5. Stakeholder consultation

Community and stakeholder consultation for mining at Nammuldi-Silvergrass has occurred since 1998. Submissions from agencies and non-government organisations on the CER were used to identify relevant issues that have been addressed in the preparation of this PER. These submissions provided an opportunity to identify stakeholder issues and enabled a more focussed consultation program for the Expansion Proposal.

Consultation specifically for this Expansion Proposal commenced in August 2009.

5.1 Identification of stakeholders

Key stakeholders were identified through Rio Tinto's ongoing activities in the region and long-term stakeholder liaison regarding Nammuldi-Silvergrass:

Government Agencies

- Office of the Environmental Protection Authority (OEPA)
- Department of Environment and Conservation (DEC)
- Department of Water (DoW)
- Department of State Development (DSD)
- Department of Mines and Petroleum (DMP)
- Department of Indigenous Affairs (DIA)
- Department of Regional Development and Lands (RDL)
- Pastoral Lands Board
- Department of Health (DoH)
- Shire of Ashburton
- Department of Agriculture and Food (DAF).

Community

- Eastern Guruma people
- Puutu Kunti Kurrama & Pinikura people
- Kuruma Marthudunera people
- Mt Stuart Pastoral Station.

5.2 Form and timing of consultation undertaken

Consultation for the Expansion Proposal comprised meetings, telephone conversations and site visits with key stakeholders and occurred prior to the submission of the PER (Table 14). Regular scheduled meetings were held with both government agencies and Traditional Owner groups. Site visits with the OEPA and DMP were conducted in October 2010, Eastern Guruma in May 2011 and DoW in August 2011.

Rio Tinto has an Indigenous Land Use Agreement (ILUA) with the Eastern Guruma group and has included this group in ongoing consultation.

Table 14 Stakeholder consultation undertaken for the Expansion Proposal to date

Date	Department / Organisation	Type	Purpose
Apr 1998 - ongoing at Jan 2012	Eastern Guruma	Aboriginal Heritage Surveys	Recording and assessment of archaeological and ethnographic sites.
Nov 2006 – May 2008	Puutu Kunti Kurrama & Pinikura	Aboriginal Heritage Surveys	Recording and assessment of archaeological and ethnographic sites.
Aug 2009 – Nov 2010	DSD	Monthly meetings	Part IV approvals, Tenure, Heritage surveys, dewatering, potential heritage impacts.
Aug 2009 – Nov 2010	DMP	Monthly meetings	Progressing clearances for leases, Applications for tenure.
Nov 2008	Eastern Guruma	Indigenous land Use Agreement Monitoring & Liaison Quarterly Meeting	Overview of proposed expansion
May 2009	Eastern Guruma	Indigenous land Use Agreement Monitoring & Liaison Quarterly Meeting	Project update
Dec 2009	Eastern Guruma	Indigenous land Use Agreement Monitoring & Liaison Quarterly Meeting	Planned surveys, dewatering and surplus water management, and Rio Tinto Indigenous Employment, Training and Enterprise programs.
Quarterly 2010	Eastern Guruma	Indigenous land Use Agreement Monitoring & Liaison Quarterly Meeting	Project update
Mar 2010	Mt Stuart Pastoral Station	Email correspondence	Contact to arrange creekline surveys on Mt Stuart Station
Apr 2010	Puutu Kunti Kurrama & Pinikura	Puutu Kunti Kurrama & Pinikura Local Implementation Committee	BS4 Mine and Nammuldi BWT, including proposed water supply pipeline from Nammuldi BWT to BS4
Late 2010	DEC, DoW, DMP	-	Provision of referral supporting document.
Aug 2010	OEPA	Meeting	Overview of proposal, discussion of key environmental factors, discussion of level of assessment.
Sep 2010	DEC Ecological Management Branch (EMB), DEC Science Division and DEC Nature Conservation Branch (NCB)	Meeting	Overview of existing approvals and operations, outline of key issues.
Sep 2010	DoW Pilbara, DEC Industrial Assessment Branch (Pilbara)	Meeting	Overview of project, discussion of concerns and PER requirements, explanation of water volume changes and surplus water management options.
Oct 2010	OEPA and DMP	Site visit	Site visit to view B2, Nammuldi and Silvergrass area, described proposal, layout and orebody details of dewatering and surplus water management.
Nov 2010	Eastern Guruma	Meeting	Discussion of forward planning for the involvement of the Eastern Guruma group in the proposed dewatering process.

Date	Department / Organisation	Type	Purpose
Nov 2010	DEC EMB, DEC NCB	Quarterly update meeting	Discussion of timelines, layout optimisation, accommodation strategy, dewatering and surplus water management and BS4 water supply.
Mar 2011	DEC EMB, Science Division	Meeting	Discussion of surplus water strategy, with detailed explanation of the proposed irrigated agriculture. Results presented for discharge modelling for Caves, Duck and Boolgeeda Creeks. Update on fauna issues and results of Biota studies.
Mar 2011	Pastoral Lands Board	Phone calls	Discussion of proposed program of geotechnical investigations for irrigated agriculture.
Mar 2011	OEPA	Comments regarding first ESD draft	Changes to document structure and figures were suggested. Discussion of further consultation requirements.
Mar 2011	DEC NCB	Meeting	Discussion of surplus water management strategy, dewatering requirements. Outlined the details of irrigated agriculture including weed management and closure planning.
Mar 2011	DoW	Meeting	Discussion of surplus water management strategy, previous reinjection and infiltration trials and the groundwater section of the ESD.
Mar 2011	Shire of Ashburton	Meeting	Overview and status of Expansion Proposal
Mar, Apr and Nov 2011	Mt Stuart Pastoral Station	Email/letter correspondence Phone call	Contact to arrange creekline surveys on Mt Stuart Station
Apr 2011	OEPA	Comments regarding ESD	Changes required with regards to irrigated agriculture
May 2011	DoW	Meeting	Discussion of current status of hydrogeological modelling and an overview of surplus water management strategy.
May 2011	Eastern Guruma	Site visit	Search for Aboriginal Heritage site Yantinha, possible location identified. Discussion of dewatering, water discharge to Duck Creek and the Irrigated Agriculture Area. DVD outlining the proposal was provided to allow a greater proportion of the Eastern Guruma Group to be informed.
May 2011	Mt Stuart Pastoral Station	Information sent (meeting was organized however organisation did not attend).	Overview of Expansion Proposal. Dewatering and surplus water discharge, including surface water quality monitoring, biological surveys and access to Mt Stuart station for monitoring. Irrigated agriculture.
May/June 2011	Eastern Guruma Puutu Kunti Kurrama & Pinikura	Provided with DVD	Nammuldi Silvergrass stakeholder consultation DVD April 2011

Date	Department / Organisation	Type	Purpose
	Kuruma Marthudunera		
	OEPA		
	DMP		
August 2011	DoW	Site visit	Inspection of Proposal Boundary with Rio Tinto hydrogeological team
October 2011	DMP	Meeting	Closure planning and waste characterisation

5.3 Stakeholder comments and responses of proponent

The key issues raised by stakeholders related to potential impacts on:

- Aboriginal heritage sites – particularly Palm Springs
- surface water and groundwater quality and quantity
- creeklines and riparian vegetation
- vegetation and flora and fauna (including subterranean fauna and short-range endemics and faunal linkages)
- effects of dust on cracking clays at TEC
- AMD
- health related to water supply and use, and wastewater treatment.

Rio Tinto has responded to the issues raised by stakeholders and these issues are addressed in this PER (Table 15).

Table 15 Key topics raised during stakeholder consultation

Stakeholder	Topics raised	Proponent response
Government agencies		
OEPA	Request further information on non-acid mobilisation of metals such as selenium and cadmium.	The potential for mobilisation of metals such as selenium and cadmium is discussed in Section 12.2.1.
	Prefer AMD testing to be conducted up front. Asbestiform material requires a management plan. Request for further details of regional context of AMD investigations.	Results from testing for AMD are discussed in Section 12.2.1. Fibrous Material Management Plan included in Appendix 3.
	Request that consultation be expanded to include Local Government and Department of Indigenous Affairs.	Consultation undertaken to date is shown in Table 14.
DMP	Discussion of need for weed management for the Irrigated Agriculture Area. Requests that crop species be considered carefully and a weed management program developed. Also discussion of potential for the discharge of surplus water to spread weeds along the creek system.	A description of the irrigated agriculture project is discussed in Section 3.3.11. Weed management for the Irrigated Agriculture Area is addressed in the AEMP (Appendix 3). Riparian vegetation and weed communities present are discussed in Section 9.2.4.
DoW	Require life of mine water balance in PER. Queries whether mine can be rescheduled to neutralise the water balance.	A description of the water balance for the life of mine can be found in Section 3.3.11. Information on options relating to the scheduling of mining and dewatering is discussed in Section 4.6.

Stakeholder	Topics raised	Proponent response
	Need to define clearly the options considered for management of surplus water and to provide reasons for selection or dismissal.	Alternatives considered for surplus water management are discussed in Section 4.2.
	Discharge to irrigated agriculture preferred over discharge to creeks. Where discharged to creeks occurs, multiple discharge points are preferred.	The discharge of surplus water to irrigated agriculture and to creeks is discussed in Section 8.4.2. Alternatives considered for surplus water management are discussed in Section 4.2.
	Require details of timescale of impacts – permanent or short term.	The recovery of groundwater levels is described in Section 14.3.3. The impact of surplus water discharge on downstream water quality and aquatic fauna is discussed in Section 8.4.2. The timescale of impacts to surplus water discharge are addressed in Table 25.
	Requested options for recharge and recirculation of surplus water.	The consideration of the option to recharge of surplus water is discussed in Section 4.2.
	Queried whether the water balance used for Dampier/Cape Lambert took into account the tonnes of ore to come from Nammuldi-Silvergrass	This was taken into consideration.
	Supports outcome-based conditions but prefers selection of a volume rather than the concept of "dewater to allow mining to an RL" where the volume is predicted rather than an absolute: DoW recognises that the volumes in the Ministerial Statement should be GL/annum rather than ML/d.	Noted. Dewatering volumes are addressed in Section 3.3.10.
	Requires that drawdown be measured on commencement of dewatering to clarify that the aquifer is performing as modelled.	Monitoring of groundwater level will be ongoing as described in the Groundwater Management Plan in Appendix 3.
	Queries regarding reinjection drilling and selection of reinjection aquifer – potential to reinject into the Wittenoom Formation.	The consideration of the option to recharge of surplus water is discussed in Section 4.2.
	Discussion on the possibility of reducing the pivot area and increasing discharge	The rationale for the size of the Irrigated Agriculture Area is discussed in Section 3.3.11.
	Queries regarding the state of Duck Creek following discharge and the time taken to return to pre-discharge state. Require further details on implications of periodic discharge.	The impact of discharge to Duck Creek on water quality and aquatic fauna is discussed in Section 8.4.2. The timescale impacts of surplus water discharge are addressed in Table 25. The impact of discharge to riparian vegetation is discussed in Section 9.4.4.
	Preference for the use of multiple discharge points over a single discharge location to facilitate the drying of the creek.	Surplus water discharge to Duck Creek is discussed in Section 8.4.2.
	Request for further details on the Irrigated Agriculture Area – predicted outcome if a shock event occurs (e.g. heavy rain or market crash). Can a third party manager be effectively handled by Rio Tinto?	A description of the irrigated agriculture project can be found in Section 3.3.11. Additional information on the IAA can be found in the AEMP Appendix 3. There will be no third party manager.
	Queries regarding the potential for the Irrigated Agriculture Area to be dedicated to the production of biodiesel.	As description of the irrigated agriculture project can be found in Section 3.3.11. Additional information on the IAA can be found in the AEMP Appendix 3.

Stakeholder	Topics raised	Proponent response
	Indication that an additional licence would be required for the sourcing of water from Nammuldi beyond the life of mine to meet any potential ongoing water demand in the area post-mining (for example BS4 supply).	Noted. As described in Section 7.5, abstraction will be done in accordance with licence conditions.
	Discussion of licensing complications regarding water use for non-mining purposes.	Resolution is ongoing via DSD.
	Request that PER includes a discussion of changes in approach between original groundwater modelling and latest models.	The groundwater modelling methodology is discussed in Section 7.2.3.
	Request that PER contains information regarding the scale of hydrogeological dewatering estimates and covers the potential impacts of dewatering.	Details of the dewatering estimates and potential impacts are discussed in Section 7.4.1.
	Suggestion to include a hydrogeological description of bedded material in the PER even though detailed hydrogeological investigations and modelling remains to be done.	A conceptual hydrogeological description of the bedded Brockman material can be found in Section 7.2.1.
DEC	Effects of dust on TEC – in particular whether the Marra Mamba dust would cement when it gets wet and thereby change the nature and behaviours of the cracking clays that form the TEC at Silvergrass.	Addressed in Section 9.4.6 and by the study conducted by Environmental Alliances 2010 (details in Section 15.2.
	The protection of the environmental and heritage values of Caves Creek.	The riparian vegetation of the Greater Nammuldi Area is discussed in Section 9.2.4. The stygofauna present in Caves Creek is discussed in Section 11. Water quality of Caves Creek is discussed in Section 8.2.2. Aquatic fauna present in Caves Creek are discussed in Section 8.2.3. The Aboriginal Heritage values of Caves Creek are discussed in Section 13.
	Queries regarding the management measures for Ghost bats.	Potential impacts to conservation significant species are summarised in Table 46. Management of fauna is addressed in the EMP (Appendix 3).
	Request for discharge point design to minimise local impact.	The proposed discharge modelling is discussed in Section 8.4.2. Discharge points will be designed in accordance with relevant standards. Specific detail on design is not in the PER, however, minimising erosion will be one of the key requirements for design.
	Concerns about the potential impacts on watercourses from discharge and riparian vegetation from cone of depression from dewatering.	Riparian vegetation is discussed in Section 9.2.4. Impacts of dewatering on vegetation including riparian vegetation are discussed in Section 9.4.3. Impacts of discharge on riparian vegetation are discussed in Section 9.4.4. The timescale impacts of surplus water discharge are addressed in Table 25. Discharge points will be designed in accordance with relevant Australian standards for waterways. Specific detail on design is not in the PER however minimising erosion will be one of the key requirements for design.

Stakeholder	Topics raised	Proponent response
	Requires investigation of a range of water management options and the justification of selection or dismissal.	The surplus water management options considered are discussed in Section 4.2.
	Request for weed management is required for the IAA.	Weed management for the IAA is addressed in the AEMP (Appendix 3).
	Queries regarding the downstream impacts of the Irrigated Agriculture Area – in particular the impact of weeds and erosion.	A description of the irrigated agriculture project can be found in Section 3.3.11. Weed and erosion management for the IAA is addressed in the AEMP (Appendix 3).
	Requirement for a commitment to rehabilitate the area used for irrigated agriculture following the completion of activities. Closure planning is required for the Irrigated Agriculture Area	Closure planning and rehabilitation for the IAA is discussed in Section 14.3.5.
Community		
Eastern Guruma Native Title Holder	A number of archaeological and ethnographic sites are located within the vicinity including burials in Silvergrass area, rock art between Nammuldi and Silvergrass and Palm Springs.	The Aboriginal heritage values of the Expansion Proposal are discussed in Section 13.
	The amount of clearing required for pivots in the Irrigated Agriculture Area.	The clearing requirement for the IAA is discussed in Section 3.3.11 and 9.4.1.
	The type of species to be used and the potential for impacts on native fauna. Expressed interest in pivots being used for native seed and/or biodiesel	Details of the IAA, including potential crop species are discussed in Section 3.3.11. The full list of species to be used in the IAA has not been finalised and the Eastern Guruma comments will be considered in the decision making process.
	Questions regarding quantities of dewatering and the length of time until groundwater rebound following mining completion.	Groundwater dewatering quantities are discussed in 7.4.1. The resulting groundwater drawdown and rebound is discussed in Section 7.4.1 and 14.3.3.
Puutu Kunti Kurrama & Pinikura	Indicated that multiple heritage sites have been recorded within their claim area and the Proposal Boundary	The Aboriginal heritage values of the Expansion Proposal are discussed in Section 13.
Mt Stuart Pastoral Station	The potential for impacts to the watertable at Mt Stuart station as a result of dewatering. Extent of surface water flow in Duck Creek from discharge: potential for drowning risks to cattle	Dewatering and the extent of drawdown are discussed in Section 7.4.1. Depths of surface expression in Duck Creek discussed in Section 8.4.2.

5.4 Ongoing consultation

Rio Tinto will continue to consult with specific stakeholders as required throughout the assessment process for the Expansion Proposal.

Additionally, this PER document is subject to a four week public review period and at the end of this period, issues raised in written public submissions are provided to Rio Tinto for an opportunity to provide responses to issues raised in the submissions (refer to invitation to comment attached with this document, and refer to Section 1.3 for details on submission procedure).

6. Framework for environmental impact assessment of proposal

6.1 Identification of key issues and their significance

The Environmental Scoping Document was prepared in accordance with the Environmental Impact Assessment (Part IV Division I) Administrative Procedures 2002.

The scoping process involved the identification of key environmental aspects of the Expansion Proposal that may affect relevant environmental factors which are components of the receiving environment. Stakeholder consultation identified issues of interest and together with preliminary qualitative risk assessments and through comparison with established environmental policies the potential significance of environmental impacts arising from the Expansion Proposal was determined.

The following relevant key environmental factors were identified during this scoping process and are addressed in detail in this PER:

- groundwater (Section 7)
- surface water (including aquatic habitats and fauna) (Section 8)
- vegetation and flora (including TEC) (Section 9)
- terrestrial fauna (Section 10)
- subterranean fauna (Section 11)
- acid and metalliferous drainage (Section 12)
- Aboriginal heritage (Section 13)
- closure (Section 14).

The detailed assessment undertaken for this PER did not identify any further key relevant environmental factors.

6.1.1 Other environmental factors

Other environmental factors addressed in this PER require less detailed assessment as they can be readily managed through standard operating procedures and adherence to regulations. A description of these other environmental factors in relation to the Expansion Proposal is provided in Section 15, as follows:

- noise and vibration (Section 15.1).
- dust (Section 15.2)
- waste (non-mineral) (Section 15.3)
- greenhouse gases (Section 15.4).

6.2 Assessment of key environmental factors

6.2.1 Assessment approach

The assessment of potential impacts arising from the Expansion Proposal and a description of mitigation to reduce impacts on key environmental factors, have been included in this PER as follows:

- statement of relevant environmental objectives to be met by the Expansion Proposal
- identification of relevant policies and guidelines, standards and procedures
- description of the factor including the results of investigations
- identification of potential sources of impact (environmental aspects) associated with the Expansion Proposal
- assessment of likely direct and indirect impacts arising from key environmental aspects
- application of management measures and performance standards to mitigate potential impacts
- comparison of predicted environmental outcomes or residual impact against environmental objectives, and key policies, guidelines, standards and procedures.

6.2.2 Relationship between key environmental factors and potential impacts

Potential impacts to an environmental factor (e.g. groundwater) arise from an environmental aspect of the Expansion Proposal (e.g. dewatering). The potential impacts addressed under each of the key factors are restricted to those directly or indirectly affecting that key factor. For example, dewatering will affect groundwater levels (as discussed in Section 7 – Groundwater) and this drawdown can affect groundwater dependent vegetation (discussed in Section 9 – Flora and Vegetation).

Table 16 provides the EPA environmental objective, key environmental aspects and a summary of potential impacts for each relevant factor and indicates where those potential impacts are addressed in this document.

Table 16 Potential impacts on environmental factors resulting from different aspects of the Expansion Proposal, which were identified in the ESD

Environmental Factor	EPA objective	Aspect	Potential Impacts	Section
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.	Dewatering	• dewatering of the mining areas at Nammuldi and Silvergrass to allow access to the ore will lower the watertable in the ore body aquifer, which has in turn the potential to affect sensitive groundwater-dependent ecosystems and heritage sites	7.4.1
		Discharge of surplus water	• discharging surplus water to creek systems may elevate the watertable locally and provide a more constant flow regime, which may in turn change the composition of creek vegetation communities over time	Not addressed under this factor, impacts associated with the discharge of surplus water are assessed in Section 8.4.2
		Final landform	• changes to landforms and hydraulic properties within backfilled or open pits after closure will alter natural groundwater flow, which has the potential to affect groundwater levels and quality,	Not addressed under this factor, impacts associated with the final landforms are assessed in Section 14.3.3
		Irrigated agriculture	• application of water for irrigated agriculture has the potential to elevate the watertable locally, which can affect the composition of adjoining vegetation communities over time if rise is sufficiently high to saturate the rootzone of tree species	7.4.2
		Exposed subsurface materials	• exposed surface materials may give rise to AMD, which may in turn contaminate groundwater	Contamination from PAF exposures in-pit is considered in Section 12.4.1 and from PAF waste storage is considered in section 12.4.2.
		Hydrocarbon storage and use	• hydrocarbons spills during storage, refuelling and general use may contaminate groundwater.	7.4.3
Surface water	To maintain the quantity of water so that existing and potential environmental values, including ecosystem maintenance, are protected.	Dewatering	• dewatering at Silvergrass will result in drawdown in the superficial aquifer along Caves Creek which would potentially modify the baseflow conditions of the watercourse and has the potential to lower the water levels of semi-permanent pools, affect aquatic fauna habitat and reduce water availability for riparian vegetation	8.4.1
		Discharge of surplus water	• discharging surplus water into ephemeral watercourses will saturate alluvium of the creek low flow channel and could initiate the merging of existing smaller pools, which would potentially modify the hydrological regime (quantity and quality) thereby affecting permanent pools, riparian vegetation and aquatic fauna habitat	8.4.2

Environmental Factor	EPA objective	Aspect	Potential Impacts	Section
	To ensure that emissions do not adversely affect environment values or the health, welfare and amenity of people and land uses by meeting statutory	Caves Creek realignment	• in Caves Creek at Silvergrass may alter the existing flow conditions, including the water levels, flow direction and velocities, of the creek system	8.4.3
		Landform modification	• modifying landforms through the construction of pits, dumps and infrastructure will affect generation of sheet flow, which may affect vegetation that is dependent on flows (where flows are reduced) or affect vegetation sensitive to inundation (where flows are increased and/or ponding introduced/prolonged)	8.4.4
		Surface water contamination	• contamination of surface water is possible from suspended solids, hydrocarbon spills, acidic and/or metalliferous drainage within mining areas	Impacts on surface water from hydrocarbon are assessed in8.4.5. Contamination from PAF exposures in-pit is considered in Section 12.4.1 and from PAF waste storage is considered in section 12.4.2.
		Stormwater runoff	• runoff from disturbed areas and overburden dumps may result in increased sediment transport to watercourses.	8.4.6
Flora and Vegetation	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.	Vegetation clearing	• additional clearing of vegetation will directly reduce the extent of vegetation communities, including vegetation communities of local conservation significance, and potentially disturb Priority Flora species	9.4.1
		Location of infrastructure waste landforms	• disruption of sheet flows through extension of mine pits, and construction of additional waste landforms, infrastructure and diversion structures has the potential to have an impact on vegetation communities that are sustained by sheet flow	9.4.2
		Dewatering	• additional dewatering will lower ground water levels in proximity to the pits and may in turn affect groundwater-dependent vegetation	9.4.3
		Discharge of surplus water	• discharge of additional surplus water to creeks may alter the composition of creek vegetation communities downstream of the discharge	9.4.4
		Vehicle movements	• vehicle movements and earthworks have the potential to introduce and spread weed species	9.4.5
		Dust	• dust generation due to earthworks, mining, processing and vehicle movements has the potential to smother vegetation	9.4.6
Terrestrial Fauna	To maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystem levels through the avoidance or management of	Vegetation clearing	• clearing of additional vegetation will directly disturb fauna habitat and will result in the displacement of fauna and the loss of individual terrestrial fauna	10.4.1
		Linear infrastructure	• disruption of sheet flow through extension of mine pits, and construction of additional waste dumps, infrastructure and diversion structures has the potential to have an impact on vegetation communities that are sustained by sheet flow and subsequently affect fauna that may use this habitat	10.4.2
		Vehicle movements	• vehicle movements within the Proposal Boundary may result in the loss of individual terrestrial fauna, especially less-mobile species	10.4.3

Environmental Factor	EPA objective	Aspect	Potential Impacts	Section
	adverse impacts and improvement in knowledge.	Dewatering	• additional dewatering will lower ground water levels in proximity to the pits and therefore may affect groundwater-dependent vegetation that may be present and subsequently affect fauna that may use this habitat	10.4.4
		Discharge of surplus water	• discharge of additional surplus water to creeks will increase the volume of available water and may alter the composition of creek vegetation communities downstream of the discharge and subsequently affect fauna that may use this habitat.	10.4.5
Subterranean Fauna	To maintain the abundance, diversity, geographic distribution and productivity of subterranean fauna at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge.	Pit expansion	• physical removal of ore and overburden from pits will remove potential subterranean fauna habitat and has the potential to result in the loss of individual fauna through the extraction of material or affect habitat quality through the generation of vibration	11.4.1
		Dewatering	• increasing the extent of groundwater drawdown, from dewatering , which will reduce the extent of stygofauna habitat during mine life and perhaps after closure to a lesser degree	11.4.2
		Surface water and groundwater contamination	• surface and groundwater contamination, through spills of hydrocarbons has the potential to affect the quality of habitat for subterranean fauna	11.4.3
		Vegetation clearing	• clearing of vegetation beyond the pit footprint can potentially lead to a alteration of nutrient inputs to the habitat of subterranean fauna.	11.4.4
Geochemical risks including AMD and asbestiform material	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.	Management of exposed PAF material	• exposure of PAF material to oxygen has the potential to generate acid and produce AMD if it comes in contact with rainwater/runoff, which may result in groundwater or surface water contamination	12.4.1
		Storage of PAF material	• storage of PAF mineral waste has the potential to cause spontaneous combustion and could generate acid water if it comes in contact with infiltration or rainwater/runoff, which may result in groundwater or surface water contamination	12.4.2
		Management of fibrous minerals	• extracting and exposing fibrous minerals during mining operations has the potential to affect the health of mine workers, post mining land users and fauna by exposure to harmful levels of fibrous minerals	12.4.4
		Dewatering	• dewatering may expose PAF material to oxidising conditions as a result of the groundwater drawdown, which has the potential to make abstracted water acidic and/or metalliferous.	12.4.5
Aboriginal heritage	To ensure that changes to the biophysical environment do not adversely affect historical and cultural associations and comply with relevant heritage legislation.	Physical disturbance of land	• physical disturbance to land during construction, mining and associated activities	13.4.1
		Dewatering	• dewatering the mining area to allow access to the below watertable ore has the potential to affect water courses within and outside the Proposal Boundary, which may have heritage significance	13.4.2
		Discharge of surplus water	• discharge of surplus water from dewatering has the potential to affect watercourses which may have ethnographic significance	13.4.3
		Drainage management	• drainage management will alter flow paths with construction of diversion channels, mine pit, waste dumps and infrastructure and re-alignment of Caves Creek which may have ethnographic significance.	13.4.4

Environmental Factor	EPA objective	Aspect	Potential Impacts	Section
Closure	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. To maintain the abundance, diversity, geographic distribution and productivity of flora and fauna at species and ecosystem levels through the avoidance or management of adverse impacts and improvement of knowledge.	Closure planning	• insufficient allocation of funds/resources for closure, particularly in the event of unforseen closure, may affect the achievement of completion criteria	14.5.1
		Rehabilitation	• progressive and final rehabilitation not conducted in a timely manner	14.5.2
		Post closure land use	• rehabilitation does not promote the establishment of the agreed post-mining land use	14.5.3
		Effect on groundwater quantity and quality of altered landforms	• final landforms not stable leading to erosion issues contaminating ground and surface water systems.	14.5.4

6.3 Consistency with environmental principles

In 2003, the EP Act was amended to include a core set of Principles that are applied by the EPA in assessments (EPA 2004a). These environmental protection principles listed in s 4a of the EP Act, are:

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

Rio Tinto has considered these principles in its design and subsequent implementation of the Expansion Proposal (Table 17).

Table 17 Consistency with principles of environmental protection

Principle	Consideration given in the Expansion 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.	Rio Tinto maintains an environmental management system that addresses all of its activities with a potential to affect the environment and is consistent with ISO14001. The key elements of the EMS include assessing environmental risk arising from environmental aspects with the intention of identifying issues early in the process to enable planning to avoid, prevent or manage impacts. Part of this process includes undertaking detailed site investigations of the biological and physical environs. Where these investigations identify significant environmental issues, management measures are incorporated into the project design to avoid, where practicable, and/or minimise any potential impacts. As a result, this Expansion Proposal has been designed to minimise potential impacts to the key environmental values of Caves Creek.	See assessment of factors in Sections 7 to 15 and environmental management and proposed conditions in Section 18.
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.	Rio Tinto integrates the principles of sustainable development into all aspects of its operations to contribute to sustainable development in Australia. These principles ensure that Rio Tinto'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 Rio Tinto operates is maintained and (where possible) enhanced for future generations. This has resulted in the protection of key environmental values (as above) and an extensive management program.	See Section 14 (Closure, including rehabilitation) and Section 18 for environmental management.

Principle	Consideration given in the Expansion Proposal	Section addressed in PER
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 Rio Tinto's approach to environmental management and is a major environmental consideration for the project. Biological investigations have been undertaken by Rio Tinto early in the project planning process to identify values of environmental conservation significance required to be protected from disturbance. This Expansion Proposal has been designed to minimise potential impacts to the key environmental values of Caves Creek. Rio Tinto has committed to restoring disturbed environments upon decommissioning, creating safe, stable, non-polluting landforms. Revegetation will be conducted with native species, and surface flows designed to avoid flooding. The aim of which is to establish sustainable endemic vegetation units consistent with reconstructed landforms and surrounding vegetation.	See assessment of factors in Sections 7 to 15 and environmental management and proposed conditions in Section 18.
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.	Rio Tinto acknowledges the need for 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 infrastructure and waste rock landform locations • Rio Tinto has put in place procedures that will ensure that pollution-type impacts are minimised as far as practicable • the cost of rehabilitation and closure requirements will be incorporated into the production costs of the Expansion Proposal from the commencement of operation.	N/A
5. Waste Minimisation All reasonable and practicable measures should be taken to minimise the generation of waste and its discharge into the environment.	Rio Tinto's approach to waste management is to, in order of priority: • avoid and reduce at source • reuse and recycle • treat and/or dispose. Rio Tinto will operate an appropriately licensed landfill for the disposal of general domestic solid wastes and recycles scrap metal, rubber, waste oil and batteries. Rio Tinto continues to investigate other waste management opportunities with the aim of minimising waste generation and disposal requirements.	N/A

7. Assessment of impact on groundwater

This section addresses the impact of the Expansion Proposal on groundwater. The effect of changes to the groundwater arising from the Expansion Proposal on environmental values (such groundwater-dependent ecosystems) is addressed under other sections dealing with the relevant environmental factor (i.e. vegetation in Section 9.4.3).

7.1 Relevant environmental objectives, policies, guidelines, standards and procedures

7.1.1 EPA objectives

The EPA applies the following objectives to the assessment of proposals that may affect 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 environmental values or the health, welfare or amenity of people and land uses by meeting statutory requirements and acceptable standards.

7.1.2 Regulatory framework

The RIWI Act makes provision for the regulation, management, use and protection of water resources, to provide for irrigation schemes, and for related purposes. Licences issued by the DoW under the RIWI Act are required for works associated with groundwater abstraction (including for mine dewatering purposes) and for the taking of groundwater. Groundwater abstraction licences specify the maximum abstraction rate from aquifers and may include conditions for monitoring and preparation of operating strategies.

Works approvals and licences to permit discharges to the environment are also required under Part V of the EP Act.

7.2 Description of factor

Groundwater modelling was undertaken for the Original Proposal by PPK Environment & Infrastructure (PPK 1999). The understanding of the groundwater system at both Nammuldi and Silvergrass has increased significantly since the CER for the Original Proposal was submitted, through the following studies:

- Nammuldi hydrogeological model (URS 2010a)
- Silvergrass hydrogeological model (URS 2010b)
- Dewatering Requirements for Nammuldi (Rio Tinto 2010a)
- Dewatering Requirements for Silvergrass East (Rio Tinto 2010b)
- Baseline groundwater sampling programme throughout Caves Creek (Rio Tinto 2010c)
- Nammuldi Numerical Modelling (Rio Tinto 2011c).

