosa, A. dictyophleba, A. pruinocarpa, A. tenuissima, Cassia* spp., *Digitaria ammophila, D. brownii, Dodonaea coriacea, Enneapogon caerulescens, E. polyphyllus, Eriachne mucronata, Eulalia aurea, Gomphrena kanisii, Goodenia stobbsiana, G. triodiophila, Hakea lorea* subsp. *lorea, Haloragis gossei, Maireana planifolia, M. villosa, Panicum effusum, Paraneurachne muelleri, Psydrax latifolia, Pterocaulon sphacelatum, Ptilotus* spp., *Salsola tragus, Sida* spp., *Solanum lasiophyllum, Trachymene oleracea* subsp. *oleracea* and *Trichodesma zeylanicum* var. *zeylanicum.* This vegetation was typically in Excellent condition.

Plate 5.25: Vegetation unit 6a (MAR37).

Plate 5.26: Vegetation unit 6b (MAR32).

6c: *Acacia aneura* low woodland to woodland on breakaways of low foothills

This vegetation unit has a limited area of representation, occurring on the breakaways of low foothills orientated north-west to south-east close to the southern border of the main Marandoo lease. Mattiske and Associates (1992) note that there is some overlap with units 5f and 6b. Site MAR38 (Plate 5.27) was established on the slope of a medium ridge and comprised a low closed forest of *Acacia aneura* var. *pilbarana* with scattered *Eucalyptus trivalva* over scattered low shrubs of *Dipteracanthus australasicus* subsp. *australasicus* over a hummock grassland of *Triodia wiseana* and *T. longiceps*. A scattered to very open tussock grassland of *Eriachne mucronata* is also typically present within this vegetation type. Other associated species include *Abutilon cryptopetalum, A. leucopetalum, A. otocarpum* (acute leaf form), *Acacia aneura* var. *intermedia, A. pruinocarpa, A. tetragonophylla, A. xiphophylla, Amphipogon sericeus, Anthobolus leptomerioides, Aristida* spp., *Boerhavia coccinea, Capparis lasiantha, Cassia* spp., *Cheilanthes sieberi* subsp. *sieberi, Dodonaea petiolaris, Enneapogon caerulescens, E. polyphyllus, Eremophila latrobei* subsp. *filiformis, E. longifolia, Hakea lorea* subsp. *lorea, Hibiscus* spp., *Jasminum didymum* subsp. *lineare*, *Maireana planifolia, M. villosa, Petalostylis labicheoides, Psydrax suaveolens, Ptilotus exaltatus* var. *exaltatus, P. obovatus, Rhagodia eremaea, Scaevola acacioides, Sida* spp., *Solanum ferocissimum, S. lasiophyllum, Spartothamnella teucriiflora* and *Trichodesma zeylanicum var. zeylanicum.* This vegetation was typically in Excellent or Very Good condition, with the main disturbance factor comprising scattered weeds (mainly **Bidens bipinnata*).

6d: *Eucalyptus trivalva, E. socialis* low mallee woodland with pockets of *Triodia angusta, T. wiseana* hummock grassland on shallow calcrete soils

This mapping unit has a limited extent, occurring in pockets near the southern edge of the main Marandoo lease area. Depending on location, the mixed low mallee woodland may also include *Eucalyptus repullulans*, and the hummock grassland may include *Triodia longiceps*. For example, site MAR31 (Plate 5.28) was established in this mapping unit, and comprised a low open mallee woodland of *Eucalyptus repullulans* over scattered shrubs of *Melaleuca eleuterostachya* over an open hummock grassland dominated by *Triodia wiseana* and *T. longiceps*. Other associated species include *Acacia ancistrocarpa, A. bivenosa, A. synchronicia, A. tetragonophylla, Brachyachne prostrata, Capparis lasiantha, Cymbopogon obtectus, Enneapogon polyphyllus, Heliotropium chrysocarpum, Lepidium pedicellosum, Maireana georgei, M. villosa, Panicum effusum, Ptilotus exaltatus* var. *exaltatus, Salsola tragus, Streptoglossa decurrens* and *Trichodesma zeylanicum* var. *zeylanicum*. This vegetation was typically in Excellent condition. Mattiske and Associates describe this mapping unit as having affinities with unit 4f, depending on location, and the two are difficult to distinguish on the basis of the information provided.

Plate 5.27: Vegetation unit 6c (MAR38).

Plate 5.28: Vegetation unit 6d (MAR31).

5.2 Vegetation Condition in the Various Study Areas

With the exception of areas in close proximity to the existing mine and associated infrastructure such as the rail line, the vegetation of the MMP2 project area is generally in Very Good to Excellent condition (see Appendix 3). Where present, weeds typically occurred as scattered individuals, with only occasional dense infestations recorded. Sections of the Mulga vegetation on the clayey flats show signs of repeated burns, however these areas are still considered to be in Good condition overall. Each of the component study areas is discussed below.

5.2.1 Main Marandoo Lease

The vegetation types of the Marandoo Ridge and areas to the south (see Map 3, Appendix 2) were in Very Good to Excellent condition: the stony hills landforms of these areas are not particularly susceptible to weed invasion, and the remoteness of the areas south of the ridge probably also renders these areas less likely to be disturbed. Large sections of the ridge had been burnt, and numerous individuals within the large population of the Priority 4 flora species *Eremophila magnifica* subsp. *magnifica* (see Section 6.2.2) were observed to be resprouting. The stony plains on the northern side of the Marandoo Ridge (Map 3, Appendix 2) were also typically in Good to Very Good condition, showing signs of weed invasion mainly in susceptible habitats (eg. in Mulga vegetation and along creeklines). Areas within and surrounding the immediate Marandoo mine project area were typically in Poor to Good condition, having been impacted by clearing and earthworks for development of the mine and various infrastructure areas, including the rail (Plate 5.29), airstrip, borrow pits, waste dumps, historic camps, offices (Plate 5.30), pipelines, powerlines, access roads and numerous exploration drilling tracks. The communications tower hill, although very close to existing infrastructure within the rail loop and being impacted by dust from the rail loadout, still supports vegetation in Very Good condition. Many of the old borrow pits and exploration tracks in the eastern side of the main mine lease have been ripped and rehabilitated quite successfully.

Plate 5.29: Vegetation in Good condition within the rail loop.

Plate 5.30: Vegetation in Poor condition from physical disturbance and significant weed invasion.

5.2.1.1 Residue Storage Facility

The area of the Residue Storage Facility, to the south-west of the Marandoo Mine rail loop, was already considerably disturbed from historic earthworks for infrastructure including an airstrip, waste dump and various access tracks. This area had also been recently burnt. Three weed species occurred as scattered individuals, mainly associated with the dense Mulga vegetation through the drainage area along the western boundary. The condition of the vegetation overall was considered to range from Poor (on the flats) to Very Good (on the hills and within the drainage area).

5.2.1.2 Dewatering Bore Drilling Area

This area comprises an approximately east-west corridor to accommodate a pipeline and access track, along with four approximately north-south corridors running to proposed dewatering bores (Map 3, Appendix 2). The east-west section of the study area has been impacted by a topsoil stockpile (Plate 5.31), mine pit flood protection bund (Plate 5.32), numerous tracks, sumps and the railway formation just to the north. The raised structures appear to have had some impact on surface drainage and possibly the health of the vegetation in addition to the direct effects of clearing. Vegetation towards the eastern end of this study area is in Very Good to Excellent condition, particularly where access is restricted, however it is generally quite fragmented (Plate 5.33 and Plate 5.34). Vegetation between the north-south extension lines is generally in Poor to Good Condition, having been heavily impacted by infill exploration drilling at 50 m intervals and associated drillpads and sumps. While several weeds were recorded from this study area, there were no major infestations.

Plate 5.31: Topsoil stockpile in the western section of the Dewatering Bore Drilling area (looking south). Vegetation in Poor Condition.

Plate 5.32: Mine pit flood protection bund (looking east) towards the western end of the Dewatering Bore Drilling area. Vegetation in Poor Condition.

Plate 5.33: Pipeline and sump near 616656 E and 7496585 N (looking south). Vegetation in Very Good Condition.

Plate 5.34: Vegetation in Very Good Condition looking south from the access track at 617067 S and 7496592 E. Sumps and access tracks continue through this area every 50 metres.

5.2.2 Dewatering Infrastructure

The Dewatering Pipeline Corridor follows an existing rail corridor for the vast majority of its length, following the Marandoo access road for some 24 km to the west-north-west (Maps 2 and 3, Appendix 2), then deviating to the north-east along a smaller access track for some 7.5 km before terminating at the Terminal Tank (Map 1, Appendix 2). Vegetation through this area had been repeatedly burnt and was also considerably disturbed from the existing rail and road structures, both in terms of physical disturbance from earthworks and weed invasion: condition was ranked as Poor to Good. Fragmented patches of vegetation on the east side of the smaller north-east running access track were in Very Good to Excellent condition, particularly the vegetation within the potential hill deviation loop and rocky creekline vegetation south of a major creek crossing (Map 1, Appendix 2). A powerline corridor with cleared access track runs parallel to and west of this smaller access track for much of its length.

5.2.3 Southern Fortescue Borefield

The Southern Fortescue Borefield (see Map 1, Appendix 2) is in a relatively low-lying area that has been used extensively for grazing. It is likely that in poor seasons this area has provided more feed and thus been subjected to higher stocking rates than the higher ground surrounding the borefield. Grazing has resulted in some minor erosion on some of the flowlines. Small patches of Mulga within the Southern Fortescue Borefield have died and no regeneration has taken place; this may be due to intense fires or grazing. Two sinkhole areas are located within the Southern Fortescue Borefield, indicating that the tree deaths may be related.

There is minimal vehicular access in the Southern Fortescue Borefield, restricted to a few north-south running tracks on the eastern side that provide access to the bore infrastructure and powerline corridor. Other historical tracks have naturally rehabilitated to the extent that they are not readily accessible by vehicle. Weeds such as **Bidens bipinnata* are ubiquitous and abundant throughout the Mulga vegetation and flowline habitats within the Southern Fortescue Borefield, however this species is common in similar habitats through the Pilbara and does not appear on its own to cause exclusion of native species. Other common weed species such as **Malvastrum americanum* are also present but not to the extent that they appear to be out-competing native species.

While quadrat data for the Southern Fortescue Borefield indicates that the vegetation is in Very Good condition, overall the condition is described as Good to Poor. The flowlines and Mulga vegetation are in relatively Poor condition and on a superficial level appear even more so because of the "bare" ground in the Mulga intergroves, which shows substantial growth only in

very good seasons. The rest of the vegetation in the Southern Fortescue Borefield is in Good to Very Good condition: although subjected to numerous fires prior to the April 2008 survey, the basic vegetation structure is intact and still quite species rich as indicated from quadrat data.

A stock-yard along the access corridor south-west of the Southern Fortescue Borefield showed considerable degradation from grazing and weed invasion and would be considered in Very Poor to Completely Degraded condition.

5.2.4 Operations Camp

With the exception of areas in close proximity to the existing rail line, the vegetation of the Operations Camp study area was generally in Very Good to Excellent condition. Where present, weeds typically occurred as scattered individuals, with only occasional dense infestations recorded. Some sections of the vegetation on the stony plains showed signs of repeated burns, however these areas were still considered to be in Good condition overall. The major creek line flowing through this area is remarkably relatively weed free. Clearing for the camp is being assessed as part of a separate environmental impact assessment process; this baseline information is provided to allow for impacts and management of activities other than clearing associated with the MMP2 project to be assessed in the PER (see Rio Tinto 2008).

5.3 Conservation Significance of the Vegetation Mapping Units

With the exception of areas in close proximity to the existing mine and associated infrastructure such as the rail line, the vegetation of the MMP2 project area is generally in Very Good to Excellent condition (see Appendix 3). All of the mapping units therefore have conservation value as relatively intact examples of native vegetation for the area.

None of the vegetation types represent Threatened Ecological Communities as listed under the Federal *Environment Protection and Biodiversity Conservation Act 1999* (see Section 3.2.5.1) or as listed by the State DEC (Section 3.2.5.2). Similarly, none are listed as Priority Ecological Communities by DEC (Section 3.2.5.3).

Unit 2d, comprising Blunt-budded River Red Gum (*Eucalyptus camaldulensis* var. *obtusa*) woodlands in major creeklines, which was mapped by Mattiske and Associates (1992) for the Marandoo locality would be considered to be of High significance, as this vegetation is typically species rich and occurs in the major drainage systems in the area. A single stand of this unit mapped within the Dewatering Pipeline Corridor by Mattiske and Associates (1992) was re-attributed as unit 2e on the basis of the April 2008 survey data, as the dominant tree species in this area comprises Coolibahs (*E. victrix*) (see Section 5.1.2). There are therefore no confirmed areas of unit 2d within the MMP2 project area, and no other units of High conservation significance.

Several of the mapping units are considered to be of Moderate conservation significance:

- Unit 1a comprises Mulga and associated vegetation of broad drainage areas and basins: this vegetation is species rich and supports some restricted taxa, including some Priority flora species. This unit is mapped through the Marandoo lease area, Southern Fortescue Borefield, and in a small stand towards the eastern end of the Dewatering Pipeline Corridor (Maps 1 and 3, Appendix 2). Based on the current development proposal, only a small proportion (less than 10%) of the mapped extent of this vegetation within the study areas will be cleared, and it should be noted that this vegetation also extends broadly outside the study area (including in the adjacent Karijini National Park).
- Units 2a, 2b and 2c comprise Mulga vegetation in the largest flowlines, which are of particular interest for the same factors mentioned above. These vegetation units are distributed throughout the study area (see Maps 1 to 3 in Appendix 2). Based on the current development proposal, approximately 15%, 48% and 36% of the mapped extent of the respective vegetation units within the Marandoo study area will be cleared, however all three

units extend more broadly through the locality (including in the adjacent Karijini National Park) and Hamersley subregion.

- Unit 2e comprises Coolibah (*Eucalyptus victrix*) woodlands in creeklines, and represents important drainage system features for the area, which are also likely to be species rich and potentially support restricted taxa. This unit is mapped within the access corridor to the Operations Camp, and along the Dewatering Pipeline Corridor (Maps 1 to 3, Appendix 2). This vegetation also extends more broadly through the locality (including in the adjacent Karijini National Park) and through the Hamersley subregion. Based on the current development proposal, this unit will not be impacted.
- Unit 4a comprises dense Mulga woodland of the clayey flats, which is species rich and potentially supports restricted taxa. A small area of this vegetation unit is mapped within the Marandoo lease and along the Dewatering Pipeline Corridor (Maps 1 to 3, Appendix 2). Only 6% of the mapped extent of this vegetation unit within the study area will be cleared based on the current development proposal.
- Units 5e, 5f and 6c comprise vegetation of breakaways and cliff habitats; these landforms have a small area of representation and support habitat restricted taxa. These units are mapped only through the southern section of the Marandoo lease area (Map 3, Appendix 2). Based on the current development proposal, approximately 30% of unit 5f will be cleared, and the remaining two units will not be impacted. All three units occur more broadly through the Hamersley subregion (including in the Karijini National Park).
- Units 4f and 6d comprise vegetation of calcretes; this substrate has a small area of representation and potentially supports restricted taxa. These units are mapped from the main Marandoo lease area through to the Dewatering Pipeline Corridor (Maps 2 and 3, Appendix 2). Based on the current development proposal, neither of these units will be impacted.

The remainder of the mapping units are considered to be of Low conservation significance, representing units which are likely to be widespread and well-represented in the locality and more broadly through the Hamersley subregion.

6.0 Flora of the Marandoo Study Areas

6.1 Overview of Flora

6.1.1 Species Richness

Based on the data presented in Mattiske & Associates (1992) together with the data from the 2007/2008 field work (Biota, this study), a total of 537 native vascular flora species from 176 genera and 60 families (see Appendix 5) has been recorded in the Marandoo study area (as shown on the mapping in Appendix 2). In addition, 20 weed species from 18 genera and 11 families have been recorded (see Section 6.3). It should be noted that the total number of native taxa may be a slight over-estimate, as there is likely to be some overlap between species named during the 2007/2008 survey work and species designated only to species or genus level in Mattiske and Associates (1992).

Species richness tends to vary on a logarithmic scale with the size of the study area, and is also affected by the shape of the study area (long linear corridors will tend to intersect a broader range of habitats than more regular rectangular polygons). The following comparisons of relative species richness are provided to put the results of the combined study areas at Marandoo (over 5,900 ha) into perspective:

- 334 taxa of native vascular flora from 141 genera and 47 families were recorded from the Mt Lionel rail corridor, 60 km to the north-west of the Marandoo mine. This area was considerably smaller in size than the current study area at 418 ha, and was intensively sampled during a single good season (Biota in prep.).
- 364 native species from 142 genera and 53 families have been recorded from the White Quartz Road study area, the easternmost end of which is approximately 51 km to the west of the Marandoo mine. This area was less than half the size of the current study area at 2,303 ha, and was intensively sampled, including in good seasons (Biota 2007).
- 466 native species from 168 genera and 56 families have been recorded from the Brockman Syncline 4 area, approximately 90 km west of the Marandoo mine. This area was much larger in size than the current study area at 12,757 ha, and was intensively sampled over a number of seasons (Biota unpubl. data), but includes fewer habitats than the study areas at Marandoo.

Even taking into account the probable slight over-estimation mentioned above, the number of species (and to a lesser extent, genera) recorded from Marandoo thus appears to be higher than would be expected for a study area of this size in this locality (see Figure 6.1). This is likely to reflect the variety of habitats encompassed by the study area, including extensive areas of Mulga vegetation on clayey substrates, which are generally recognised to be species rich.

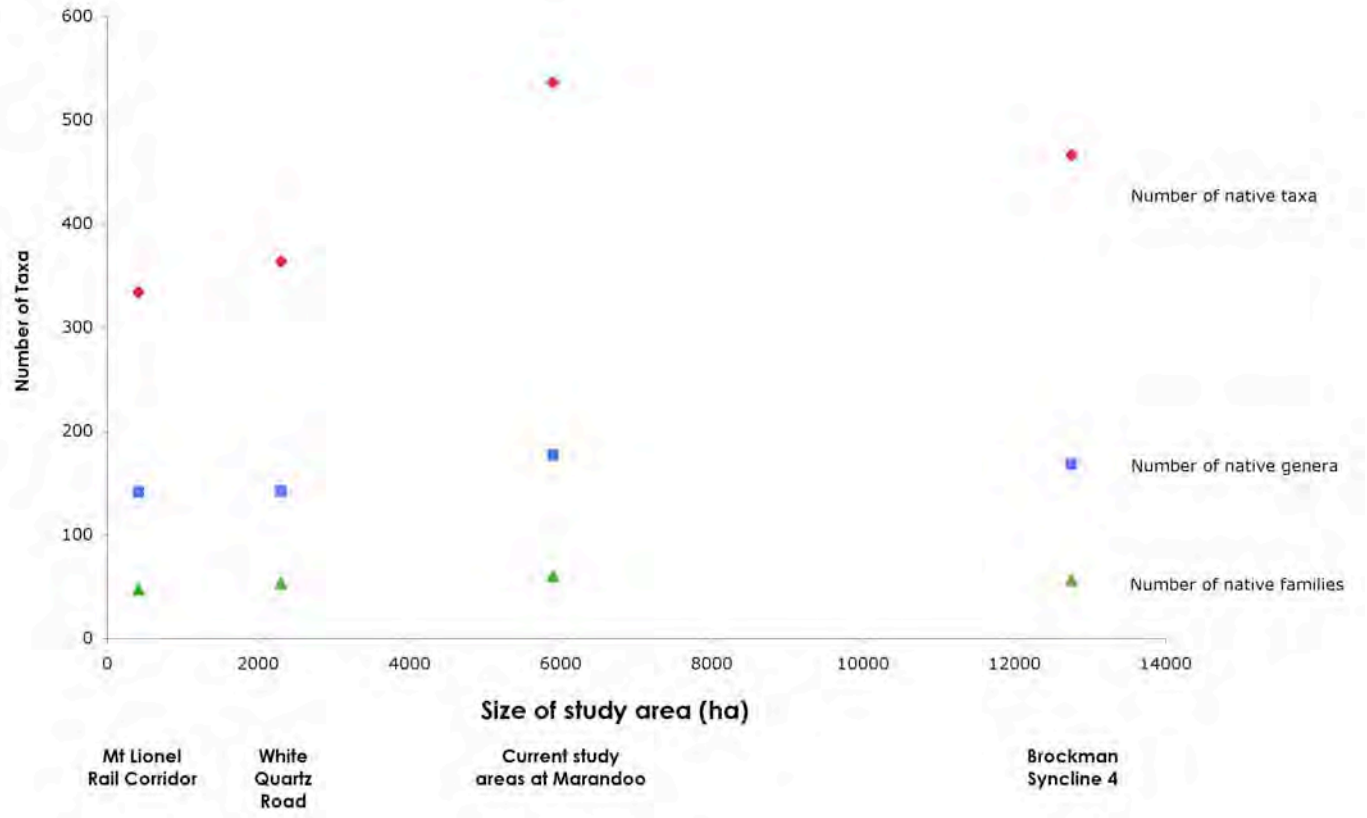

Figure 6.1: Number of native taxa, genera and plant families recorded from the current study areas at Marandoo and three comparison areas of varying sizes.

6.1.2 Dominant Plant Groups

The families and genera with the greatest number of native taxa within the combined study areas assessed at Marandoo are shown in Table 6.1 and Table 6.2 respectively. These families and genera are those that are predominant in the vegetation of the Pilbara, and that usually have most representatives on flora lists from this region, due to their prominence in the Eremaean flora. Some of the families (eg. the Amaranthaceae, Malvaceae and Poaceae) are more species rich in the Northern flora and poorer in the Southern flora, while others (such as the Mimosaceae and Papilionaceae) are abundant in all three provinces. In contrast to these plant groups with many representatives, 19 families and 84 genera recorded0 from the study areas are represented by only a single native species (Appendix 5).

A relatively large number of grasses (Poaceae) and daisies (Asteraceae) was recorded for the size of the study area, which is likely to reflect the presence of substantial areas of clayey plains supporting Mulga vegetation, which typically contain abundant species from these families.

On the whole the species were typical of this section of the Hamersley subregion, however the record of *Amaranthus* sp. A Kimberley Flora (C.A. Gardner s.n. PERTH 00326518) represents a range extension from the Kimberley bioregion, and the record of *Sporobolus blakei* is the first for the Pilbara bioregion.

Table 6.1: Plant families with the greatest number of native species within the study areas at Marandoo.

Family	No. of Native Species
Poaceae (grass family)	79
Malvaceae (hibiscus family)	52
Mimosaceae (wattle family)	46
Asteraceae (daisy family)	33
Papilionaceae (pea family)	30
Amaranthaceae (mulla-mulla family)	29
Caesalpiniaceae (cassia family)	25
Goodeniaceae (goodenia family)	21
Chenopodiaceae (saltbush, bluebush family)	17
Myoporaceae (emu-flower, poverty bush family)	14
Myrtaceae (eucalypt family)	14
Euphorbiaceae (spurge family)	13
Convolvulaceae (morning glory family)	12
Solanaceae (tomato family)	11

Table 6.2: Genera with the greatest number of native species within the study areas at Marandoo.

Genus	No. of Native Species
Acacia (wattles)	46
Cassia (cassias)	24
Sida (sidas)	22
Ptilotus (mulla-mullas)	17
Abutilon (lantern-flowers)	16
Eremophila (emu-flowers, poverty bushes)	14
Goodenia (goodenias)	14
Hibiscus (hibiscus)	12
Triodia (spinifex)	11
Aristida (three awn grasses, kerosene grasses)	10
Euphorbia (spurges)	10
Eucalyptus (eucalypts)	9
Eragrostis (lovegrasses, wanderrie grasses)	8
Indigofera (indigo peas)	7
Solanum (native tomatoes)	7
Tephrosia (flinders river poison)	7

6.2 Flora of Conservation Significance

The framework under which conservation significance is assigned to WA flora species is presented in Appendix 1.

6.2.1 Declared Rare Flora Recorded from the Study Area

No Declared Rare Flora species have been recorded from Marandoo to date. Mountain Thryptomene (*Thryptomene wittweri*) would not be expected to occur due to a lack of suitable habitat (high altitude mountain tops). Suitable habitat for Hamersley Lepidium (*Lepidium catapycnon*) occurs throughout the lease area and the additional survey areas, however this species has not been recorded from the Marandoo locality to date, despite relatively intensive sampling both at Marandoo and in the surrounding Karijini National Park.

6.2.2 Priority Flora Recorded from the Study Area

Five Priority flora were recorded from the study areas at Marandoo during the 2007/2008 survey work, a sixth species has been previously recorded from the flats north of the mine (Pilbara Iron 2006a), and a seventh species was recorded during the 1991 survey from a collection locality within the lease area which remains outside of the current cleared mine areas (Mattiske and Associates 1992). Up to four additional Priority species appear to have been recorded from the Marandoo lease area from locations which probably no longer exist (Mattiske and Associates 1992). All of these species had been recorded from other locations in the Hamersley subregion in suitable habitats. Each species is briefly described below and location details provided where possible.

- *Calotis latiuscula* (Priority 1)

This annual daisy was recorded from two locations within the current Marandoo study areas (Table 6.2): once along the Dewatering Pipeline Corridor (Map 1, Appendix 2), and once in the Operations Camp area (Map 2, Appendix 2). Both records were associated with Mulga vegetation. *C. latiuscula* has a disjunct distribution, extending over a range of >150 km within the Hamersley subregion of the Pilbara, and also occurring >900 km east in the Central Ranges bioregion. This species is probably under-collected due to its annual growth form, and is likely to be more widespread through the Marandoo area than the current records indicate.

Table 6.2: Locations of *Calotis latiuscula* records in the Marandoo study areas.

Location	Easting (WGS84, Zone 50)	Northing (WGS84, Zone 50)	Density
MARA04 (Dewatering Pipeline Corridor)	595331	7507421	scattered
MARA07 (Operations Camp)	604847	7501468	scattered

- *Goodenia lyrata* (Priority 1)

This species was recorded four times in 2002 from the Marandoo Below Water Table Evaluation Drilling – Eastern Area (see Pilbara Iron 2006a; Table 6.4). All of the records were from the stony plains on the northern side of the Marandoo Ridge, from areas with clayey substrates (see Map 3, Appendix 2). These locations lie within the current proposed Marandoo pit expansion area, and will be cleared. Although this species has a relatively broad range (extending some 400 km east into the Gibson Desert bioregion and 600 km south into the Murchison bioregion; see Section 3.2.6.3), it is infrequently recorded, and the records from the mining lease are thought to represent the only records from the Marandoo locality (Emil Thoma, Pilbara Iron, pers. comm. 2008).

Table 6.3: Locations of *Goodenia lyrata* records in the Marandoo lease area (data from Pilbara Iron 2006a).

Location	Easting (WGS84, Zone 50)	Northing (WGS84, Zone 50)
Opportunistic (Marandoo lease)	620220	7495160
Opportunistic (Marandoo lease)	621340	7494670
Opportunistic (Marandoo lease)	621540	7494620
Opportunistic (Marandoo lease)	622340	7493920

- *Josephinia* sp. Marandoo (M.E. Trudgen 1554) (Priority 1)

An unidentified species of *Josephinia* was listed as being recorded from the Marandoo lease area by Mattiske and Associates (1992), and this specimen was subsequently assigned the phrase-name *Josephinia* sp. Marandoo (M.E. Trudgen 1554). This taxon was also recorded from the Operations Camp area during 2008 (Table 6.4, Map 2 of Appendix 2). *Josephinia* species are annual herbs which are only recorded in very good seasons due to their habit. There are vouchered specimens of this Priority 1 taxon from a small number of locations over a relatively broad range through the central Pilbara

.

Table 6.4: Location of *Josephinia* sp. Marandoo (M.E. Trudgen 1554) record in the Marandoo study areas.

Location	Easting (WGS84, Zone 50)	Northing (WGS84, Zone 50)	Density
MARA07 (Operations Camp)	604847	7501468	scattered

- *Lobelia heterophylla* subsp. Pilbara (R. Meissner & Y. Caruso 1) (Priority 1)

There is a single vouchered collection of this species from near the southern boundary of the main Marandoo lease area, 800 m south of the current mine pits (see Section 3.2.6.3; Map 3 of Appendix 2). An unidentified species of *Lobelia* was also recorded from the "Manganese Gorge" area at Marandoo and in the North West Transport Corridor by Mattiske and Associates (1992). Given the vouchered location mentioned above, it is quite probable that this entity refers to the Priority 1 species, although it could also refer to the common *L. quadrangularis*. The vouchered location is well removed from the current development areas and should not be impacted.

- *Rhagodia* sp. Hamersley (M. Trudgen 17794) (Priority 1)

This tall shrub species was recorded five times during the study: there were three records from the main Marandoo lease, one record from the Dewatering Bore Drilling area and one record from the Dewatering Pipeline Corridor (Table 6.5). The locations at MAR24 and in the rail loop are outside the proposed development areas. This species has only recently been added to the Priority flora listing, and while it is very poorly vouchered, we do not consider it uncommon. This species is routinely collected in Mulga (*Acacia aneura*) and Snakewood (*A. xiphophylla*) vegetation in the Hamersley subregion and the southern Chichester subregion, and has been recorded from various study areas including Nammuldi and the Mt Lionel rail corridor (both near Brockman 2, approximately 60 km north-west of Tom Price), the proposed Wildflower rail construction camp (55 km south-east of Marandoo), West Angelas, Juna Downs, Yandi, and various points along the Fortescue Metals Group Stage A and Stage B rail corridors (over 100 km north of Newman) (Biota, ME Trudgen, unpubl. data).

Table 6.5: Locations of *Rhagodia* sp. Hamersley (M. Trudgen 17794) records in the Marandoo study areas.

Location	Easting (WGS84, Zone 50)	Northing (WGS84, Zone 50)	Density
MAR24 (Marandoo lease)	624786	7489404	scattered
MAR30 (Marandoo lease)	620359	7494900	scattered
Opportunistic within rail loop (Marandoo lease)	coordinates not recorded but estimated at 614505	coordinates not recorded but estimated at 7496980	scattered
Opportunistic (Dewatering Bore Drilling Area)	coordinates not recorded	coordinates not recorded	scattered
MARA04 (Dewatering Pipeline Corridor)	595331	7507421	scattered

- *Indigofera ixocarpa* (Priority 2)

This low to moderate-height shrub was recorded from three locations within the Marandoo lease area during the 2007/2008 survey work (Table 6.6; Map 3 of Appendix 2). All records were associated with rocky hills. One of these locations is within a proposed waste dump expansion area, however the remaining two locations are outside the current proposed development areas, in the south-east section of the lease. It is probable that the entity referred to as *Indigofera* sp. (1) (MET7024) in Mattiske and Associates refers to *I. ixocarpa*; this was only described as occurring in the "Marandoo lease area", with no specific location details provided.

Table 6.6: Locations of *Indigofera ixocarpa* records in the Marandoo study areas.

Location	Easting (WGS84, Zone 50)	Northing (WGS84, Zone 50)	Density
MAR29 (Marandoo lease)	623762	7491473	scattered
Opportunistic (Marandoo lease)	623998	7491529	scattered
MAR28 (Marandoo lease)	624220	7490375	scattered

- *Eremophila magnifica* subsp. *magnifica* (Priority 4)

This moderate-height shrub has been recorded numerous times from the Marandoo Ridge within the Marandoo lease (Map 3, Appendix 2). Representative locations are presented in Table 6.7. All records were associated with rocky hillslopes, which is typical habitat for this species. While many of the records within the Marandoo lease lie within areas already approved for clearing, or are within the currently proposed pit expansion area, there are also numerous records on the hillslopes to the south.

Table 6.7: Some representative locations of *Eremophila magnifica* subsp. *magnifica* in the Marandoo lease.

Location	Easting (WGS84, Zone 50)	Northing (WGS84, Zone 50)	Density
Opportunistic (Marandoo lease; HI 2003)	615161	7495768	50
Opportunistic (Marandoo lease; HI 2004b)	615124	7495287	70+
Opportunistic (Marandoo lease; HI 2004b)	615167	7495066	10
Opportunistic (Marandoo lease; PI 2005)	617407	7494454	10
Opportunistic (Marandoo lease; PI 2005)	617628	7494604	20+
Opportunistic (Marandoo lease; PI 2005)	617629	7494490	10
Opportunistic (Marandoo lease; PI 2005)	617706	7494520	10
Opportunistic (Marandoo lease; PI 2005)	617746	7494415	25
Opportunistic (Marandoo lease; PI 2005)	617913	7494552	1
Opportunistic (Marandoo lease; PI 2005)	617952	7494418	15
Opportunistic (Marandoo lease; PI 2005)	618003	7494490	100
Opportunistic (Marandoo lease; PI 2005)	618105	7494523	30+
Opportunistic (Marandoo lease; PI 2005)	618135	7494411	100
Opportunistic (Marandoo lease; PI 2005)	618165	7494573	100+
Opportunistic (Marandoo lease; PI 2005)	618182	7494482	100+
Opportunistic (Marandoo lease; PI 2005)	618426	7494363	10
Opportunistic (Marandoo lease; PI 2005)	618597	7494397	100+
Opportunistic (Marandoo lease; PI 2005)	618647	7494452	50
Opportunistic (Marandoo lease; PI 2005)	618718	7494468	50
Opportunistic (Marandoo lease; PI 2005)	618757	7494430	100
Opportunistic (Marandoo lease; PI 2005)	618775	7494443	50
Opportunistic (Marandoo lease; PI 2005)	618881	7494399	100+
Opportunistic (Marandoo lease; PI 2005)	618988	7494404	100
Opportunistic (Marandoo lease; PI 2005)	619097	7494415	100+
Opportunistic (Marandoo lease; PI 2005)	619314	7494391	100
Opportunistic (Marandoo lease; PI 2005)	619377	7494358	20
Opportunistic (Marandoo lease; PI 2006a)	618909	7494308	
Opportunistic (Marandoo lease; PI 2006a)	618937	7494294	25+
Opportunistic (Marandoo lease; PI 2006a)	619034	7494285	100+
Opportunistic (Marandoo lease; PI 2006a)	619137	7494287	1
Opportunistic (Marandoo lease; PI 2006a)	619224	7494291	50+
Opportunistic (Marandoo lease; PI 2006a)	619297	7494247	100+
Opportunistic (Marandoo lease; PI 2006a)	619514	7494270	1000+
Opportunistic (Marandoo lease; PI 2006a)	619594	7494315	10+
Opportunistic (Marandoo lease; PI 2006a)	619689	7494237	50+
Opportunistic (Marandoo lease; PI 2006a)	619705	7494332	5+
Opportunistic (Marandoo lease; PI 2006a)	619771	7494273	20+
Opportunistic (Marandoo lease; PI 2006a)	619801	7494167	1000+
Opportunistic (Marandoo lease; PI 2006a)	619995	7494201	20
Opportunistic (Marandoo lease; PI 2006a)	620030	7494146	50+
Opportunistic (Marandoo lease; PI 2006a)	620065	7494090	50
Opportunistic (Marandoo lease; PI 2006a)	620115	7494042	50

Location	Easting (WGS84, Zone 50)	Northing (WGS84, Zone 50)	Density
Opportunistic (Marandoo lease; PI 2006a)	620131	7494027	50
Opportunistic (Marandoo lease; PI 2006a)	620191	7494135	50
Opportunistic (Marandoo lease; PI 2006a)	620229	7494093	100
Opportunistic (Marandoo lease; PI 2006a)	620355	7493853	50
Opportunistic (Marandoo lease; PI 2006a)	620448	7493872	100
Opportunistic (Marandoo lease; PI 2006a)	620556	7493928	50+
Opportunistic (Marandoo lease; PI 2006a)	620916	7493730	30
Opportunistic (Marandoo lease; PI 2006b)	620916	7493730	30
Opportunistic (Marandoo lease)	619175	7494339	scattered
MAR20 (Marandoo lease)	619235	7494220	scattered
Opportunistic (Marandoo lease)	619522	7494654	scattered
MAR06 (Marandoo lease)	619799	7494250	scattered
MAR08 (Marandoo lease)	620925	7493702	scattered
MAR18 (Marandoo lease)	621370	7492802	scattered; 1% cover
MAR10 (Marandoo lease)	622940	7491890	scattered
Opportunistic (Marandoo lease)	623635	7490121	scattered
Opportunistic (Marandoo lease)	623892	7490459	scattered
Opportunistic (Marandoo lease)	624003	7490421	scattered
MARA05 (Marandoo lease)	624203	7491176	5% cover; x30 individuals
Opportunistic (Marandoo lease)	623884	7491551	x35 individuals
Opportunistic (Marandoo lease)	623957 to 624147	7491251 to 7491434	several hundred individuals along this section of ridge
Opportunistic (Marandoo lease)	624037 to 624205	7491177 to 7491395	~150 individuals along this section of ridge
Opportunistic (Marandoo lease)	624046	7491538	x20 individuals
Opportunistic (Marandoo lease)	624236	7490241	scattered
MAR12 (Marandoo lease)	624770	7491190	scattered

Four other Priority flora either have occurred or may potentially occur in the Proposal Area:

- Two other Priority species (the P2 *Dicladanthera glabra* and P3 *Eremophila magnifica* subsp. *velutina*) were described by Mattiske and Associates (1992) as occurring in the "Initial Mining Area", however no site details or location coordinates were presented. These locations were presumably within the area of the current mine pits and probably no longer exist.
- It is probable that the unidentified *Cynanchum* sp. listed in Mattiske and Associates (1992) refers to the Priority 3 *Cynanchum* sp. Hamersley (M. Trudgen 2302). The *Cynanchum* sp. was described only as occurring in the "Manganese Gorge" area. There are two vouchered specimens of the Priority species from Marandoo, both from locations which appear to be within the area of the current mine pits and probably no longer exist (see Section 3.2.6.3).
- There is a single vouchered collection of the Priority 3 *Triumfetta leptacantha* from a location which appears to be within the current mine pit at Marandoo, and probably no longer exists (see Section 3.2.6.3). It is probable that the entity referred to as *Triumfetta* aff. *micracantha* by Mattiske and Associates (1992) equates to *T. maconochieana,* in which case it is possible that the other unidentified *Triumfetta* on the species list refers to *T. leptacantha.* This entity was described only as occurring in the "Manganese Gorge" area. Given the findings for *Cynanchum* (see above), and the location of the vouchered specimen of *T. leptacantha*, it is probable that this collection location no longer exists.

Two further Priority 2 species (*Acacia daweana* and *A. effusa*) were listed by Mattiske and Associates (1992) as having been "recorded previously in the Marandoo area; neither species was found in 1990 and 1991, despite extensive searching". Neither species was located within the MMP2 project area during the more recent survey work in 2007 or 2008. These taxa have been retained on the list of species for the area presented in Appendix 5, however it is considered most

likely that records for "Marandoo" actually refer to the nearby records from Mt Bruce and other locations within the Karijini National Park.

6.3 Introduced Flora

Twenty weed species have been recorded from the study area (Table 6.8). Almost half of these species belonged to two families, the Asteraceae (daisies) and Poaceae (grasses). None of the species recorded comprise Declared Plants under the *Agriculture and Related Resources Protection Act 1976,* however **Cenchrus* species and **Acetosa vesicaria* are considered to be serious environmental weeds.

Most of the weed species are widespread through the Marandoo locality and typically occurred as scattered plants within the project area, hence not all individual locations were recorded. The most common habitats in which weeds were recorded were the Mulga communities on clayey plains and in drainage areas.

Table 6.8: Weed species recorded from the Marandoo study areas.

FAMILY (Family Code) / Species	Mattiske (1992)	Biota (this study; √) and Pilbara Iron (2006a; ¥)					
	Marandoo lease [1]	Marandoo lease (including mine pit and waste dump expansion areas) [1]	Residue Storage Facility [1]	Southern Fortescue Borefield [1]	Dewatering Bore Drilling Area [2]	Dewatering Pipeline Corridor [2]	Operations Camp [2]
ASTERACEAE (345)							
**Bidens bipinnata*	√	√	√	√	√	√	√
**Sigesbeckia orientalis*	√						
**Sonchus oleraceus*		√					
CHENOPODIACEAE (105)							
**Bassia scoparia*	√						
CUCURBITACEAE (337)							
**Cucumis melo* subsp. *agrestis*	√						√
EUPHORBIACEAE (185)							
**Euphorbia hirta*	√						
**Euphorbia peplus*	√						
MALVACEAE (221)							
**Malvastrum americanum*	√	√	√	√	√	√	√
MIMOSACEAE (163)							
**Vachellia farnesiana*	√	√		√	√	√	√
NYCTAGINACEAE (107)							
**Bougainvillea* sp. (planted)		√					
POACEAE (31)							
**Cenchrus ciliaris*	√	√	√	√		√	√
**Cenchrus setiger*				√		√	√
**Chloris virgata*	√			√			
**Cynodon dactylon*					√	√	
**Echinochloa colona*				√		√	√
**Setaria verticillata*		√		√			
POLYGONACEAE (103)							
**Acetosa vesicaria*	√	¥			√		
PORTULACACEAE (111)							
**Portulaca oleracea*	√	√		√	√	√	
SOLANACEAE (315)							
**Datura leichhardtii*	√						√
**Solanum nigrum*	√					√	

[1] Project Area; [2] Proposal Area

A brief description of each species follows:

- **Bidens bipinnata* (Bipinnate Beggartick) is a common and widespread weed of Mulga vegetation and creeklines of the Pilbara. This annual daisy may occur in very high densities within suitable habitat and given appropriate conditions. Scattered individuals were recorded from numerous locations within the MMP2 project area, including throughout the main Marandoo lease and within all of the additional infrastructure areas. This species was particularly common within Mulga vegetation on clayey plains, and occasional dense infestations were recorded within drainage areas.
- **Sigesbeckia orientalis* (Indian Weed) is a slender herbaceous weed occurring through the southern Pilbara, particularly in Mulga vegetation, drainage areas and rocky habitats. This species was listed as occurring in the Marandoo lease area by Mattiske and Associates (1992) but was not resampled during the more recent survey work.
- **Sonchus oleraceus* (Common Sowthistle) is a common and widespread annual weed of creeklines and floodplains, particularly through the southern Pilbara. This daisy was recorded at a single site in the main Marandoo lease area (MAR30), located in vegetation unit 1c.
- **Bassia scoparia* is an annual herbaceous chenopod which usually grows on loam around salt lakes. This species is most common in the South-west of WA, with a single record from the Pilbara (being the record from Marandoo). This species is listed by Mattiske and Associates (1992) as occurring in the Marandoo lease area, but no further location details were provided.
- **Cucumis melo* subsp. *agrestis* (Ulcardo Melon) is a widespread weed through the Kimberley and Pilbara bioregions. This creeper was recorded from a single site in the area of the proposed Operations Camp (MARA07), comprising a Mulga woodland fringing a drainage line.
- **Euphorbia hirta* (Asthma Plant) is common and widespread through the Kimberley, and there are occasional records of this species from the Pilbara. **E. hirta* was listed by Mattiske and Associates (1992) for the Marandoo lease area, but no further location details are available.
- **Euphorbia peplus* (Petty Spurge) is a widespread weed through the South-west of WA but there are no lodged voucher specimens for the Pilbara. This species was listed by Mattiske and Associates (1992) for the Marandoo lease area, but no further location details were provided.
- **Malvastrum americanum* (Spiked Malvastrum) is a common weed of Mulga and creekline vegetation in the Pilbara. There were numerous records of this species from the MMP2 project area, from throughout the main lease area (including all the infrastructure areas), as well as from the Operations Camp, Dewatering Pipeline Corridor and Southern Fortescue Borefield.
- **Vachellia farnesiana* (Mimosa Bush) is a tall spiny shrub which is widespread from the Kimberley to near Perth, typically occurring along drainage systems and in adjacent low-lying areas. This species was recorded from scattered locations through the main Marandoo lease area (including the Dewatering Bore Drilling area), as well as in the Opertations Camp, Dewatering Pipeline Corridor and Southern Fortescue Borefield.
- One planted individual of **Bougainvillea* sp. (Bougainvillea) survives within the rail loop at the site of the old Marandoo camp. This species occurs occasionally through the Pilbara near old settlements and occupied townsites, but does not appear to have become naturalised (ie. it persists only where initially planted). Other dead ornamental species were also noted in this area.
- **Cenchrus ciliaris* (Buffel Grass) and **C. setiger* (Birdwood Grass) are tufted perennial grass species which were introduced to the Pilbara as fodder species. These highly invasive species can cause severe degradation of native vegetation along creeklines, in loamy coastal habitats and on rockpiles, particularly where there has been previous physical disturbance of the soil profile and/or heavy grazing. Buffel Grass was listed for the Marandoo lease area by Mattiske and Associates (1992) and was recorded from the Residue Storage Facility area and from dense infestations within the rail loop in 2008, as well as from the Operations Camp, Dewatering Pipeline Corridor and Southern Fortescue Borefield. Birdwood Grass was also recorded from scattered locations within the Operations Camp, Dewatering Pipeline Corridor and Southern Fortescue Borefield in 2008.

- **Chloris virgata* (Feathertop Rhodes Grass) is a widespread grass weed from the Kimberley through to the South-west of WA. This species was listed as occurring in the Marandoo lease area by Mattiske and Associates (1992), and was collected at a single site in the Southern Fortescue Borefield during 2008.
- **Cynodon dactylon* (Couch) is a perennial grass species which is widespread through WA, typically occurring in damp drainage areas. This species was recorded from single locations in the Dewatering Bore Drilling area and along the Dewatering Pipeline Corridor during 2008.
- **Echinochloa colona* (Awnless Barnyard Grass) is a widespread weed of creeklines through the northern Pilbara and Kimberley. This species was recorded from scattered locations in the Operations Camp, Dewatering Pipeline Corridor and Southern Fortescue Borefield in 2008.
- **Setaria verticillata* (Whorled Pigeon Grass) is a loosely tufted annual grass growing to 1 m in height. This species is widespread through WA and is a common weed of creeklines and mulga vegetation in the Pilbara, although it rarely occurs in large numbers. There was a single record of this species from an area of mulga (MAR02) during the 2007 survey work in the main Marandoo lease area, and this species was also noted within the Southern Fortescue Borefield in 2008.
- **Acetosa vesicaria* (Ruby Dock) is a widespread weed from the Pilbara to the south coast of WA, typically occurring in disturbed areas, rocky habitats and Mulga vegetation, particularly near the minesites to which it was initially introduced to assist with rehabilitation. This species was listed by Mattiske and Associates (1992) as occurring in the Marandoo lease area, however no further location details were provided. This species was recorded from a single location in 2008, from a soil stockpile within the Dewatering Bore Drilling area, and was recorded once from the Marandoo Ridge in 2006 (Pilbara Iron 2006a) (Table 6.9; Map 3, Appendix 2).

Table 6.9: Locations of **Acetosa vesicaria* records in the Marandoo lease area.

Location	Easting (WGS84, Zone 50)	Northing (WGS84, Zone 50)
Opportunistic (Dewatering Bore Drilling Area)	615807	7496815
Opportunistic (Marandoo lease; PI 2006a)	620692	7493663

- **Portulaca oleracea* (Purslane) is a widespread succulent herb, which occurs from the Kimberley to the South-west of WA. This species was recorded from several sites within the main Marandoo lease area, including from the Dewatering Bore Drilling area, and was also present along the Dewatering Pipeline Corridor and in the Southern Fortescue Borefield.
- **Datura leichhardtii* (Native Thornapple) is a widespread annual weed through the Pilbara, Gascoyne and Carnarvon bioregions, typically occurring in drainage areas. This species was listed by Mattiske and Associates (1992) as occurring in the Marandoo lease area, and was recorded from two locations within the Operations Camp in 2008 (both associated with drainage habitats).
- **Solanum nigrum* (Black Berry Nightshade) is a widespread annual or short-lived perennial herb occurring from the Kimberley to the south coast of WA. This species is recorded occasionally in the Pilbara, usually from creeklines or Mulga vegetation. This species was listed by Mattiske and Associates (1992) for the Marandoo lease area, and there was a single record within the Dewatering Pipeline Corridor during the 2008 survey.

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7.0 Acknowledgements

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8.0 References

Aplin, T.E.H. (1979). The Flora. Chapter 3 *In* O'Brien, B.J. (ed.) (1979). *Environment and Science.* University of Western Australia Press.

Atkins, K.J.A. (2008). Declared Rare and Priority Flora List for Western Australia. Department of Environment and Conservation, 26 February 2008.

Beard, J.S. (1975). Vegetation Survey of Western Australia. 1:100,000 Vegetation Series Map sheet 5 - Pilbara.

Biota Environmental Sciences (2007). A Vegetation and Flora Survey of the White Quartz Road Corridor, near Tom Price. Unpublished report prepared for Pilbara Iron Company, November 2007.

Biota Environmental Sciences (in prep.) A Vegetation and Flora Survey of the Nammuldi – Mt Lionel Rail Corridor, near Tom Price. Report being prepared for Pilbara Iron Company.

Biota Environmental Sciences and ME Trudgen (2002). Hope Downs Rail Corridor, Port Hedland to Weeli Wolli Creek – Vegetation and Flora Survey. Unpublished report prepared for Hope Downs Management Services, February 2002.

Christian, C.S. and G.A. Stewart (1953). General report on Survey of Katherine-Darwin region 1946. CSIRO Australian Land Research Series 1. *cited in* Environmental Protection Authority (2002). *Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection.* Environmental Protection Authority, March 2002.

CRA Services Ltd (1982). Marandoo Biological Report. Unpublished report prepared by the Iron Ore Division, CRA Services Limited, Perth.

Environment Australia (2000). *Revision of the Interim Biogeographic Regionalisation for Australia (IBRA) and Development of Version 5.1, Summary Report.* Environment Australia, November 2000.

Hamersley Iron Pty Ltd (2003). Marandoo Crusher Access Rare Flora Survey. Internal report prepared by Anna Joder and Emil Thoma, Environmental Division, Hamersley Iron, May 2003.

Hamersley Iron Pty Ltd (2004a). Marandoo North West Area Ground Disturbance Authorisation: Project No. 2004/27; Docs #102686. Internal report, 23/06/2004.

Hamersley Iron Pty Ltd (2004b). Marandoo South West Pit Rare Flora Survey; Docs #100775. Internal report prepared by Anna Joder and Emil Thoma, Environmental Division, Hamersley Iron, January 2004.

Kendrick, P. (2001). Pilbara 3 (PIL3 – Hamersley subregion). Pp568-580 *in* May, J.E. and N.L. McKenzie (2003). *A Biodiversity Audit of Western Australia's Biogeographical Subregions in 2002.* Department of Conservation and Land Management, Perth.

Mattiske and Associates (1992). Flora and Vegetation: Marandoo Project Area. Unpublished report prepared for Enviroscan, January 1992.

May, J.E. and N.L. McKenzie (2003). *A Biodiversity Audit of Western Australia's Biogeographical Subregions in 2002.* Department of Conservation and Land Management, Perth.

Payne, A.L., A.A. Mitchell and W.F. Holman (1988). *An inventory and condition survey of rangelands in the Ashburton River catchment, Western Australia.* Department of Agriculture Technical Bulletin No. 62, revised edition 1988.

Pilbara Iron (2005). Marandoo Tail Pit Rare Flora Survey. Botanical Survey Advice, Environment Department, Project No. 2005/12; Docs #108565. 02/02/2005.

Pilbara Iron (2006a). Marandoo Below Water Table Evaluation Drilling – Eastern Area GD_05_01237 Rare Flora Survey. Botanical Survey Advice, Environment Department, BAF No. 2006/094; Rio Tinto-HSE-0017216. 16/09/2006.

Pilbara Iron (2006b). Marandoo Old Grid and Baseline GD_05_01306 Rare Flora Survey. Botanical Survey Advice, Environment Department, BAF No. 2006/036; Docs No. 116467. 27/04/2006.

Randell, B.R. (1989). Revision of the Cassiinae in Australia. 2. *Senna* Miller Sect. Psilorhegma (J. Vogel) Irwin and Barneby. *J. Adelaide Bot. Gard.* 12(2): 165-272.

Specht, R.L. (1970). Vegetation. *In* G.W. Leeper (ed). *The Australian Environment.* 4th edn. Melbourne.

Rio Tinto Iron Ore (2008). Marandoo Mine Phase 2 Project Public Environmental Review. PER prepared by Strategen, 2008.

Symon, D.E. (1966). A revision of the genus *Cassia* L. Caesalpiniaceae in Australia. *Trans. Roy. Soc. S. Australia* 90: 73-146.

Trudgen, M.E. (1975). Floristic Report on Marandoo Mining Site, May 1975. Unpublished report prepared for Texasgulf Australia Limited, Perth.

Trudgen, M.E. (1977a). Report on Visit to Marandoo, 7-10 October, 1977. Unpublished report prepared for Texasgulf Australia Limited, Perth.

Trudgen, M.E. (1977b). Report on Visit to Marandoo and Identification of Plant Specimens. Unpublished report prepared for Texasgulf Australia Limited, Perth.

Trudgen, M.E. (1978). Report on Visit to Marandoo and Mount Whaleback, 14-17 February 1978. Unpublished report prepared for Texasgulf Australia Limited, Perth.

Trudgen, M.E. (1988). A Report on the Flora and Vegetation of the Port Kennedy Area. Unpublished report prepared for Bowman Bishaw and Associates, West Perth.

Trudgen M.E. and N. Casson (1998). Flora and vegetation surveys of Orebody A and Orebody B in the West Angela Hill area, an area surrounding them, and of rail route options considered to link them to the existing Robe River Iron Associates rail line. Unpublished report for Robe River Iron Associates.

van Vreeswyk, A.M.E., A.L. Payne, K.A. Leighton and P. Hennig (2004). *An inventory and condition survey of the Pilbara region, Western Australia.* Department of Agriculture Technical Bulletin No. 92, December 2004.

Weston, A.S. (1977). Report on Visit to Marandoo, December 17-19, 1977. Unpublished report prepared for Texasgulf Australia Limited, Perth.

Appendix 1

Framework for Conservation Significance Ranking of Communities and Species

A. Definitions, Categories and Criteria for Threatened and Priority Ecological Communities

1. General Definitions

Ecological Community
A naturally occurring biological assemblage that occurs in a particular type of habitat.

Note: The scale at which ecological communities are defined will often depend on the level of detail in the information source, therefore no particular scale is specified.

A threatened ecological community (TEC) is one which is found to fit into one of the following categories; "presumed totally destroyed", "critically endangered", "endangered" or "vulnerable".

Possible threatened ecological communities that do not meet survey criteria are added to DEC's Priority Ecological Community Lists under Priorities 1, 2 and 3. Ecological Communities that are adequately known, are rare but not threatened, or meet criteria for Near Threatened, or that have been recently removed from the threatened list, are placed in Priority 4. These ecological communities require regular monitoring. Conservation Dependent ecological communities are placed in Priority 5.

An assemblage is a defined group of biological entities.

Habitat is defined as the areas in which an organism and/or assemblage of organisms lives. It includes the abiotic factors (eg. substrate and topography), and the biotic factors.

Occurrence: a discrete example of an ecological community, separated from other examples of the same community by more than 20 metres of a different ecological community, an artificial surface or a totally destroyed community.

By ensuring that every discrete occurrence is recognised and recorded future changes in status can be readily monitored.

Adequately Surveyed is defined as follows:
"An ecological community that has been searched for thoroughly in most likely habitats, by relevant experts."

Community structure is defined as follows:
"The spatial organisation, construction and arrangement of the biological elements comprising a biological assemblage" (eg. Eucalyptus salmonophloia woodland over scattered small shrubs over dense herbs; structure in a faunal assemblage could refer to trophic structure, eg. dominance by feeders on detritus as distinct from feeders on live plants).

Definitions of Modification and Destruction of an ecological community:

Modification: "changes to some or all of ecological processes (including abiotic processes such as hydrology), species composition and community structure as a direct or indirect result of human activities. The level of damage involved could be ameliorated naturally or by human intervention."

Destruction: "modification such that reestablishment of ecological processes, species composition and community structure within the range of variability exhibited by the original community is unlikely within the foreseeable future even with positive human intervention."

Note: Modification and destruction are difficult concepts to quantify, and their application will be determined by scientific judgement. Examples of modification and total destruction are cited below:

<u>Modification of ecological processes:</u> The hydrology of Toolibin Lake has been altered by clearing of the catchment such that death of some of the original flora has occurred due to dependence on fresh water. The system may be bought back to a semblance of the original state by redirecting saline runoff and pumping waters of the rising underground watertable away to restore the hydrological balance. Total destruction of downstream lakes has occurred due to hydrology being altered to the point that few of the original flora or fauna species are able to tolerate the level of salinity and/or water logging.

<u>Modification of structure:</u> The understorey of a plant community may be altered by weed invasion due to nutrient enrichment by addition of fertiliser. Should the additional nutrients be removed from the system the balance may be restored, and the original plant species better able to compete. Total destruction may occur if additional nutrients continue to be added to the system causing the understorey to be completely replaced by weed species, and death of overstorey species due to inability to tolerate high nutrient levels.

Modification of species composition: Pollution may cause alteration of the invertebrate species present in a freshwater lake. Removal of pollutants may allow the return of the original inhabitant species. Addition of residual highly toxic substances may cause permanent changes to water quality, and total destruction of the community.

Threatening processes are defined as follows:
"Any process or activity that threatens to destroy or significantly modify the ecological community and/or affect the continuing evolutionary processes within any ecological community."

Examples of some of the continuing threatening processes in Western Australia include: general pollution; competition, predation and change induced in ecological communities as a result of introduced animals; competition and displacement of native plants by introduced species; hydrological changes; inappropriate fire regimes; diseases resulting from introduced micro-organisms; direct human exploitation and disturbance of ecological communities.

Restoration is defined as returning an ecological community to its pre-disturbance or natural state in terms of abiotic conditions, community structure and species composition.

Rehabilitation is defined as the re-establishment of ecological attributes in a damaged ecological community although the community will remain modified.