The hydrogeology at both Nammuldi and Silvergrass is characterised by fractured bedrock aquifers, which are in hydraulic connection with thick successions of variably saturated Tertiary palaeovalley sediments. These palaeovalley sediments lie between the ridgelines of outcropping Marra Mamba and Brockman Iron Formation bedrock at both Nammuldi and Silvergrass. The palaeovalley-fill sediments comprise predominantly undifferentiated clastic deposits with a matrix dominated by clay in addition to calcretes which are collectively referred to as detritals. The complex stratigraphy of the valley-fill sediments results in a variable transmissivity.

7.2.1 Nammuldi

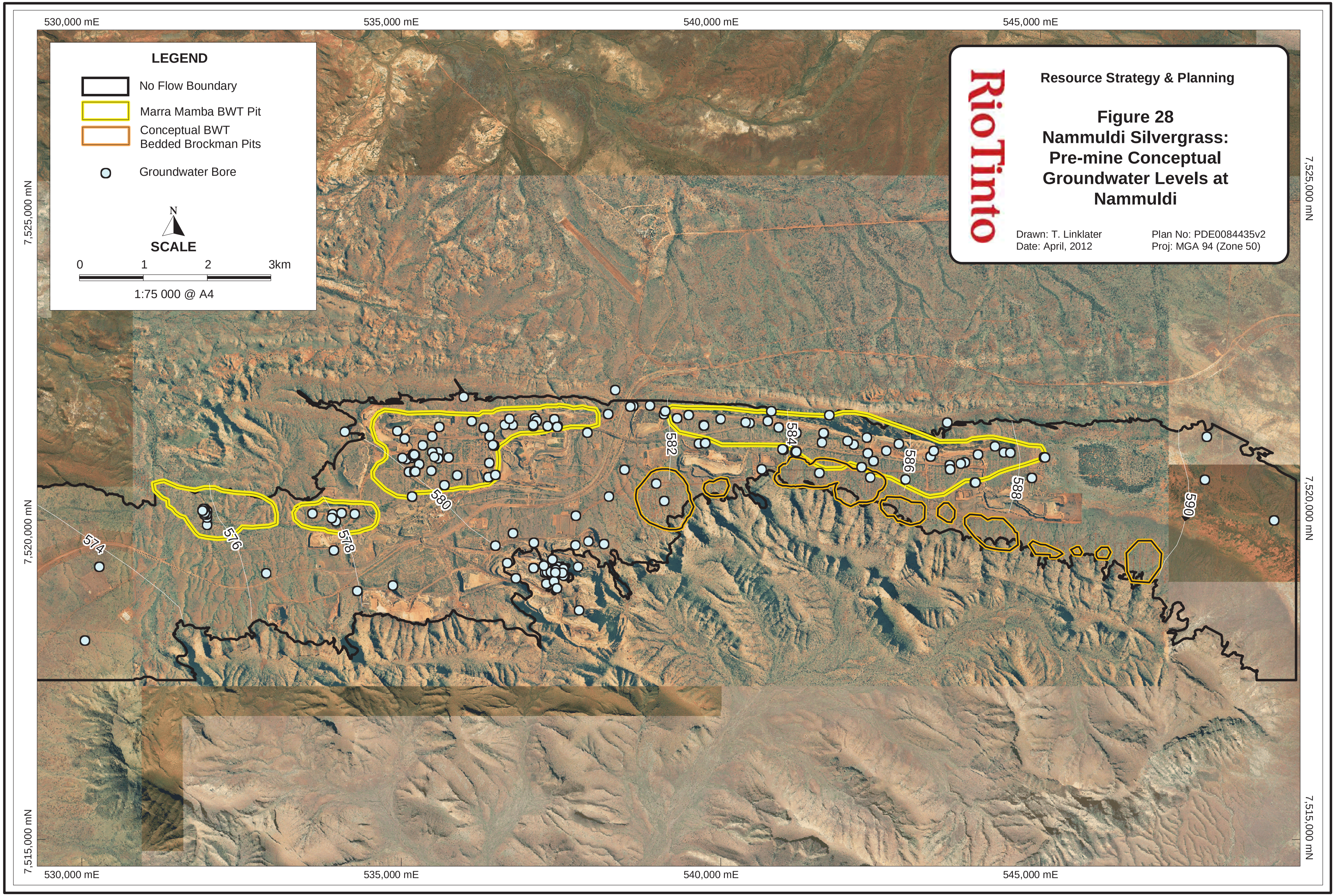
The primary aquifers at Nammuldi are associated with the mineralised Mount Newman Member that forms the orebody at Nammuldi (the orebody aquifer) and the Wittenoom Formation, especially where it has been exposed resulting in weathering and the formation of secondary permeabilty. The overlying Wittenoom Formation and valley fill material, when saturated, also hosts significant volumes of groundwater. Previous conceptual models of the hydrogeology presented in the CER for the Original Proposal suggested the orebody aquifer was confined by the overlying West Angela Member, however, water levels from hydrogeological drilling programs in 2008 and 2009 have revealed that the bedrock aquifers and overlying detritals are hydraulically connected and show low hydraulic gradients between the different units (URS 2010a). No groundwater-dependent ecosystems have been identified by any of the vegetation surveys conducted within this valley (Halpern Glick Maunsell 1999a; Biota 2010a, 2010b).

Groundwater levels and flow

Groundwater levels at Nammuldi are approximately 40 m below ground level, which corresponds to 590 m AHD in the east to 574 m AHD in the west of the deposit. This groundwater gradient indicates flow in a westerly direction along the valley between the Nammuldi ridge (to the north) and Brockman Ridge (to the south). Groundwater flow is bounded by low permeability Macleod Member to the north of the valley and Mt Sylvia Formation to the south. The conceptual pre-mine groundwater levels at Nammuldi are shown in Figure 28.

The Marra Mamba Iron Formation Member, which underlies the orebody aquifer, forms an effective hydraulic barrier to groundwater flow. The boundary to groundwater flow is generally considered to be where either un-weathered, competent Wittenoom Formation or the Mount Sylvia Formation out-crop.

Information available to date in the area of the proposed bedded Brockman Iron Detritals pits south of Lens E/F is limited. This area will be the subject of further phases of investigation, with ongoing reports to be made available in addition to information presented in this PER. Groundwater level data in the area indicates a watertable elevation between approximately 580 and 586 m RL, which is similar to that seen in the Marra Mamba Iron Formation in nearby Lens E/F. Conceptual hydrological modelling indicates that the bedded Brockman Iron Detritals Pits 9, 10 and 13 are likely to be in connection with the aquifer at Nammuldi Pit E/F. Due to the presence of the Mt Sylvia Formation acting as a barrier to groundwater flow, the water table at Brockman Iron Detritals Pits 8, 11 and 12 is unlikely to be connected to that at Pit E/F.


Resource Strategy & Planning
Figure 28
Nammuldi Silvergrass:
Pre-mine Conceptual
Groundwater Levels at
Nammuldi
Drawn: T. Linklater
Date: April, 2012
Plan No: PDE0084435v2
Proj: MGA 94 (Zone 50)
LEGEND
No Flow Boundary
Marra Mamba BWT Pit
Conceptual BWT
Bedded Brockman Pits
Groundwater Bore
N
SCALE
0
1
2
3km
1:75 000 @ A4
530,000 mE
535,000 mE
540,000 mE
545,000 mE
7,525,000 mN
7,520,000 mN
7,515,000 mN
574
576
578
580
582
584
586
588
590

Groundwater quality

The groundwater at Nammuldi is typically fresh to marginal, with electrical conductivities varying between 550 and 1400 µS/cm. The pH is generally neutral (6.8 to 7.8). Groundwater quality is generally within ANZECC & ARMCANZ (2000) guidelines for aquatic ecosystems, with the exception of copper and zinc, which were elevated at some sites (Rio Tinto 2010c). The groundwater meets all guideline values for drinking water with the exception of the aesthetic guideline value for total dissolved solids (Rio Tinto 2010c).

7.2.2 Silvergrass

The main aquifer at the Silvergrass deposit consists of mineralised sections of the Mt Newman Member of the Marra Mamba Iron Formation or fractured and/or weathered Wittenoom Formation (pre-dominantly the West Angela Member), and detrital units (Figure 29). The aquifer units are surrounded by less permeable basement units to the north and south as also observed in Nammuldi.

The overlying West Angela has highly variable transmissivity, ranging typically from low to moderate hydraulic conductivity (URS 2010b). The valley-fill material (detritals) that overlies the mineralised section varies in transmissivity from low to moderate. Although there is considerable lithological heterogeneity (including sand and gravel with distinct pisolite pebbles and cobbles in calcareous clay matrix), water quality and groundwater levels would suggest that all the stratigraphic units are hydraulically connected between the bedrock aquifer and lower detrital valley fill deposits. This lower detrital unit is overlain by a consistent and extensive clay of the order of 15 to 20 m thick especially in the vicinity of Caves Creek which is overlain by more recent variable alluvium and colluvium deposits of variable clay, silt, gravel and calcrete. The clay layer as a result can be considered an aquitard separating the alluvial surface water fed shallow aquifer and the deeper basement and lower detritals aquifer.

Hydrogeological connection between groundwater and surface water at Silvergrass

Geochemical and isotope analysis was undertaken to determine the relationship between surface water at Caves Creek and groundwater in the underlying aquifer. This geochemical analysis focused on major ions, in particular chloride ions, from water samples from pools along Caves Creek and the groundwater (Rio Tinto 2010c). As chloride ions are largely derived from rainfall, and any variations in its concentration are attributed to evaporation it provides an indication of the inherent surface and groundwater dynamics. The analysis of samples indicated that the geochemistry of groundwater and the water found in pools is similar and that variations can be attributed to evaporation in the pools and mineral dissolution in the groundwater. This indicates that the permanent pools sampled (including Palm Springs and small nearby pools) are likely to be groundwater fed.

Isotopic signature analysis for stable isotopes oxygen 18 ($\delta18O$) and deuterium (δD) showed that groundwater and the majority of surface water tested had depleted isotopic values. Depleted isotopic values correspond to intense rainfall events during which there is little evaporation. This indicates that the groundwater is recharged only by high intensity rainfall events, typically cyclones or cyclone remnants, and that the permanent pools sampled (including Palm Springs and small nearby pools) are groundwater fed.

To support the geochemical and isotopic understanding of Caves Creek a drilling program established 41 monitoring bores along Caves Creek in six transects. The monitoring bores were constructed in calcrete, detrital units and also in weathered West Angela shale between Silvergrass and Palm Springs, which occurs approximately 28 km downstream (Figure 30).

The results indicate that the hydrogeological units from Silvergrass to Palm Springs are relatively consistent, with the clay layer acting as an aquitard. At Palm Springs the calcrete, detrital and clay layers have been eroded, exposing the lower detrital layer.

Groundwater levels and flow

The watertable at Silvergrass generally follows the topography of Caves Creek. Groundwater flows from east to west along the orebody aquifer and valley fill sediments. The gradient is not uniform, which probably reflects the heterogeneity encountered within both the bedrock and valley fill.

In 2007 groundwater levels at Silvergrass were between 5 m below ground level close to the Caves Creek, and 53 m below ground to the southwest of Silvergrass (Rio Tinto 2010c). These correspond to 554 AHD near Caves Creek to the northeast of Silvergrass to 546 m AHD to the west, implying groundwater flow to the west.

Groundwater levels along Caves Creek vary temporarlly due to changes in rainfall. Groundwater levels were much lower in 1997/1998 as a result of below average rainfall from 1985 – 1998 than they were during a 2007 survey (undertaken to support the URS [2010b] groundwater model), which occurred after a period of above average rainfall (Rio Tinto 2010c). The conceptual pre-mine groundwater levels at Silvergrass are shown in Figure 31.

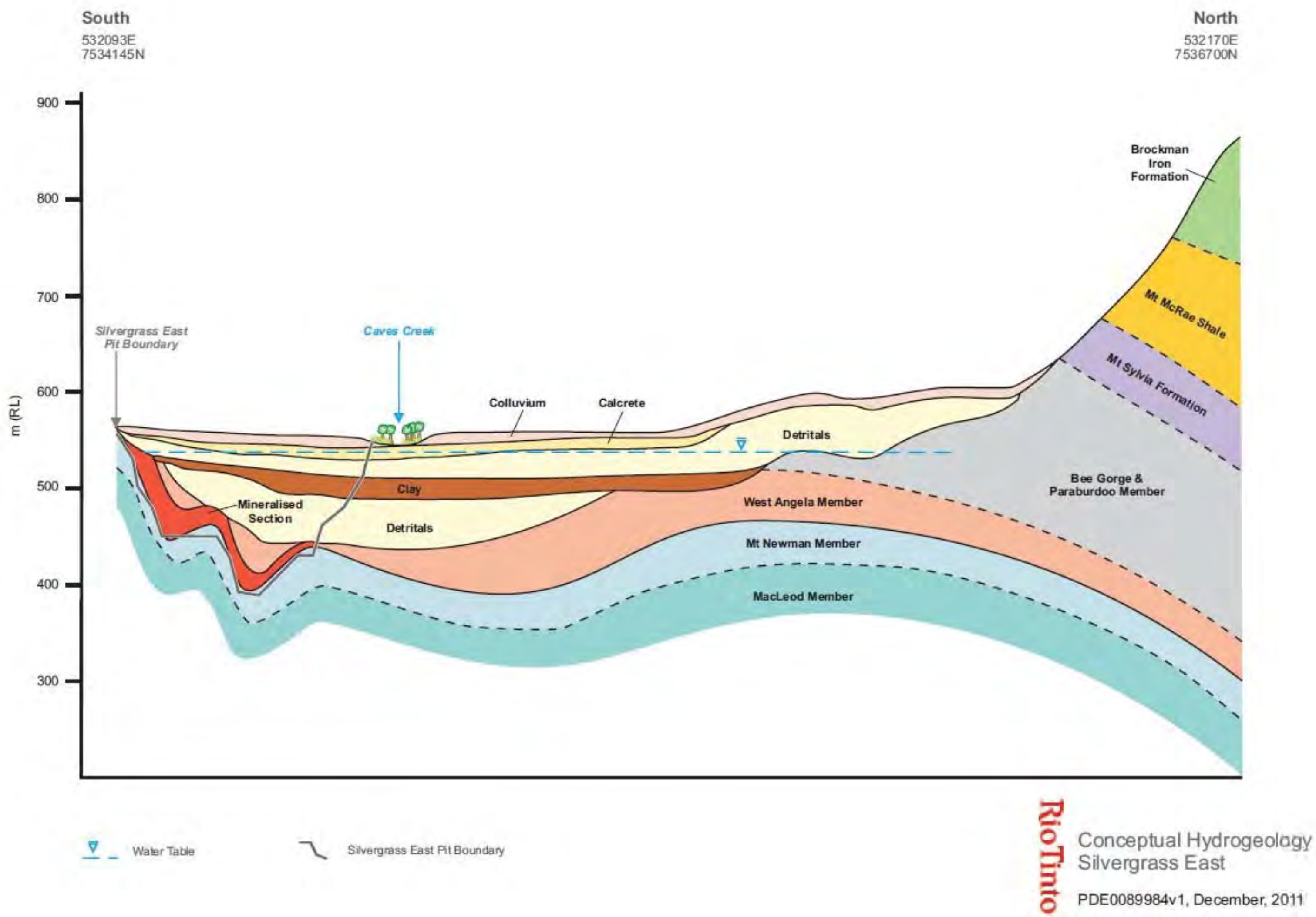


Figure 29 Schematic hydrogeological section

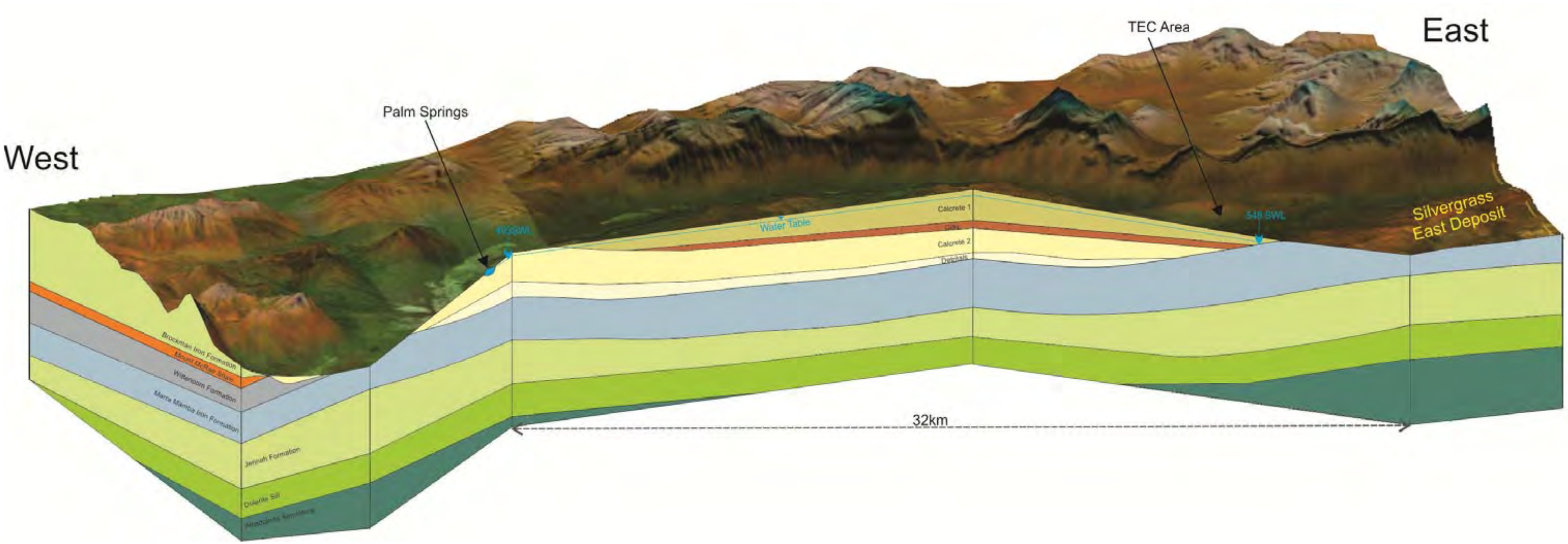
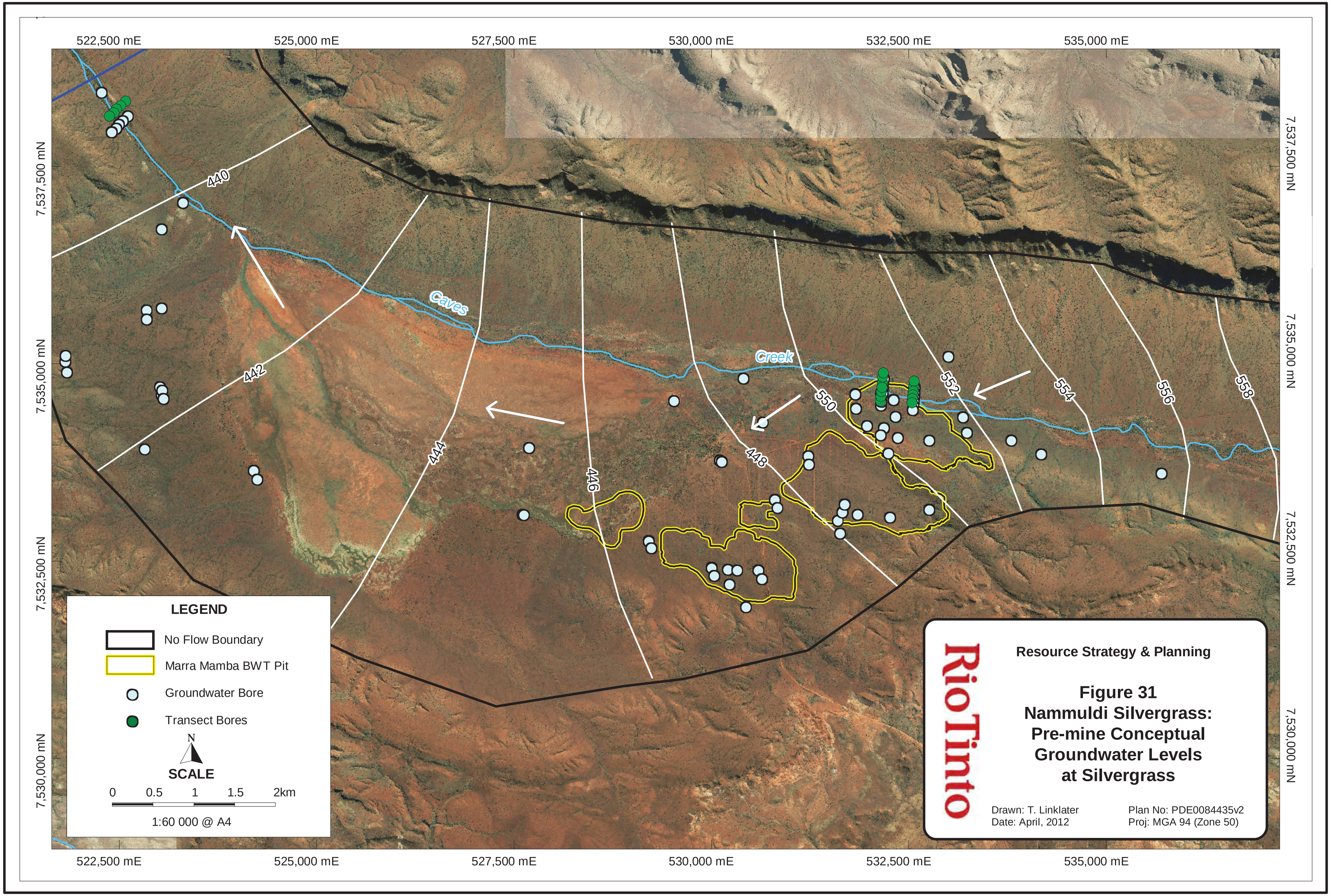


Figure 30 Caves Creek Conceptual Hydrogeology (3D View)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7,530,000 mN
440
442
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446
448
550
552
554
556
558
Caves
Creek
LEGEND
No Flow Boundary
Marra Mamba BWT Pit
Groundwater Bore
Transect Bores
N
SCALE
0 0.5 1 1.5 2km
1:60 000 @ A4
Rio Tinto
Resource Strategy & Planning
Figure 31
Nammuldi Silvergrass:
Pre-mine Conceptual
Groundwater Levels
at Silvergrass
Drawn: T. Linklater
Date: April, 2012
Plan No: PDE0084435v2
Proj: MGA 94 (Zone 50)

Groundwater quality

Groundwater at Silvergrass typically has a pH of 7.1 to 8.3, which reflects the carbonates of the Tertiary valley fill and Wittenoom Formation. The water is fresh with a mean electrical conductivity of 980 µS/cm (WRM 2011b). The groundwater meets all guideline values for drinking water with the exception of the aesthetic guideline value for total dissolved solids (Rio Tinto 2010c).

7.2.3 Hydrogeological modelling

Numerical hydrogeological modelling was used to estimate approximate dewatering volumes and rates required for mining and predict the extent of groundwater drawdown. The hydrogeological models developed by URS (2010a and 2010b) represent substantial revisions of the earlier model used for the CER (PPK 1999). The models were revised based on an enhanced understanding of the geological and hydrogeological characteristics of both Nammuldi and Silvergrass.

The major change to the hydrogeological model resulted from the increased knowledge of the extent of variability within the West Angela Member, thickness of the valley fill material and presence of the Paraburdoo Member. The previous model assumed that the West Angela Member confined the orebody aquifers, however, recent hydrogeological investigations have shown that there is hydraulic connection between the orebody, Wittenoom Formation and the valley fill (URS 2010a).

Sources of recharge to the system for the Nammuldi model were assumed to be direct infiltration of rainfall (as measured at the weather station at B2) and throughflow. The average recharge component has been calculted as approximately 2.5 % of mean annual rainfall through calibration of the groundwater model. The Silvergrass model assumed recharge to the aquifer from rainfall as being an average of 0.3% of mean annual rainfall with the rest being contributed from leakage from Caves Creek.

The models were calibrated in steady and transient state conditions. The steady state calibration was used to refine the hydraulic conductivity parameters using a pre-mining dataset (Nammuldi only) of observed data (1991/1992 groundwater level data), while the transient calibration aimed to match model groundwater hydrographs with historical trends based on observed stresses to the system (from January 1991 to April 2010).

Model simulation performance was evaluated with the measurement of the percentage discrepancy error. Errors were contained between ± 0.2%. A discrepancy error within 5% is usually considered acceptable for complex flow systems (URS 2010a).

The conceptual hydrogeological models for both Nammuldi and Silvergrass have been peer reviewed by Hydroconcepts. The peer reviews have been provided to the OEPA.

As described in Section 3.3.10, modelling has indicated approximately 643 GL may need to be dewatered over the life of the mines to allow their safe development based on the revised hydrogeological models and pit development schedules for Nammuldi and Silvergrass. The schedule of dewatering volumes may be modified by changes in the dewatering strategy, geological block model, hydrogeological numerical model, mine plan and schedule; however, the volumes to be abstracted over the life of mine are not expected to change significantly. The current estimated maximum dewatering requirement of approximately 138 ML/day and 90 ML/day will be required at Nammuldi and Silvergrass respectively (Figure 22).

7.3 Potential sources of impact

Activities or aspects of the Expansion Proposal that have the potential to affect groundwater, not considering mitigation measures, include:

- **dewatering** of the mining area at Nammuldi and Silvergrass to allow access to the ore will lower the watertable, which has the potential to affect groundwater-dependent ecosystems and heritage sites
- **discharging surplus water** to creek systems may elevate the watertable locally and provide a more constant flow regime, which may change the current composition of vegetation communities over time
- **changes to landforms arising from mining persisting after closure** will alter the flow of groundwater, which has the potential to affect surface water values and/or groundwater-dependent ecosystems in Caves Creek
- **groundwater contamination** from AMD or hazardous material spills may affect groundwater quality
- **application of water for irrigated agriculture** has the potential to elevate the watertable locally, which can affect the composition of adjoining vegetation communities over time if rise is sufficiently high to saturate the rootzone of tree species.

The potential impacts associated with AMD are addressed in Section 12. Potential impacts relating to surplus water management are addressed in Section 8. Groundwater recovery post-closure is addressed in Section 14. Indirect impacts on vegetation from the alteration of the groundwater regime are discussed in Section 9.4.3.

7.4 Assessment of likely direct and indirect impacts

7.4.1 Dewatering

The Expansion Proposal requires dewatering to a greater depth than the Original Proposal in order to support an increase in depth and width of the pits to allow safe access of the ore below the watertable at Nammuldi and Silvergrass. The extent of drawdown is defined in this assessment as the area subject to a groundwater drawdown of 2 m, as represented by the modelled 2 m drawdown contour. Drawdown of 2 m was selected as a threshold for potential environmental effects in recognition of the error margin of the groundwater modelling, root zone depth of most plants (Rio Tinto 2010b) and variability of the watertable below Caves Creek over time in response to large rainfall events.

The Themeda grassland TEC does not use groundwater and will not be affected by the dewatering.

There are no third party water users within the predicted extent of drawdown.

Nammuldi

The deposit at Nammuldi occurs within a valley between the Brockman Ridge to the south and Nammuldi Ridge to the north. The aquifer is hosted within the Marra Mamba orebody and adjacent formations, and the overlying saturated valley fill material. The extent of groundwater drawdown has been modelled for the end of 2015, 2020,and 2030 at the completion of mining at Nammuldi (Figure 32). Based on the results of the modelling, the extent of groundwater drawdown from dewatering is predicted to be entirely constrained within this valley.

Dewatering at Nammuldi is due to start in Q1 2013. Propagation of the drawdown extent indicates the following:

- at the end of 2020, dewatering will result in the predicted 5 m groundwater drawdown contour extending east and west approximately 18 km
- at the cessation of dewatering in Lens A, B, C/D and E/F, groundwater levels will start recovering in the pits; however, the predicted drawdown will still propagate and affect the entire modelled area. In particular, it is estimated a drawdown of approximately 5 m at the western boundary and 35 m at the eastern boundary.

Additional dewatering will be required to mine the bedded Brockman Iron Detritals, the subject of a series of small additional pits at Nammuldi (pits 8 – 13). The hydrogeological modelling and water management strategy for these deposits is being developed and will be finalised prior to commencement of mining in these pits. The conceptual modelling of groundwater within these proposed pits suggests that dewatering at Pit E/F will sufficiently low groundwater levels in order to allow access to the ore in pits 9, 10 and 13. Due to the presence of the Mt Sylvia Formation acting as a barrier to groundwater flow, the watertable at Brockman Iron Detrital pits 8, 11 and 12 is unlikely to be sufficiently lowered by dewatering at Pit E/F. Conceptual models indicate that a separate dewatering scheme will be required for these pits. The volumes required to be dewatered from these pits is likely to be significantly less than the quantities at the main Nammuldi pits.

Groundwater drawdown at Nammuldi is expected to be limited to the Nammuldi valley due to the relatively low permeability of the unmineralised Marra Mamba Formation to the north of the valley and Mt Sylvia Formation to the south.

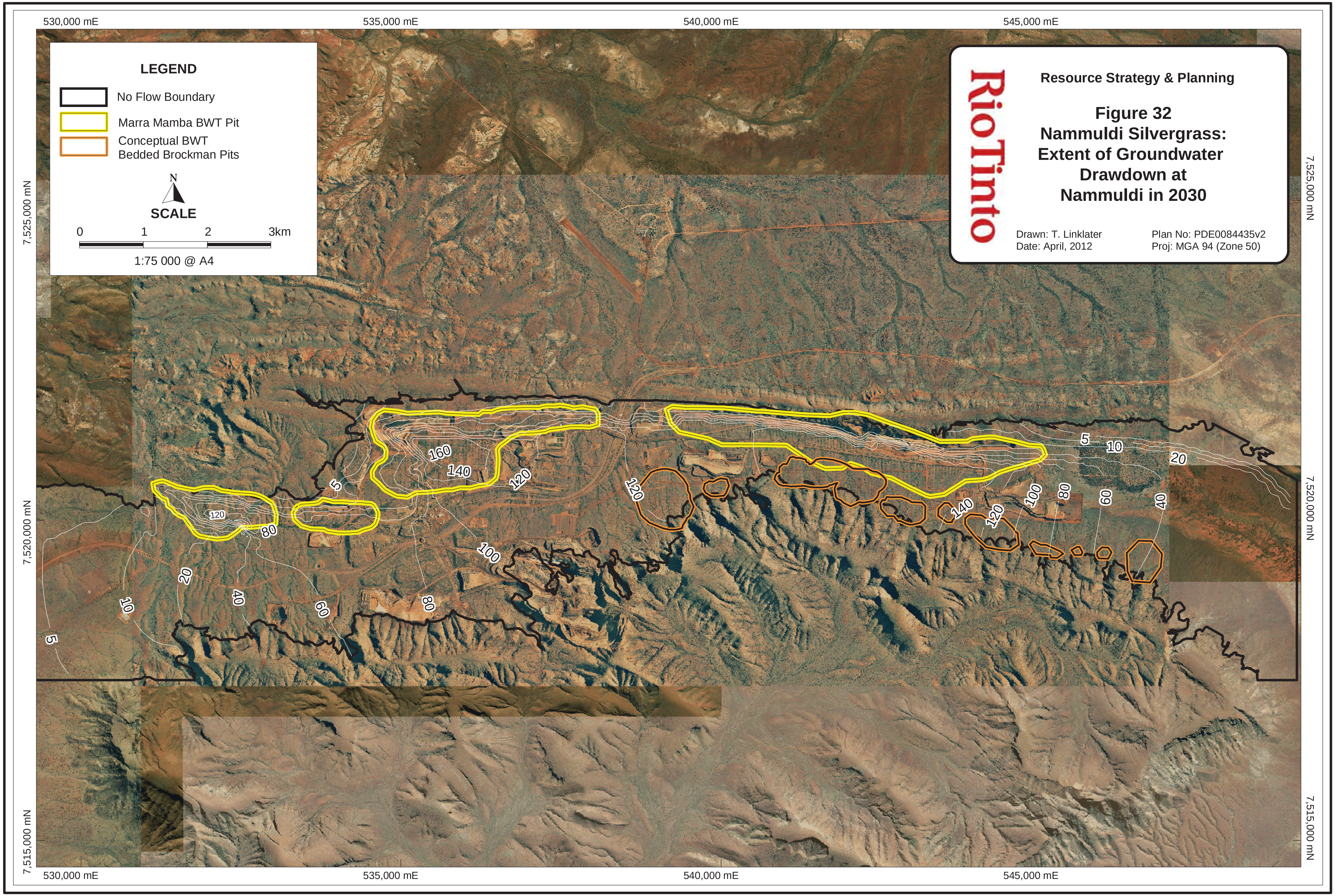
Silvergrass

Dewatering at Silvergrass is due to start in Q1 2015. Modelling of propagation of the drawdown extent indicates the following:

- initially the predicted 2 m groundwater drawdown contour will be limited to the areas surrounding actively mined pits
- at completion of dewatering, the predicted 2 m groundwater drawdown contour will extend beneath the colluvium on the north side of Caves Creek approximately 15 km along Caves Creek and cover an area approximately 46 km^2 (Figure 33 and Figure 34).

The predicted 10 m groundwater drawdown contour identified for the Original Proposal at Silvergrass would extend approximately 4 km east-west along Caves Creek. In comparison, the revised modelling predicts the 10 m drawdown contour will now extend to approximately 7 km east-west, increasing the length of Caves Creek that would be affected at this drawdown by 3 km. The extent of drawdown is expected to extend at the completion of pumping as surounding groundwater flows in to the area subject to dewatering.

Drawdown will not affect Palm Springs due to the the distance (28 km) from the Expansion Proposal in addition to the presence of the clay layer identified from the intensive hydrogeological drilling campaign during 2011. This layer would mitigate any downward leakage of water supported by the shallow clay aquitard in the unlikely event of drawdown propagating this far from Silvergrass. In addition,Palm Springs is fed by a calcrete aquifer, which is not connected to the orebody aquifer.


530,000 mE
535,000 mE
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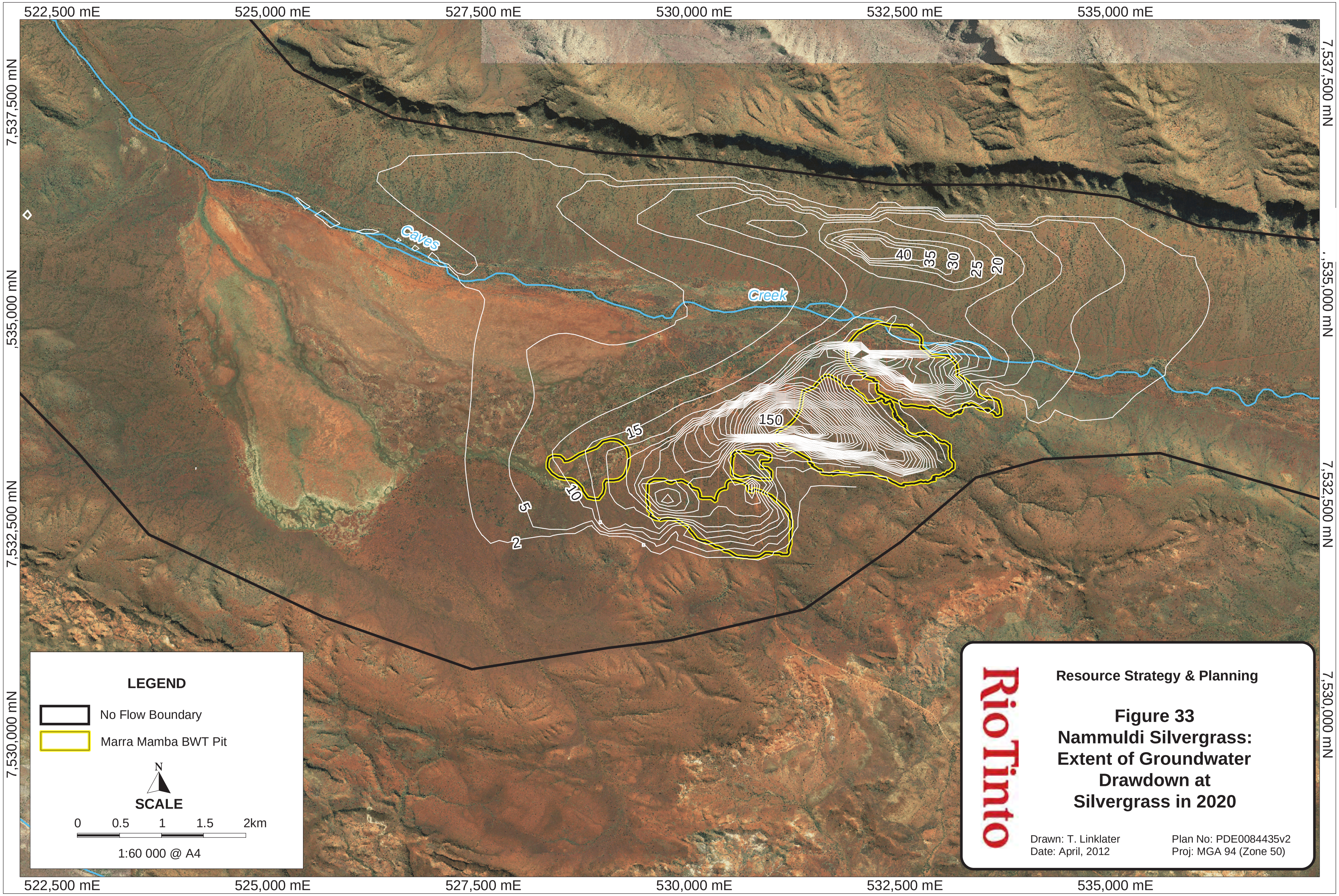
7,525,000 mN
7,520,000 mN
7,515,000 mN
LEGEND
No Flow Boundary
Marra Mamba BWT Pit
Conceptual BWT
Bedded Brockman Pits
N
SCALE
0
1
2
3km
1:75 000 @ A4
Resource Strategy & Planning
Figure 32
Nammuldi Silvergrass:
Extent of Groundwater
Drawdown at
Nammuldi in 2030
Drawn: T. Linklater
Date: April, 2012
Plan No: PDE0084435v2
Proj: MGA 94 (Zone 50)
5
10
20
40
60
80
100
120
140
160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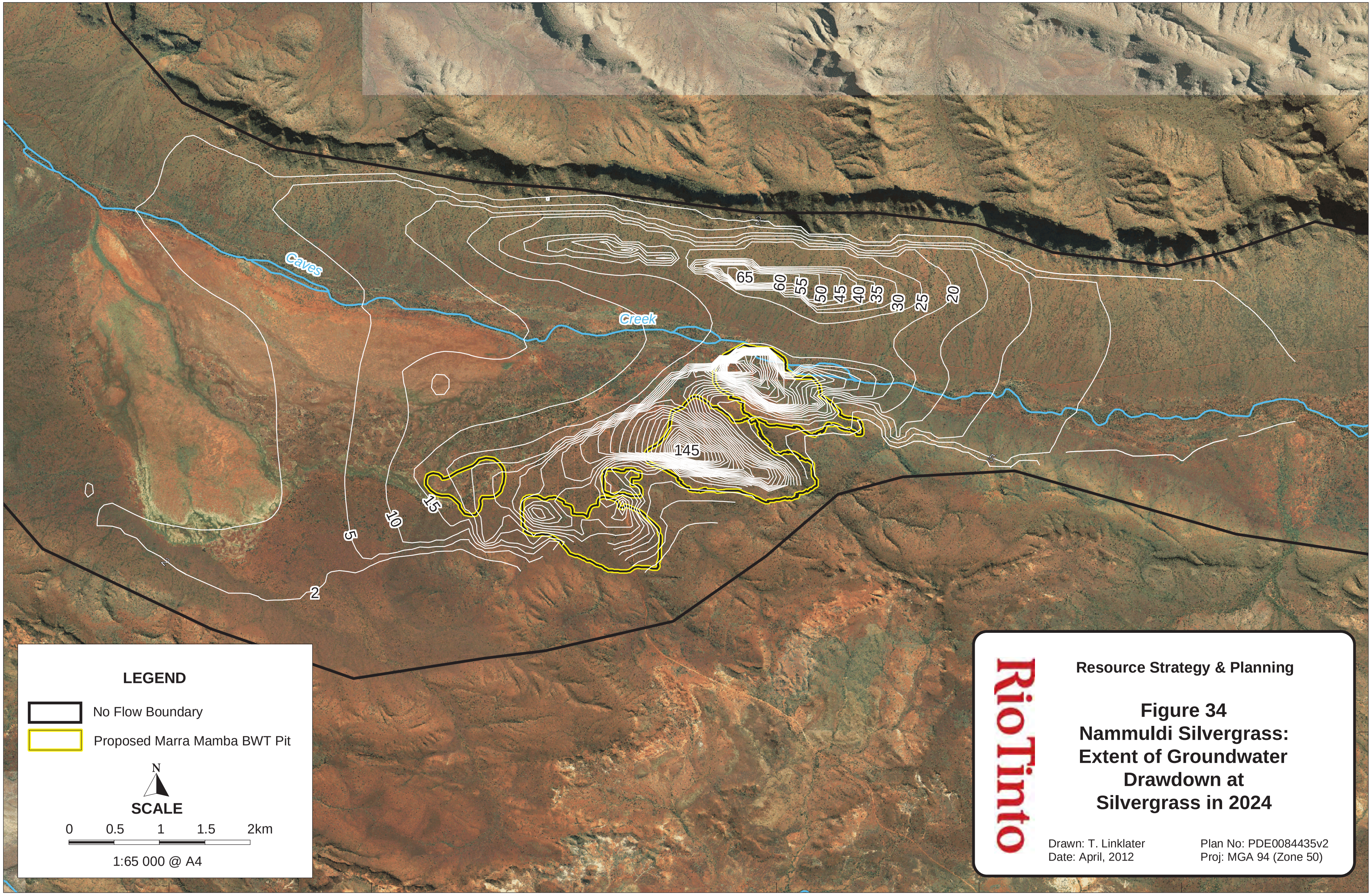
Caves
Creek
40
35
30
25
20
150
15
10
5
2
LEGEND
No Flow Boundary
Marra Mamba BWT Pit
N
SCALE
0 0.5 1 1.5 2km
1:60 000 @ A4
Resource Strategy & Planning
Figure 33
Nammuldi Silvergrass:
Extent of Groundwater
Drawdown at
Silvergrass in 2020
Drawn: T. Linklater
Date: April, 2012
Plan No: PDE0084435v2
Proj: MGA 94 (Zone 50)



Resource Strategy & Planning

Figure 34
Nammuldi Silvergrass: Extent of Groundwater Drawdown at Silvergrass in 2024

Drawn: T. Linklater
Date: April, 2012

Plan No: PDE0084435v2
Proj: MGA 94 (Zone 50)

7.4.2 Irrigated agriculture

Irrigation of 2000 ha of Hamersley Pastoral Station with surplus water from the mine has been designed to prevent changes to groundwater quality or groundwater levels of the area. Management measures, described in the AEMP (Appendix 3), in place for the operation of the IAA will prevent significant increase in the rate of accession of water to the watertable. The management measures involve optimisation of the irrigation system based on the management regime, evapotranspiration and evaporation rates and real-time monitoring to ensure that the volume of irrigation water does not exceed crop use capacity.

Real-time monitoring using soil moisture probes will regulate the volume of water applied. Sensors will be calibrated to turn the irrigation system off to prevent accession to the watertable. As a result of these management measures, the Expansion Proposal will not increase groundwater level.

Fertilisers and chemicals (including pesticides and herbicides) will be applied to crops via the irrigation system. The irrigation system is able to deliver precise nutrient and fertiliser requirements to ensure that crops achieve optimal growth and water use without nutrient or pesticide losses occurring. The nutrient requirements of the crop will be calculated using plant growth requirements, soil types and water quality.

Nutrients will be applied via the irrigation system in concentrations that are generally lower than drinking water guidleline values. The irrigated agriculture is not expected to affect groundwater quality, in terms of fertilisers or chemicals.

Physical and biological process will ensure that manure, under a stand and graze management regime, will be rapidly incorporated into the soil therefore minimising the risk to groundwater (Global Groundwater 2012). Internal fencing will also be used to enable grazing management to reduce the risk of nutrient hotspots resulting from manure.

As specified in the AEMP (Appendix 3), real-time soil condition data loggers and regular soil and plant analyses will be undertaken to ensure there is no chemical contamination as a result of application of chemicals and management practices. Operation of agriculture irrigation is not expected to increase salinity of the soil. Saturation of soil and subsequent evaporation of water from near the soil surface can concentrate salts in the soil. Rising watertables can also mobilise salts from within the soil profile. By using real-time soil moisture probes to monitor soil moisture and delivering the amount of water that the crop can use, the irrigation system will prevent the area from being over-watered, avoid the excessive accumulation of salts in the soil and prevent the watertable from rising. In addition, the content of elements in the (in the form of salts, such as potassiam) within the water is taken into account when determining plant fertiliser requirements, which limits the potential for build up of salts within the root zone. Given that the quality of water to be used is fresh (TDS of 340 – 840 mg/L) it is unlikely that irrigation will increase the salinity of the soil (Global Groundwater 2010). Rainfall is expected to leach any residual salts if they accumulate in the soil. However, should regular monitoring of soil determine that rainfall has not been sufficient to remove the salts then the pivots can be used to flush the soil without significantly affecting groundwater quality or watertable levels.

To ensure adequate groundwater monitoring is recorded, the AEMP (Appendix 3) includes installation of groundwater monitoring bores prior to operation of the irrigation. During irrigation operation, monitoring of groundwater levels will continue to ensure there is no rise in groundwater levels. As the application of water will be matched to the volume that can be used, the limited duration of the operation and quality of the water is not expected to significantly affect groundwater quality, however, in the event that there is, the AEMP (Appendix 3) contains contingency measures to ensure that the there is no detrimental environmental effect. In the event of rising watertables the AEMP includes:

- comparison with reference levels outside the IAA
- increasing the intensity of monitoring actions
- checking irrigation infrastructure
- temporarily diverting surplus water to Duck Creek to allow the elevated watertable to decline.

7.4.3 Groundwater contamination

Hydrocarbon spills, from usage and storage, have the potential to contaminate groundwater. The greatest risk of hydrocarbon spillage comes from maintenance and refuelling of vehicles and plant with diesel.

The risk of groundwater contamination from hydrocarbons is expected to be very low and will be managed through application of existing design, infrastructure and operational procedures, and the Hydrocarbon Management Plan as part of the EMP (Appendix 3). The Hydrocarbon Management Plan details procedures for maintaining and refuelling vehicles in compliance with relevant internal and external procedures and standards.

There is potential that groundwater will be contaminated by AMD which may affect groundwater quality. This risk is considered in Section 12. Final landform configurations also have significant potential to impact surface and groundwater quality both positively and negatively. These risks are discussed in Section 14.

7.5 Management measures and performance standards

Groundwater-dependent environmental values within the Greater Nammuldi Area will be protected through implementation of the following management and mitigation measures:

- minimising the volume of groundwater to be abstracted through optimisation of dewatering to minimum required to ensure safe and efficient mining conditions
- pits at Silvergrass will be backfilled above pre mine water table to assist gradual recovery of aquifer
- conducting hydrogeological modelling to examine the potential effects of post-closure landform on groundwater flow and development of a conceptual closure strategy
- monitoring of groundwater levels in the vicinity of the dewatering bores and update of hydrogeological model throughout dewatering and post closure
- monitoring of groundwater levels along Caves Creek and near Palm Springs
- storage and handling of hydrocarbons to minimise and manage spills and thereby prevent contamination of groundwater
- monitoring of IAA for evidence of groundwater contamination and changes in groundwater level as a result of irrigation
- development of an Adaptive Surface Water Management Plan that includes adaptive management measures and contingencies measures as well as key internal accountabilities.

7.6 Predicted environmental outcomes against environmental objectives, policies, guidelines, standards and procedures

After application of management mitigation measures described in Section 7.5, the Expansion Proposal is expected to result in the following outcomes in relation to groundwater:

- dewatering of approximately 643 GL over the life of the mines
- at cessation of dewatering 2 m drawdown contour is expected to extend approximately 24 km along the valley containing the Nammuldi Mine and approximately 15 km along Caves Creek as a result of dewatering at the Silvergrass Mine
- no contamination of groundwater from mining or agricultural activities
- no increase in watertables under the IAA.

8. Assessment of impact on surface water

This section addresses the impact of the Expansion Proposal on surface water and aquatic fauna. The effect of changes to the surface water regime on other environmental values is addressed under the sections dealing with the relevant environmental factor (i.e. vegetation in Section 9).

8.1 Relevant environmental objectives, policies, guidelines, standards and procedures

8.1.1 EPA objective

The EPA applies the following objectives in the assessment of proposals that may affect surface water:

To maintain the quantity and quality 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.

8.1.2 Regulatory framework

State

The Government of Western Australia implemented the RIWI Act to provide for the regulation, management, use and protection of water resources, to provide for irrigation schemes, and related purposes. Permits to interfere with bed and banks of a watercourse are also issued by the DoW under the RIWI Act to control impacts on watercourses and require suitable management strategies to address these impacts.

Surface water discharges and potentially polluting activities are managed under an environmental licence issued under Part V of the EP Act.

In 2000, the Water and Rivers Commission (now DoW) and Department of Minerals and Energy (now DMP) developed a series of Water Quality Protection Notes and 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, mine site stormwater management and acid mine drainage.

National

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).

A series of guidelines on national water quality management have also been released by the Natural Resource Management Ministerial Council (NRMMC) and, in some cases, in collaboration with the National Health and Medical Research Council (NHMRC) and the Australian Health Ministers Conference. These guidelines address a range of issues including policies and processes for water quality management, water quality benchmarks, groundwater management, diffuse and point sources, guidelines for sewerage systems, effluent management and water recycling.

8.2 Description of factor

Rio Tinto has commissioned several surveys to investigate surface water values within the Proposal Boundary and surrounds in order to assess the potential impact of the Expansion Proposal. These surveys and investigations are detailed in Table 18.

Table 18 Surface water surveys and investigations

Survey	Reference
Creek characterisation and modelling of discharge	
Preliminary Ecological Assessment of Creek Systems Potentially Affected by Proposed Developments in the Greater Nammuldi Area	Biota 2010d
Baseline hydrology assessment for Duck Creek discharge	Rio Tinto 2011d
Baseline hydrology assessment for Caves Creek discharge	Rio Tinto 2010d
Groundwater surface water interaction	
Baseline groundwater sampling programme throughout the Caves Creek	Rio Tinto 2010c
Riparian vegetation	
Greater Nammuldi Creeks Monitoring Survey: Report on Vegetation Component	Biota 2010e, 2011b
Aquatic Fauna	
Aquatic monitoring program conducted in December 2009 (dry season) and April 2010 (wet season)	WRM 2011a
Aquatic monitoring program conducted in October 2010 (dry season) and March 2011 (wet season)	WRM 2011b
Aquatic monitoring program conducted in October 2011 (dry season) and April 2012 (wet season)	WRM in prep.
TEC hydrology	
Caves Creek Floodplain Assessment for Silvergrass East deposits	Rio Tinto 2012
Hydrology drivers for the TEC at Silvergrass East	Rio Tinto 2010e

The Nammuldi and Silvergrass sites are located in the Ashburton River Basin, within the Indian Ocean Drainage Division.

The Nammuldi site is located at the headwaters of Duck Creek and Beasley River catchments, which are tributaries of the Ashburton River (Figure 12). The Nammuldi pits are situated in a valley sub-catchment where surface water flows exit the valley north through several low points in the Nammuldi Ridge to Duck Creek and to the south towards Beasley River. Runoff from small catchments located above the deposits enters the Nammuldi site. Local surface flows are affected by existing road infrastructure associated with the mining operations of the Original Proposal.

The Silvergrass site is located between a steep Brockman range along the northern side of Caves Creek and a low-lying Marra Mamba ridge on the southern side. To the west of Silvergrass, and immediately south of Caves Creek, is a flat *Themeda* grassland cracking clay TEC. The TEC is within the 20 year ARI flood extent of Caves Creek (Rio Tinto 2012). The headwaters of Caves Creek are located east of Silvergrass, encompassing the large flat plain of Wackilina and Barnett creeks which merge to form Caves Creek. Caves Creek joins Duck Creek approximately 40 km downstream of the Silvergrass site.

Preliminary ecological characterisation of Duck Creek, Caves Creek and Boolgeeda Creek was conducted in 2009 by Biota Environmental Sciences (Biota) and Wetlands Research and Management (WRM) to support development of a Surplus Water Management Strategy (Biota 2010d), and to develop baseline and long-term biological monitoring programs. Ecological characterisation consisted of a preliminary review of the habitats, vegetation and ecological features of the creek systems and a desktop assessment of the conservation significance of the creeks. This characterisation identified that Boolgeeda Creek was a much drier system with more sparse vegetation than Caves Creek or Duck Creek (Biota 2010d). Discharging water to Boolgeeda Creek was considered to be less suitable than discharge to the other two creeks as it would result in greater modification of the creek hydrology and vegetation. Scopes for (baseline and long-term) monitoring of riparian vegetation and aquatic fauna to determine the impact of discharging surplus water are outlined in the EMP (Appendix 3).

Hydroecological characteristics (including the geomorphology of the creek bed, vegetation density and composition in the riparian zone) of Duck Creek and Caves Creek were also identified to support modelling of the downstream surface water expression from the discharge of surplus water (Rio Tinto 2011d, 2010e).

8.2.1 Watercourses

Duck Creek

Duck Creek has a total catchment of approximately 6500 km^2 and drains from east to west discharging into the Ashburton River. The major tributaries of Duck Creek are Caves Creek and Boolgeeda Creek.

Duck Creek typically has a well defined and relatively stable drainage channel that meanders within an active floodplain (Figure 35). The vegetation on the banks of the creeklines varies from dense woodlands of *Eucalyptus camaldulensis* (river red gum), *E. victrix* (coolibah) and *Acacia citrinoviridis* (black mulga) or *Melaleuca argentea* (silver leaved paperbark) while in other areas the creeklines support mainly grasses and some Mulga species (Rio Tinto 2011d).

Flood conditions within Duck Creek are estimated to be 50 m^3/s for a 2 year ARI event and up to more than 1000 m^3/s for a 100 year ARI flood event immediately upstream of the confluence with Caves Creek, and 270 m^3/s for a 2 year ARI event and up to more than 15 000 m^3/s to 100 year ARI flood event immediately upstream of the confluence with Boolgeeda Creek (Rio Tinto 2011d).

The upper Duck Creek catchment is dominated by outcropping Jeerinah and Bunjinah Formations associated with the anticline in the region. Dolerite dyke intrusions are common and extensive within the Jeerinah Formation, with intrusions across the creek bed potentially forcing groundwater to express and flow along the surface of the creek, creating small reaches with perennial flow. Calcrete outcrops are found adjacent to the creek, particularly in the section up-gradient from the Caves Creek confluence in the upper Duck Creek catchment. Calcrete is present along sections of the creek that are dominated by permanent/semi-permanent water holes and pools believed to be linked to the shallow groundwater table.

The lower part of the Duck Creek system, down-gradient from the confluence with Boolgeeda Creek, displays more extensive and potentially deeper units of Tertiary and Quaternary sediments, comprising mainly alluvial and colluvial deposits. This system is typical of large floodplains in the Pilbara and is expected to have deep groundwater flows with transient pools dependent on rainfall, surface water and shallow alluvial flow.

The hydrological characteristics of Duck Creek downstream of the proposed discharge location were determined by analysing the river/floodplain geometry, soil profile, underlying geology, vegetation patterns and community distribution, amongst other characteristics (Rio Tinto 2011d). These characteristics were used to describe the movement of water along the creek for various magnitude flow events. The characteristics were then used to predict a discharge footprint arising from discharging surplus water into the creek for a range of volumes.

For the purposes of flow modelling, ten reaches were identified along the 193 km length of the creek between the identified lowest discharge point and the confluence with Ashburton River. The water balance model produced from the reach characteristics demonstrated complex, reach-dependent interactions between surface water and groundwater. Reaches were characterised as gaining, losing or no loss or gain (indirectly connected to the groundwater system) (Rio Tinto 2011d). A summary of the key characteristics of the ten reaches is provided in Table 19, with further details available in Appendix 2.

Table 19 Summary of characterisation of Duck Creek reaches

Reach	Reach length (m)	Low flow channel - base width (m)	Bed slope (m/m)	Manning's roughness	Riparian width (m)	Common riparian vegetation types	Evapo-transpiration (mm/year)	Alluvial/valley-fill depth (m)	Surface water and groundwater interactions	Recharge rate (m/s)	Limiting factor to water loss
1	2568	8	0.003	0.045	29	Ec; Ev; Ac	700	< 5	Losing	2×10^{-7}	Subsurface geology
2	2496	10	0.006	0.05	49	Ec; Ev; Ac	700	< 10	Gaining	-8×10^{-8}	-
3	14 269	11	0.002	0.045	39	Ec; Ev; Ac	600	< 10	Losing	2×10^{-7}	Subsurface geology
4	16 425	15	0.003	0.05	45	Ec; Ac	700	< 10	Gaining	-8×10^{-8}	-
5	8240	18	0.002	0.055	92	Ec; Ev; Ma	700	~ 10	Gaining	-8×10^{-8}	-
6	6338	12	0.005	0.045	46	A; Tu	300	< 1	No loss/gain	0	-
7	15 560	12	0.003	0.045	66	Ev; A; Tu	530	~ 1 to 2	No loss/gain	0	-
8	18 780	17	0.003	0.055	91	Ec; Ev	600	~ 10	Gaining	-8×10^{-8}	-
9	13 900	19	0.002	0.05	110	Ec; Ev; Ac	600	~ 10 to 20	Gaining	-8×10^{-8}	-
10	94 093	20	0.002	0.045	140	Ev; A; Tu	530	~ 20 to 30	Losing	2×10^{-7}	Subsurface geology

Ec = *Eucalyptus camaldulensis*, Ev = *Eucalyptus victrix*, Ac = *Acacia citrinoviridis*, Ma = *Melaleuca argentea*, A = Acacia Scrub, Tu = Tussock grasslands

Source: Rio Tinto 2011d

Duck Caves Confluence – Wet 11

Duck Creek downstream – Dry 10

Duck Creek upstream – Wet 11

Duck Creek upstream – Dry 10

Duck Creek tributary – Wet 11

Duck creek downstream – Wet 11

Figure 35 Photos of Duck Creek showing range of habitats

Caves Creek

Surface drainage at Silvergrass is dominated by Caves Creek, which flows westwards, draining a catchment area of around 1530 km^2 before discharging into Duck Creek approximately 40 km west of the Greater Nammuldi Area. The headwaters of Caves Creek are located east of Silvergrass, encompassing the large flat floodplain of Wackilina and Barnett creeks, which merge to form Caves Creek. During large flood events, some water on the floodplain flows north down Weelumurra Creek and eventually into the Fortescue River. However, the majority of flows are conveyed west down Caves Creek.

Local accumulations of alluvial sands and gravels occur in the modern Caves Creek drainage line; however, the creek is underlain by the Caves Creek palaeochannel, which contains alluvial deposits fining upwards from coarse sand and gravel. There is likely to be direct hydraulic connection between the quaternary alluvial materials and underlying palaeochannel, such that creek conditions directly influence groundwater recharge to the palaeochannel.

The low flow drainage channel in Caves Creek is poorly defined with minor braiding in some reaches and significant in-channel vegetation comprising *Eucalyptus camaldulensis* (river red gum) and *E. victrix* (coolibah) (Figure 36). In places, the channel is relatively straight and has a high flow velocity during floods as evidenced by the actively eroding channel (Rio Tinto 2010d).

A hydroecological investigation of this creek was undertaken using the same methodology as Duck Creek (Rio Tinto 2010d). Caves Creek has been described as a dominantly losing system with transient pools forming for extended periods within topographic depressions in the creek bed. The pools form as the watertable within the palaeochannel rises and from water moving through the creekbed alluvials (interflow).

Surface water sampling was conducted at seven pool sites along Caves Creek (including Palm Springs) as part of a groundwater sampling program in April 2010 (Rio Tinto 2010c). The seven samples had similar patterns in the values for major cations and anions, with relatively higher concentrations compared to the adjacent groundwater. The matching trends between groundwater and the pool water concur with the hydroecological assessment, that the water in pools is derived from groundwater.

Caves Creek upstream – Wet 11

Caves Creek upstream – Wet 11

Caves Creek upstream – Wet 11

Caves Creek (Palm Springs) – Dry 10

Caves Creek (Homestead) – Dry 10

Caves Creek (Homestead) – Wet 11

Figure 36 Photos of Caves Creek showing range of habitats

8.2.2 Semi-permanent and permanent pools

There are a number of minor springs throughout the Greater Nammuldi Area, most of which are ephemeral. One spring located on Caves Creek (Palm Springs) supports a number of semi-permanent / permanent pools. During sampling for aquatic fauna, WRM included sites containing water along the reaches of creeks in the Greater Nammuldi Area (Table 20).

Table 20 Number of sites containing water during aquatic fauna sampling

System	Reach	Dry 2009	Wet 2010	Dry 2010	Wet 2011
Caves Creek	Caves Creek Upstream				4
	Homestead	5	3	3	6
	Palm Springs	6	6	6	6
Duck Creek	Duck Creek Upstream Discharge				6
	Duck Creek Upstream	3	3	3	6
	Duck Creek Downstream	3	6	11	14
	Duck Creek Tributaries		3	3	3
Boolgeeda Creek	Boolgeeda Creek			1	1
Beasley River	Beasley River			2	2
Total		**17**	**21**	**29**	**48**

Over the four WRM sampling periods (a further two sampling periods have been undertaken and the interpretation of these results currently being undertaken), 14 sites contained water during all visits and are likely to represent semi-permanent pools:

- six located on Caves Creek at Palm Springs
- three located on Caves Creek at Homestead (north-northwest of Silvergrass)
- three on Duck Creek upstream of the confluence with Caves Creek
- two on Duck Creek downstream of the confluence with Caves Creek.

Palm Springs

Palm Springs is an area of permanent pools located approximately 28 km downstream of Silvergrass. Hydrogeochemical analysis of major ion concentrations suggest the water was similar to other surface water pools in the area during the sampling period. The hydrogeochemical profile was similar to the groundwater; concluding the pools are sustained by groundwater (Rio Tinto 2010c).

As a permanent pool, Palm Springs has significant environmental values, particularly for Aboriginal culture (described in Section 13). A permanent water source contributes to high riparian vegetation as described in Sections 9.2.4 and as well as high aquatic fauna values. Investigation of the Palm Springs area is recommended in the Red Book Status Report (EPA 1993) to determine conservation values due to the presence of the Millstream Palm. The Red Book identifies the area of Millstream Palm occurrence as a 300 m wide strip of land on either side of Caves Creek.

Rio Tinto maintains a permanent EC and water level logger at Palm Springs. A series of monitoring bores have been installed by Rio Tinto along Caves Creek downstream from the Silvergrass site (as mentioned in Section 7.2.2). These bores will assist in confirming the connection between surface water and groundwater levels, and will ultimately provide an early warning system should groundwater drawdown occur in the vicinity of Palm Springs.

Water quality

The water quality of sites sampled across the Greater Nammuldi Area during the dry 2010/wet 2011 period were characterised by slightly basic pH (6.88 to 9.62), moderate dissolved oxygen levels (24% to 160%) and predominantly fresh to brackish waters (150 µS/cm to 4370 µS/cm) (WRM 2011b) (Table 21). Considerably higher salinities (6330 to 6440 µS/cm) were recorded in Duck Creek tributaries during the dry season (Figure 37). The water quality of all sites sampled (including Caves Creek and Duck Creek) was found to be generally similar during the dry 2010/wet 2011 sampling period.