2. Definitions and Criteria for Presumed Totally Destroyed, Critically Endangered, Endangered and Vulnerable Ecological Communities

ECOLOGICAL COMMUNITIES

Presumed Totally Destroyed (PD)
An ecological community that has been adequately searched for but for which no representative occurrences have been located. The community has been found to be totally destroyed or so extensively modified throughout its range that no occurrence of it is likely to recover its species composition and/or structure in the foreseeable future.

An ecological community will be listed as presumed totally destroyed if there are no recent records of the community being extant and either of the following applies (A or B):

A) Records within the last 50 years have not been confirmed despite thorough searches of known or likely habitats or

B) All occurrences recorded within the last 50 years have since been destroyed

Critically Endangered (CR)
An ecological community that has been adequately surveyed and found to have been subject to a major contraction in area and/or that was originally of limited distribution and is facing severe modification or destruction throughout its range in the immediate future, or is already severely degraded throughout its range but capable of being substantially restored or rehabilitated.

An ecological community will be listed as Critically Endangered when it has been adequately surveyed and is found to be facing an extremely high risk of total destruction in the immediate future. This will be determined on the basis of the best available information, by it meeting any one or more of the following criteria (A, B or C):

A) The estimated geographic range, and/or total area occupied, and/or number of discrete occurrences since European settlement have been reduced by at least 90% and either or both of the following apply (i or ii):

   i) geographic range, and/or total area occupied and/or number of discrete occurrences are continuing to decline such that total destruction of the community is imminent (within approximately 10 years);

   ii) modification throughout its range is continuing such that in the immediate future (within approximately 10 years) the community is unlikely to be capable of being substantially rehabilitated.

B) Current distribution is limited, and one or more of the following apply (i, ii or iii):

   i) geographic range and/or number of discrete occurrences, and/or area occupied is highly restricted and the community is currently subject to known threatening processes which are likely to result in total destruction throughout its range in the immediate future (within approximately 10 years);

   ii) there are very few occurrences, each of which is small and/or isolated and extremely vulnerable to known threatening processes;

iii) there may be many occurrences but total area is very small and each occurrence is small and/or isolated and extremely vulnerable to known threatening processes.

C) The ecological community exists only as highly modified occurrences that may be capable of being rehabilitated if such work begins in the immediate future (within approximately 10 years).

Endangered (EN)
An ecological community that has been adequately surveyed and found to have been subject to a major contraction in area and/or was originally of limited distribution and is in danger of significant modification throughout its range or severe modification or destruction over most of its range in the near future.

An ecological community will be listed as Endangered when it has been adequately surveyed and is not Critically Endangered but is facing a very high risk of total destruction in the near future. This will be determined on the basis of the best available information by it meeting any one or more of the following criteria (A, B, or C):

A) The geographic range, and/or total area occupied, and/or number of discrete occurrences have been reduced by at least 70% since European settlement and either or both of the following apply (i or ii):

i) the estimated geographic range, and/or total area occupied and/or number of discrete occurrences are continuing to decline such that total destruction of the community is likely in the short term future (within approximately 20 years);

ii) modification throughout its range is continuing such that in the short term future (within approximately 20 years) the community is unlikely to be capable of being substantially restored or rehabilitated.

B) Current distribution is limited, and one or more of the following apply (i, ii or iii):

i) geographic range and/or number of discrete occurrences, and/or area occupied is highly restricted and the community is currently subject to known threatening processes which are likely to result in total destruction throughout its range in the short term future (within approximately 20 years);

ii) there are few occurrences, each of which is small and/or isolated and all or most occurrences are very vulnerable to known threatening processes;

iii) there may be many occurrences but total area is small and all or most occurrences are small and/or isolated and very vulnerable to known threatening processes.

C) The ecological community exists only as very modified occurrences that may be capable of being substantially restored or rehabilitated if such work begins in the short-term future (within approximately 20 years).

Vulnerable (VU)
An ecological community that has been adequately surveyed and is found to be declining and/or has declined in distribution and/or condition and whose ultimate security has not yet been assured and/or a community that is still widespread but is believed likely to move into a category of higher threat in the near future if threatening processes continue or begin operating throughout its range.

An ecological community will be listed as Vulnerable when it has been adequately surveyed and is not Critically Endangered or Endangered but is facing a high risk of total destruction or significant modification in the medium to long-term future. This will be determined on the basis of the best available information by it meeting any one or more of the following criteria (A, B or C):

A) The ecological community exists largely as modified occurrences that are likely to be capable of being substantially restored or rehabilitated.

B) The ecological community may already be modified and would be vulnerable to threatening processes, is restricted in area and/or range and/or is only found at a few locations.

C) The ecological community may be still widespread but is believed likely to move into a category of higher threat in the medium to long term future because of existing or impending threatening processes.

3. Definitions and Criteria for Priority Ecological Communities

PRIORITY ECOLOGICAL COMMUNITY LIST

Possible threatened ecological communities that do not meet survey criteria or that are not adequately defined are added to the Priority Ecological Community Lists under Priorities 1, 2 and 3. These three categories are ranked in order of priority for survey and/or definition of the community, and evaluation of conservation status, so that consideration can be given to their declaration as threatened ecological communities. Ecological Communities that are adequately known, and are rare but not threatened or meet criteria for Near Threatened, or that have been recently removed from the threatened list, are placed in Priority 4. These ecological communities require regular monitoring. Conservation Dependent ecological communities are placed in Priority 5.

Priority One: Poorly-known ecological communities

Ecological communities with apparently few, small occurrences, all or most not actively managed for conservation (e.g. within agricultural or pastoral lands, urban areas, active mineral leases) and for which current threats exist. Communities may be included if they are comparatively well-known from one or more localities but do not meet adequacy of survey requirements, and/or are not well defined, and appear to be under immediate threat from known threatening processes across their range.

Priority Two: Poorly-known ecological communities

Communities that are known from few small occurrences, all or most of which are actively managed for conservation (e.g. within national parks, conservation parks, nature reserves, State forest, unallocated Crown land, water reserves, etc.) and not under imminent threat of destruction or degradation. Communities may be included if they are comparatively well known from one or more localities but do not meet adequacy of survey requirements, and/or are not well defined, and appear to be under threat from known threatening processes.

Priority Three: Poorly known ecological communities

(i) Communities that are known from several to many occurrences, a significant number or area of which are not under threat of habitat destruction or degradation or:

(ii) communities known from a few widespread occurrences, which are either large or within significant remaining areas of habitat in which other occurrences may occur, much of it not under imminent threat, or;

(iii) communities made up of large, and/or widespread occurrences, that may or not be represented in the reserve system, but are under threat of modification across much of their range from processes such as grazing by domestic and/or feral stock, and inappropriate fire regimes.

Communities may be included if they are comparatively well known from several localities but do not meet adequacy of survey requirements and/or are not well defined, and known threatening processes exist that could affect them.

Priority Four: Ecological communities that are adequately known, rare but not threatened or meet criteria for Near Threatened, or that have been recently removed from the threatened list. These communities require regular monitoring.

(a) Rare. Ecological communities known from few occurrences that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently threatened or in need of special protection, but could be if present circumstances change. These communities are usually represented on conservation lands.

(b) Near Threatened. Ecological communities that are considered to have been adequately surveyed and that do not qualify for Conservation Dependent, but that are close to qualifying for Vulnerable.

(c) Ecological communities that have been removed from the list of threatened communities during the past five years.

Priority Five: Conservation Dependent ecological communities

Ecological communities that are not threatened but are subject to a specific conservation program, the cessation of which would result in the community becoming threatened within five years.

Reference: Department of Environment and Conservation 2007.

B. Threatened Flora Statutory Framework

In Western Australia, all native flora species are protected under the *Wildlife Conservation Act 1950-1979,* making it an offence to remove or harm native flora species without approval. In addition to this basic level of statutory protection, a number of plant species are assigned an additional level of conservation significance based on the fact that there are a limited number of known populations, some of which may be under threat.

Species of the highest conservation significance are designated Declared Rare Flora (DRF), either extant or presumed extinct:

- X: Declared Rare Flora - Presumed Extinct: taxa which have not been collected, or otherwise verified, over the past 50 years despite thorough searching, or of which all known wild populations have been destroyed more recently, and have been gazetted as such, following approval by the Minister for the Environment, after recommendation by the State's Endangered Flora Consultative Committee;
- R: Declared Rare Flora - Extant: taxa which have been adequately searched for, and are deemed to be in the wild either rare, in danger of extinction, or otherwise in need of special protection, and have been gazetted as such, following approval by the Minister for the Environment, after recommendation by the State's Endangered Flora Consultative Committee (Atkins 2008). *(= Threatened Flora = Endangered + Vulnerable)*

Species that appear to be rare or threatened, but for which there is insufficient information to properly evaluate their conservation significance, are assigned to one of four Priority flora categories:

- P1: Priority One - Poorly Known: taxa which are known from one or a few (generally <5) populations which are under threat, either due to small population size, or being on lands under immediate threat, e.g. road verges, urban areas, farmland, active mineral leases, etc., or the plants are under threat, e.g. from disease, grazing by feral animals, etc. May include taxa with threatened populations on protected lands. Such taxa are under consideration for declaration as 'rare flora', but are in urgent need of further survey.
- P2: Priority Two - Poorly Known: taxa which are known from one or a few (generally <5) populations, at least some of which are not believed to be under immediate threat (i.e. not currently endangered). Such taxa are under consideration for declaration as 'rare flora', but are in urgent need of further survey.
- P3: Priority Three - Poorly Known: taxa which are known from several populations, at least some of which are not believed to be under immediate threat (i.e. not currently endangered). Such taxa are under consideration for declaration as 'rare flora', but are in need of further survey.
- P4: Priority Four - Rare: taxa which are considered to have been adequately surveyed and which, whilst being rare (in Australia), are not currently threatened by any identifiable factors. These taxa require monitoring every 5–10 years.

Note that of the above classifications, only 'Declared Rare Flora' has statutory standing. The Priority Flora classifications are employed by the Department of Environment and Conservation to manage and classify their database of species considered potentially rare or at risk, but these categories have no legislative status. Note also that proposals that appear likely to affect DRF require formal written approval from the Minister for the Environment under Section 23(f) of the *Wildlife Conservation Act 1950-1979* in addition to the requirements of the *Environmental Protection (Native Vegetation Clearing) Regulations 2004*.

References:

Atkins, K.J. (2008). Declared Rare and Priority Flora List for Western Australia. Prepared by the Department of Environment and Conservation, 26 February 2008.

Appendix 2

Vegetation of the Marandoo Mine Phase 2 Study Areas

Broad Drainage Areas and Basins

- **1a** *Acacia aneura* woodland on broad flat alluvial and colluvial areas
- **1b** Open grassland
- **1c** *Triodia melvillei* hummock grassland
- **1a/1b**

Major Creeklines & Floodplains

- **2a** *Acacia aneura – A. pruinocarpa* woodland in major flowlines
- **2b** *Eucalyptus xerothermica – Acacia aneura* woodland in major flowlines
- **2c** *Eucalyptus xerothermica – Acacia aneura* woodland over *Acacia citrinoviridis* tall shrubland in major flowlines
- **2e** *Eucalyptus victrix* woodland in secondary creeklines

Minor Creeks

- **3a** *Acacia* species shrubland in minor flowlines

Flats

- **4a** *Acacia aneura – A. pruinocarpa* woodland
- **4b** *Acacia synchronicia – *Vachellia farnesiana* tall shrubland
- **4c** *Acacia aneura* scattered low trees over open grassland
- **4d** *Acacia xiphophylla* low woodland
- **4e** *Triodia wiseana, T. pungens* hummock grassland
- **4f** *Triodia wiseana, T.* sp. Shovelanna Hill, *T. angusta* hummock grassland
- **4g** *Triodia angusta, T. longiceps* hummock grassland

Vegetation Mapping for Marandoo Mine Phase 2

Legend Sheet 1 of 2

Biota Environmental Sciences

Ridges and Erosional Spurs

5a *Eucalyptus leucophloia* scattered low trees over *Acacia* spp. scattered shrubs over *Triodia brizoides, T. wiseana* hummock grassland

5b *Eucalyptus leucophloia* scattered low trees over *Acacia* spp. scattered shrubs over *Triodia wiseana (T. brizoides, T.* sp. Shovelanna Hill)

5c *Eucalyptus leucophloia* scattered low trees over *Acacia* spp. scattered shrubs over *Triodia* sp. Shovelanna Hill *(T. wiseana)* hummock grassland

5d *Eucalyptus gamophylla* scattered low mallees over *Acacia* spp. scattered tall shrubs over *Triodia* sp. Shovelanna Hill *(T. wiseana)* hummock grassland

5e Mixed community supporting a range of structural formations from *Acacia aneura* low woodlands to sheer rock faces with *Astrotricha hamptonii* scattered shrubs to *Eriachne mucronata* open grasslands

5f *Acacia aneura* low woodland to woodland on rocky ledges and upper slopes of ranges

5g *Eucalyptus gamophylla* scattered low mallees over *Triodia wiseana* hummock grassland

5h *Triodia wiseana* hummock grassland with mixed *Acacia* spp. emergent shrubs

Low Foothills and Escarpments

6a *Mixed Triodia* spp. hummock grassland on upper slopes and ridges of small foothills and escarpments

6b Mixed *Acacia aneura, Acacia* spp. low woodland to woodland on upper slopes of low foothills

6c *Acacia aneura* low woodland to woodland on breakaways of low foothills

6d *Eucalyptus trivalva, E. socialis* low mallee woodland with pockets of *Triodia angusta, T. wiseana* hummock grassland on shallow calcrete soils

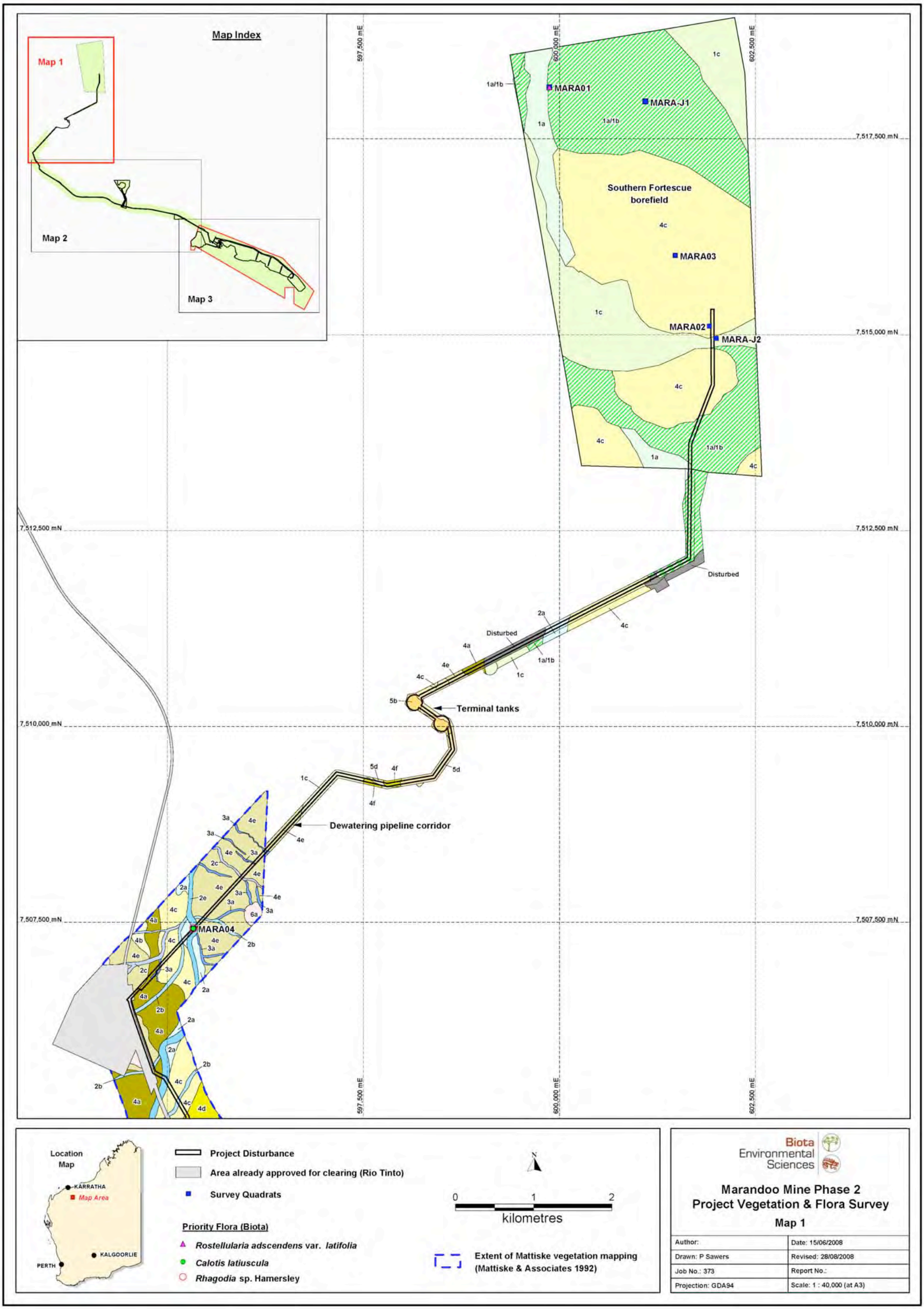
Other

Disturbed

Vegetation Mapping for Marandoo Mine Phase 2

Legend Sheet 2 of 2

Biota Environmental Sciences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Map 1
Map 2
Map 3
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602,500 mE
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7,510,000 mN
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MARA01
MARA-J1
MARA02
MARA-J2
MARA03
MARA04
Southern Fortescue borefield
Terminal tanks
Dewatering pipeline corridor
Disturbed
1a/1b
1a
1c
2a
2b
2c
2e
3a
4a
4b
4c
4d
4e
4f
5b
5d
6a
Location Map
KARRATHA
Map Area
PERTH
KALGOORLIE
Project Disturbance
Area already approved for clearing (Rio Tinto)
Survey Quadrats
Priority Flora (Biota)
Rostellularia adscendens var. latifolia
Calotis latiuscula
Rhagodia sp. Hamersley
N
0
1
2
kilometres
Extent of Mattiske vegetation mapping (Mattiske & Associates 1992)
Biota Environmental Sciences
Marandoo Mine Phase 2
Project Vegetation & Flora Survey
Map 1
Author:
Date: 15/06/2008
Drawn: P Sawers
Revised: 28/08/2008
Job No.: 373
Report No.:
Projection: GDA94
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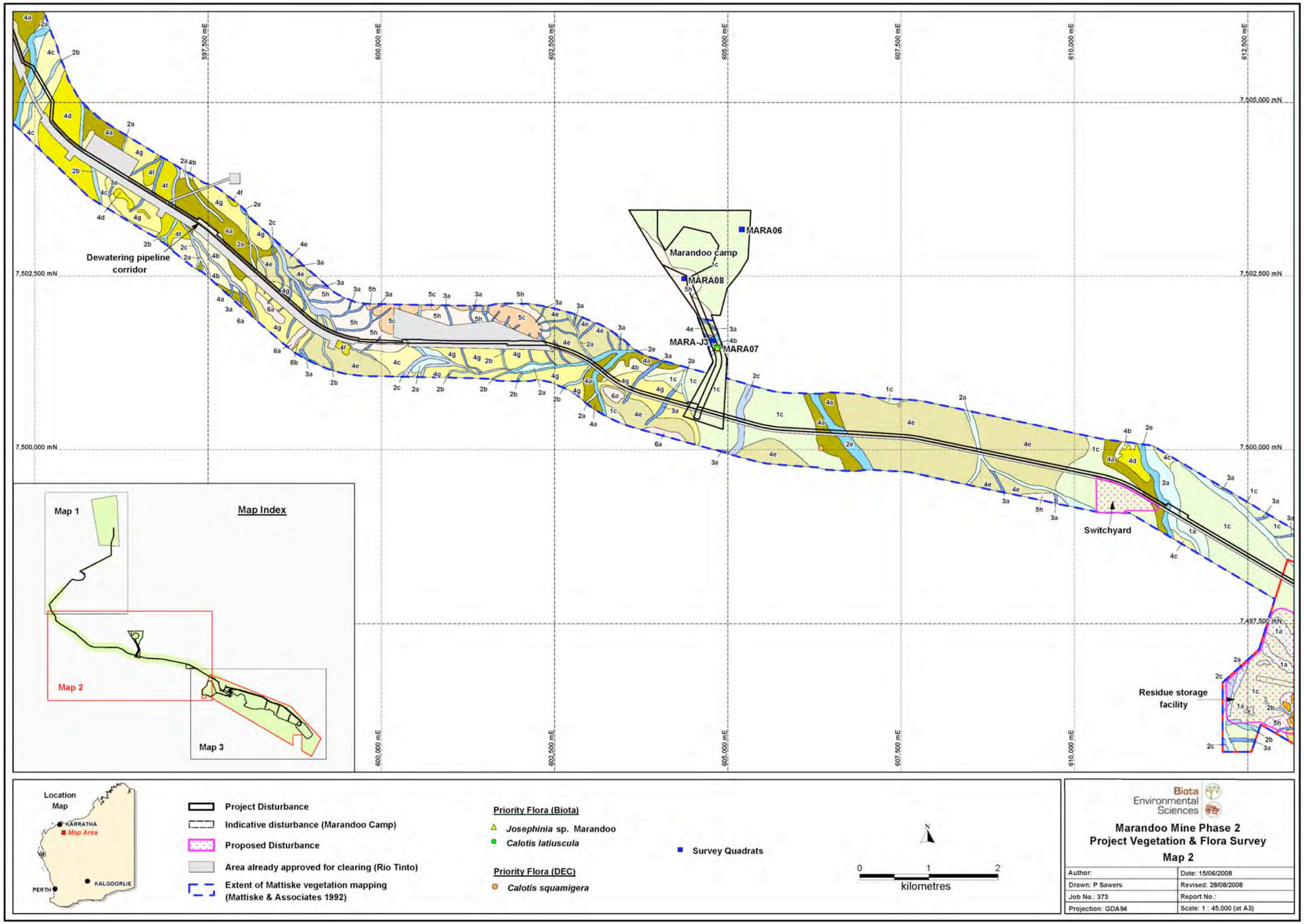
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7,502,500 mN
7,500,000 mN
7,497,500 mN
Dewatering pipeline corridor
MARA06
Marandoo camp
MARA08
MARA-J3
MARA07
Switchyard
Residue storage facility
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Map 3
Location Map
KARRATHA
Map Area
PERTH
KALGOORLIE
Project Disturbance
Indicative disturbance (Marandoo Camp)
Proposed Disturbance
Area already approved for clearing (Rio Tinto)
Extent of Mattiske vegetation mapping (Mattiske & Associates 1992)
Priority Flora (Biota)
Josephinia sp. Marandoo
Calotis latiuscula
Priority Flora (DEC)
Calotis squamigera
Survey Quadrats
N
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1
2
kilometres
Biota Environmental Sciences
Marandoo Mine Phase 2
Project Vegetation & Flora Survey
Map 2
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Revised: 28/08/2008
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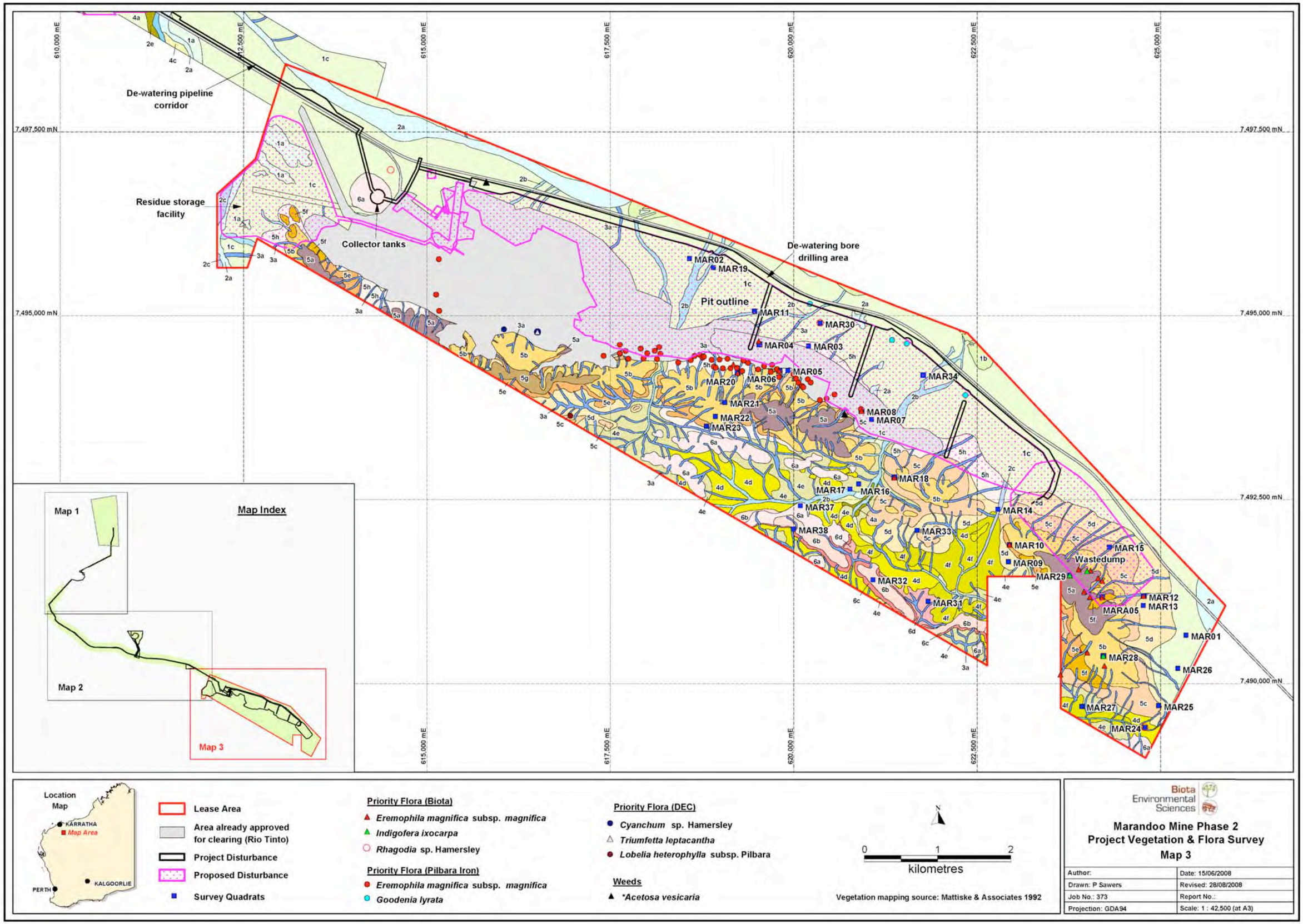
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De-watering pipeline corridor
Residue storage facility
Collector tanks
De-watering bore drilling area
Pit outline
MAR02
MAR19
MAR11
MAR30
MAR04
MAR03
MAR05
MAR06
MAR20
MAR34
MAR21
MAR22
MAR23
MAR08
MAR07
MAR18
MAR17
MAR16
MAR37
MAR38
MAR33
MAR14
MAR10
MAR09
MAR15
Wastedump
MAR29
MAR32
MAR31
MAR12
MAR13
MARA05
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MAR26
MAR27
MAR25
MAR24
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Map 2
Map 3
Location Map
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Map Area
PERTH
KALGOORLIE
Lease Area
Area already approved for clearing (Rio Tinto)
Project Disturbance
Proposed Disturbance
Survey Quadrats
Priority Flora (Biota)
Eremophila magnifica subsp. magnifica
Indigofera ixocarpa
Rhagodia sp. Hamersley
Priority Flora (Pilbara Iron)
Eremophila magnifica subsp. magnifica
Goodenia lyrata
Priority Flora (DEC)
Cyanchum sp. Hamersley
Triumfetta leptacantha
Lobelia heterophylla subsp. Pilbara
Weeds
*Acetosa vesicaria
N
0
1
2
kilometres
Vegetation mapping source: Mattiske & Associates 1992
Biota Environmental Sciences
Marandoo Mine Phase 2
Project Vegetation & Flora Survey
Map 3
Author:
Date: 15/06/2008
Drawn: P Sawers
Revised: 28/08/2008
Job No.: 373
Report No.:
Projection: GDA94
Scale: 1 : 42,500 (at A3)

Appendix 3

Vegetation Structural Classification and Condition Ranking Scale

Vegetation Structural Classes*

Stratum	Canopy Cover (%)				
	70-100%	30-70%	10-30%	2-10%	<2%
Trees over 30 m	Tall closed forest	Tall open forest	Tall woodland	Tall open woodland	Scattered tall trees
Trees 10-30 m	Closed forest	Open forest	Woodland	Open woodland	Scattered trees
Trees under 10 m	Low closed forest	Low open forest	Low woodland	Low open woodland	Scattered low trees
Shrubs over 2 m	Tall closed scrub	Tall open scrub	Tall shrubland	Tall open shrubland	Scattered tall shrubs
Shrubs 1-2 m	Closed heath	Open heath	Shrubland	Open shrubland	Scattered shrubs
Shrubs under 1 m	Low closed heath	Low open heath	Low shrubland	Low open shrubland	Scattered low shrubs
Hummock grasses	Closed hummock grassland	Hummock grassland	Open hummock grassland	Very open hummock grassland	Scattered hummock grasses
Grasses, Sedges, Herbs	Closed tussock grassland / bunch grassland / sedgeland / herbland	Tussock grassland / bunch grassland / sedgeland / herbland	Open tussock grassland / bunch grassland / sedgeland / herbland	Very open tussock grassland / bunch grassland / sedgeland / herbland	Scattered tussock grasses / bunch grasses / sedges / herbs

* Based on Muir (1977), and Aplin's (1979) modification of the vegetation classification system of Specht (1970): Aplin T.E.H. (1979). The Flora. Chapter 3 *In* O'Brien, B.J. (ed.) (1979). *Environment and Science.* University of Western Australia Press; Muir B.G. (1977). Biological Survey of the Western Australian Wheatbelt. Part II: Vegetation and habitat of Bendering Reserve. *Records of the Western Australian Museum, Suppl.* No. 3; Specht R.L. (1970). Vegetation. *In The Australian Environment.* 4th edn (Ed. G.W. Leeper). Melbourne.

Vegetation Condition Scale*

E = Excellent (=Pristine of BushForever) Pristine or nearly so; no obvious signs of damage caused by the activities of European man.
VG = Very Good (= Excellent of BushForever) Some relatively slight signs of damage caused by the activities of European man. For example, some signs of damage to tree trunks caused by repeated fire, the presence of some relatively non-aggressive weeds such as **Ursinia anthemoides* or **Briza* spp., or occasional vehicle tracks.
G = Good (= Very Good of BushForever) More obvious signs of damage caused by the activities of European man, including some obvious impact on the vegetation structure such as that caused by low levels of grazing or by selective logging. Weeds as above, possibly plus some more aggressive ones such as **Ehrharta* spp.
P = Poor (= Good of BushForever) Still retains basic vegetation structure or ability to regenerate to it after very obvious impacts of activities of European man, such as grazing, partial clearing (chaining) or frequent fires. Weeds as above, probably plus some more aggressive ones such as **Ehrharta* spp.
VP = Very Poor (= Degraded of BushForever) Severely impacted by grazing, very frequent fires, clearing or a combination of these activities. Scope for some regeneration but not to a state approaching good condition without intensive management. Usually with a number of weed species including very aggressive species.
D = Completely Degraded (= Completely Degraded of BushForever) Areas that are completely or almost completely without native species in the structure of their vegetation; ie. areas that are cleared or 'parkland cleared' with their flora comprising weed or crop species with isolated native trees or shrubs.

* Based on Trudgen M.E. (1988). A Report on the Flora and Vegetation of the Port Kennedy Area. Unpublished report prepared for Bowman Bishaw and Associates, West Perth.

Appendix 4

Raw Data from Floristic Survey Sites Established During 2007 / 2008 Survey Work

NB. * denotes introduced species (weeds)
Numbers indicate estimated percent foliar cover; + indicates <1%.

Marandoo Site MAR01

Described	RW	Date	6/03/2007			Type	Q	50m x 50m
MGA	50	625322	mE	7490681	mN			
Habitat	Flat plain, gently sloping north-east							
Soil	Red-brown clay to clay-loam							
Rock Type	Ironstone							
Vegetation	Acacia aneura (various forms) tall open shrubland over Eremophila forrestii open shrubland over Triodia melvillei open hummock grassland							
Veg Condition	Excellent							
Fire Age	Burnt ~5 years ago							

Marandoo Site MAR02

Described	RW	Date	7/03/2007			Type	Q	50m x 50m
MGA	50	618547	mE	7495792	mN			
Habitat	Drainage area through flat plain between low rise and mountain.							
Soil	Red-brown clay							
Rock Type	Few ironstone rocks present							
Vegetation	Acacia aneura var. pilbarana low open forest over A. pruinocarpa scattered tall shrubs over Themeda triandra (Bothriochloa ewartiana) closed tussock grassland							
Veg Condition	Very Good: some *Bidens bipinnata and *Setaria verticillata							
Fire Age	Burnt >3 years ago							

Marandoo Site MAR03

Described	MM	Date	7/03/2007			Type	Q	50m x 50m
MGA	50	620182	mE	7494618	mN			
Habitat	Colluvial lower slope, gently sloping north							
Soil	Red fine clay-loam; patchy stony surface							
Rock Type	Possibly chert							
Vegetation	Acacia pruinocarpa, Hakea chordophylla scattered tall shrubs over A. ancistrocarpa open shrubland over Triodia wiseana hummock grassland							
Veg Condition	Excellent							
Fire Age	Burnt ~5 years ago							
Notes	Incomplete quadrat; don't use in an analysis.							

Marandoo Site MAR04

Described	RW	Date	7/03/2007			Type	Q	80m x 30m
MGA	50	619523	mE	7494654	mN			
Habitat	Stony plain (moderate slope to north-east) at base of a low rise							
Soil	Red-brown clay (loam)							
Rock Type	Ironstone							
Vegetation	Eucalyptus leucophloia scattered low trees over Acacia aneura var. pilbarana, A. pruinocarpa tall shrubland over Cassia luerssenii, Gossypium robinsonii, Acacia tenuissima scattered shrubs over Triodia wiseana (T. melvillei, T. sp. Shovelanna Hill) hummock grassland							
Veg Condition	Excellent							
Fire Age	Burnt >3 years ago							
Notes	Quadrat dimensions adjusted to fit community							

Marandoo Site MAR05

Described	RO	Date	7/03/2007			Type	Q	
MGA	50	619951	mE	7494306	mN			
Habitat	Creekline (about 2 m across) and banks							
Soil	Red fine clay-loam							
Rock Type	Chert, jasper, rocky surface							
Vegetation	Eucalyptus leucophloia scattered low trees over Acacia maitlandii tall shrubland over Triodia sp. Shovelanna Hill hummock grassland							
Veg Condition	Excellent							
Fire Age	Burnt >5 years ago							
Notes	Fauna pit line on north-west edge of quadrat.							

Marandoo Site MAR06

Described	PH	Date	7/03/2007			Type	Q	50 m x 50
MGA	50	619818	mE	7494278	mN			
Habitat	Rocky hillslope of a medium rise; sloping east.							
Soil	Red-brown clay (loam)							
Rock Type	Ironstone							
Vegetation	Eucalyptus leucophloia, Corymbia hamersleyana scattered low trees over Acacia pyrifolia, A. aneura var. pilbarana scattered tall shrubs over A. maitlandii, A. pyrifolia, Cassia glutinosa open shrubland over Eremophila magnifica subsp. magnifica scattered low shrubs over Triodia wiseana, T. sp. Shovelanna Hill hummock grassland							
Veg Condition	Excellent							
Fire Age	Burnt >3-5 years ago							

Marandoo Site MAR07

Described	JA	Date	8/03/2007		Type	Q	50m x 50m
MGA	50	621062	mE	7493623 mN			
Habitat	Gentle hillslope (sloping to north-east).						
Soil	Red fine clay loam with a continuous layer of pebbles on surface						
Rock Type	Banded ironstone rocks <8 cm on surface; minor outcropping.						
Vegetation	Eucalyptus leucophloia scattered low trees over Acacia maitlandii, A. atkinsiana, A. bivenosa scattered shrubs over Triodia sp. Shovelanna Hill closed hummock grassland						
Veg Condition	Excellent						
Fire Age	No evidence of recent fire						

Marandoo Site MAR08

Described	PH	Date	8/03/2007		Type	Q	50 m x 50
MGA	50	620911	mE	7493735 mN			
Habitat	Slope of a low rise (sloping to the north-east)						
Soil	Red-brown clay to clay-loam with rocky surface cover						
Rock Type	Ironstone						
Vegetation	Corymbia hamersleyana, Eucalyptus leucophloia scattered low trees over Acacia pruinocarpa, Grevillea wickhamii subsp. hispidula scattered tall shrubs over A. maitlandii, A. atkinsiana, Eremophila magnifica subsp. magnifica shrubland over Triodia wiseana, T. sp. Shovelanna Hill hummock grassland						
Veg Condition	Excellent						
Fire Age	Burnt >5 years ago						

Marandoo Site MAR09

Described	JA	Date	8/03/2007		Type	Q	50m x 50m
MGA	50	622928	mE	7491695 mN			
Habitat	Colluvial foothills; massive breakaway to east/north-east						
Soil	Red fine clay-loam						
Rock Type	Continuous surface layer of ironstone						
Vegetation	Acacia ancistrocarpa, A. atkinsiana open shrubland over Triodia sp. Shovelanna Hill hummock grassland						
Veg Condition	Excellent						
Fire Age	Burnt >5 years ago						

Marandoo Site MAR10

Described	PH	Date	8/03/2007		Type	Q	30m x 80m
MGA	50	622940	mE	7491890 mN			
Habitat	South-facing breakaway of east-west low range						
Soil	Red-brown skeletal clay-loam						
Rock Type	Ironstone						
Vegetation	Eucalyptus leucophloia low open woodland over Gossypium robinsonii, Acacia maitlandii open shrubland over Triodia brizoides hummock grassland						
Veg Condition	Excellent						
Fire Age	Burnt >5 years ago						
Notes	Quadrat dimensions modified to fit vegetation community. Coordinate approximate - site sheet misplaced.						

Marandoo Site MAR11

Described	B/PH	Date	18/05/2007		Type	Q	30x70
MGA	50	619462	mE	7495080 mN			
Habitat	Drainage line through broad valley/plain; seasonally wet.						
Soil	Red-brown clay						
Rock Type	Ironstone						
Vegetation	Acacia aneura var. pilbarana low woodland over Indigofera georgei shrubland over Triodia melvillei hummock grassland with Cymbopogon obtectus, Aristida pruinosa open tussock grassland						
Veg Condition	Very good						
Fire Age	No sign of recent fire						

Marandoo Site MAR12

Described	RW/PH	Date	19/05/2007		Type	Q	50x50
MGA	50	624743	mE	7491212 mN			
Habitat	Base of medium rise in wider valley						
Soil	Red-brown clay-loam						
Rock Type	Ironstone						
Vegetation	Acacia pruinocarpa scattered tall shrubs over A. atkinsiana (A. ancistrocarpa, Hakea chordophylla) open shrubland over Triodia sp. Shovelanna Hill hummock grassland						
Veg Condition	Excellent						
Fire Age	Burnt 3-5 years ago						

Marandoo Site MAR13

Described	BrMa	Date	19/05/2007		Type	Q	50x50
MGA	50	624739	mE	7491085 mN			
Habitat	Minor flowline off ridge; very slight easterly aspect.						
Soil	Red-brown clay-loam						
Rock Type	Ironstone						

Vegetation	Corymbia deserticola low open woodland over Acacia atkinsiana (A. maitlandii) open heath over Triodia sp. Shovelanna Hill, T. wiseana open hummock grassland
Veg Condition	Excellent
Fire Age	3-5 years since fire
Notes	Mosaic vegetation

Marandoo Site MAR14

Described	B/PH	Date	19/05/2007		Type	R	
MGA	50	622787	mE	7492404	mN		
Habitat	Creek						
Soil	Red-brown alluvial clay						
Rock Type	Ironstone						
Vegetation	Eucalyptus leucophloia scattered low trees over E. gamophylla low mallee woodland over Acacia ancistrocarpa, A. aneura var. pilbarana shrubland over Triodia schinzii very open hummock grassland and Themeda triandra, Eulalia aurea very open tussock grassland						
Veg Condition	Very Good						
Fire Age	No sign of recent fire						

Marandoo Site MAR15

Described	RW	Date	19/05/2007		Type	Q	50*50m
MGA	50	624289	mE	7491891	mN		
Habitat	Foot of medium rise within broader valley						
Soil	Red-brown clay						
Rock Type	Ironstone						
Vegetation	Acacia atkinsiana tall open shrubland over Acacia ancistrocarpa (Cassia pruinosa, C. glutinosa) open shrubland over Triodia sp. Shovelanna Hill hummock grassland						
Veg Condition	Excellent						
Fire Age	No sign of recent fire						

Marandoo Site MAR16

Described	RW	Date	20/05/2007		Type	Q	50x50m
MGA	50	620850	mE	7492732	mN		
Habitat	Crest of a low ridge.						
Soil	Red-brown loam						
Rock Type	Ironstone; some calcrete in SW corner.						
Vegetation	Eucalyptus leucophloia low open woodland over Acacia pruinocarpa, A. pyrifolia scattered tall shrubs over Triodia sp. Shovelanna Hill, T. wiseana hummock grassland						
Veg Condition	Excellent						
Fire Age	Burnt >5 years ago						

Marandoo Site MAR17

Described	B/PH	Date	20/05/2007		Type	Q	30x70
MGA	50	620722	mE	7492656	mN		
Habitat	Creek						
Soil	Alluvial red-brown clay loam						
Vegetation	Eucalyptus xerothermica, Acacia aneura var. pilbarana low open forest over A. bivenosa, Santalum lanceolatum scattered shrubs over Triodia longiceps open hummock grassland with Themeda triandra, Eulalia aurea very open tussock grassland						
Veg Condition	Very Good: scattered *V. farnesiana, *Bidens and *Malvastrum						
Notes	Quadrat dimensions adjusted to fit creek habitat						

Marandoo Site MAR18

Described	B/PH	Date	20/05/2007		Type	Q	50x50
MGA	50	621359	mE	7492835	mN		
Habitat	Gully and adjacent 10 metre high cliff						
Soil	Red-brown skeletal clay-loam						
Vegetation	Eucalyptus leucophloia, Corymbia ferriticola low open woodland over Gossypium robinsonii, Acacia hamersleyensis scattered tall shrubs over Acacia maitlandii, A. marramamba, A. ancistrocarpa, A. atkinsiana open shrubland over Eremophila magnifica subsp. magnifica scattered low shrubs over Triodia sp. Shovelanna Hill hummock grassland with Eriachne mucronata, Themeda triandra very open tussock grassland						
Veg Condition	Very Good						
Fire Age	No sign of recent fire						

Marandoo Site MAR19

Described	RW/PH	Date	21/05/2007		Type	Q	50x50m
MGA	50	618879	mE	7495863	mN		
Habitat	Broad valley; gently sloping south.						
Soil	Red-brown clay						
Rock Type	Ironstone						
Vegetation	Acacia aneura var. pilbarana (A. pruinocarpa) low woodland over Ptilotus obovatus, Eremophila forrestii subsp. forrestii scattered low shrubs over Triodia schinzii scattered hummock grasses with Themeda triandra very open tussock grassland						
Veg Condition	Very Good: some weeds present.						

Fire Age	Burnt 3-4 years ago
Notes	Small flow line through quadrat, but vegetation appears relatively uniform

Marandoo Site MAR20

Described	B/PH	Date	21/05/2007		Type	Q	30x70
MGA	50	619229	mE	7494257 mN			
Habitat	Creekline						
Soil	Red-brown clay loam						
Rock Type	Ironstone						
Vegetation	Eucalyptus leucophloia low open woodland over Gossypium robinsonii scattered tall shrubs over Acacia maitlandii (A. marramamba) shrubland over Triodia brizoides, T. wiseana closed hummock grassland						
Veg Condition	Very Good: scattered *Bidens						
Fire Age	No sign of recent fire						

Marandoo Site MAR21

Described	BrMa	Date	21/05/2007		Type	Q	50x50
MGA	50	619040	mE	7493845 mN			
Habitat	Hill crest.						
Soil	Red-brown clay						
Vegetation	Eucalyptus gamophylla low open mallee woodland over Petalostylis labicheoides, Acacia atkinsiana tall open shrubland over Gompholobium karijini scattered low shrubs over Triodia sp. Shovelanna Hill, T. wiseana closed hummock grassland						
Veg Condition	Excellent						
Fire Age	No sign of recent fire						

Marandoo Site MAR22

Described	BB	Date	22/05/2007		Type	Q	50x50
MGA	50	618926	mE	7493663 mN			
Habitat	Ridge top (just below crest); gentle slope to south						
Soil	Red-brown gravelly, pebbly loam						
Rock Type	Ironstone						
Vegetation	Eucalyptus leucophloia, Corymbia deserticola scattered low trees over Acacia atkinsiana tall shrubland over Keraudrenia velutina subsp. elliptica (Gompholobium karijini) low open shrubland over Triodia sp. Shovelanna Hill, T. wiseana hummock grassland						
Veg Condition	Excellent						
Fire Age	No sign of recent fire						

Marandoo Site MAR23

Described	RW/PH	Date	21/05/2007		Type	Q	50x50m
MGA	50	618800	mE	7493526 mN			
Habitat	Scree slope (south-facing)						
Soil	Red-brown clay loam with some calcrete-based clays and rocky surface crust						
Vegetation	Eucalyptus leucophloia, E. repullulans, E. gamophylla low woodland over Acacia bivenosa (wispy form) tall shrubland over Acacia maitlandii, Cassia pruinosa scattered shrubs over Triodia brizoides, T. wiseana closed hummock grassland						
Veg Condition	Excellent						
Fire Age	No sign of recent fire						

Marandoo Site MAR24

Described	BB	Date	23/05/2007		Type	Q	200x5m
MGA	50	624874	mE	7489370 mN			
Habitat	Creek floodbanks						
Soil	Red-brown clay loam						
Vegetation	Eucalyptus xerothermica, Acacia aneura var. pilbarana, A. pruinocarpa low open woodland over Petalostylis labicheoides, Rulingia luteiflora, Acacia citrinoviridis, A. maitlandii (Gossypium robinsonii) tall shrubland over Themeda triandra tussock grassland with Triodia wiseana open hummock grassland						
Veg Condition	Excellent						
Fire Age	Burnt 4-5 years ago						
Notes	Survey area restricted to the vegetation unit including Petalostylis and Rulingia						

Marandoo Site MAR25

Described	BB	Date	23/05/2007		Type	Q	
MGA	50	624972	mE	7489737 mN			
Habitat	Mid-slope of colluvial spur (gentle slope, south-east facing)						
Soil	Red-brown gravelly clay-loam						
Rock Type	Ironstone						
Vegetation	Acacia pruinocarpa scattered low trees over Acacia ancistrocarpa scattered shrubs to tall open shrubland over Triodia sp. Shovelanna Hill hummock grassland						
Veg Condition	Excellent						
Notes	Fence peg and raised linear area within quadrat: may be pipe underground?						

Marandoo Site MAR26

Described	BB	Date	24/05/2007		Type	Q	50x50
MGA	50	625216	mE	7490235 mN			
Habitat	Flat plain on valley floor (near base of colluvial spur, on west side).						
Soil	Red-brown gravelly, pebbly loam						
Rock Type	Ironstone						
Vegetation	Acacia ayersiana, A. aneura var. pilbarana (A. pruinocarpa) low open forest over Eremophila forrestii open heath over Triodia schinzii hummock grassland						
Veg Condition	Excellent						
Fire Age	No sign of recent fire						
Notes	Quadrat on edge of plain at base of colluvial spur and may be ecotonal.						

Marandoo Site MAR27

Described	RW/PH	Date	23/05/2007		Type	Q	50x50m
MGA	50	623917	mE	7489725 mN			
Habitat	Stony undulating plain (low rises and depressions with a westerly aspect)						
Soil	Orange-brown powdery loam with a surface layer of ironstone (or manganese?) and						
Rock Type	Ironstone/calcrete						
Vegetation	Eucalyptus socialis low mallee woodland over Acacia bivenosa scattered shrubs over Triodia wiseana, T. longiceps hummock grassland						
Veg Condition	Excellent						
Fire Age	Burnt 4-5 years ago						
Notes	South-west corner pegged.						

Marandoo Site MAR28

Described	RW/PH	Date	23/05/2007		Type	Q	50x50m
MGA	50	624189	mE	7490392 mN			
Habitat	Stony hill crest						
Soil	Red-brown skeletal soil						
Rock Type	Ironstone						
Vegetation	Eucalyptus leucophloia, Acacia aneura low open woodland over Acacia atkinsiana, A. pyrifolia open shrubland over Triodia wiseana, sp. Shovelanna Hill hummock grassland						
Veg Condition	Excellent						
Fire Age	Burnt 3-5 years ago						
Notes	Acacia aneura mostly resprouting from fire 3-5 years ago; average height 1 m. Dead						

Marandoo Site MAR29

Described	BB	Date	24/05/2007		Type	Q	50x50
MGA	50	623739	mE	7491501 mN			
Habitat	Upper slope of ridge (just below crest); gentle north-facing slope						
Rock Type	Ironstone						
Vegetation	Eucalyptus leucophloia scattered low trees to low open woodland over Acacia pruinocarpa scattered tall shrubs over Acacia maitlandii open heath over Triodia wiseana, T. brizoides hummock grassland						
Veg Condition	Excellent						
Fire Age	Burnt 3-4 years ago						

Marandoo Site MAR30

Described	BB	Date	25/05/2007		Type	Q	50x50
MGA	50	620331	mE	7494922 mN			
Habitat	Broad flat plain						
Soil	Red-brown clay loam						
Rock Type	Ironstone						
Vegetation	Acacia aneura var. pilbarana low open woodland over Triodia bitextura very open hummock grassland with Aristida ingrata, Chrysopogon fallax very open tussock grassland						
Veg Condition	Very Good: only scattered weeds						
Fire Age	No sign of recent fire						
Notes	Dense annual grasses and herbs also present						

Marandoo Site MAR31

Described	RW/PH	Date	24/05/2007		Type	Q	50x50
MGA	50	621808	mE	7491141 mN			
Habitat	Valley floor between steep-sided slopes						
Soil	Calcrete, rocky surface crust over powdery loam substrate.						
Rock Type	Calcrete						
Vegetation	Eucalyptus repullulans low open woodland over Melaleuca eleuterostachya scattered shrubs over Triodia wiseana, T. longiceps hummock grassland						
Veg Condition	Excellent						
Fire Age	Burnt 5-7 years ago						

Marandoo Site MAR32

Described	RW/PH	Date	24/05/2007		Type	Q	50x50m
MGA	50	621047	mE	7491419	mN		
Habitat	Hill crest						
Soil	Red-brown clay						
Rock Type	Ironstone (pebbles and cobbles)						
Vegetation	Eucalyptus leucophloia, Acacia aneura var. aneura low woodland (A. pruinocarpa) over Petalostylis labicheoides shrubland over Triodia wiseana open hummock grassland						
Veg Condition	Excellent						
Fire Age	Burnt 3-5 years ago						
Notes	Mulga here is predominantly burnt.						

Marandoo Site MAR33

Described	RW/PH	Date	24/05/2007		Type	Q	50x50
MGA	50	621652	mE	7492101	mN		
Habitat	Colluvial spur.						
Soil	Red-brown clay loam with a surface layer of shale and ironstone pebbles						
Rock Type	Colluvial, ironstone						
Vegetation	Eucalyptus leucophloia low open woodland over Acacia pruinocarpa, A. pyrifolia scattered tall shrubs over Acacia ancistrocarpa, A. bivenosa open shrubland over Triodia wiseana closed hummock grassland						
Veg Condition	Excellent						
Fire Age	Burnt 3-5 years ago						

Marandoo Site MAR34

Described	BB	Date	25/05/2007		Type	Q	50x45
MGA	50	621749	mE	7494219	mN		
Habitat	Very gentle slope on edge of broad flat plain (north-facing)						
Soil	Red-brown loamy clay						
Vegetation	Acacia aneura var. pilbarana, A. aneura var. intermedia low woodland over Dipteracanthus australasicus subsp. australasicus, Ptilotus obovatus low open shrubland over Themeda triandra (Chrysopogon fallax, Digitaria brownii) closed tussock grassland						
Veg Condition	Very Good: scattered weeds						
Fire Age	Burnt >4-5 years ago						

Marandoo Site MAR37

Described	RW/PH	Date	25/05/2007		Type	Q	50m * 50m
MGA	50	620078	mE	7492447	mN		
Habitat	Ridge crest						
Soil	Red-brown clay-loam						
Rock Type	Colluvial ironstone (boulders, cobbles)						
Vegetation	Eucalyptus leucophloia, Acacia aneura var. pilbarana low woodland over Grevillea wickhamii scattered tall shrubs over Petalostylis labicheoides, Acacia maitlandii open shrubland over Triodia brizoides, T. wiseana closed hummock grassland						
Veg Condition	Excellent						
Fire Age	Burnt 3-5 years ago						

Marandoo Site MAR38

Described	RW/PH	Date	25/05/2007		Type	Q	50m *50m
MGA	50	619966	mE	7492122	mN		
Habitat	Slope of a medium ridge						
Soil	Orange-brown clay-loam						
Rock Type	Laterite and ironstone						
Vegetation	Acacia aneura var. pilbarana low closed forest over Dipteracanthus australasicus subsp. australasicus scattered low shrubs over Triodia wiseana, T. longiceps hummock grassland						
Veg Condition	Very good: only scattered weeds						
Fire Age	No sign of recent fire						

Marandoo Site MARA01

Described	JAJCF	Date	21/04/2008		Type	Q	50*50M
MGA	50	599840	mE	7518171	mN		
Habitat	Higher area adjacent to floodplain						
Soil	Red-brown clay						
Vegetation	Acacia aneura low open forest over Chrysopogon fallax, Digitaria brownii tussock grassland						
Veg Condition	Good: considerable *Bidens						
Fire Age	Burnt 2 years ago						

Marandoo Site MARA02

Described	JAJCF	Date	22/04/2008		Type	Q	50x50M
MGA	50	601888	mE	7515136	mN		
Habitat	Small rise on a flat plain						
Soil	Red clay-loam						
Rock Type	Ironstone						
Vegetation	Acacia aneura, A. pruinocarpa open woodland over Triodia melvillei scattered hummock grasses and						

	Chrysopogon fallax scattered tussock grasses
Veg Condition	Good
Fire Age	Burnt 2-3 years ago

Marandoo Site MARA03

Described	JAJCF	Date	22/04/2008		Type	Q	50*50M
MGA	50	601444	mE	7516281 mN			
Habitat	Slight rocky rise in low flat plain						
Soil	Red loam						
Rock Type	Ironstone						
Vegetation	Acacia pruinocarpa, A. aneura tall open shrubland over A. ancistrocarpa open shrubland over Triodia melvillei, T. wiseana hummock grassland						
Veg Condition	Excellent						
Fire Age	No sign of recent fire						

Marandoo Site MARA04

Described	JAJCF	Date	23/04/2008		Type	Q
MGA	50	595331	mE	7507421 mN		
Habitat	Plain					
Soil	Red-brown clay-loam					
Vegetation	Acacia aneura (two forms) low open forest over Santalum spicatum tall open shrubland over Acacia sclerosperma subsp. sclerosperma open shrubland					

Marandoo Site MARA05

Described	JAJCF	Date	24/04/2008		Type	Q
MGA	50	624203	mE	7491176 mN		
Habitat	Rocky slope (rugged massive outcrops, sloping east; gully through centre)					
Soil	Red-brown shallow clay loam					
Rock Type	BIF, quartz and chert?					
Vegetation	Acacia aneura (Eucalyptus leucophloia) low open forest over Eremophila magnifica subsp. magnifica, Acacia marramamba, Dodonaea pachyneura, D. petiolaris open shrubland over Triodia brizoides open hummock grassland					
Veg Condition	Very Good: only scattered weeds					
Fire Age	No sign of recent fire					
Notes	Burnt areas around quadrat					

Marandoo Site MARA06

Described	JAJCF	Date	25/04/2008		Type	Q	50x50M
MGA	50	605181	mE	7503202 mN			
Habitat	Flat rise in stony plain						
Soil	Red-brown clay						
Rock Type	Quartz and ironstone pebbles and cobbles						
Vegetation	Acacia aneura, A. pruinocarpa tall open shrubland over A. ancistrocarpa, A. bivenosa open shrubland over Triodia wiseana (T. melvillei) hummock grassland						
Veg Condition	Excellent						
Fire Age	Burnt 3-4 years ago						

Marandoo Site MARA07

Described	JAJCF	Date	26/04/2008		Type	Q	50*50M
MGA	50	604812	mE	7501474 mN			
Habitat	Floodplain of creekline						
Soil	Red-brown clay						
Vegetation	Acacia aneura low open forest over Ptilotus obovatus low open shrubland over Themeda triandra tussock grassland						
Veg Condition	Very Good: signs of cattle, scattered weeds						
Fire Age	Burnt 2-3 years ago						

Marandoo Site MARA08

Described	JAJCF	Date	28/04/2008		Type	Q	50*50m
MGA	50	604331	mE	7502482 mN			
Habitat	Rocky rise, some surface outcropping						
Soil	Red-brown clay loam						
Rock Type	Ironstone and quartz pebbles and cobbles						
Vegetation	Eucalyptus leucophloia scattered trees over Acacia maitlandii shrubland over Triodia wiseana hummock grassland						
Veg Condition	Excellent						
Fire Age	Burnt ~4 years ago						

Marandoo Site MARA-J1

Described	JAJCF	Date	22/04/2008		Type	R
MGA	50	601094	mE	7517977 mN		
Habitat	Poorly defined stony creek					
Vegetation	Acacia aneura low woodland over Themeda triandra, Eulalia aurea, Aristida ingrata tussock grassland					

Marandoo Site MARA-J2

Described	JAJCF	Date	23/04/2008			Type	R
MGA	50	601999	mE	7514953	mN		
Habitat	Clayey plain						
Soil	Red cracking clay (with patches of gilgai)						
Vegetation	Acacia aneura, A. pruinocarpa (Hakea lorea subsp. lorea) low open forest over Chrysopogon fallax, (Themeda triandra, Aristida ingrata) closed tussock grassland						
Notes	Incomplete releve; don't use in an analysis.						