During the dry 2010/wet 2011 sampling period, low values of dissolved metals were recorded, however, boron, copper and zinc levels exceeded ANZECC & ARMCANZ (2000) guidelines at the majority of sites (WRM 2011b) (Figure 38 to Figure 40). Although nutrient levels were found to be low, a number of sites recorded total nitrogen and total phosphorus levels exceeding ANZECC & ARMCANZ (2000) guidelines (Figure 41 and Figure 42).

Table 21 Summary of water quality sampling results

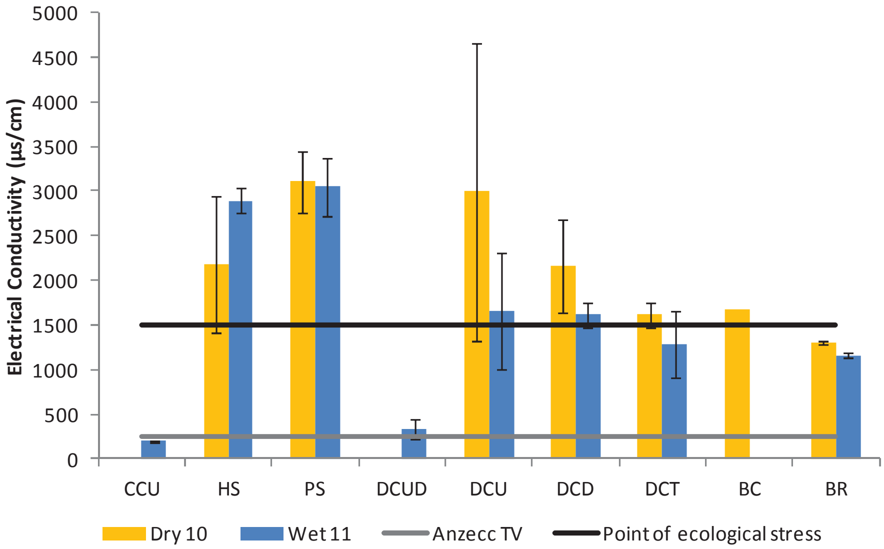
Sampling period	Max DO (%)	Min DO (%)	Max pH	Min pH	Max EC (µs/cm)	Min EC (µs/cm)
Dry 2009	163.8	28.2	9.9	7.5	4370	1100
Wet 2010	120.3	22.1	9.1	7.4	4370	651
Dry 2010	160.1	23.8	9.6	7.5	6440	885
Wet 2011	147.5	21.5	8.6	6.9	4370	149

Source: WRM 2011a, 2011b

The majority of sites sampled along Caves Creek have recorded pH values above 8. The maximum pH at Palm Springs was recorded at 8.9 during the dry season 2009 sampling; pH levels in the Caves Creek system are higher in the dry season compared to the wet. This relatively basic pH is likely to be a result of local geology (including the presence of calcrete) and has been recorded from a number of other systems in the Pilbara Region including Marillana Creek, Weeli Wolli Creek and Mindy Mindy Creek (WRM 2011b).

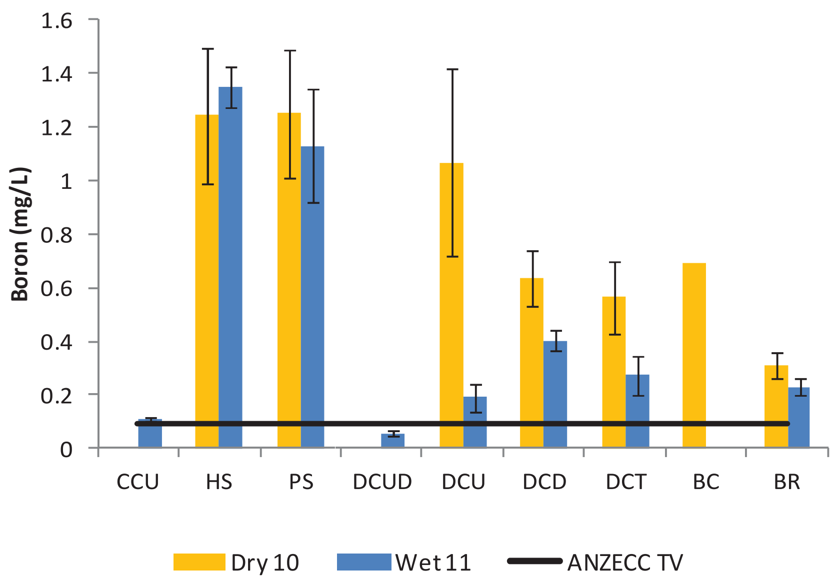
Dissolved oxygen (DO) is acceptable within a range of 85% to 120% for freshwater ecosystems (ANZECC & ARMCANZ 2000). The maximum and minimum DO recorded during the sampling of Caves Creek are outside of the ANZECC & ARMCANZ range, however, this is the natural state of the system (WRM 2011b).

Freshwater ecosystems start experiencing ecological stress when electrical conductivity (EC) is greater than 1500 – 2000 µS/cm (WRM 2011b). Sites sampled along Caves Creek recorded highly variable natural EC values which were generally greater than 2000 µS/cm during the dry season and generally greater than 1500 µS/cm during the wet season (Figure 37). This indicates that the waters in this system are slightly brackish in their natural state and suggests that macroinvertebrate assemblages in the Caves Creek catchment are characterised by brackish tolerant species (WRM 2011b).



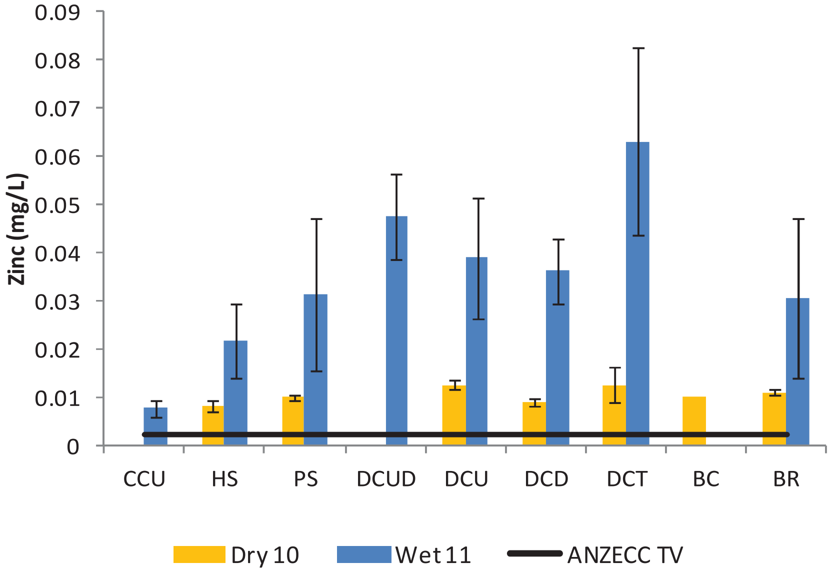
CCU = Caves Creek Upstream, HS = Homestead, PS = Palm Springs, DCUD = Duck Creek Upstream Discharge, DC = Duck Creek Upstream, DCD = Duck Creek Downstream, DCT = Duck Creek Tributaries, BC = Boolgeeda Creek, BR = Beasley River. TV = Trigger Value

Figure 37 Electrical conductivity



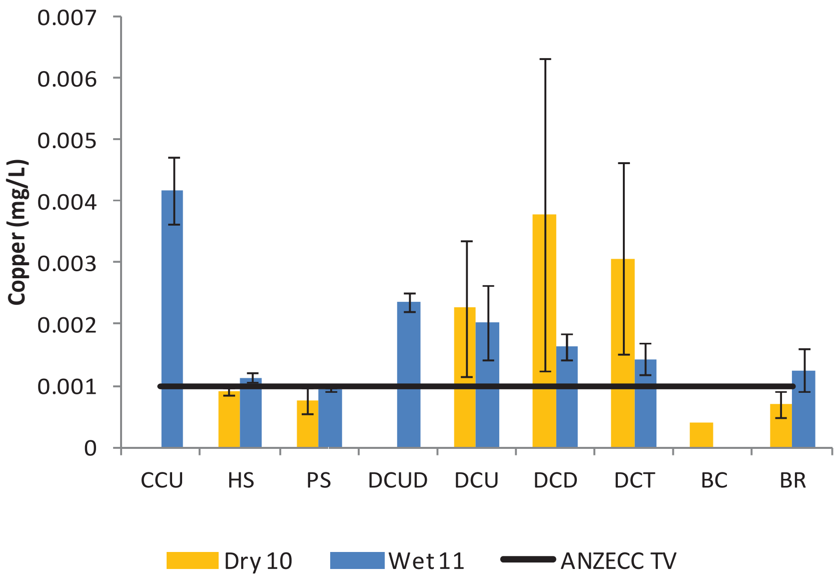
CCU = Caves Creek Upstream, HS = Homestead, PS = Palm Springs, DCUD = Duck Creek Upstream Discharge, DC = Duck Creek Upstream, DCD = Duck Creek Downstream, DCT = Duck Creek Tributaries, BC = Boolgeeda Creek, BR = Beasley River. TV = Trigger Value

Figure 38 Boron concentration in comparison to corresponding 99% trigger value



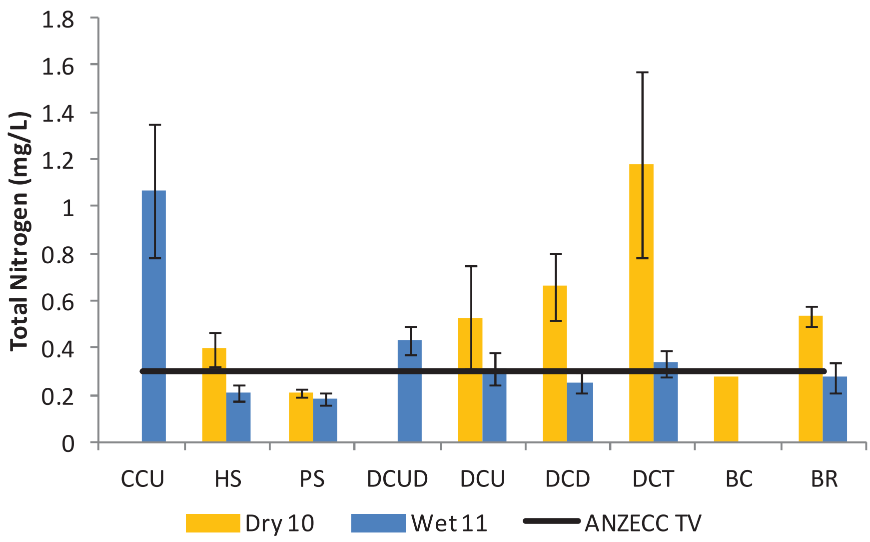
CCU = Caves Creek Upstream, HS = Homestead, PS = Palm Springs, DCUD = Duck Creek Upstream Discharge, DC = Duck Creek Upstream, DCD = Duck Creek Downstream, DCT = Duck Creek Tributaries, BC = Boolgeeda Creek, BR = Beasley River. TV = Trigger Value

Figure 39 Zinc concentration in comparison to corresponding 99% trigger value



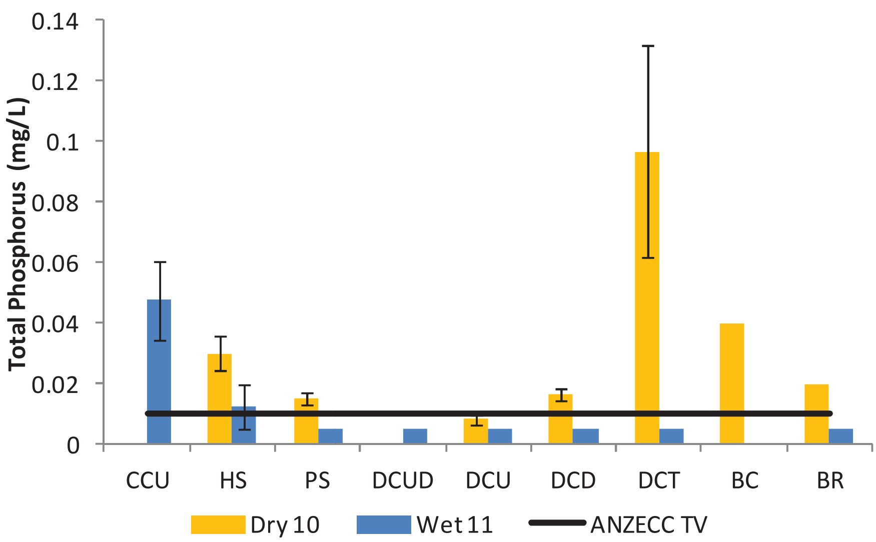
CCU = Caves Creek Upstream, HS = Homestead, PS = Palm Springs, DCUD = Duck Creek Upstream Discharge, DC = Duck Creek Upstream, DCD = Duck Creek Downstream, DCT = Duck Creek Tributaries, BC = Boolgeeda Creek, BR = Beasley River. TV = Trigger Value

Figure 40 Copper concentration in comparison to corresponding 99% trigger value



CCU = Caves Creek Upstream, HS = Homestead, PS = Palm Springs, DCUD = Duck Creek Upstream Discharge, DC = Duck Creek Upstream, DCD = Duck Creek Downstream, DCT = Duck Creek Tributaries, BC = Boolgeeda Creek, BR = Beasley River. TV = Trigger Value

Figure 41 Total nitrogen



CCU = Caves Creek Upstream, HS = Homestead, PS = Palm Springs, DCUD = Duck Creek Upstream Discharge, DC = Duck Creek Upstream, DCD = Duck Creek Downstream, DCT = Duck Creek Tributaries, BC = Boolgeeda Creek, BR = Beasley River

Figure 42 Total phosphorus

8.2.3 Aquatic fauna

Wetland Research and Management (WRM) commenced an aquatic fauna sampling and ecosystem analysis program along Duck and Caves creeks in 2009. Sampling was conducted in six stages :

1. Dry season 2009 (WRM 2011a).
2. Wet season 2010 (WRM 2011a).
3. Dry season 2010 (WRM 2011b).
4. Wet season 2011 (WRM 2011b).
5. Dry season 2010 (WRM in prep.).
6. Wet season 2011 (WRM in prep.).

The following is based on the first four surveys as identification of species and analysis of data is still being conducted for the last two surveys. The program includes documentation of the current ecological condition of the creeks based on sampling for fish, microinvertebrates, macroinvertebrates and hyporheic fauna. The sampling established pre-development baseline water quality benchmarks including nutrients, major ions and metals.

Of the 12 freshwater fish species known from the Pilbara, seven species were recorded in the four stages of sampling (WRM 2011a and 2011b):

- *Melanotaenia australis* (Western rainbowfish)
- *Neosilurus hyrtlii* (Hyrtl's tandan, eel-tailed catfish)
- *Leiopotherapon unicolour* (spangled perch)
- *Leiopotherapon aheneus* (Fortescue grunter)
- *Amniataba percoides* (barred grunter)
- *Glossogobius giurus* (flathead goby)
- *Neosilirus erebi* (bony bream).

Western rainbowfish, spangled perch, and the barred grunter were the most commonly recorded species.

These fish species are generally widespread in Australia; however, the Fortescue grunter has a relatively restricted distribution within the Pilbara Region of Western Australia. The Fortescue grunter is only known from the Fortescue, Robe and upper Ashburton (Nicholls Spring) river systems but is reasonably common within its range (WRM 2011a, 2011b). This species is currently listed as 'Lower Risk/near Threatened' on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species although this status may require updating (Wager 1996).

Hyporheoic fauna

Species considered to be either restricted to the hyporheoic zone (the region beneath and alongside a stream bed, where there is mixing of shallow groundwater and/or surface water) or occasional hyporheos stygophiles are endemic to the Pilbara region. The two most important factors that control hyporheos distribution and composition include sediment porosity (which influences interstitial volume and surface area [useable pore space, habitat area]) and hydraulic conductivity (which influences interstitial flow and consequently variables such as oxygen content, temperature and organic matter storage) (WRM 2011a).

The preliminary sampling of the hyporheic zone during the dry 2009/wet 2010 survey collected a total of 63 taxa. Of these, 90% were classified as stygoxene (species that spend part of their lifecycle in a groundwater habitat), which do not have specialised adaptations for groundwater, with the remaining 10% considered possible hyporheic fauna.

A total of 106 taxa were collected from the hyporheic zone along Caves and Duck creeks, during the dry 2010/wet 2011 survey (WRM 2011b). Similar to results from the previous sampling period, the majority of these taxa were classified as stygoxene (approximately 80%). The collected taxa were considered to be possible hyporheic fauna included occasional hyporheos stygophiles (10%), stygobites (species restricted to groundwater and/or hyporheic environments) (6%), or possible hyporheic species (2%) (WRM 2011b). A summary of the potentially hyporheic species collected from the Greater Nammuldi Area is provided in Table 22.

Table 22 Summary of potential hyporheic fauna collected from Caves and Duck creeks

Possible hyporheic status	Phylum/Sub Phylum	Sub Class/Order	Family	Genera
Stygobites	Crustacea	Amphipoda	-	*Melitidae* sp.
				Paramelitidae sp.
	Ostracoda	-	Candoninae	*Areacandona* sp.
Occasional hyporheos stygophiles	Copepoda	Cyclopoida	Cyclopidae	*Microcyclops varicans*
				Thermocyclops sp.
	Ostracoda	-	Darwinulidae	*Vestalenula* sp.
	Collembolla	-	-	*Entomobryoidea* spp.
				Poduroidea spp.
				Symphypleona spp.
	Insecta	Coleoptera	Hydraenidae	*Hydraena* sp.
			Scirtidae	*Scirtidae* spp.
Possible hyporheics	Nematoda	-	-	*Nematoda* spp.
	Annelida	Oligochaeta	-	*Oligochaeta* spp.

Source: WRM 2011b

Microinvertebrates

Approximately 116 microinvertebrate taxa were recorded in Caves Creek, Duck Creek, Palm Springs and Boolgeeda Creek during the dry 2009/wet 2010 survey (WRM 2011a). Of the species collected, only 4% are known to be Australian endemic species, including Protist *Difflugia australis*, Rotifera *Lecane noobijupi*, and Copepods *Eucyclops australiensis*, *Mesocyclops* cf. *Darwini, and Mesocyclops notius.* The level of endemism of microinvertebrate fauna collected during this sampling period was similar for both Caves Creek and Duck Creek, with Australian endemic speices collected from all reaches of the creek systems. Significant variation was noted in the assemblage composition between the two systems, however, no seasonal variation was detected in the assemblage composition (WRM 2011a).

The dry 2010/wet 2011 survey recorded 131 microinvertebrate taxa, five percent of which are Australian endemic species including Rotifers *Brachionus* cf. *ibericus* and *Lecane noobijupi*, and Copepods *Mesocyclops* cf. *Darwini*, and *Mesocyclops notius*. The Australian endemic *Mesocyclops* cf. *Notius* was recorded along Caves Creek, particularly at Palm Springs and Homestead; and had been recorded along both Caves and Duck creeks during the previous sampling period. The Rotifer *Lecane noobijupi* was recorded along Caves Creek, Duck Creek, Boolgeeda Creek, and the Beasley River.

During the dry 2010 sampling, an undescribed brachionid rotifer was recorded, which could not be identified to species level based on morphology. The specimen was observed to closely resemble *Brachionus ibericus* (Spanish morphotype) and is likely a new species of rotifer, endemic to the region (WRM 2011b). Additional morphological description and/or genetic analysis would be required to determine if this species is of conservation significance.

As with the earlier survey period, a signficiant difference was apparent in assemblage composition (based on abundance data) between the creek systems, however, no variation in assemblage between seasons was noted in data (WRM 2011b).

Macroinvertebrates

Sampling conducted during the dry 2009/wet 2010 survey collected a total of 196 macroinvertebrate taxa from the Greater Nammuldi Area (WRM 2011a). The composition of these taxa is typical of freshwater systems around the world, with species richness comparable to similar water bodies in the east Pilbara (WRM 2011a).

The majority of macroinvertebrates recorded during this period were from the Insecta phylum, with dominant orders being Diptera (33.8%), closely followed by Coleoptera (32.2%), Hemiptera (13.3%), and Odonata (12.2%) (WRM 2011a). No significant difference in the abundance of taxa was recorded during this sampling period between sites at Palm Springs, Homestead, Caves Creek and Duck Creek. However seasonal variation in numbers sampled was observed, with a higher abundance of taxa recorded during the wet season.

A total of 244 macroinvertebrate taxa were recorded during the dry 2010/wet 2011 survey (WRM 2011b). As with the previous sampling period, the majority of taxa recorded are common to freshwater systems around the world. Of the collected species, approximately 2% are considered to be endemic to Western Australia and 3% endemic to the Pilbara. Two species collected during this sampling period are listed on the IUCN Redlist of Threatened Species: the Pilbara emerald dragonfly *Hemicordulia koomina* and the Pilbara pin dameselfly *Eurysticta coolawanyah.*

The Pilbara emerald dragonfly was recorded at one site on Duck Creek during the dry season. During the wet season, the Pilbara emerald dragonfly was recorded at five sites on Duck Creek (both up and downstream of the confluence with Caves Creek) and at Homestead during the wet period. This species is known from no more than five locations in the Pilbara region within an area smaller than 500 km^2, including pools on the Fortescue River and within the Millstream Chichester National Park (WRM 2011b).

The Pilbara pin damselfly has a similarly restricted distribution (less that 500 km^2), with records from the Fortescue River and on Millstream Station (WRM 2011b). During the dry 2010/wet 2011 survey, this species was recorded at eight sites on Duck Creek (both upstream and downstream of the confluence with Caves Creek) and on Beasley River.

As outlined in Table 23, some seasonal variation in the number of taxa recorded was observed between the dry and wet season.

Table 23 Macroinvetebrates recorded in Duck and Caves creeks (dry 2010/wet 2011 survey)

Macroinvetebrates	No. of taxa	
	Dry 2010	Wet 2011
Cnidaria (freshwater hydra)	1	1
Nematoda (round worms)	1	1
Nemertea (ribbon worms)	1	0
Macro-Crustacea (side swimmers)	0	1
Oligochaeta (aquatic segmented worms)	1	1
Mollusca (snails)	5	8
Hydracarina (water mites)	2	2
Coleoptera (aquatic beetles)	48	58
Diptera (two-winged flies)	44	59
Ephemeroptera (mayflies)	4	5
Hemiptera (true bugs)	25	28
Lepidoptera (moths)	2	4
Odonata (dragonflies & damselflies)	20	17
Trichoptera (caddis-flies)	12	12
Total number of taxa	**166**	**197**

Source: WRM 2011b

8.2.4 TEC hydrology

The TEC adjacent to the Silvergrass deposit on the Caves Creek floodplain is a very flat area that receives local surface runoff from a small catchment to the east and south. The TEC surface water runoff catchment is approximately 54 km^2, which consists of hill slope catchments to the south and east of the TEC (39 km^2) and the flat sheetflow area (15 km^2) (Figure 43) (Rio Tinto 2010e). The eastern portion of this catchment (i.e. the area east of the TEC) will be disturbed for mining. Runoff from hill slope catchments is conveyed through the TEC via three channel systems:

- northern creek, which is likely to be activated by Caves Creek during 20 year ARI or greater storm events and/or surface water runoff sourced from the eastern slopes
- central creek, which receives runoff sourced from the eastern slopes (37% of the entire catchment or 20 km^2)
- southern creek, which lies just inside the southern boundary of the TEC and is fed by runoff originating from the southern valley slopes (30% of the entire catchment or 16.2 km^2)..

The northern creek in the TEC does not receive surface water runoff from the eastern valley slopes during the 2, 5 and 10 year ARI events. Hence the northern half of the system is likely to be sustained by incident rainfall during smaller storm events (up to 10 year ARI) and will be influenced by Caves Creek -during 20 year ARI or greater events (Rio Tinto 2012). Flooding of the southern and central creeks from runoff covers only a very small proportion of the TEC during the 2 and 5 year ARI events, signifying incident rainfall would be the more dominant water source for the system on an annual basis.

An analysis of flood magnitudes along Caves Creek predicted that a 20 year ARI flood event or larger would flood the TEC (Rio Tinto 2010e). This modelling determined that these events are likely to have produced water ponding on the TEC for a duration of approximately 10 days.

A review by the University of New South Wales (Ingram 2011) into water use of *Themeda triandra* in the Pilbara determined that *Themeda* predominantly relies on rainfall for growth and production. This review was based on a consideration of rooting depth and growing season. This indicates that the TEC is sustained by incidental rainfall and periodically submerged by Caves Creek during 20 year ARI and larger magnitude flood events.

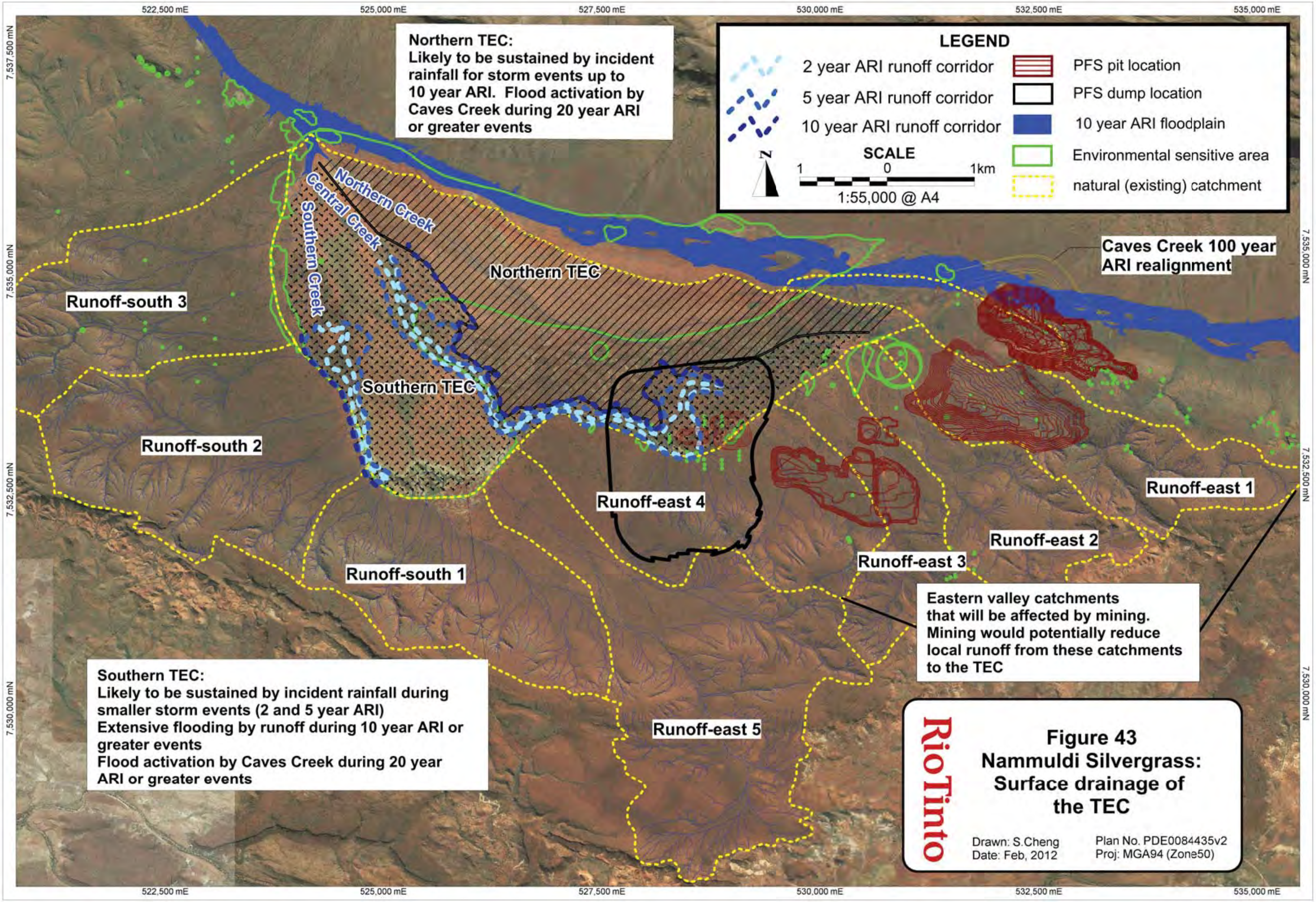


Figure 43
Nammuldi Silvergrass: Surface drainage of the TEC

8.3 Potential sources of impact

The following aspects of the Expansion Proposal may affect surface water values:

- **dewatering** at Silvergrass will result in drawdown in the superficial aquifer along Caves Creek which would potentially modify the baseflow conditions of the watercourse and has the potential to lower the water levels of semi-permanent pools, affect aquatic fauna habitat and reduce water availability for riparian vegetation
- **discharging surplus water** into ephemeral watercourses will saturate alluvium of the creek low flow channel and could initiate the merging of existing smaller pools, which would potentially modify the hydrological regime (quantity and quality) thereby affecting permanent pools, riparian vegetation and aquatic fauna habitat
- **constructing the channel diversion** in Caves Creek at Silvergrass may alter the existing flow conditions, including the water levels, flow direction and velocities, of the creek system
- **modifying landforms** through construction of pits, dumps and infrastructure may affect surface flows, which may indirectly affect flow dependent vegetation (where flows are reduced) or affect vegetation sensitive to inundation (where flows are increased and/or ponding is introduced or prolonged)
- **runoff from disturbed areas and overburden dumps** may result in increased sediment transport to watercourses
- **contamination** of surface water is possible from suspended solids, hydrocarbon spills, AMD within mining areas.

Potential impacts of contamination from AMD and other mineral wastes are discussed in Section 12. Indirect impacts on vegetation from changes to surface water are discussed in Section 9.

The effect of linear infrastructure on sheetflow has not been considered as the Expansion Proposal does not involve addition of substantial linear infrastructure in proximity to sheetflow-dependent communities. As described in Section 3.3.11, the IAA been designed to avoid sensitive receptors in proximity, including watercourses, and only deliver the volume of water that crops can utilise. Therefore, runoff is not expected to occur from the IAA and impacts to surface water from the IAA have not been considered.

8.4 Assessment of likely direct and indirect impacts

8.4.1 Dewatering

Section 7.4.1 identifies that the extent of groundwater drawdown at Nammuldi will not affect any surface water features or groundwater-dependent ecosystems. Therefore dewatering at Nammuldi will not affect the quality of surface water given that the existing watertable is well below ground level.

Dewatering at Silvergrass will result in the 2 m groundwater drawdown contour extending along Caves Creek for approximately 15 km. The drawdown has the potential to affect the hydrological conditions of the watercourse where the groundwater interacts with the alluvium and pools along Caves Creek.

No permanent waterholes (i.e. groundwater-fed waterholes) have been identified within the extent of the 2 m groundwater drawdown contour. Transient pools that develop along the creek after heavy rainfall, are not expected to be affected given the formation of these pools requires rainfall events to sufficiently saturate the alluvium.

However, the increased infiltration capacity within the creek alluvials has the potential to reduce the duration of water in the creek. Similarly, water in the creek sustained as a result of sub-surface water movement (interflow) after flood events will also have reduced durations due to the increased infiltration capacity produced by the dewatering activities. Surface pools in the creek are naturally transient, with water quality shown to deteriorate during the dry season due to increased evaporation. Therefore the reduction to the duration of of water in the creek is not expected to affect the water quality of the surface water compared to natural conditions.

Aquatic fauna species are not expected to be affected as no species is restricted to the area subject to drawdown and all species have been consistently recorded throughout the Greater Nammuldi Area (WRM 2011b).

8.4.2 Discharge of surplus water

The surplus water management strategy (presented in Section 3.3.10) identifies that all water will preferentially be used on-site or by the surrounding operations of Rio Tinto which includes transferring water to the Hamersley Pastoral Station for irrigated agriculture. The irrigated agriculture scheme on Hamersley Pastoral Station has been designed to operate in response to a varying volume of water and will have up to 40 pivots that can be used.

The Original Proposal included continuous discharge of surplus water to Duck and Caves creeks but subsequent studies (Rio Tinto 2011d, 2010e) determined that discharge of surplus water to Duck Creek would modify the hydrological characteristics of this creek the lest. Therefore, restricting discharge to only Duck Creek is considered to provide a better environmental outcome. The discharge of surplus water is likely to occur from two discharge points shown on Figure 18.

Discharge modelling estimated the width and depths of flows at continuous discharge volumes of 10, 50, 100 and 200 ML every day until steady state was reached (Figure 45). For all cases, the modelling showed that the flow would be entirely contained within the low flow channel. The exception to this is a discharge of 200 ML/day in Reach 1 (scenario considered unlikely) where the volume would exceed the low flow channel capacity in some locations along the reach, however overtopping of the creek banks is not anticipated (Rio Tinto 2011d).

Modelling of the discharge footprint[3] downstream of the Duck Creek discharge points identified that a steady state discharge of 20 ML/day is expected to travel over 80 km down the creek (Rio Tinto 2011d). The distance is influenced by the number of springs and associated gaining reaches that limit water loss via infiltration. However, flows above 20 ML/day would extend over reaches disconnected from the groundwater system, facilitating increased volume loss via infiltration, and the footprint would extend downstream at a slower rate (Table 24).

Modelling of the discharge footprint was undertaken using a steady state model, where discharge rates are continuous and modelled until the discharge footprint remains constant. The use of steady state conditions in the modelling is considered conservative as it does not take into account the periodic discharge regime, which will include periods of drying between discharges. In addition, the model does not allow for local variations in climate which, especially during summer months, will increase evaporation and evapotranspiration rates.

The conceptual surplus water discharge model was reviewed by SKM as part of the Rio Tinto Yandicoogina Junction South West and Oxbow Iron Ore Project. Changes recommended as part of that review were subsequently included in the conceptual model and this was then used in the discharge modelling for the Nammuldi Silvergrass Expansion Project.

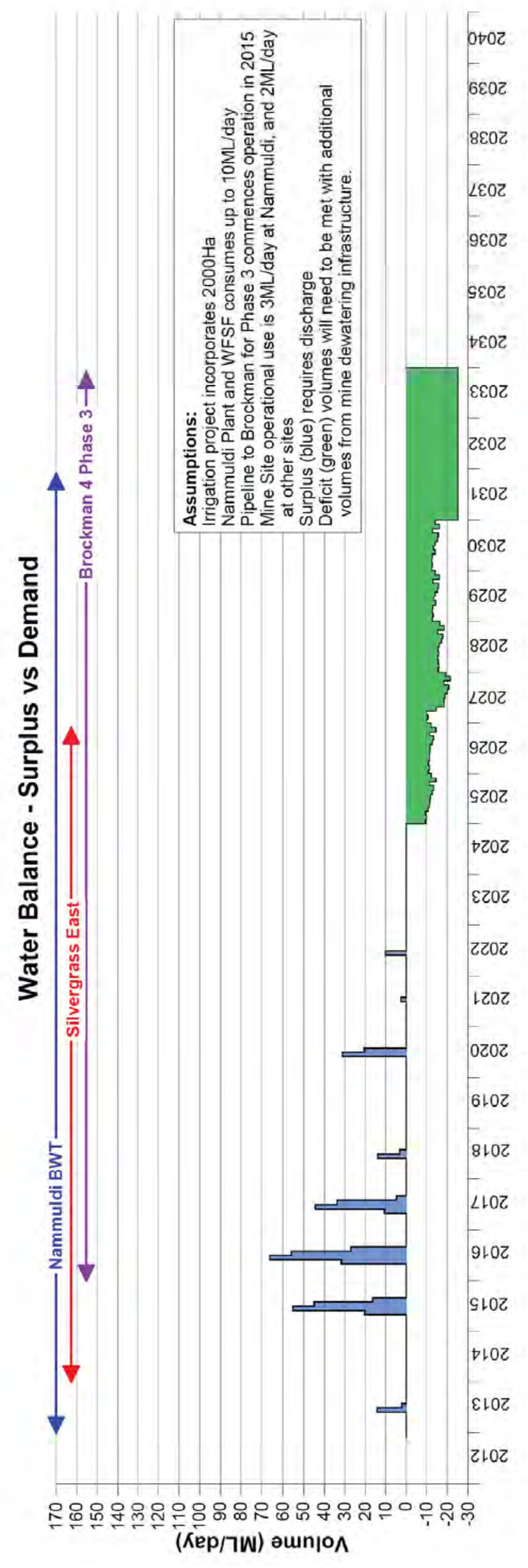
[3] The discharge footprint is the maximum possible extent of surface water expression where the creek bed may become saturated after a period of continuous discharge once steady state conditions are established, but may not have constant surface water flow.

Table 24 Predicted discharge footprint at different discharge volumes

Continuous discharge volume modelled (ML/day)	Maximum discharge footprint (km)*
15	30
20	83
50	109
100	124
150	140
200	157

*this modelling was conducted under the assumption that all water would be discharged from a single downstream discharge point, not two discharge points as per the Expansion Proposal (i.e. worst case scenario)

The predicted average daily volume of surplus water expected to be discharged each month to Duck Creek is shown in Figure 44. Over the life of the mine (17–20 years), the predicted average discharge as a result of dewatering exceeding the volume of water that can be used in the IAA is expected to exceed the 20 ML/day threshold for a total of 17 months over an eight year period, which will predominantly occur during 2015 to 2017. Of this, the predicted discharge will exceed 40 ML/day for nine months over six years. These predictions do not include short-term events, such as the release of water due to rainfall events or emergencies that may temporarily interrupt operation of the pipelines or IAA.



STRATEGEN

Nammuldi-Silvergrass Expansion Proposal

Predicted average discharge volumes

Figure 44

The irrigated agricultural project will be managed to irrigate at a rate commensurate with the plant water use requirements while minimising the volume of water moving beyond the root zone to avoid artificial groundwater recharge and nutrient leaching. During, and following heavy rainfall when the ground is saturated, surplus water from dewatering will need to be discharged to Duck Creek.

The discharge of surplus water during, and following major rainfall events is expected to roughly mimic the natural water cycle of the riparian system. As soon as rainfall ceases and soil moisture measurements indicate there is renewed capacity to support irrigation water for plant uptake, water will be directed back to the IAA. The discharge of water to the creek in response to rainfall is expected to contribute only a small volume compared with natural flow on an annualised basis. Natural flow volume from a 2 year ARI in Duck Creek has been modelled at 50 m^3/s (equivalent to 4.3 GL/day) at the confluence of Caves Creek. This is substantially greater than the peak dewatering rate of approximately 195 ML/day (0.195 GL/day), which is expected in 2016.

The expected recovery of the Duck Creek reaches is considered analogous to the response and recovery of either a single or a series of flood/storm events, varying depending on the characteristics of that reach. The modelled behaviour of each reach to discharge (and cessation of) is summarised in Table 25 (refer to Table 19 for a summary of characteristics of reaches). For a majority of the reaches, the water level is expected to drop quickly once discharge has ceased, with minor flow and pools dissipating within a few weeks. In some of these reaches, a small amount of flow will be sustained for a longer time by water from the previous reach. At reaches 2 and 5, base flow may continue for many months resulting from the slower release of water from pools and surface aquifers. If a steady state condition is established in some reaches prior to discharge being terminated, semi-permanent and permanent pools are expected to be sustained for a number of months as a result of localised groundwater level increase and residual inflow from upstream.

The outcomes of disposal of surplus mine water primarily relate to an increased frequency of episodic discharges to Duck Creek, that would mimic the current irregular flow regimes, with no significant long-term effect on the associated ecosystems.

Table 25 Response of Duck Creek reaches to discharge

Reach	During discharge	Following cessation of discharge
1	For peak discharge rates smaller than 200 ML/d, water will likely be contained within the low flow channel. At the rate of 200 ML/d[4], there is the potential for the discharged volume to exceed the low flow channel capacity in some locations along the reach, however overtopping of the creek banks is not anticipated. Constant surface water flows are expected for all modelled discharge rates.	Expected to respond and recover analogous to a flood. Creek flow will be immediately terminated, allowing the creek bed to start drying out. Groundwater recharge mounds beneath the creek, previously sustained by the discharge, will dissipate within weeks. The system is expected to return to natural conditions within a few weeks.
2	Water discharged into the creek will likely be contained within the low flow channel, hence overtopping of the creek banks is not anticipated. Continual surface water flows are expected for all modelled discharge rates.	Expected to respond and recover analogous to a series of flood events or multiple above average rainfall years. Surface flow from the previous reach will terminate immediately. As a result of the discharge, topographic depressions are expected to have been filled by the surface water flows. These pools will continue to contribute flow to the system at a significantly reduced rate. Thus water availability within the creek is expected to remain elevated for a few months after the discharge is terminated. If steady state conditions were established before the discharge is terminated, semi-permanent and permanent pools will continue to be fed by sub-surface flows associated with a local increase in groundwater level as well as residual interflow. This water will sustain the pool levels and is likely to also sustain surface water flow downstream of the pools for many months after the creek discharge is terminated, gradually returning to the natural discharge rate and pool depths.
3	Water discharged into the creek will likely be contained within the low flow channel, hence overtopping of the creek banks is not anticipated. For peak discharge rates greater than 60 ML/d, constant surface water flows are expected down the reach.	Expected to respond and recover analogous to a flood. Creek flow will be immediately terminated, allowing the creek bed to start drying out. A small volume of surface water flow, originating from the pools of the previous reach, may be sustained for a short time at the start of the reach only. Groundwater recharge mounds beneath the creek, previously sustained by the discharge, will dissipate within weeks. The system is expected to return to natural conditions with a few weeks.
4	Water discharged into the creek will likely be contained within the low flow channel, hence overtopping of the creek banks is not anticipated. For peak discharge rates greater than 10 ML/d, constant surface water flows are expected down the reach.	Expected to respond and recover analogous to a flood. Creek flow will be immediately terminated, although a small, significantly reduced volume of surface water flow may continue to flow from pools for several weeks until the system gradually returns to natural conditions.
5	Water discharged into the creek will likely be contained within the low flow channel, hence overtopping of the creek banks is not anticipated. For peak discharge rates greater than 15 ML/d, constant surface water flows are expected down the reach.	Expected to respond and recover analogous to a series of flood events or multiple above average rainfall years. The water level will drop quickly in response to the terminated flow. A base flow will continue for many months resulting from the slower release of water from pools and aquifers upstream of the reach. If steady state conditions were established before the discharge is terminated, semi-permanent and permanent pools will be sustained for many months by sub-surface flows associated with a local increase in groundwater level as well as residual interflow. Some surface water flows may continue between pools for several weeks after the discharge is ceased until the system gradually returns to natural conditions.

[4] Modelling of 2000 ML/d represents a scenario beyond the predicted maximum dewatering rate in any year, therefore, is highly conservative.

Reach	During discharge	Following cessation of discharge
6	Water discharged into the creek will be contained within the low flow channel, hence overtopping of the creek banks is not anticipated. For peak discharge rates greater than 15 ML/d, constant surface water flows are expected down the reach.	Expected to respond and recover analogous to a flood or storm event. Surface water flow will cease between pools and the pools will dissipate via evaporation predominantly over the following weeks.
7	Water discharged into the creek will likely be contained within the low flow channel, hence overtopping of the creek banks is not anticipated. Constant surface water flows along this reach is expected for peak discharge rates greater than 15 ML/d.	Expected to respond and recover analogous to a flood or storm event. Surface water flow will cease between pools and the pools will dissipate via evaporation and evapotranspiration over the following weeks.
8	Water discharged into the creek will likely be contained within the low flow channel, hence overtopping of the creek banks is not anticipated. For peak discharge rates greater than 15 ML/d, constant surface water flows are expected down the reach.	Expected to respond and recover analogous to a flood. Similar to conditions following the peak of a flood event, the water level will drop quickly in response to the terminated flow and surface flow will cease. No base flow is expected to be sustained after the surface water flows terminate in the previous reach. Thus conditions are expected to return to a natural state within weeks of the discharge termination.
9	Water discharged into the creek will likely be contained within the low flow channel, hence overtopping of the creek banks is not anticipated. For peak discharge rates greater than 20 ML/d, constant surface water flows are expected down the reach.	Expected to respond and recover analogous to a series of flood events or multiple above average rainfall years. Similar to conditions following the peak of a flood event, the water level will drop quickly in response to the terminated flow and surface flow will cease, allowing the creek bed to start drying out. If steady state conditions were established before the discharge is terminated, semi-permanent and permanent pools will be sustained for many months by sub-surface flows associated with a local increase in groundwater level as well as residual interflow until the system gradually returns to natural conditions.
10	Water discharged into the creek will likely be contained within the low flow channel, hence overtopping of the creek banks is not anticipated. The footprint distances for all modelled discharge rates terminate at this reach. However the sub-surface geological constraints suggest that transient flow conditions may dominate within this reach. Surface water flow could extend for 20 km down the reach for the 200 ML/d discharge (the maximum rate modelled).	Expected to respond and recover analogous to a flood. Water levels will drop quickly in response to the terminated flow and surface flow will cease and the creek bed will quickly return to naturally dry conditions.

Source: Rio Tinto 2011d

Effect of discharge on surface water quality

Discharge of groundwater to watercourses can potentially alter surface water chemistry depending on the quality of the groundwater compared with that of the receiving creek (WRM 2011b). Discharge has the potential to increase erosion, sedimentation, siltation and calcification of the creekbed.

Site specific water quality trigger values will be determined prior to surplus water discharge, in accordance with ANZECC/ARMCANZ (2000) guidelines. The primary objective of the guidelines is to “maintain and enhance the ‘ecological integrity’ of freshwater and marine ecosystems, including biological diversity, relative abundance, and ecological processes.”

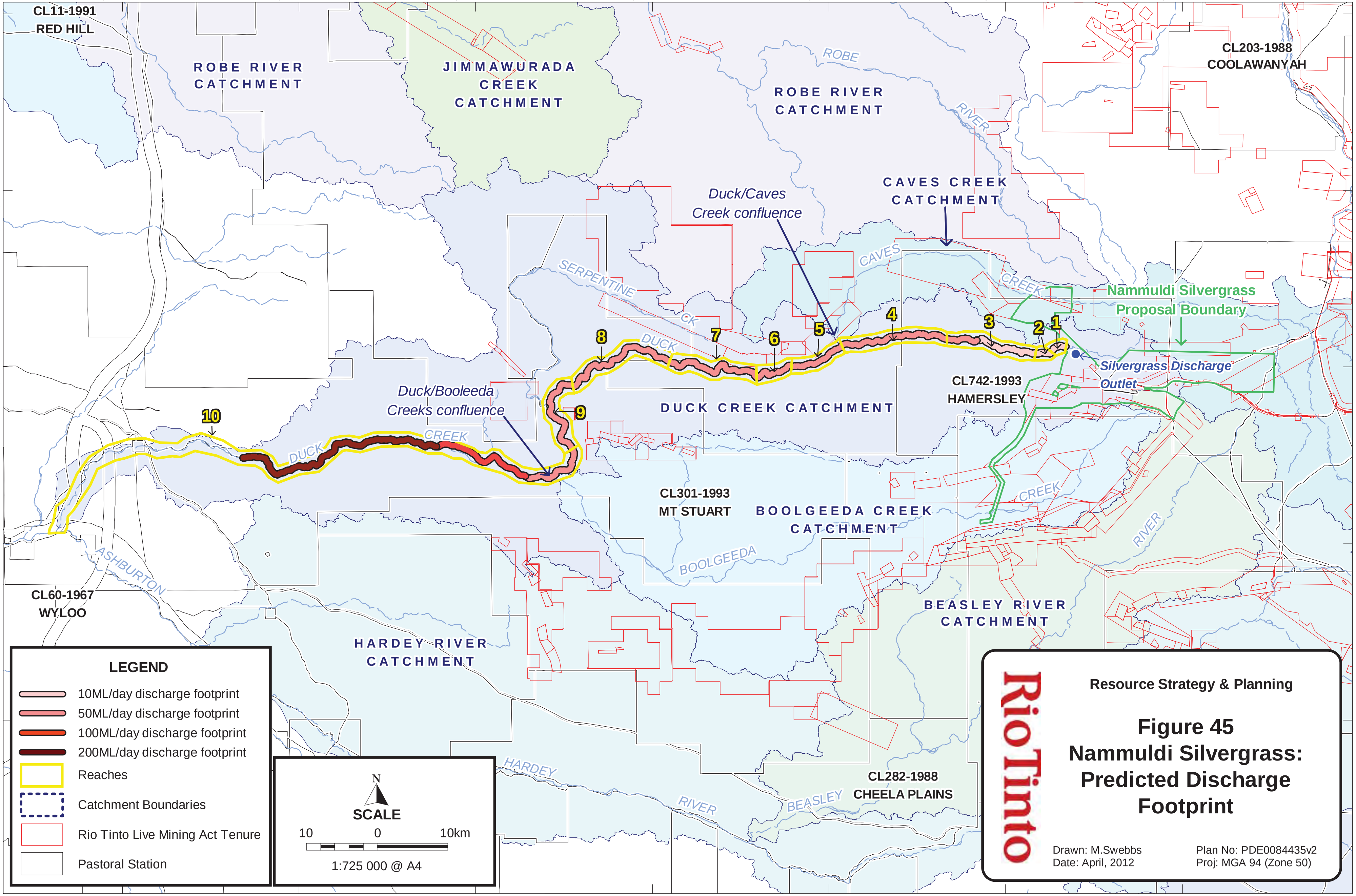
Discharge of surplus water will be managed to ensure that these triggers are met. Therefore, surface water quality is unlikely to be significantly affected. Although surface water quality is not likely to be adversely affected by dewatering discharge, ongoing monitoring will take place to ensure that there are no adverse changes in water quality over time (frequency of monitoring may vary depending on discharge volumes, frequencies and results).

Effect on downstream aquatic fauna

The periodic releases of surplus water in Duck Creek has the potential to affect populations of some invertebrate fauna that are adapted to seasonal flows.

Aquatic fauna diversity and abundance in Duck Creek and Caves Creek is greater than other semi-permanent/ seasonal systems in the Pilbara region (WRM 2011b). In addition, species found have been consistently recorded throughout the Greater Nammuldi Area (WRM 2011b).

Due to the periodic nature of the discharge and consistency of aquatic fauna populations in the watercourses, the discharge of water is considered unlikely to significantly affect aqatic fauna populations (WRM 2011b).



Resource Strategy & Planning

Figure 45
Nammuldi Silvergrass: Predicted Discharge Footprint

8.4.3 Caves Creek realignment

Pit 1 extends into the main channel of Caves Creek, which will necessitate a short realignment of approximately 2.5 km of the main channel (Figure 27).

The realignment has the potential to affect flow velocities, which could alter sediment load and consequently affect water quality. The realignment will move the channel to the north, and will require construction of a flood levee between the pit and creek. The flood levee will be designed to accommodate a 100 year ARI flood event without over topping. For flood events greater than 100 year ARI, flows will continue to be conveyed down Caves Creek with some potential loss of water over the levee into the mine area. The flood levee will be installed 100 m from the boundary of Pit 1. Installation of a permanent cut channel will facilitate diversion of water around the pit.

The realigned channel section will have a dedicated low flow channel and the channel bed slope will be consistent with current conditions. Water will be conveyed in manner that:

- avoids overtopping of water into the pit
- minimises infiltration while maintaining stability of underlying materials during the life of the pit (approximately 10 years).

This will help minimise groundwater abstraction volumes and maintain pit wall stability.

Sensitive receptors downstream of the realignment are the TEC, Caves Creek and Palm Springs. The basis of design is to ensure that the following key features of the diverted channel are comparable to the natural channel:

- flow velocities
- flow regime
- sediment transport rates.

Provided that these key features, measured at the end of the diversion, are comparable to those of the natural system, all downstream receptors can be expected to remain unaffected by the diversion. This approach has been discussed with, and accepted in principle by, both DoW and DEC.

The realignment will be designed to contain a 100 ARI event flow and the structure will be designed to withstand Possible Maximum Flood (PMF). A hydrology assessment will be undertaken in consultation with DoW and DEC as part of the design process to ensure the long term stability of the infrastructure and to protect the surrounding environment. The results of this assessment and the final engineering design will be provided to DoW.

Energy dissipation structures may be constructed in the channel to reduce flow velocities and erosion control measures may be required to limit erosion. The start and end of the realignment will be designed to transition local low flow conditions through the realignment with minimal disruption to the upstream and downstream natural environment. The realignment has the potential to alter creek flows and sediment loads, which may in turn affect downstream riparian vegetation and any fauna using this habitat. The realignment will be designed to limit any increase in velocity or sediment-load of the creek, which will ensure any change to water quality or the natural flow regime is unlikely to have any long-term effect on downstream riparian vegetation. These design features will ensure that flooding events of the downstream *Themeda* grassland TEC from the creek are not affected.

Following completion of mining at Pit 1, the northern section of the pit will be backfilled to within the 100 year ARI floodplain extent to convey flows. The diversion levee may or may not be removed or modified depending on the impact of additional disruption and modification to the creek, such that flows will be preferentially maintained along the realigned course after closure.

The management measures that will be applied in construction of the realignment are summarised in Section 8.5.

8.4.4 Landform modification

To ensure protection of infrastructure and to prevent contamination the Expansion Proposal includes the modification of surface water flows around mine pits and waste dumps.

The construction of mine pits and waste dumps at Silvergrass will decrease the surface runoff reaching the DEC mapped TEC boundary (Figure 62). Catchment areas to the east of the TEC DEC boundary, which dominantly feed the central creek (37% of the catchment) through the TEC DEC boundary, will be diverted, reducing flow along the central creek after rainfall. The Proposal footprint will not modify runoff volumes to the southern creek (30% of catchment) or the northern creek (7% of catchment). Therefore, flow volumes received by the TEC within the vicinity of these creeks will not be affected. The majority of the remainder of the TEC boundary is not considered to be sustained by the three creek catchments (the remaining 26%), and will not be affected by the reduced catchment runoff.

Management of drainage from modified landforms from the Expansion Proposal is expected to be similar to the Original Proposal. All runoff from the Expansion Proposal will be diverted to sediment settling ponds or similar structures to ensure the sediment load of surface runoff does not increase above natural levels and will not affect creek water quality or sedimentation levels downstream.

The Themeda grassland TEC has been mapped within the northwest corner of the TEC DEC boundary, between the southern and central creeks (Figure 14). The remainder of the TEC DEC boundary, is primarily comprised of mosaic Astrebla grasslands including the *Astrebla lappacea* PEC (Figure 15)(Biota 2011a). These vegetation complexes are discussed in further detail in Section 9.2.2.

The plant species within the TEC DEC boundary, including those comprising the *Themeda* grassland TEC and mosaic *Astrebla* PEC, predominately rely on water available within the unsaturated zone of the soil profile (Biota 2010c), derived from direct infiltration of rainfall. This suggests these species prefer unsaturated soil conditions and are likely to adapt to drought conditions. The changes in flows reaching the catchment of the central creek is therefore unlikely to have a signficant impact on these vegetation units.The construction of bunds around waste dumps will result in relatively small volumes of water being directed to prevent flooding or standing water occurring. This construction is not expected to significantly modify catchment characteristics.

8.4.5 Surface water contamination

The risk of potential hydrocarbon spills and resultant contamination will be minimised through implementation of management, monitoring and contingency measures as detailed in the Hydrocarbon Management Plan, contained in the EMP (Appendix 3). Management measures to be implemented include bunding hydrocarbon storage facilities, provision of re-fuelling locations, and stationary hydrocarbon usage areas in compliance with relevant standards. Hydrocarbon treatment facilities will be constructed and maintained at the workshop and wash-down facilities.

The risk of surface water contamination from disharge of AMD will be minimised through implementation of management, monitoring and contingency measures as detailed in the Mineral Waste Management Plan, contained in the EMP (Appendix 3). Management measures to be implemented include constructing bunding to reduce surface runoff flowing over exposed PAF material and material with enriched elements in the pit face and storing waste material in appropriately designed waste dumps.

Water discharged from operational areas will meet site specific requirements, developed in accordance with the ANZECC & ARMCANZ (2000) guidelines for determining water quality trigger levels. Contamination of surface water by the Expansion Proposal is unlikely to represent a significant environmental risk given the management measures to be implemented.

8.4.6 Stormwater runoff

Natural runoff generated in the Pilbara typically has a high sediment load as rainfall events frequently occur in response to intense storms or cyclones. Loose material produced from construction activities and areas where the vegetation cover has been removed may increase the supply of sediment and the sediment load in runoff. Runoff from construction areas will be subject to sediment retention measures before release to the environment in order to reduce off-site sediment loads in runoff.

Runoff from disturbed areas and overburden dumps created during the mine life is likely to have a high sediment load. Bunds, sumps and other drainage control structures will be used across the mine areas to control surface water runoff and thereby control sediment movement. Stormwater runoff from within the mine pits and from the infrastructure servicing areas will be diverted to settling basins prior to discharge.

At Nammuldi, a settling pond to the north of Lens A will be used to remove excess sediment from runoff prior to returning the water to a tributary of Duck Creek. Runoff diverted to the Nammuldi settling pond will largely be sourced from the catchment that naturally contributes runoff to the tributary and the volume of runoff flowing into the tributary is not expected to change as a result of the Expansion Proposal.

Uncontrolled runoff generated within the Silvergrass area will be diverted to a number of temporary sediment ponds, adjacent to the Silvergrass operation. These temporary sediment ponds and associated surface water control structures will be built and modified to fit the evolving mine infrastructure layout to prevent high sediment load water returning directly to the environment.

The sediment load and characteristics of the flow to natural drainage lines is not expected to be significantly modified due to diversion of runoff to settling ponds and subsequent release during storm events.

8.5 Management measures and performance standards

Surface water values within the Greater Nammuldi Area will be protected through implementation of the following measures:

- implement an Adaptive Surface Water Management Plan that includes monitoring and adaptive management measures as well as contingency measures to ensure that discharge does not have an adverse effect on the water quality of Duck Creek
- design the creek realignment to protect downstream channel, TEC, water quality and Palm Springs
- construct the creek realignment channel prior to the ‘cut-over’ from the old channel to ensure that it is completed prior to water being conveyed through it
- use sediment retention basins to remove excess sediments prior to the release of stormwater runoff from within the Proposal Boundary to the environment
- hydrocarbons will be transported and stored in accordance with Australian Standard 1940:2004
- install erosion protection at stormwater and surplus water discharge points
- continue sampling to confirm water quality in creeks is not compromised.

8.6 Predicted environmental outcomes against environmental objectives, policies, guidelines, standards and procedures

After application of mitigation measures described in Section 8.5, the Expansion Proposal is expected to result in the following outcomes in relation to surface water:

- alteration of the current flow regime by the presence of longer periods of flow in Duck Creek as a result of the discharge of surplus water. Discharge will be restricted to the low flow channel of the creek (the implication of this for riparian vegetation is described in Section 9.4.4)
- no significant changes to water quality, which are naturally outside the ANZECC & ARMCANZ range for a number of factors (e.g. dissolved oxygen)
- realignment of approximately 2.5 km of Caves Creek but with no significant change to the water quality or flow regime measured downstream from the diversion
- no impact on the *Themeda* grassland TEC as a result of the minor reduction in volume of flow reaching the TEC as a result of the Expansion Proposal.

9. Assessment of impact on vegetation and flora

9.1 Relevant environmental objectives, policies, guidelines, standards and procedures

9.1.1 EPA objective

The EPA applies the following objectives to the assessment of proposals that may affect vegetation and flora:

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

9.1.2 EPA statements and guidelines

EPA Position Statement No. 2

EPA Position Statement No. 2 (EPA 2000a) provides an overview of the EPA position on the clearing of native vegetation in Western Australia. In assessing a proposal, the EPA consideration of biological diversity will include the following basic elements:

- comparison of project scenarios, or options, to evaluate biodiversity protection 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 project 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 project
- there is a comprehensive, adequate and secure representation of scarce or endangered habitats within and/or in areas biologically comparable to the project 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 project 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 project 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.

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 Environmental Impact Assessment of proposals.

9.1.3 Regulatory framework

State protection

In a legislative context, the preservation and conservation of flora and ecological communities is covered primarily by the following Western Australian legislation:

- *Wildlife Conservation Act 1950* (WA) (WC Act), which specifies Declared Rare Flora (DRF)
- *Conservation and Land Management Act 1984* (WA).

The DEC (Nature Conservation Division) Priority Flora List also nominates conservation species from Priority One to Four (Table 26). The potential impacts of a proposal on these Priority listed species should be managed such that the species do not meet the IUCN criteria for threatened species.

Table 26 Categories of conservation significance

Priority	Description
Priority 1	Poorly Known Taxa: taxa which are known from one or a few (generally <5) populations which are under threat.
Priority 2	Poorly Known Taxa: 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.
Priority 3	Poorly Known Taxa: taxa which are known from several populations, and the taxa are not believed to be under immediate threat.
Priority 4	Rare Taxa: taxa which are considered to have been adequately surveyed and which, whilst being rare (in Australia), are not currently threatened by any identifiable factors.

Threatened Ecological Communities (TECs), as listed by the DEC are of high significance. Ecological communities with insufficient information available to be considered a TEC, or which are rare but not currently threatened, are placed on the Priority list and referred to as Priority Ecological Communities (PECs).

Australian Government protection

The Australian Government 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). An official list of these endangered species is prepared and is regularly updated by SEWPAC. The current list differs from the various State lists; however, some species are common to both.

9.2 Description of factor

The Greater Nammuldi Area has been subject to a number of flora and vegetation surveys undertaken to map the vegetation communities and document flora species present as well as to identify any vegetation communities and flora species of conservation significance. The key flora and vegetation surveys of the Greater Nammuldi Area are shown in Table 27.

Table 27 Vegetation and flora surveys of Greater Nammuldi Area

Survey	Reference
Homestead Exploration Lease Biological Survey Report	Hamersley Iron 1996
Nammuldi Trial Operation Vegetation and Flora Survey	Halpern Glick Maunsell 1998
Nammuldi / Silvergrass Soils, Vegetation and Flora and Soils Survey	Halpern Glick Maunsell 1999a
Nammuldi/Silvergrass Transport Corridor Vegetation and Flora Survey	Halpern Glick Maunsell 1999b
Botanical Survey Work for Silvergrass West – Marra Mamba Evaluation Drilling	Pilbara Iron 2007a
Botanical Survey Work for Nammuldi- Lens A&B	Pilbara Iron 2007b
Botanical Survey Work for the B4R Regrade & B4R Rail Construction Camp	Pilbara Iron 2007c
Various rare flora searches conducted by Pilbara Iron botanists	Pilbara Iron 2006 (unpub.)
Vegetation and Flora Survey of the Approved Powerline Corridor (East of Brockman Operation) for the Brockman Syncline 4 Project	Biota 2007a
Regional Survey for *Ptilotus* sp. Brockman, *Aluta quadrata* and *Geijera* aff. *salicifolia*	Biota 2007b
Vegetation and Flora Survey of Nammuldi Expansion Areas	Biota 2010a
Nammuldi Infill Areas Vegetation and Flora Survey	Biota 2010b
Vegetation and Flora Survey of Silvergrass West	Biota 2010c
Themeda Grasslands Threatened Ecological Community – Phase 1 Botanical Survey	Biota 2011a
Flora and Vegetation Survey of the Greater Nammuldi Irrigated Agriculture Survey Area	Mattiske 2011

In addition, Rio Tinto has conducted a significant number of targeted searches for DRF and Priority Flora that provides a considerable reference for the distribution of these species.

The combined coverage of these flora and vegetation surveys has enabled a detailed understanding of existing vegetation and flora in the Greater Nammuldi Area. The area required for the proposed haul road to BS4 will be subject to flora and vegetation surveys prior to the construction of the road. The extent of these surveys is shown in Figure 16.

9.2.1 Vegetation within the Greater Nammuldi Area

Vegetation condition

The region has been grazed, firstly by sheep then (since 1970) by cattle. Grazing and periodic wild fires (from lightning strikes) as well as construction and clearing in relation to mining activities; represent recent and historical threatening processes to flora and vegetation in the area.