Marandoo Site MARA-J3

Described	JAJCF	Date	26/04/2008			Type	R
MGA	50	604779	mE	7501571	mN		
Habitat	Creek bank						
Soil	Red-brown clay-loam						
Vegetation	Eucalyptus victrix low open woodland over Acacia citrinoviridis tall open scrub over Themeda triandra (Aristida ingrata) open tussock grassland						
Notes	Dense cover of Dichanthium sericeum subsp. humilius also present						

NB: numbers = estimated foliar cover within site; "+" = <1% cover; "nc" = present but cover not recorded.

Species	MAR 01	MAR 02	MAR 03	MAR 04	MAR 05	MAR 06	MAR 07	MAR 08	MAR 09	MAR 10	MAR 11	MAR 12	MAR 13	MAR 14	MAR 15	MAR 16	MAR 17	MAR 18	MAR 19	MAR 20	MAR 21	MAR 22	MAR 23	MAR 24	MAR 25	MAR 26	MAR 27	MAR 28	MAR 29	MAR 30	MAR 31	MAR 32	MAR 33	MAR 34	MAR 37	MAR 38	MARA 01	MARA 02	MARA 03	MARA 04	MARA 05	MARA 06	MARA 07	MARA 08	MARA - J1	MARA - J2	MARA - J3
Abutilon cryptopetalum		nc																																+		+						+				
Abutilon cunninghamii																											+																			
Abutilon dioicum					nc													+		+																										
Abutilon aff. *dioicum*																+				+			+																								
Abutilon fraseri																								+												+						+			+	
Abutilon lepidum																+																												nc			
Abutilon aff. *lepidum* (1) (MET 15 352)		nc																	+																	+	+					+				
Abutilon aff. *lepidum* (4)																																+														
Abutilon leucopetalum																																				+										
Abutilon macrum																			+															+												
Abutilon otocarpum (acute leaf form)	nc	nc								nc	+		+	+				+	+				+	+	+				+					+		+	+								
Abutilon trudgenii											+																																		
Acacia adoxa var. *adoxa*	2-5																			+	+	+																								
Acacia ancistrocarpa			2-10						5			+	1%	15%	4			1%					+	2-4%						+		3					+	4			3		+			
Acacia aneura var. *aneura*													+					+													15-20															
Acacia aneura var. *? aneura*																						+																								
Acacia aneura var. *conifera*										nc															+			6																		
Acacia aneura var. *intermedia*	2-5							nc																										5-8%		+										
Acacia aneura var. *pilbarana*	2-5	30-70		2-5	nc	nc					15%			10%			40%		12	+	+			1-2%		15-20%			+	+				5-10%	15	70								30			
Acacia aneura (grey flat recurved tips; MET 15 828)																																										+				
Acacia aff. *aneura* (narrow fine veined; site 1259)																																			50	+				5	50	+			
Acacia aneura (form not recorded)																															+							30	50-70				20	+
Acacia arida														+																																
Acacia atkinsiana					nc	nc	nc	10-30	3			8%	40%	+	5			1%		+	2%	10-15%	+	+	+			5	+		+	+															
Acacia ayersiana																									25-30%																					
Acacia bivenosa				<1		+	<1	+								+	2%	+						1-2%	+						+	+	3	+					nc		1		+			
Acacia bivenosa (wispy/weeping form)	nc	nc								nc	nc									+			20				+																			
Acacia citrinoviridis																								3-5%		+																	+	+	nc	+	50
Acacia colei var. *colei*														+																																
Acacia dictyophleba				nc										+					+													+													
Acacia exilis																																												+		
Acacia hamersleyensis										nc								+							+			+	+																
Acacia inaequilatera																				+																										
Acacia kempeana				nc							1%								+					1%																						
Acacia maitlandii				nc	30	5	<1	8		2-5		+	3%	+	+	+	+	2%		30%		+	1	2-3%				+	30-35%		+			3								20			
Acacia marramamba						nc		2		+	+							2%		1%	+	+						+	+												2				
Acacia monticola						nc		nc																																				nc		
Acacia pachyacra	nc						+	nc	+		2%			+																								+								
Acacia pruinocarpa	+	1	nc	5			+	+		+	+	1%	1%			1	+	+	1	+	+			2-4%	2-3%	2-4%		+	1-2%	+		5	+	<1%		+		4	1		+	5		+	nc	20	
Acacia pyrifolia (slender form)																					+	+																								
Acacia pyrifolia var. *pyrifolia*					nc	nc				nc						+									+			1	+			1					+	nc					+	nc		
Acacia rhodophloia																																									+					
Acacia sclerosperma subsp. *sclerosperma*																																						3							
Acacia sibirica																	+											+																	
Acacia sibirica (linear form)																								1%																						
Acacia synchronicia													+										+								+		+			+									
Acacia tenuissima			nc	nc				nc	+														+									+	+		+										
Acacia tetragonophylla				nc			+				+			+		+		+													+														
Acacia tumida var. *pilbarensis*																		+																												
Acacia xiphophylla																																			+	+									
Achyranthes aspera																																													+
Alternanthera angustifolia																														<1%															
Alternanthera nana		nc									+						+		+															+			+			nc			+			+	+
Amaranthus cuspidifolius																		+																												
Amaranthus interruptus										nc																																				
Amaranthus undulatus																									+																					
Amphipogon sericeus			nc	nc			nc		nc																	+										+						+		+		
Anthobolus leptomerioides				nc								+						+						+		+										+	+				+					
Aristida burbidgeae										nc																																			
Aristida contorta	nc			+							+		+	+		+		+	2-3		+			+		+				+		+	+	+	+	+		+	nc	+	+		+			
Aristida holathera var. *holathera*	+			+			+					+		+	+							+		+		+			+							+				+		+			
Aristida inaequiglumis	nc															+																														
Aristida ingrata		nc	nc	nc	nc		nc	nc						+	+							+		+	+	+				5-10%		+		+			+	+			nc	20	+
Aristida jerichoensis var. *subspinulifera*																						+																							
Aristida latifolia																	+																												
Aristida obscura																																		+		+	+								
Aristida pruinosa											5%								+																											
Astrotricha hamptonii										nc								+																												
**Bidens bipinnata*		+									+			+		+	+	+	+	+				+		+				+				<1%		+	50	+		nc	+		+		20-30	50	+
Blumea tenella																								+										+											
Boerhavia coccinea		nc															+		+																	+		+							
Boerhavia paludosa											+								+																											
Boerhavia repleta		nc																						+										+			+								
Bothriochloa ewartiana		2-10																																			+		nc			+				
Brachyachne prostrata																															+														
Brachyscome ciliocarpa																								+										nc			+					+			
Bulbostylis barbata	+									+								+								+				+					+										
Bulbostylis turbinata																+								+																					
Calandrinia sp.																								+																					
Calotis latiuscula																																						nc			+					
Capparis lasiantha		+					+			nc			+			+	+	+				+	+				+	+		+		+					+				+				
Capparis umbonata										+																																				
Cassia artemisioides											1%						+																													
Cassia ferraria																						+																								
Cassia ferraria x *glutinosa*																																											+			
Cassia glaucifolia	nc					nc	nc											+							+			+					+												
Cassia glaucifolia x *oligophylla*																																												+		
Cassia glutinosa		nc		nc	nc	nc		nc		nc			1%			+		+		+		+	+		+			+	+		+	+		+				+		+		+		
Cassia aff. *glutinosa*					nc			+																					+			+													
Cassia glutinosa x *stricta*																+					+							+	+			+					+								
Cassia helmsii												+	+					+	+			+												+				+						+		
Cassia luerssenii	nc		nc	nc			+					+				+		+		+		+	+	+			+			+	+			+								+		
Cassia notabilis																				+		+		+		+	+									+	+	+		1				nc		
Cassia oligophylla																																						+						+		
Cassia oligophylla x *helmsii*			nc		nc		nc							+	+			nc		+		+	+	+			+					+			+	+									
Cassia oligophylla x *stricta*																																+														

Species	MAR 01	MAR 02	MAR 03	MAR 04	MAR 05	MAR 06	MAR 07	MAR 08	MAR 09	MAR 10	MAR 11	MAR 12	MAR 13	MAR 14	MAR 15	MAR 16	MAR 17	MAR 18	MAR 19	MAR 20	MAR 21	MAR 22	MAR 23	MAR 24	MAR 25	MAR 26	MAR 27	MAR 28	MAR 29	MAR 30	MAR 31	MAR 32	MAR 33	MAR 34	MAR 37	MAR 38	MARA 01	MARA 02	MARA 03	MARA 04	MARA 05	MARA 06	MARA 07	MARA 08	MARA - J1	MARA - J2	MARA - J3
Cassia aff. *oligophylla* (thinly sericeous) x *glutinosa*											+						+		+																										
Cassia pruinosa				nc		nc	+	nc		nc				+	+	+				+			+					+					+									+			
Cassia stricta				nc	nc	nc			nc						+									+																					
Cassia symonii																												+																		
**Cenchrus ciliaris*																																						nc					nc	2	
**Cenchrus setiger*																																											nc		+
Centipeda minima																														+															
Cheilanthes sieberi subsp. *sieberi*	nc										+						+	+				+				+				+					+						+	+			
Chloris pectinata																														+				+			2									
**Chloris virgata*																																				+										
Chrysopogon fallax	nc	+									+						+		+					+						1%				1-2%		30	2		nc			+		nc	50	
Cleome viscosa		+								+								+	+															+		+	+							nc	+	
Clerodendrum tomentosum var. *lanceolatum*																						+																								
Codonocarpus cotinifolius	+						+	+								+			+		+						+	+																		
Commelina ensifolia																														+							+			nc					nc	+	
Convolvulus angustissimus subsp. *angustissimus*		nc																	+											+				+								+				
Convolvulus clementii																																					+										
Convolvulus remotus																																		+					nc							
Corchorus crozophorifolius																																														+
Corchorus lasiocarpus subsp. *lasiocarpus*					nc		nc					+			+	+						+			+										+										
Corchorus lasiocarpus subsp. *parvus*																																			+			+							
Corchorus sidoides													+																																
Corymbia deserticola subsp. *deserticola*						nc		nc		nc			+									1-2%																				+				
Corymbia ferriticola subsp. *ferriticola*										nc								1																													
Corymbia hamersleyana								nc																																nc						
Cucumis maderaspatanus	+	nc					+	+			+								+						+	+								+	+		+				+		nc		+	
**Cucumis melo* subsp. *agrestis*																																										+				
Cymbopogon ambiguus	nc		nc	nc	nc	nc	nc			nc		+		+		+				+		+		+										+	+					+		nc		+	
Cymbopogon obtectus											10%		+		+			+						+	+	+				1%	+	+						+			+				
Dactyloctenium radulans																																		+			+	+				+		nc		
Dampiera candicans						nc																																								
**Datura leichhardtii*																																										+				
Daucus glochidiatus																		+																												
Dichanthium sericeum subsp. *humilius*																	1%							+						+				+			+			nc			+			60
Dicladanthera forrestii																																										+				+
Digitaria ammophila								nc			+							+			+		+			+				30-40%		+			+					nc	+		+		nc		+
Digitaria brownii	nc			nc				nc			+		+			+			+		+			+		+				+		+		1-2%		30	1					+				+
Digitaria ctenantha																																		+			1	+					+				
Diplatia grandibractea																							+																								
Dipteracanthus australasicus subsp. *australasicus*	nc															+	+		+															3-5%		2						2				
Dodonaea coriacea	nc						+																										+										+				
Dodonaea lanceolata var. *lanceolata*																				+																											
Dodonaea pachyneura								nc		nc																									+						2						
Dodonaea petiolaris																												+							+	+						+						
Dodonaea viscosa subsp. *spatulata*																		+																													
Duperreya commixta	nc	+	nc	+			+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+		+				+	+	+				nc	+	+	+		nc		
Dysphania kalpari															+																																
Dysphania rhadinostachya	+									+								+																	+												
**Echinochloa colona*																																					+						+				
Enchylaena tomentosa var. *tomentosa*		nc									+												+																							
Enneapogon caerulescens																+							+	+	+	+						+	+		+				nc							
Enneapogon lindleyanus					nc		nc										+																														+
Enneapogon polyphyllus	nc	+				nc					+		+	+		+	+	+	1		+		+	+	+	+		+	+	+	+	+	+	5-8%	+	+		+					+	+		+	
Enneapogon robustissimus											+																																		+	
Eragrostis cumingii	+										+			+			+													+				+			+									
Eragrostis eriopoda															+												+																		
Eragrostis exigua																														+															
Eragrostis pergracilis	+																									+																			
Eragrostis setifolia																										+																			
Eragrostis tenellula																	+													+															
Eremophila cuneifolia																																	+		+	+						+				
Eremophila forrestii subsp. *forrestii*	2-10							nc											+					+	+	30-40%			+								+									
Eremophila fraseri																			+						+	+																				
Eremophila jucunda subsp. *pulcherrima*																																												1			
Eremophila lanceolata																																													+	
Eremophila latrobei subsp. *filiformis*	nc		nc	nc			nc	nc								+							+											+	+							+	+			
Eremophila latrobei subsp. *latrobei*	nc																																													
Eremophila longifolia		+	nc										+			+	+		+						+										+		+									
Eremophila magnifica subsp. *magnifica*						nc		nc		nc		+						1%		+																							5					
Eremophila petrophila subsp. *petrophila*										nc																																			1				
Eriachne benthamii																																			+												
Eriachne lanata																						+																								
Eriachne mucronata			nc		nc	+	+	nc		nc					+	+		3		+		+	+	1%	+				+			+	+	+	+	+						1			+			
Eriachne mucronata (xerophytic form)		nc																																												
Eriachne pulchella															+	+				+					+	+				+					+				nc	+					
Eucalyptus gamophylla														25%							8%	+	1																							
Eucalyptus leucophloia subsp. *leucophloia*				nc	2	2	+	nc		4				1%		+		1-2%		2%		1-2%	3					5	2-3%			5-10	8		3-4					5	+		5			
Eucalyptus repullulans																							5								8															
Eucalyptus socialis subsp. *eucentrica*																											25																		
Eucalyptus trivalva																								+												1										
Eucalyptus victrix																																														2-10
Eucalyptus xerothermica																	15%							1-2%																						
Eulalia aurea											+	+		3%		+	1%		+														+				+			nc			+		10		
Euphorbia australis															+	+								+	+																		+				
Euphorbia aff. *australis* var. 1 (MET 12 337)																																			+											
Euphorbia biconvexa		nc			nc						+			+			+		+					+		+					+					+	+								
Euphorbia boophthona																		+								+														nc						
Euphorbia tannensis subsp. *eremophila* (Hamersley form)																																														
Euphorbia sp. (site 1089)																																													nc		
Evolvulus alsinoides var. *decumbens*																																														
Evolvulus alsinoides var. *villosicalyx*		+									+		+	+		+	+	+	+	+				+	+	+				+					+	+	+	+	+		nc		+		nc	+	+
Fimbristylis dichotoma																+																														
Flaveria australasica																+								+										+												
Glycine canescens																																						+		nc			+				
Glycine tabacina		nc																+																													
Gompholobium karijini						nc	nc		+				+			+				+	1%	+						+	+						+								+			
Gomphrena canescens subsp. *canescens*																																			+											+

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Gomphrena cunninghamii																									+											+									nc		
Gomphrena kanisii		nc		nc							+				+	+			+											+								+	+				+			
Goodenia cusackiana																												+				+										+			
Goodenia forrestii																																					+					+				
Goodenia heterochila											5%																																			
Goodenia microptera																+								+	+	+											+								
Goodenia muelleriana																+										+	+			+	+					+			nc						
Goodenia stellata																	+																	+												
Goodenia stobbsiana							+	nc	+							+					+	+		+				+	+			+					+					+			
Goodenia aff. *tenuiloba*																																		+							+	+			
Goodenia triodiophila																			+		+	+			+			+	+			+		+											
Gossypium australe (Burrup Peninsula form)																													+																	
Gossypium robinsonii				+				+		5				+	+			1%		+				1%	+			+	+														nc		
Grevillea berryana									nc													+						+													1			2	nc		
Grevillea wickhamii subsp. *hispidula*						+		nc													+	+						+							+									nc		
Hakea chordophylla			nc									+										+				+		+	+																
Hakea lorea subsp. *lorea*		nc					+				+																+					+	+	+		+		+					5		
Haloragis gossei							+																							+		+													
Helichrysum gilesii											+								+					+					+				+												
Heliotropium chrysocarpum																									+		+				+														
Heliotropium inexplicitum																						+																							
Hibiscus burtonii	nc														+										+	+									+		+					+			
Hibiscus aff. *coatesii* (MET 16,542)																+																													
Hibiscus aff. *coatesii* (site 733)															+			+														+				+									
Hibiscus aff. *coatesii* (form not recorded)																																											+			
Hibiscus gardneri																								+																					
Hibiscus sturtii var. *campylochlamys*					nc		nc	nc				+	+			+			+					+			+	+	+					+								+			
Hibiscus sturtii var. aff. *grandiflorus*											+																																			
Hibiscus sturtii var. *platychlamys*	nc																		+					+													+									
Hibiscus aff. *sturtii* (Site B9)																																				+										
Hybanthus aurantiacus																																												nc		+
Indigofera georgei	nc	nc									15%			+																						+										
Indigofera ixocarpa																												+	+																
Indigofera linnaei																																											+			
Indigofera monophylla												+			+	+		+		+	+	+			+			+	+				+		+			+				+	5	nc		
Ipomoea lonchophylla																	+																													
Ipomoea muelleri																																		+			+			nc					+	+
Ipomoea plebeia																																											+			
Iseilema dolichotrichum																									+												+								
Iseilema macratherum																																		+											
Iseilema membranaceum																																					+					+				
Iseilema vaginiflorum																														+															
Jasminum didymum subsp. *lineare*										+		+	+					+						+	+											+									
Josephinia sp. Marandoo (M.E. Trudgen 1554)																																											+			
Keraudrenia velutina subsp. *elliptica*	nc						+	nc	+				1%	+		+		+		+	+	2-3%		1%				+	+		+				+				+			+				
Lepidium pedicellosum																							+								+															
Leptopus decaisnei																								+																						
Lobelia quadrangularis																		+																												
Lysiana murrayi											+																			+															
Maireana georgei																															+															
Maireana planifolia	nc			nc	nc																				+							+				+					+				
Maireana villosa	nc	nc			nc						nc								+						+						+	+	+				+					+				
**Malvastrum americanum*		1									+						+	+	+											+				+		+	2			nc			+		nc	+	+
Marsdenia australis																																				+										
Melaleuca eleuterostachya																															1															
Melhania oblongifolia																		+																												
Nicotiana benthamiana										+								+																												
Ophioglossum lusitanicum	nc																																													
Pandorea pandorana																						+																								
Panicum decompositum																	+																													
Panicum effusum	nc						nc		nc		+		+	+		+			+	+		+	+	+	+	+	+	+		1-3%	+	+		+	+	+					+				
Paraneurachne muelleri	+			nc	+	nc	+	nc			+	3%	1%	+	1	+		+	+			+	+	+	+	+	+		+		+	+			+			+	+			+		2		
Paspalidium clementii																																											+				
Paspalidium constrictum																																						+								
Paspalidium rarum																										+												+								
Perotis rara																									+					+				+	+		1			nc	+		+			
Petalostylis labicheoides																				+	7%	+		15-20%								15			3	+									
Phyllanthus erwinii																								+																			+			
Phyllanthus maderaspatensis																	+																											nc		
Pluchea dentex																														+															
Pluchea dunlopii																														+															
Plumbago zeylanica																																														+
Polycarpaea corymbosa var. *corymbosa*	+	+		+																																									
Polycarpaea holtzei																									+			+							+										
Polycarpaea longiflora																																			+				+							
Polygala isingii																						+		+				+			+														
Polygala sp.																														+															
**Portulaca oleracea*																			+						+			+	+					+				+		nc	+				
Psydrax latifolia														+	+									+								+													
Psydrax suaveolens	+		nc										+	+										+		+										+	+								
Pterocaulon serrulatum										nc	+					+	+	+	+			+	+	+			+							+	+									
Pterocaulon sphacelatum	nc	nc			nc			nc			+			+							+													+	+		+	+	+	nc	nc	+		+		nc		
Ptilotus astrolasius var. *astrolasius*						nc	+			nc						+								+								+													
Ptilotus calostachyus var. *calostachyus*				+			+	+	+			+			+	+					+	+			+	+		+	+		+	+	+	+				+			+		+		
Ptilotus clementii							nc												+						+																					
Ptilotus exaltatus var. *exaltatus*	+	+		+					+	+		+			+	+			+			+	+	+	+	+		+			+	+	+	+	1		+	+				+			
Ptilotus fusiformis var. *fusiformis*													+											+					+						+										
Ptilotus gaudichaudii var. *gaudichaudii*																			+							+								+										
Ptilotus gomphrenoides var. *gomphrenoides*																	+																												
Ptilotus helipteroides var. *helipteroides*		nc					+									+			+		+					+								+										
Ptilotus incanus var. *incanus*																																			+										
Ptilotus macrocephalus																																		+											
Ptilotus obovatus	nc	nc		nc			+				1%	+	+	+			+	+	+					+	+		+	+	+	+				1%		+	+	+				3	+		+	+
Ptilotus polystachyus var. *polystachyus*																																						+							
Ptilotus rotundifolius								nc							+				+	+													+		+			+					+		
Rhagodia eremaea		nc					+			+	+							+	+																+	+									+	
Rhagodia sp. Hamersley (M. Trudgen 17794)																								+						+									nc						

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Rhodanthe margarethae										+								+																											
Rhodanthe propinqua																												+	+																
Rhyncharrhena linearis			nc										+											+						+							+								
Rhynchosia minima														+			+																	+							+		nc		+
Rostellularia adscendens var. *clementii*																																				+										
Rulingia loxophylla														+	+													+																	
Rulingia luteiflora		nc																						2-4%																						+
Rutidosis helichrysoides																	+													+															
Salsola tragus	+	+		+			+												+					+	+		+				+	+		+	+	+		+						
Santalum lanceolatum												1%		+			1%					+																							
Santalum spicatum																																							3							
Scaevola acacioides																																				+									
Scaevola amblyanthera var. *centralis*														+										+																					
Scaevola browniana																					+	+							+													+			
Scaevola parvifolia subsp. *pilbarae*															+																														
Schizachyrium fragile																									+	+			+																
Sclerolaena cornishiana																+			+																							+				
Sclerolaena lanicuspis																															+														
Setaria dielsii																																					+									
Setaria surgens																																					+									
**Setaria verticillata*		+																																											
Sida arenicola												+																														+				
Sida echinocarpa																+								+	+			+														+				
Sida ? echinocarpa																																+														
Sida aff. *excedentifolia* (FML58-14A)																																										+				
Sida aff. *excedentifolia* (MET16086)																																												+		
Sida aff. *fibulifera* (FMG125-20)											+	+		+				+	+							+				+				+										
Sida aff. *fibulifera* (HD12-39)																																					+							+			
Sida aff. *fibulifera* (MET Site 1308)																	+																												
Sida aff. *fibulifera* (site 1506)																																								+	+				
Sida pilbarensis (ferruginous form)									nc													+			+																				
Sida platycalyx																																						+								
Sida sp. dark green fruit (S. van Leeuwen 2260)	nc																									+						+		+	+					+				
Sida sp. excedentifolia (J.L. Egan 1925)							nc	nc		nc												+										+		+										
Sida sp. spiciform panicles (E. Leyland s.n. 14/8/90)		nc									+			+					+			+		+									+		+		+							
Sida sp. Supplejack Station (T.S. Henshall 2345)									nc			+	+		+									+																				
Solanum centrale																														+															
Solanum ferocissimum	nc										+													+	+	+				+				+	+	+		+		nc	+			
Solanum horridum																		+				+											+										+		
Solanum lasiophyllum	+			+			+	+	+	+		+			+	+			+	+	+	+				+		+	+			+			+	+		+		+				
Solanum phlomoides																																										+				
Solanum sturtianum				nc	+		+	nc	+			+	+	+	+								+					+								+	+			+				
**Sonchus oleraceus*																														+															
Spartothamnella teucriiflora	nc				nc		+				+							+						+						+						+					+		+		
Spermacoce brachystema																			+						+					+				+			+					+			
Sporobolus australasicus		nc														+			+														+	+			+		+			+		+	
Sporobolus blakei																																												+		
Stackhousia intermedia							nc		nc																						+														
Stackhousia muricata																											+																		
Stemodia grossa																														+															
Stenopetalum pedicellare		nc																												+				+										
Streptoglossa decurrens					nc			nc			+								+			+									+														
Streptoglossa liatroides																							+													+									
Streptoglossa odora																																		+											
Stylobasium spathulatum																		+																									nc		
Synaptantha tillaeacea var. *tillaeacea*																														+															
Tephrosia rosea var. *glabrior*																																											nc		+
Themeda triandra		70-100							nc	2%		+	5%		3	5%	2%	5	+				+	30-40%					+				+	70-80%	+		+	1	+			50		nc	20	20
Trachymene oleracea subsp. *oleracea*				+		+		+	+	+				+		+		+	+	+		+			+			+	+			+	+		+		+						
Tragus australianus																																						+						+		
Tribulus astrocarpus																																						+								
Tribulus macrocarpus		nc																																			+									
Tribulus suberosus				+						+					+			+						+		+								+							+				
Trichodesma zeylanicum var. *zeylanicum*		+					+	+		+					+	+			+		+	+			+	+			+			+	+		+	+	+					nc			
Triodia bitextura																														5-10%																
Triodia brizoides										30										45%			60						10-15%																
Triodia longiceps										3						+	30%						2				15			10					15									
Triodia melvillei	10-30			nc			+				35%																										+	40			+				
Triodia schinzii											+	+	+	5%	+				+					+	+		30-40%									+									
Triodia wiseana			30-50	40		50	nc	nc	<1	nc	+		5%	+	1	35	1%	+		30%	20%	10-15%	20	20-30%	1-2%		20	40	30-40%		20	30	70-80		35	55			10			40		70			
Triodia sp. Shovelanna Hill (S. van Leeuwen 3835)				nc	30-50	nc	70	nc	30-50			55%	10%		60	35		40%			60%	45-50%			50-60%	+		20																	
Tripogon loliiformis		nc																																											
Urochloa occidentalis var. *ciliata*																																						+		nc			+		+	
Urochloa occidentalis var. *occidentalis*																																				+									
Urochloa piligera																																											+		
**Vachellia farnesiana*																	+																												
Vigna sp. central (M.E. Trudgen 1626)																																		+											
Vittadinia arida					nc										+									+						+	+			+		+								
Vittadinia dissecta var. *hirta*																														50-60%															
Vittadinia eremaea	nc																					+						+																
Vittadinia obovata																								+																				+	
Vittadinia virgata																						+		+																					
Wahlenbergia tumidifructa																														+				+			+								
Waltheria indica																																											+		+
Waltheria virgata																					+																								

Appendix 5

List of Flora Species Recorded from the Study Areas at Marandoo

NB. * denotes introduced species

Comparison of *Cassia* versus *Senna* nomenclature:

Cassia artemisioides = *Senna artemisioides* subsp. *artemisioides*	*Cassia nemophila* = *Senna artemisioides* subsp. *petiolaris*
Cassia chatelainiana = *Senna glutinosa* subsp. *charlesiana*	*Cassia notabilis* = *Senna notabilis*
Cassia ferraria = *Senna ferraria*	*Cassia oligophylla* = *Senna artemisioides* subsp. *oligophylla*
Cassia glaucifolia = *Senna glaucifolia*	*Cassia pleurocarpa* var. *angustifolia* = *Senna pleurocarpa* var. *angustifolia*
Cassia glutinosa = *Senna glutinosa* subsp. *glutinosa*	*Cassia pruinosa* = *Senna glutinosa* subsp. *pruinosa*
Cassia helmsii = *Senna artemisioides* subsp. *helmsii*	*Cassia stricta* = *Senna stricta*
Cassia luerssenii = *Senna glutinosa* subsp. x *luerssenii*	*Cassia symonii* = *Senna symonii*

FAMILY (FAMILY CODE) / *Species*	MARANDOO LEASE		RESIDUE STORAGE FACILITY	DEWATERING BORE DRILLING AREA (based on OPP-NVCP)	SFB PIPELINE CORRIDOR (based on MARA04, OPP PLL)	SOUTHERN FORTESCUE BOREFIELD (based on MARA01, MARA02, MARA03, MARA-J1, MARA J2, OPP-SFB)	MARANDOO CAMP (based on MARA06, MARA07, MARA08, MARA-J3, OPP-CAMP)
	Mattiske (1992) √; Pilbara Iron (2006a) ¥	Biota (this study; based on MAR01-MAR38, excluding sites in other development areas; MARA05, MAR OPP, OPP-DPR, OPP-RL, OPP-WDE)					
ACANTHACEAE (325)							
Dicladanthera forrestii					√		√
Dicladanthera glabra	√						
Dipteracanthus australasicus subsp. *australasicus*	√	√			√	√	√
Rostellularia adscendens var. *clementii*						√	
Rostellularia adscendens var. *pogonanthera*	√						
ADIANTACEAE (007)							
Cheilanthes austrotenuifolia	√						
Cheilanthes lasiophylla	√						
Cheilanthes sieberi subsp. *sieberi*		√				√	√
Paraceterach reynoldsii	√						
AMARANTHACEAE (106)							
Achyranthes aspera	√				√		√
Alternanthera angustifolia		√					
Alternanthera nana	√	√			√	√	√
Alternanthera nodiflora	√						
Amaranthus cuspidifolius		√			√		
Amaranthus interruptus		√					
Amaranthus mitchellii	√						
Amaranthus undulatus	√	√					
Amaranthus sp. A Kimberley Flora (C.A. Gardner s.n. PERTH 00326518)						√	
Gomphrena canescens subsp. *canescens*	√	√					√
Gomphrena cunninghamii	√	√			√	√	√
Gomphrena kanisii		√				√	√
Ptilotus aervoides	√						
Ptilotus astrolasius var. *astrolasius*	√	√					
Ptilotus calostachyus var. *calostachyus*	√	√				√	√
Ptilotus carinatus	√						
Ptilotus clementii	√	√					
Ptilotus exaltatus var. *exaltatus*	√	√				√	√
Ptilotus fusiformis var. *fusiformis*		√					√
Ptilotus gaudichaudii var. *gaudichaudii*	√	√		√		√	
Ptilotus gomphrenoides var. *gomphrenoides*	√	√					
Ptilotus helipteroides var. *helipteroides*	√	√		√		√	
Ptilotus incanus var. *incanus*		√					
Ptilotus leucocoma	√						
Ptilotus macrocephalus		√		√		√	
Ptilotus obovatus	√	√		√	√	√	√
Ptilotus polystachyus var. *polystachyus*	√					√	
Ptilotus rotundifolius	√	√				√	√
Ptilotus schwartzii var. *schwartzii*	√					√	
APIACEAE (281)							
Daucus glochidiatus		√					
Trachymene didiscoides	√						
Trachymene oleracea subsp. *oleracea*	√	√					√

FAMILY (FAMILY CODE) / *Species*	MARANDOO LEASE		RESIDUE STORAGE FACILITY	DEWATERING BORE DRILLING AREA (based on OPP-NVCP)	SFB PIPELINE CORRIDOR (based on MARA04, OPP PLL)	SOUTHERN FORTESCUE BOREFIELD (based on MARA01, MARA02, MARA03, MARA-J1, MARA J2, OPP-SFB)	MARANDOO CAMP (based on MARA06, MARA07, MARA08, MARA-J3, OPP-CAMP)
	Mattiske (1992) √; Pilbara Iron (2006a) ¥	Biota (this study; based on MAR01-MAR38, excluding sites in other development areas; MARA05, MAR OPP, OPP-DPR, OPP-RL, OPP-WDE)					
ARALIACEAE (280)							
Astrotricha hamptonii	√	√					
ASCLEPIADACEAE (305)							
Cynanchum floribundum	√						
Cynanchum sp. (probably *Cynanchum* sp. Hamersley (M. Trudgen 2302))	√						
Marsdenia australis		√					
Rhyncharrhena linearis	√	√		√		√	√
Sarcostemma viminale subsp. *australe*	√						
ASTERACEAE (345)							
**Bidens bipinnata*	√	√	√	√	√	√	√
Blumea tenella		√					
Brachyscome ciliocarpa		√				√	√
Brachyscome iberidifolia	√						
Calocephalus knappii	√						
Calocephalus sp.	√						
Calotis hispidula	√						
Calotis latiuscula					√		√
Calotis multicaulis	√						
Calotis plumulifera				√			
Centipeda minima	√	√				√	
Flaveria australasica	√	√					√
Helichrysum gilesii	√	√		√			
Helichrysum luteoalbum	√						
Olearia xerophila	√						
Pluchea dentex		√					√
Pluchea dunlopii		√		√			
Pluchea tetranthera		√					
Pterocaulon serrulatum		√					
Pterocaulon sphacelatum	√	√		√	√	√	√
Rhodanthe floribunda	√						
Rhodanthe margarethae	√	√					
Rhodanthe propinqua		√					
Rutidosis helichrysoides	√	√					
Senecio magnificus	√						
**Sigesbeckia orientalis*	√						
**Sonchus oleraceus*		√					
Streptoglossa decurrens	√	√			√	√	√
Streptoglossa liatroides		√					
Streptoglossa odora		√					
Vittadinia arida	√	√			√		
Vittadinia dissecta var. *hirta*		√		√			
Vittadinia eremaea		√					
Vittadinia obovata		√			√		√
Vittadinia virgata		√					
Vittadinia sp.	√						
BIGNONIACEAE (317)							
Pandorea pandorana	√	√					
BORAGINACEAE (310)							
Heliotropium chrysocarpum		√					
Heliotropium cunninghamii					√		
Heliotropium inexplicitum		√					
Heliotropium ovalifolium	√						
Heliotropium tenuifolium	√						
Heliotropium sp.	√						

FAMILY (FAMILY CODE) / *Species*	MARANDOO LEASE		RESIDUE STORAGE FACILITY	DEWATERING BORE DRILLING AREA (based on OPP-NVCP)	SFB PIPELINE CORRIDOR (based on MARA04, OPP PLL)	SOUTHERN FORTESCUE BOREFIELD (based on MARA01, MARA02, MARA03, MARA-J1, MARA J2, OPP-SFB)	MARANDOO CAMP (based on MARA06, MARA07, MARA08, MARA-J3, OPP-CAMP)
	Mattiske (1992) √; Pilbara Iron (2006a) ¥	Biota (this study; based on MAR01-MAR38, excluding sites in other development areas; MARA05, MAR OPP, OPP-DPR, OPP-RL, OPP-WDE)					
Trichodesma zeylanicum var. *zeylanicum*	√	√				√	√
BRASSICACEAE (138)							
Cuphonotus andraeanus	√						
Lepidium echinatum	√						
Lepidium muelleri-ferdinandii	√						
Lepidium oxytrichum	√						
Lepidium pedicellosum		√					
Lepidium phlebopetalum	√						
Stenopetalum nutans	√			√			
Stenopetalum pedicellare		√					
CAESALPINIACEAE (164)							
Cassia artemisioides	√	√					
Cassia chatelainiana	√						
Cassia ferraria	√	√					√
Cassia ferraria x *glutinosa*		√					√
Cassia glaucifolia		√					
Cassia glaucifolia x *oligophylla*						√	√
Cassia glutinosa	√	√		√		√	√
Cassia glutinosa x *stricta*		√				√	
Cassia aff. *glutinosa*		√					
Cassia helmsii	√	√				√	√
Cassia luerssenii	√	√		√	√	√	√
Cassia luerssenii x *stricta*							√
Cassia nemophila	√						
Cassia notabilis	√	√				√	√
Cassia oligophylla	√	√			√	√	√
Cassia oligophylla x *helmsii*	√	√					
Cassia oligophylla x *stricta*		√					
Cassia oligophylla (thinly sericeous MET 15,035)		√					
Cassia aff. *oligophylla* (thinly sericeous) x *glutinosa*		√					
Cassia pleurocarpa var. *angustifolia*	√	√		√			
Cassia pruinosa	√	√					√
Cassia stricta		√			√		
Cassia symonii		√					
Cassia sp.	√						
Petalostylis labicheoides	√	√				√	√
CAMPANULACEAE (339)							
Wahlenbergia tumidifructa	√	√		√		√	
CAPPARACEAE (137A)							
Capparis lasiantha	√	√			√		√
Capparis umbonata	√	√			√	√	√
Cleome oxalidea	√					√	
Cleome viscosa	√	√			√	√	√
CARYOPHYLLACEAE (113)							
Polycarpaea corymbosa var. *corymbosa*		√		√			
Polycarpaea holtzei		√					
Polycarpaea longiflora	√	√				√	√
CELASTRACEAE (199)							
Maytenus aff. *cunninghamii*	√						
CHENOPODIACEAE (105)							
**Bassia scoparia*	√						
Chenopodium melanocarpum	√						
Dysphania kalpari		√					√
Dysphania littoralis	√						

FAMILY (FAMILY CODE) / *Species*	MARANDOO LEASE		RESIDUE STORAGE FACILITY	DEWATERING BORE DRILLING AREA (based on OPP-NVCP)	SFB PIPELINE CORRIDOR (based on MARA04, OPP PLL)	SOUTHERN FORTESCUE BOREFIELD (based on MARA01, MARA02, MARA03, MARA-J1, MARA J2, OPP-SFB)	MARANDOO CAMP (based on MARA06, MARA07, MARA08, MARA-J3, OPP-CAMP)
	Mattiske (1992) √; Pilbara Iron (2006a) ¥	Biota (this study; based on MAR01-MAR38, excluding sites in other development areas; MARA05, MAR OPP, OPP-DPR, OPP-RL, OPP-WDE)					
Dysphania rhadinostachya	√	√					√
Enchylaena tomentosa var. *tomentosa*	√	√					
Maireana georgei	√	√					
Maireana melanocoma	√						
Maireana planifolia	√	√					√
Maireana tomentosa	√						
Maireana triptera	√						
Maireana villosa	√	√		√		√	√
Rhagodia eremaea	√	√				√	√
Rhagodia sp. Hamersley (M. Trudgen 17794)		√		√	√		
Salsola tragus	√	√				√	√
Sclerolaena cornishiana	√	√				√	√
Sclerolaena lanicuspis		√					
Sclerolaena tetragona	√						
COMMELINACEAE (047)							
Commelina ensifolia	√	√			√	√	
CONVOLVULACEAE (307)							
Convolvulus angustissimus subsp. *angustissimus*		√					√
Convolvulus clementii						√	
Convolvulus erubescens	√						
Convolvulus remotus		√			√	√	
Duperreya commixta	√	√			√	√	√
Evolvulus alsinoides var. *decumbens*					√		√
Evolvulus alsinoides var. *villosicalyx*	√	√			√	√	√
Ipomoea lonchophylla		√					
Ipomoea muelleri	√	√			√	√	√
Ipomoea plebeia							√
Polymeria ambigua					√		
Polymeria sp.	√						
CUCURBITACEAE (337)							
Cucumis maderaspatanus	√	√				√	√
**Cucumis melo* subsp. *agrestis*	√						√
CYPERACEAE (032)							
Bulbostylis barbata	√	√					√
Bulbostylis turbinata	√	√					
Cyperus cunninghamii	√						
Cyperus iria				√		√	
Fimbristylis dichotoma		√					√
Fimbristylis microcarya						√	
ELATINACEAE (235)							
Bergia pedicellaris						√	
Bergia trimera	√			√			
EUPHORBIACEAE (185)							
Euphorbia atoto	√						
Euphorbia australis	√	√					
Euphorbia aff. *australis* var. 1 (MET 12 337)		√					
Euphorbia biconvexa		√				√	√
Euphorbia boophthona	√	√			√		
Euphorbia coghlanii	√						
**Euphorbia hirta*	√						
**Euphorbia peplus*	√						
Euphorbia tannensis subsp. *eremophila* (Hamersley form)						√	
Euphorbia sp. (BPBS10-50)				√			
Euphorbia sp. (site 1089)						√	

FAMILY (FAMILY CODE) / *Species*	MARANDOO LEASE		RESIDUE STORAGE FACILITY	DEWATERING BORE DRILLING AREA (based on OPP-NVCP)	SFB PIPELINE CORRIDOR (based on MARA04, OPP PLL)	SOUTHERN FORTESCUE BOREFIELD (based on MARA01, MARA02, MARA03, MARA-J1, MARA J2, OPP-SFB)	MARANDOO CAMP (based on MARA06, MARA07, MARA08, MARA-J3, OPP-CAMP)
	Mattiske (1992) √; Pilbara Iron (2006a) ¥	Biota (this study; based on MAR01-MAR38, excluding sites in other development areas; MARA05, MAR OPP, OPP-DPR, OPP-RL, OPP-WDE)					
Euphorbia sp.	√						
Leptopus decaisnei	√	√					
Phyllanthus erwinii	√	√		√			√
Phyllanthus maderaspatensis	√	√			√	√	√
GOODENIACEAE (341)							
Brunonia australis	√						
Dampiera candicans	√	√					√
Goodenia cusackiana	√	√					√
Goodenia forrestii					√	√	√
Goodenia heterochila	√	√		√		√	
Goodenia lyrata	¥						
Goodenia maideniana	√						
Goodenia microptera	√	√				√	√
Goodenia muelleriana	√	√			√	√	
Goodenia prostrata	√						
Goodenia stellata		√					
Goodenia stobbsiana	√	√				√	√
Goodenia aff. *tenuiloba*		√				√	√
Goodenia triodiophila	√	√					√
Goodenia vilmoriniae	√						
Goodenia sp.	√						
Scaevola acacioides	√	√					
Scaevola amblyanthera var. *centralis*		√					
Scaevola browniana	√	√					√
Scaevola parvifolia subsp. *pilbarae*	√	√		√			
Velleia discophora	√						
GYROSTEMONACEAE (108)							
Codonocarpus cotinifolius	√	√				√	√
HALORAGACEAE (276)							
Haloragis gossei	√	√					
LAMIACEAE (313)							
Clerodendrum tomentosum var. *lanceolatum*	√	√					
Prostanthera striatiflora	√						
Spartothamnella teucriiflora	√	√					√
LOBELIACEAE (340)							
Lobelia quadrangularis		√					
Lobelia sp. (probably *Lobelia heterophylla* subsp. Pilbara (R. Meissner & Y.	√						
LORANTHACEAE (097)							
Amyema fitzgeraldii	√				√		
Amyema gibberula var. *gibberula*	√						
Amyema miquelii	√						
Diplatia grandibractea	√	√					
Lysiana casuarinae	√						
Lysiana murrayi	√	√					
MALVACEAE (221)							
Abutilon amplum	√						
Abutilon cryptopetalum		√					√
Abutilon cunninghamii	√	√					
Abutilon dioicum		√					√
Abutilon aff. *dioicum*		√					
Abutilon fraseri	√	√			√	√	√
Abutilon indicum	√						
Abutilon lepidum		√				√	
Abutilon aff. *lepidum* (1) (MET 15 352)		√				√	√

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Abutilon aff. *lepidum* (4)		√					
Abutilon leucopetalum		√					
Abutilon macrum	√	√			√		
Abutilon otocarpum (acute leaf form)	√	√				√	
Abutilon oxycarpum subsp. *prostratum*					√		
Abutilon trudgenii		√		√			
Abutilon sp.	√						
Gossypium australe (Burrup Peninsula form)	√	√			√	√	√
Gossypium robinsonii	√	√			√	√	√
Hibiscus burtonii	√	√				√	√
Hibiscus coatesii	√						
Hibiscus aff. *coatesii* (MET 16,542)		√					
Hibiscus aff. *coatesii* (site 733)		√					
Hibiscus aff. *coatesii* (form not recorded)		√				√	√
Hibiscus gardneri		√					
Hibiscus sturtii	√						
Hibiscus sturtii var. *campylochlamys*		√		√			√
Hibiscus sturtii var. aff. *grandiflorus*		√					
Hibiscus sturtii var. *platychlamys*		√				√	
Hibiscus aff. *sturtii* (Site B9)		√					
Hibiscus sp.	√						
**Malvastrum americanum*	√	√	√	√	√	√	√
Sida arenicola		√					√
Sida cardiophylla				√		√	
Sida aff. clementii	√						
Sida echinocarpa	√	√					√
Sida ? echinocarpa		√					
Sida aff. *fibulifera* (FMG125-20)		√		√			
Sida aff. *fibulifera* (HD12-39)						√	√
Sida aff. *fibulifera* (HD186.1)		√					
Sida aff. *fibulifera* (MET Site 1308)		√					
Sida aff. *fibulifera* (oblong; MET 15 220)		√			√		
Sida aff. *fibulifera* (site 1506)				√		√	
Sida aff. *fibulifera* (form not recorded)	√						
Sida pilbarensis (ferruginous form)		√					
Sida platycalyx	√			√		√	
Sida rohlenae	√						
Sida sp. dark green fruit (S. van Leeuwen 2260)	√	√					
Sida sp. excedentifolia (J.L. Egan 1925)	√	√					
Sida aff. excedentifolia (FML58-14A)		√					√
Sida aff. excedentifolia (MET16086)							√
Sida sp. spiciform panicles (E. Leyland s.n. 14/8/90)		√		√	√	√	
Sida sp. Supplejack Station (T.S. Henshall 2345)		√			√		√
Sida sp.	√						
MARSILEACEAE (013)							
Marsilea drummondii	√						
Marsilea hirsuta		√		√	√		
MENISPERMACEAE (122)							
Tinospora smilacina	√						
MIMOSACEAE (163)							
Acacia adoxa var. *adoxa*	√	√					
Acacia ancistrocarpa	√	√		√		√	√
Acacia aneura var. *aneura*		√					
Acacia aneura var. *? aneura*		√					

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Acacia aneura var. *conifera*		√					
Acacia aneura var. *intermedia*		√			√		
Acacia aneura var. *pilbarana*		√				√	
Acacia aneura (grey bushy form; MET 15 732)		√					
Acacia aneura (grey flat recurved tips; MET 15 828)		√			√	√	√
Acacia aff. *aneura* (narrow fine veined; site 1259)					√	√	√
Acacia aneura (form not recorded)	√	√			√	√	√
Acacia arida	√	√					
Acacia atkinsiana	√	√			√		√
Acacia ayersiana		√					
Acacia bivenosa	√	√			√	√	√
Acacia bivenosa (wispy/weeping form)		√					
Acacia citrinoviridis	√	√			√	√	√
Acacia colei var. *colei*		√					
Acacia coriacea	√						
Acacia daweana	√						
Acacia dictyophleba	√	√		√	√		
Acacia effusa	√						
Acacia elachantha					√		
Acacia exilis	√						√
Acacia hamersleyensis	√	√					
Acacia inaequilatera	√	√					√
Acacia kempeana	√	√				√	√
Acacia maitlandii	√	√					√
Acacia marramamba	√	√			√	√	
Acacia monticola	√	√				√	√
Acacia pachyacra	√	√				√	√
Acacia paraneura						√	
Acacia pruinocarpa	√	√		√		√	√
Acacia pyrifolia (slender form)		√					
Acacia pyrifolia var. *pyrifolia*	√	√			√	√	√
Acacia rhodophloia	√	√		√			
Acacia sclerosperma subsp. *sclerosperma*					√		
Acacia sibirica	√	√					√
Acacia sibirica (linear form)		√					
Acacia spondylophylla	√						
Acacia synchronicia		√					
Acacia tenuissima	√	√		√	√		√
Acacia tetragonophylla	√	√					
Acacia tumida var. *pilbarensis*	√	√		√			
Acacia victoriae	√						
Acacia xiphophylla	√	√					
**Vachellia farnesiana*	√	√		√	√	√	√
MOLLUGINACEAE (110A)							
Glinus lotoides				√			
Mollugo molluginea	√						
MORACEAE (087)							
Ficus brachypoda	√	√					
MYOPORACEAE (326)							
Eremophila cuneifolia	√	√			√		√
Eremophila forrestii subsp. *forrestii*		√				√	√
Eremophila fraseri	√	√			√	√	
Eremophila jucunda subsp. *pulcherrima*		√					
Eremophila lanceolata	√				√	√	

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Eremophila latrobei	√						
Eremophila latrobei subsp. *filiformis*		√					√
Eremophila latrobei subsp. *latrobei*		√					
Eremophila longifolia	√	√				√	
Eremophila magnifica subsp. *magnifica*	√	√					
Eremophila magnifica subsp. *velutina*	√						
Eremophila oppositifolia subsp. *angustifolia*	√	√					
Eremophila petrophila subsp. *petrophila*	√	√					
Eremophila tietkensii	√						
MYRTACEAE (273)							
Calytrix carinata	√						√
Corymbia deserticola subsp. *deserticola*	√	√		√		√	√
Corymbia ferriticola subsp. *ferriticola*	√	√					
Corymbia hamersleyana	√	√			√		√
Eucalyptus camaldulensis var. *obtusa*				√	√		
Eucalyptus gamophylla	√	√		√			√
Eucalyptus leucophloia subsp. *leucophloia*	√	√		√		√	√
Eucalyptus repullulans		√					
Eucalyptus socialis subsp. *eucentrica*	√	√					
Eucalyptus striaticalyx (may equate to *E. repullulans?*)	√						
Eucalyptus trivalva	√	√					
Eucalyptus victrix	√	√			√		√
Eucalyptus xerothermica	√	√					
Melaleuca eleuterostachya	√	√					
NYCTAGINACEAE (107)							
Boerhavia coccinea	√	√				√	√
Boerhavia paludosa		√					
Boerhavia repleta		√				√	
Boerhavia sp.	√						
**Bougainvillea* sp.		√					
OLEACEAE (301)							
Jasminum didymum subsp. *lineare*	√	√					√
OPHIOGLOSSACEAE (005)							
Ophioglossum lusitanicum	√	√					
OXALIDACEAE (168)							
Oxalis sp.	√						
PAPILIONACEAE (165)							
Cajanus cinereus	√						
Crotalaria medicaginea	√						√
Crotalaria novae-hollandiae subsp. *novae-hollandiae*	√						
Cullen lachnostachys	√						
Glycine canescens					√	√	√
Glycine tabacina	√	√					
Gompholobium karijini	√	√		√		√	√
Indigofera boviperda	√						
Indigofera georgei		√		√			
Indigofera hirsuta	√						
Indigofera ixocarpa		√					
Indigofera linnaei					√		√
Indigofera monophylla	√	√		√	√	√	√
Indigofera sp. (1) (MET7024) (quite probably *I. ixocarpa*)	√						
Isotropis atropurpurea	√						
Isotropis forrestii						√	
Lotus cruentus	√						

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Mirbelia viminalis	√						
Rhynchosia minima	√	√			√	√	√
Swainsona canescens	√						
Swainsona kingii	√						
Templetonia egena	√						
Tephrosia clementii	√						
Tephrosia densa	√						
Tephrosia rosea	√						
Tephrosia rosea var. *glabrior*						√	√
Tephrosia aff. *supina* (HD133-20)		√					
Tephrosia sp. Bungaroo Creek (M.E. Trudgen 11601)		√					
Tephrosia sp.	√						
Vigna sp. central (M.E. Trudgen 1626)	√	√					
PEDALIACEAE (318)							
Josephinia sp. Marandoo (M.E. Trudgen 1554)	√						√
PLUMBAGINACEAE (294)							
Plumbago zeylanica	√					√	√
POACEAE (031)							
Amphipogon caricinus	√						
Amphipogon sericeus		√				√	√
Aristida burbidgeae		√					
Aristida contorta	√	√			√	√	√
Aristida holathera var. *holathera*	√	√				√	√
Aristida inaequiglumis		√					√
Aristida ingrata		√				√	√
Aristida jerichoensis var. *subspinulifera*		√					
Aristida latifolia		√					√
Aristida nitidula	√						
Aristida obscura	√	√				√	
Aristida pruinosa		√					
Bothriochloa ewartiana		√			√	√	√
Brachyachne prostrata	√	√					
**Cenchrus ciliaris*	√	√	√		√	√	
**Cenchrus setiger*					√	√	√
Chloris pectinata		√					√
Chloris sp.	√						
**Chloris virgata*	√					√	
Chrysopogon fallax	√	√			√	√	√
Cymbopogon ambiguus	√	√		√		√	√
Cymbopogon bombycinus	√						
Cymbopogon obtectus		√				√	√
**Cynodon dactylon*				√	√		
Dactyloctenium radulans	√	√		√	√	√	√
Dichanthium sericeum subsp. *humilius*	√	√			√	√	√
Digitaria ammophila	√	√		√	√		√
Digitaria brownii	√	√				√	√
Digitaria ctenantha		√				√	√
**Echinochloa colona*					√	√	√
Enneapogon caerulescens	√	√			√		√
Enneapogon lindleyanus	√	√					√
Enneapogon pallidus	√						
Enneapogon polyphyllus		√			√	√	√
Enneapogon robustissimus		√		√		√	
Eragrostis cumingii		√		√		√	

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Eragrostis dielsii	√						
Eragrostis eriopoda	√	√					
Eragrostis exigua		√				√	
Eragrostis falcata	√						
Eragrostis pergracilis	√	√		√			√
Eragrostis setifolia		√				√	√
Eragrostis tenellula	√	√					
Eriachne aristidea		√					
Eriachne benthamii	√	√					√
Eriachne lanata		√					
Eriachne mucronata	√	√			√	√	√
Eriachne mucronata (xerophytic form)		√					
Eriachne pulchella	√	√			√	√	√
Eulalia aurea	√	√			√	√	√
Iseilema dolichotrichum		√				√	
Iseilema macratherum		√					
Iseilema membranaceum						√	√
Iseilema vaginiflorum	√	√			√		
Panicum decompositum	√	√					
Panicum effusum		√				√	√
Paractaenum novae-hollandiae	√						
Paraneurachne muelleri	√	√			√	√	√
Paspalidium clementii	√	√					
Paspalidium constrictum						√	
Paspalidium rarum		√				√	√
Perotis rara	√	√			√	√	√
Schizachyrium fragile		√					
Setaria dielsii						√	
Setaria surgens						√	
**Setaria verticillata*		√				√	
Sporobolus australasicus	√	√			√	√	√
Sporobolus blakei							√
Themeda triandra	√	√			√	√	√
Tragus australianus	√				√	√	√
Triodia angusta	√						
Triodia basedowii (may equate to sp. Shovelanna Hill)	√						
Triodia bitextura		√					
Triodia brizoides	√	√					
Triodia bynoei	√						
Triodia longiceps	√	√					√
Triodia melvillei	√	√		√		√	√
Triodia pungens	√						
Triodia schinzii		√					
Triodia wiseana	√	√		√	√	√	√
Triodia sp. Shovelanna Hill (S. van Leeuwen 3835)	√	√		√			√
Tripogon loliiformis		√					
Urochloa occidentalis var. *ciliata*					√	√	√
Urochloa occidentalis var. *occidentalis*	√					√	
Urochloa piligera							√
POLYGALACEAE (183)							
Polygala isingii		√					
Polygala sp.	√	√					
POLYGONACEAE (103)							
**Acetosa vesicaria*	√			√			

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Muehlenbeckia florulenta	√						
PORTULACACEAE (111)							
Calandrinia ptychosperma	√						
Calandrinia sp. Mt Bruce (M.E. Trudgen 1544) (listed as *?Trianthema* sp. (M	√						
Calandrinia sp.		√					
**Portulaca oleracea*	√	√		√	√	√	
Portulaca pilosa		√					
Portulaca sp.	√						
PROTEACEAE (090)							
Grevillea berryana		√				√	√
Grevillea wickhamii subsp. *hispidula*	√	√		√	√	√	
Grevillea sp.	√						
Hakea chordophylla	√	√					√
Hakea lorea subsp. *lorea*	√	√			√	√	√
RUBIACEAE (331)							
Oldenlandia crouchiana	√	√					
Psydrax attenuata	√						
Psydrax latifolia	√	√				√	√
Psydrax suaveolens	√	√				√	√
Spermacoce brachystema	√	√				√	√
Synaptantha tillaeacea var. *tillaeacea*		√		√			
SANTALACEAE (092)							
Anthobolus leptomerioides	√	√		√	√		√
Exocarpos aphyllus	√						
Santalum lanceolatum	√	√					
Santalum spicatum	√				√		√
SAPINDACEAE (207)							
Diplopeltis stuartii var. *stuartii*	√						
Dodonaea coriacea	√	√		√	√		√
Dodonaea lanceolata var. *lanceolata*	√	√					
Dodonaea pachyneura	√	√					
Dodonaea petiolaris		√			√		√
Dodonaea viscosa subsp. *mucronata*	√						
Dodonaea viscosa subsp. *spatulata*		√					
SCROPHULARIACEAE (316)							
Mimulus gracilis	√						
Peplidium muelleri				√			
Stemodia grossa	√	√					√
SOLANACEAE (315)							
**Datura leichhardtii*	√						√
Nicotiana benthamiana	√	√					
Nicotiana occidentalis	√						
Nicotiana simulans						√	
Nicotiana sp.	√						
Solanum centrale		√		√			
Solanum ferocissimum	√	√			√	√	
Solanum horridum	√	√				√	√
Solanum lasiophyllum	√	√				√	√
**Solanum nigrum*	√				√		
Solanum phlomoides	√	√					
Solanum sturtianum	√	√		√	√	√	√
Solanum sp.	√						
STACKHOUSIACEAE (202)							
Stackhousia intermedia	√	√			√		√

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Stackhousia muricata		√					
STERCULIACEAE (223)							
Brachychiton acuminatus	√						
Keraudrenia nephrosperma	√						
Keraudrenia velutina subsp. *elliptica*	√	√		√		√	√
Melhania oblongifolia	√	√			√	√	√
Rulingia loxophylla		√					
Rulingia luteiflora	√	√					√
Waltheria indica	√						√
Waltheria virgata	√	√					
SURIANACEAE (160)							
Stylobasium spathulatum	√	√				√	
TILIACEAE (220)							
Corchorus crozophorifolius					√		√
Corchorus lasiocarpus subsp. *lasiocarpus*		√					√
Corchorus lasiocarpus subsp. *parvus*		√				√	√
Corchorus sidoides		√					
Corchorus tridens	√						
Corchorus aff. *walcottii*	√						
Triumfetta maconochieana	√	√					
Triumfetta sp. (possibly *T. leptacantha*)	√						
URTICACEAE (088)							
Parietaria debilis (possibly *P. cardiostegia?*)	√						
VIOLACEAE (243)							
Hybanthus aurantiacus	√				√	√	√
ZYGOPHYLLACEAE (173)							
Tribulus astrocarpus	√					√	
Tribulus macrocarpus		√		√		√	
Tribulus platypterus	√						
Tribulus suberosus		√				√	√
Tribulus terrestris	√						
Zygophyllum iodocarpum	√						

Biota Environmental Sciences

Rio Tinto

Marandoo Mine Phase 2 Seasonal Fauna Survey

Prepared for Rio Tinto

August 2008

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Marandoo Mine Phase 2 Seasonal Fauna Survey

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1.0 Summary

1.1 Background

Pilbara Iron operates the Marandoo Iron Ore Mine, which is located in the central Pilbara, approximately 37 km east of Tom Price. The Marra Mamba type iron ore resource at Marandoo occurs both above and below the water table (BWT) and Pilbara Iron currently has approval to mine above the water table only. Between 1994 and 2006, a number of technical investigations were conducted to test the feasibility of extending mining BWT: 'Marandoo Mine Phase 2 (MMP2) Project' (Pilbara Iron 2008).

Biota Environmental Sciences (Biota) was commissioned to complete a desktop review of existing fauna related data and a seasonal fauna survey of the proposed Phase 2 area in April and November 2007. The survey was planned and implemented in accordance with the Environmental Protection Authority (EPA) Position Statement No. 3 "Terrestrial Biological Surveys as an Element of Biodiversity Protection" (EPA 2002) and Guidance Statement No. 56 "Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia".

The scope of the study was to:

- Identify the fauna habitats, particularly those with conservation significance, within the study area;
- Document the vertebrate and SRE invertebrate fauna assemblage within the study area utilising a combined approach of a desk-top review of existing data and a site-specific fauna survey using established sampling techniques; and
- Identify fauna (particularly Schedule and Priority listed fauna as well as potential short-range endemic taxa) of particular conservation significance occurring within the area.

Environmental clearing approvals for the camp and dewatering pipeline are being sought through a separate environmental impact assessment process. Baseline information is provided here for the assessment of impacts of other activities during construction/operation on fauna.

1.2 Methods

The survey took place in two phases conducted in April 2007 and in November 2007.

Systematic censusing of terrestrial fauna assemblages, including avifauna, mammals and herpetofauna, was carried out at thirteen sites, each located within defined habitats. The central component of the censusing consisted of trapping grids at ten sites, comprising ten pit-fall traps (alternating 20 litre buckets and 20 cm diameter PVC tubes) spaced at 10 m intervals and connected by a single length (100 m) of 30 cm high flywire fence. Three further sampling sites exclusively comprised 50 to 75 Elliott traps.

Fifty-seven avifauna censuses were conducted during the surveys at 13 sites. Censuses were conducted between approximately 6:30 am and 12:00 pm, and were supplemented by opportunistic sightings of birds while traversing the study area.

Invertebrates were collected from both systematic sampling sites and opportunistic sampling sites. Groups targeted during these activities included:

- Mygalomorph (Trap-door) spiders;
- Pseudoscorpions;
- Scorpions;

- Millipedes; and
- Terrestrial snails.

Additional non-systematic collection techniques were undertaken by the survey team to supplement trapping efforts, and to investigate habitats not sampled using systematic methods.

1.3 Fauna

The survey of the Marandoo Mine Phase 2 project area yielded a combined total of 125 vertebrate species, comprising 54 avifauna species, 20 mammals and 51 herpetofauna species: four frogs and 49 reptiles (Table 1.1; Section 4.0).

Table 1.1: Number of vertebrate fauna species recorded during the survey of the Marandoo Mine Phase 2 project area.

Fauna Group	Number of Species		
	Phase I (Autumn)	Phase 2 (Spring)	Total
Avifauna	47	39	54
Non-volant Mammals (native)	9	6	10
Non-volant Mammals (introduced)	2	2	3
Bats	1	7	7
Herpetofauna	31	42	51
Total	90	96	125

One Schedule 1 species and two Priority 4 listed species were recorded by Biota from the survey area (Table 1.2). A further five Schedule and six Priority listed species have either been recorded or may occur in the region (as determined by a search of the DEC Threatened Fauna Database and the WAM FaunaBase; Appendix 2 and Appendix 3). The Northern Quoll and the Night Parrot are listed as Endangered at the Federal level, while the Orange Leafnosed-Bat, Bilby and Pilbara Olive Python are listed as Vulnerable, and the Fork-tailed Swift and Rainbow Bee-eater are listed as Migratory under the *EPBC Act 1999*. These species are discussed further in Section 5.6.2.

Table 1.2: Fauna of conservation significance recorded during the Biota (2007) surveys at, or with the potential to occur in the Marandoo Mine Phase 2 Area.

Fauna Species	Category	
	State level	Federal level
Night Parrot *Pezoporus occidentalis*	Schedule 1	Endangered
Northern Quoll *Dasyurus hallucatus#**	Schedule 1	Endangered
Orange Leafnosed-bat *Rhinonicteris aurantius*	Schedule 1	Vulnerable
Bilby *Macrotis lagotis*	Schedule 1	Vulnerable
Pilbara Olive Python *Liasis olivaceus barroni**	Schedule 1	Vulnerable
Peregrine Falcon *Falco peregrinus**	Schedule 4	
Little North-western Mastiff Bat *Mormopterus loriae cobourgiana**	Priority 1	
Spectacled Hare-wallaby (mainland) *Lagorchestes conspicillatus leichardti*	Priority 3	
Western Pebble-mound Mouse *Pseudomys chapmani#**	Priority 4	
Ghost bat *Macroderma gigas#**	Priority 4	
Short-tailed Mouse *Leggadina lakedownensis*	Priority 4	
Australian Bustard *Ardeotis australis**	Priority 4	
Bush Stone-curlew *Burhinus grallarius**	Priority 4	
Star Finch (western) *Neochmia ruficauda subclarescens*	Priority 4	
Fork-tailed Swift *Apus pacificus**		Migratory
Rainbow Bee-eater *Merops ornatus#**		Migratory

\# recorded by Biota in 2007.

* recorded by Ninox in 1991.

Three groups of invertebrate fauna potentially harbouring short-range endemics were recorded during the surveys at Marandoo. These are:

- Pulmonata (terrestrial snails);
- Pseudoscorpionida (pseudoscorpions); and
- Scorpionida (scorpions).

These taxa are discussed further in Section 4.6.

1.4 Conclusions

It appears unlikely that the proposed development of the Marandoo Mine Phase 2 area will have effects on the existing fauna habitats and fauna that will result in alterations to the conservation status of these elements on a local or regional scale. The size of the area, and therefore the available habitat within it, is very limited and any adverse affects are likely to be restricted to individual animals. Therefore the conservation status of these species is unlikely to be altered either at the local or regional level.

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2.0 Introduction

2.1 Project Background

Pilbara Iron operates the Marandoo Iron Ore Mine, which is located in the central Pilbara, approximately 37 km east of Tom Price. The Marra Mamba type iron ore resource at Marandoo occurs both above and below the water table (BWT) and Pilbara Iron currently has approval to mine above the water table only. Between 1994 and 2006, a number of technical investigations were conducted to test the feasibility of extending mining BWT: 'Marandoo Mine Phase 2 (MMP2) Project' (Pilbara Iron 2008).

The major components of the MMP2 Project are:

- expansion of existing mine pits;
- new waste dumps, topsoil stockpiles and haul roads;
- a dewatering system including bores, pipelines, collector tanks and associated infrastructure at, and from, the Marandoo mine to Southern Fortescue Borefield;
- a potential residue storage facility depending on the processing requirements for the ore; and
- construction and operation camp.

The MMP2 proposal was referred to the Environmental Protection Authority (EPA) on July 3rd 2007, which determined the proposal would be assessed at the level of Public Environmental Review (PER) the following December. An Environmental Scoping Document (ESD) was subsequently approved by the EPA Service Unit (EPASU) on March 20th 2008 (Pilbara Iron 2008).

·Additional components related to this project, but which are being assessed under separate environmental impact processes, include:

- a dewatering pipeline route to carry dewatering water from the Marandoo Mine to the Southern Fortescue Borefield;
- dewatering reinjection sites in the Southern Fortescue Borefield; and
- an accommodation village within the proposed Camp Site 6.

2.2 Study Area

The Marandoo Phase 2 study area lies entirely within an area excised from the Karijini National Park. The impact area adjoins the eastern extremity of the existing Marandoo mine site, encompassing an area of approximately 5,000 hectares and includes the deposit and extended infrastructure areas (Figure 2.1).

2.3 Study Objectives and Scope

Biota Environmental Sciences (Biota) was commissioned to complete a desktop review of existing fauna related data and a seasonal fauna survey of the proposed Phase 2 area in April and November 2007. The survey was planned and implemented in accordance with the EPA Position Statement No. 3 "Terrestrial Biological Surveys as an Element of Biodiversity Protection" (EPA 2002) and Guidance Statement No. 56 "Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia".

The scope of the study was to:

- Identify the fauna habitats, particularly those with conservation significance, within the study area;

- Document the vertebrate and SRE invertebrate fauna assemblage within the study area utilising a combined approach of a desk-top review of existing data and a site-specific fauna survey using established sampling techniques; and

- Identify fauna (particularly Schedule and Priority listed fauna as well as potential short-range endemic taxa) of particular conservation significance occurring within the area.

2.4 Purpose of this Report

This report describes the methodology employed for the fauna survey of the Marandoo Mine Phase 2 project area. It documents the methods and results of the survey and discusses the impacts of the project on fauna habitats and assemblages. Its intended use is as a supporting document for the environmental assessment of the project. Both the survey and report are subject to specific limitations that are discussed in detail in Section 3.5.

2.5 Previous Fauna Surveys

Previous fauna surveys in the locality of the Marandoo Mine Phase 2 project area include:

- A fauna survey of Hamersley Range (Karijini) National Park (Muir 1980);
- Vertebrate fauna assessments of the Marandoo Project Area (Ninox 1992);
- Vertebrate Fauna of the Marandoo to Great Northern Highway Road (Kendrick 1995); and
- Southern Plains and Southern Detritals Fauna and Vegetation Monitoring (Biota 2001).

2.6 Geological and Physiographic Context of the Study Area

2.6.1 Geology

Thorne and Trendall (2001) surveyed geological types within the Marandoo area (Table 2.1 and Figure 2.2).

Table 2.1: Geological units occurring within the Marandoo Mine Phase 2 project area (Thorne and Trendall 2001).

Unit	Geological Description
Qx	Undivided Quaternary deposits; includes colluvium, reworked alluvium, eolian sand, and clay
Qa	Alluvium – unconsolidated silt, sand, and gravel; in river channels
AHm	MARRA MAMBA IRON FORMATION: chert, banded iron-formation, mudstone, and siltstone; metamorphosed
AFj	JEERINAH FORMATION: carbonaceous mudstone and siltstone, thin-bedded sandstone, chert, felsic volcaniclastic rock, basalt, and dolomite; metamorphosed
Czp	ROBE PISOLITE: pisolite limonite deposits; developed along palaeodrainage lines
Czx	Undivided Cainozoic deposits; includes partly consolidated colluvium and alluvium, and silcrete and laterite
AHc	CARAWINE DOLOMITE: thin- to thick-bedded dolomite, stromatolitic dolomite, and chert; metamorphosed

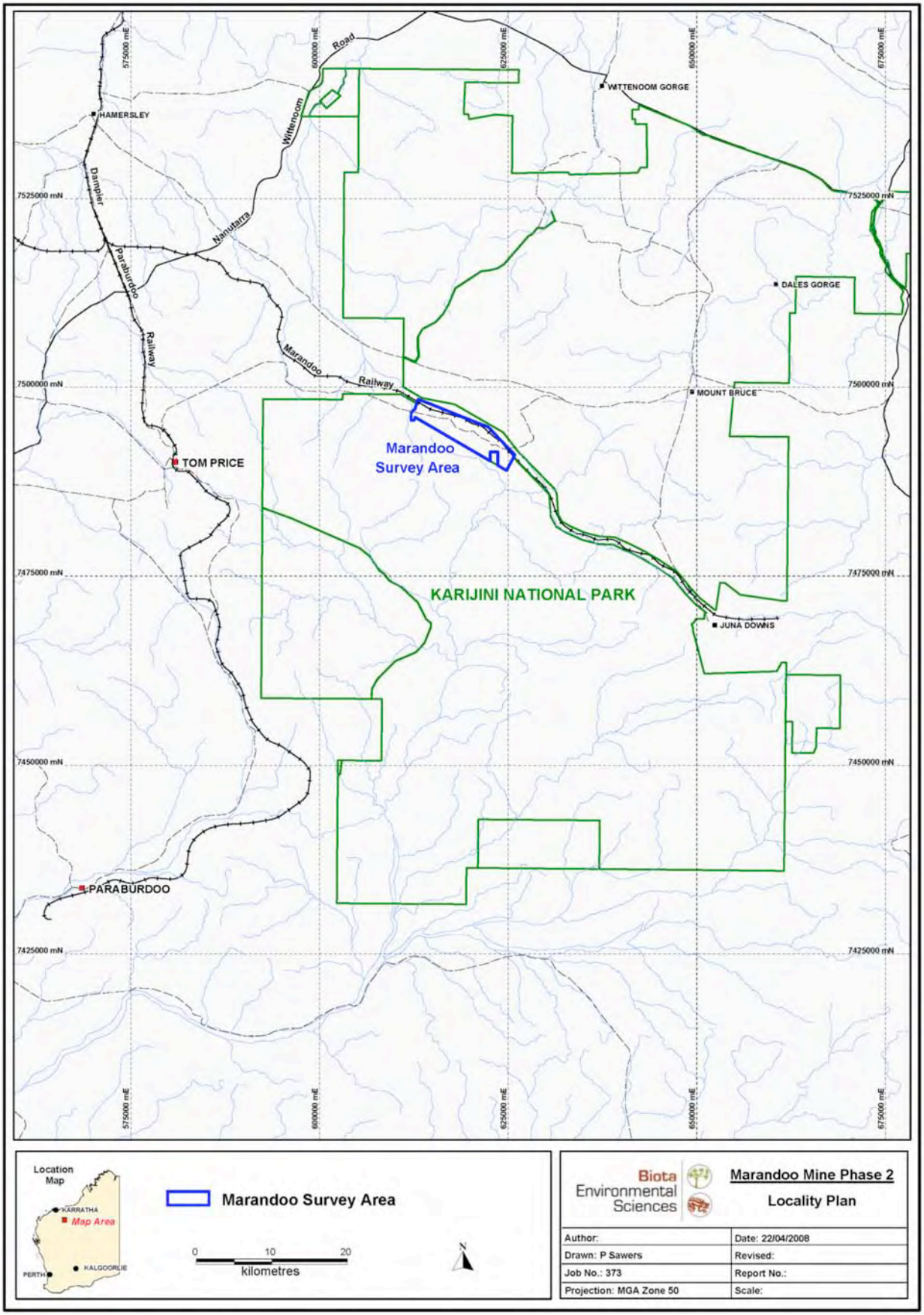

Figure 2.1: Locality map for the Marandoo Mine Phase 2 project area.

2.6.2 Major Physiographic Units

Beard (1975) identified four major physiographic units within the Fortescue District:

- Abydos Plain - extending from Cape Preston east to Pardoo Creek, and south to the Chichester Range; including alluvial plains, low stony hills and granite outcrops; comprising largely granitic soils, with alluvial sands on the coastal portion;
- Chichester Plateau - a plateau of mainly basalts, with included siltstone, mudstone, shale, dolomite and jaspilite; forming a watershed between numerous rivers flowing north through the Abydos Plain to the coast, and the Fortescue drainage on the southern side of the range;
- Fortescue Valley - occupying a trough between the Chichester and Hamersley Plateaux; the eastern portion drains into the Fortescue Marshes; and
- Hamersley Plateau - rounded hills and ranges, mainly of jaspilite and dolomite with some shale, siltstone and volcanics.

The Marandoo Mine Phase 2 project area sits within the Hamersley Plateau as defined by Beard.

2.6.3 Land Systems of the Study Area

Land Systems (Rangelands) mapping covering the study area has been prepared to a draft stage by the Western Australian Department of Agriculture (van Vreeswyk et al. 2004). Land Systems are comprised of repeating patterns of topography, soils, and vegetation (Christian and Stewart 1953) (ie. a series of "land units" that occur on characteristic physiographic types within the Land System).

A total of 107 Land Systems occur in the Pilbara bioregion. [This information was obtained by combining the Land System mapping for the Pilbara (van Vreeswyk et al. 2004) and Ashburton (Payne et al. 1988), and intersecting this with the Pilbara bioregion (Environment Australia 2000) in ArcView 3.2.]

Land Systems mapped by the Department of Agriculture (van Vreeswyk et al. 2004) for the region including the Marandoo Mine Phase 2 project area are shown in Figure 2.3. Descriptions for each Land System within the project area are provided in Table 2.2.

Table 2.2: Land Systems occurring within the Marandoo Mine Phase 2 project area (descriptions from van Vreeswyk et al. 2004).

Land System	Description
Newman (RGENEW)	Rugged jaspilite plateaux, ridges and mountains supporting hard spinifex grasslands.
McKay (RGEMCK)	Hills, ridges, plateaux remnants and breakaways of meta sedimentary and sedimentary rocks supporting hard spinifex grasslands.
Wannamunna (RGEWNM)	Hardpan plains and internal drainage tracts supporting mulga shrublands and woodlands (and occasionally eucalypt woodlands).
Boolgeeda (RGEBGD)	Stony lower slopes and plains below hill systems supporting hard and soft spinifex grasslands and mulga shrublands.
Platform (RGEPLA)	Dissected slopes and raised plains supporting hard spinifex grasslands.
Jurrawarrina (RGEJUR)	Hardpan plains and alluvial tracts supporting mulga shrublands with tussock and spinifex grasses.

Van Vreeswyk et al. (2004) identified a number of Land Units within each Land System, as follows:

- Newman Land System
  1. Plateaux, ridges, mountains and hills – mountain tracts, plateaux and strike ridges, relief up to 400 m; level or rounded plateaux summits and mountain crests, ridges and indented escarpments with vertical upper cliff faces and moderately inclined to very steep upper

scree slopes; surface mantles of abundant to very abundant pebbles, cobbles and stones of ironstone, jaspilite, chert and other rocks. Also outcrop of parent rock.
2. Lower slopes – gently inclined concave slopes mostly less than 400 m in extent with mantles of very abundant pebbles and cobbles of ironstone and other rocks.
3. Stony plains – gently undulating lower plains and interfluves up to 500 m in extent with mantles of abundant to very abundant pebbles of ironstone.
4. Narrow drainage floors with channels – almost level floors up to 400 m wide but usually much less in valleys, mantles of abundant pebbles of ironstone and other rocks; channels up to 200 m wide with cobble bedloads.

- McKay Land System
  1. Hills, ridges and plateaux remnants – rounded hill and ridge crests, level to gently inclined plateaux surfaces, moderately inclined to very steep upper slopes; surface mantles of very abundant pebbles, cobbles and stones of shale, chert, ironstone, sandstone or dolomite, also rock outcrop; relief up to 100 m.
  2. Breakaways – indurated mesa caps of ironstone or laterite with vertical breakaway faces up to 15 m high over weathered parent rock and with short, moderately inclined to steep slopes below; mantles of very abundant ironstone gravels and other rocks.
  3. Lower footslopes – very gently inclined slopes extending for up to 500m below unit 1, mantles of very abundant pebbles of mixed lithology.
  4. Stony plains – level to undulating plains and interfluves extending for up to 2 km below units 1, 2 and 3; mantles of abundant to very abundant pebbles of chert, shale, dolomite and other rocks.
  5. Drainage floors – dendritic floors less than 100 m wide with channels incised in narrow valleys in upper parts of system becoming broader (up to 50 m wide) with channels up to 50 m wide further downstream.
- Wannamunna Land System
  1. Stony plains – level or very gently inclined plains up to 500 m in extent, usually on outer margins of system; surface mantles of abundant pebbles of ironstone.
  2. Hardpan plains – level plains up to 5-6 km in extent, subject to overland sheet flow; surface mantles of very few to few pebbles of ironstone.
  3. Calcrete platforms – level plains up to 300 m in extent and raised 1-2 m above adjacent hardpan plains (unit 2); surface mantles of abundant calcrete pebbles and fragments.
  4. Groves – arcuate drainage foci up to 1 km long and 150 m wide arranged on hardpan plains (unit 2) with long axes at right angles to direction of sheet flow, receiving run-on from adjacent plains; often with gilgai microrelief.
  5. Internal drainage plains – level plains and drainage sumps up to 5 km in extent, receiving run-on from adjacent hill land systems and hardpan plains (unit 2), microrelief may be gilgaied or non-gilgaied.
- Boolgeeda Land System
  1. Low hills and rises – isolated hills and low rises usually <500 m in extent, surface mantles of very abundant pebbles and cobbles of ironstone, basalt and other rocks; relief up to 20 m.
  2. Stony slopes and upper plains – very gently inclined slopes and upper interfluves immediately downslope from adjacent hill systems, dissected up to 5 m by dendritic or sub-parallel small creeklines, surface mantles of common to very abundant pebbles of chert ironstone, quartz and other rocks.
  3. Stony lower plains – almost level plains downslope from unit 2, surface mantles vary from few to very abundant ironstone and other pebbles; subject to sheet and channelised flow from units 1 and 2.
  4. Groves – small (up to 20 m long) arcuate drainage foci occurring infrequently on units 2 and 3.
  5. Narrow drainage floors and channels – dendritic and parallel flow zones and creeklines on slopes and plains (units 2 and 3), only 5-10 m wide in upper parts becoming wider on lower plains, larger channels may be braided and incised up to 3 m.
- Platform Land System
  1. Stony upper plains – very gently inclined upper surfaces occurring mostly as raised, narrow interfluves 50-200 m wide and 0.5-1 km long interdigitated between dendritic or sub-parallel incised drainage, also as broader plains; surface mantles of very abundant pebbles and cobbles of ironstones and other rocks.

2. Dissected slopes – gently inclined to moderately inclined convex and concave stable slopes with narrow creeklines incised up to 30 m below unit 1; surface mantles of very abundant pebbles and cobbles.
3. Drainage floors – almost level floors 20-50 m wide and 3-4 km long, few to very abundant surface mantles of pebbles; unchannelled or with braided channels incised in central areas with bedloads of pebbles, cobbles and stones of jaspilite and other rocks.

- Jurrawarrina Land System
  1. Stony plains – very gently inclined plains up to 1 km in extent on outer margins of system; surface mantles of abundant pebbles and cobbles of ironstone, chert and quartz.
  2. Hardpan plains – level plains receiving overland sheet flow from unit 1 and adjacent land systems, surface mantle varies from very few to abundant ironstone pebbles.
  3. Drainage tracts – level, channelled or unchannelled tracts and alluvial plains with clayey soils, up to about 750 m wide, receiving more concentrated through flow, usually without surface mantles, sometimes with gilgai microrelief.
  4. Groves and drainage foci – foci as bands up to 400 m long by 30 m wide (but usually much smaller) arranged with long axes at right angles to direction of sheet flow on stony and hardpan plains (units 1 and 2), also less uniformly shaped foci and depressions 30-300 m in extent on hardpan plains and drainage tracts (units 2 and 3); both frequently with gilgai microrelief.
  5. Gilgai plains – level plains up to 500 m in extent with gilgai microrelief, surface mantles vary from few to many pebbles of ironstone.
  6. Channels – channels up to 50 m wide with banks up to 4 m high.

2.7 Biological Context of the Study Area

2.7.1 IBRA Bioregion

The Interim Biogeographic Regionalisation for Australia (IBRA) recognises 85 bioregions (Environment Australia 2000). The Marandoo Mine Phase 2 project area lies within the Pilbara bioregion, which is divided into four subregions: Roebourne Plains, Chichester, Fortescue Plains and Hamersley. These subregions are largely equivalent to the physiographic regions of Beard (1975), although the coastal portion of Beard's Abydos Plain unit comprises the Roebourne Plains subregion, while the inland portion is included under the Chichester subregion. The Marandoo Mine Phase 2 project area is located within the Hamersley subregion.

With increasing survey work, it is becoming apparent that the Pilbara Bioregion is one of the centres of biodiversity in the State (go to www.deh.gov.au/minister/env/2003/mr03oct03.html). This appears to be related to the diversity of geological, altitudinal and climatic elements in the region, as well as a function of its location. The Pilbara is located in a transitional zone between the floras of the Eyrean (central desert) and southern Torresian (tropical) bioclimatic regions, and contains elements of all of these floras (see for example van Leeuwen and Bromilow (2002) for a detailed discussion of the significance of the Hamersley Range). The Pilbara is similarly an area of transition for fauna. In recognition of this high species diversity and the high levels of endemism in the region, the Pilbara has been nominated as one of 15 national biodiversity "hotspots" by the Minister for the Environment and Heritage (go to www.deh.gov.au/minister/env/2003/mr03oct03.html).

2.7.2 Conservation Reserves in the Locality

The Marandoo Mine Phase 2 project lies within State Agreement Lease AML 70/272, which was granted under the *Iron Ore* (Hamersley Range) *Agreement Act 1963*. The mining lease was excised from the Karijini National Park in 1991 and is adjacent to the National Park.

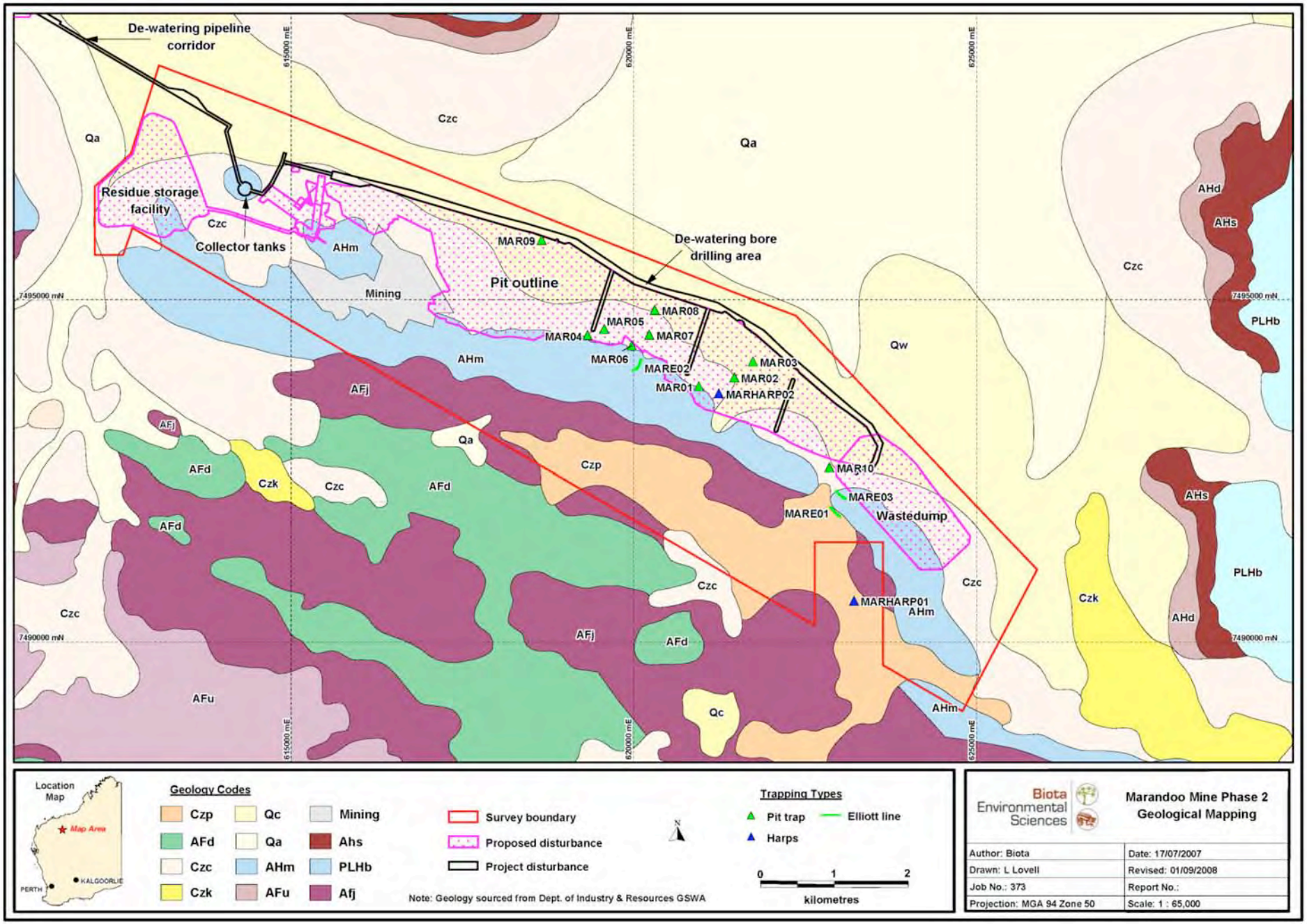

Figure 2.2: Geological Mapping for the Marandoo Mine Phase 2 project area.

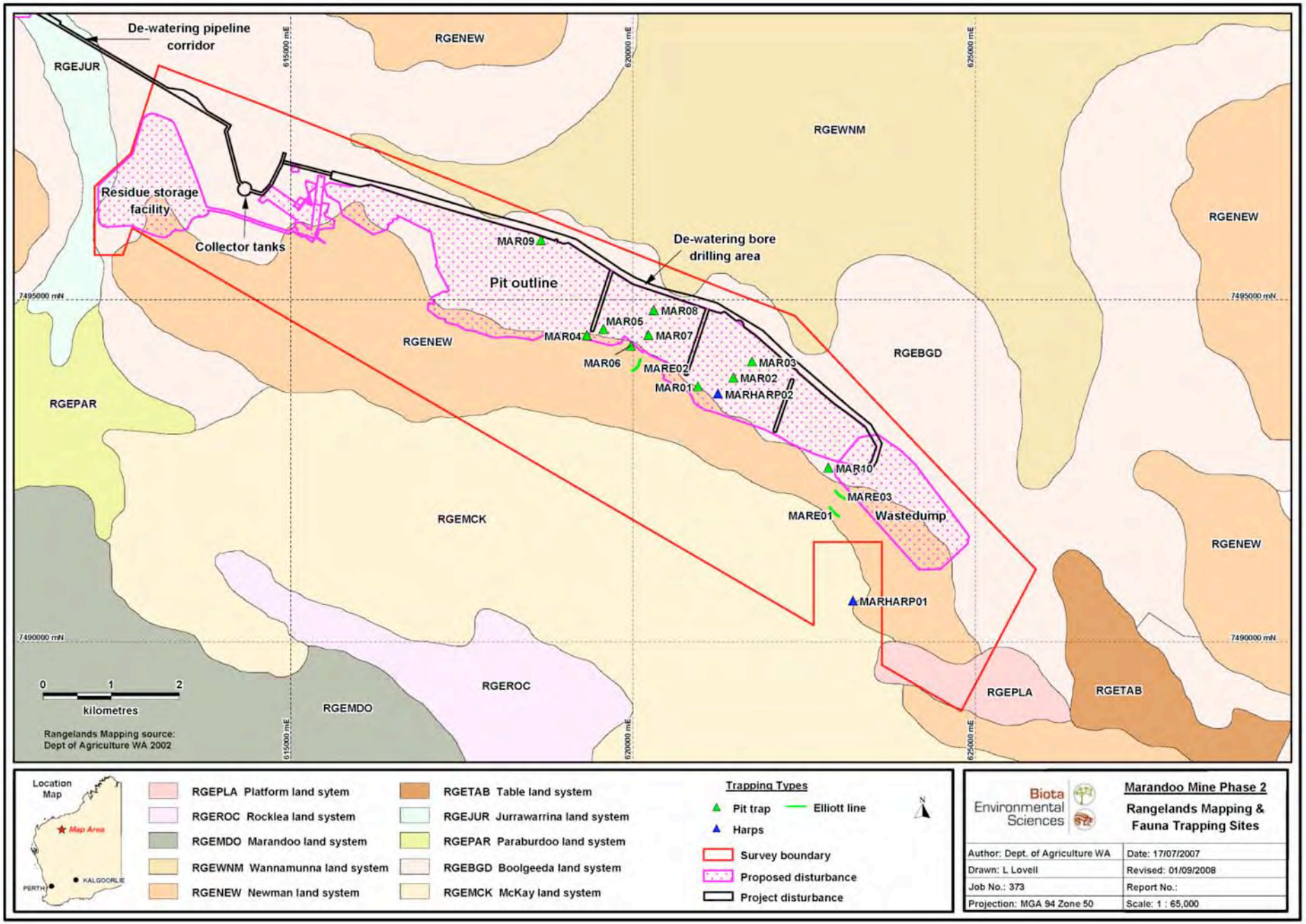

Figure 2.3: Rangelands Mapping for the Marandoo Mine Phase 2 project area.

3.0 Study Methodology

3.1 Database Searches

Database searches were conducted for the Department of Environment and Conservation (DEC) Threatened Fauna database (Appendix 2), the Environmental Protection and Biodiversity Conservation (EPBC) Act Protected Matters database (Appendix 4) and the WA Museum FaunaBase (Appendix 3).

The bounding coordinates for these searches were:

- 22.161°S 117.669°E; and
- 23.102°S 118.645°E.

3.2 Survey Timing and Weather

An initial survey was carried out between March 1st and March 11th 2007, and was interrupted by rainfall associated with tropical cyclone Jacob. This survey comprised installation of the systematic trapping sites and commencement of trapping. The survey was subsequently re-commenced and completed between April 10th and 15th 2007. The seasonal survey was carried out between November 6th and November 12th 2007.

Table 3.1: Daily meteorological observations for Tom Price during the Marandoo Mine Phase 2 study period (data provided by the Western Australian Bureau of Meteorology).

Date	Minimum Temperature (°C)	Maximum Temperature (°C)	Rainfall (mm)
Initial Survey			
1/03/07	18.4	37.3	0
2/03/07	22.5	38.8	0
3/03/07	24.2	40.4	0
4/03/07	No data available	No data available	0
5/03/07	No data available	No data available	0.6
6/03/07	24.8	40.2	0.6
7/03/07	28.7	38.8	0
8/03/07	24.5	No data available	0
9/03/07	No data available	36.1	No data available
10/03/07	20.7	32.6	77.2
11/03/07	20.6	32.6	2.2
10/04/07	18.8	31.9	0
11/04/07	16.9	No data available	0
12/04/07	19.9	No data available	0
13/04/07	18.9	No data available	0
14/04/07	16.3	No data available	0
15/04/07	15.5	No data available	0
Seasonal Survey			
6/11/07	17.0	34.0	0
7/11/07	17.5	35.0	0
8/11/07	19.0	36.0	0
9/11/07	15.5	37.0	0
10/11/07	19.5	36.5	0
11/11/07	20.5	35.0	0.6
12/11/07	21.0	34.5	0

3.3 Fauna Survey Team

The vertebrate fauna sampling for these surveys was conducted under "Licence to Take Fauna for Scientific Purposes" No. SF005700 issued to Dr Phil Runham (Appendix 1).

The fauna survey team comprised Dr Phil Runham, Mr Michael Greenham, Ms Leah Beesley, Ms Erin Harris, Ms Jane Adcroft, Mr Ash Johnsen (all of Biota Environmental Sciences), and Mr Greg Harold (private consultant).

Invertebrate identification was undertaken by Mark Harvey and Erich Volschenk of the Western Australian Museum.

3.4 Systematic Censusing

3.4.1 Selection and Location of the Survey Sites

Systematic terrestrial fauna sampling was carried out at thirteen sites (Table 3.2 and Figure 3.2). This included ten trapping grids of ten pit-traps, spaced at 10 metre intervals and connected by 100 metres of fly-wire fenceline (30 cm in height), and three transects of Elliott traps. Avifauna were censused at each of these sites as well as two opportunistic sites.

3.4.2 Trapping Effort and Layout of the Trapping Grids

The trapping effort at each site is shown in Table 3.2. A decision was made to not use funnel traps during the Marandoo survey, as it was considered that the high diurnal temperatures would result in trap deaths of captured animals.

An indicative layout for the Marandoo Mine Phase 2 project pit-trapping sites is shown in Figure 3.1. On this survey, pit-traps at each site were arranged in a single row of 10 traps, alternating between 20 litre buckets (~40 cm diameter) and PVC tubes (~20 cm diameter). Pit-traps were spaced at ~10 m intervals and connected with a single length of 30 cm tall flywire fence. Elliott traps were placed in three rocky gorges.

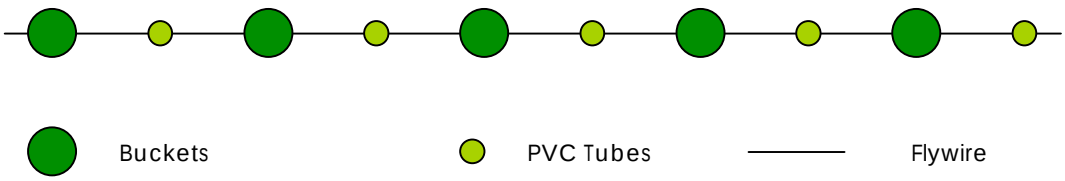

Figure 3.1: Indicative layout of trapping grids for the Marandoo Mine Phase 2 survey (NB. not to scale).

3.4.3 Avifauna Sampling

The avifauna of the project area was sampled using a combination of techniques, which included:

- unbounded area searches conducted at all the systematic sampling grids;
- unbounded area searches conducted at opportunistic locations containing habitats or microhabitats likely to support previously unrecorded species; and
- opportunistic observation of birds while driving around the study area.

An opportunistic avifauna census was also completed at an ephemeral pool (MARSWAMP) present during the initial survey phase.

Table 3.2: Trapping Effort and Trap Location (WGS84 datum, Zone 50) for the survey of the Marandoo Mine Phase 2 Project Area.

Site	Location (AMG)	Trap Type	Date Opened	Date Closed	Nights Open	No. of Traps	Total Effort (trap nights)
MAR01	620950mE; 7493735mN	Pit-traps	5/03/07	8/03/07	3	10	30
			10/04/07	15/04/07	5	10	50
			6/11/07	12/11/07	6	10	60
MAR02	621466mE; 7493861mN	Pit-traps	5/03/07	8/03/07	3	10	30
			10/04/07	15/04/07	5	10	50
			6/11/07	12/11/07	6	10	60
MAR03	621739mE; 7494097mN	Pit-traps	5/03/07	8/03/07	3	10	30
			10/04/07	15/04/07	5	10	50
			6/11/07	12/11/07	6	10	60
MAR04	619327mE; 7494480mN	Pit-traps	6/03/07	8/03/07	2	10	20
			10/04/07	15/04/07	5	10	50
			6/11/07	12/11/07	6	10	60
MAR05	619571mE; 7494572mN	Pit-traps	6/03/07	8/03/07	2	10	20
			10/04/07	15/04/07	5	10	50
			6/11/07	12/11/07	6	10	60
MAR06	619970mE; 7494327mN	Pit-traps	6/03/07	8/03/07	2	10	20
			10/04/07	15/04/07	5	10	50
			6/11/07	12/11/07	6	10	60
MAR07	620226mE; 7494484mN	Pit-traps	6/03/07	8/03/07	2	10	20
			10/04/07	15/04/07	5	10	50
			6/11/07	12/11/07	6	10	60
MAR08	620305mE; 7494848mN	Pit-traps	5/03/07	8/03/07	3	10	30
			10/04/07	15/04/07	5	10	50
			6/11/07	12/11/07	6	10	60
MAR09	618656mE; 7495873mN	Pit-traps	6/03/07	8/03/07	2	10	20
			10/04/07	15/04/07	5	10	50
			6/11/07	12/11/07	6	10	60
MAR10	622855mE; 7492546mN	Pit-traps	5/03/07	8/03/07	3	10	30
			10/04/07	15/04/07	5	10	50
			6/11/07	12/11/07	6	10	60
MARE01	622869mE; 7491968mN	Elliott traps	6/03/07	8/03/07	2	42	84
			11/04/07	15/04/07	4	42	168
MARE02	620134mE; 7494127mN	Elliott traps	7/03/07	8/03/07	1	42	42
			11/04/07	15/04/07	4	42	168
			7/11/07	12/11/07	5	42	210
MARE03	622953mE; 7492209mN	Elliott traps	7/11/07	12/11/07	5	36	180
					Pit Nights		1350
					Elliott Nights		852
					Total Trap Nights		2202

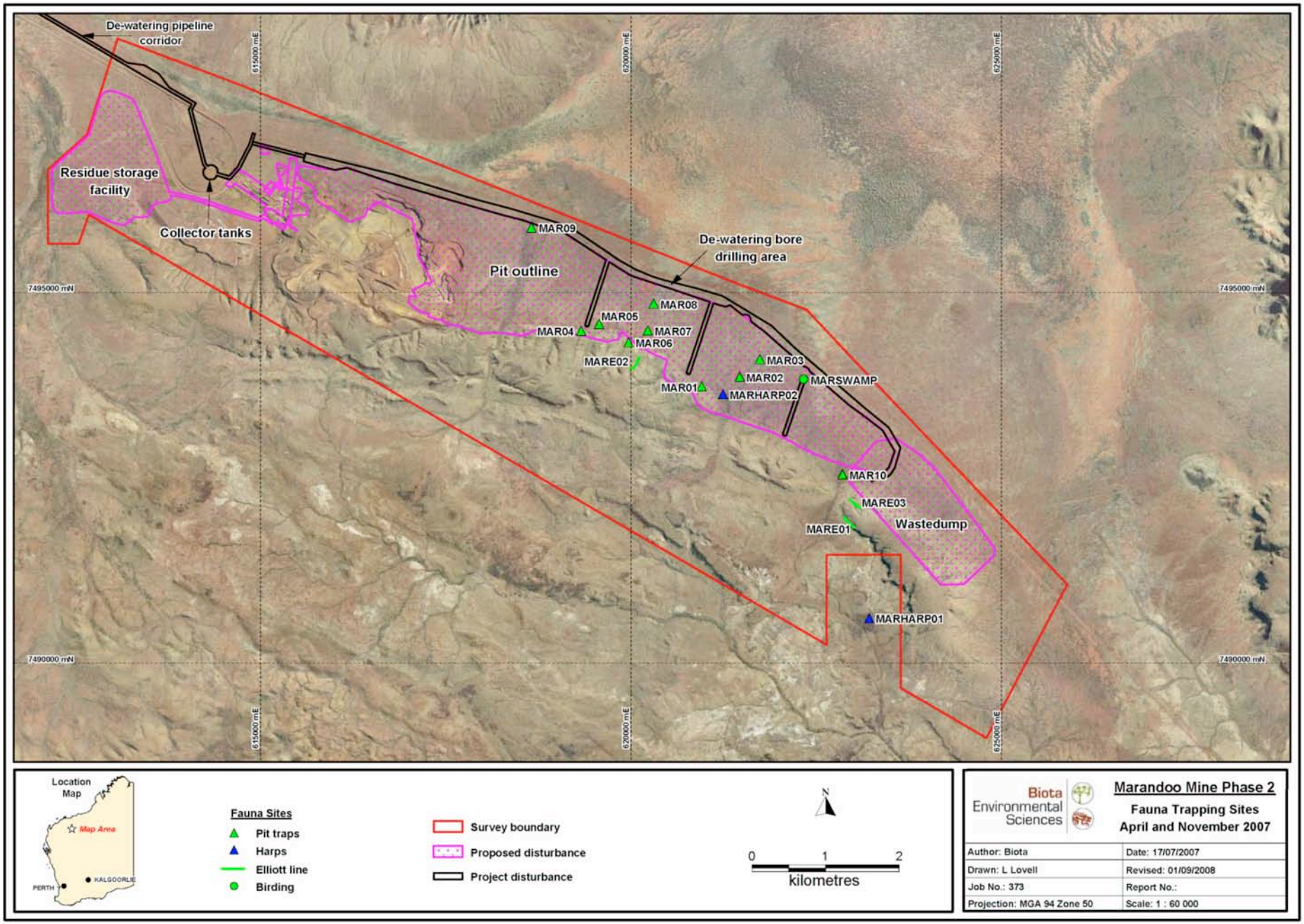

Figure 3.2: Marandoo Mine Phase 2 Fauna Trapping Sites

Table 3.3: Timing of Avifauna Censuses during the Marandoo Mine Phase 2 project surveys.

Site	6/03/07	7/03/07	8/03/07	11/04/07	12/04/07	13/04/07	15/04/07	7/11/07	8/11/07	9/11/07	11/11/07	Total (min)
MAR01	0855 - 0935			0900 - 0945		0950 - 1030		0905 - 0945	0900 - 0930			195
MAR02	0945 - 1025			1015 - 1100		0850 - 0930		*	0815 - 0845	0715 - 0745		185
MAR03	1040 - 1120	0900 - 0940			1010 - 1050				0945 - 1015	0955 - 1030		185
MAR04		0700 - 0740			0815 - 0855	0950 - 1030		0800 - 0830	0900 - 0930			180
MAR05		0750 - 0820			0900 - 0930	0910 - 0940		0845 - 0915	0830 - 0850			140
MAR06		0830 - 0900				0730 - 0820		0925 - 0955	0730 - 0800			140
MAR07		0925 - 0955			0940 - 1020	0835 - 0905			0810 - 0825		0815 - 0845	145
MAR08	1125 - 1205	0810 - 0850			0900 - 0940			0800 - 0835	0730 - 0800			185
MAR09		1020 - 1050		*	0730 - 0810	*		0720 - 0750	0940 - 1010			130
MAR10	0655 - 0735	0950 - 1030		0805 - 0845		1040 - 1120	*	0715 - 0750		0800 - 0830		225
MARE01		1035 - 1115	0640 - 0715		0750 - 0830							115
MARE02			0715 - 0755		*	0730 - 0820				0710 - 0740	0735 - 0805	150
MARE03									1020 - 1050			30
MARSWAMP						*						*
											Total Census Time (min)	2,005

* denotes opportunistic sightings

3.4.4 Bat Sampling

Bats were sampled at two sites using harp traps (Table 3.4; Plates 3.1 and 3.2) and at two sites; MARE02 and MARE03, using Anabat echolocation call detectors (Table 3.2). MARHARP02 was not sampled during the seasonal survey as the pool had dried out.

Table 3.4: Location of Harp Traps and trap nights during the Marandoo Mine Phase 2 fauna survey.

Site	Location (WGS84, Zone 50)	Structure	Date Opened	Date Closed	Nights Open
MARHARP01	623213mE; 7490604mN	Pool	7/03/07	8/03/07	1
			8/11/07	12/11/07	4
MARHARP02	621240mE; 7493628mN	Pool	7/03/07	8/03/07	1
				Harp Trap Nights	6

Plate 3.1: Survey Site MARHARP01

Plate 3.2: Survey Site MARHARP02

3.4.5 Non-systematic Sampling of Vertebrate Fauna

A range of non-systematic fauna survey activities was also undertaken by the survey team to supplement the trapping and investigate additional habitats identified during the course of the survey. These included:

- habitat-specific searches for Schedule and Priority listed fauna species;
- searching of microhabitats for reptile, frog and small mammal species;
- opportunistic sightings and records;
- identification of road kills and other animal remains; and
- recording and identification of secondary signs (where possible) including tracks, scats and diggings.

3.4.6 Invertebrate Sampling

Invertebrates were collected from systematic sampling sites in the course of removing vertebrates from traps, as well as searches being conducted in these habitats. Additional non-systematic sampling for invertebrate groups supporting potential short-range endemic (SRE) taxa was conducted at six sites across the study area (Table 3.5). Groups targeted during these activities included:

- Mygalomorph (Trap-door) spiders;
- Pseudoscorpions;
- Scorpions;
- Millipedes; and
- Terrestrial snails.

Table 3.5: Sites searched for invertebrate SRE taxa during the survey of the Marandoo Mine Phase 2 survey.

Site	Location (WGS84, Zone 50)	Habitat	Groups Targeted
MARSN01	621337mE; 7493386mN	*Triodia* on loam	Terrestrial snails, mygalomorphs, scorpions
Pseud01	623043mE; 7490527mN	*Cormybia* sp.	Pseudoscorpions
Pseud02	622806mE; 7492448mN	*Cormybia* sp.	Pseudoscorpions
Pseud03	621252mE; 7493406mN	*Cormybia* sp.	Pseudoscorpions
Pseud04	621082mE; 7494122mN	*Cormybia* sp.	Pseudoscorpions

3.5 Survey Limitations

Funnel traps were not deployed during the survey due to high temperatures (Table 3.1) and the higher likelihood of individual animal deaths.

Sampling for bats was carried out using harp traps, as this method provides voucher specimens that can be definitively identified, which is not always possible using alternative methods such as recording echolocation calls. However, harp-traps limit sampling to specific roost sites or flyways, and do not exhaustively sample all bat species, such as high flying taxa, that may be present.

The WA Museum's curatorial staff indicated that only key specimens would be accepted for vouchering. As a consequence, terrestrial invertebrate sampling was targeted at specific groups, and voucher specimens were not provided for all invertebrate species collected opportunistically during the survey.

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4.0 Results

4.1 Fauna Habitat

The study area contained four primary habitat types identified on the basis of vegetation structure and landforms. These comprised:

- small drainage lines vegetated with *Acacia aneura* over tussock grasses on loamy substrates;
- stony hillslopes vegetated with *Acacia* shrubs over *Triodia* on stony loam substrates;
- flat outwash plains vegetated with Acacia shrubs on loamy substrates; and
- rocky gorges.

Table 4.1: Fauna habitats within the Marandoo Mine Phase 2 project area.

Landform	Site	Vegetation Description	Plate Reference
Small drainage line	MAR02	Open *Acacia aneura*/Scattered *Corymbia* over *Triodia*/dense tussock grasses on loam	Plate 4.2
	MAR03	Open *Acacia aneura* over mid to dense tussock grasses on loam	Plate 4.3
	MAR09	Open *Acacia aneura* over tussock grasses on gravely loam	Plate 4.9
Stony hillslope	MAR01	Scattered *Acacia* shrubs over *Triodia* on stony loam	Plate 4.1
	MAR04	Open to mid dense *Acacia* over dense *Triodia* on stony loam	Plate 4.4
	MAR05	Mid-dense *Acacia* and scattered *Acacia* over *Triodia* on stony loam	Plate 4.5
	MAR06	Mid dense *Acacia* shrubland (to 2 m) with scattered *Corymbias* over *Triodia* on stony loam	Plate 4.6
Plain	MAR07	Mid-dense *Acacia* shrubs (to 2 m) over dense *Triodia* on stony loam	Plate 4.7
	MAR08	Scattered *Acacia* over *Triodia* on loam	Plate 4.8
	MAR10	Open *Acacia* over mid-dense *Triodia*, some tussock grasses on gravely loam	Plate 4.10
Rocky gorge	MARE01	Rocky gorge	Plate 4.11
	MARE02	Rocky gorge	Plate 4.12
	MARE03	Rocky gorge	Plate 4.13

Plate 4.1: Survey Site MAR01

Plate 4.2: Survey Site MAR02

Plate 4.3: Survey Site MAR03

Plate 4.4: Survey Site MAR04

Plate 4.5: Survey Site MAR05

Plate 4.6: Survey Site MAR06

Plate 4.7: Survey Site MAR07

Plate 4.8: Survey Site MAR08

Plate 4.9: Survey Site MAR09

Plate 4.10: Survey Site MAR10

Plate 4.11: Survey Site MARE01

Plate 4.12: Survey Site MARE02

Plate 4.13: Survey Site MARE03

4.2 Overview

The first phase of the survey carried out at the Marandoo Mine Phase 2 project area yielded a total of 90 vertebrate fauna species (Table 4.2). The seasonal phase yielded a total of 96 vertebrate fauna species. The combined total of 125 species for the Marandoo Mine Phase 2 survey, comprised 54 avifauna species, 20 mammal species and 51 herpetofauna species, comprising four frogs and 49 reptiles (Table 4.2).

Table 4.2: Number of vertebrate fauna species recorded during the survey of the Marandoo Mine Phase 2 project area.

Fauna Group	Number of Species		
	Phase I (Autumn)	Phase 2 (Spring)	Total
Avifauna	47	39	54
Non-volant Mammals (native)	9	6	10
Non-volant Mammals (introduced)	2	2	3
Bats	1	7	7
Herpetofauna	31	42	51
Total	90	96	125

4.3 Avifauna

4.3.1 The Assemblage

A total of 54 species of birds were recorded during the survey, comprising 26 families. This total includes 24 non-passerine species and 30 passerine species (Table 4.3).

The most commonly recorded species was the Zebra Finch *Taeniopygia guttata* with a total of 1,129 records, representing 47.66% of all avifauna records. The Little Corella *Cacatua sanguinea* was also relatively common, with 357 records representing a total of 15.07% of all avifauna records for the survey. All other species recorded during the survey each represented less than 5% of total avifauna records. The most abundant avifauna Family was the Passeridae, with 1,207 records accounting for 50.95% of all records. The most speciose Families observed were the Accipitridae and the Meliphagidae, which both comprised five species.

Notable differences between the two survey phases included the absence of waterfowl from the second phase. These Families (Anatidae and Charadriidae) were recorded from a shallow ephemeral water body (MARSwamp) in the northern portion of the study area during the March phase, which had dried out by November. Other significant changes to the inventory included the absence of Budgerigars *Melopsittacus undulatus* and Rainbow Bee-eaters *Merops ornatus* and large reduction in numbers of Zebra finches *Taeniopygia guttata* during the seasonal phase.

The richest sites were MAR10 with 28 species (it should be noted that MAR10 was the most intensively censused site [Table 3.3]) and MAR01 with 24 species.

Table 4.3 presents data for all bird species recorded from each fauna survey site over both phases.

4.3.2 Breeding Records

Two Zebra Finches, *Taeniopygia guttata*, were recorded with a nest at MAR10 during the initial survey.

4.3.3 Regional Endemism and Restricted Taxa

The Pilbara subspecies of the Striated Grasswren *Amytornis striatus whitei*, which was recorded during the Marandoo surveys (see Table 4.3) is endemic to the bioregion.

4.3.4 Avifauna of Conservation Significance

Only one avifauna species of elevated conservation significance, the federally listed Migratory Rainbow Bee-eater *Merops ornatus* (see Table 4.3) was recorded during the Marandoo Mine Phase 2 fauna survey.

A further ten avifauna species of elevated conservation significance could be recorded within the Marandoo Mine Phase 2 project area according to searches of the DEC Threatened Fauna database and the EPBC Protected Matters database. The Night Parrot *Geopsittacus occidentalis* is listed as Endangered under the Federal EPBC Act and Schedule 1 under the WA *Wildlife Conservation Act 1950-1979*. The Peregrine Falcon *Falco peregrinus* is a Schedule 4 listed species under the WA *Wildlife Conservation Act 1950-1979*. Three Priority 4 listed species could also be found in the study area, these are the Australian Bustard *Ardeotis australis*, the Bush Stone-curlew *Burhinus grallarius* and the Star Finch *Neochmia ruficauda subclarescens*. Additionally, the White-bellied Sea Eagle *Halaeetus leacogaster*, Great Egret *Ardea alba*, Little Egret *Ardea ibis*, Oriental Plover *Charadrius veredus* and Fork-tailed Swift *Apus pacificus* are all federally listed as Migratory species.

Further information on these species of elevated conservation significance can be found in Section 5.6.2.

Table 4.3: Avifauna results for the Marandoo Mine Phase 2 fauna survey (initial survey/seasonal survey).