The majority of vegetation communities were generally found to be in Very Good to Excellent condition, particularly areas away from historic disturbance sites such as the B2 camp and access roads. Evidence of grazing was apparent in the lower foothills and slopes near Silvergrass and dense grazing has occurred on the flats and clay plains (including the *Themeda* grasslands TEC) resulting in vegetation of poor condition (Biota 2010c).

Mattiske (2011) found the vegetation within the IAA to range in condition from Very Good to Pristine.

Vegetation units

A broad area in the vicinity of the Proposal Boundary has been covered by vegetation mapping during a number of surveys to date (approximately 58 600 ha). Biota (2012) reviewed the previous studies and developed an integrated vegetation mapping system for the Greater Nammuldi Area. The integrated mapping units are presented in Table 28, which includes the corresponding vegetation codes from previous mapping. Vegetation mapping is shown in Figure 46.

Table 28 Vegetation units mapped in the Greater Nammuldi Area (Biota 2012)

Integrated Vegetation Code	Habitat	Vegetation Description	Previous Vegetation Unit Code*	Extent within the Greater Nammuldi Area
Creeklines and drainages				
CD1	Major creeklines	*Eucalyptus camaldulensis, E. victrix* open woodland over *Acacia citrinoviridis* tall shrubland over mixed open tussock grassland	3 (Homestead) B1(HGM) B1 (HGM) EcEvAciAcMgCEc EcEvAbGOrAciPlEUaTHt Drainage Euc vic / Aca cit EvEcAciEUaERIb	520
CD2	Moderate creeklines	*Eucalyptus camaldulensis, E. xerothermica* low woodland over *Acacia citrinoviridis, Acacia aneura* tall open shrubland over mixed tussock grassland and *Triodia epactia* very open hummock grassland	C2 (IAA)	633
CD3	Moderate creeklines	*Eucalyptus camaldulensis, E. xerothermica* woodland over *Melaleuca glomerata, Gossypium robinsonii, Acacia coriacea* subsp. *pendens* tall shrubland over *Triodia epactia* open hummock grassland	EcExMgGOrAcApyTe	16
CD4	Channels of moderate creeklines	*Eucalyptus victrix* scattered low trees to open woodland over *Goodenia lamprosperma, Pluchea dentex* very open herbland	C1 (BS4)	183
CD5	Moderate creeklines	*Eucalyptus victrix, E. xerothermica* open woodland over *Acacia citrinoviridis* tall open scrub over mixed tussock grassland	C18 (BS4) EvExAciCEc C1 (IAA)	137
CD6	Minor creeklines	*Eucalyptus xerothermica* low open woodland over *Acacia citrinoviridis* tall open scrub over *Triodia epactia* open hummock grassland and/or mixed tussock grassland	B4 (HGM) B4 (HGM) C3 (BS4) ExAciAbTe ExAciAanTHtCHf	242
CD7	Minor creeklines	*Acacia citrinoviridis* tall shrubland over mixed tussock grassland or *Triodia epactia* hummock grassland	C4, C11 (BS4) AciThtCEc	69
CD8	Minor creeklines	*Eucalyptus xerothermica, Acacia aneura* open forest over *Triodia epactia* open hummock grassland over *Chrysopogon fallax* very open tussock grassland	AanExTeCHf	34
CD9	Minor creeklines	*Acacia citrinoviridis, A. aneura* tall open shrubland over mixed open hummock grassland	C20 (BS4) AciAanAsyTloTeTw	9

Integrated Vegetation Code	Habitat	Vegetation Description	Previous Vegetation Unit Code*	Extent within the Greater Nammuldi Area
CD10	Minor creeklines	*Acacia aneura* low open forest to tall open shrubland over mixed open tussock grassland and *Triodia epactia* open hummock grassland	B2, B5 (HGM) C17 (BS4) AanCHfTe, AanSEd	30
CD11	Minor creeklines	*Eucalyptus xerothermica* low open woodland over *Acacia pyrifolia, Gossypium sturtianum* var. *sturtianum, Petalostylis labicheoides* tall shrubland over *Triodia epactia* hummock grassland	ExApyGOsPlTe	25
CD12	Minor flowlines	*Eucalyptus xerothermica, Corymbia hamersleyana* scattered low trees over *Acacia bivenosa, A. cowleana, A. elachantha, A. exilis* tall shrubland over *Triodia epactia* hummock grassland and *Eulalia aurea* open tussock grassland	C5 (BS4)	277
CD13	Minor flowlines	*Eucalyptus xerothermica, E. gamophylla* low open woodland over mixed *Acacia* tall open scrub over mixed *Triodia* closed hummock	4 (Homestead)	387
CD14	Broad drainages	*Eucalyptus xerothermica* scattered trees over *Chrysopogon fallax, Aristida latifolia, Eulalia aurea* tussock grassland over *Triodia epactia* very open hummock grassland or mixed tussock grassland	ExCHfARlEUaTe ChExEUaCHf	251
CD15	Minor flowlines	*Corymbia hamersleyana, Eucalyptus xerothermica* scattered trees over *Acacia bivenosa* open heath over *Triodia angusta* open hummock grassland and *Themeda triandra* very open tussock grassland	C7 (BS4)	8
CD16	Minor flowlines	*Eucalyptus xerothermica* low woodland over *Acacia bivenosa, A. atkinsiana, A. maitlandii* shrubland to closed heath over *Triodia epactia* hummock grassland	ElExAbCAoTHtTe ExAbAatAmTe	57
CD17	Minor flowlines	*Eucalyptus xerothermica* scattered low trees over *Gastrolobium grandiflorum* open heath over *Chrysopogon fallax, Eulalia aurea* tussock grassland	C6 (BS4)	1
CD18	Minor flowlines	*Eucalyptus xerothermica* low open woodland over *Acacia monticola, A. tumida* var. *pilbarensis, A. bivenosa, A. maitlandii* tall open shrubland over *Triodia epactia* scattered hummock grasses	ChExAmoAtuGAgTe C5 (IAA)	63
CD19	Minor flowlines	*Eucalyptus leucophloia* low woodland over *Acacia citrinoviridis, Acacia monticola, Dodonaea pachyneura* tall shrubland over *Triodia epactia* hummock grassland	C14 (BS4)	4
CD20	Minor flowlines	*Eucalyptus leucophloia* low woodland over *Gossypium robinsonii, Acacia maitlandii, A. monticola, A. bivenosa* tall shrubland over *Triodia wiseana, T. epactia* very open hummock grassland	ElGOrAmAmoTeTw I-IG-EFw C3 (IAA)	593
CD21	Minor flowlines through gorges	*Eucalyptus leucophloia* low open woodland over *Gossypium robinsonii* tall open shrubland over *Eremophila magnifica* subsp. *velutina* low open shrubland over *Cymbopogon ambiguus, Eriachne mucronata* open tussock grassland	ElGOrERmCYaERlm	2
CD22	Minor flowlines	*Eucalyptus leucophloia, Corymbia deserticola* scattered low trees over *Acacia tumida* var. *pilbarensis* tall open scrub over *Triodia epactia, T. wiseana* open hummock grassland	C10 (BS4) ElCdAtuTeTw	28
CD23	Minor flowlines	*Corymbia hamersleyana* low open woodland over *Gossypium robinsonii, Acacia tumida* var. *pilbarensis* tall open shrubland over *Triodia epactia* open hummock grassland	ChGOrAtuTe	16
CD24	Minor flowlines	*Corymbia hamersleyana, Eucalyptus leucophloia* low woodland over *Grevillea wickhamii* tall	B7 (HGM)	131

Integrated Vegetation Code	Habitat	Vegetation Description	Previous Vegetation Unit Code*	Extent within the Greater Nammuldi Area
		shrubland over *Gossypium robinsonii* open shrubland over *Themeda* sp. Mt. Barricade, *Eulalia aurea, Paraneurachne muelleri* open tussock grassland or *Triodia epactia* open hummock grassland	C9 (BS4)	
			C9 (Boolgeeda)	
CD25	Minor flowlines	*Corymbia hamersleyana* low open woodland over *Triodia epactia* hummock grassland and *Eriachne tenuiculmis, E. mucronata, Themeda* sp. Mt. Barricade open tussock grassland	C8 (BS4)	60
CD26	Narrow floodplains fringing major creek (Caves Creek)	*Eucalyptus victrix, Corymbia hamersleyana* low open woodland over *Acacia bivenosa, A. ancistrocarpa, A. inaequilatera*, mixed *Senna* open heath over *Triodia epactia, T. angusta* hummock grassland	7 (Homestead)	352
CD27	Minor flowlines	*Corymbia hamersleyana, Eucalyptus gamophylla* low open woodland over *Acacia monticola, A. ancistrocarpa, A. bivenosa, Rulingia luteiflora* tall closed scrub over *Triodia epactia* hummock grassland	C13 (BS4)	6
CD28	Minor flowlines	*Corymbia hamersleyana* scattered low trees over *Acacia bivenosa, Petalostylis labicheoides* shrubland over *Triodia epactia* hummock grassland	C16 (BS4)	22
CD29	Minor flowlines	*Corymbia hamersleyana* scattered low trees over *Acacia atkinsiana* tall shrubland over *Triodia epactia* hummock grassland	C19 (BS4)	57
CD30	Minor flowlines	*Acacia pyrifolia, A. ancistrocarpa, Petalostylis labicheoides* shrubland over *Triodia epactia* hummock grassland and *Themeda triandra* tussock grassland	C2 (BS4)	580
CD31	Minor flowlines	*Acacia monticola, A. maitlandii, A. atkinsiana, A. exilis, A. ancistrocarpa* tall shrubland over *Triodia epactia, T. wiseana* open hummock grassland	11 (Homestead)	1018
			B8 (HGM)	
			B8 (HGM)	
			C12 (BS4)	
			AmoAmAatTeTw	
CD32	Minor flowlines	*Petalostylis labicheoides* shrubland over *Triodia epactia* hummock grassland	C21 (BS4)	3
CD33	Minor flowlines	*Stylobasium spathulatum* shrubland over *Triodia epactia* hummock grassland	C15 (BS4)	1
CD34	Minor flowlines	*Acacia bivenosa, Melaleuca glomerata* tall shrubland over *Triodia angusta* hummock grassland	AbMgTa	26
Mosaic communities on creeklines and drainage				
CD4/CD22	Channels of moderate creeklines/minor flowlines	*Eucalyptus victrix* scattered low trees to open woodland over *Goodenia lamprosperma, Pluchea dentex* very open herbland /*Eucalyptus leucophloia, Corymbia deserticola* scattered low trees over *Acacia tumida* var. *pilbarensis* tall open scrub over *Triodia epactia, T. wiseana* open hummock grassland	As above	8

Integrated Vegetation Code	Habitat	Vegetation Description	Previous Vegetation Unit Code*	Extent within the Greater Nammuldi Area
Calcareous plains				
PL1	Calcareous plains	*Eucalyptus repullulans* scattered low mallees over *Melaleuca eleuterostachya, A. maitlandii* scattered shrubs over *Triodia wiseana* hummock grassland	T4, T5 (IAA)	589
PL2	Calcareous plains	*Eucalyptus socialis* and/or *E. leucophloia* low open woodland over *Acacia bivenosa, A. exilis* scattered shrubs over *Triodia wiseana, T. angusta* hummock grassland	5 (Homestead)	1265
			A8 (HGM)	
			P9, P10 (BS4)	
			ElAexAaTwTa	
			ElEsEtAbTw	
PL3	Calcareous plains	*Eucalyptus leucophloia* scattered low trees over *Acacia bivenosa* scattered shrubs over *Triodia longiceps, T. wiseana* hummock grassland	AiTlo, ElAbTloTw	242
PL4	Calcareous plains	*Eucalyptus leucophloia* scattered low trees over *Acacia xiphophylla, A. sibirica, A. tetragonophylla, Melaleuca eleuterostachya* scattered shrubs over *Triodia angusta* hummock grassland	A9 (HGM)	1700
PL5	Calcareous plains	*Melaleuca eleuterostachya* open shrubland over *Triodia wiseana, (T. angusta)* hummock grassland	AexMeTw, MeTwTa	230
PL6	Calcareous plains	*Acacia synchronicia* scattered shrubs over *Triodia angusta* hummock grassland	P11 (BS4)	76
PL7	Calcareous plains	*Eucalyptus leucophloia, E. socialis* scattered low trees over *Acacia bivenosa* scattered shrubs over *Triodia brizoides* hummock grassland	A10 (HGM)	19
PL8	Calcareous plains	*Eucalyptus leucophloia* scattered low trees over *Triodia longiceps, T. epactia* hummock grassland	ElTloTe	22
Mulga (*Acacia aneura* complex) shrublands on clay plains				
PC1	Clay plains	*Acacia aneura* low woodland to tall open scrub over *Triodia epactia, T. wiseana* very open hummock grassland	AanTe/AanTw	1601
			M1 (IAA)	
			Mulga (TEC)	
			UP1-Aa-TOS	
Snakewood (*Acacia xiphophylla*) shrublands on clay plains				
PC2	Clay plains	*Acacia xiphophylla* open shrubland to scattered shrubs over *Eremophila maculata, Senna* spp. low shrubland over mixed bunch grasses and herbs	C4 (HGM)	247
			Snakewood	
			UP2-Ax-S, UP6-Em-LS	
PC3	Clay plains	*Acacia xiphophylla* open shrubland over *Triodia epactia* open hummock grassland	AxDIPa	23
			UP5-AxTe-S	

Integrated Vegetation Code	Habitat	Vegetation Description	Previous Vegetation Unit Code*	Extent within the Greater Nammuldi Area
PC4	Clay plains	*Acacia xiphophylla* open shrubland over *Triodia basedowii* open hummock grassland	13 (Homestead)	3
Other shrublands on clay plains				
PC5	Clay plains	*Eucalyptus leucophloia* scattered low trees over *Acacia tetragonophylla, A. bivenosa, A. synchronicia, A. tenuissima* open shrubland over *Triodia basedowii* hummock grassland with mixed herbs	T3 (IAA)	540
			THtCHfBTb/h	
Grasslands on clay plains				
PC6	Clay plains	*Astrebla elymoides* tussock grassland	ASe, ASspp / Stony rise	415
			M-Ast-TG	
			CHfBRcPOsph; ASlPOsph; PANlUoSls	
			THtCHfBTb/h	
PC7	Clay plains	*Astrebla lappacea, A. pectinata* tussock grassland	ASlASp	149
			THsCHfPOsph	
PC8	Clay plains	*Themeda* sp. Hamersley Station (M.E. Trudgen 11431) tussock grassland	THs	204
			THsCHfPOsph; THsDlCLfPOsph	
PC9	Clay plains	*Eriachne benthamii* tussock grassland	ERlb	55
			DC-Eb-TG	
			CHfBRcPOsph; ERlbSTkPOsph	
PC10	Clay plains	*Aristida latifolia, Chrysopogon fallax, (Eragrostis xerophila, Astrebla elymoides)* tussock grassland	ARlASeCHf	539
			G1 (IAA)	
			UP3-CfDf-MTG, UP4-MOTG	
			CHfBRcPOsph; CAoENpBRcDlCh; CHfASpARlPOsph; AiAbAatTePAm	
Herblands on clay plains				
PC11	Clay plains	Mixed herbland	C1 (IAA)	58
			LPC-SkPl-HL	
Mulga shrublands on stony plains				
PS1	Stony plains	*Acacia aneura, A. ayersiana* tall open shrubland over *Triodia epactia, T. wiseana* hummock grassland	P1, P2, P3 (BS4)	667
			AanAprAexAbAaTwTe	

Integrated Vegetation Code	Habitat	Vegetation Description	Previous Vegetation Unit Code*	Extent within the Greater Nammuldi Area
PS2	Stony plains	*Acacia aneura* low woodland over low mixed shrubs over *Eriachne benthamii, Eragrostis tenellula, Chrysopogon fallax* open tussock grassland	M2 (IAA)	108
Snakewood shrublands on stony plains				
PS3	Stony plains	*Acacia xiphophylla, A. aneura* low woodland to tall open shrubland over *Triodia wiseana, (T. epactia)* open hummock grassland	A7 (HGM)	324
			P4 (BS4)	
			P4 (Boolgeeda)	
			AxTw/AxTe	
			M3 (IAA)	
PS4	Stony plains	*Acacia xiphophylla* tall open shrubland over *Triodia epactia, T. longiceps* hummock grassland	AxTeTlo	35
PS5	Stony plains	*Acacia xiphophylla, A. aneura* tall shrubland over *Triodia brizoides, T. epactia* open hummock grassland	P5 (BS4)	5
Other shrublands on stony plains				
PS6	Stony plains	*Eucalyptus leucophloia, (E. gamophylla, Corymbia deserticola, C. hamersleyana)* scattered low trees over *Acacia atkinsiana, A. exilis, A. bivenosa, A. ancistrocarpa, Senna* spp. shrubland over *Triodia epactia* and/or *T. wiseana* hummock grassland	2 (Homestead)	20,810
			A5, A6 (HGM)	
			A6 (HGM)	
			P6, P7, P13, P14, P15 (BS4)	
			P6 (Boolgeeda)	
			AbTe	
			EgAexAbAatTw, ElAbAaTw, ElAbTeTw	
			ChEgAatAexTe, ChElAatAbAexAiTe, ElAatAexTw	
			AprAexTw	
			I-SF-Ch/Ash	
			Spinifex	
			T2 (IAA)	
PS7	Stony plains	*Eucalyptus leucophloia, (Corymbia hamersleyana)* scattered low trees over *Acacia inaequilatera* scattered shrubs to tall open shrubland over *Triodia wiseana, (T. epactia)* hummock grassland	AiAmAexTw, ChAiTw, ElAiTwTe	623
			AiTw, ElAeAiTw	
PS8	Stony plains	*Eucalyptus leucophloia* scattered low trees over *Acacia atkinsiana, A. maitlandii* open shrubland over *Triodia epactia, T. melvillei* hummock grassland	ElAatAmAspTeTm	111
PS9	Stony plains	*Eucalyptus xerothermica* low open woodland over *Eremophila fraseri* scattered shrubs over *Triodia wiseana* hummock grassland	P8 (BS4)	28

Integrated Vegetation Code	Habitat	Vegetation Description	Previous Vegetation Unit Code*	Extent within the Greater Nammuldi Area
PS10	Stony plains	*Acacia synchronicia, A. bivenosa, Senna* spp. shrubland over *Triodia brizoides* hummock grassland	P12 (BS4)	112
			AsyAbCApCAlTbr	
PS11	Stony plains	*Acacia inaequilatera* open shrubland to shrubland over *Triodia brizoides* hummock grassland	AiTbr	122
PS12	Stony plains	*Acacia maitlandii* open shrubland over *Triodia brizoides* open hummock grassland	AmTbr	81
PS13	Stony plains	*Eucalyptus leucophloia* scattered low trees over *Acacia exilis* open shrubland to shrubland over *Triodia brizoides* hummock grassland	ElAexTbr	54
PS14	Stony plains	*Eucalyptus leucophloia* scattered low trees over *Acacia inaequilatera, Mirbelia viminalis* scattered shrubs over *Triodia ?basedowii* open hummock grassland	8 (Homestead)	949
PS15	Stony plains	*Eucalyptus gamophylla* low open woodland over *Senna artemisioides* subsp. *oligophylla* open shrubland over *Triodia basedowii* open hummock grassland	10 (Homestead)	178
Spinifex hummock grasslands on stony plains				
PS16	Stony plains	*Eucalyptus leucophloia* scattered low trees over *Triodia longiceps, T angusta* hummock grassland	P16 (BS4)	275
			AsyTloTa, ElTloTaTbr	
Mosiac communities on stony plains				
PS1/PS6	**Stony plains**	***Acacia aneura, A. ayersiana* tall open shrubland over *Triodia epactia, T. wiseana* hummock grassland /*Eucalyptus leucophloia, (E. gamophylla, Corymbia deserticola, C. hamersleyana)* scattered low trees over *Acacia atkinsiana, A. exilis, A. bivenosa, A. ancistrocarpa, Senna* spp. shrubland over *Triodia epactia* and/or *T. wiseana* hummock grassland**	**As above**	**718**
Mulga woodlands / tall shrublands on hills				
H1	Hills	*Acacia aneura* low open woodland over *Triodia wiseana, T. epactia* hummock grassland	AanTeTw, ElAprAanTeTw	122
			AanTwTe	
H2	Hills	*Acacia aneura* low woodland over *Triodia epactia* hummock grassland	AanAkTp, AanAprTe, AanElTe, AanTpTe	299
H3	Rocky slopes of hills	*Acacia aneura, Corymbia ferriticola* low woodland over *Triodia epactia* hummock grassland or *Cymbopogon ambiguus, Themeda triandra* open tussock grassland	AanGbCfTe	6
			CfAanCYaTHtDIPaDICLf	
H4	Hills	*Acacia aneura* low woodland over mixed bunch grassland and open herbland	14 (Homestead)	23
Other shrublands on hills				
H5	Hills	*Eucalyptus leucophloia* scattered low trees over *Acacia maitlandii* shrubland over *Triodia wiseana* hummock grassland	9 (Homestead)	6133
			A1 (HGM)	
			H3 (BS4)	
			H3 (Boolgeeda)	
			ElAexAmoAmTw, ElAmAexTwERlm	

Integrated Vegetation Code	Habitat	Vegetation Description	Previous Vegetation Unit Code*	Extent within the Greater Nammuldi Area
			ElAmAhiTw, ElAmTw	
			T1 (IAA)	
H6	Hills	*Acacia hamersleyensis* tall open shrubland over *Triodia wiseana* closed hummock grassland	H4 (BS4)	22
H7	Hills	*Eucalyptus leucophloia* scattered low trees over *Acacia pruinocarpa* open shrubland over *Triodia epactia* or *T. wiseana* hummock grassland	H6 (BS4)	519
			AprTe, ElAprAatTw, ElAprTe	
H8	Hills	*Eucalyptus leucophloia* scattered low trees over *Acacia atkinsiana, A. exilis, A. bivenosa, A. ancistrocarpa* open shrubland over *Triodia wiseana* or *T. epactia* hummock grassland	H2, H2/H16, H5, H8	1115
			ElAbTe	
H9	Hills	*Eucalyptus leucophloia* scattered low trees over *Acacia inaequilatera* tall shrubland over *Triodia wiseana* hummock grassland	H9 (BS4)	210
H10	Hills (and stony plains)	*Eucalyptus leucophloia* low open woodland over *Acacia exilis, A. ancistrocarpa, A. sibirica, Senna* spp. open shrubland over *Triodia wiseana, T. basedowii* hummock grassland	1 (Homestead)	4261
H11	Hills	*Acacia sibirica* low open woodland over *Eremophila exilifolia* scattered shrubs over *Triodia epactia* hummock grassland	H7 (BS4)	140
H12	Crests and slopes of mesas	*Acacia bivenosa, A. exilis, A. synchronicia* scattered shrubs to open shrubland over *Triodia longiceps, T. wiseana* open hummock grassland	AsyAbAxTloTw	11
H13	Hill slopes	*Corymbia ferriticola, Eucalyptus leucophloia* low open woodland over *Acacia pruinocarpa* tall open shrubland over mixed shrubland over *Triodia epactia* open hummock grassland with *Eriachne mucronata* scattered tussock grasses	I-MS-Eflow, I-LS-ElAp	17
Spinifex hummock grasslands on hills				
H14	Hills	*Eucalyptus leucophloia* scattered low trees over *Triodia epactia* and/or *T. wiseana* hummock grassland	A2, A3 (HGM)	3048
			A3 (HGM)	
			H1, H14, H15 (BS4)	
			ElTeTHmERlm, ElTw	
			ElTe, ElTeTw	
			ElTw, ElTwCYa	
H15	Steep hillslopes	*Eucalyptus leucophloia* scattered low trees over *Triodia brizoides* hummock grassland	A4 (HGM)	62
Gorges and breakaways				
HG1	Rocky gorges	*Corymbia ferriticola, Eucalyptus leucophloia* low open woodland over *Acacia hamersleyensis, A. pruinocarpa* scattered tall shrubs over *Dodonaea pachyneura* open shrubland over *Triodia epactia* or *T. wiseana* open hummock grassland and mixed open tussock grassland	6, 12 (Homestead)	549
			H11, H13 (BS4)	
HG2	Gorges	*Eucalyptus leucophloia* low open woodland over *Acacia hamersleyensis* open shrubland over *Triodia brizoides, T. epactia* hummock grassland and *Themeda triandra, Eriachne mucronata* open tussock grassland	H12 (BS4)	10

Integrated Vegetation Code	Habitat	Vegetation Description	Previous Vegetation Unit Code*	Extent within the Greater Nammuldi Area
HG3	Gorges	*Eucalyptus leucophloia* low open woodland over *Acacia bivenosa* open shrubland over *Triodia brizoides, T. epactia* hummock grassland and *Themeda* sp. Mt. Barricade, *Cymbopogon ambiguus* open tussock grassland	H10 (BS4)	126
HG4	Breakaways	*Eucalyptus leucophloia* scattered low trees to low open woodland over *Astrotricha hamptonii, Ficus brachypoda* scattered tall shrubs over *Themeda* sp. Mt Barricade, *Eriachne mucronata* open tussock grassland and *Triodia brizoides, T. epactia* open hummock grassland	H16 (BS4)	7

* To avoid confusion where multiple mapping systems us similar categories the following systems have been used HGM, IAA, Homestead, BS4.

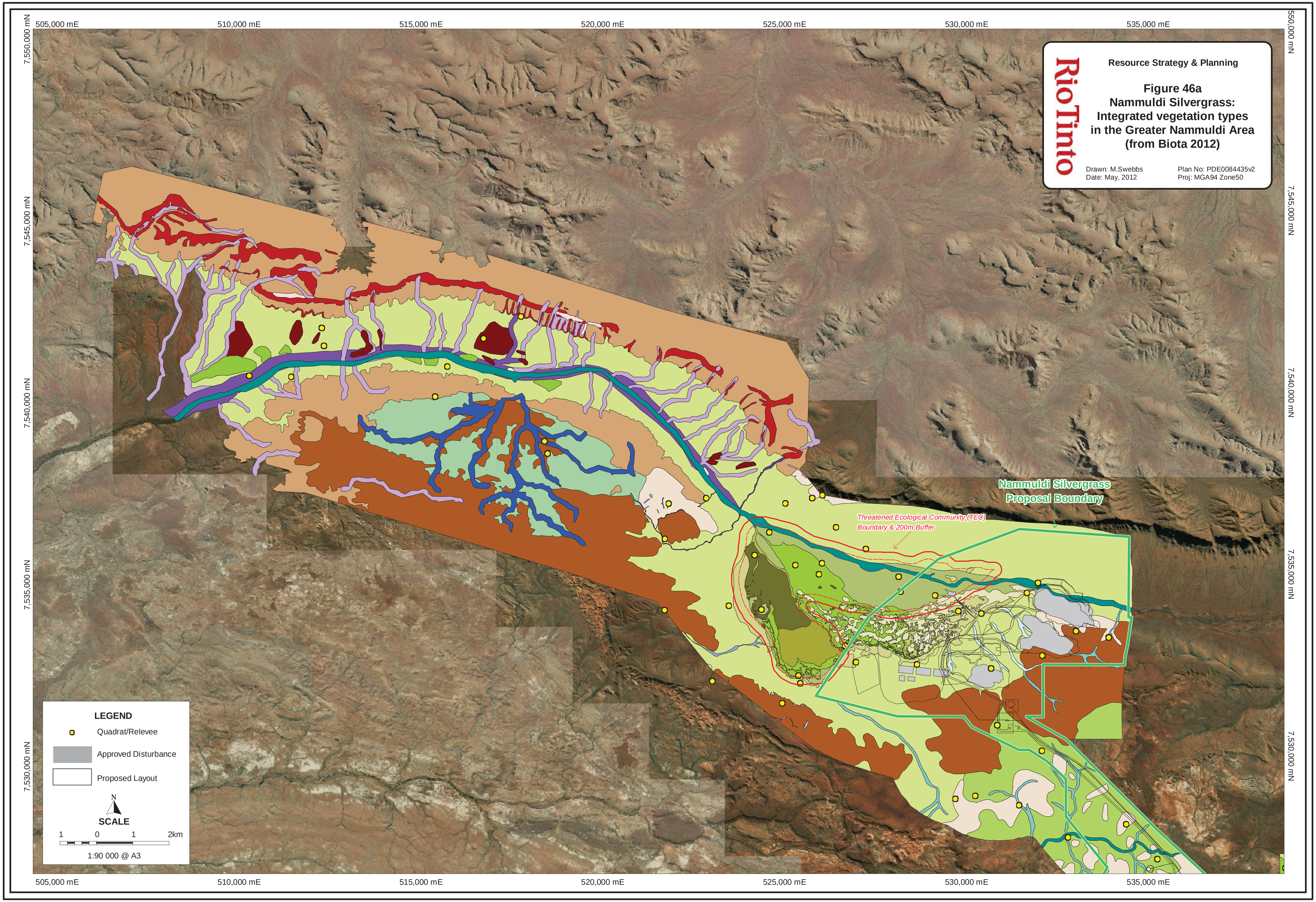
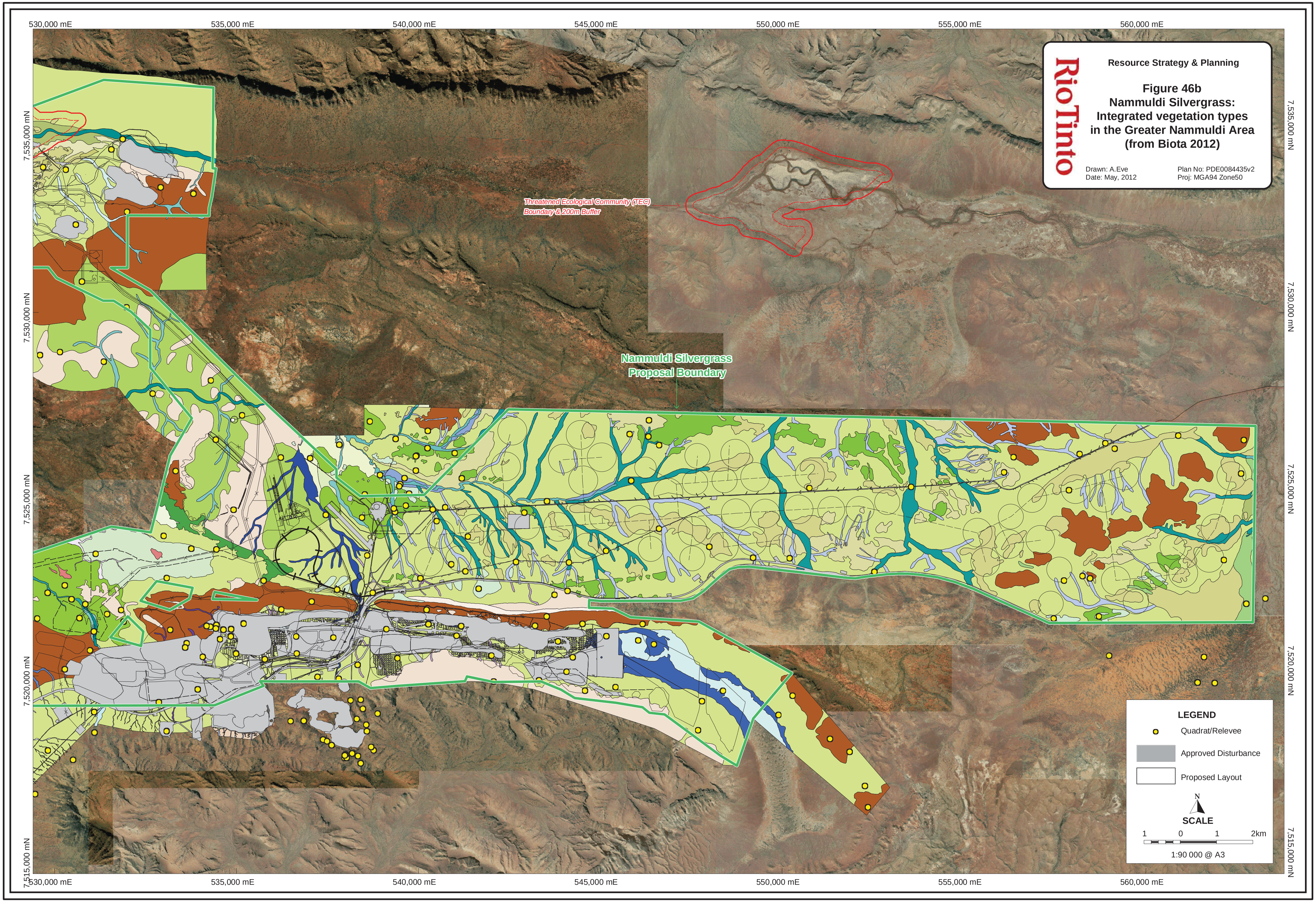