Family & Common Name	Species Name	MAR01	MAR02	MAR03	MAR04	MAR05	MAR06	MAR07	MAR08	MAR09	MAR10	MARE01	MARE02	MARE03	MARSN01*	MARSWAMP	Total
PHASIANIDAE																	
Stubble Quail	*Coturnix navaezelandiae*									0/2							0/2
ANATIDAE																	
Australian Wood Duck	*Chenonetta jubata*															3/0	3/0
Straw-necked Ibis	*Threskiornis spinicollis*														6/0		6/0
ACCIPITRIDAE																	
Black-shouldered Kite	*Elanus caeruleus*			0/1	1/0	1/0		2/0	2/0				2/0				8/1
Whistling Kite	*Haliastur sphenurus*							0/1									0/1
Collared Sparrowhawk	*Accipiter cirrocephalus*					0/1				0/1							0/2
Little Eagle	*Aquila morphnoides*					0/1							0/1				0/2
Wedge-tailed Eagle	*Aquila audax*			1/0							2/0						3/0
FALCONIDAE																	
Brown Falcon	*Falco berigora*	1/1	0/1	1/0	2/0	1/0	1/0	0/1		4/1	1/0	2/0	0/1				13/5
Australian Kestrel	*Falco cenchroides*					0/1	1/0	0/1			1/0						2/2
TURNICIDAE																	
Little Button-quail	*Turnix velox*	3/0		5/0						0/1							8/1
CHARADRIIDAE																	
Black-fronted Dotterel	*Charadrius melanops*															8/0	8/0
COLUMBIDAE																	
Common Bronzewing	*Phaps chalcoptera*		0/1														0/1
Crested Pigeon	*Ocyphaps lophotes*	1/0	2/2			0/1				1/14	1/0	10/0					15/17
Spinifex Pigeon	*Geophaps plumifera*				0/2	3/0							0/2				3/4
Diamond Dove	*Geopelia cuneata*	6/0	4/0	2/0	2/5	4/3	0/2		3/0		1/0						22/10
PSITTACIDAE																	
Little Corella	*Cacatua sanguinea*		0/25				0/3	4/81	0/235		0/4		0/5				4/353
Cockatiel	*Nymphicus hollandicus*	2/0	6/0			3/0	0/10			21/0	0/8						32/18
Australian Ringneck	*Platycercus zonarius*		1/3	9/0					0/9		4/0	2/0					16/12
Budgerigar	*Melopsittacus undulatus*	20/0							20/0	17/0	6/0						63/0
CUCULIDAE																	
Pallid Cuckoo	*Cuculus pallidus*			1/0													1/0
Horsfield's Bronze Cuckoo	*Chrysococcyx basalis*		1/0		1/0	3/0		4/0			0/1		2/1				11/2

Family & Common Name	Species Name	MAR01	MAR02	MAR03	MAR04	MAR05	MAR06	MAR07	MAR08	MAR09	MAR10	MARE01	MARE02	MARE03	MARSN01*	MARSWAMP	Total
HALCYONIDAE																	
Red-backed Kingfisher	*Todiramphus pyrrhopygia*		1/0					1/0		1/0	1/0			0/1			4/1
MEROPIDAE																	
Rainbow Bee-eater	*Merops ornatus*				1/0						6/0	3/0	6/0				16/0
MALURIDAE																	
Variegated Fairy-wren	*Malurus lamberti*	0/7	4/8	0/7	8/0	9/0	0/2	8/0	0/9	7/5	0/3		0/5				36/46
White-winged Fairy-wren	*Malurus leucopterus*			0/4						2/0	0/1						2/5
Striated Grasswren	*Amytornis striatus*	0/3															0/3
PARDALOTIDAE																	
Red-browed Pardalote	*Pardalotus rubricatus*						0/2					1/0					3/0
ACANTHIZIDAE																	
Weebill	*Smicrornis brevirostris*	0/10			2/0	1/0	2/2					5/0	0/6				10/18
Western Gerygone	*Gerygone fusca*	1/1	2/1						0/1								3/3
MELIPHAGIDAE																	
Brown Honeyeater	*Lichmera indistincta*											1/0					1/0
Singing Honeyeater	*Lichenostomus virescens*	3/3	3/7	0/1	3/0	2/2			2/0	2/2	4/1	1/0	4/0				24/16
Grey-headed Honeyeater	*Lichenostomus keartlandi*	0/4				2/0	0/1				2/2	2/0					6/7
Yellow-throated Miner	*Manorina flavigula*	1/0															1/0
Spiny-cheeked Honeyeater	*Acanthagenys rufogularis*	1/0	3/0	2/0	4/0	0/2		3/1	0/2	8/2	0/14	1/0	0/1				22/22
PETROICIDAE																	
Hooded Robin	*Petroica cucullata*	0/1	1/0	1/1	0/1		0/1		1/0	1/0	2/1						6/5
POMATOSTOMIDAE																	
Grey-crowned Babbler	*Pomatostomus temporalis*		3/0	2/0		0/1				1/5	6/0						12/6
PACHYCEPHALIDAE																	
Crested Bellbird	*Oreoica gutturalis*	1/0	1/0		1/0			0/1	2/0		0/1						5/2
Rufous Whistler	*Pachycephala rufiventris*	2/6	2/3		1/0	1/0		1/0	0/2	1/0	1/1		1/4				10/16
Grey Shrike-thrush	*Colluricincla harmonica*	1/1									1/0		1/6				3/7
DICRURIDAE																	
Willie Wagtail	*Rhipidura leucophrys*	3/5	1/3	1/0	8/1	1/0	1/1	2/0	0/3	2/1	2/3	4/0	0/5	0/1			25/23
Magpie-lark	*Grallina cyanoleuca*								0/1								0/1

Family & Common Name	Species Name	MAR01	MAR02	MAR03	MAR04	MAR05	MAR06	MAR07	MAR08	MAR09	MAR10	MARE01	MARE02	MARE03	MARSN01*	MARSWAMP	Total
CAMPEPHAGIDAE																	
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*		1/0	1/0		0/1			2/9		5/0						9/10
ARTAMIDAE																	
Black-faced Woodswallow	*Artamus cinereus*	2/0		3/0	0/2	0/2		2/0	1/0	9/1	8/3	1/0	0/14				26/22
Little Woodswallow	*Artamus minor*				6/0		10/0						1/0				17/0
CRACTICIDAE																	
Grey Butcherbird	*Cracticus torquatus*	1/0									1/0						2/0
Pied Butcherbird	*Cracticus nigrogularis*	1/0	4/0	3/0	1/0		0/1		0/1	1/1			1/0				11/3
CORVIDAE																	
Torresian Crow	*Corvus orru*		0/2					2/1	0/1	5/0			1/1	0/1			8/6
Little Crow	*Corvus bennetti*											3/0					3/0
PTILONORHYNCHIDAE																	
Western Bowerbird	*Ptilonorhynchus maculatus*	1/0															1/0
SYLVIIDAE																	
Spinifex-bird	*Eremiornis carteri*				2/0		1/0	4/1		1/0		2/0	2/0				12/0
Rufous Songlark	*Cincloramphus mathewsi*		0/1	1/2	0/1				2/0	1/3							4/7
PASSERIDAE																	
Zebra Finch	*Taeniopygia guttata*	26/16	127/34	137/12	18/18	52/70	5/5	84/80	8/74	111/33	50/13	50/0	15/11			80/0	763/366
Painted Finch	*Emblema pictum*				12/22		2/0		1/0		2/0	9/0	20/0			10/0	56/22
	Total Individuals	77/58	167/91	170/28	73/52	83/85	25/28	117/167	44/347	196/72	107/56	97/0	56/63	0/3	6/0	101/0	1319/1050
	Total Species	19/12	18/13	15/7	17/8	13/11	9/10	12/8	11/12	19/14	21/14	16/0	12/14	0/3	1/0	4/0	47/39

* Denotes a site where avifauna were recorded opportunistically during unrelated SRE searches.

4.4 Mammals

4.4.1 The Assemblage – Non-volant mammals

A total of ten species of non-volant native mammals were recorded during the survey, comprising four dasyurids (carnivorous marsupials), one macropod (kangaroos and wallabies), four native murid rodents (native mice) and one species of Canidae. Cats (Felidae), House Mice (Muridae) and Donkeys (Equidae) were also noted (Table 4.4).

The most commonly recorded species was the Common Rock-rat *Zyzomys argurus* with a total of 93 records across three sites, representing 56.36% of all non-volant mammal records. The Desert Mouse *Pseudomys desertor* was also relatively common, with fourteen records across eight sites, representing a total of 8.48% of all non-volant mammal records for the survey. The most abundant Family of non-volant mammals was the Muridae, with 121 records accounting for 73.33% of all records. The most speciose families documented were the Muridae and the Dasyuridae, which comprised five and four species respectively.

The predominant change in the species inventory between survey phases was the decline in numbers of individuals representing most species as well as in species diversity. Seven of the ten non-volant native mammals recorded showed a reduction of greater than 50% in the November survey compared to March. Conversely, two mammal species not recorded in March were represented in November, but only by one individual in each case.

The richest site, MAR06 yielded five species across both survey phases, with all but one pit-trapping site (MAR03) yielding two or more mammal taxa. Every site however, yielded fewer individuals and species in November compared to the March phase mirroring the overall results. It should be noted here that MARE01 was replaced by MARE03, and MARHARP02 by MARHARP03 in the latter phase and that the apparent increases in animal numbers at these sites are therefore artificial.

Table 4.4 presents data for all mammal species recorded from each fauna survey site over both the initial and seasonal phases.

4.4.2 The Assemblage – Bats

Seven species of bats were recorded from the Marandoo Mine Phase 2 project area; one vespertilionid, *Vespadelus finlaysoni* was recorded during both survey phases whilst the remaining six species, comprising two emballuronids, three vespertilionids and one megadermatid (Table 4.4) were recorded only during the seasonal component of the survey.

4.4.3 Breeding Records

Three species of mammal were recorded breeding during the Marandoo Mine Phase 2 fauna survey.

Thirteen Common Rock-rat, *Zyzomys argurus* individuals were either gravid or lactating during the initial survey from MARE01 and MARE02.

During the seasonal survey a Pilbara Ningaui, *Ningaui timealeyi*, was recorded at MAR05 with six pouched young. One individual of the *Pseudantechinus* spp. was recorded lactating heavily at MARE3.

4.4.4 Regional Endemism and Restricted Taxa

Three mammal species endemic, or near endemic to the Pilbara were recorded during the current survey: the Pilbara Ningaui *Ningaui timealyi*, *Pseudantechinus sp*. and the Pebble-mound Mouse *Pseudomys chapmani* (see Table 4.4).

4.4.5 Mammals of Conservation Significance

Three species of elevated conservation significance were recorded during the Marandoo Mine Phase 2 fauna survey (see Table 4.4). The Schedule 1 Northern Quoll *Dasyurus hallucatus* was recorded during the initial phase of the survey; this species is also federally listed as Endangered.

The Priority 4 listed species Western Pebble-mound Mouse *Pseudomys chapmani* was also recorded during the initial phase of the fauna survey, whilst the Priority 4 listed Ghost Bat *Macroderma gigas* was recorded from calls at MARE03 in the eastern portion of the study area.

A further five species of mammals of elevated conservation significance could be recorded from the study area, these are the Schedule 1 listed Bilby *Macrotis lagotis*, and Orange Leafnosed-bat *Rhinonicteris aurantius*, the Priority 3 listed Spectacled Hare-wallaby *Lagorchestes conspicillatus*, and the Priority 4 listed Short-tailed Mouse *Leggadina lakedownensis*. The Bilby and the Orange Leafnosed-bat are also federally listed as Vulnerable.

Further information on these species of elevated conservation significance can be found in Section 5.6.2.

Table 4.4: Mammal results for the Marandoo Mine Phase 2 fauna survey (initial survey/seasonal survey).

Family & Species Name	Common Name	MAR01	MAR02	MAR03	MAR04	MAR05	MAR06	MAR07	MAR08	MAR09	MAR10	MARE01	MARE02	MARE03	Total
DASYURIDAE															
Dasyurus hallucatus	Northern Quoll												1/0		1/0
Ningaui timealeyi	Pilbara Ningaui				0/1	2/1	1/0	2/0	4/1		1/0				10/3
Pseudantechinus sp.														0/1	0/1
Sminthopsis macroura	Stripe-faced Dunnart	1/0	3/0	2/0	1/0				1/0	3/0					11/0
MACROPODIDAE															
Macropus robustus	Euro						2/0						3/0		5/0
MURIDAE															
**Mus musculus*	House Mouse			0/1		1/0				1/0					2/1
Pseudomys chapmani	Western Pebble-mound Mouse						1/0								1/0
Pseudomys desertor	Desert Mouse	3/0			1/0	1/0	3/0	2/1	1/0	1/0	1/0				13/1
Pseudomys hermannsburgensis	Sandy Inland Mouse		4/0		1/0	1/1	0/1	1/0			1/0				8/2
Zyzomys argurus	Common Rock-rat											29/0	36/22	0/6	65/28
CANIDAE															
Canis lupus dingo	Dingo	6/1							0/1	0/1					6/3
FELIDAE															
**Felis catus*	Cat										0/1				0/1
EQUIDAE															
**Equus asinus*	Donkey											3/0			3/0
	Total Individuals	10/1	7/0	2/1	3/1	5/2	7/1	5/1	6/2	5/1	3/1	32/0	40/22	0/7	125/40
	Total Species	3/1	2/0	1/1	3/1	4/2	4/1	3/1	3/2	3/1	3/1	2/0	3/1	0/2	11/8

* denotes introduced mammals

Table 4.5: Bats recorded at Marandoo during the Marandoo Mine Phase 2 survey (Initial survey/Seasonal survey).

Family & Species name	Common Name	MARHARP01	MARHARP02	MARE02	MARE03	Total
EMBALLURONIDAE						
Saccolaimus flaviventris	Yellow-bellied Sheathtail Bat			0/X		
Taphozous georgianus	Common Sheathtail bat			0/X		
VESPERTILIONIDAE						
Chalinolobus gouldii	Gould's Wattled Bat	0/12		0/0/X		0/12
Scotorepens balstoni	Inland Broad-nosed Bat	0/11				0/11
Scotorepens greyii	Little Broad-nosed Bat			0/X		
Vespadelus finlaysoni	Finlayson's Cave Bat	0/1	1/0	0/X	0/X	1/1
MEGADERMATIDAE						
Macroderma gigas	Ghost Bat				0/X	
	Total Individuals	0/24	1/0	-	-	1/24
	Total Species	0/3	1/0	0/5	0/2	1/7

* MARHARP01 was not used in March and MARHARP02 was not used in November. MARE02 and MARE03 utilised Anabat Echolocation call recorders and records from these sites are indicated only by X, as it is not possible to infer numbers of individuals from call records.

4.5 Herpetofauna

4.5.1 The Assemblage

Fifty-one herpetofauna species were recorded from the study area during the fauna survey (Table 4.6). This total comprised two hylid (tree) and one myobatrachid (ground) frogs, six agamids (dragons), seven gekkonids (geckos), six pygopodids (legless lizards), thirteen scincids (skinks), six varanids (goannas), two typhlopids (blind snakes) and eight elapids (front-fanged snakes).

The most abundant species were the frogs *Limnodynastes spenceri* and *Cyclorana maini* with 46 and 37 records, comprising 13.45% and 10.82% of the total records respectively. The most abundant family encountered were the skinks, with 109 records comprising 31.87% of all the herpetofauna records for the survey. The skinks were also the most speciose group with thirteen species recorded.

Comparison of the two survey phases predominantly revealed a decrease in the number of representatives of most herpetofauna species, with thirteen of the species yielding 50% fewer individuals in the seasonal survey phase than in the initial phase. In contrast, whilst 27 species showed increases in the number of individuals, only five taxa were represented by five or more individuals in the November trapping period. Similarly, the apparent increase in species richness in November was based on 26 of 42 species being represented by one or two individuals, compared to 14 from 32 species with comparable representation in March.

The most speciose trapping site was MAR10 with 21 species, although MAR02, MAR04 and MAR07 also yielded relatively diverse herpetofauna assemblages with 15 species recorded for each.

The data for all herpetofauna recorded from each site during both phases of the Marandoo Mine Phase 2 fauna survey are presented in Table 4.6.

4.5.2 Breeding Records

There were no breeding records for herpetofauna during the Marandoo Mine Phase 2 fauna survey.

4.5.3 Regional Endemism and Restricted Taxa

Eight species recorded during the survey of the Marandoo Mine Phase 2 project area are considered to be endemic, or near-endemic, to the Pilbara Bioregion. The agamid *Diporiphora valens*, a pygopod *Delma elegans*, two skinks *Ctenotus duricola* and *Menetia surda surda*, *Varanus pilbarensis* and *Varanus bushi* (Varanidae) and the elapid snakes *Acanthophis wellsi* and *Vermicella snelli* (see Table 4.6).

4.5.4 Herpetofauna of Conservation Significance

No herpetofauna of elevated conservation significance were recorded during the fauna survey of the Marandoo Mine Phase 2 area.

The Pilbara Olive python *Liasis olivaceous barroni*, listed under Federal legislation as Vulnerable and under State legislation as Schedule 1, is the only herpetofauna species of elevated conservation significance that might occur in the study area.

Table 4.6: Herpetofauna results for the Marandoo Mine Phase 2 fauna survey (initial survey/seasonal survey).

Family & Species Name	MAR01	MAR02	MAR03	MAR04	MAR05	MAR06	MAR07	MAR08	MAR09	MAR10	MARE01	MARE02	MARE03	MARHARP01	Total
HYLIDAE															
Cyclorana maini		6/0	1/0							30/0					37/0
Litoria rubella														0/1	0/1
MYOBATRACHIDAE															
Limnodynastes spenceri	3/0	3/0	12/0	1/0	1/0	3/0	3/0	15/0	1/0	4/0					46/0
AGAMIDAE															
Caimanops amphiboluroides									1/0						1/0
Ctenophorus caudicinctus	0/1				0/1	0/2			0/1			0/1			0/6
Ctenophorus isolepis										0/6					0/6
Diporiphora valens		1/1		1/0			1/2	1/0	1/0	1/1					6/4
Lophognathus longirostris	3/0	1/0				1/0				1/0					6/0
Pogona minor							0/1								0/1
GEKKONIDAE															
Diplodactylus conspicillatus										2/5					2/5
Diplodactylus stenodactylus										0/1					0/1
Oedura marmorata				0/1									0/1		0/2
Strophurus elderi							0/1	0/1							0/2
Strophurus wellingtonae					0/1	0/2	1/0	0/1							1/4
Gehyra variegata								0/1							0/1
Heteronotia binoei	2/0			1/2						2/0					5/2
PYGOPODIDAE															
Delma elegans	1/0			1/0											2/0
Delma haroldi						1/0	1/0	0/2		3/0					5/2
Delma nasuta				1/0	1/0			1/0		0/1					3/1
Delma pax				0/1	0/1	0/1									0/3
Delma tincta	1/0	3/0			0/3	1/0			2/0	2/0					9/3
Lialis burtonis		2/0		2/3			1/0	1/0							6/3
SCINCIDAE															
Carlia munda	1/0	4/1	3/1	3/2		2/0	2/2	2/0	1/1	1/0					19/7
Cryptoblepharus carnabyi											1/0				1/0
Cryptoblepharus sp.		1/0											0/3	0/6	1/9

Family & Species Name	MAR01	MAR02	MAR03	MAR04	MAR05	MAR06	MAR07	MAR08	MAR09	MAR10	MARE01	MARE02	MARE03	MARHARP01	Total
Ctenotus aff. helenae	0/1	1/0	3/0			0/1	0/3	4/0		1/0					9/5
Ctenotus duricola					0/2		2/2			1/0					3/4
Ctenotus pantherinus	0/1	0/1		0/2	0/3		0/4		0/3						0/14
Ctenotus saxatilis											1/0	1/1			2/1
Ctenotus schomburgkii			0/1						0/1						0/2
Cyclodomorphus melanops		0/1						0/1							0/2
Egernia formosa											9/0	4/5	0/1		13/6
Menetia greyii			1/1	0/2											1/3
Menetia surda						0/1									0/1
Tiliqua multifasciata	2/0	1/0	1/0				1/0			0/1					5/1
VARANIDAE															
Varanus acanthurus	0/1			0/1		1/0									1/2
Varanus brevicauda					0/1		3/0	0/1	2/0	2/0					7/2
Varanus bushi		0/1													0/1
Varanus panoptes									0/1						0/1
Varanus pilbarensis												1/0			1/0
Varanus tristis tristis				0/1											0/1
TYPHLOPIDAE															
Ramphotyphlops grypus	4/1			1/0		2/1									7/2
Ramphotyphlops hamatus			0/5						0/3	0/1					0/9
ELAPIDAE															
Acanthophis wellsi	1/0					1/0	0/1								2/1
Brachyurophis approximans				0/1											0/1
Demansia psammophis cupreiceps			0/1				1/0		1/0						2/1
Furina ornata	1/1	3/0							1/0	1/1					6/2
Parasuta monachus		1/0			1/0					0/1					2/1
Pseudonaja modesta					1/0				2/0						3/0
Suta fasciata										0/1					0/1
Vermicella snelli										0/1					0/1
Total Individuals	19/6	27/5	21/9	11/16	4/12	12/8	16/16	24/7	12/10	51/20	11/0	6/7	0/5	0/7	214/128
Total Species	10/6	12/5	6/5	8/10	4/7	8/6	10/8	6/6	9/6	13/10	3/0	3/3	0/3	0/2	31/42

4.6 Short-range Endemic (SRE) Taxa

Three groups of invertebrate fauna potentially harbouring short-range endemics were recorded during the surveys at Marandoo: terrestrial snails (Pulmonata), pseudoscorpions (Pseudoscorpionida) and scorpions (Scorpionida). The distribution of the sites from which these fauna were collected is shown in Figure 4.1.

Terrestrial Snails
Snails were collected from one site (MARSN01) and were all representatives of the genus *Bothriembryon*.

Pseudoscorpions
Pseudoscorpions were collected from under flaking bark on *Corymbia* sp. at a number of sites throughout the study area (sites PSEUD1, PSEUD2, PSEUD3, PSEUD4). These animals have been identified as a single species of *Synsphyronus* (Dr Mark Harvey, WA Museum) and were found both within the project disturbance area as well as in similar habitat outside this area (see Figure 4.1).

Scorpions
The collected scorpion specimens have been identified and all specimens appear to represent the same species belonging the genus *Lychas* (Erich Volschenk, WA Museum, pers. comm.). Similarly to the other invertebrates, the scorpions were recorded from three sites within (MAR02, MAR05 and MAR08), and from one sites outside (MAR10) of the tail pit clearance area (Figure 4.1).

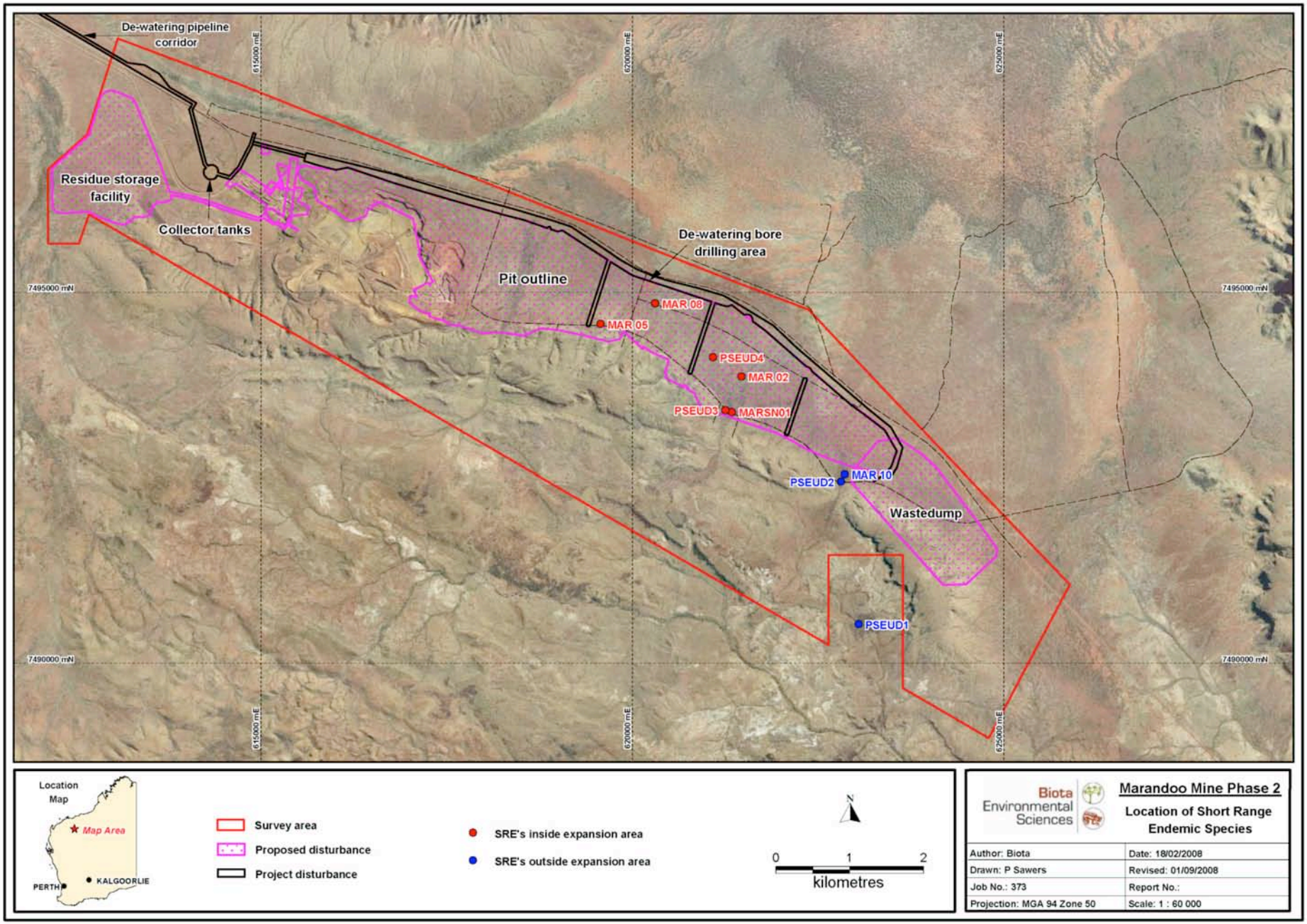

Figure 4.1: Short-range endemic records in the Marandoo Mine Phase 2 project area.

5.0 Discussion

5.1 Overview

The species inventory recorded from the Marandoo Mine Phase 2 survey area, while comparatively low for the Pilbara Bioregion, is representative of both the relatively small total area encompassed by the study, and the consequently low degree of habitat diversity available to fauna. This is further reflected in comparisons of the current results with previous surveys conducted in the vicinity of the Marandoo Mine Phase 2.

The four basic habitat types of this study yielded a total of 125 fauna species across two survey phases, the first in early autumn and the second in late spring. In comparison, Johnstone (1980) conducted a survey of the entire Hamersley Range National Park, identifying habitats incorporating landforms, soil types and vegetation types for a combined total in excess of twenty potential macrohabitats. Accordingly, the survey yielded a total of 247 fauna species. Similarly, eight habitats identified in a study of the Marandoo Mine area and an adjacent portion of rail corridor (Ninox 1992) documented 148 species, whilst a survey completed prior to construction of the Marandoo to Great Northern Hwy road (Kendrick 1995) also incorporated eight habitat types and yielded a total of 137 species.

The following sections contain more detailed comparisons of the fauna comparisons above, and document specific examples of species not recorded during the Marandoo Mine Phase 2 survey and the habitats in which they occur.

5.2 Avifauna

The 54 avifauna species recorded during the two phases of the current study represents approximately 40% of the 135 species collated by Johnstone (1980) for the Hamersley Range National Park, 72% of those documented by Ninox (1992: 75 species) for the Marandoo mine area and its environs and 80% of the numbers recorded by Kendrick (1995: 67 species) for the Marandoo – Great Northern Hwy Link. Despite the relatively smaller size of the inventory compiled, the list is considered reasonable for the size of the study area and the available habitats and comparisons demonstrate that the absence of previously recorded avifauna species from the current survey are characterised by preferences for habitats that were not found within the Marandoo Mine Phase 2 survey area.

The four habitat types identified within the survey area by this study (see Section 4.1), on the basis of vertical stratification and foraging opportunity, in effect yield only two avifauna habitat types comprising:

- *Acacia* spp. Shrubs over *Triodia* on hillslopes and flats; and
- *Corymbia* spp. over *Acacia* spp. and *Triodia* spp. in small drainage lines and gorges.

This relative lack of habitat diversity and vertical stratification accounts, at least in part, for the absence of avifauna species such as thornbills (*Acanthiza* spp.), which are characterised by a preference for dense habitats including *Acacia aneura* woodlands. Similarly, the absence of dense creekline vegetation precludes the likelihood of observing species including the Blue-winged Kookaburra *Dacelo leachii*, and White-plumed honeyeater *Lichenostomus penicillatus* (Johnstone 1980). Additionally, a small number of waterfowl were recorded at an ephemeral pool during the intial survey phase, but many potentially occurring species were absent due to the lack of permanent water in the study area.

Notwithstanding the significance of the low habitat diversity in the current study area, other factors have undoubtedly contributed to the absence of other species that may be expected to occur in the area. Taxa such as the Emu *Dromaius novahollandiae* and birds of prey

(Accipitridae, Falconidae) have large ranges and may only occur periodically in any given area. Still other species such as Tree creepers (Climacteridae) and Sitellas (Neosittidae) are not always commonly recorded. Finally, species characterised by nocturnal activity patterns were unlikely to be documented due to the prohibition placed on night-time work on the mine site.

5.3 Mammals

5.3.1 Non-volant Mammals

The total of thirteen non-volant mammals documented during the Marandoo Mine Phase 2 survey compares favourably with the twelve species recorded by Johnstone (1980) in the Hamersley Range National Park study, sixteen species documented by Ninox (1992) at Marandoo and also with the fifteen species of Kendrick's 1995 road corridor survey. This relative uniformity in species assemblages across these studies probably reflects both the distribution of sampling phases across multiple seasons and the relative lack of habitat specificity in many of the small mammals found in the Pilbara Bioregion. Differences between the assemblages in contrast, can largely be attributed to either the generally low abundances and distributional plasticity of many species over time combined with the small size of the study area, as well as habitat specificity in the small number of species where this is a factor.

Species that are considered to be common and non-specialists, including the Pilbara Ningaui *Ningaui timealyi*, the Stripe-faced dunnart *Sminthopsis macroura*, the house mouse *Mus musculus* and the Sandy inland mouse *Pseudomys hermansbergensis* were typically recorded during all four studies. However, even species considered to be specialised in their habitat preferences such as the Pebble-mound mouse *Pseudomys chapmani* and the Common rock rat *Zyzomys argurus*, which favour stony surfaces and rocky gorges respectively, were documented in all studies due to their relative abundance in their preferred habitat and the prevalence of those habitats in the study areas.

Typically, where species were not recorded by one or more surveys, their absence can be attributed to a lack of suitable habitat or their relatively sparse distribution where habitat is available. The Spinifex hopping-mouse *Notomys alexis* for example favours hummock grasslands on sandy substrates, which did not occur in the Marandoo Mine Phase 2 study area. Alternatively, Planigale species would be expected to occur on the scree slopes and loamy flats in the Marandoo Mine area but were not recorded, whilst this survey was the only study to record the Northern Quoll *Dasyurus hallucatus* (see Table 4.4). In both cases, this can be attributed to the relative scarcity of these species across their preferred habitats at specific times.

5.3.2 Bats

The total of seven bat species documented during the Marandoo Mine Phase 2 survey compares favourably with the inventories reported elsewhere. Johnstone (1980) recorded twelve species across the extent of the Hamersley Range National Park using varied techniques including mist-netting, shooting and collection by hand from roost sites. Hence the greater total recorded by Johnstone (1980) probably relates to the size of the study area, greater variety of techniques utilised and the length of time over which data was collected.

The survey efforts by Ninox (1992) and Kendrick (1995) documented four and three bat species respectively, these totals probably reflect the direct sampling techniques (Harp or other trapping) used by these surveys and the absence of echolocation call recording. In comparison, these techniques yielded three of the seven species recorded during the Marandoo Mine Phase 2 survey whilst echolocation call recording yielded six species.

Of the bat species recorded, only one is currently considered to be of elevated conservation significance. The Ghost Bat *Macroderma gigas* is listed as a Priority 4 species under State Legislation (see Section 5.6.2). Significantly, the rocky gorge at which this species was recorded

(MARE03) contained no deep caves that might represent permanent roost sites and it seems more likely that the gorge contains only temporary roosts.

5.4 Herpetofauna

The inventory list compiled for the herpetofauna during the phases of the Marandoo Mine Phase 2 survey, as with the mammal inventory, compares well with the species records from previous studies in the vicinity. Whilst the 53 herpetofauna species documented by the study of the Phase 2 area falls considerably short of the 92 documented by Johnstone (1980), it should be noted that the latter report drew on collections not limited to their own survey, but encompassing contemporary work by several other parties. Johnstone (1980) is therefore more indicative of the species that may be expected to occur in the habitats available throughout Hamersley Range National Park. In contrast, both remaining studies used here for comparative purposes (Ninox 1992; Kendrick 1995) each recorded 52 herpetofauna species, despite being conducted over larger, more diverse study areas.

For the greater part, the minor differences between the assemblages recorded by the Marandoo Mine Phase 2 survey, the study of the Marandoo Mine Area and adjacent corridor (Ninox 1992) and the road corridor to the north (Kendrick 1995) centres on species that, while not necessarily uncommon, may be not be abundant at a given time, as is the case for many of the monitors (Varanidae), blind snakes (Typhlopidae) and front-fanged snakes (Elapidae). Significantly, this pattern recurs even in comparisons with the more substantial species inventory provided for the Hamersley range national Park (Johnstone 1980), in which the majority of the species not recorded by us are represented by only single specimens. These include taxa from all Families recorded at Marandoo and is once again indicative of the influence of the small size and relatively low habitat diversity found in the Marandoo Mine Phase 2 Study area.

5.5 Short Range Endemic (SRE) Taxa

Three groups of invertebrate fauna potentially harbouring short-range endemics were recorded during the surveys at Marandoo: terrestrial snails (Pulmonata), pseudoscorpions (Pseudoscorpionida) and scorpions (Scorpionida). None of the earlier studies being utilised here for comparison included such studies however, and there is therefore only a limited quantity of contextual data currently available for this portion of the work. Individual groups are discussed below.

Terrestrial Snails
All snails were collected from one site and represent a single genus, *Bothriembryon*. Members of this genus have been collected from a number of sites in the vicinity of Marandoo, and molecular studies have shown that the type found at Marandoo includes representatives of a single species occurring throughout the Pilbara bioregion (Roy Teale, pers. comm.). A wider scale programme addressing potential SRE land snail taxa is also currently underway. This includes DNA analysis of specimens from the Marandoo Mine Phase 2 project area and the wider locality.

Pseudoscorpions
Pseudoscorpions collected during the survey have been identified as a single species of *Synsphyronus* (Dr Mark Harvey, WA Museum) and were found both within the project footprint area as well as in similar habitat outside this area (but still within the mining lease) (Section 4.6). *Corymbia* species are widespread throughout the Pilbara Bioregion, and the association of this pseudoscorpion species with this vegetation indicates that it is likely to be similarly widespread in the bioregion.

Scorpions
Scorpion identifications are yet to be finalised, but all specimens appear to represent one species from the genus *Lychas* (Erich Volschenk, WA Museum, pers. comm.). Similar to the other

invertebrates, the scorpion taxon was recorded from both within and outside the tail pit clearance area (but still within the mining lease) and occupied habitat types that extend across the Pilbara Bioregion (Section 4.6).

5.6 Fauna of Conservation Significance

5.6.1 Threatened Fauna Statutory Framework

Native fauna species that are rare, threatened with extinction, or have high conservation value are specially protected by law under the *Western Australian Wildlife Conservation Act 1950-1979*. In addition, many of these species are listed under the Federal *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act 1999*).

5.6.1.1 EPBC Act 1999

Fauna species of national conservation significance are listed under the *EPBC Act 1999*, and may be classified as 'critically endangered', 'endangered', 'vulnerable' or 'conservation dependent' (consistent with IUCN categories: http://www.iucn.org/themes/ssc/redlist2006/categories.htm).

Migratory wader species are also protected under the *EPBC Act 1999*. The national List of Migratory Species consists of those species listed under the following International Conventions:

- Japan-Australia Migratory Bird Agreement (JAMBA);
- China-Australia Migratory Bird Agreement (CAMBA); and
- Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention).

5.6.1.2 Wildlife Conservation Act 1950-1979

Classification of rare and endangered fauna under the Wildlife Conservation (Specially Protected Fauna) Notice 2006 recognises four distinct schedules of taxa:

1. Schedule 1 taxa are fauna which are rare or likely to become extinct and are declared to be fauna in need of special protection;
2. Schedule 2 taxa are fauna which are presumed to be extinct and are declared to be fauna in need of special protection;
3. Schedule 3 taxa are birds which are subject to an agreement between the governments of Australia and Japan relating to the protection of migratory birds and birds in danger of extinction, which are declared to be fauna in need of special protection; and
4. Schedule 4 taxa are fauna that are in need of special protection, otherwise than for the reasons mentioned in paragraphs (1), (2) and (3).

In addition to the above, fauna are also classified under five different Priority codes:

Priority One	Taxa with few, poorly known populations on threatened lands. Taxa which are known from a few specimens or sight records from one or a few localities on lands not managed for conservation. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna
Priority Two	Taxa with few, poorly known populations on conservation lands, or taxa with several, poorly known populations not on conservation lands. Taxa which are known from few specimens or sight records from one or a few localities on lands not under immediate threat of habitat destruction or degradation. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.
Priority Three	Taxa with several, poorly known populations, some on conservation lands. Taxa which are known from few specimens or sight records from several localities, some of which are on lands not under immediate threat of habitat destruction or degradation. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.

Priority Four	Taxa in need of monitoring. Taxa which are considered to have been adequately surveyed or for which sufficient knowledge is available and which are considered not currently threatened or in need of special protection, but could be if present circumstances change. These taxa are usually represented on conservation lands. Taxa which are declining significantly but are not yet threatened.
Priority Five	Taxa in need of monitoring. Taxa which are not considered threatened but are subject to a specific conservation program, the cessation of which would result in the species becoming threatened within five years.

5.6.2 Threatened Fauna Species from the Marandoo Mine Phase 2 Project Area

Four species of elevated conservation significance were recorded during the Marandoo Mine Phase 2 survey. The Northern Quoll *Dasyurus hallucatus* is listed under State legislation as Schedule 1 (Fauna that is rare or likely to become extinct) and under Federal legislation as "Endangered". The Western Pebble-mound Mouse and the Ghost Bat are listed as Priority 4 under State legislation and the Rainbow Bee-eater is listed us Migratory under the *EPBC Act 1999*.

No other fauna of elevated conservation significance were recorded during the Marandoo Mine Phase 2 survey, including any of those recorded in the original survey in 1991 by Ninox (Table 5.1). However, a further eleven of the species listed in Table 5.1 may occur in the project area.

All species of elevated conservation significance and of relevance to the development of the Marandoo Mine Phase 2 study area are discussed individually in the following sections.

Table 5.1: Fauna of conservation significance recorded during the Biota (2007) surveys at, or with the potential to occur in the Marandoo Mine Phase 2 Area.

Fauna Species	Category	
	State level	Federal level
Night Parrot *Pezoporus occidentalis*	Schedule 1	Endangered
Northern Quoll *Dasyurus hallucatus#**	Schedule 1	Endangered
Orange Leafnosed-bat *Rhinonicteris aurantius*	Schedule 1	Vulnerable
Bilby *Macrotis lagotis*	Schedule 1	Vulnerable
Pilbara Olive Python *Liasis olivaceus barroni**	Schedule 1	Vulnerable
Peregrine Falcon *Falco peregrinus**	Schedule 4	
Little North-western Mastiff Bat *Mormopterus loriae cobourgiana**	Priority 1	
Spectacled Hare-wallaby (mainland) *Lagorchestes conspicillatus leichardti*	Priority 3	
Western Pebble-mound Mouse *Pseudomys chapmani#**	Priority 4	
Ghost bat *Macroderma gigas#**	Priority 4	
Short-tailed Mouse *Leggadina lakedownensis*	Priority 4	
Australian Bustard *Ardeotis australis**	Priority 4	
Bush Stone-curlew *Burhinus grallarius**	Priority 4	
Star Finch (western) *Neochmia ruficauda subclarescens*	Priority 4	
Fork-tailed Swift *Apus pacificus**		Migratory
Rainbow Bee-eater *Merops ornatus#**		Migratory

\# recorded by Biota in 2007.
* recorded by Ninox in 1991.

5.6.2.1 Night Parrot Pezoporus occidentalis

State: Schedule 1 'Critically Endangered'
Federal: Endangered
Distribution: Night Parrots have been reported from every state on the Australia mainland. Apparently suitable habitat occurs, or has occurred, across most of the inland, covering at least

half of the continent. Records are sparsely distributed through this area, however there do appear to be concentrations of records in western Queensland and the eastern Pilbara (Higgins 1999). There is an unconfirmed record from Moojarri Well north of the Fortescue Marsh (approx. 180 km east-northeast of Marandoo) and one from near Yandicoogina on the edge of the Marshes (Mr Roy Teale, Biota, pers. obs.).

Ecology: This species is listed as Endangered under the *EPBC Act 1999* and as Schedule 1 under the Wildlife Conservation Notice 2006. Night Parrots inhabit areas where there is dense, low vegetation, which provides them shelter during the day. Most records come from hummock grasslands with spinifex (porcupine grass, *Triodia*), from areas dominated by samphire or, particularly, where these two habitats are juxtaposed. It has been suggested that birds move into the grasslands when Triodia is seeding. They have also been reported in low chenopod shrublands with saltbush and bluebush, and from areas of Mitchell grass (*Astrebla*) with scattered chenopods.

Many records have come from waterholes, and almost all reports from areas of *Triodia* have noted the presence of nearby water. The species is secretive and almost all confirmed sightings of feeding or drinking birds have come after dark. Sightings during the day have almost always been of birds flushed from hiding places by herds of stock, dogs or fire. Birds typically sit very tight, flushing only if the disturbance is very close, actually affecting the clump of vegetation in which they are hiding. Early observers stressed the dependence of the parrot upon dense spinifex or samphire for daytime roosting spots and for nesting.

The Night Parrot is presumably like other arid zone birds in being markedly nomadic. The extent of the movements and the possibility of some seasonality in any part of the range are unknown. Several possible reasons have been proposed for the decline of this species in recent years, including (1) habitat loss through clearing, (2) changes in habitat from burning practices, (3) changes in habitat caused by or competition from stock grazing or rabbits, (4) reduced availability of water holes or surrounding suitable food plants and (5) predation from feral animals, particularly cats and foxes (cats were mentioned as a major problem by several early observers). The relative importance of each of these factors is unclear.

Likelihood of occurrence: Not recorded and unlikely this species would occur within the study area due to a lack of suitable habitat.

Potential Impacts: As a Schedule 1 and federally listed species the Night Parrot is considered fauna in need of special protection. However, the proposed development is not considered likely to have a significant impact upon this species.

5.6.2.2 Northern Quoll *Dasyurus hallucatus*

State: Schedule 1 'Endangered'
Federal: Endangered
Distribution: The Northern Quoll was originally recorded across Northern Australia from the Northwest Cape, Western Australia to south-east Queensland but has declined in recent years. Its distribution is now restricted to six main areas: the north and western top end of the Northern Territory, north of Cape York, the Atherton-Cairns area, the Carnarvon Range-Bowen area of Queensland (Menkhorst and Knight 2001), and the northwest Kimberley and Pilbara regions of Western Australia (Braithwaite and Griffiths 1994). It also occurs on numerous islands off the Australian coast (Abbott and Burbidge 1995, Burbidge and McKenzie 1978).

Ecology: The Northern Quoll, *Dasyurus hallucatus*, is classed as a medium-sized marsupial, with adult weight ranging from 300 g up to 1,200 g. It is considered a partially arboreal and aggressive carnivore, preying on a varied diet of small invertebrates and vertebrates, including lizards, birds, snakes, small mammals and frogs (Oakwood 1997).

The Northern Quoll is a short-lived mammal with both sexes maturing at 11 months. Females reproduce only once each year, and all males die shortly after reproducing (Dickman and

Braithwaite 1992, Oakwood 2000). The discrete male cohorts that arise within populations make quolls vulnerable to extinction. If no juvenile male quolls survive to adulthood, there will be no males for females to mate with the following year, and the local population will rapidly go extinct (Braithwaite and Griffiths 1994, Oakwood 2000). Therefore, any factor that results in significant increases in mortality rates of female and juvenile quolls could cause local extinction of quoll populations.

Likelihood of occurrence: The Northern Quoll was recorded at site MARE02 (Table 4.4 and Figure 3.2). This species was also recorded by Ninox in 1991 (Ninox 1992). However, typical habitat, comprising rocky gullies and breakaways, for the Northern Quoll is extremely limited in the disturbance area

Potential Impacts: Under the EPBC Act 1999, an action requires referral to the Federal Environment Minister if it is deemed likely to have a significant impact on a matter of national environmental significance (eg. a listed threatened species such as the Northern Quoll *Dasyurus hallucatus*). Given the apparently broad distribution of the Northern Quoll in the Pilbara bioregion, it is considered that the action will not result in a significant impact. The single record of this species was Federally referred in July 2007 and ruled not to be a controlled action by DEWHA.

5.6.2.3 Orange Leaf-nosed Bat *Rhinonicteris aurantius*

State: Schedule 1 'Vulnerable'
Federal: Vulnerable
Distribution: The Orange Leaf-nosed Bat is a relictual monotypic genus of the Hipposideridae found in the Pilbara region of Western Australia, through the Kimberley and across the Top End into north-western Queensland (Churchill 1991). This species is an Australian endemic.

Populations found in the Pilbara bioregion of Western Australia are considered to be isolated from northern populations by nearly 400 km of the Great Sandy Desert.

Ecology: This species is often found in monsoon rainforest, tall open forest, open savanna woodland, black soil grassland and spinifex-covered hills (Churchill 1998). They are more influenced by the availability of suitable roost caves than habitat types (Churchill 1998). High humidity is particularly important to this species (Armstrong 2001, Churchill 1998). In the Pilbara, they are thought to be restricted to caves where at least semi-permanent water is nearby (Dr Kyle Armstrong, Kyoto University Museum, pers. comm. 2005).

Likelihood of occurrence: No suitable roost sites were located for this species during the Biota surveys of the Marandoo Mine Phase 2 area and no individuals were recorded. However, It is possible that individuals may occur within the project area periodically.

Potential Impacts: As a Schedule 1 and federally listed species the Orange Leaf-nosed Bat is considered fauna in need of special protection. However, the proposed development is not considered likely to have a significant impact upon this species.

5.6.2.4 Bilby *Macrotis lagotis*

State: Schedule 1 'Vulnerable'
Federal: Vulnerable
Distribution: The former range of the Bilby included most of the semi-arid areas of mainland Australia, however, it is now confined to *Triodia* hummock grassland and Acacia scrub across parts of northern Australia. It has been reintroduced to parts of the south-west of Western Australia (eg. Dryandra Woodlands).

Ecology: The Bilby *Macrotis lagotis* is a medium sized ground mammal, ranging in weight from 1.0-2.5 kg. The species is apparently strictly nocturnal and constructs a substantial burrow system, which may be up to 3 m in length (Flannery 1990; Strahan 1995). Similar to the Mulgara, the species has been documented as holding temporary home ranges and showing relatively rapid changes in distribution in response to variation in habitat resources (Johnson 1995).

Likelihood of occurrence: The species was not recorded during the Marandoo Mine Phase 2 surveys and is considered unlikely to occur within the study area due to a lack of suitable habitat.

Potential Impacts: As a Schedule 1 and Federally listed species the Bilby is considered fauna in need of special protection. However, the proposed development is not considered likely to have a significant impact upon this species.

5.6.2.5 Pilbara Olive Python *Liasis olivaceous barroni*

State: Schedule 1 'Vulnerable'
Federal: Vulnerable
Distribution: Regarded as a Pilbara endemic, this subspecies has a known distribution that coincides roughly with the Pilbara bioregion (Environment Australia 2000).

Ecology: Occurs in rocky areas within the Pilbara, showing a preference for rocky habitats near water, particularly rock pools. May shelter in deep rock crevices, with a diet that includes birds, reptiles, and mammals as large as rock wallabies (Wilson and Knowles 1988). Breeding occurs in June and July, with eggs hatching in mid-January.

Likelihood of Occurrence: No core habitat was encountered for the Pilbara Olive Python within the proposed disturbance area during the Biota survey in 2007, although the report by Ninox in 1992 indicates that the species can occur in the area.

Potential Impacts: As a Schedule 1 and federally listed species the Pilbara Olive Python is considered fauna in need of special protection. However, the proposed development is not considered likely to have a significant impact upon this species.

5.6.2.6 Peregrine Falcon *Falco peregrinus*

State: Schedule 4
Distribution: The Peregrine Falcon has an almost cosmopolitan distribution, but is absent from most deserts and the Nullarbor Plain (Johnstone and Storr 1998). The only subspecies in Australia, *F. p. macropus*, is widespread throughout Australia and Tasmania (Marchant and Higgins 1993). The Australian population has been estimated at 3,000 to 5,000 pairs (Cade 1982). Whilst its status is difficult to determine in the Pilbara, it is certainly more common than its Priority 4 listed cogener *Falco hypoleucos*.

Ecology: This species inhabits a wide range of habitats including forest, woodlands, wetlands and open country (Pizzey and Knight 1997). The availability of prey is apparently more important than habitat in determining its distribution. Home ranges are probably defended year round and are variable in size, though typically not less than 480 ha (Marchant and Higgins 1993).

This species typically nests on cliffs (81% of nests Australia-wide) but also on stick nests (11%) and in tree hollows (8%). Breeding typically occurs from August to November (Johnstone and Storr 1998). Food is almost exclusively birds such as pigeons, parrots and passerines, which are captured in flight (Johnstone and Storr 1998). Mammals such as possums and rabbits have been recorded as rare prey items (Marchant and Higgins 1993).

Likelihood of Occurrence: The report by Ninox in 1992 indicates that the species can occur within the study area.

Potential Impacts: Loss of potential nesting and foraging habitat. With its cosmopolitan distribution, the conservation status of this species is unlikely to be affected by the proposal. The reason for initially listing this species was a global decline associated with the use of DDT.

5.6.2.7 Little North-western Mastiff Bat *Mormopterus loriae cobourgiana*

State: Priority 1
Distribution: Endemic to Australia, this sub-species' distribution encompasses the Western Australian coastal areas from Derby to the Exmouth Gulf (Churchill 1998).

Ecology: The sub-species is a mangrove specialist, being restricted to mangrove forest and adjacent areas. (Churchill 1998) and has been found roosting in small sports and crevices in dead upper branches of the mangrove *Avicennia marina*. Individuals emerge early in the evening in groups of up to 100 individuals above the mangrove canopy, before dispersing to forage alone or in pairs. *M. loriae cobourgiana* prey on insects above and beside the forest canopy. They give birth to single young, which are born in the wet season (summer) (Churchill 1998).

Likelihood of occurrence: It is highly unlikely this species will occur within the study area due to lack of suitable habitat and it is considered that the records from Ninox in 1991 (Ninox 1992), represent a mis-identification.

Potential Impacts: The conservation status of this species is unlikely to be affected by the proposal.

5.6.2.8 Spectacled Hare-wallaby (mainland) *Lagorchestes conspicillatus leichardti*

State: Priority 3
Distribution: Occurs in the Pilbara and remains widespread and locally common through a broad swathe of the Northern Territory and northern Queensland. This species has declined drastically in the Great Sandy Desert (Menkhorst and Knight 2001). There are scattered records of this species from the Kimberley and Pilbara regions of Western Australia.

The distribution of the Spectacled Hare Wallaby is shown as an arc across much of northern Australia (Strahan 2004), with a sub-species (*L. c. conspicillatus*) also occurring on Barrow Island. The Western Australian populations appear to have declined drastically (Dr Dave Pearson, DEC, pers comm. 2006) and this species is now considered extinct in the Great Sandy and Gibson Deserts (Strahan 2004). Whilst the Barrow Island subspecies is listed as Vulnerable under the *EPBC Act 1999*, the WA mainland population is considered to be only Priority 3 despite localised extinctions and apparent substantial decline.

Ecology: Inhabits tussock or hummock grassland with mid-dense or sparse tree and shrub cover. Apparently prefers large spinifex (*Triodia*) clumps in which to shelter during the day, and the species' decline has been attributed to the absence of these hummocks, possibly as a result of increased frequency in burning and extensive grazing by cattle.

Likelihood of occurrence: It is unlikely this species would occur within the study area due to a lack of suitable habitat, which typically comprises very large *Triodia* spp. on sand plains.

Potential Impacts: Given the lack of suitable habitat and the small probability of the species occurring in the study area, the conservation status of this species is unlikely to be affected by the proposal.

5.6.2.9 Western Pebble-mound Mouse *Pseudomys chapmani*

State: Priority 4
Distribution: Confined to the central and eastern Pilbara including Karijini National Park (Menkhorst and Knight 2001). This species is found on stony hillsides with hummock grasslands. (Menkhorst and Knight 2001). This species is common to very common in suitable habitat within the Hamersley and Chichester subregions of the Pilbara bioregion. Records from areas where it is considered locally extinct (e.g. the Burrup Peninsula) are of interest.

Ecology: Found on stony hillsides with hummock grassland. Well known for its behaviour of constructing extensive mounds of small stones covering areas from 0.5 to 9.0 m^2 (Strahan 2004). This mound formation is most common on spurs and gentle slopes with suitable size class stones.

The mouse's home range is up to 14 ha for males (reproductively active) and 5 ha for females (Anstee 1994).

Likelihood of Occurrence: This species was recorded within the study area by Ninox in 1991 (Ninox 1992) and by Biota in 2007 at MAR06 (Table 4.4 and Figure 3.2).

Potential Impacts: Impacts would include loss of habitat and deaths of individuals, but are unlikely to make an impact on the conservation status of this species.

5.6.2.10 Ghost Bat *Macroderma gigas*

State: Priority 4
Distribution: Previously distributed across most of inland and northern Australia, but now restricted to the tropical north of the continent (Churchill 1998). Occurs in a broad range of habitats, with their distribution being influenced by the availability of suitable caves and mines for roost sites (Churchill 1998). The distribution of Ghost Bats is fragmented, with each population showing some genetic differentiation (Armstrong and Wilmer 2004; Biota 2004; and Dr. Kyle Armstrong, pers. comm. 2004). Populations in the Pilbara bioregion appear to be isolated from those in the Kimberley and Northern Territory.

Ecology: Ghost Bats are efficient predators of small birds, mammals and reptiles, and large insects, and they have highly developed echolocation, visual and hearing systems (Churchill 1998). Vocalisations audible to humans are used in their complex social interactions (Churchill 1998). Bats forage over large distances (ranges of ~ 60 ha; Churchill 1998), and the size of their foraging area is probably inversely related to the productivity of their landscape. Bats are known to have overlapping ranges (Churchill 1998).

Scat material from *M. gigas* is quite distinctive and can be used to identify temporary roosts or feeding sites. Fairy Martin (*Hirundo ariel*) nests within culverts provide a roosting substrate for *M. gigas* and culverts may function either as a night or feeding roost or (probably less commonly) as a temporary day roost. This is an example of where man-made habitat has benefited bats (Biota 2002).

Likelihood of Occurrence: This species has been recorded previously within the study area (Ninox 1992) and was recorded at MARE03 during the seasonal phase of the Marandoo Mine Phase 2 survey.

Potential Impacts: Possible loss or disturbance of roosting sites and foraging habitat. No effect on the conservation status of the species is expected.

5.6.2.11 Short-tailed Mouse *Leggadina lakedownensis*

State: Priority 4
Distribution: Since 1997, the number of records of this species has increased substantially, such that it has now been recorded from over 20 locations (Armstrong et al. in prep). In Western Australia the distribution includes the Pilbara and Kimberley regions (Menkhorst and Knight 2001). We have recorded this species on cracking clay communities from Cape Preston (60 km west of Dampier) in the west to the northern flanks of the Fortescue Marshes in the east (Halpern Glick Maunsell and Biota 2000).

A recent taxonomic revision of *Leggadina* (Cooper et al. 2003) found that despite morphological variation, *L. lakedownensis* are genetically similar across their range and the variation is insufficient to warrant subspecific status for any regional populations

Ecology: Regional records suggest that the primary mainland habitat comprises areas of cracking clay and adjacent habitats, although this species has also been recorded from hill tops (Dr Peter Kendrick, DEC Karratha, pers. comm. 2003) and sandy coastal areas near Onslow (Mr Garth Humphreys, Biota, pers. obs.). At Cape Preston this species was recorded from *Acacia xiphophylla* open shrubland over a mosaic of *Triodia wiseana* and *Eragrostis xerophila* mixed hummock and

tussock grassland (Halpern Glick Maunsell and Biota 2000). At the Southern Plains study site (near Tom Price), numerous individuals were recorded from *Acacia xiphophylla* shrubland over *Triodia longiceps* and annual grasses (Biota 2002b). Along the proposed Hope Downs rail alignment, this species was recorded from *Astrebla pectinata* tussock grassland (Biota 2002). During the FMG Stage A rail corridor survey (Biota 2004), this species was recorded from *Astrebla pectinata, Aristida latifolia* tussock grassland on the self-mulching clays at a similar location in the Chichester Range.

Likelihood of occurrence: Not recorded to date and considered unlikely to occur within the study area due to a lack of suitable habitat.

Potential Impacts: The conservation status of this species is unlikely to be affected by the proposal.

5.6.2.12 Australian Bustard *Ardeotis australis*

State: Priority 4
Distribution: The Australian Bustard occurs over much of Western Australia, with the exception of the more heavily wooded southern portions of the state (Johnstone and Storr 1998). Its wider distribution includes eastern Australia and New Guinea. This species is classified as Near Threatened by Garnett and Crowley (2000).

Ecology: This species prefers open or lightly wooded grassland including *Triodia* sandplains (Johnstone and Storr 1998) and is considered scarce to common depending on season and habitat. It has an omnivorous diet and occurs in a relatively broad range of habitats, but appears to have some preference for grasshoppers and is often attracted to recently burnt areas (Marchant and Higgins 1993). This species is typically nomadic and has a large home range (Marchant and Higgins 1993). This species breeds from March to September and the eggs are laid on bare, preferably stony, ground (Johnstone and Storr 1998), which makes the eggs and young vulnerable to predation by foxes and cats.

Likelihood of Occurrence: This species has been recorded within the study area (Ninox 1992).

Potential Impacts: Impacts would include loss of habitat and deaths of individuals, but are unlikely to make an impact on the conservation status of this species.

5.6.2.13 Bush Stone-curlew *Burhinus grallarius*

State: Priority 4
Distribution: This species is widespread in Australia and southern New Guinea. It remains common in tropical Australia, but has declined alarmingly in temperate Australia and has disappeared from many regions (Marchant and Higgins 1993). It is found in the Kimberley and western portion of the remainder of the state west of a line joining Port Hedland, Leonora and Albany. Populations are apparently secure in the Pilbara (Ron Johnstone, WA Museum, pers. comm. 2003). The Australian population has been estimated at c. 15,000 individuals.

Ecology: The nocturnal Bush Stone-curlews inhabit sparsely grassed, lightly timbered forest or woodland. In southern Australia, they persist most often where there is a well-structured litter layer and fallen timber debris. Individuals have an estimated home range of about 250 ha (Johnson and Baker-Gabb 1993). Foxes are usually considered to be the primary cause for their decline, hence their relative abundance in the tropics, but habitat clearance has also been identified as a threatening process (Garnett and Crowley 2000).

Likelihood of Occurrence: This species has been recorded within the study area (Ninox 1992).

Potential Impacts: Impacts would include loss of habitat and deaths of individuals, but are unlikely to make an impact on the conservation status of this species.

5.6.2.14 Star Finch (western) *Neochmia ruficauda subclarescens*

State: Priority 4
Distribution: This species is endemic to Australia where it is found from the Pilbara to south-eastern Australia. It remains most common in the tropics. Its population has not been estimated but the species is typically patchy and highly variable in abundance.

Ecology: This species is typically confined to reedbeds and adjacent vegetation communities along permanent waterways in the Pilbara. It is considered to be resident in most of its range but, as with all finches, the species can wander widely. Its ecology in the Pilbara is not well known but it has been observed feeding on the seed of sedges (*Cyperus* spp.) and Buffel Grass (*Cenchrus ciliaris*) (Dr Mike Craig, pers. obs.). In other parts of its range it feeds mainly on seeds, but insects are a common part of the diet during the breeding season. It typically nests in March and April, as seeds are maturing after summer cyclones, and its domed nest is usually built in reeds up to several metres from the ground. The clutch is between three and six and the young usually fledge after about 16 days. In captivity, Star Finches may produce as many as three broods per year. The main threat to the species is considered to be overgrazing by stock along waterways, which destroys the riparian vegetation on which they depend (Garnett and Crowley 2000).

Likelihood of occurrence: The species has not been recorded at Marandoo thus far and is highly unlikely to occur within the study area due to lack of suitable habitat.

Potential Impacts: There is unlikely to be an impact on the conservation status or distribution of this species.

5.6.2.15 Migratory Avifauna

Six species of avifauna are listed as Migratory in the EPBC Act Protected Matters Report (Appendix 4) as possibly occurring within the Marandoo Mine Phase 2 study area. Of these the Rainbow Bee-eater was recorded by Biota in 2007 (see Table 4.3) and by Ninox in 1991 (Ninox 1992), and the Fork-tailed Swift was also recorded by Ninox in 1991 (Ninox 1992).

Four further species could occur, they are the White-bellied Sea-Eagle, Great Egret, Cattle Egret and Oriental Plover. Any of these species could utilise the study area seasonally but the proposed development is unlikely to have a significant impact on the conservation status of any of these species.

5.7 Conclusions

It appears unlikely that the proposed development of the Marandoo Mine Phase 2 area will have significant effects on the existing fauna habitats and fauna that will result in alterations to the conservation status of these elements on a local or regional scale.

The fauna habitats identified in the study area appear typical of the area surrounding the Marandoo Mine Site and are well represented across the Pilbara. Similarly, the fauna assemblages documented during the dual phases of the survey are comparable to those recorded during earlier work and seem typical of assemblages occurring where similar habitats are found elsewhere in the Pilbara. The differences between the species inventories compiled during this study and earlier studies (see Sections 5.1 to 5.4) are largely attributable to factors including differences in the size of the areas and diversity of the habitats surveyed, as well as normal variation in the relative numbers of fauna recorded during such work.

The invertebrate groups recorded are considered unlikely to harbour species likely to represent Short-range endemic taxa, primarily due to the extensive distributions of their preferred habitats outside the proposed disturbance area. Moreover, each of these groups was recorded not only from inside the disturbance footprint, but also from areas adjacent to it (see Section 5.5).

Only three fauna species of conservation significance, the Northern quoll *Dasyurus hallucatus*, the Western Pebble-mound Mouse *Pseudomys chapmani* and the Ghost bat *Macroderma gigas* were documented during the study period, although there are numerous others for which suitable habitat occurs within the Mine Phase 2 area. The size of the area however, and therefore the available habitat within it, is very limited and any adverse affects are likely to be restricted to individual animals. The conservation status of these species is therefore unlikely to be altered either at the local or regional level.

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6.0 References

Abbott, I. and Burbidge, A.A. 1995. The occurrence of mammal species on the islands of Australia: a summary of existing knowledge. CALM Science 1: 259-324.

Anstee, S. 1994. A study of the movement patterns and social structure of the pebblemound mouse, Pseudomys chapmani. Unpublished report, Zoology Department, The University of Western Australia.

Armstrong, K.N. 2001. The distribution and roost habitat of the orange leaf-nosed bat, *Rhinonicteris aurantius*, in the Pilbara region of Western Australia. Wildlife Research 28(1): 95 – 104.

Armstrong K.N. and W.J. Wilmer 2004. The importance of determining genetic population structure for the management of Ghost Bats, Macroderma gigas, in the Pilbara region of Western Australia. Oral presentation at the 11th Australasian Bat Society Conference, Toowoomba, Queensland, 12-14 April 2004.

Armstrong K.N., S.D. Anstee, P.A. Landman and R.J. Teale (in prep.). Gilgai soils as core habitat for the mainland Pilbara population of the rodent Leggadina lakedownensis [Watts, 1976] (Muridae).

Beard J.S. 1975. Vegetation Survey of Western Australia. 1:100,000 Vegetation Series Map Sheet 5 - Pilbara.

Biota Environmental Sciences. 2001. Southern Plains and Southern Detritals Fauna and Vegetation Monitoring 2001. Unpublished Consultants Report.

Biota Environmental Sciences. 2002. Local Population Assessment of Ghost Bats at Coondawanna Flats. Unpublished consultants report prepared for Hamersley Iron.

Biota Environmental Sciences 2002a. Proposed Hope Downs Rail Corridor from Weeli Wolli Siding to Port Hedland - Vertebrate Fauna survey. Unpublished report for Hope Downs Management Services.

Biota Environmental Sciences. 2004. Monitoring of Ghost Bat Roosts at West Angelas 2003. Unpublished consultants report prepared for Robe River Mining.

Biota Environmental Sciences 2004a. Vegetation and Flora Survey of the Proposed FMG Stage A Rail Corridor. Unpublished report for Fortescue Metals Group Ltd.

Braithwaite R.W. and Griffiths A. 1994. Demographic variation and range contraction in the Northern Quoll Dasyurus hallucatus (Marsupialia: Dasyuridae). Wildlife Research 21: 203-217.

Burbidge A.A. and McKenzie, N.L. eds. 1978. The Islands of the North-west Kimberley. Wildlife Research Bulletin of Western Australia. No 7.

Cade T.J. 1982. The Falcons of the World. Collins, London.

Christian C.S. and G.A. Stewart 1953. General report on Survey of Katherine-Darwin region 1946. CSIRO Australian Land Research Series 1. cited in Environmental Protection Authority (2002). Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection. Environmental Protection Authority, March 2002.

Churchill, S.K. 1991. Distribution, abundance and roost selection of the orange horseshoebat, Rhinonicteris aurantius, a tropical cave dweller. Wildlife Research 18: 343-353.

Churchill, S.K. 1998. Australian bats. Reed New Holland: Frenchs Forest, NSW.

Cooper N.K, M. Adams, C. Anthony and L.H. Schmitt 2003. Morphological and genetic variation in *Leggadina* [Thomas, 1910] with special reference to western Australian populations. Records of the Western Australian Museum 21: 333-351.

Dickman C.R. and Braithwaite 1992. Post-mating mortality of males in the Dasyurid Marsupials Dasyurus and Parantechinus. Journal of Mammalogy. 73(1): 143-147.

Environment Australia 2000. Revision of the Interim Biogeographic Regionalisation for Australia (IBRA) and Development of Version 5.1, Summary Report. Environment Australia, November 2000.

Flannery T. 1990. The Bilby *Macrotis lagotis*. In: Australia's Vanishing Mammals: Endangered and Extinct Native Species. WWF Press.

Garnett S.T. and G.M. Crowley 2000. The Action Plan for Australian Birds 2000. Environment Australia, Canberra.

Halpern Glick Maunsell and Biota Environmental Sciences 2000. Austeel Biological Survey, Cape Preston. Unpublished report prepared for Austeel, Perth.

Higgins, P.J. 1999. Handbook of Australian, New Zealand & Antarctic Birds Volume 4: Parrots to Dollarbird. Oxford University Press, South Melbourne.

Johnson 1995. The Bilby *Macrotis lagotis*. In: Strahan, R. (ed). 1995. The Mammals of Australia. Australian Museum / Reed Books.

Johnson and Baker-Gabb 1993. Bush Thick-knee in Northern Victoria (Part 1): Conservation and Management. Arthur Rylah Institute of Environmental Research Technical Report 129(A).

Johnstone, R.E. and G.M. Storr 1998. Handbook of Western Australian Birds: Volume 1 – Nonpasserines (Emu to Dollarbird). Western Australian Museum, Perth.

Kendrick, P. 1995. Vertebrate Fauna of the Marandoo to Great Northern Highway Road. Unpublished report for Main Roads Western Australia, Pilbara Region, the Shire of Ashburton from the Pilbara region and Department of Conservation and Land Management.

Marchant, S. and Higgins, P.J. 1993. Handbook of Australian, New Zealand & Antarctic Birds Volume 2: Raptors to Lapwings. Oxford University Press, South Melbourne.

Menkhorst P. and F. Knight 2001. A Field Guide to the Mammals of Australia. Oxford University Press.

Muir, B.G. 1980. A fauna survey of Hamersley Range National Park, Western Australia.

Oakwood M. 1997. The ecology of the northern quoll, Dasyurus hallucatus. PhD thesis, Australian National University.

Oakwood M. 2000. Reproduction and demography of the northern quoll, Dasyurus hallucatus, in the lowland savanna of northern Australia. Australian Journal of Zoology 48:519–539.

Ninox Wildlife Consulting. 1992. Marandoo Project Area: Vertebrate fauna assessments. Unpublished Consultants Report prepared for Enviroscan.

Payne P.L., A.A. Mitchell and W.F. Holman (1988). An inventory and condition survey of the rangelands in the Ashburton River catchment, Western Australia. Technical Bulletin No. 62. Western Australian Department of Agriculture.

Pilbara Iron. 2008a. Marandoo Mine Phase 2 Project, Draft Environmental Scoping Document. Prepared by Pilbara Iron, Perth.

Pizzey, G. and Knight, F. 1997. Field Guide to the Birds of Australia. Harper Collins, Sydney.

Strahan R. 1995. The Mammals of Australia. Reed Books, Chatswood.

Strahan R. 2004. The Mammals of Australia. Reed Books, Chatswood.

Thorne, A.M. and Trendall, A.F. 2001. Geology of the Fortescue Group, Pilbara Craton, Western Australia. Western Australia Geological Survey Bulletin 144.

van Vreeswyk, A.M.E., A.L. Payne, K.A. Leighton and P. Hennig 2004. An inventory and condition survey of the Pilbara region, Western Australia. Department of Agriculture Technical Bulletin No. 92, December 2004.

Wilson, S.K. and Knowles, D.G. 1988. Australia's Reptiles: A Photographic Reference to the Terrestrial Reptiles of Australia. Collins Angus & Robertson, Pymble.

Appendix 1

Licence to take Fauna for Scientific Purposes

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WILDLIFE CONSERVATION ACT 1950
REGULATION 17

LICENCE TO TAKE FAUNA FOR SCIENTIFIC PURPOSES

THE UNDERMENTIONED PERSON MAY TAKE FAUNA FOR RESEARCH OR OTHER SCIENTIFIC PURPOSES AND WHERE AUTHORISED, KEEP IT IN CAPTIVITY, SUBJECT TO THE FOLLOWING AND ATTACHED CONDITIONS, WHICH MAY BE ADDED TO, SUSPENDED OR OTHERWISE VARIED AS CONSIDERED FIT.

EXECUTIVE DIRECTOR

CONDITIONS

1. THE LICENSEE SHALL COMPLY WITH THE PROVISIONS OF THE WILDLIFE CONSERVATION ACT AND REGULATIONS AND ANY NOTICES IN FORCE UNDER THIS ACT AND REGULATIONS.
2. UNLESS SPECIFICALLY AUTHORISED IN THE CONDITIONS OF THIS LICENCE OR OTHERWISE IN WRITING BY THE EXECUTIVE DIRECTOR, SPECIES OF FAUNA DECLARED AS LIKELY TO BECOME EXTINCT, RARE OR OTHERWISE IN NEED OF SPECIAL PROTECTION SHALL NOT BE CAPTURED OR OTHERWISE TAKEN.
3. NO FAUNA SHALL BE TAKEN FROM ANY NATURE RESERVE, WILDLIFE SANCTUARY, NATIONAL PARK, MARINE PARK, TIMBER RESERVE OR STATE FOREST WITHOUT PRIOR WRITTEN APPROVAL OF THE EXECUTIVE DIRECTOR. NO FAUNA SHALL BE TAKEN FROM ANY OTHER PUBLIC LAND WITHOUT THE WRITTEN APPROVAL OF THE GOVERNMENT AUTHORITY MANAGING THAT LAND.
4. NO ENTRY OR COLLECTION OF FAUNA TO BE UNDERTAKEN ON ANY PRIVATE PROPERTY OR PASTORAL LEASE WITHOUT THE CONSENT IN WRITING OF THE OWNER OR OCCUPIER, OR FROM ANY ABORIGINAL RESERVE WITHOUT THE WRITTEN APPROVAL OF THE DEPARTMENT OF INDIGENOUS AFFAIRS.
5. NO FAUNA OR THEIR PROGENY SHALL BE RELEASED IN ANY AREA WHERE IT DOES NOT NATURALLY OCCUR, NOR HANDED OVER TO ANY OTHER PERSON OR AUTHORITY UNLESS APPROVED BY THE EXECUTIVE DIRECTOR, NOR SHALL THE REMAINS OF SUCH FAUNA BE DISPOSED OF IN SUCH MANNER AS TO CONFUSE THE NATURAL OR PRESENT DAY DISTRIBUTION OF THE SPECIES.
6. THIS LICENCE AND THE WRITTEN PERMISSION REFERRED TO AT CONDITIONS 3 & 4 MUST BE CARRIED BY THE LICENSEE OR AUTHORISED AGENT AT ALL TIMES FOR THE PURPOSE OF PROVING THEIR AUTHORITY TO TAKE FAUNA WHEN QUESTIONED AS TO THEIR RIGHT TO DO SO BY A WILDLIFE OFFICER, ANY OTHER STATE OR LOCAL GOVERNMENT EMPLOYEE OR ANY MEMBER OF THE PUBLIC.
7. **********ANY INTERACTION INVOLVING GAZETTED THREATENED FAUNA THAT MAY BE HARMFUL AND/OR INVASIVE MAY REQUIRE APPROVAL FROM THE COMMONWEALTH DEPARTMENT OF THE ENVIRONMENT AND HERITAGE, PHONE 02 6274 1900. INTERACTION WITH SUCH SPECIES IS CONTROLLED BY THE COMMONWEALTH GOVERNMENT'S "ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION ACT 1999" & "ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION REGULATIONS 2000" AS WELL AS CALM'S WILDLIFE CONSERVATION ACT & REGULATIONS.**********
8. NO BIOPROSPECTING INVOLVING THE REMOVAL OF SAMPLE AQUATIC AND TERRESTRIAL ORGANISMS (BOTH FLORA AND FAUNA) FOR CHEMICAL EXTRACTION AND BIOACTIVITY SCREENING IS PERMITTED TO BE CONDUCTED WITHOUT SPECIFIC WRITTEN APPROVAL BY THE EXECUTIVE DIRECTOR OF C.A.L.M.
9. FURTHER CONDITIONS (NUMBERED 1 TO 10) ARE ATTACHED.

SPECIES	ALL PROTECTED FAUNA (Fauna)
PURPOSE	INVENTORY SURVEY OF VERTEBRATES AND INVERTEBRATES FOR THE PROPOSED EXPANSION OF THE MARANDOO MINE (PILBARA IRON) FOR THE PURPOSES OF ENVIRONMENTAL IMPACT ASSESSMENT.

Appendix 2

DEC Threatened Fauna Database Search Results

Threatened and Priority Fauna Database Page 1 of 2

22.161 °S 117.669 °E / 23.102 °S 118.645 °E Marandoo Mine expansion study area

* Date	Certainty	Seen	Location Name	Method
Schedule 1 - Fauna that is rare or is likely to become extinct				
Dasyurus hallucatus			**Northern Quoll**	*1 records*
1990	1	1	Wittenoom Gorge	
Schedule 4 - Other specially protected fauna				
Falco peregrinus			**Peregrine Falcon**	*1 records*
This species is uncommon and prefers areas with rocky ledges, cliffs, watercourses, open woodland or margins with cleared land.				
2001	1	1	Tom Price	Day sighting
Priority Three: Taxa with several, poorly known populations, some on conservation lands				
Lagorchestes conspicillatus leichardti			**Spectacled Hare-wallaby (mainland)**	*1 records*
This species has declined in many parts of its range and is vulnerable to cat and fox predation. It inhabits tropical grasslands and also suffers from the impacts of frequent fires.				
1966	1	1	Mount Shiela	Caught or trapped
Priority Four: Taxa in need of monitoring				
Leggadina lakedownensis			**Lakeland Downs Mouse (Kerakenga)**	*1 records*
This secretive species is known to occur in the Pilbara and the Kimberley. Its populations rise and fall dramatically, probably in response to climatic fluctuations and availability of seeds.				
2001	1	2	Tom Price	Caught or trapped
Pseudomys chapmani			**Western Pebble-mound Mouse (Ngadji)**	*33 records*
This species is well-known for the characteristic pebble-mounds which it constructs over underground burrow systems. These mounds are most common on spurs and lower slopes of rocky hills.				
1980	1		Karijini NP	Caught or trapped
1980	1		Mt Bruce	Caught or trapped
1981	1		Karijini NP	Caught or trapped
1981	1	3	Karijini NP	Caught or trapped
1991	2	0	Karijini NP	
1991	1		Mt Windell	Caught or trapped
1991	1	1	Marandoo	
1992	1	4	Marandoo	Caught or trapped
1992	1		Mt Sheila	Caught or trapped
1992	1	5	Marandoo	
1992	1	1	Marandoo	
1992	1	5	Marandoo	
1993	1	3	Marandoo	
1993	1	8	Marandoo	
1993	1	1	Karijini NP	
1994	1		Karijini NP	
1994	1		Karijini NP	
1994	1		Karijini NP	

Friday, 2 November 2007

Department of Environment and Conservation

Threatened and Priority Fauna Database Page 1 of 2

22.161 °S 117.669 °E / 23.102 °S 118.645 °E Marandoo Mine expansion study area

*	Date	Certainty	Seen	Location Name	Method
	1994	1		Karijini NP	
	1994	1		Karijini NP	
	1994	1		Karijini NP	
	1994	1		Karijini NP	
	1994	1		Marandoo	
	1994	1		Mt Bruce	
	1994	1		Mt Hanwright	
	1994	1	35	Mt Bruce	Caught or trapped
	1995	1	0	Mt Brockman	Definite signs
	2001	1	1	Tom Price	Caught or trapped
	2001	1	2	Tom Price	Caught or trapped
	2001	1	1	Tom Price	Caught or trapped
	2001	1	1	Tom Price	Caught or trapped
	2001	1	1	Tom Price	Caught or trapped
	2001	1	1	Tom Price	Caught or trapped

Ardeotis australis **Australian Bustard** *2 records*

This species is uncommon and may occur in open or lightly wooded grasslands.

	2001	1	2	Tom Price	Day sighting
	2001	1	1	Tom Price	Day sighting

* Information relating to any records provided for listed species:-
Date: date of recorded observation
Certainty (of correct species identification): 1=Very certain; 2=Moderately certain; and 3=Not sure.
Seen: Number of individuals observed.
Location Name: Name of reserve or nearest locality where observation was made
Method: Method or type of observation

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Appendix 3

WAM FaunaBase Search Results

Birds collected between
-22.161, 117.669 and -23.102, 118.645

Acanthizidae
Acanthiza apicalis
Acanthiza robustirostris
Acanthiza uropygialis
Gerygone fusca
Gerygone fusca fusca
Gerygone fusca mungi
Pyrrholaemus brunneus
Smicrornis brevirostris

Accipitridae
Accipiter cirrocephalus cirrocephalus
Accipiter fasciatus fasciatus

Aegothelidae
Aegotheles cristatus
Aegotheles cristatus cristatus

Alaudidae
Mirafra javanica horsfieldii

Campephagidae
Coracina novaehollandiae
Coracina novaehollandiae novaehollandiae
Coracina novaehollandiae subpallida

Caprimulgidae
Eurostopodus argus

Climacteridae
Climacteris melanura wellsi

Columbidae
Geopelia cuneata
Geopelia striata
Geopelia striata placida
Geophaps plumifera
Phaps chalcoptera

Corvidae
Corvus orru

Cracticidae
Cracticus nigrogularis
Cracticus tibicen
Cracticus torquatus

Cuculidae
Chrysococcyx osculans

Dicaeidae
Dicaeum hirundinaceum

Dicruridae
Rhipidura fuliginosa alisteri
Rhipidura fuliginosa preissi
Rhipidura leucophrys

Falconidae
Falco berigora berigora
Falco longipennis longipennis

Halcyonidae
Dacelo leachii leachii
Todiramphus sanctus sanctus

Laridae
Sterna albifrons

Maluridae
Amytornis striatus striatus
Amytornis striatus whitei
Malurus lamberti
Malurus lamberti assimilis
Stipiturus ruficeps
Stipiturus ruficeps ruficeps

Meliphagidae
Acanthagenys rufogularis
Certhionyx niger
Lacustroica whitei
Lichenostomus keartlandi
Lichenostomus penicillatus
Lichenostomus virescens
Lichmera indistincta indistincta
Manorina flavigula
Phylidonyris albifrons

Motacillidae
Anthus australis australis

Neosittidae
Daphoenositta chrysoptera pileata

Pachycephalidae
Colluricincla harmonica
Colluricincla harmonica rufiventris
Pachycephala rufiventris rufiventris

Pardalotidae
Pardalotus rubricatus
Pardalotus striatus murchisoni

Passeridae
Neochmia ruficauda clarescens

Petroicidae
Petroica cucullata
Petroica goodenovii

Podargidae
Podargus strigoides

Pomatostomidae
Pomatostomus temporalis rubeculus

Psittacidae
Cacatua roseicapilla assimilis
Cacatua sanguinea westralensis
Neophema bourkii
Pezoporus occidentalis
Platycercus zonarius zonarius

Ptilonorhynchidae
Ptilonorhynchus maculatus guttatus

Rallidae
Porzana fluminea
Porzana tabuensis

Sylviidae
Eremiornis carteri

Turnicidae
Turnix velox

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Mammals collected between
-22.161, 117.669 and -23.102, 118.645

Dasyuridae
Dasykaluta rosamondae
Dasyurus hallucatus
Ningaui timealeyi
Planigale sp
Pseudantechinus roryi
Sminthopsis longicaudata
Sminthopsis macroura
Sminthopsis ooldea

Emballonuridae
Saccolaimus flaviventris
Taphozous georgianus
Taphozous hilli

Hipposideridae
Rhinonicteris aurantius

Macropodidae
Macropus robustus erubescens
Macropus rufus
Petrogale rothschildi

Molossidae
Chaerephon jobensis
Mormopterus beccarii
Tadarida australis

Muridae
Leggadina lakedownensis
Mus musculus
Notomys alexis
Pseudomys chapmani
Pseudomys desertor
Pseudomys hermannsburgensis
Zyzomys argurus

Phalangeridae
Trichosurus vulpecula arnhemensis

Pteropodidae
Pteropus scapulatus

Vespertilionidae
Chalinolobus gouldii
Nyctophilus geoffroyi
Scotorepens greyii
Vespadelus finlaysoni

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Amphibia collected between
-22.161, 117.669 and -23.102, 118.645

Hylidae
Cyclorana australis
Cyclorana maini
Cyclorana platycephala
Litoria rubella

Myobatrachidae
Limnodynastes spenceri
Pseudophryne douglasi
Uperoleia russelli

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Reptiles collected between
-22.161, 117.669 and -23.102, 118.645

Agamidae
Caimanops amphiboluroides
Ctenophorus caudicinctus
Ctenophorus caudicinctus caudicinctus
Ctenophorus isolepis isolepis
Ctenophorus nuchalis
Ctenophorus reticulatus
Diporiphora valens
Lophognathus longirostris
Pogona minor
Pogona minor minor

Boidae
Antaresia perthensis
Antaresia stimsoni stimsoni
Aspidites melanocephalus
Liasis olivaceus barroni

Cheluidae
Chelodina steindachneri

Elapidae
Acanthophis wellsi
Brachyurophis approximans
Demansia psammophis cupreiceps
Demansia rufescens
Furina ornata
Parasuta monachus
Pseudechis australis
Pseudonaja modesta
Pseudonaja nuchalis
Suta fasciata
Vermicella snelli

Gekkonidae
Crenadactylus ocellatus horni
Diplodactylus conspicillatus
Diplodactylus pulcher
Diplodactylus savagei
Diplodactylus stenodactylus
Diplodactylus wombeyi
Gehyra pilbara

Gehyra punctata
Gehyra variegata
Heteronotia binoei
Heteronotia spelea
Nephrurus wheeleri cinctus
Oedura marmorata
Rhynchoedura ornata
Strophurus elderi
Strophurus wellingtonae

Pygopodidae
Delma butleri
Delma elegans
Delma haroldi
Delma nasuta
Delma pax
Delma tincta
Lialis burtonis
Pygopus nigriceps

Scincidae
Carlia munda
Carlia triacantha
Cryptoblepharus carnabyi
Cryptoblepharus megastictus
Cryptoblepharus plagiocephalus
Ctenotus atlas
Ctenotus duricola
Ctenotus grandis titan
Ctenotus helenae
Ctenotus pantherinus ocellifer
Ctenotus robustus
Ctenotus rubicundus
Ctenotus rutilans
Ctenotus saxatilis
Ctenotus schomburgkii
Cyclodomorphus melanops melanops
Egernia formosa
Eremiascincus richardsonii
Lerista flammicauda
Lerista muelleri
Lerista zietzi
Menetia greyii
Menetia surda surda
Morethia ruficauda exquisita
Notoscincus ornatus ornatus
Proablepharus reginae
Tiliqua multifasciata

Typhlopidae
Ramphotyphlops ammodytes
Ramphotyphlops grypus
Ramphotyphlops hamatus
Ramphotyphlops waitii

Varanidae
Varanus acanthurus
Varanus brevicauda
Varanus caudolineatus
Varanus eremius
Varanus gouldii
Varanus panoptes rubidus
Varanus pilbarensis
Varanus tristis
Varanus tristis tristis

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Appendix 4

EPBC Act 1999 Protected Matters Report

Matters of National Environmental Significance		
Threatened Species	Status	Type of Presence
Birds		
Pezoporus occidentalis Night Parrot	Endangered	Species or species habitat likely to occur within area
Mammals		
Dasyurus hallucatus Northern Quoll	Endangered	Species or species habitat may occur within area
Macrotis lagotis Greater Bilby	Vulnerable	Species or species habitat may occur within area
Rhinonicteris aurantius (Pilbara form) Pilbara Leaf-nosed Bat	Vulnerable	Community likely to occur within area
Reptiles		
Liasis olivaceus barroni Olive Python (Pilbara subspecies)	Vulnerable	Species or species habitat may occur within area
Migratory Species	Status	Type of Presence
Migratory Terrestrial Species		
Birds		
Haliaeetus leucogaster White-bellied Sea-Eagle	Migratory	Species or species habitat likely to occur within area
Merops ornatus Rainbow Bee-eater	Migratory	Species or species habitat may occur within area
Pezoporus occidentalis Night Parrot	Migratory	Species or species habitat likely to occur within area
Migratory Wetland Species		
Birds		
Ardea alba Great Egret, White Egret	Migratory	Species or species habitat may occur within area
Ardea ibis Cattle Egret	Migratory	Species or species habitat may occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel	Migratory	Species or species habitat may occur within area
Migratory Marine Birds		
Apus pacificus Fork-tailed Swift	Migratory	Species or species habitat may occur within area
Ardea alba Great Egret, White Egret	Migratory	Species or species habitat may occur within area
Ardea ibis Cattle Egret	Migratory	Species or species habitat may occur within area
Other Matters Protected by the EPBC Act		
Listed Marine Species	Status	Type of Presence
Birds		
Apus pacificus Fork-tailed Swift	Listed - overfly marine area	Species or species habitat may occur within area
Ardea alba Great Egret, White Egret	Listed - overfly marine area	Species or species habitat may occur within area
Ardea ibis Cattle Egret	Listed - overfly marine area	Species or species habitat may occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel	Listed - overfly marine area	Species or species habitat may occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle	Listed	Species or species habitat likely to occur within area
Merops ornatus Rainbow Bee-eater	Listed - overfly marine area	Species or species habitat may occur within area

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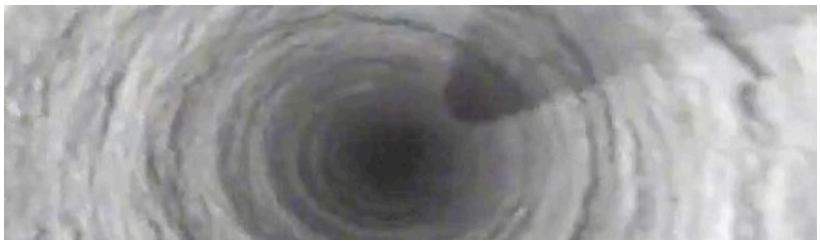
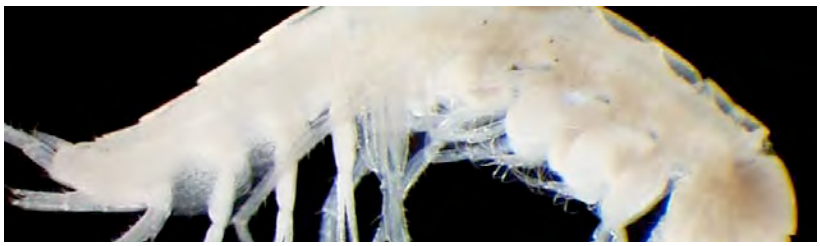
Rio Tinto

Marandoo Mine Phase 2 Subterranean Fauna Assessment





Prepared for Rio Tinto

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Marandoo Mine Phase 2 Extension Subterranean Fauna Assessment

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1.0 Introduction

1.1 Project Background

Pilbara Iron operates the Marandoo Iron Ore Mine, which is located in the central Pilbara, approximately 37 km east of Tom Price (Figure 1.2). The Marra Mamba type iron ore resource at Marandoo occurs both above and below the water table (BWT) and Pilbara Iron currently has approval to mine above the water table only. Between 1994 and 2006, a number of technical investigations were conducted to test the feasibility of extending mining BWT: 'Marandoo Mine Phase 2 (MMP2) Project' (Pilbara Iron 2008).

The major components of the MMP2 Project are:

- expansion of existing mine pits;
- new waste dumps, topsoil stockpiles and haul roads;
- a dewatering system including bores, pipelines, collector tanks and associated infrastructure at, and from, the Marandoo mine to Southern Fortescue borefield;
- a residue storage facility; and
- an accommodation camp (see Figure 1.2 for general arrangement).

The MMP2 proposal was referred to the Environmental Protection Authority (EPA), which determined the proposal would be assessed at the level of Public Environmental Review (PER). An Environmental Scoping Document (ESD) was subsequently prepared and submitted to EPA Service Unit (EPASU) for comment and approval (Pilbara Iron 2008a). The current report has been prepared as a technical supporting document for the PER for the Marandoo Mine Phase 2 proposal and to address the subterranean fauna assessment requirements identified in the ESD for the project.

1.2 Previous Subterranean Fauna Work at Marandoo

Stygofauna surveys have previously been completed at Marandoo on six occasions from 1999 through to 2003 (see Section 2.1 for more detail). Hamersley Iron coordinated the first survey, with all other subsequent work being managed or completed by Biota Environmental Sciences.

Over the course of the six sampling occasions, a combined total of 51 bores were successfully sampled. Stygofauna were collected from 11 of these 51 bores, primarily in the Mt Bruce flats valley bores to the north of the proposed MMP2 footprint. Many of the remaining bores had been sampled multiple times without yielding fauna, and are considered unlikely to have value in any further re-sampling (Biota 2008).

Sampling to date has also included six nested bores where bores targeting the superficial and deep aquifers have been sampled. In all cases, no stygofauna have been collected from the deeper bores and the fauna appears to be associated with the calcrete and alluvium aquifer in the superficial unit of the valley (see Sections 4.0 and 4.2 for further discussion).

1.3 General Scope of Additional 2008 Work

Given the results of earlier sampling work, it was known that a stygal ecosystem occurs in association with the shallow aquifer system in the valley north of the MMP2 project area (Biota 2008). This earlier sampling work covered the general extent of the project's groundwater drawdown, but did not address the Southern Fortescue borefield reinjection area. Further field sampling of stygofauna was therefore carried out as part of the current study, forming part of scope of the additional field survey (Biota 2008; Section 2.3).

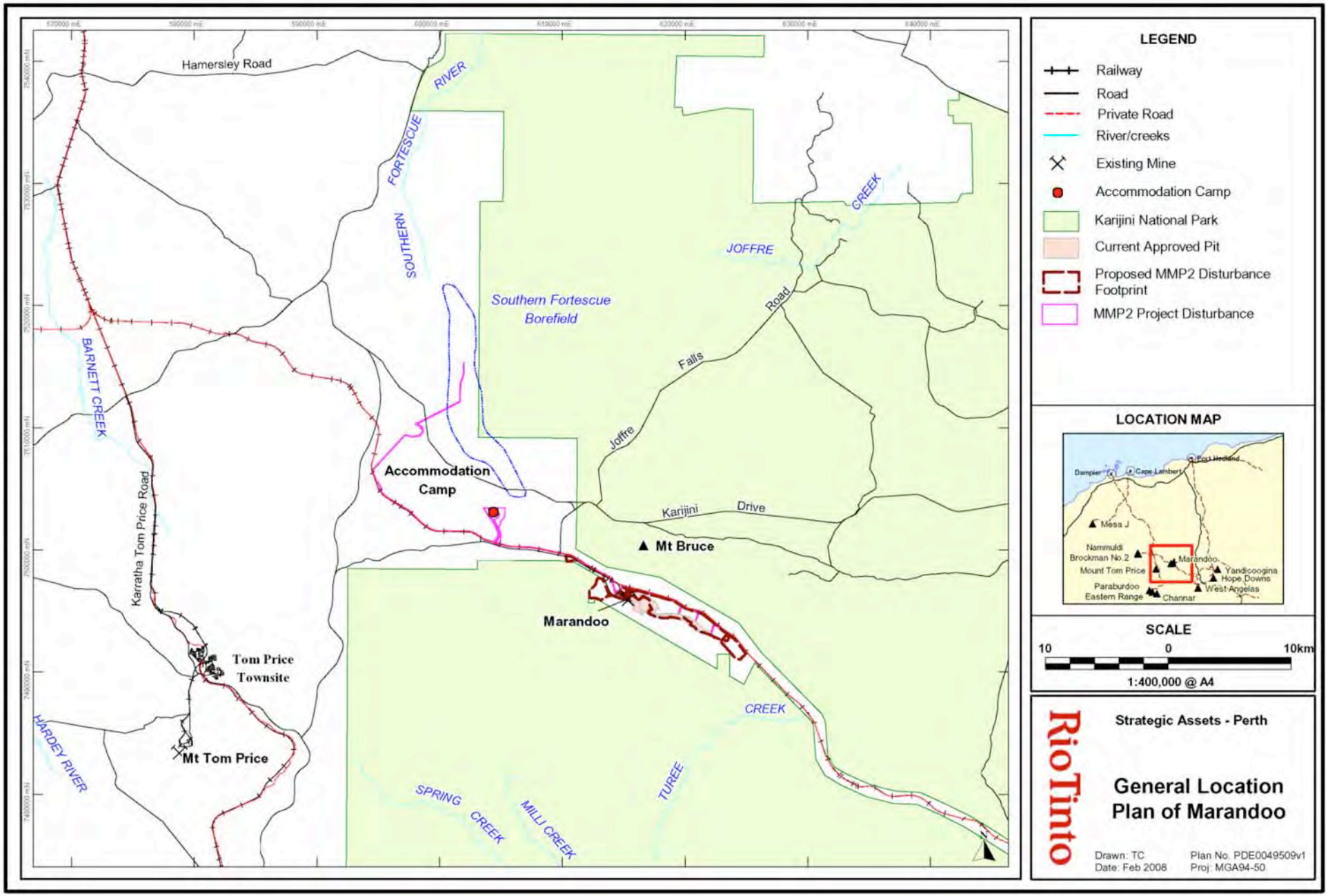

Figure 1.1: Locality map for the Marandoo Mine Phase 2 project area (source Pilbara Iron 2008).

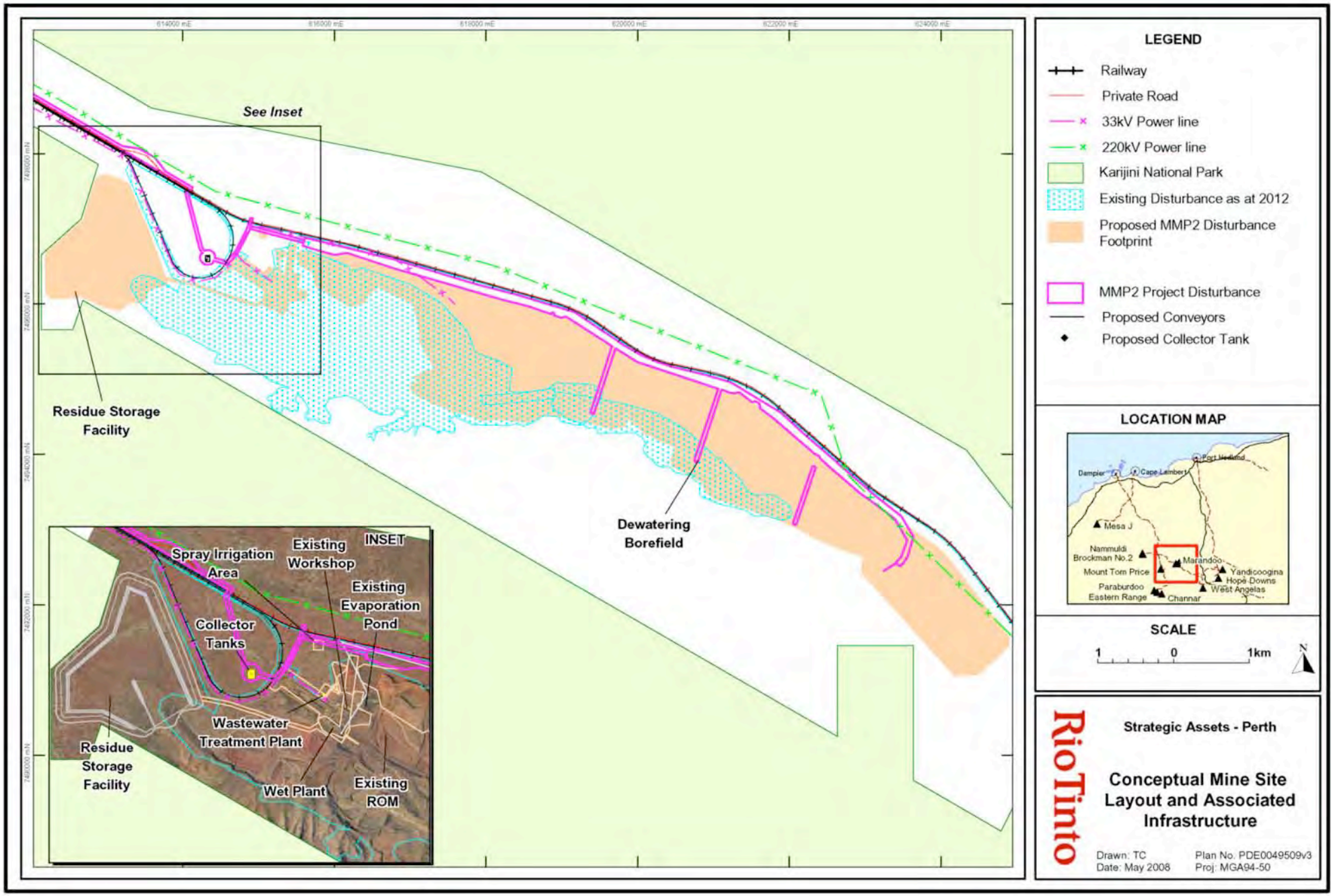

Figure 1.2: General arrangement for the Marandoo Mine Phase 2 project (source Pilbara Iron 2008).

1.4 Summary Subterranean Fauna Background

Two broad categories of fauna are generally considered to comprise the true subterranean fauna:

1. Stygofauna: groundwater-dwelling, aquatic fauna (including stygobites; obligate groundwater dwellers); and
2. Troglofauna: obligate cave or karst-dwelling, terrestrial subterranean fauna occurring above the watertable.

Stygofauna inhabit groundwater, sometimes occurring close to the surface. They are highly specialised to, and obligate dwellers of, subterranean groundwater habitats ('stygobites'; Humphreys 2000). Stygofauna are known to be present in a variety of rock types including karst (limestones), fissured rock (e.g. granite) and porous rock (e.g. alluvium) (Marmonier et al. 1993). The types of animals that have become stygal in Western Australia include a range of crustacean taxa (which often dominate the fauna numerically), platyhelminthes, oligochaetes, water mites and beetles (Humphreys 1999, Watts and Humphreys 1999, Biota unpublished data).

Troglobites occur in the strata between the superficial soil layer and the watertable, where suitable habitat space is available. Troglobitic fauna has historically been collected primarily from karstic limestone systems in Western Australia (at Cape Range, Barrow Island and in the Kimberley; Harvey 1988, Biota 2002, Humphreys 2001). Recent work along the Robe River has, however, also collected this fauna from vuggy and cavernous strata in pisolitic mesa formations in the Pilbara (Biota 2006).

Troglobitic fauna species have the potential to have restricted distributions and as a result short-range endemism (*sensu* Harvey 2002) is common in this fauna. In the arid zone, the troglobitic fauna is generally considered to be relictual rainforest litter fauna, having arisen from tropical fauna lineages that descended into subterranean environments during the aridification of Australia (in the late Miocene; Humphreys 1993). This is inferred from affinities of the taxonomic groups represented amongst the troglofauna with other extant taxa in tropical climates. These groups include the Schizomida, Pseudoscorpionida, Araneae, Scolopendrida, Polydesmida, Diplura, Thysanura, Coleoptera and Blattodea (Humphreys 2001, Biota 2006).

2.0 Scope and Methodology

2.1 Previous Subterranean Fauna Surveys at Marandoo

Stygofauna have been previously sampled at Marandoo over six phases: September 1999, November 2000, June 2001, April 2002, July 2002, and May 2003. The first survey was coordinated by Stuart Anstee of Hamersley Iron, with all subsequent phases managed or completed by Biota Environmental Sciences. A combined total of 51 bores was sampled across the six phases of work. A brief description of the sampling effort undertaken during each survey phase is provided below, with more detail on historically sampled bores provided in Appendix 1.

1. September 1999: Twenty-two bores were sampled between the 16th to the 18th by Stuart Anstee (Hamersley Iron) and Paul West (Halpern Glick Maunsell).
2. November 2000: Twenty-five bores were visited on the 27th of the month by Kyle Armstrong (Biota) and Paul West. All bores were successfully sampled.
3. June 2001: Twenty-two bores were visited between the 5th and 6th of the month by Garth Humphreys and Paul West. All bores were successfully sampled.
4. April 2002: Eighteen bores were sampled between the 24th and 25th of the month by Kyle Armstrong and Garth Humphreys. All bores were successfully sampled.
5. July 2002: Six bores were visited on the 7th of the month by Kyle Armstrong, Piers Higgs, Prof. Mike Johnson (UWA) and Dr. Terrie Finston (UWA). All bores were successfully sampled.
6. May 2003: Sixty-one bores were visited between the 12th to the 15th of the month by Kyle Armstrong and Roy Teale (both of Biota). Of these only 29 were successfully sampled. This last phase was completed as part of pump test trials for the planned Marandoo mine Phase 2.

2.2 Troglofauna Review and Risk Assessment

As outlined in the subterranean fauna sampling programme for Marandoo Mine Phase 2 (Biota 2008), and the ESD for the project (Pilbara Iron 2008), potential troglofauna impacts associated with the proposal were addressed via desktop review and risk assessment. This was approached from two aspects:

1. assessment of the likelihood that troglofauna occur in the subterranean habitats present at the site; and
2. the types of impacts to troglobitic ecosystems that may arise as a result of the proposal.

This approach enabled an assessment of the likelihood of impacts to troglobitic fauna arising the proposed extension of the Marandoo mining operation. More detailed accounts of the methodology for each assessment component follow.

2.2.1 Likelihood of Troglofauna Occurrence

The likelihood of troglofauna occurring in the project area was assessed using a combination of regional information and site-specific habitat data. Inputs considered in this process included:

1. the likely spatial extent of impacts at the site (to define the area that may be affected);
2. regional geology mapping;
3. hydrological and hydrogeological information from other technical studies completed for the project;
4. geological information from holes drilled in the project area as part of resource assessment, geotechnical and hydrogeological work being undertaken for the project;
5. previous sampling efforts in the locality and the results of published and unpublished studies on subterranean fauna from the region;

6. qualitative results from downhole video camera work on the site (Section 2.4); and
7. locations of other troglobitic fauna records from Biota's database and the Department of Environment and Conservation (DEC) Pilbara Biological Survey.

Based on the outcomes of this process, the proposal was assigned a level of likelihood to support troglofauna of 'Low', 'Moderate' or 'High/Definite', consistent with the categorisation defined in Section 2.2.3.

2.2.2 Identification of Potential Troglofauna Impact Mechanisms

Potential impacts to troglobitic fauna include a range of possible influences from mining and infrastructure developments. Listed in typical ascending order of likely impact to troglobitic ecosystems, these include:

1. clearing by surface operations, with the potential to create increased sediment loads and reduce habitat space in karstic or fracture strata above the watertable;
2. reduction in organic inputs to subterranean ecosystems due to vegetation clearing;
3. changes to groundwater recharge or discharge areas due to sealing of surface areas, with increase in run-off and reduction in recharge;
4. shock and vibration effects on subterranean habitats from blasting activities.
5. pollution (e.g. chemical pollutants spills, unlined landfills and direct discharge of waste or different quality water; Sket 1999);
6. direct excavation or mining resulting in removal and destruction of karstic strata.

Dewatering, groundwater abstraction and other aquifer impacts are of more direct relevance to stygal ecosystems rather than troglobitic systems, and are considered separately in Section 4.2.

In evaluating the relevance of these factors to this proposal, consideration will be given to the magnitude, duration and spatial extent of the impacts. This assessment has taken the approach of considering these broad categories of potential impact mechanisms and evaluating their risk of occurrence and likely severity against the context of the project area's perceived significance for trogloauna. In order to achieve this in a structured fashion, a broad categorisation process will been carried out, similar to that performed for risk assessments (see Section 2.2.3).

2.2.3 Evaluation Framework

The evaluation framework to be used combines the likelihood of troglobitic fauna occurring in the area (as set out in Section 2.2.1), with the relevance of the potential impact mechanisms listed in Section 2.2.2. This is presented in Table 2.1 below, with accompanying explanatory notes.

Table 2.1: Evaluation framework for considering potential project impacts on troglobitic fauna.

Part A – Assessment of Impact Mechanisms

Impact mechanisms	Likelihood of subterranean habitat change *	Typical duration **	Spatial extent ***	->	Potential Impact Score
1. Ground clearing/sedimentation	Small – Moderate	Mod. – Long	Localised – Wider		1-2
2. Vegetation clearing/nutrient removal	Small – Moderate	Mod – Long	Localised – Wider		1-2
3. Changes to surface hydrology	Small – Moderate	Mod. – Long	Localised – Wider		1-2
4. Shock and vibration from blasting	Moderate	Short – Mod.	Localised – Wider		1-2
5. Pollution	Moderate	Moderate	Localised - Wider		1-2
6. Excavation / mining of habitat strata	High	Permanent	Localised - Wider		2-3

* In the context of effects on troglobitic ecosystems.

** Short= weeks to months, Moderate= <1 year; Long= >1 year.

*** Immediate area= within 0.5 km radius of the central impact point, Localised= within 1 km radius of the impact point, Wider area:= >1 km radius of the impact point.

Part B – Risk Assessment	Likelihood of Troglobitic Fauna Occurrence		
Overall Impact Category	Low †	Moderate ††	High / Definite †††
Low (impact score 0-5)	1	1	2
Moderate (impact score 6-10)	1	2	3
High (impact score 11-15)	2	3	3

† No records of troglobitic fauna from within 5 km radius (giving consideration to sampling effort); affected geological units unlikely to represent core subterranean fauna habitat).

†† Records of troglobitic fauna from within 5 km radius (giving consideration to sampling effort), and/or affected geological units may represent core subterranean fauna habitat).

††† Known records of troglobitic fauna from within 1 km radius (giving consideration to sampling effort), and/or affected geological units likely to represent core subterranean fauna habitat).

Risk assessment outcome levels (as shown in the Part B of Table 2.1):

1 Low risk of potential impacts to troglobitic fauna that would require detailed assessment and/or approval under relevant legislation.

2 Moderate risk of potential impacts to troglobitic fauna that would require detailed assessment and/or approval under relevant legislation.

3 High risk of potential impacts to troglobitic fauna that would require detailed assessment and/or approval under relevant legislation.

In evaluating each potential impact mechanism, consideration was also given to the extent to which environmental management measures might reduce risks or the intensity of impacts.

2.3 Additional Stygofauna Field Survey

2.3.1 Sampling Design and Effort

With the requirement for reinjection at the South Fortescue borefield area, an additional stygofauna field sampling phases was needed for the project. The design of the additional survey phase was set out in Biota (2008) and also allowed for resampling of bores where fauna had previously been collected in the mine locality.

Considerations that were taken into account in selecting boreholes for the 2008 sampling phase (effectively Phase VII at Marandoo) were:

- provision of good spatial spread of sampling points across the project area;
- locations and anticipated extent of the groundwater dewatering impact area (conservatively limiting this to the predicted 2 m drawdown contour as this is within normal seasonal fluctuations in groundwater level; Finlayson and McMahon (1988), Batini (2008));
- sampling of the recharge area at Southern Fortescue borefield (as this had not previously been sampled)
- collecting more data to validate the vertical distribution of the fauna from earlier sampling (i.e. that the stygofauna present are associated with the superficial aquifer and not deeper systems); and
- re-sampling holes that had previously yielded stygofauna (to improve information on individual species distributions).

In total, 43 boreholes were selected for sampling on the basis of the above requirements (30 impact area bores and 13 reference area bores; Biota (2008); Table 2.2). The location and distribution of these sampling points are provided in Table 2.2 and Figure 2.1.

Table 2.2: Boreholes sampled as part of the Marandoo Mine Phase 2 Extension in 2008 (coordinates in GDA94; 'Status' determined by position relative to 2m drawdown contour).

Borehole	Easting	Northing	Status	Locality
S5-1	601440	7513894	Impact	South Fortescue borefield
S3-1	601625	7513606	Impact	South Fortescue borefield
SFPOLD1	602019	7513603	Impact	South Fortescue borefield
S2-1	601854	7513509	Impact	South Fortescue borefield
SFPOLD2	601666	7512789	Impact	South Fortescue borefield
SFO3B	602441	7512392	Impact	South Fortescue borefield
SFO6	602127	7512285	Impact	South Fortescue borefield
D01MN004	617704	7495842	Impact	Marandoo mine area
DD07MN013	619739	7494603	Impact	Marandoo mine area
D01MN012	619951	7494535	Impact	Marandoo mine area
D01MN013	620258	7494510	Impact	Marandoo mine area
DD07MN016	620237	7494437	Impact	Marandoo mine area
OW10S	621335	7494380	Impact	Marandoo mine area
SFO16	601957	7518204	Reference	South Fortescue borefield
SFO07A	602307	7514416	Reference	South Fortescue borefield
SFO13	603465	7508092	Reference	South Fortescue borefield
SFO3A	604724	7507607	Reference	South Fortescue borefield
MNP0295	613343	7497461	Reference	Marandoo mine area
MNWB0007	610782	7497370	Reference	Marandoo mine area
MNP0300	614812	7497127	Impact	Marandoo mine area
OW3	616548	7496564	Reference	Marandoo mine area
OW15S	625615	7496494	Reference	Mt Bruce Flats
OW15D	625615	7496494	Reference	Mt Bruce Flats
OW28S	622528	7496193	Impact	Mt Bruce Flats
OW28D	622528	7496193	Impact	Mt Bruce Flats
OW30S	622436	7496173	Impact	Mt Bruce Flats
OW12S	622967	7496065	Impact	Mt Bruce Flats
OW12D	622967	7496061	Impact	Mt Bruce Flats
OW11M	622044	7494959	Impact	Marandoo mine area
OW11S	622044	7494959	Impact	Marandoo mine area
OW11I	622041	7494956	Impact	Marandoo mine area
DD07MN104	618336	7494908	Impact	Marandoo mine area
DD07MN101	619124	7494656	Impact	Marandoo mine area
PW20	621386	7493827	Impact	Marandoo mine area
OW20	621178	7493698	Impact	Marandoo mine area
OW24	622732	7493533	Impact	Marandoo mine area
D01MN018	621777	7493369	Impact	Marandoo mine area
DD07MN110	622868	7492850	Impact	Marandoo mine area
MNP0202	624003	7492466	Impact	Marandoo mine area
MNP0200	625061	7491847	Reference	Marandoo mine area
MNP0196	625376	7490899	Reference	Marandoo mine area
OW8S	629629	7487170	Reference	Marandoo mine area
OW8D	629629	7487170	Reference	Marandoo mine area

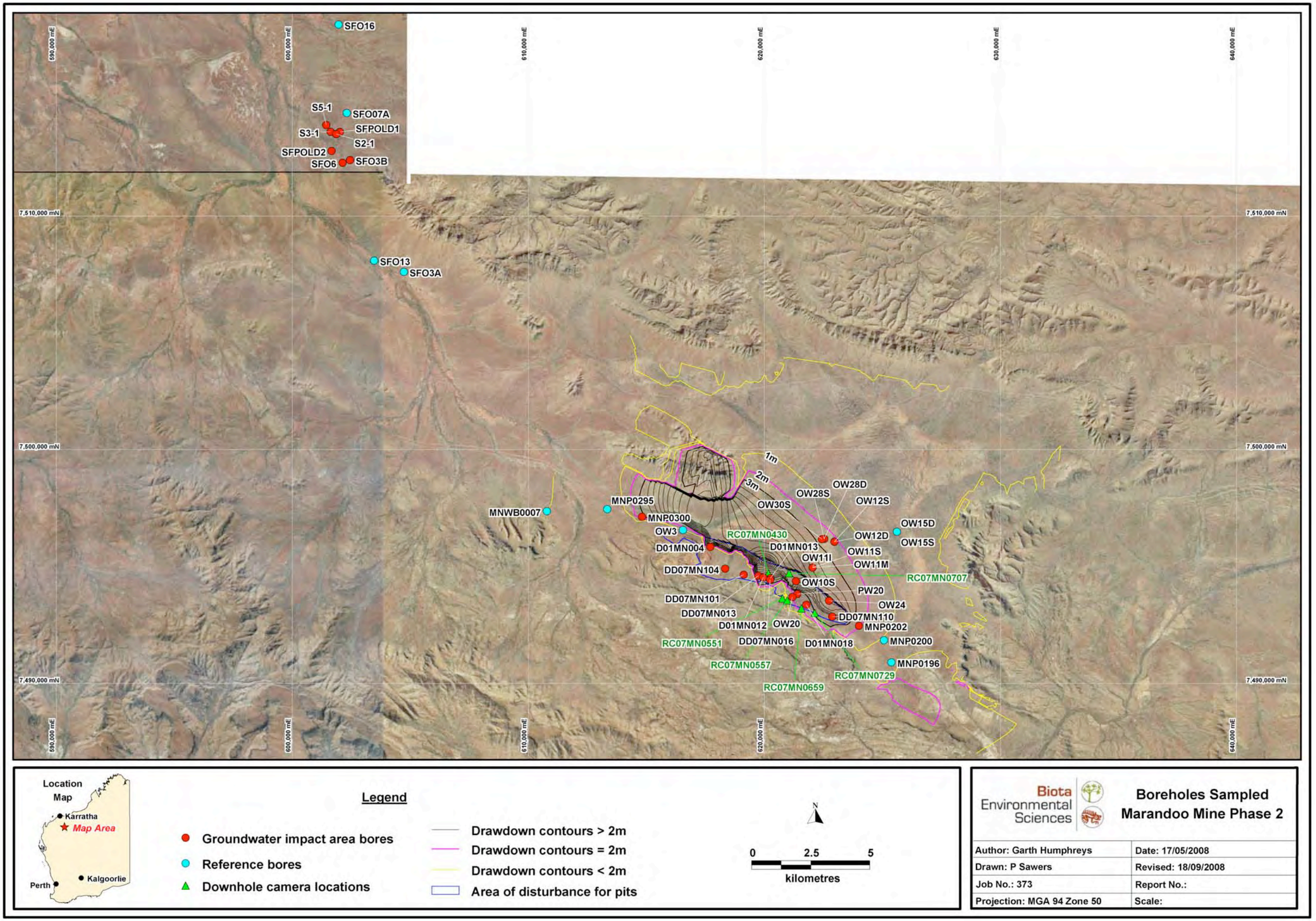

Figure 2.1: Bores sampled for stygofauna during the 2008 (Phase VII) field survey.

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2.3.2 Stygofauna Sampling Methods and Data Management

Stygofauna sampling at Marandoo and the South Fortescue borefield followed a similar format to other stygofauna sampling projects undertaken previously around the Pilbara. Methodologies and approach are consistent with those outlined in the Environmental Protection Authority (EPA) Guidance Statement 54 (EPA 2003) and draft Guidance Statement 54a (EPA 2007).

Groundwater sampling was undertaken by the use of modified plankton haul nets. These sampling nets were constructed from 70 μm plankton mesh, with 50 mm and 100 mm apertures attached to a weighted catch jar. Each bore was dragged a minimum of three times unless fauna were detected, in which case five hauls were completed. On the final haul the net was agitated gently, which acts to stir the benthos layer and mobilises any fauna present for more effective specimen collecting. On the surface, the net was flushed thoroughly with fresh water and the resulting sample placed in a uniquely labelled container and into a shaded esky in order to preserve the sample until sorting and identification.

Following the completion of a bore, the nets were thoroughly rinsed with water before using on another hole. This prevented cross contamination between aquifers and boreholes.