Figure 46a
Nammuldi Silvergrass:
Integrated vegetation types
in the Greater Nammuldi Area
(from Biota 2012)


Resource Strategy & Planning
Figure 46b
Nammuldi Silvergrass:
Integrated vegetation types
in the Greater Nammuldi Area
(from Biota 2012)
Drawn: A.Eve
Date: May, 2012
Plan No: PDE0084435v2
Proj: MGA94 Zone50
Threatened Ecological Community (TEC)
Boundary & 200m Buffer
Nammuldi Silvergrass
Proposal Boundary
LEGEND
Quadrat/Relevee
Approved Disturbance
Proposed Layout
N
SCALE
1 0 1 2km
1:90 000 @ A3
530,000 mE
535,000 mE
540,000 mE
545,000 mE
550,000 mE
555,000 mE
560,000 mE
7,535,000 mN
7,530,000 mN
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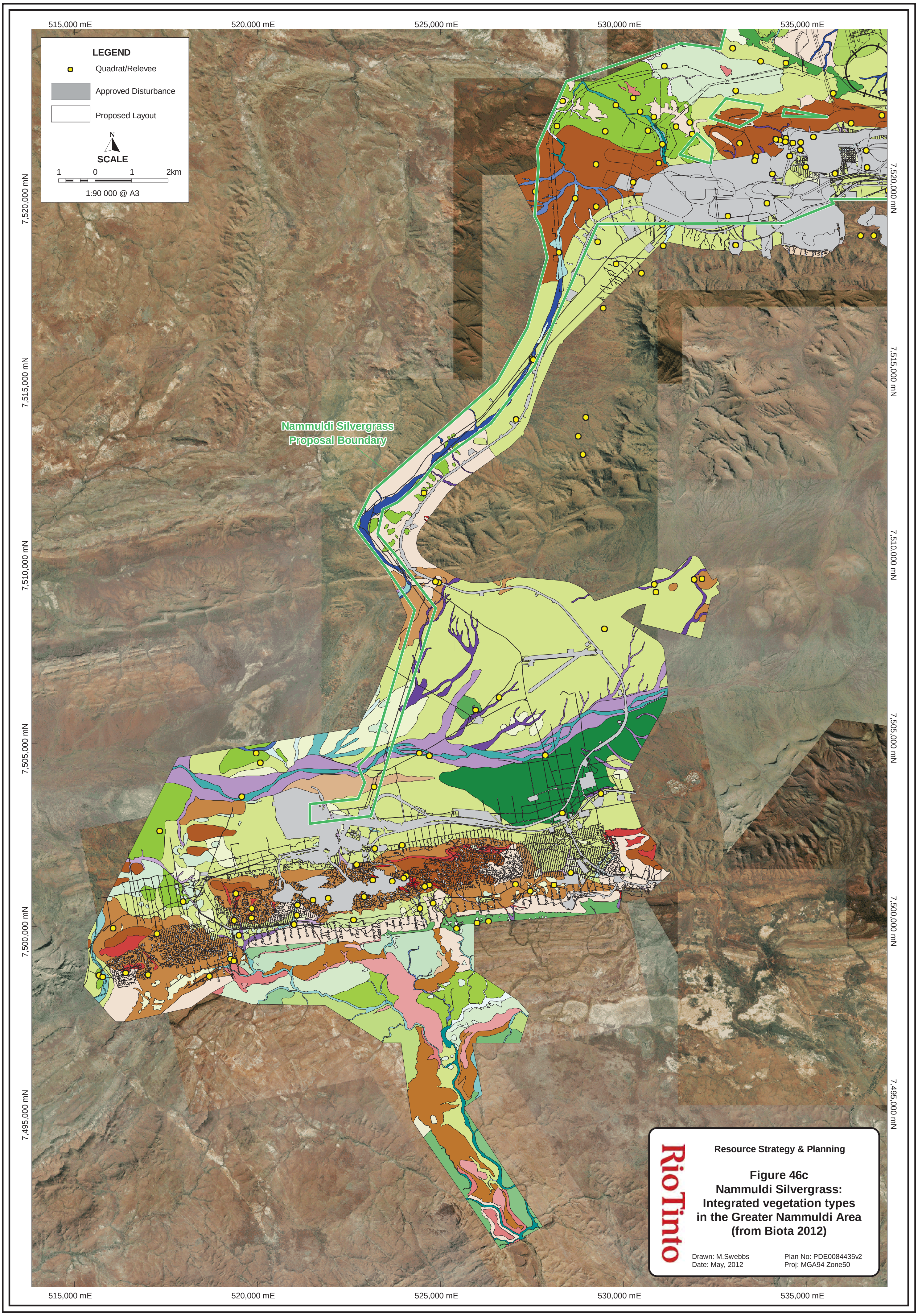
7,520,000 mN
7,515,000 mN



515,000 mE
520,000 mE
525,000 mE
530,000 mE
535,000 mE
LEGEND
Quadrat/Relevee
Approved Disturbance
Proposed Layout
N
SCALE
1 0 1 2km
1:90 000 @ A3
7,520,000 mN
7,515,000 mN
7,510,000 mN
7,505,000 mN
7,500,000 mN
7,495,000 mN
Nammuldi Silvergrass
Proposal Boundary
Rio Tinto
Resource Strategy & Planning
Figure 46c
Nammuldi Silvergrass:
Integrated vegetation types
in the Greater Nammuldi Area
(from Biota 2012)
Drawn: M.Swebbs
Date: May, 2012
Plan No: PDE0084435v2
Proj: MGA94 Zone50

Code	Description
CD1	Eucalyptus camaldulensis, E. victrix open woodland over Acacia citrinoviridis tall shrubland over mixed open tussock grassland
CD10	Acacia aneura low open forest to tall open shrubland over mixed open tussock grassland and Triodia epactia open hummock grassland
CD11	Eucalyptus xerothermica low open woodland over Acacia pyrifolia, Gossypium sturtianum var. sturtianum, Petalostylis labicheoides tall shrubland over Triodia epactia hummock grassland
CD12	Eucalyptus xerothermica, Corymbia hamersleyana scattered low trees over Acacia bivenosa, A. cowleana, A. elachantha, A. exilis tall shrubland over Triodia epactia hummock grassland and Eulalia aurea open tussock grassland
CD13	Eucalyptus xerothermica, E. gamophylla low open woodland over mixed Acacia tall open scrub over mixed Triodia closed hummock
CD14	Eucalyptus xerothermica scattered trees over Chrysopogon fallax, Aristida latifolia, Eulalia aurea tussock grassland over Triodia epactia very open hummock grassland or mixed tussock grassland
CD15	Corymbia hamersleyana, Eucalyptus xerothermica scattered trees over Acacia bivenosa open heath over Triodia angusta open hummock grassland and Themeda triandra very open tussock grassland
CD16	Eucalyptus xerothermica low woodland over Acacia bivenosa, A. atkinsiana, A. maitlandii shrubland to closed heath over Triodia epactia hummock grassland
CD17	Eucalyptus xerothermica scattered low trees over Gastrolobium grandiflorum open heath over Chrysopogon fallax, Eulalia aurea tussock grassland
CD18	Eucalyptus xerothermica low open woodland over Acacia monticola, A. tumida var. pilbarensis, A. bivenosa, A. maitlandii tall open shrubland over Triodia epactia scattered hummock grasses
CD19	Eucalyptus leucophloia low woodland over Acacia citrinoviridis, Acacia monticola, Dodonaea pachyneura tall shrubland over Triodia epactia hummock grassland
CD2	Eucalyptus camaldulensis, E. xerothermica low woodland over Acacia citrinoviridis, Acacia aneura tall open shrubland over mixed tussock grassland and Triodia epactia very open hummock grassland
CD20	Eucalyptus leucophloia low woodland over Gossypium robinsonii, Acacia maitlandii, A. monticola, A. bivenosa tall shrubland over Triodia wiseana, T. epactia very open hummock grassland
CD21	Eucalyptus leucophloia low open woodland over Gossypium robinsonii tall open shrubland over Eremophila magnifica subsp. velutina low open shrubland over Cymbopogon ambiguus, Eriachne mucronata open tussock grassland
CD22	Eucalyptus leucophloia, Corymbia deserticola scattered low trees over Acacia tumida var. pilbarensis tall open scrub over Triodia epactia, T. wiseana open hummock grassland
CD23	Corymbia hamersleyana low open woodland over Gossypium robinsonii, Acacia tumida var. pilbarensis tall open shrubland over Triodia epactia open hummock grassland
CD24	Corymbia hamersleyana, Eucalyptus leucophloia low woodland over Grevillea wickhamii tall shrubland over Gossypium robinsonii open shrubland over Themeda sp. Mt. Barricade, Eulalia aurea, Paraneurachne muelleri open tussock grassland or Triodia epactia op
CD25	Corymbia hamersleyana low open woodland over Triodia epactia hummock grassland and Eriachne tenuiculmis, E. mucronata, Themeda sp. Mt. Barricade open tussock grassland
CD27	Corymbia hamersleyana, Eucalyptus gamophylla low open woodland over Acacia monticola, A. ancistrocarpa, A. bivenosa, Rulingia luteiflora tall closed scrub over Triodia epactia hummock grassland
CD28	Corymbia hamersleyana scattered low trees over Acacia bivenosa, Petalostylis labicheoides shrubland over Triodia epactia hummock grassland
CD29	Corymbia hamersleyana scattered low trees over Acacia atkinsiana tall shrubland over Triodia epactia hummock grassland
CD3	Eucalyptus camaldulensis, E. xerothermica woodland over Melaleuca glomerata, Gossypium robinsonii, Acacia coriacea subsp. pendens tall shrubland over Triodia epactia open hummock grassland
CD30	Acacia pyrifolia, A. ancistrocarpa, Petalostylis labicheoides shrubland over Triodia epactia hummock grassland and Themeda triandra tussock grassland
CD31	Acacia monticola, A. maitlandii, A. atkinsiana, A. exilis, A. ancistrocarpa tall shrubland over Triodia epactia, T. wiseana open hummock grassland
CD32	Petalostylis labicheoides shrubland over Triodia epactia hummock grassland
CD33	Stylobasium spathulatum shrubland over Triodia epactia hummock grassland
CD34	Acacia bivenosa, Melaleuca glomerata tall shrubland over Triodia angusta hummock grassland
CD4	Eucalyptus victrix scattered low trees to open woodland over Goodenia lamprosperma, Pluchea dentex very open herbland
CD4/CD22	
CD5	Eucalyptus victrix, E. xerothermica open woodland over Acacia citrinoviridis tall open scrub over mixed tussock grassland
CD6	Eucalyptus xerothermica low open woodland over Acacia citrinoviridis tall open scrub over Triodia epactia open hummock grassland and/or mixed tussock grassland
CD7	Acacia citrinoviridis tall shrubland over mixed tussock grassland or Triodia epactia hummock grassland
CD8	Eucalyptus xerothermica, Acacia aneura open forest over Triodia epactia open hummock grassland over Chrysopogon fallax very open tussock grassland
CD9	Acacia citrinoviridis, A. aneura tall open shrubland over mixed open hummock grassland
Disturbed	
H1	Acacia aneura low open woodland over Triodia wiseana, T. epactia hummock grassland
H11	Acacia sibirica low open woodland over Eremophila exilifolia scattered shrubs over Triodia epactia hummock grassland
H12	Acacia bivenosa, A. exilis, A. synchronicia scattered shrubs to open shrubland over Triodia longiceps, T. wiseana open hummock grassland
H13	Corymbia ferriticola, Eucalyptus leucophloia low open woodland over Acacia pruinocarpa tall open shrubland over mixed shrubland over Triodia epactia open hummock grassland with Eriachne mucronata scattered tussock grasses
H14	Eucalyptus leucophloia scattered low trees over Triodia epactia and/or T. wiseana hummock grassland
H15	Eucalyptus leucophloia scattered low trees over Triodia brizoides hummock grassland
H2	Acacia aneura low woodland over Triodia epactia hummock grassland
H3	Acacia aneura, Corymbia ferriticola low woodland over Triodia epactia hummock grassland or Cymbopogon ambiguus, Themeda triandra open tussock grassland
H5	Eucalyptus leucophloia scattered low trees over Acacia maitlandii shrubland over Triodia wiseana hummock grassland
H6	Acacia hamersleyensis tall open shrubland over Triodia wiseana closed hummock grassland
H7	Eucalyptus leucophloia scattered low trees over Acacia pruinocarpa open shrubland over Triodia epactia or T. wiseana hummock grassland
H8	Eucalyptus leucophloia scattered low trees over Acacia atkinsiana, A. exilis, A. bivenosa, A. ancistrocarpa open shrubland over Triodia wiseana or T. epactia hummock grassland
H9	Eucalyptus leucophloia scattered low trees over Acacia inaequilatera tall shrubland over Triodia wiseana hummock grassland
HG1	Corymbia ferriticola, Eucalyptus leucophloia low open woodland over Acacia hamersleyensis, A. pruinocarpa scattered tall shrubs over Dodonaea pachyneura open shrubland over Triodia epactia or T. wiseana open hummock grassland and mixed open tussock grass
HG2	Eucalyptus leucophloia low open woodland over Acacia hamersleyensis open shrubland over Triodia brizoides, T. epactia hummock grassland and Themeda triandra, Eriachne mucronata open tussock grassland
HG3	Eucalyptus leucophloia low open woodland over Acacia bivenosa open shrubland over Triodia brizoides, T. epactia hummock grassland and Themeda sp. Mt. Barricade, Cymbopogon ambiguus open tussock grassland
HG4	Eucalyptus leucophloia scattered low trees to low open woodland over Astrotricha hamptonii, Ficus brachypoda scattered tall shrubs over Themeda sp. Mt Barricade, Eriachne mucronata open tussock grassland and Triodia brizoides, T. epactia open hummock gra
PC1	Acacia aneura low woodland to tall open scrub over Triodia epactia, T. wiseana very open hummock grassland
PC10	Aristida latifolia, Chrysopogon fallax, (Eragrostis xerophila, Astrebla elymoides) tussock grassland
PC11 Mixed herbland	
PC2	Acacia xiphophylla open shrubland to scattered shrubs over Eremophila maculata, Senna spp. low shrubland over mixed bunch grasses and herbs
PC3	Acacia xiphophylla open shrubland over Triodia epactia open hummock grassland
PC5	Eucalyptus leucophloia scattered low trees over Acacia tetragonophylla, A. bivenosa, A. synchronicia, A. tenuissima open shrubland over Triodia basedowii hummock grassland with mixed herbs
PC6	Astrebla elymoides tussock grassland
PC7	Astrebla lappacea, A. pectinata tussock grassland
PC8	Themeda sp. Hamersley Station (M.E. Trudgen 11431) tussock grassland
PC9	Eriachne benthamii tussock grassland
PL1	Eucalyptus repullulans scattered low mallees over Melaleuca eleuterostachya, A. maitlandii scattered shrubs over Triodia wiseana hummock grassland
PL2	Eucalyptus socialis and/or E. leucophloia low open woodland over Acacia bivenosa, A. exilis scattered shrubs over Triodia wiseana, T. angusta hummock grassland
PL3	Eucalyptus leucophloia scattered low trees over Acacia bivenosa scattered shrubs over Triodia longiceps, T. wiseana hummock grassland
PL4	Eucalyptus leucophloia scattered low trees over Acacia xiphophylla, A. sibirica, A. tetragonophylla, Melaleuca eleuterostachya scattered shrubs over Triodia angusta hummock grassland
PL5	Melaleuca eleuterostachya open shrubland over Triodia wiseana, (T. angusta) hummock grassland
PL6	Acacia synchronicia scattered shrubs over Triodia angusta hummock grassland on calcareous plains
PL7	Eucalyptus leucophloia, E. socialis scattered low trees over Acacia bivenosa scattered shrubs over Triodia brizoides hummock grassland
PL8	Eucalyptus leucophloia scattered low trees over Triodia longiceps, T. epactia hummock grassland
PS1	Acacia aneura, A. ayersiana tall open shrubland over Triodia epactia, T. wiseana hummock grassland
PS1/PS6	
PS10	Acacia synchronicia, A. bivenosa, Senna spp. shrubland over Triodia brizoides hummock grassland
PS11	Acacia inaequilatera open shrubland to shrubland over Triodia brizoides hummock grassland
PS13	Eucalyptus leucophloia scattered low trees over Acacia exilis open shrubland to shrubland over Triodia brizoides hummock grassland
PS14	Eucalyptus leucophloia scattered low trees over Acacia inaequilatera, Mirbelia viminalis scattered shrubs over Triodia ?basedowii open hummock grassland
PS16	Eucalyptus leucophloia scattered low trees over Triodia longiceps, T angusta hummock grassland
PS2	Acacia aneura low woodland over low mixed shrubs over Eriachne benthamii, Eragrostis tenellula, Chrysopogon fallax open tussock grassland
PS3	Acacia xiphophylla, A. aneura low woodland to tall open shrubland over Triodia wiseana, (T. epactia) open hummock grassland
PS4	Acacia xiphophylla tall open shrubland over Triodia epactia, T. longiceps hummock grassland
PS5	Acacia xiphophylla, A. aneura tall shrubland over Triodia brizoides, T. epactia open hummock grassland
PS6	Eucalyptus leucophloia, (E. gamophylla, Corymbia deserticola, C. hamersleyana) scattered low trees over Acacia atkinsiana, A. exilis, A. bivenosa, A. ancistrocarpa, Senna spp. shrubland over Triodia epactia and/or T. wiseana hummock grassland
PS7	Eucalyptus leucophloia, (Corymbia hamersleyana) scattered low trees over Acacia inaequilatera scattered shrubs to tall open shrubland over Triodia wiseana, (T. epactia) hummock grassland
PS8	Eucalyptus leucophloia scattered low trees over Acacia atkinsiana, A. maitlandii open shrubland over Triodia epactia, T. melvillei hummock grassland
PS9	Eucalyptus xerothermica low open woodland over Eremophila fraseri scattered shrubs over Triodia wiseana hummock grassland

RioTinto

Resource Strategy & Planning

Figure 46
Nammuldi Silvergrass: Integrated vegetation types in the Greater Nammuldi Area (from Biota 2012)
LEGEND

Drawn: A.Eve
Date: May, 2012

Plan No: PDE0084435v2
Proj: MGA94 Zone50

9.2.2 Conservation significance

The majority of vegetation types within the Proposal Boundary are considered to be widespread and representative of the Pilbara bioregion. There are, however, six vegetation communities considered to be of high conservation significance because of their limited local occurrence or ecological function. These vegetation communities are associated with the riparian vegetation of major creek lines (CD1) and the vegetation communities of the cracking clay plains (PC6 – 10) (Table 30 and shown in Figure 47).

The six vegetation communities of conservation significance described in Table 30 are mapped using the integrated mapping system developed by Biota (2012). As the integrated mapping system comprises a range of previously mapped vegetation units this has meant that a number of vegetation units with different conservation significance rankings have been grouped together. Vegetation units CD1, PC6, PC9 and PC10 include vegetation units that were either not considered to be of conservation significance or that previously were given a moderate ranking. To ensure that the approach to assigning conservation significance ranking is conservative the high ranking has been extended to all of these units.

The conservation significant vegetation communities associated with the cracking clays represent a restricted landform in the local environment and have several species of grasses that comprise poorly represented communities in the local area. The cracking clays contain the *Themeda* grassland TEC and *Astrebla* tussock grassland, which may represent the Brockman cracking clay PEC.

Threatened Ecological Community

The *Themeda* grassland TEC is dominated by the perennial, tussock-forming *Themeda* and includes a number of annual herbs and grasses. The TEC occurs at other locations along Caves Creek, upstream of the Silvergrass site, with the largest occurrence on Hamersley Station, located south of the Hamersley Station homestead (approximately 25 km east) (Figure 14). As this area is located on a pastoral lease, the main threat to this TEC is considered to be grazing and trampling.

The detailed mapping conducted by Biota (2010c) of the area defined as the TEC identified a number of different grassland communities, including around 120 ha of *Astrebla lappacea* grasslands along the southern boundary of the *Themeda* grassland TEC at Silvergrass (mapping shown in Figure 14). The *Themeda* grassland TEC is represented by Vegetation Unit PC8 at a local scale.

Priority Ecological Community

The *Astrebla* tussock grassland PEC is a Priority 1 PEC that comprises rare tussock grassland dominated by *Astrebla lappacea* on the Newman land system (Biota 2011c).

Detailed mapping of the PEC determined that the extent of the potential *Astrebla* tussock grassland PEC is approximately 21 276 ha, which has been rated as having as Good, Mosaic or Marginal representation (Table 29). Approximately 6529 ha of the mapped PEC is within the existing TEC boundaries across three sites (Figure 48).

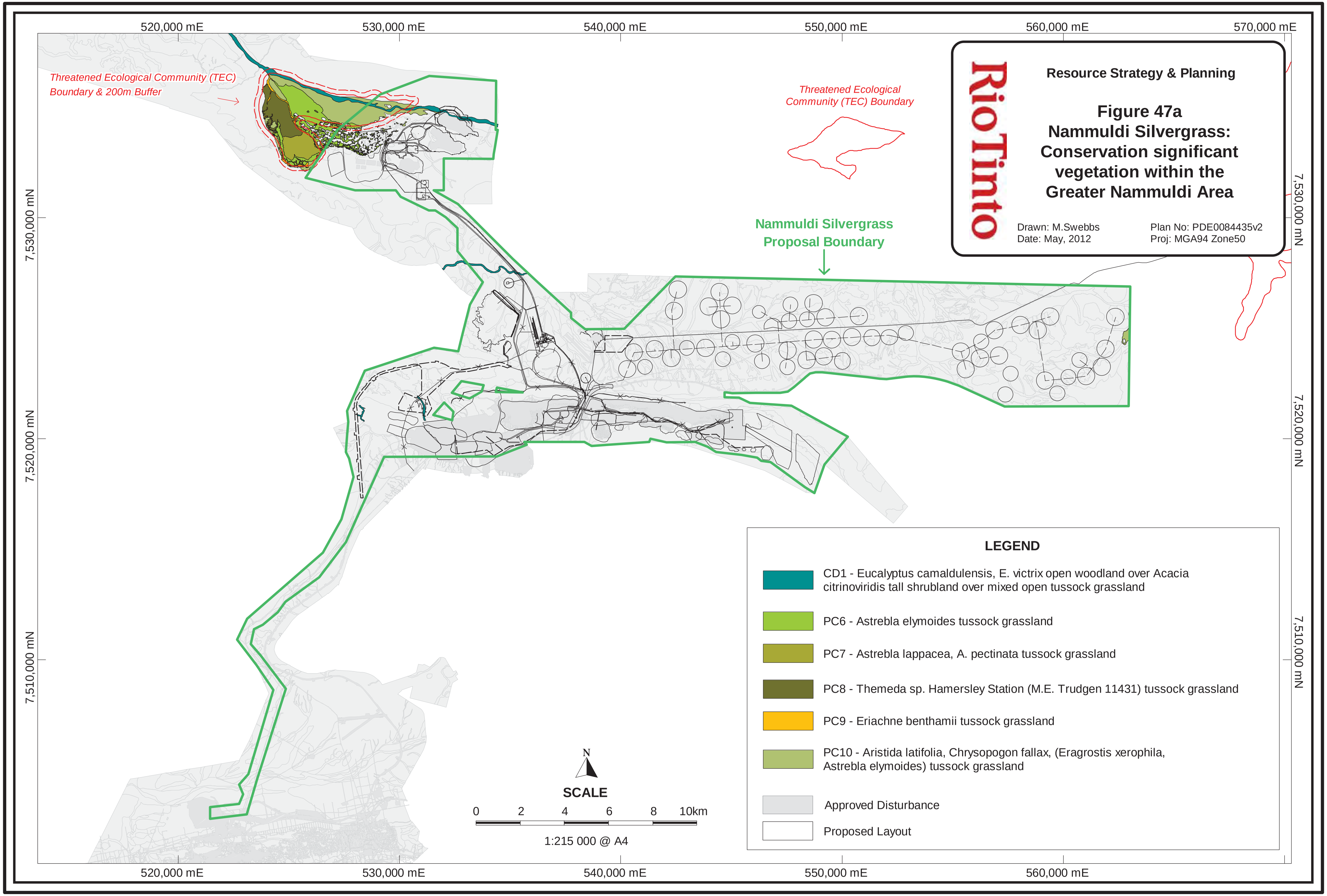
The portion of the PEC mapped as a Good representation is associated with all of Vegetation unit PC7 and the continuous portion of PC6. The area mapped as a Mosaic representation represents the remainder of PC6 and small portions of PC9 and PC10 with the area mapped as Marginal representation comprising PC10.

Table 29 Extent of the *Astrebla* tussock grassland PEC

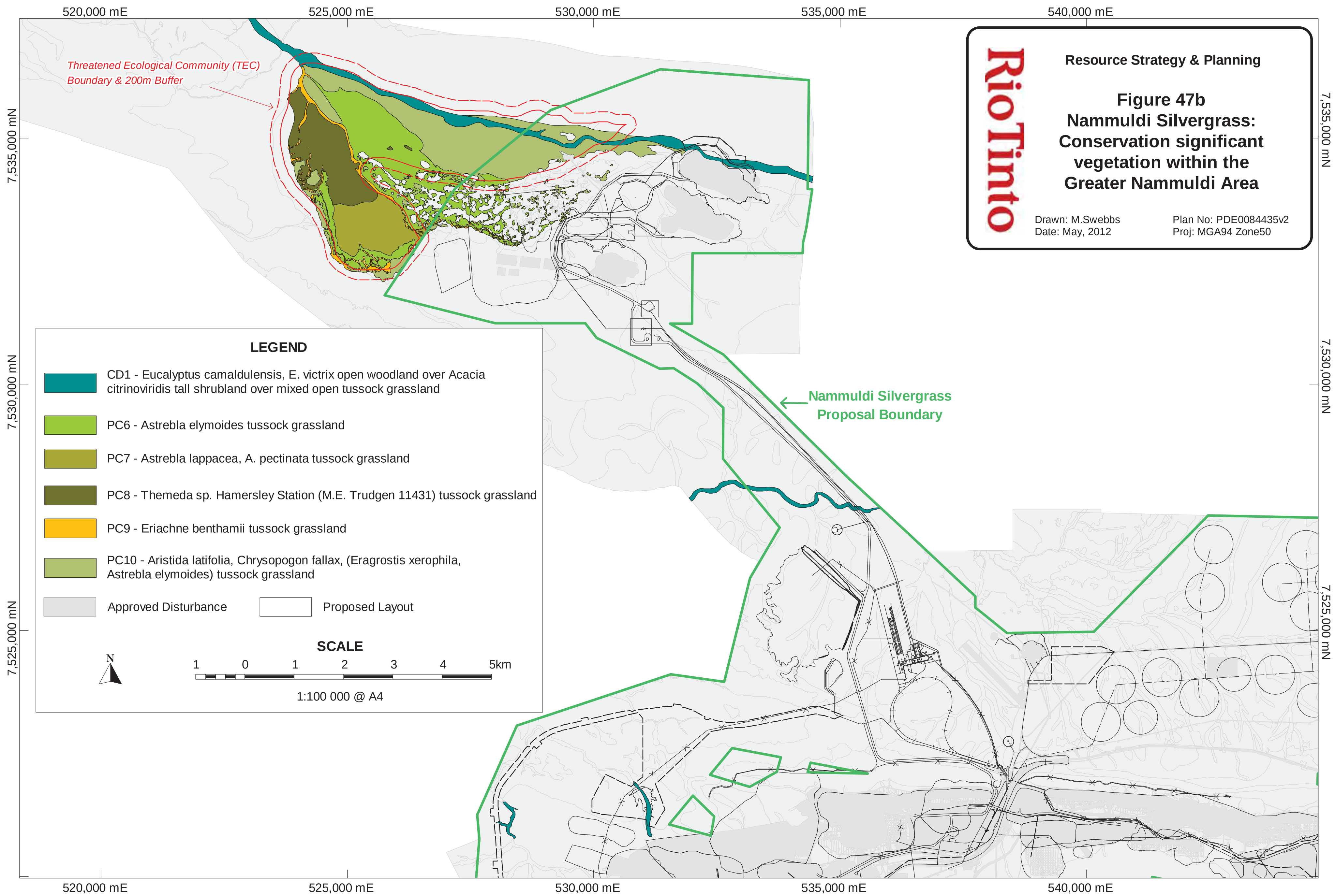
Representation	Veg units	Extent (ha)	Area within existing TEC boundary (ha)	Area disturbed by Expansion Proposal (ha)	Extent disturbed by Expansion Proposal (%)
Good	PC7, PC6	10390	6099	0	0
Mosaic	PC6,P C10	8676	229	91 (of which only 47 ha is from vegetation units PC6, PC9 and PC10 (as described in Table 30) and therefore considered to be significant.	1
Marginal	PC10	2210	201	0	0
Total		**21276**	**6529**	**91**	**0.4**

Table 30 Vegetation communities of high conservation significance within the Greater Nammuldi Area

Veg Code	Habitat	Vegetation community	Location	Equivalent vegetation units in previous mapping	Previous conservation significance	Extent within Greater Nammuldi Area (ha)
CD1	Major creeklines	*Eucalyptus camaldulensis, E. victrix* open woodland over *Acacia citrinoviridis* tall shrubland over mixed open tussock grassland.	Duck Creek and Caves Creek, Silvergrass West (Caves Creek)	3		520
				B1	High (Halpern Glick Maunsell 1999a)	
				EcEvAciAcMgCEc		
				EcEvAbGOrAciPlEUaTHt	Moderate (Biota 2010b)	
				Drainage Euc vic / Aca cit		
PC6	Clay plains	*Astrebla elymoides* tussock grassland.	Silvergrass cracking clay	ASe, ASspp / Stony rise		415
				M-Ast-TG		
				CHfBRcPOsph; ASlPOsph; PANlUoSIs	High (Biota 2010c)	
				THtCHfBTb/h	Moderate (Biota 2010a)	
PC7	Clay plains	*Astrebla lappacea, A. pectinata* tussock grassland.	Silvergrass cracking clay	ASlPOsph, THsCHfPOsph	High (Biota 2010c)	149
				ASlASp	High (Biota 2011a)	
PC8	Clay plains	*Themeda* sp. Hamersley Station (M.E. Trudgen 11431) tussock grassland.	Silvergrass cracking clay	THsDICLfPOsph, THsCHfPOsph	High (Biota 2010c)	204
				THs	High (Biota 2011a	
PC9	Clay plains	*Eriachne benthamii* tussock grassland.	Silvergrass cracking clay	ERlb		55
				DC-Eb-TG		
				CHfBRcPOsph; ERlbSTkPOsph	High (Biota 2010c)	
PC10	Clay plains	*Aristida latifolia, Chrysopogon fallax, (Eragrostis xerophila, Astrebla elymoides)* tussock grassland.	Silvergrass cracking clay	ARlASeCHf		539
				G1		
				UP3-CfDf-MTG, UP4-MOTG		
				CHfBRcPOsph; CAoENpBRcDICh; CHfASpARlPOsph; AiAbAatTePAm	High (Biota 2010c)	
					Total	**1882**