Samples were live sorted in an on-site laboratory, under a dissecting microscope (magnification up to 40x). Stygofauna specimens were tracked using Biota's standard tracking forms and preserved in 100% ethanol (which provides for both morphological and DNA analysis).

2.4 Downhole Video Camera Assessment

As part of characterising subterranean habitats, a GeoVision stainless steel colour downhole camera system was used to profile a selection of drillholes on the Marandoo deposit. This device enables a qualitative and direct assessment of subterranean habitats and geological strata, particularly in respect of extent of fracturing and cavities. This method is also capable of detecting both troglofauna and stygofauna when these are present in drillholes (established through footage obtained at Mesa A and other areas with known subterranean ecosystems).

Six drillholes were profiled at Marandoo as part of this work (see Table 2.3 and Figure 2.1). These sites were selected to provide a representative spatial spread across the deposit, and also to target the hydrated portion of the Marra Mamba ore; the unit most likely to host cavities and fractures in the pit area (Pilbara Iron 2008b).

Table 2.3: Drillholes profiled using downhole video to characterise subterranean habitats.

Borehole	Easting	Northing
RC07MN0430	620165	7494701
RC07MN0551	620761	7493633
RC07MN0557	620963	7493552
RC07MN0659	621563	7493202
RC07MN0707	621044	7494720
RC07MN0729	620514	7492969

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3.0 Troglofauna Review and Risk Assessment

3.1 Likelihood of Troglobitic Fauna Occurrence

3.1.1 General Geology of the Study Area

Marandoo lies within the largely Proterozoic cratonic crustal element underlying much of the Pilbara region. The area is nested within the litho stratigraphic Hamersley Iron Province and includes the Jeerinah Formation of the Fortescue Group and the Marra Mamba of the Hamersley Group. Marra Mamba iron ore outcrops as a curvilinear ridge called the Marandoo Ridge (Liquid Earth 2006).

Thorne and Trendall (2001) described several geological units from the Marandoo area (Table 3.1 and Figure 3.1).

Table 3.1: Geological units occurring within the Marandoo Mine Phase 2 project area (Thorne and Trendall 2001).

Unit	Geological Description
Qw	Undivided Quaternary deposits; includes colluvium, reworked alluvium, eolian sand, and clay
Qa	Alluvium – unconsolidated silt, sand, and gravel; in river channels
AHm	Marra Mamba Iron Formation: chert, banded iron-formation, mudstone, and siltstone; metamorphosed
AFj	Jeerinah Formation: carbonaceous mudstone and siltstone, thin-bedded sandstone, chert, felsic volcaniclastic rock, basalt, and dolomite; metamorphosed
Czp	Robe Pisolite: pisolite limonite deposits; developed along palaeodrainage lines
Czc	Undivided Cainozoic deposits; includes partly consolidated colluvium and alluvium, and silcrete and laterite

Of these units, troglofauna have been recorded elsewhere from Robe Pisolite (Biota 2006), and from bores intersecting the *Qa* unit in the Mt Bruce Flats area at Marandoo (Section Account of the Collected Fauna). Dolomite is also karstic and contains voids, but at Marandoo this geology all occurs below watertable, making the unit unsuitable for troglofauna utilisation. The planned pit area comprises *Qw* and *Czc*: quaternary sand, clay and colluvium and similar Cainozoic units (Figure 3.1; Table 3.1). These units have not previously been shown to be core habitat for troglobitic fauna (Biota 2006).

3.1.2 Hydrology and Hydrogeology

The project area is situated on the southern margin of a significant, flat lying, internally draining catchment known as the Mt Bruce Flats. This area is subject to periodic inundation following cyclonic rainfall. There are no well-developed creek systems in the area although the headwaters of the Southern Fortescue and Turee Creek drainage systems rise from the margins of the Mt Bruce Flats (Liquid Earth 2005; Figure 3.2). The median annual rainfall at the Marandoo recording station is 346 mm, with a range of 242 to 802 mm over the 28-year record (Liquid Earth 2005). During the dry season, the project area experiences very little rainfall, averaging 8 mm per month. Watertable levels can vary naturally by up to 6.5 m between recharge events (Batini 2008).

The groundwater system at Marandoo and the Mt Bruce flats can be broadly considered as two aquifers. The first is an unconfined aquifer associated with a shallow calcrete horizon within a valley fill sequence (hereafter the shallow aquifer) (Liquid Earth 2005). There is also a confined aquifer associated with the deeper Wittenoom Dolomite and mineralised Marra Mamba bedrock (hereafter the deep aquifer). The two systems are separated by a thick sequence of valley fill clays, which significantly limits vertical connectivity between the shallow and deep aquifers across most of the project area (Liquid Earth 2005).

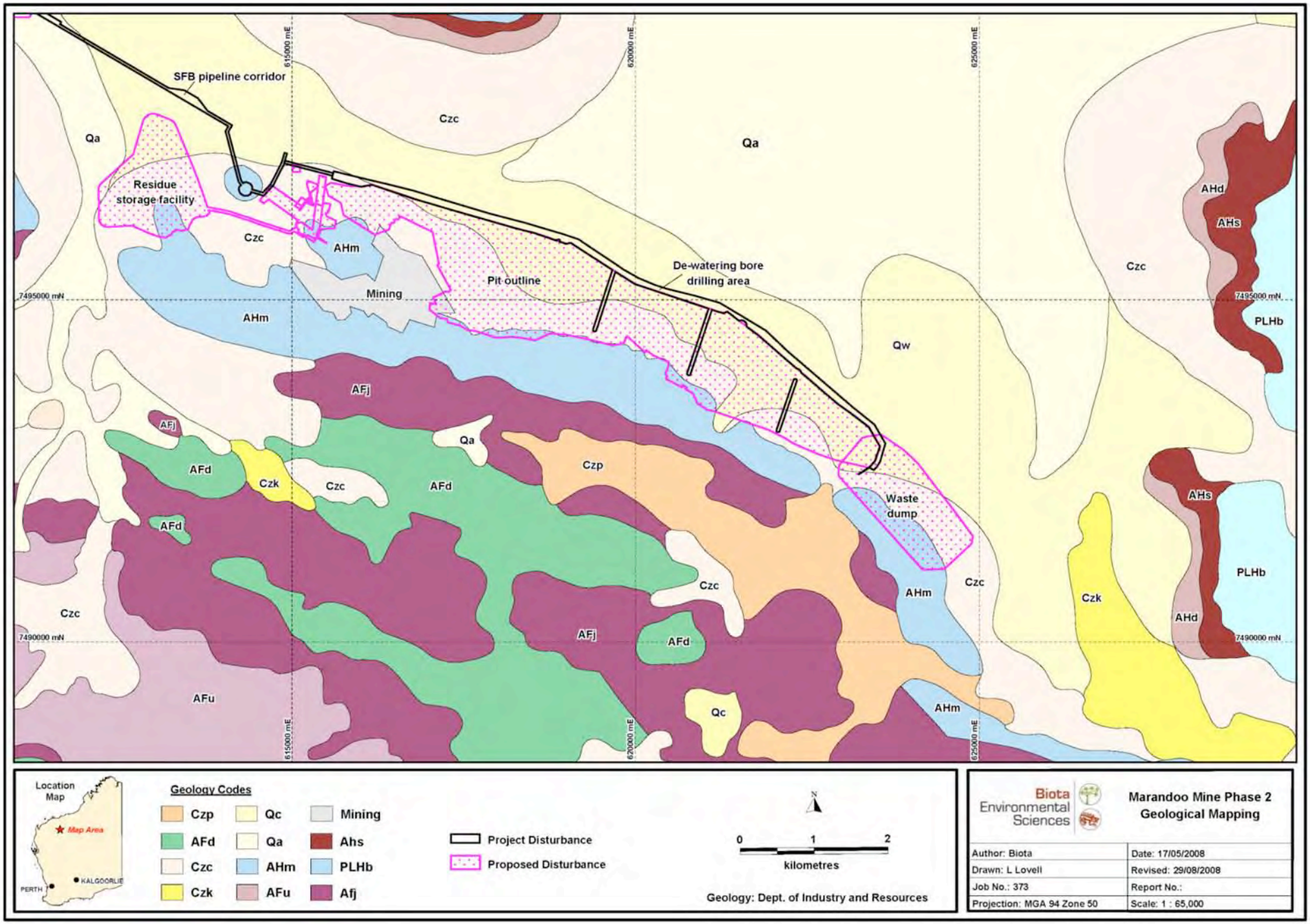


Figure 3.1: Geological Mapping for the Marandoo Mine Phase 2 project area.

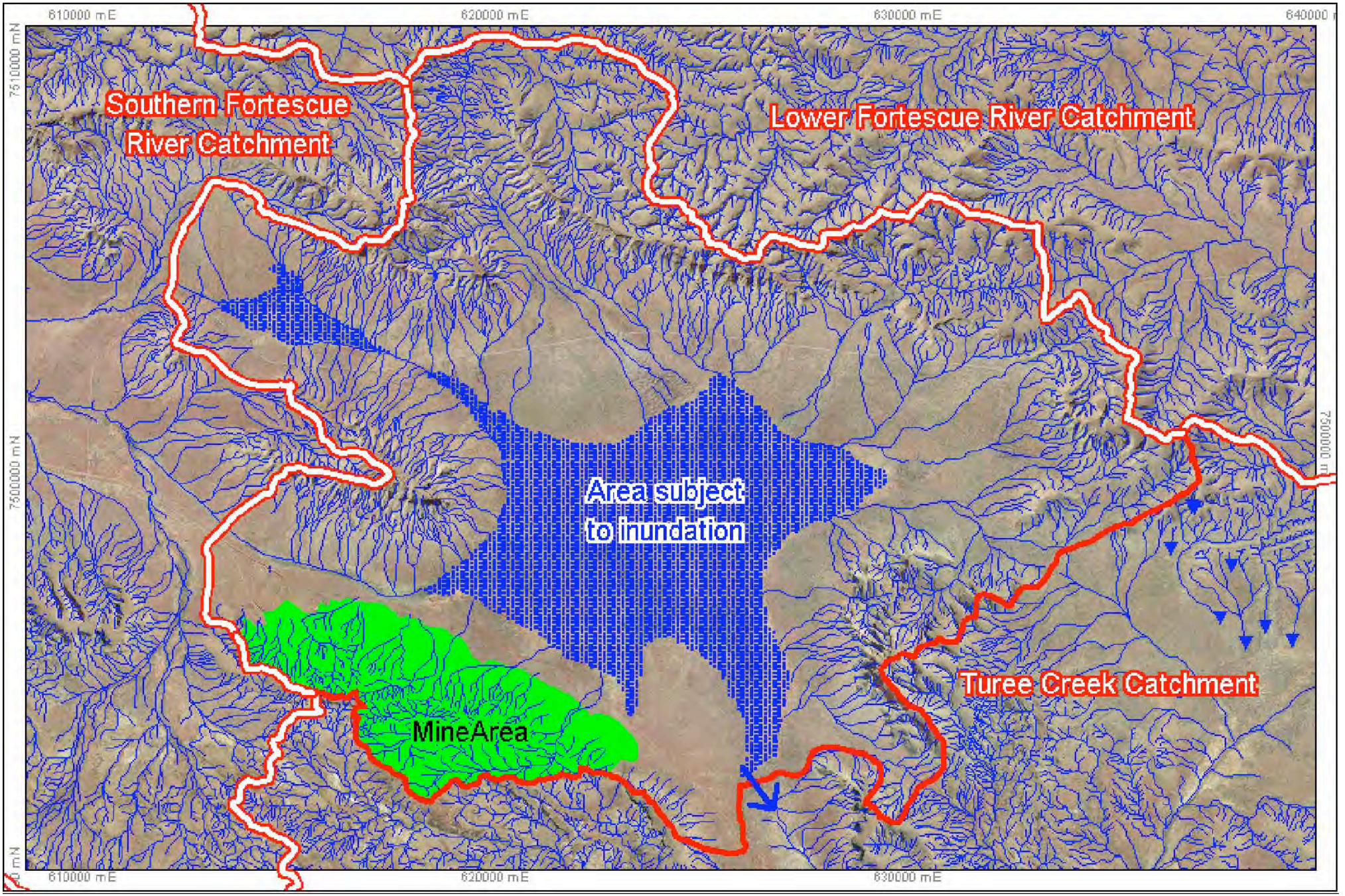


Figure 3.2: Locality scale surface water catchment hydrology for the Marandoo Mine Phase 2 project area (source: Pilbara Iron 2008).

3.1.3 Drillhole Logs and Diamond Drill Core

Diamond drilling was completed at 24 locations across the Marandoo Mine Phase 2 project area. This drilling method provides the maximum information on subterranean habitats, as core is recovered and available for physical inspection and more detailed geological and geotechnical logging. While individual drillholes varied in thickness and representation of strata, several main units were repeated across the project area (Table 3.2). Representative core photos of each unit are provided in Plate 3.1 to Plate 3.6.

Table 3.2: Summary of stratigraphic units present at Marandoo based on diamond drilling (listed in typical sequence from most superficial to deepest, where present).

Unit	Depth Range (mbgl)	Representative Core Photo
Quaternary detrital deposits	0 - 65 m	Plate 3.1
Upper calcrete	15 – 40 m	Plate 3.2
Tertiary clay	35 – 90 m	Plate 3.3
Lower calcrete	65 - 110 m	Plate 3.4
West Angela Shale	65 – 110+ m	Plate 3.5
Mineralised Banded Iron Formation	70 – 110+ m	Plate 3.6

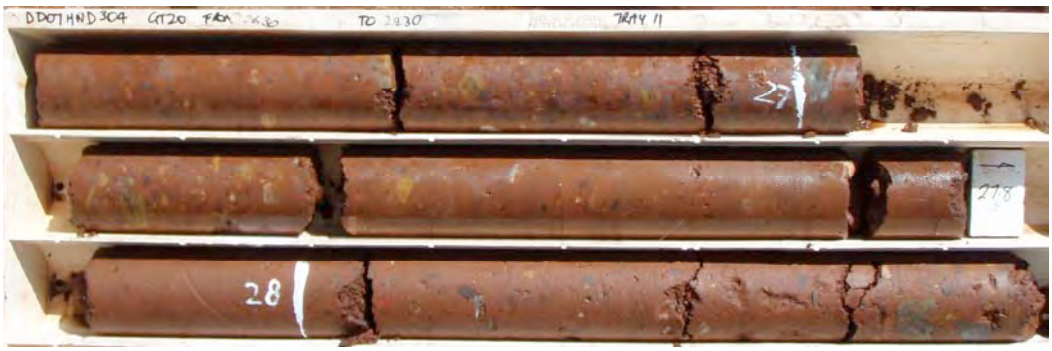


Plate 3.1: Representative quaternary detrital deposits (hole DD07MND304; 26-29 m).

Plate 3.2: Representative upper calcrete (hole DD07MND314; 39-42 m).

Plate 3.3: Representative tertiary clay (hole DD07MND301; 56-59 m).

Plate 3.4: Representative lower calcrete (hole DD07MND306; 86-89 m).

Plate 3.5: Representative shale (hole DD07MND317; 128-131 m).

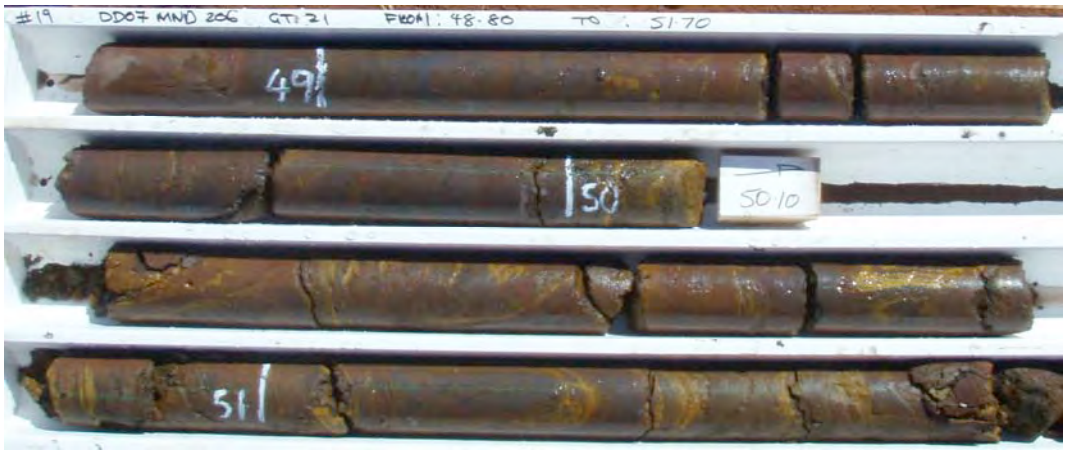


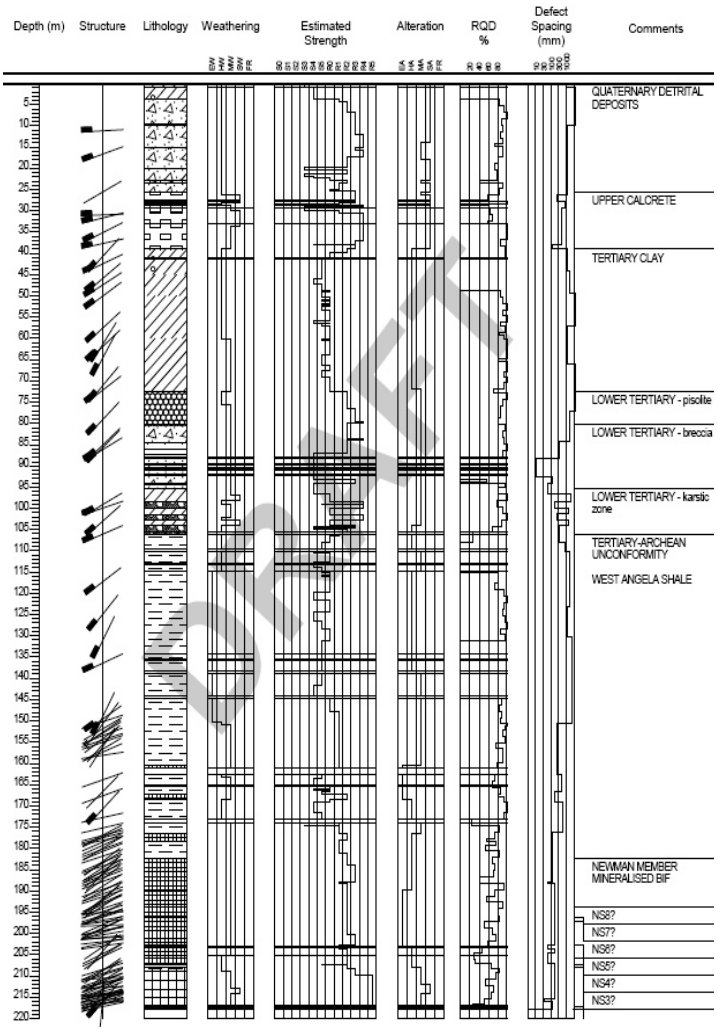
Plate 3.6: Representative mineralised BIF (hole DD07MND206; 48-51 m).

The diamond drill core and logs did not generally indicate a cavernous or vuggy profile, with most of the major stratigraphic units generally solid in nature (see Plate 3.1 to Plate 3.6). The more prospective units, *a priori* the upper and lower calcrete sequences (Plate 3.2 and Plate 3.4 respectively), were structurally relatively competent and consolidated, with minimal evidence of cavities (note that some of the drill core itself is broken in the above plates as opposed to in situ cavities). Fracturing was evident in some units (particularly mineralised BIF; Plate 3.6), but this was often at depth and beneath the widespread tertiary clay layer. Compared to diamond drill core from other locations with known troglobitic communities (e.g. Biota 2006, 2007, 2008), there was no strong evidence of habitat likely to be suitable for troglofauna from the cores from the Marandoo pit area.

A representative stratigraphic sequence is provided with accompanying drill core photos in Figure 3.3. This illustrates the main units present, including their relative thicknesses. Quaternary detrital deposits (ground level to 30 m) are underlain by a relatively thin upper calcrete stratum (30-40 m), followed by a thick (~40 m) layer of tertiary clay, underlain by a variable sequence of tertiary formations and shales, over mineralised BIF at depth (~180 m) (see Figure 3.3).

Figure 3.3: Geological logging and diamond drill core photos from hole DD07MND318, illustrating the main stratigraphic units.

Drill Log



Representative core photos of main units

Quaternary deposits (6-9 m)

Calcrete (35-38 m)

Tertiary clay (60-63 m)

West Angela Shale (113-115 m)

3.1.4 Habitat Characterisation

A selection of six drillholes on the Marandoo orebody was profiled using downhole video to characterise subterranean fauna habitat and to directly observe troglofauna if present (see Section 2.4). No troglofauna were observed in any of the bores profiled with the camera system (fauna are reliably observed when present e.g. at Mesa A; Biota 2006).

The physical nature of the stratigraphy also did not appear suitable as troglofauna habitat, comprising large extents of clay-dominated or otherwise tightly packed geology, with few cavities or other openings (see Plate 3.7 to Plate 3.10). This was consistent with information obtained from the drill logs and diamond drill cores (see Section 3.1.3), and with previous geological assessments of the area (Pilbara Iron 2008a).

Known troglofauna habitat at Mesa A (Plate 3.11 and Plate 3.12), is considerably more fractured and vuggy by comparison.

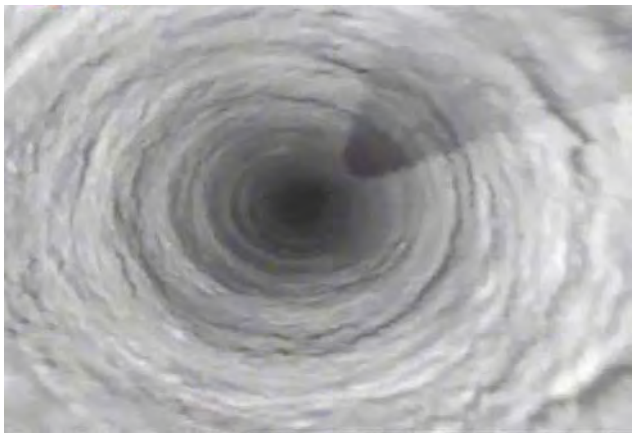


Plate 3.7: Still from downhole video of drillhole RC07MN0430 at Marandoo.

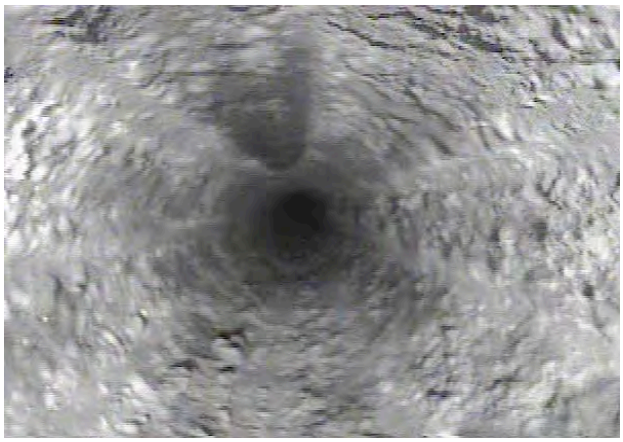


Plate 3.8: Still from downhole video of drillhole RC07MN0551 at Marandoo.

Plate 3.9: Still from downhole video of drillhole RC07MN0557 at Marandoo.

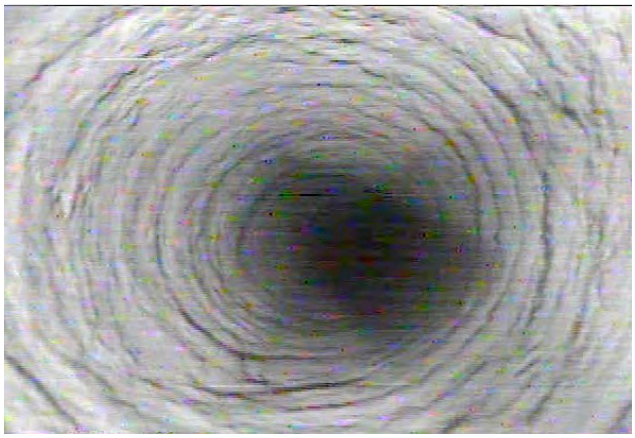


Plate 3.10: Still from downhole video of drillhole RC07MN0659 at Marandoo.

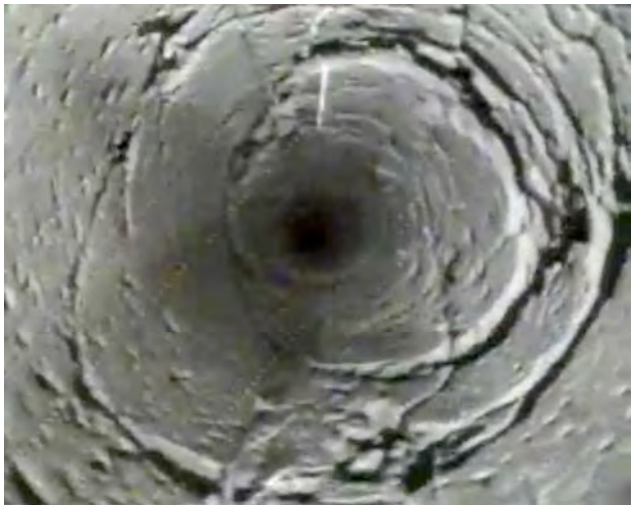


Plate 3.11: Representative still from downhole video of known troglofauna habitat at Mesa A (note extensive fracturing, cavities and vugs).

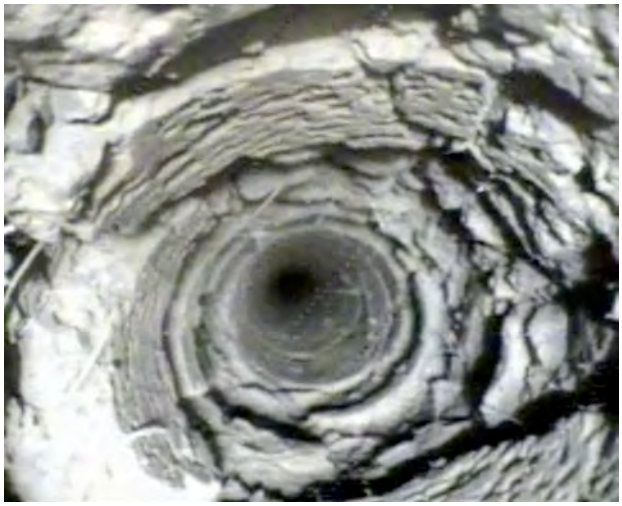


Plate 3.12: Representative still from downhole video of known troglofauna habitat at Mesa A (note extensive fracturing, cavities and vugs).

3.1.5 Troglobitic Fauna Records from the Locality

A review of the literature, previous formal assessments and consultation with DEC and WA Museum staff was completed to identify any previous work done in the locality. No sampling specifically targeting troglobitic fauna has previously been completed in the Marandoo project area.

Previous stygofauna work at Marandoo did, however, also collect troglobitic fauna from two locations. Both of these records are from outside the proposed Marandoo Mine Phase 2 footprint however, and are associated with alluvial material overlying dolomite (geologically distinct from

the quarternary deposits overlying the Marra Mamba ore of the planned pit area; Figure 3.1; see Section 3.1.6 for further discussion).

3.1.6 Likelihood of Troglofauna Occurrence

The review of available information completed here suggests that there is differential likelihood of troglofauna occurrence in different sections of the Marandoo Mine Phase 2 extension project locality.

There appears to be a relatively low risk that the pit area itself represents a troglobitic community, as:

- geological mapping does not indicate any units representing known troglofauna habitat occur in the pit;
- drill logs and diamond core did not show evidence of widespread cavities, vugs or thick karstic sequences in the top 100 m of the sequence;
- down hole video profiling did not show any fauna to be present (including at the base of drillholes where experience at Mesa A indicates troglofauna naturally accrue through pitfall effect when present); and
- direct observation of subterranean habitats with down hole video did not indicate any significant cavities or fractures, showing a relatively solid, clay dominated profile, unlike that of known troglofauna habitat elsewhere.

There are, however, known records of troglofauna from the Mt Bruce Flats, outside of the direct footprint of the mine pit (Section 4.1). These records appear to be associated with more extensive and lower lying alluvial / calcrete units overlying dolomite in the coolibah flats area and associated tributaries (which is a receiving site for surface water recharge; Figure 3.2). It is possible that this fauna is associated with a superficial calcrete sequence, which is shallower in the flats area and above watertable. There has been evidence from elsewhere in the Pilbara that troglofauna may also occur in extensive calcrete patches rather than channel iron deposits such as Mesa A (Biota 2004).

The only other area that appears prospective for troglofauna is the area of Robe Pisolite shown on regional geology mapping to the south of the Marandoo mine (see Figure 3.1). This formation has been shown to support troglofauna elsewhere (Biota 2006), and may also support fauna in this location. No diamond core was available for this area however, and the likelihood of troglofauna occurrence here would also be affected by position of the pisolite relative to the water table. As this unit will not be affected by the project, a more detailed assessment has not be carried out here.

Assessment: *Low likelihood of troglofauna occurrence in the Marandoo Phase 2 pit area.*

Moderate likelihood of troglofauna occurrence in pisolite south of the Marandoo mine.

Known occurrence of troglofauna in the Mt Bruce Flats area.

3.2 Potential Impact Mechanisms

Potential impacts from the Marandoo Mine Phase 2 project also vary between the pit area, the pisolite to the south and the Mt Bruce Flats. Key project characteristics in the pit area that could present impacts to any troglofauna fauna present include:

1. clearing of terrestrial vegetation for excavation of the new pit, waste dumps and associated infrastructure;
2. drilling and blasting associated with mining operations; and
3. excavation of the planned Marandoo Phase 2 pit.

Table 3.3 summarises the impact process for the project after considering relevant environmental management measures, following the structure set out in Table 2.1.

Table 3.3: Summary of potential troglofauna impact mechanisms relevant to the Marandoo Mine Phase 2 project.

Impact mechanism	Relevant?	Project Element / Relevant Management Measures	Potential Impact Score
1. Ground clearing / sedimentation	Yes	Surface stabilisation; Revegetation of temporarily cleared areas	2
2. Vegetation clearing/nutrient removal	Yes	Clearing controls during construction and operation; Revegetation of temporarily cleared areas	2
3. Changes to surface hydrology	Yes	Drainage management to re-establish larger-scale surface drainage patterns	2
4. Shock and vibration from blasting	Yes	Equipment maintenance; Storage and handling controls	2
5. Pollution	No	Workshops and primary fuel storage will remain at the existing Marandoo mine facilities	-
6. Excavation / mining of habitat strata	Yes	Excavation of the mine pit	3
		Total:	11

Overall assessment: High Potential Impact Category.

The Mt Bruce Flats area and the Robe pisolite to the south of the mine will not be directly affected by the proposal in terms of troglofauna, and would be assessed as 'Low' potential impact category.

3.3 Summary Evaluation

The available data suggest a low likelihood of trogofauna occurring in the subterranean habitats that would be affected by the Marandoo Phase 2 pit area (Section 3.1.6). The review of potential impact mechanisms indicates that the project has a 'High' potential impact level in regards to any troglobitic ecosystems present (see Section 3.2). Table 3.4 jointly considers these aspects to yield an overall assessment of the risk of impact to subterranean fauna associated with the proposal (following the framework provided by Table 2.1). Following the structure presented in Table 2.1 then, the proposal is consider to present a relatively low risk to troglobitic biodiversity values:

Table 3.4: Assessment of risk of impacts to troglobitic fauna presented by the Marandoo Mine Phase 2 project.

	Likelihood of troglofauna occurrence		
Overall Impact Category	Low †	Moderate ††	High / Definite †††
High *(impact score: 11)*	2		

† No records of subterranean fauna from within 5 km radius (giving consideration to sampling effort); and/or affected geological units unlikely to represent core subterranean fauna habitat).

†† Records of subterranean fauna from within 5 km radius (giving consideration to sampling effort), and/or affected geological units may represent core *subterranean* fauna habitat).

††† Known records of subterranean fauna from within 1 km radius (giving consideration to sampling effort), and/or affected geological units likely to represent core subterranean fauna habitat).

This assessment suggests that the Marandoo Mine Phase 2 project generally presents a 'Low' risk to troglobitic fauna. While the structure of Table 2.1 dictates that the pit component presents a 'Moderate' risk level due to its High impact score, the available data suggest it is unlikely that troglofauna occur in this part of the project area. Given these outcomes, a dedicated troglofauna sampling programme is not currently planned for this project.

The Mt Bruce Flats area, where troglobitic specimens were collected during earlier stygofauna work (Section 4.1), will not be disturbed as a result of the Marandoo Phase 2 extension. As this area is known to support troglofauna, any changes to the proposal or further investigations that indicate this area will be directly affected would elevate the risk level and trigger the requirement for more detailed surveys.

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4.0 Survey Results

4.1 Account of the Collected Fauna

Subterranean fauna were collected from just nine of the 64 bores sampled during the multiple phase study (14%; Table 4.1). Fauna collections were generally limited to the area extending north-east from the existing Marandoo mine into the Mt Bruce Flats area. No subterranean fauna were collected from the Southern Fortescue borefield during the 2008 sampling phase. The locations where fauna were collected are shown in Figure 4.2.

Table 4.1: Subterranean fauna collected from the Marandoo Mine Phase 2 locality, summarised by borehole ('indet.' = juvenile or damaged and unable to be morphologically determined).

Bore	Phylum	Class	Order	Family	Taxon	n	Total
OW10S	Crustacea	Malacostraca	Amphipoda	Paramelitidae	Genetic sp. A	1	
	Crustacea	Malacostraca	Amphipoda	Paramelitidae	Amphipoda indet.	5	
	Crustacea	Malacostraca	Amphipoda	Paramelitidae	Paramelitidae sp. 2	1	
	Crustacea	Malacostraca	Syncarida	Parabathynellidae	*Notobathynella* sp.	1	8
OW11I	Crustacea	Malacostraca	Amphipoda	Paramelitidae	Amphipoda indet.	1	1
OW11M	Crustacea	Malacostraca	Syncarida	Parabathynellidae	*Notobathynella* sp.	1	1
OW12S	Crustacea	Malacostraca	Amphipoda	Paramelitidae	Amphipoda indet.	4	
	Crustacea	Malacostraca	Amphipoda	Paramelitidae	Paramelitidae sp. 2	1	
	Annelida	Oligochaeta	Tubificidae		Tubificidae sp.	1	
	Crustacea	Copepoda	Cyclopoida	Cyclopidae	*Diacyclops humphreysi*	2	
	Crustacea	Copepoda	Cyclopoida	Cyclopidae	*Diacyclops* sp.	1	
	Crustacea	Copepoda	Cyclopoida	Cyclopidae	*Microcyclops varicans*	1	
	Crustacea	Malacostraca	Syncarida	Parabathynellidae	*Notobathynella* sp.	7	17
OW15S	Uniramia	Symphyla	Symphyla		Symphyla sp. *	1	
	Crustacea	Malacostraca	Syncarida	Parabathynellidae	*Notobathynella* sp.	3	
	Annelida	Oligochaeta	Tubificidae		Tubificidae sp.	2	
	Crustacea	Malacostraca	Amphipoda	Paramelitidae	Amphipoda indet.	5	11
OW28S	Crustacea	Malacostraca	Amphipoda	Paramelitidae	Genetic sp. A	5	
	Crustacea	Malacostraca	Amphipoda	Paramelitidae	Paramelitidae sp. 2	2	
	Crustacea	Malacostraca	Amphipoda	Paramelitidae	Amphipoda indet.	13	20
OW3	Platyhelminthes				Platyhelminthes sp.	2	2
OW30S	Crustacea	Malacostraca	Amphipoda	Paramelitidae	Amphipoda indet.	9	9
OW8S	Uniramia	Diplura	Diplura	Japygidae	?*Japyx* sp. *	1	1
					Total:	70	

* troglobitic specimens

Seventy specimens were collected during the field surveys, the majority of which were stygofauna (Table 4.1). Troglobitic fauna were collected from two bores (OW15S and OW8S), both of which are outside of the project footprint (see Section 4.2 and Figure 4.2). The two troglobites, a symphylan and a dipluran, have been submitted to the Western Australian Museum to assist in ongoing taxonomic efforts on this fauna. These records indicate that a troglobitic fauna community is probably more widespread in the Mt Bruce Flats area (see Section 2.2.1).

In order to place the collected stygofauna into context, a search was conducted of stygofauna records from the Department of Environment (DEC) Pilbara Biological Survey (PBS) (data kindly provided by Brad Durrant and David Cale of DEC) (see Appendix 2).

Crustaceans numerically dominated the collected fauna, and most of these were accounted for by the Amphipoda (47 of the total of 68 stygal specimens; 69%; Table 4.1). Amphipods were collected from six of the nine bores yielding subterranean fauna, covering the spatial extent of the records (Figure 4.2). All of the amphipod specimens belonged to the family Paramelitidae, but many of the specimens were not of sufficient maturity or intactness for any more detailed morphological identification to be made. A selection of the amphipod specimens were subject to genetic analysis as part of a regional study being completed by Dr Terrie Finston at the School of Animal Biology at the University of Western Australia. Mitochondrial DNA was successfully extracted, amplified and sequenced from specimens from two of these bores. This indicated that animals collected from both OW15S and OW28S (a distance of approximately 3.1 km) were the

same species (Figure 4.1). This is consistent with both the morphological identifications that could be completed (all Paramelitidae sp. 2; Table 4.1) and the outcomes of ongoing research indicating that most stygal amphipod species in the Pilbara are distributed across at least local surface water catchments (Finston et al. 2007).

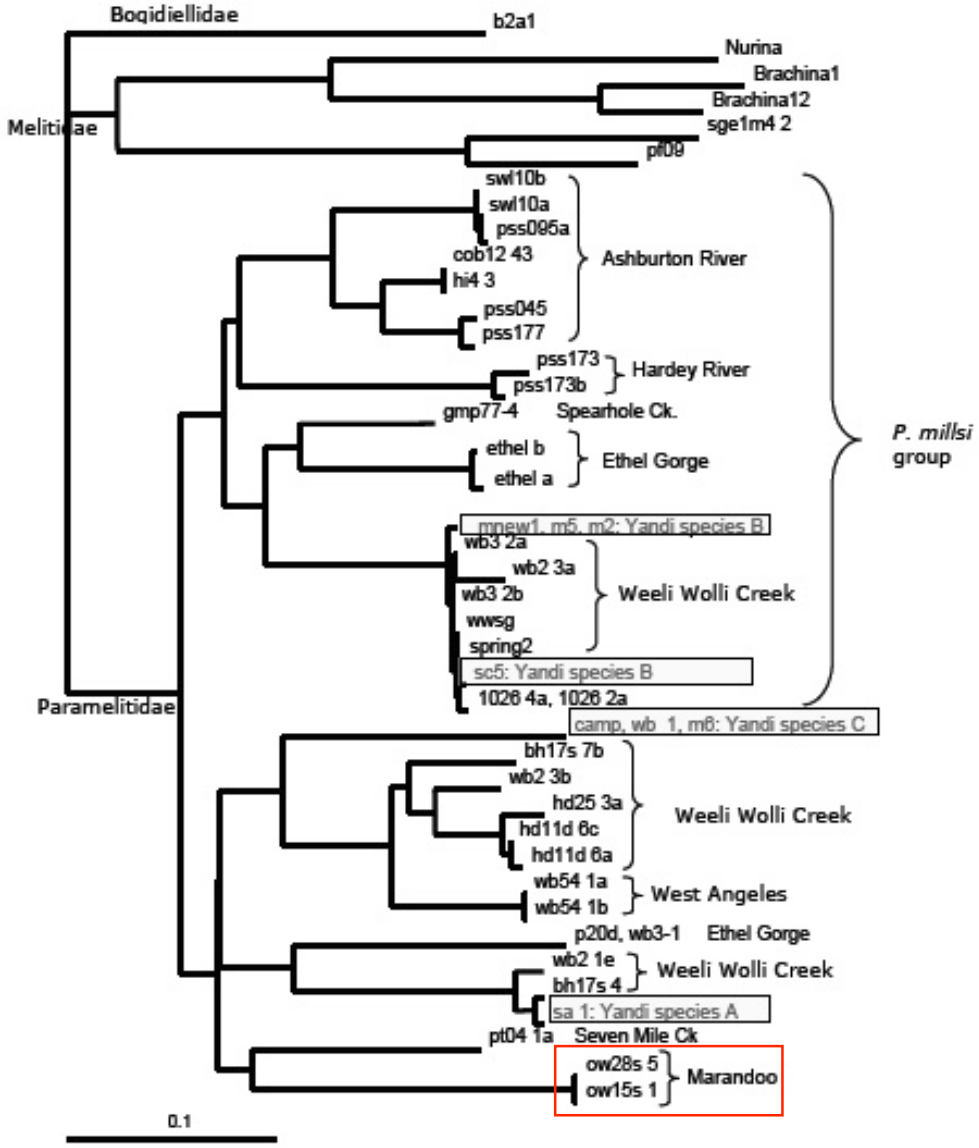

Figure 4.1: Phylogenetic tree showing relationship among amphipod collection sites at Marandoo, in context with other collections from the region (source: Finston et al. 2007).

Phylogenetic comparison of the Marandoo individuals with those collected from bores elsewhere in the Pilbara indicated that Marandoo amphipods are distinct from those collected elsewhere in the bioregion, and should be viewed as a separate genetic type, probably corresponding to a single species (Figure 4.1).

At least two species of copepod were collected during the Marandoo surveys, with a further specimen that could not be determined below genus level (Table 4.1). Both *Diacyclops humphreysi humphreysi* and *Microcyclops varicans* were also collected during the DEC PBS (Appendix 2), and have also been collected from further afield in the Pilbara region.

Twelve bathynellaceans were collected from four of the bores, all of which belonged to the genus *Notobathynella* (Table 4.1). These were all assigned to the same taxon '*Notobathynella* sp.' on a preliminary basis, and several other '*Notobathynella* sp.' records were made during the DEC PBS survey (see Appendix 2). It is unclear, however, whether the Marandoo specimens correspond to the other PBS collections from the Marandoo locality, and taxonomic work is currently continuing on this order.

The oligochaete and platyhelminth worms have not yet been determined to species level, but previous studies (Biota 2007b and 2008c), suggest that the risk of these worm taxa being restricted to an area the size of the current study is low.

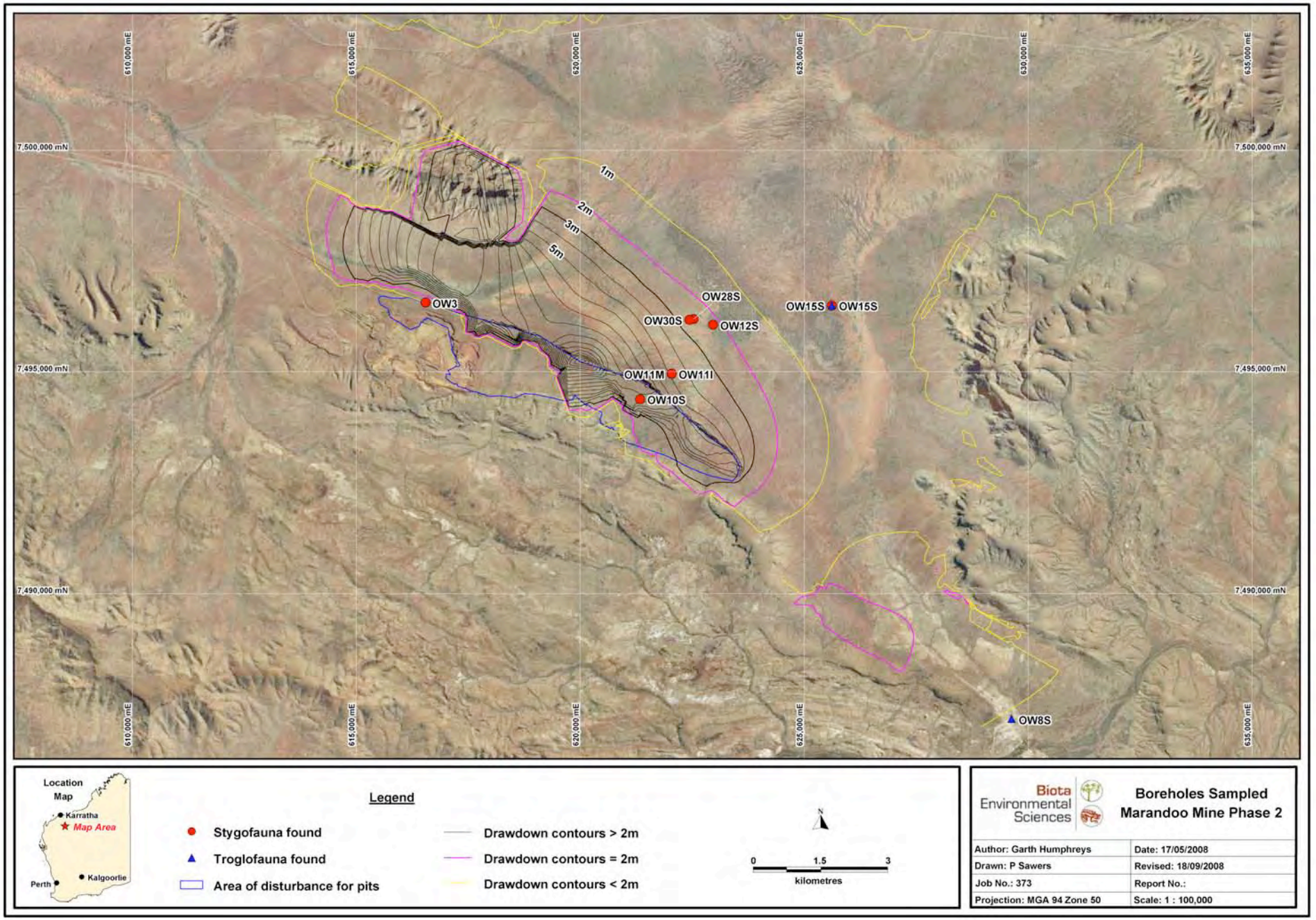

Figure 4.2: Locations where subterranean fauna were recorded during field surveys at Marandoo.

4.2 Distribution of Stygofauna at Marandoo

As stygofauna live in a three-dimensional habitat space, the distribution of this fauna must be considered both vertically and spatially for the purposes of impact assessment. Our ability to accurately document the true distribution of stygofauna is always limited by the potential for artefacts associated with borehole construction and other chance factors to affect sampling results. However, with several repeat phases of sampling (as is the case here), the effect of variation will be reduced, leading to improved confidence in observed distributions.

With the exception of site OW3 (where a single platyhelminth worm was collected; Table 4.1), stygofauna were reliably collected along a gradient north-east from the Marandoo Phase 2 pit area into the Mt Bruce Flats (Figure 4.2). Almost all of these records are situated outside of the modelled 2 m drawdown contour predicted for project dewatering (Figure 4.2).

A number of the borehole locations sampled at Marandoo were designed as nested shallow and deep bores. This arrangement provides for sampling of two bores in the same location, with one targeting the shallow aquifer and the second the deep aquifer (which will be dewatered for the project). Six of these were sampled over multiple phases

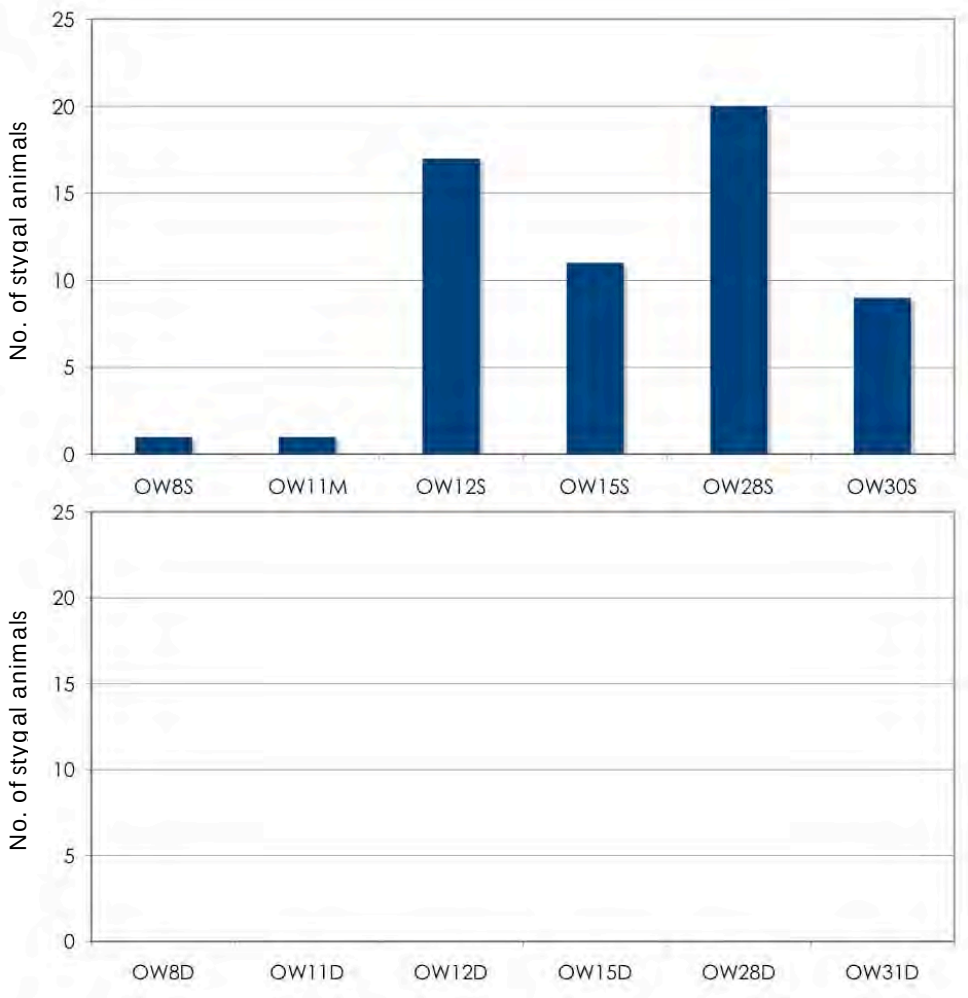

Figure 4.3: Comparison of stygofauna occurrence in bores targeting the shallow aquifer ('S' suffix) with bores targeting the deep aquifer ('D' suffix) at the same location at Marandoo.

The pattern in these results is reasonably clear: the stygofauna present in the Marandoo locality appears to be associated with the shallow aquifer, rather than the deeper aquifer. As these two groundwater systems are largely separated by a clay aquatard up to 40 m thick (Table 3.2), this finding has important implications for the assessment of dewatering impacts on stygofauna at Marandoo (Section 5.0).

5.0 Summary and Conclusions

A total of 70 specimens of subterranean fauna was collected from nine of the 64 bores sampled during the study. Eight stygal taxa (68 specimens) were collected over the sampling phases, and a summary of their distribution and wider status is provided in Table 5.1.

Table 5.1: Summary of stygal taxa collected from the Marandoo Mine Phase 2 project area (dewatering impact sites (> 2m drawdown) shown in red).

Taxon	Total n	Sites	Drawdown (m)	Comments
Paramelitidae sp. 2	4	OW10S OW12S OW28S	3m 2-3m 2-3m	Equivalent to specimens collected from the wider Marandoo locality during the DEC PBS – not restricted to the drawdown area
Paramelitidae sp. A	6	OW15S OW28S	<1m 2-3m	DNA analysis indicates that the same species occurs at these sites, but that amphipods from the Marandoo locality are distinct from those elsewhere in the Pilbara - represented inside and outside of the drawdown area
Amphipoda indet.	37	OW10S OW11I OW12S OW15S OW28S OW30S	3m 4m 2-3m <1m 2-3m 2-3m	Cannot be determined in any further detail due to the condition of the specimens. Based on the amphipod specimens that could be identified - unlikely to be restricted to dewatering impact pit area
Notobathynella sp.	13	OW10S OW11M OW15S	3m 4m <1m	Will not be determined in any further detail - unlikely to be restricted to impact area and - represented inside and outside of the drawdown area
Tubificidae sp.	3	OW12S OW15S	2-3m <1m	Will not be determined in any further detail - unlikely to be restricted to impact pit area
Diacyclops humphreysi	2	OW12S	2-3m	Described from elsewhere and collected from the wider Marandoo locality during the DEC PBS – not restricted to the impact area
Microcyclops varicans	1	OW12S	2-3m	Described from elsewhere and collected from the wider Marandoo locality during the DEC PBS – not restricted to the impact area
Platyhelminthes sp.	2	OW3	<2m	Will not be determined in any further detail - unlikely to be restricted to impact pit area

None of the bores sampled in the core impact area for the project yielded any subterranean fauna (Figure 2.1 and Figure 4.2). GIS analysis indicates that all the stygofauna records from this study were situated in areas predicted to experience 4 m or less of drawdown as a result of the project (Figure 4.2). In addition, the data indicate that the fauna occurs within the shallow aquifer, and the deep aquifer is the system that will primarily be affected by dewatering for the project (Liquid Earth 2005). While some local dewatering effects on the shallow aquifer are expected close to the pit itself, pump testing trials indicate the extent of this will be limited and the shallow groundwater systems of the Mt Bruce Flats will experience less than a metre of drawdown (Liquid Earth 2005); well within natural seasonal fluctuations (Batini 2008). It therefore appears unlikely that any species of stygofauna would be placed at risk as a result of the project, or that widespread affects on stygofauna habitats and populations in the locality will result from the planned dewatering.

No stygofauna were collected from the South Fortescue borefield area, which is proposed as recipient site for groundwater reinjection for the project. It is likely that the stresses placed on this aquifer as a result of long-term abstraction for water supply have already affected any fauna that may been present, or compromised opportunities to collect them from the available bores. The main potential impact, if a stygal community still persists in this area, would be in regard to any differences in water chemistry between the dewatering area and the South Fortescue borefield. Water quality data indicate that there is negligible difference in water chemistry between the areas. Given this, it is possible that the recovery in groundwater levels that should result from the reinjection may lead to an increase in potential stygofauna habitat at South Fortescue.

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6.0 References

Batini, F. (2008). Marandoo Phase 2 Proposal – Mining Below Water Table Summary. Unpublished report prepared for Pilbara Iron, Perth.

Biota Environmental Sciences (2002). Exmouth Limestone Project Troglobitic Fauna Sampling Programme Phase III. Unpublished report prepared for Exmouth Limestone, Perth.

Biota Environmental Sciences (2004). Hope Downs Rail Corridor Extension - Hamersley Range, Terrestrial Fauna Survey. Unpublished report for Hope Downs Management Services, Perth.

Biota Environmental Sciences (2006). Mesa A and Robe Valley Troglofauna Survey. Unpublished report prepared for Robe River Iron Associates, Perth.

Biota Environmental Sciences (2007a). Mesa K Remnant Mining Project Troglofauna Survey. Unpublished report prepared for Robe river Iron Associates, Perth.

Biota Environmental Sciences (2007b). Hope Downs Project Subterranean Fauna Assessment. Unpublished report for Pilbara Iron, Perth.

Biota Environmental Sciences (2008a). Marandoo Mine Phase 2 Subterranean Fauna Sampling Plan. Unpublished report prepared for Pilbara Iron, Perth.

Biota Environmental Sciences (2008b). Maret Islands Ichthys Gas Project Subterranean Fauna Assessment. Unpublished report for Inpex, Perth.

Biota Environmental Sciences (2008c). Bungaroo Trial Pit Project Subterranean Fauna Assessment. Unpublished report for Pilbara Iron, Perth.

Danielopol, D., M. Creuze des Chatelliers, F, Moeszlacher, P. Pospisil and R. Popa. (1994). Adaptation of Crustacea to Interstitial Habitats: A practical agenda for ecological studies. In: (J. Gibert, Danielopol, D.L. and Stanford, J.A. eds.) *Groundwater ecology*. Academic Press: San Diego, California.

Environmental Protection Authority (2003). Sampling of fauna from Groundwater and Caves for Environmental Impact Assessment. EPA Guidance Statement 54., EPA, Perth.

Environmental Protection Authority (2007). Sampling considerations for collecting subterranean fauna for Environmental Impact Assessment. Draft EPA Guidance Statement 54a. EPA, Perth.

Finlayson, R. I. and T. A. McMahon (1988). Australia vs. the World: A comparative analysis of streamflow characteristics. In Warner, R.F. (Ed.), *Fluvial Geomorphology of Australia*. Academic Press, Sydney.

Finston, T. and Johnson, M.S. (2004). Geographic patterns of genetic diversity in subterranean amphipods of the Pilbara, Western Australia. Marine and Freshwater Research 2004. 55:619-628.

Finston T, Johnson MS, Humphreys, WF, Eberhard and Halse SA (2007). Cryptic speciation n two widespread subterranean amphipod genera reflects historical drainage patterns in an ancient landscape. Molecular Ecology 16: 355-365.

Gibert, J., Stanford, J.A., Dole-Olivier, M.-J. and Ward, J.V. (1994). Basic attributes of groundwater ecosystems and prospects for research. In: (J. Gibert, Danielopol, D.L. and Stanford, J.A. eds.) Groundwater ecology. Academic Press: San Diego, California.

Harvey, M.S. (1988). A new troglobitic schizomid from Cape Range, Western Australia (Chelicerata: Schizomida). *Records of the Western Australian Museum*, 14(1): 15-20.

Harvey, M.S. (2002). Short-range endemism among the Australian fauna: some examples from non-marine environments. *Invertebrate Systematics*, 16: 555-570.

Humphreys, W.F. (1993), Cave Fauna in Semi-Arid Tropical Western Australia: A diverse relict wet-forest litter fauna. *Memoires de Biospeologie*, Tome XX: 105-110.

Humphreys, W.F. (1991). Experimental reactivation of pulse driven populations in a terrestrial troglobite community. *Journal of Animal Ecology*, 60: 609-623

Humphreys, W.F. (1999). Relict stygofaunas living in sea salt, karst and calcrete habitats in arid northwestern Australia contain many ancient lineages. In: *The other 99%. The conservation and biodiversity of invertebrates*. Ed W. Ponder and D. Lunney Transactions of the Royal Zoological Society of New South Wales, Mosman. Pp.219-227

Humphreys, W.F. (2000). The Pilbara stygofauna: a synopsis. Unpublished report to the Water and Rivers Commission, March 2000.

Humphreys, W.F. (2001). The subterranean fauna of Barrow Island (Northwestern Australia). *Memoires de Biospeologie (International Journal of Subterranean Biology)*, 28 2001.

Humphreys, W.F. and Adams, M. (1991). The subterranean aquatic fauna of the North West Cape peninsula, Western Australia. *Rec. West. Aust. Mus*. 15(2): 383-411.

Liquid Earth (2005). Marandoo Hydrogeological Investigation Report, unpublished report prepared for Pilbara Iron.

Marmonier, P., Vervier, P., Gibert, J. and Dole-Olivier, M.J. (1993). Biodiversity in groundwaters. *TREE* 8(11): 392-395.

Pilbara Iron (2008a). *Marandoo Mine Phase 2 Project, Draft Environmental Scoping Document.* Prepared by Pilbara Iron, Perth.

Pilbara Iron (2008b). *Marandoo Mine Tail Pit, Section 45c Application.* Prepared by Pilbara Iron, Perth.

Sket, B. (1999). The nature of biodiversity in hypogean waters and how it is endangered. *Biodiversity and Conservation* 8: 1319-1338.

Strayer (1994). Limits to Biological Distributions in Groundwater. In: (J. Gibert, Danielopol, D.L. and Stanford, J.A. eds.) *Groundwater ecology*. Academic Press, California.

Watts, C.H.S. and Humphreys, W.F. (1999). Three new genera and five species of Dytiscidae (Coleoptera) from underground waters in Australia. *Rec. South Aust. Mus* 32: 121-142.

Appendix 1

Details of Historical Subterranean Fauna Sampling (Phases I – VI) at Marandoo

Appendix 1: Details of historical subterranean fauna sampling at Marandoo. Sampling was conducted between September 1999 and May 2003. Information for each bore*time combination includes: whether the bore was visited, if it was successfully sampled, and whether stygofauna (stygo) was collected. Bore locations are provided in AGM, zone 50, WGS84 datum.

	Location		September 1999			November 2000			June 2001			April 2002			July 2002			May 2003		
Bore	Easting	Northing	visited	sampled	stygo	visited	sampled	stygo	visited	sampled	stygo	visited	sampled	stygo	visited	sampled	stygo	visited	sampled	stygo
OW2	616866	7497145	√	√		√	√	n	√	√	n	√	√	n				√	√	n
OW3	616548	7496564	√	√		√	√	n	√	√	n	√	√	n				√	√	y
OW6	625794	7496091	√	√		√	√	n	√	√	n	√	√	n						
OW7	627165	7489344	√	√		√	√	n	√	√	n									
OW7S	627165	7489344	√	√		√	√	n				√	√	n						
OW8D	629629	7487170	√	√		√	√	n	√	√	n	√	√	n						
OW8S	629629	7487170	√	√	y	√	√	n	√	√	y	√	√	y						
OW9	616898	7497607	√	√		√	√	n	√	√	n	√	√	n				√	√	n
OW10I	621335	7494380																√	n	
OW10S	621335	7494380	√	√	y	√	√	n	√	√	n							√	√	y
OW11D	622040	7494953	√	√		√	√	n	√	√	n	√	√	n	√	√	n			
OW11I	622041	7494956	√	√		√	√	y				√	√	n						
OW11M	622044	7494959	√	√		√	√	y	√	√	n				√	√	n			
OW11S	622044	7494959	√	x		√	x		√	√	n	√	√	n						
OW12D	622967	7496061	y	√		y	√	n	√	√	n	√	√	n	√	√	n			
OW12S	622967	7496065	√	√	y	√	√	y	√	√	n	√	√	n	√	√	n			
OW13	610794	7499178	√	√		√	√	n	√	√	n									
OW15D	625615	7496494	√	√		√	√	n	√	√	n	√	√	n						
OW15S	625615	7496494	√	√		√	√	y	√	√	y	√	√	y	√	√	y	√	√	n
OW19	621556	7494587	√	√		√	√	n												
OW20	621178	7493698	√	√	n	√	√	n	√	√	n	√	√	n				√	√	n
OW21D	617761	7496184																√	√	n
OW21S	617760	7496190																√	√	n
OW22S	618781	7495864																√	n	
OW23D	620205	7494857																√	n	
OW23I1	620205	7494857																√	n	
OW23I2	620205	7494857																√	n	
OW23S	620212	7494850																√	√	n
OW24I	622728	7493529																√	n	
OW24S	622734	7493523																√	√	n
OW25D	621806	7494919																√	n	
OW25I	621806	7494919																√	n	
OW25S	621797	7494920																√	√	n
OW26D	622555	7494528																√	√	n
OW26I	622555	7494528																√	√	n

	Location		September 1999			November 2000			June 2001			April 2002			July 2002			May 2003		
Bore	Easting	Northing	visited	sampled	stygo	visited	sampled	stygo	visited	sampled	stygo	visited	sampled	stygo	visited	sampled	stygo	visited	sampled	stygo
OW26S	622561	7494532																√	√	
OW27D	622557	7495515																√	√	n
OW27I	622557	7495515																√	n	
OW27S	622553	7495516																√	√	n
OW28D	622522	7496192																√	√	n
OW28I	622522	7496192																√	n	
OW28S	622528	7496193																√	√	y
OW29D	622647	7496162																√	√	n
OW30S	622436	7496173																√	√	y
OW31D	617703	7495842																√	√	n
OW32D	618171	7495836																√	n	
OW33D	617881	7494987																√	n	
OW34D	618647	7494662																√	n	
OW35D	621777	7493380																√	√	
OW36D	622305	7493059																√	√	n
OW36S	622292	7493034																√	√	
PW2Iron			√	√	n	√	√	n	√	√	n	√	√	n						
PW12	622938	7496052	√	√	n	√	√	n	√	√	n	√	√	n	√	√	n			
PW20	621386	7493827	√	√	n	√	√	n	√	√	n	√	√	n				√	√	n
RCB2						√	√	n												
TIB1	622431	7496173																√	√	n
TIB1A	622436	7496175																√	√	n
TPB1	617763	7496145																√	√	n
TPB2	618775	7495868																√	n	
TPB3	620028	7494832																√	√	n
TPB4	621296	7494412																√	√	n
TPB4AB	621299	7494418																√	n	
WARP9						√	√	n	√	√	n									
WARP9(2)									√	√	n									

Appendix 2

Stygofauna Records from the DEC Pilbara Biological Survey from the Marandoo Locality

Order	Family	Identification	Site	Date	latitude deg	latitude min	longitude deg	longitude min
Amphipoda	Paramelitidae	Paramelitidae sp. 2 (PSS)	Warp2	16/10/04	22	25	117	51
Amphipoda	Paramelitidae	Paramelitidae sp. 2 (PSS)	Warp2	25/9/05	22	25	117	51
Amphipoda	Paramelitidae	Paramelitidae sp. 2 (PSS)	Warp2	11/5/05	22	25	117	51
Amphipoda	Paramelitidae	Paramelitidae sp. 2 (PSS)	Warp2	21/11/02	22	25	117	51
Amphipoda	Paramelitidae	Paramelitidae sp. 2 (PSS)	Warp2	6/4/03	22	25	117	51
Amphipoda	Paramelitidae	Paramelitidae sp. 2 (PSS)	Warp2	19/5/04	22	25	117	51
Amphipoda	Paramelitidae	Chydaekata sp.	Warp2	19/5/04	22	25	117	51
Amphipoda	Paramelitidae	Paramelitidae sp. 2 (PSS)	Karajini	15/10/04	22	33	118	27
Amphipoda	Paramelitidae	Pilbarus millsi	Tom Price North	27/7/03	22	37	117	53
Amphipoda	Paramelitidae	Paramelitidae sp. 2 (PSS)	Tom Price North	27/7/03	22	43	117	52
Amphipoda	Paramelitidae	Paramelitidae sp. 2 (PSS)	Tom Price North	18/10/04	22	43	117	52
Amphipoda	Paramelitidae	Pilbarus millsi	Hamersley Station	19/5/04	22	27	117	45
Amphipoda	Paramelitidae	Paramelitidae sp. 2 (PSS)	RCB18	11/5/05	22	46	118	18
Copepoda	Cyclopidae	Mesocyclops brooksi	Warp2	25/9/05	22	25	117	51
Copepoda	Cyclopidae	Diacyclops humphreysi humphreysi	Warp2	19/5/04	22	25	117	51
Copepoda	Cyclopidae	Microcyclops varicans	Karajini	15/10/04	22	33	118	27
Copepoda	Canthocamptidae	Canthocamptidae	Karajini	15/10/04	22	33	118	27
Copepoda	Cyclopidae	Diacyclops humphreysi humphreysi	Tom Price North	27/7/03	22	37	117	53
Copepoda	Diosaccidae	Schizopera sp.	Tom Price North	27/7/03	22	37	117	53
Copepoda	Parastenocarididae	Parastenocaris jane	Tom Price North	27/7/03	22	37	117	53
Copepoda	Cyclopidae	Diacyclops humphreysi humphreysi	Tom Price North	27/7/03	22	43	117	52
Copepoda	Cyclopidae	Microcyclops varicans	Hamersley Station	19/5/04	22	27	117	45
Ostracoda	Cyprididae	Cypretta sp. 1 (PSS)	Hamersley Mount Bruce Road	6/4/03	22	30	117	57
Ostracoda	Cyprididae	Cypretta sp. 1 (PSS)	Hamersley Mount Bruce Road	21/11/02	22	30	117	57
Ostracoda	Candonidae	Areacandona 'ake' (PSS)	Tom Price North	27/7/03	22	37	117	53
Ostracoda	Candonidae	Candonidae	Tom Price North	18/10/04	22	43	117	52
Ostracoda	Candonidae	Origocandona cf. 'inanitas' (PSS)	Tom Price North	27/7/03	22	43	117	52
Syncarida	Parabathynellidae	Notobathynella sp.	Warp2	6/4/03	22	25	117	51
Syncarida	Parabathynellidae	Notobathynella sp.	Warp2	16/10/04	22	25	117	51
Syncarida	Parabathynellidae	Notobathynella sp.	Warp2	19/5/04	22	25	117	51
Syncarida	Parabathynellidae	Notobathynella sp.	Warp2	21/11/02	22	25	117	51
Syncarida	Parabathynellidae	Notobathynella sp.	Warp2	11/5/05	22	25	117	51
Syncarida	Parabathynellidae	Notobathynella sp.	Karajini	15/10/04	22	33	118	27
Syncarida	Bathynellidae	Bathynella sp.	Karajini	15/10/04	22	33	118	27
Tubificida	Phreodrilidae	Phreodrilidae	Hamersley Mount Bruce Road	6/4/03	22	30	117	57
Tubificida	Phreodrilidae	Phreodrilus linnae (ms name) = WA27	Hamersley Mount	21/11/02	22	30	117	57

Order	Family	Identification	Site	Date	latitude deg	latitude min	longitude deg	longitude min
		(PSS)	Bruce Road					
Tubificida	Phreodrilidae	Phreodrilid with dissimilar ventral chaetae	Warp2	6/4/03	22	25	117	51
Tubificida	Phreodrilidae	Phreodrilid with dissimilar ventral chaetae	Warp2	19/5/04	22	25	117	51
Tubificida	Phreodrilidae	Phreodrilid with dissimilar ventral chaetae	Warp2	25/9/05	22	25	117	51
Tubificida	Phreodrilidae	Phreodrilid with dissimilar ventral chaetae	Warp2	11/5/05	22	25	117	51
Tubificida	Phreodrilidae	Phreodrilid with dissimilar ventral chaetae	Karajini	27/7/03	22	33	118	27

Resource Development, Technical Projects

Marandoo Phase II spring and gorge water assessment

August 2008

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1. Introduction

Riotinto Iron Ore are investigating the feasibility of extending the current above watertable Marandoo iron ore mine to below watertable to extend mine life and supply Marra Mamba lump and fines to support its Pilbara blend product. Mine planning is yet to be finalised but preliminary investigations suggest a lowering of the groundwater table by up to 120m in the vicinity of the mine is required for effective and safe extraction of the iron ore. Dewatering would be affected by conventional vertical bores with down hole submersible pump systems.

The mine site is located on an excised lease surrounded to the north and south by the Karijini National Park (KNP). The KNP is a popular tourist destination and provides sanctuary for the Pilbara region biodiversity. A particular attraction for the estimated 100,000 visitors per year is the scenic, perennial water filled gorges in the north of the park. Thus there is sensitivity to any dewatering operation within the vicinity of the KNP to ensure unacceptable impacts do not affect the natural amenities of the park.

This report provides a brief summary of conceptual modes of occurrence for the perennial water sources in the KNP that have social and cultural heritage associated with them. The models were developed after two field visits to KNP, one in October 2007 and another in July 2008. These models require validation by measurement of relative levels and potentially on going monitoring. However, given the sensitive nature and location, conventional groundwater monitoring points, such as bores or stream gauging constructions, are unlikely to be acceptable. Thus a program to understand the natural waters chemistry and relate that to source rocks of the area has been proposed to support the conceptual modes of occurrence. This work will be conducted through late 2008/09.

This report is organised into a brief description of the area, its physiography, climate, geology and hydrogeology. This summary allows for the synthesis of various models of occurrence; however it is to be stressed these models are conceptual and require validation through monitoring and further analyses. The summary is followed by a diagnostics table with specific detail about the spring or gorge and the mode of occurrence for those sites where access was readily available to investigate.

2. Physiography

This area comprises the most prominent hills in Western Australia in Mt Bruce over 1200m AHD, Mt Oxer, Mt Vigors and Mt Frederick all over 1100m AHD. Mt Bruce lies to the north of Marandoo mine and to the west of Mt Bruce Flats. The major topographic features have resulted from differential erosion of gently folded and northward dipping Proterozoic basement.

The area comprising Marandoo mine straddles an ill defined, yet significant catchment divide between two major drainages of the Pilbara, the north draining tributaries to the Fortescue drainage basin and the southern draining tributaries of the Ashburton drainage basin. Recent analysis by RTIO (Beckett, 2008) has determined the flat lying internal draining Mt Bruce Flats will flow to the Ashburton drainage system via the southern draining Turee Creek sub drainage. However, during significant events where the Mt Bruce surface water levels fill beyond a certain level owing to intense rainfall; surface flow may also over top the western margin of the flats south of Mt Bruce and contribute to the

Fortescue basin via the Southern Fortescue tributary. All the major drainages on the higher peneplain are largely ephemeral.

To the north of Mt Bruce Flats lies a prominent east-west ridge of the Hamersley range that directs all surface flow on the north side to the north and towards the series of gorges within the KNP. Surface water south of this ridge flows to Mt Bruce Flats. South of Marandoo are two small catchments that have breached the ridge and also direct flow to the Mt Bruce Flats.

The low lands between ridges are dominated by early Tertiary plains that in places have been rejuvenated, particularly in the north, where drainage courses deeply dissect the Tertiary plains and underlying basement creating spectacular gorges. Within these gorges perennial surface flow over several to tens of kilometres is common as a result of groundwater discharge.

3. Climate

The climate is semi arid to arid with a sub-tropical distribution in rainfall. That is the regions wet season is associated with summer rains from December to March and is usually driven by rain bearing lows or tropical cyclones. Rainfall is measured at nearby Wittenoom, comprising records since 1950's, with a long term annual average of 460mm. Mean pan evaporation for Wittenoom is reported as 8.7mm/day for an annual total of 3177mm by the Bureau of Meteorology web site.

4. Geology

The stratigraphy of the area comprises Proterozoic rocks of the Hamersley Province overlain by widely distributed Cainozoic rocks and soils. The significant units to Marandoo/KNP area are summarised in Table 1.

Table 1 Stratigraphic Summary of Karijini National Park

		Formation / Member	Description
Cainozoic		Quaternary	Alluvium / Colluvium
		Tertiary - Tertiary Detritals (TD)	
		TD3	-High matrix zone (silty gravel) -Oakover Formation[1]
		TD2	-Channel Iron deposit (CID)[1] / indurated goethitic clay -Calcrete
		TD1	-Clay -Pisoliths and silty clay
Lower Proterozoic	Hamersley Group	Boolgeeda Iron Formation[3]	Jaspilite, siltstone, shale and BIF
		Woongarra Volcanics[3]	Lavas, pyroclastic rocks and BIF
		Weeli Wolli Formation	Jaspilite and shale
		Brockman Iron Formation[2] - Yandicoogina Shale Member - Joffre Member - Whaleback Shale Member - Dales Gorge Member	 Shale and BIF BIF with minor shale bands Interbedded shale, chert and BIF Interbedded BIF and shale
		Mt McRae Shale	Graphitic and chloritic shales interbedded with BIF
		Mt Sylvia Formation	Shale, dolomite and BIF bands
		Wittenoom Formation[1] - Bee Gorge Member - Paraburdoo Member[1] - West Angela Member	 Argillaceous sediments (shale, mudstone, siltstone, marl) Dolomite- some karstic, minor chert and argillite Dolomite and shaley dolomite, manganese-rich, with minor BIF and chert bands
		Marra Mamba Iron Formation - Mount Newman Member[2] - MacLeod Member - Nammuldi Member	 BIF with thin shale bands BIF with extensive interbedded shales and "podded" BIF horizons Cherty BIF with occasional shale bands
	Fortescue Group	Jeerinah Formation - Roy Hill Shale Member - Warrie Member - Woodiana Member	 Shale with some dolomitic shale. Carbonaceous and pyritic Chert, quartzite, shale and jaspilite. Pyrite cubes Silicified mudstone, shale, siltstone, chert, quartzite and tuff
		Bunjinah Formation (Maddina Basalt - Chichester Range)	Metabasaltic flows and breccia
		Pillingini Tuff	Bedded tuffs, shales, siltstones and sandstone
		Kylena Basalt	Altered basic and intermediate lavas (locally porphyritic)
		Cliff Springs Formation - Lyre Creek Agglomerate Member	Acid tuff, tuffaceous shale, sandstone, greywacke, conglomerate Bedded to massive agglomerate and tuff
		Mt Roe Basalt	Altered vesicular, columnar and massive basic lavas with distinct porphyritic flows and basal sandstone.

5. Field Program

Two field programs have been conducted, one to familiarise and plan the subsequent trip, the latter to collect water samples, take field chemistry (EC, pH and Temperature) and surface flow measurements where practical. A TPS Handheld WP-81 pH-Cond-Salinity metre was used to measure the electrical conductivity (EC), water temperature and pH. The metre was calibrated using a standard 12.88mS/cm solution and pH buffer solutions prior to use.

A handheld FP201 Global Water flow probe was used to measure average surface flow velocity to within one tenth of a metre/sec across a section. The width and depth of the mid point of each section was measured and the average flow velocity used to calculate stream discharge. In some cases the cross sections were deemed as inverted triangles, elsewhere the blocky nature of the BIF allowed for a flat bottomed assumption in calculating the flow area. As this process was some what arbitrary, the flow measurements presented in this report are indicative only.

In total 17 water samples were collected from different sites, including one duplicate sample, and sent for laboratory analysis of major ions, TDS & TSS. The results were not available at the time of compilation of this report.

The location of sample sites visited during the 2007 and 2008 field trips, in relation to Marandoo, are presented in Figure 1. Detailed locations are presented in subsequent Figures 2-4. A summary of field surface flow measurements from July 2008 is provided in Table 2.

Table 2. Surface flow measurements

Site*	Section Length (m)	Section depth (cm)	mean velocity (m/sec)	Flow (m^3/sec)	Flow (L/sec)	Flow (m^3/day)
Hamersley 1	0.20	7	0.70	0.0098	9.8	847
Hamersley 2	0.10	9	0.64	0.0058	5.8	498
Dales 1	1.30	3	0.39	0.0152	15.2	1314
Fortescue 1	2.30	18	0.13	0.0538	53.8	4650
Fortescue 2	1.60	13	0.19	0.0395	39.5	3415
Kalamina 2	1.20	5	0.21	0.0126	12.6	1089
Joffre 2	0.85	6	0.37	0.0189	18.9	1630
Weano 2	0.19	14	0.15	0.0039	3.9	336
Weano 3	0.40	2	0.64	0.0051	5.1	442
Hancock 2	0.81	4	0.67	0.0217	21.7	1876

**For location coordinates see Table 3.*

A summary of field EC, pH and Temperature from July 2008 is provided in Table 3. Preliminary filed chemistry (EC and pH) has demonstrated significant differences in the water types that support technical arguments for different sources of origin of groundwater at Marandoo and the majority of spring or gorge waters. Water chemistry has been used to support planning for an environmental isotope survey of the ground and surface waters of KNP for comparison with the groundwater of the Marandoo ore body aquifer. The water chemistry for each site is provided in Appendix B.

Table 3. Field chemistry data

Site	Description	Date	GPS mE	GPS mN	Flow measure	Field EC (uS/cm)	Field pH	Temp (^{o}C)	Water samples	Comments
Banjima Pool	banjima pool; ponded surface water in creek line	23/07/2008	623183	7490609	No flow	118	7	9.7	banjima	sheltered from sun; ~1m deep, ~5m long, ~3m wide; pool with green algae, high watermarks roughly 0.7m from waterlevel
Mindthi Spring	mindthi spring; likely groundwater fed pool in creek line	23/07/2008	629720	7486480	No flow	1628	7.6	17	mindthi	small pool in riverbed gravel, surrounded by date palm; white NaCl or NaCO3 staining lines cut off bank of creek.
Hamersley 1	hamerlsey gorge; surface flow	23/07/2008	601718	7538298	Yes	870	8.4	15.9	hamersley #1	white $CaC0_3$ staining evident along bedding planes of Bee Gorge Member BIF
Hamersley 2	hamerlsey gorge; surface flow 100m upstream of hamersley #1	23/07/2008	601645	7538273	Yes	891	7.8	16.3	No	
Circular Pool 1	dales gorge; groundwater issuing from bedded Dales Gorge Member	24/07/2008	660714	7513745	No	580	6.5	19.6	No	groundwater sample seeping from wall rock of bedded Dales Gorge Member
Circular Pool 2	dales gorge; groundwater issuing from bedded Dales Gorge Member	24/07/2008	660714	7513745	No	583	6.78	21.7	Circular pool	groundwater sample seeping from wall rock of bedded Dales Gorge Member
Circular Pool 3	dales gorge; ponded groundwater	24/07/2008	660714	7513745	No	583	7.9	11.6	no	Ponded water in circular pool
Dales 1	dales gorge; surface water in gorge; ~200m downstream of circular pool	24/07/2008	660788	7513582	Yes	544	8.4	6.8	no	flowing stream; 611mRL ±15m
Fortescue 1	fortescue falls; surface water downstream of falls	24/07/2008	660218	7513526	Yes	790	8.4	8.9	no	
Fortescue 2	fortescue falls; surface water at head of falls	24/07/2008	659512	7513464	Yes	778	7.79	14.5	no	
Fern Pool 1	fern pool; ponded surface water in pool	24/07/2008	659278	7513508	No	786	7.8	14.9	Fern pool	could not get any higher to source of flow
Fern Pool 2	groundwater discharge from wall near fern pool; top of Dales Gorge Member?	24/07/2008	659273	7513508	No	739	6.5	20.3	no	small tributary from north side of gorge running out of crack within chert bed

Table 3. Field chemistry data

Site	Description	Date	GPS mE	GPS mN	Flow measure	Field EC (uS/cm)	Field pH	Temp (°C)	Water samples	Comments
Kalamina 1	kalamina gorge; headwaters of surface flow, likely Tertiary groundwater	24/07/2008	643658	7519341	No flow	1216	7.44	14.1	Kalamina #1	area where paperbarks first appear in creek line; 674mRL ±6m, small pools in creek bed.
Kalamina 2	kalamina gorge falls surface flow	24/07/2008	644395	7520285	Yes	893	8.3	11.7	Kalamina #2	Mixed surface flow from upper Tertiary waters and lower bedded BIF groundwaters
Kalamina 3	Kalamina falls groundwater seepage from bedded BIF	24/07/2008	644395	7520285	No	556	8.24	15	Kalamina #3	on west side of bank, adjacent & downstream of falls; groundwater seep as evidenced by higher temperature and lower EC.
Joffre 1	Joffre Falls tributary; ponded water downstream of road culvert	25/07/2008	630163	7521398	No flow	1211	7.34	6.7	Joffre #2	678mRL ±4m
Joffre 2	Joffre Falls; surface water at head of falls	25/07/2008	630530	7521398	Yes	2217	8.13	6.4	joffre falls #1; joffre falls #2	algae apparent; duplicate sample taken
Joffre 3	Joffre Falls rocky pool	25/07/2008	630530	7521398	No	8679	8.67	7.6	no	ponded salty pools adjacent to flowing stream; salt crust around pools
Weano 1	Weano gorge, upstream extent of surface flow attainable	25/07/2008	632282	7527650	No	260.4	7.08	11.8	Weano #1	orange algae pool, oily stain on surface, some minor flow; floor of gorge had bedded Joffre Member with goethite infilled bedded planes
Weano 2	Weano gorge, surface flow	25/07/2008	632495	7527278	Yes	275	7.52	7.1	no	
Weano 3	Weano gorge, surface flow	25/07/2008	632658	7526863	Yes	297	7.69	8.2	Weano #2	
Weano 4	Weano gorge, groundwater seepage upstream of Handrail pool	25/07/2008	632528	7527158	No	304	7.65	11.9	Weano #3	groundwater seeping from bedded Joffre Member just upstream of handrail pool
Hancock 1	Hancock stream	25/07/2008	628860	7527380	No	409	6.84	8	hancock stream	taken from just upstream of road crossing, algae filled pool; flow across road <2L/sec
Hancock 2	hancock gorge, surface flow	25/07/2008	632313	7526901	Yes	274	7.77	11.7	hancock #2	rapid surface flow in gorge
Hancock 3	hancock gorge, surface flow	25/07/2008	631204	7526656	No	276.7	7.88	8.7	hancock #3	rapid surface flow in gorge just downstream of Kermits pool
Windmill	windmill	25/07/2008	628270	7520557	Not possible	2132	6.58	21.8	windmill #1	on west side of banjima drive before dales gorge turn-off; 696mRL ±7m

6. Hydrogeology

Groundwater occurs in Tertiary detritus sediments and bedded Hamersley Group Formations across the Karijini National Park. Whilst the Tertiary detritus comprise both loosely consolidated alluvium, colluvium and indurated chemical (calcrete/goethitic) sediments that act predominantly as sedimentary aquifers, the Hamersley Group bedded formations are distinctly fractured rock aquifers.

Other than Marandoo, there is very limited bore or groundwater level information within the area. Watertable levels at Marandoo range between 678 and 685m RL from mineral exploration hole dipping and regional temporal monitoring of the bore network. Groundwater level monitoring has also occurred consistently at Southern Fortescue Borefield since at least 1998, although earlier data must also occur in hard copy reports. Groundwater levels here vary between 620 to 600m RL, however pre pumping groundwater levels were originally around 660 to 640m RL in early 1970.

Groundwater levels can be inferred from surface pools within drainage lines where evidence that the pools are groundwater fed is apparent (visual evidence, higher water temperatures, salt or $CaCO_3$ crusts on walls and seepage faces). Generally the regional watertable upstream of the gorges is in the order of 680m RL. Where the topographic drainage intersects this 680m RL groundwater occurs in small pools which turn to surface flow further downstream. Within the gorges and downstream (to the north) the regional groundwater table will vary dependent on the gorge floor topography. Generally, gorge water levels occur between 650 and 600m RL, decreasing to the north towards the Fortescue valley. Whilst most of the drainage lines on the higher planes comprise ephemeral streams (losing streams) the gorges of the KNP are gaining streams (groundwater dependent) based on measured surface flow data, visual anecdotal evidence and water temperature measurements.

Groundwater quality is predominantly fresh within the Hamersley Group formations owing to the significant depth to the regional watertable and minimal opportunity for evapotranspiration and evaporation within the gorges (despite the climate). Groundwater from the larger Tertiary catchments, such as those of Joffre Falls and Fern Pool, are more brackish, as regional watertable are near surface to support some groundwater dependent ecosystems (E. Victrix, E. Camaldelensis, and Melaleuca). However, small Tertiary catchment areas such as those above Hancock and Weano gorges also contain fresh groundwater within the Tertiary sediments, probably owing to shorter flow lengths of smaller catchments.

7. Modes of occurrence for springs and pools

All springs and gorge pools identified occur within natural drainage lines. Generally the pools occur where the local topography has intersected the regional watertable and thus groundwater discharge occurs and the sites are generally groundwater dependent, with the exception of Banjima Pool. The rate of discharge of groundwater varies according to the host rock of the drainage and the topographic gradient.

A table summarising the key characteristics from each pool or gorge visited is provided in Appendix 1.

8. Potential for impacts from dewatering

To understand the potential for groundwater abstraction from the Marandoo ore body aquifer (nominally Marra Mamba Iron Formation, Wittenoom Formation and lower Tertiary

detritus of the Mt Bruce Flats) to impact the gorges and springs of the KNP the sources of groundwater for each perennial flow system need to be documented. The potential for connection between these groundwater sources and Marandoo groundwater will then be discussed.

The source of water for each flow system is described in detail in Appendix A, based on a conceptual mode of occurrence for each gorge/spring. These 'conceptual models' are supported by one or several of the following; visual evidence, water chemistry, hydrologic measurement (surface flow), geology and physiography of the catchments.

The following is a brief summary of the source of water for each flow system, for detailed supporting evidence, the reader is referred to Appendix A and B.

Hamersley Gorge is supported by groundwater discharge from Tertiary sediments and Wittenoom Formation basement where the Southern Fortescue River has eroded below the 580m RL level.

Hancock Gorge is supported by groundwater discharged from Tertiary sediments above the gorge where Hancock Creek has eroded below the 700m RL. Surface flow increases downstream for several kilometres and is supported by further groundwater discharge from preferential flow paths (bedding planes, joints and faults) in the Joffre Member of the Brockman Iron Formation.

Weano Gorge is supported by groundwater discharged from the Joffre Member of the Brockman Iron Formation where the Weano Creek has eroded below the 660m RL. Surface flow increase occurs downstream via visible groundwater discharge from preferential flow paths (bedding planes, joints and faults) in the Joffre Member of the Brockman Iron Formation.

Joffre Falls is supported by groundwater discharge from Tertiary sediments to the south of the falls in several drainage lines eroded below the 680m RL. It is not known if flow increases downstream of the falls (not able to be measured) but it is likely, as wet areas could be seen associated with bedding planes, joints and faults in the Joffre Member of the Brockman Iron Formation which makes up the walls of the gorge.

Kalamina Gorge is supported by groundwater discharge from Tertiary sediments to the south of the falls in Kalamina Creek where it has eroded below the 680m RL. Surface flow increases occur downstream via groundwater discharge from preferential flow paths (bedding planes, joints and faults) in the Joffre Member of the Brockman Iron Formation.

Fern Pool is supported by groundwater discharge from Tertiary sediments upstream of the pool. The approximate elevation is ill determined as access was not possible. Downstream of the pool perennial surface flow increases through groundwater discharge from the Dales Gorge Member of the Brockman Iron Formation.

Circular Pool is supported by groundwater visibly discharging along bedding planes in the Dales Gorge Member of the Brockman Iron Formation at approximately 635m RL.

Mindthi Spring (also known as Minthicoondunna) is supported by groundwater discharge from a near surface calcrete aquifer that has been eroded along a section of a river bank of a tributary to the Turee Creek drainage system. Salt scolds (evaporation of discharge) are evident along the extent of the calcrete bank, however the spring occurs

only in two small pools and maybe a result of preferential flow paths in the calcrete or historical anthropogenic influences (the spring is located with adjacent date palms that 'Afghan' camel trainers were thought to introduce to the Pilbara at water holes).

Banjima Pool is a surface water supported pool in a small south bound tributary behind Marandoo ridge. The pool elevation is approximately 705m RL which is ~25m above the local groundwater table.

The potential for hydraulic connection between the Marandoo ore body aquifer and the various spring and gorge groundwater systems is discussed below.

- The ore body aquifer is generally more than 30km's distant from any of the gorge groundwater systems limiting the potential for impact owing to the lateral extent.

- The ore body aquifer is associated with basement rocks older in the geological sequence. These rocks are overlain by low permeability shale, BIF & chert basement rocks relative to the gorge basement rocks in an area with a relatively gentle dip to the north. For example, the gorge groundwater is issuing from elevations greater 600m RL; whereas the Wittenoom Formation outcrops to the at the edge of the Fortescue valley around 470m RL. The Marra Mamba Iron Formation must therefore be below 470m RL at least.

- The Joffre Falls, Kalamina Gorge and Fern Pool are fed from groundwater discharging from Tertiary sediments that overlie the Brockman Iron Formation. There is no physical connection between these Tertiary sediments and the Tertiary sediments of the Mt Bruce Flats i.e. they are separated by significant basement highs.

- Circular Pool is fed from groundwater derived from groundwater flow to the south within the Dales Gorge Member (i.e. groundwater is flowing to the pool from the opposite direction to Marandoo, which lies to the south).

- The water chemistry of the Hancock and Weano Gorges is considerably fresher than the Marandoo groundwater and bears no relation to it.

- The water chemistry of the Tertiary sediments overlying the Brockman Iron Formation in the north of KNP is impacted by evapotranspiration, is saturated in calcite and is unrelated to Marandoo groundwater.

- Banjima Pool is too fresh to be derived from groundwater and is dependent on accumulated surface flow and rainfall in a catchment that will not be impacted by proposed mining activity.

There are two exceptions, Hamersley Gorge, which is fed from groundwater that is connected to an upper catchment area (to the south) where the Southern Fortescue Borefield (SFB) is operated. Groundwater abstraction from the SFB is conducted to meet water supply demand at Tom Price, and is unrelated to Marandoo. Adjacent to pumping bores in the SFB groundwater levels have been drawn down by 30-40m since pumping began in 1970. Within regional monitoring bores several kilometres distal from the abstraction centre the watertable has been draw down by 5-10m. However, there is insufficient historical information to determine whether abstraction related draw down at SFB has had any negative impact on groundwater discharge to Hamersley Gorge, which lies a further 15km down gradient. The Marandoo BWT project will review opportunities to either "rest" or actively re-inject into the SFB using surplus dewatering water from Marandoo to meet supply to Tom Price.

The other exception is Mindthi Spring. Mindthi Spring is thought to be associated with the watertable and near surface calcrete aquifer. The western limit of the calcrete thought to support the spring is roughly 3 km from the proposed BWT eastern pit edge. Although dewatering does not target the surface aquifer; a portion of this aquifer within the pit area will be mined and removed creating a hydraulic gradient in the upper watertable towards the pit edge. This has the potential reverse flow direction over time and carries the risk of capturing groundwater flow in the southeast towards Mindthi Spring and directing it back to the open pit. This will largely be dependent on the hydraulic properties of the upper Tertiary sediments in this area and the length of mining (and thus active dewatering) period. The absence of the clay would increase the risk of impacts occurring at the spring. Mindthi Spring is sufficiently distant that any impacts may take considerable time to manifest; however this risk will persist for the life of BWT mining and beyond until the watertable has recovered to pre-mining levels, particularly if the mode of occurrence proves correct (i.e. the spring is supported by groundwater flow in the calcrete).

Figure 1. General location of gorges and water sites with respect to Marandoo

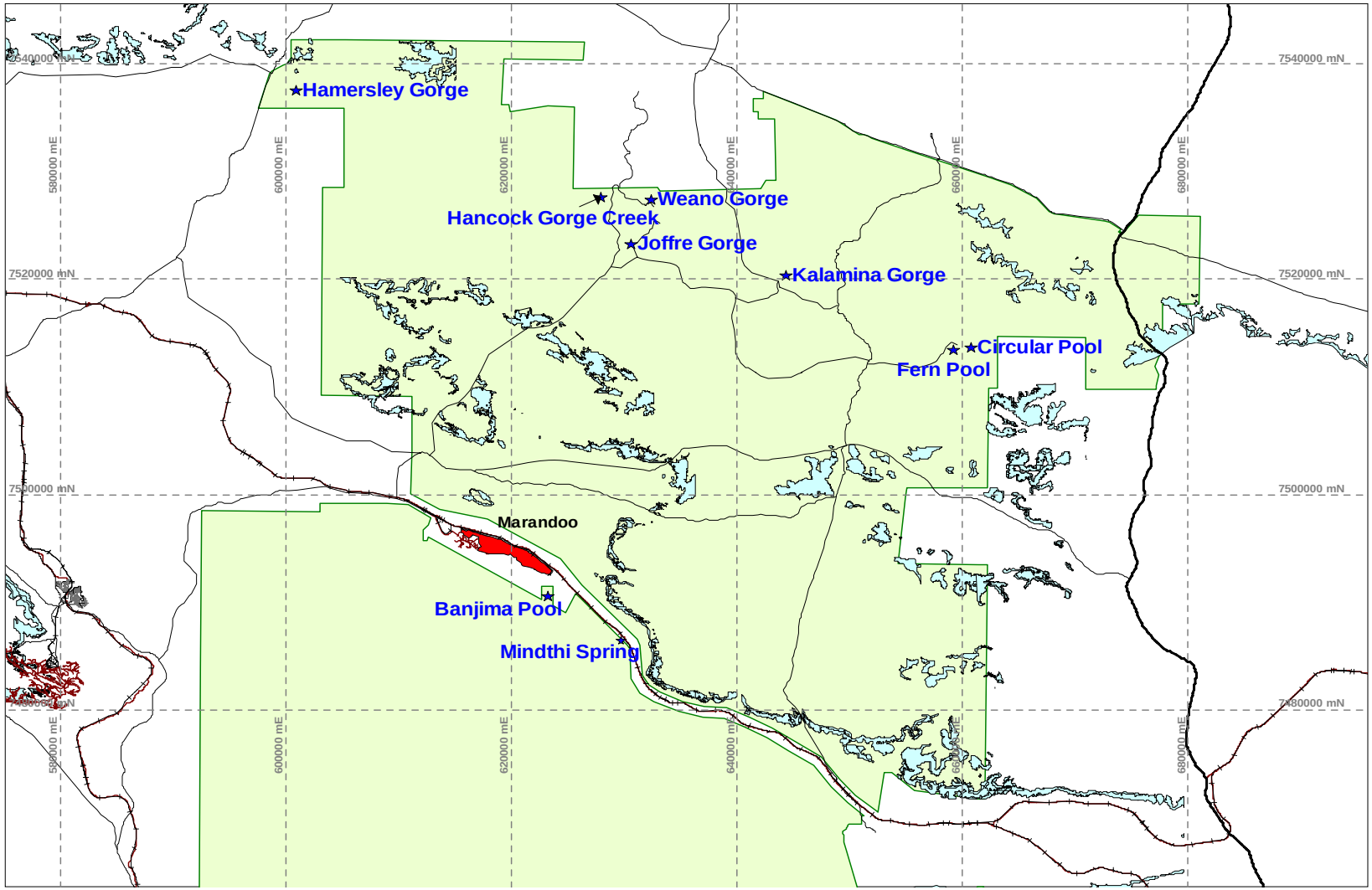


Figure 2. Dales Gorge site sampling locations

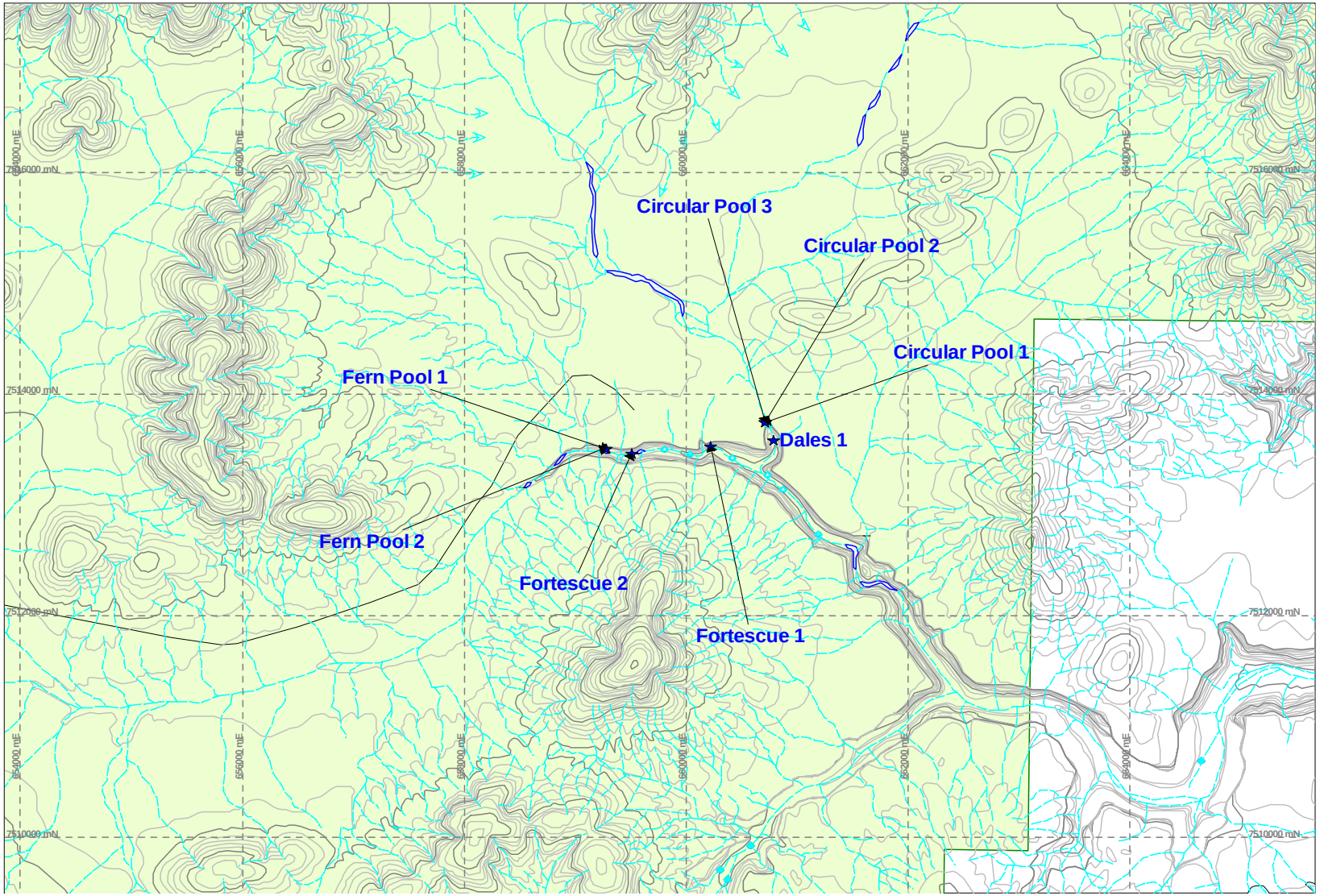


Figure 3. Central Gorges site sampling locations

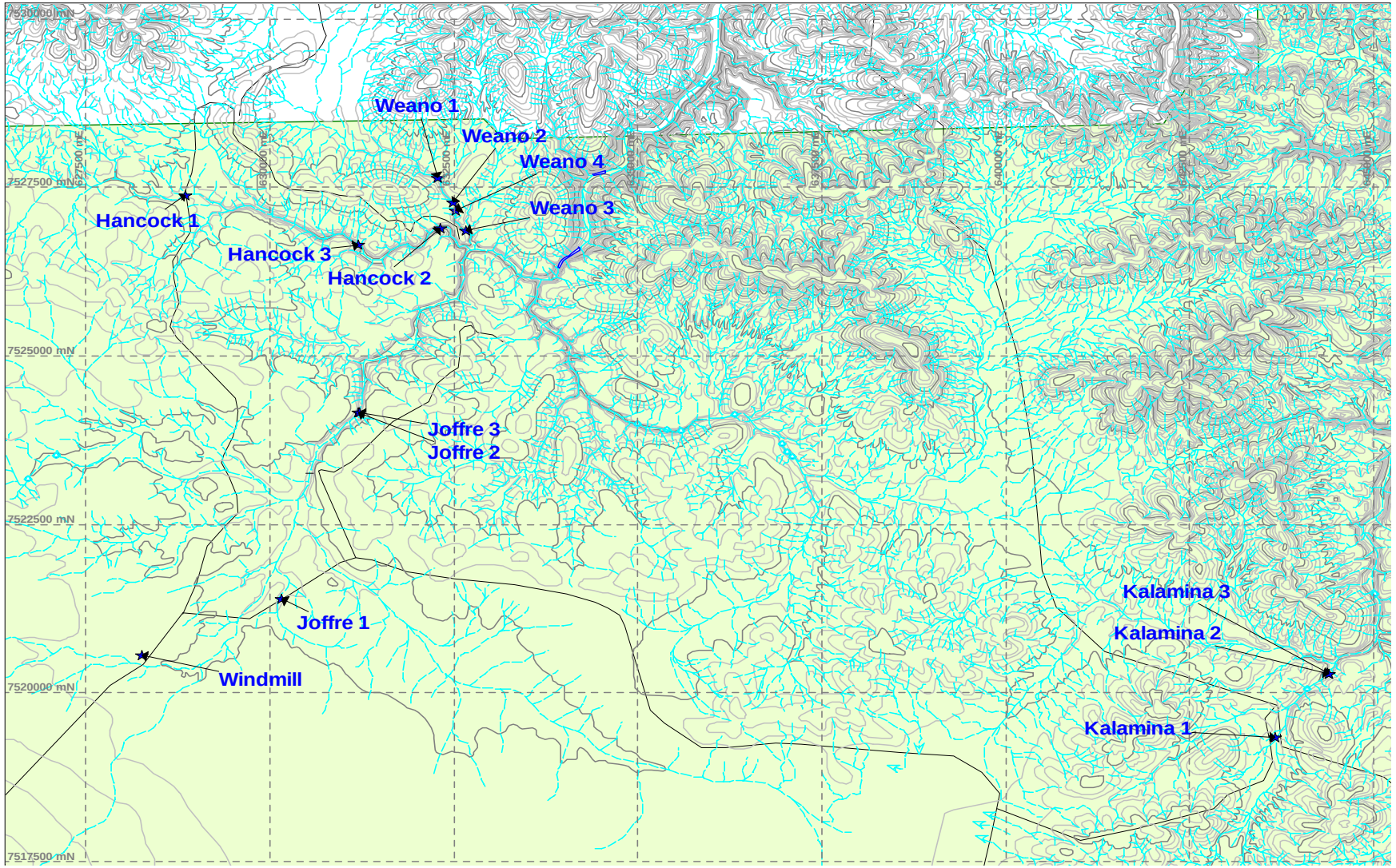
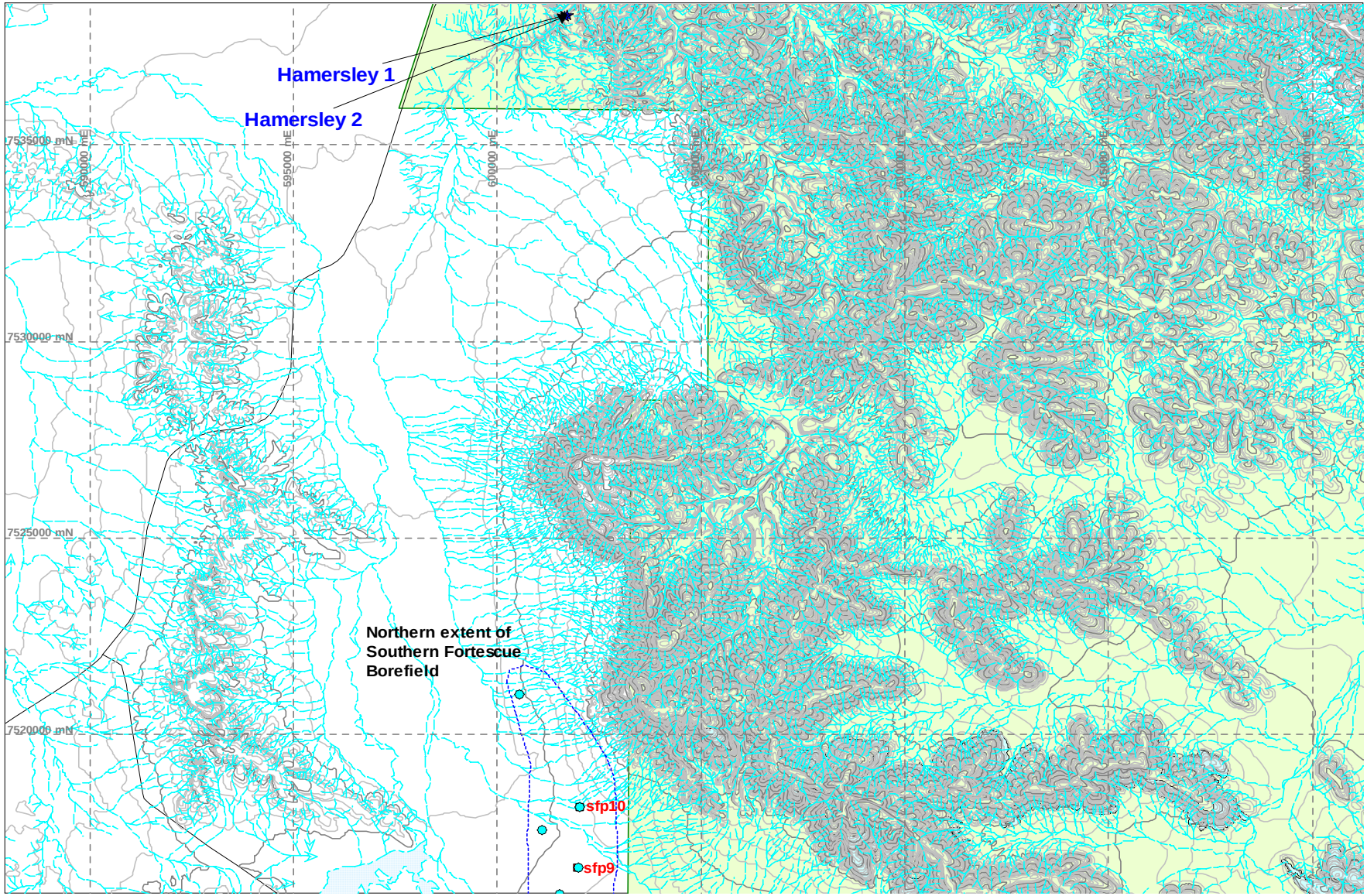


Figure 4. Hamersley Gorge sample locations and Southern Fortescue borefield



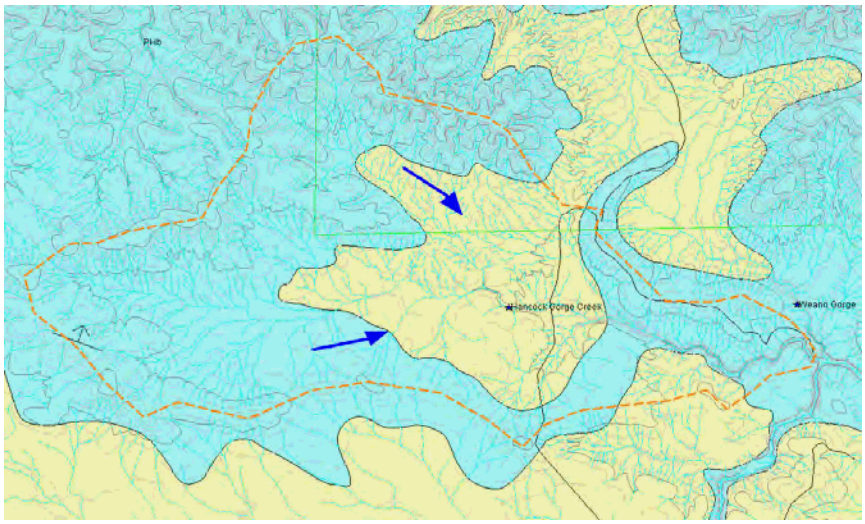
Appendix A. Water Diagnostics Tables

Site	Hamersley Gorge
Classification	Perennial groundwater fed falls and pools
GDA94 Reference	50,601,610mE, 7,538,370mN (Car park at Gorge)
Location	Hamersley Gorge is located inside Karijini National Park approximately 45km north northwest of Marandoo on the Southern Fortescue River, a tributary to the Fortescue River catchment
RL of groundwater discharge	~580m RL from 1:50,000 digital topography & based on observation of upper limit of dense phreatophytic vegetation on field visit in Oct 2007.
Catchment Area	Approximately 920 km^2
Water Quality	Measured 24th July 2007 at 800-900uS/cm. Uncompensated TDS is approximately 490mg/L. Water temperature was in the order of 16^{o}C, atypical of groundwater derivation, and pH was between 7.8 and 8.4. Groundwater EC in SFB ranged between 700 and 900 uS/cm in 2007 and is typically hard (>200mg/L).
Flow	Measured using a hand held flow probe at 0.8ML/day. Flow increasing downstream.
Geological Setting	Gorge cuts through geothitic Tertiary gravely clays and the top of the Bee Gorge Member shales and base of surface flow lies on the Main Tuff Interval (MTI) of Simonson, et, al.
Hydrogeological Setting	Groundwater flow direction is generally north northeast sub parallel with the regional drainage pattern of the Southern Fortescue drainage. Upstream of the gorge is one of the Tom Price town water supply borefields known as Southern Fortescue Borefield (SFB). Groundwater abstraction at SFB began in 1972. Groundwater recharge to the area is anticipated via direct infiltration from incident rainfall, indirect recharge from overland surface flow and via throughflow from up gradient (namely Mt Bruce Flats) where groundwater levels indicate groundwater flow to the northwest. Groundwater discharges from the system via groundwater throughflow and discharge to surface flow and evapotranspiration at the Hamersley Gorge where vegetation with groundwater dependence occur. Incident rainfall recharge over the upper catchment area (including the SFB borefield) assuming an effective catchment of 160km^2 and 0.5% of annual rainfall gives recharge of 1000m^3/day, roughly equivalent to measured flow at the gorge. Current groundwater levels within regional monitoring bores in the SFB range between 620 to 600m RL in the south. Overall groundwater levels have been

	drawn down roughly 50m since 1970. AGC (1985) predicted that groundwater abstraction of 13,000m^3/d would be sustained through the depletion of storage within the wellfield. Since 1998, groundwater levels have stabilised suggesting either a recharge boundary or continued expansion of the extent of the cone of drawdown across a wider area than currently monitored. Ephemeral drainage with alluvium gravel to the west of and parallel to the borefield represents a potential recharge boundary if saturated.
	  Photo 1. Bee Gorge Member shale in outcrop with surface pools on MTI at Hamersley Gorge (Vegetation with groundwater dependence occur upstream for a further ~1km). **Photo 2**. Mature Cajeput near upstream limit of perennial flow, Hamersley Gorge (~580m RL).
References	***AGC Pty Ltd***, 1985, Tom Price Water Supply Review of Long Term Capacity. ***SIMONSON, B.M., HASSLER, S.W. and SCHUBEL, K.A.***, 1993, Lithology

	and proposed revisions in stratigraphic nomenclature of the Wittenoom Formation (Dolomite) and overlying formations, Hamersley Group, Western Australia: Western Australia Geological Survey, Report 34, Professional Papers, p.65-79.

Site	**Hancock Gorge**
Classification	Perennial groundwater fed river bed pools that fed into gorge
GDA94 Reference	50,631,440mE, 7,526,410mN (approximate mid point of gorge)
Location	Hancock Gorge is located inside Karijini National Park approximately 34km north of Marandoo mine site on small a tributary to the Fortescue River catchment.
RL of groundwater discharge	~700m RL from 1:50,000 digital topography & based on observation of surface flow in upper stream reach above Hancock Gorge in Oct 2007.
Catchment Area	Approximately 30km^2
Water Quality	Upstream of the gorge EC of ponded water was 410uS/cm; further downstream as flow increased EC in the gorge was in the order of 275uS/cm. pH varied between 6.8 and 7.8, whilst water temperatures where bn 7 and 11^{o}C.
Flow	Surface flow was measured using a hand held flow probe at 1.8ML/day upstream of Kermits Pool. At the upstream road crossing surface flow was not measured owing to low flow; but indicatively was less than 0.2ML/day (1-2L/sec)
Geological Setting	Gorge cuts through Tertiary colluvium over lying Joffre Member of the Brockman Iron Formation, Hamersley Group.
Hydrogeological Setting	Upstream of Hancock Gorge lies a small surface catchment with saturated Tertiary colluvium overlying relatively low permeability Joffre Member basement. Incident rainfall and run-off that percolates into the Tertiary sediments infiltrates down to the top of the relatively impermeable Joffre Member BIF; where groundwater flow is then intercepted by Tertiary drainage. Groundwater discharges to surface drainage and low flow can be seen upstream of the gorge proper at <5L/sec. Downstream within the gorge groundwater contribution from the bedded Joffre Member is indicated by decreasing EC and increasing surface flow. Surface water is first visible in the upstream tributary to Hancock Gorge at roughly ~700m RL. Limited groundwater level information or knowledge of the thickness of the Tertiary outcrop is available to estimate storage, throughflow or discharge. However based on the effective catchment area upstream of the gorge with Tertiary cover (15km^2) and assuming recharge of 3% of annual rainfall; groundwater discharge to the upstream drainage would be in the order of 500m^3/day (~5L/sec). The measured increase in surface flow within the gorge indicates that up to 0.6ML/km is contributed to surface flow from the bedded Joffre Member through the gorge. The reduction in EC downstream also indicates that groundwater within the Joffre member is fresher than the Tertiary groundwater and that

	evaporation from Hancock gorge is minimal.  Fig 1. Hancock Gorge catchment (Blue: BIF; Yellow: Tertiary colluvium after 1:250,000 geology map).
	  Photo 1. Groundwater discharge to streambed in Tertiary colluvium upstream of Hancock Gorge. Flow continues downstream to support pool levels in Hancock Gorge. Vegetation comprising bulrushes & Cajuputs indicative of the relative permanency of pools.
References	**de la Hunty, L. E**., 1965, 1:250,000 Mt Bruce Geological Sheet; Geological Survey of Western Australia,.