520,000 mE
530,000 mE
540,000 mE
550,000 mE
560,000 mE
570,000 mE
7,530,000 mN
7,520,000 mN
7,510,000 mN
Threatened Ecological Community (TEC) Boundary & 200m Buffer
Threatened Ecological Community (TEC) Boundary
Nammuldi Silvergrass Proposal Boundary
Resource Strategy & Planning
Figure 47a
Nammuldi Silvergrass: Conservation significant vegetation within the Greater Nammuldi Area
Drawn: M.Swebbs
Date: May, 2012
Plan No: PDE0084435v2
Proj: MGA94 Zone50
LEGEND
CD1 - Eucalyptus camaldulensis, E. victrix open woodland over Acacia citrinoviridis tall shrubland over mixed open tussock grassland
PC6 - Astrebla elymoides tussock grassland
PC7 - Astrebla lappacea, A. pectinata tussock grassland
PC8 - Themeda sp. Hamersley Station (M.E. Trudgen 11431) tussock grassland
PC9 - Eriachne benthamii tussock grassland
PC10 - Aristida latifolia, Chrysopogon fallax, (Eragrostis xerophila, Astrebla elymoides) tussock grassland
Approved Disturbance
Proposed Layout
N
SCALE
0 2 4 6 8 10km
1:215 000 @ A4



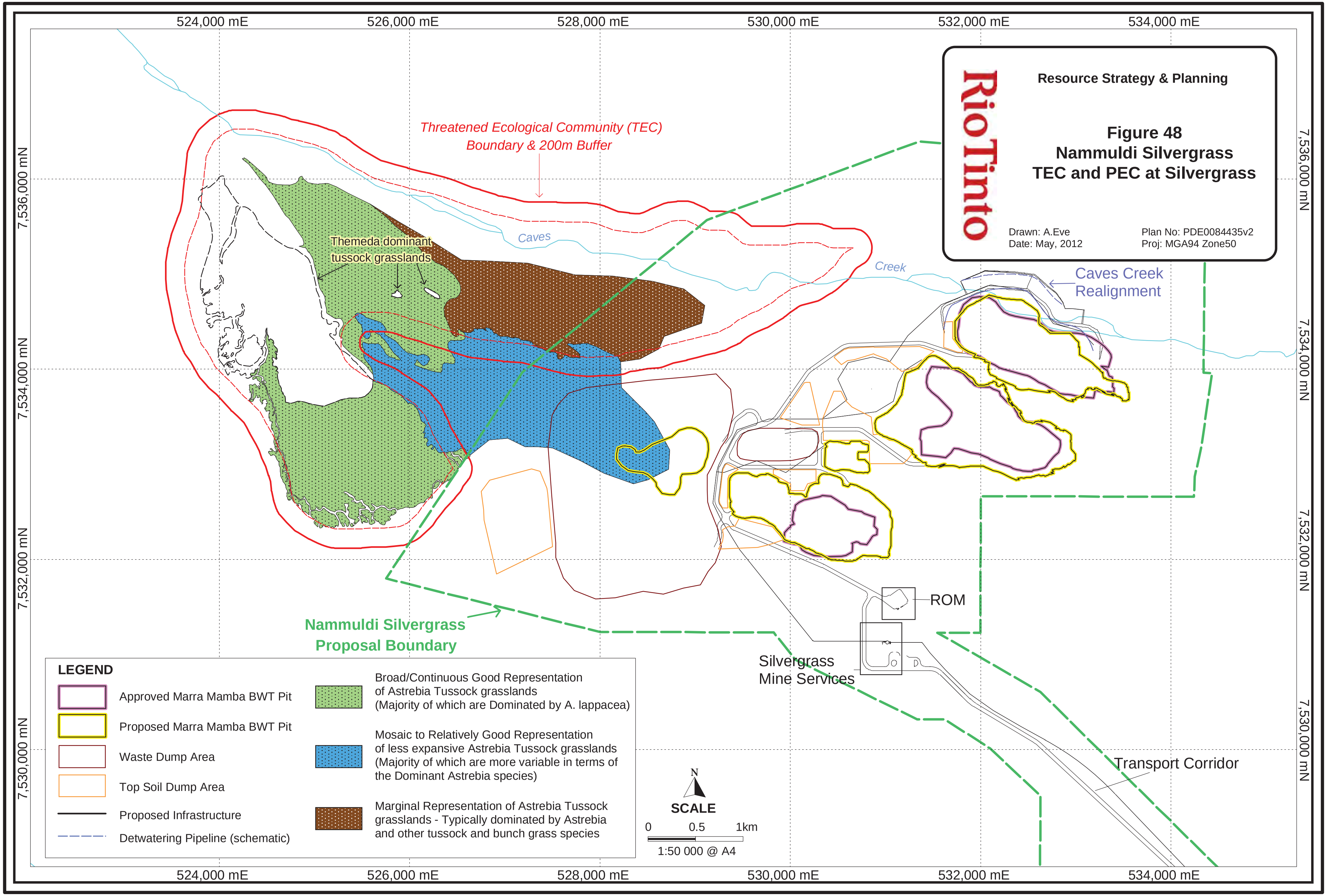
Rio Tinto

Resource Strategy & Planning

Figure 47b
Nammuldi Silvergrass: Conservation significant vegetation within the Greater Nammuldi Area

Drawn: M.Swebbs
Date: May, 2012

Plan No: PDE0084435v2
Proj: MGA94 Zone50



Resource Strategy & Planning
Figure 48
Nammuldi Silvergrass
TEC and PEC at Silvergrass
Drawn: A.Eve
Date: May, 2012
Plan No: PDE0084435v2
Proj: MGA94 Zone50
524,000 mE
526,000 mE
528,000 mE
530,000 mE
532,000 mE
534,000 mE
7,536,000 mN
7,534,000 mN
7,532,000 mN
7,530,000 mN
Threatened Ecological Community (TEC)
Boundary & 200m Buffer
Caves
Creek
Caves Creek
Realignment
Themeda dominant
tussock grasslands
ROM
Silvergrass
Mine Services
Transport Corridor
Nammuldi Silvergrass
Proposal Boundary
LEGEND
Approved Marra Mamba BWT Pit
Proposed Marra Mamba BWT Pit
Waste Dump Area
Top Soil Dump Area
Proposed Infrastructure
Detwatering Pipeline (schematic)
Broad/Continuous Good Representation of Astrebia Tussock grasslands (Majority of which are Dominated by A. lappacea)
Mosaic to Relatively Good Representation of less expansive Astrebia Tussock grasslands (Majority of which are more variable in terms of the Dominant Astrebia species)
Marginal Representation of Astrebia Tussock grasslands - Typically dominated by Astrebia and other tussock and bunch grass species
N
SCALE
0
0.5
1km
1:50 000 @ A4

9.2.3 Flora within the Greater Nammuldi Area

The surveys conducted in the Greater Nammuldi Area to date have recorded more than 600 taxa of native vascular flora from around 165 genera and 60 families. In addition, 14 species of introduced flora were recorded. The most common families recorded were Poaceae (grass family), Fabaceae (wattle, pea and cassia family), Malvaceae (hibiscus family), Asteraceae (daisy family), and Amaranthaceae (Amaranth family). The most species-rich genera in the Greater Nammuldi Area were *Acacia* (wattles), *Ptilotus* (mulla-mullas) and *Cassia* (cassia/senna). These families and genera constitute a flora typical of the Pilbara region.

The flora species recorded within the IAA were considered to be representative of the broader area, as were the vegetation communities identified in the IAA (Mattiske 2011). A total of 189 vascular plant taxa from 99 genera and 40 families were recorded within IAA.

Declared Rare Flora

Two species of Declared Rare Flora (DRF) are known to occur within the Pilbara; *Lepidium catapycnon* (Hamersley lepidium) and *Thryptomene wittweri* (mountain thryptomene). To date, neither species has been recorded within the Greater Nammuldi Area or the wider Brockman locality to the south (Biota 2010b).

Suitable habitat for *L. catapycnon* occurs in hummock grasslands on low stony hills and occasionally stony plains in the Hamersley sub-region. This species is a relatively short-lived low shrub and has often been recorded from areas that have recently been disturbed, persisting for only a few years. Previous searches of the Greater Nammuldi Area have not located any populations to date notwithstanding suitable habitat for *L. catapycnon* may occur within areas to the west and east of the current Nammuldi mining operation.

T. wittweri is less common than *L. catapycnon,* occurring only on high-altitude hilltops further east in the Hamersley sub-region. There is no suitable habitat for *T. wittweri* in the Greater Nammuldi Area and this species is not expected to occur.

Priority Flora

Thirteen Priority Flora species have been recorded in a variety of habitats during surveys in the Proposal Boundary (Table 31 and Figure 49). These habitats are generally well represented throughout the Pilbara (Biota 2010b).

Table 31 Priority flora occurring in the Proposal Boundary

Species	Priority	Habitat
Calotis squamigera	Priority 1	Rocky creeks, hillsides and floodplains
Sida sp. Hamersley Range	Priority 1	Rocky slopes
Abutilon sp. Quobba	Priority 2	Rocky slopes
Spartothamnella puberula	Priority 2	Rocky loam, sandy, skeletal soils or clay on sand plains and hills
Vigna ? Sp. Central (M.E. Trudgen 1626)	Priority 2	Edge of flats and alluvial outwash areas
Astrebla lappacea	Priority 3	Clayey plains
Dampiera anonyma	Priority 3	Rocky slopes
Eremophila magnifica subsp. *velutina*	Priority 3	Rocky hills
Glycine falcata	Priority 3	Black clayey sand along drainage depressions in crabhole plains on river floodplains.
Gymnanthera cunninghamii	Priority 3	Sandy soil along inland watercourses
Indigofera gilesii subsp. gilesii	Priority 3	Rocky slopes
Indigofera sp. Bungaroo Creek (S. van Leeuwen 4301)	Priority 3	Creekline and drainage areas

Species	Priority	Habitat
Ptilotus subspinescens	Priority 3	Stony plains and gentle, rocky slopes with a fine calcareous substrate
Rhagodia sp. Hamersley (M. Trudgen 17794)	Priority 3	Minor drainage area
Rostellularia adscendens var. *latifolia*	Priority 3	Creekline vegetation
Sida sp. Barlee Range	Priority 3	Rocky slopes
Swainsona sp. Hamersley Station (A.A. Mitchell 196)	Priority 3	Cracking clay plains
Themeda sp. Hamersley Station (M.E Trudgen 11431)	Priority 3	Cracking clay plains
Goodenia nuda	Priority 4	Alluvial plains
Ptilotus mollis	Priority 4	Stony hills and screes

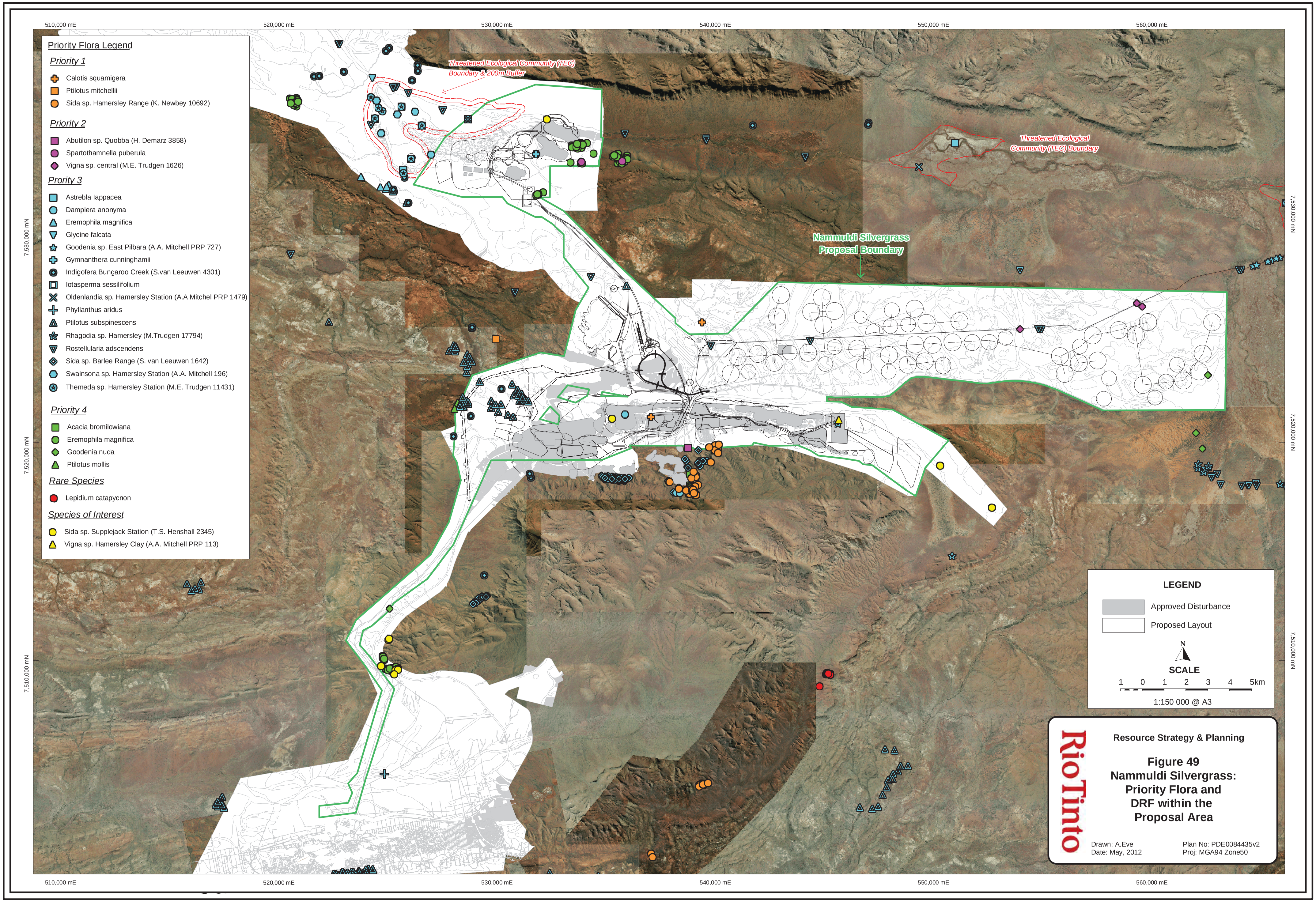
Introduced flora

Sixteen weed species have been identified within the Proposal Boundary (Figure 50):

- *Acetosa vesicaria* (ruby dock)
- *Bidens bipinnata* (beggars ticks)[#]
- *Cenchrus ciliaris* (buffel grass)[#]
- *Cenchrus setiger* (birdwood grass)[#]
- *Citrullus lanatus* (watermelon)[#]
- *Conyza bonariensis*
- *Cucumis melo* subsp. *agrestis* (ulcardo melon)[#]
- *Datura leichhardtii* (native thornapple)
- *Eragrostis tenuifolia*
- *Flaveria trinervia* (speedy weed).
- *Malvastrum americanum* (spiked malvastrum)[#]
- *Oxalis corniculata* (yellow woodsorrel)[#]
- *Portulaca oleracea* (purslane)
- *Setaria verticillata* (whorled pigeon grass)
- *Sigesbeckia orientalis* (Indian weed)
- *Vachellia farnesiana* (mimosa bush) [#].

[#] denotes species recorded within the IAA

Most of these species are common and widespread throughout the Greater Nammuldi Area and usually associated with drainage areas but none are listed as Declared Plants by the Department of Agriculture and Food WA. Nonetheless, *Cenchrus* species, ruby dock and mimosa bush are considered to be serious environmental weeds (Biota 2010a; Mattiske 2011).



510,000 mE
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550,000 mE
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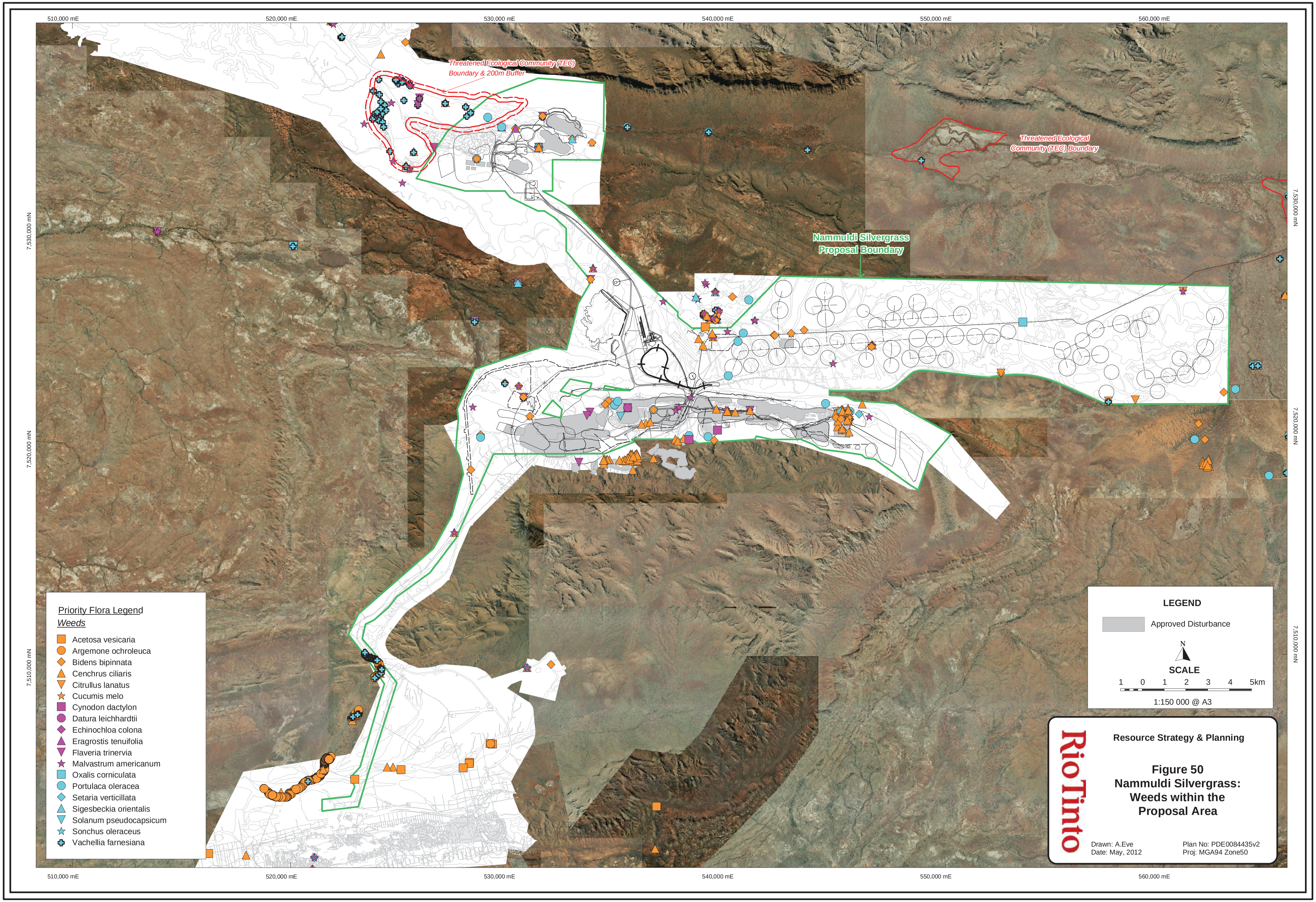
7,530,000 mN
7,520,000 mN
7,510,000 mN
Priority Flora Legend
Priority 1
Calotis squamigera
Ptilotus mitchellii
Sida sp. Hamersley Range (K. Newbey 10692)
Priority 2
Abutilon sp. Quobba (H. Demarz 3858)
Spartothamnella puberula
Vigna sp. central (M.E. Trudgen 1626)
Prority 3
Astrebla lappacea
Dampiera anonyma
Eremophila magnifica
Glycine falcata
Goodenia sp. East Pilbara (A.A. Mitchell PRP 727)
Gymnanthera cunninghamii
Indigofera Bungaroo Creek (S.van Leeuwen 4301)
Iotasperma sessilifolium
Oldenlandia sp. Hamersley Station (A.A Mitchel PRP 1479)
Phyllanthus aridus
Ptilotus subspinescens
Rhagodia sp. Hamersley (M.Trudgen 17794)
Rostellularia adscendens
Sida sp. Barlee Range (S. van Leeuwen 1642)
Swainsona sp. Hamersley Station (A.A. Mitchell 196)
Themeda sp. Hamersley Station (M.E. Trudgen 11431)
Priority 4
Acacia bromilowiana
Eremophila magnifica
Goodenia nuda
Ptilotus mollis
Rare Species
Lepidium catapycnon
Species of Interest
Sida sp. Supplejack Station (T.S. Henshall 2345)
Vigna sp. Hamersley Clay (A.A. Mitchell PRP 113)
Threatened Ecological Community (TEC) Boundary & 200m Buffer
Threatened Ecological Community (TEC) Boundary
Nammuldi Silvergrass Proposal Boundary
LEGEND
Approved Disturbance
Proposed Layout
N
SCALE
1 0 1 2 3 4 5km
1:150 000 @ A3
Rio Tinto
Resource Strategy & Planning
Figure 49
Nammuldi Silvergrass: Priority Flora and DRF within the Proposal Area
Drawn: A.Eve
Date: May, 2012
Plan No: PDE0084435v2
Proj: MGA94 Zone50



510,000 mE
520,000 mE
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7,520,000 mN
7,510,000 mN
Threatened Ecological Community (TEC) Boundary & 200m Buffer
Threatened Ecological Community (TEC) Boundary
Nammuldi Silvergrass Proposal Boundary
Priority Flora Legend
Weeds
Acetosa vesicaria
Argemone ochroleuca
Bidens bipinnata
Cenchrus ciliaris
Citrullus lanatus
Cucumis melo
Cynodon dactylon
Datura leichhardtii
Echinochloa colona
Eragrostis tenuifolia
Flaveria trinervia
Malvastrum americanum
Oxalis corniculata
Portulaca oleracea
Setaria verticillata
Sigesbeckia orientalis
Solanum pseudocapsicum
Sonchus oleraceus
Vachellia farnesiana
LEGEND
Approved Disturbance
N
SCALE
1 0 1 2 3 4 5km
1:150 000 @ A3
Rio Tinto
Resource Strategy & Planning
Figure 50
Nammuldi Silvergrass:
Weeds within the
Proposal Area
Drawn: A.Eve
Date: May, 2012
Plan No: PDE0084435v2
Proj: MGA94 Zone50

9.2.4 Riparian vegetation

Following a preliminary fieldtrip in 2009, Biota conducted baseline flora and vegetation surveys of the riparian vegetation within, and downstream of the Proposal Boundary in 2010 and 2011 (Biota 2010d, 2010e, 2011b). The 2010 and 2011 surveys of Caves Creek and Duck Creek (including Donkey Pool tributary) included undertaking detailed transects of 22 and 16 sites, respectively. This surveying characterised the riparian vegetation for more than 160 km and was part of a comprehensive program undertaken by Rio Tinto designed to describe the baseline condition of riparian vegetation for the different reaches of Caves and Duck creek (Table 32). The sites were selected prior to the fieldtrip on the basis of aerial photography, with final site selection based on accessibility and even spread within each reach.

Table 32 Reaches of Caves Duck creeks surveyed in 2010 and 2011 (Biota 2010d, 2010e, 2011b).

Location	Reach
Caves creek	Upper Caves
	Silvergrass
	Homestead
	Palm Springs
Confluence	Caves Creek / Duck Creek confluence
Duck creek	Upper Duck
	Lower Duck
	New Duck (Downstream of confluence
Duck Creek tributary	Control
	Donkey Pool

Creek Morphology

The riparian vegetation surveys identified four general morphology categories:

1. **Broad and shallow creeks with poorly defined channels:** found at the Palm Springs end of Caves Creek and western reaches of Duck Creek.
2. **Narrow creeks with a distinct channel of 2.5 – 4 m depth:** the most common morphology type, occurring at numerous sites along Caves Creek and Duck Creek above the confluence.
3. **Moderately broad to broad creeks with some channel definition:** found at the confluence of Duck and Caves creeks, as well as the eastern end of Duck Creek.
4. **Narrow, shallow and poorly defined channels:** found at the Homestead reach of Caves Creek and along a tributary.

There were no major changes in creek morphology between the two sampling years, however, some minor changes were observed at two sites. Sites at both the Homestead and Palm Springs reaches of Caves Creek showed low points which were not recorded during the 2010 survey, potentially created due to streamflow scour occurring before the survey period (Biota 2011b).

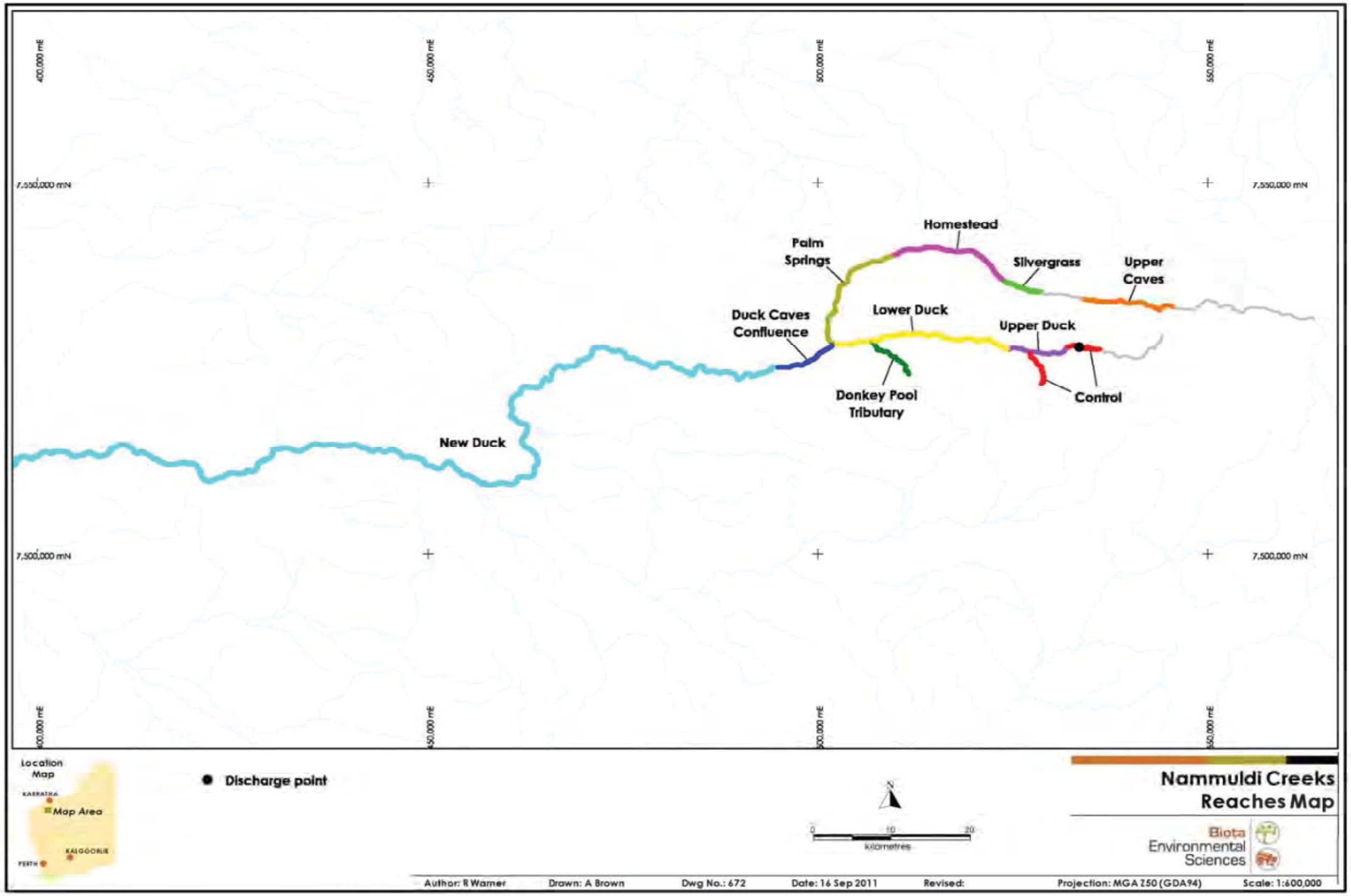


Figure 51 Riparian vegetation survey reaches

Flora

The families and genera recorded during the surveys were typical of the vegetation of the Pilbara, with the dominant families and genera outlined in Table 33 and Table 34 respectively. There was no discernible link indentified between morphology of the drainage features and mean species number within reaches (Biota 2010e).

The total number of native species recorded, and mean number of species within reaches were higher in 2011 than 2010. This is likely to be a result of the significant rainfall (approximately 400 mm in the area) between the two surveys (Biota 2011b). The dominant families and genera recorded during the 2011 and 2010 surveys remained similar (Table 33 and Table 34), and the differences in the number of native flora species between survey years can be attributed to the vegetation responses to seasonal variations (Biota 2011b).

Table 33 Families with the highest number of native species richness in creek monitoring sites

Family	No. of native species	
	2011	2010
Poaceae (grass family)	50	23
Fabaceae (pea, wattle, cassia family)	35	26
Malvaceae (malva family)	18	13
Cyperaceae (sedge family)	17	6
Euphorbiaceae (spurge family)	12	6
Convolvulaceae (morning glory family)	12	4
Total	**144**	**78**

Table 34 Genera with the highest number of native species richness in creek monitoring sites

Genus	No. of native species	
	2011	2010
Acacia (wattles)	12	11
Euphorbia (spurges)	12	6
Sida (sidas)	6	5
Cassia (cassias)	6	4
Cyperus (sedges)	6	4
Total	**42**	**30**

Introduced Flora

A total of 17 introduced flora species were recorded during the 2011 survey (Table 35). Weed species identified during the creek line survey were similar to species recorded in the IAA by Mattiske (2011), which recorded 14 weed species typically associated with creek lines and areas with high water availability (Section 9.2.3).

Ten of the introduced flora species identified in the 2011 creek survey were not recorded in 2010 (Biota 2011b). The population of each introduced species generally increased from 2010 to 2011; however, this did not result in an appreciable change to the weed density of any individual introduced species. The higher number of weed species and their individual populations was attributed to the higher rainfall before the 2011 survey season facilitating the germination growth and spread of weeds (Biota 2011b).

Table 35 Introduced flora populations recorded during 2011 and 2010

Species	No. of plants	
	2011	2010
Avera javanica (kapok)	NR	2
Argemone ochroleuca subsp. *ochroleuca* (Mexican poppy)	5	28
Bidens bipinnata (beggars tick)	NR	7
Cenchrus ciliaris (buffel grass)	8	39
Cenchrus setiger (birdwood grass)	NR	26
Citrullus colocynthis (colocyth)	NR	2
Cucumis melo subsp. *agrestis* (ulcardo melon)	NR	4
Cynodon dactylon (couch)	NR	1
Echinochloa colona (awnless barnyard grass)	2	9
Flaveria trinervia (speedy weed)	13	35
Malvastrum americanum (spiked malvastrum)	23	26
Oxalis corniculata (yellow wood sorrel)	NR	1
Portulaca oleracea (purslane)	NR	2
Setaria verticillata (whorled pigeon grass)	1	10
Sigebeckia orientalis (Indian weed)	NR	2
Sonchus oleraceus (common sowthistle)	NR	6
Vachellia farnesiana (mimosa bush)	20	19
Total	**72**	**219**

NR = not recorded

Community structure

Tree density recorded during the 2010 and 2011 surveys was broadly similar (Biota 2011b). The dominant tree species structure varied between the different sites with Caves Creek having the highest density of *Eucalyptus victrix* while Duck Creek had the highest density for *Eucalyptus Camaldulensis,* particularly at the confluence of the two creeks. *Melaleuca argentea* was present in both the Duck Creek and Palm Springs reaches of Caves Creek, with the highest density at Palm Springs. Permanent waterholes, such as Palm Springs, exhibited the highest tree density overall for *Melaleuca argentea* (Biota 2010e). The typical riparian vegetation profiles observed at each reach (by Biota 2010e) within the Proposal Boundary are shown in Figure 52 and Figure 53.

The three dominant riparian tree species have varying dependence on ground water (Table 36). *Melaleuca argentea* must have access to groundwater, while *Eucalyptus camaldulensis* is partially dependent on groundwater, and *Eucalyptus Victrix* relies mostly on soil water in the unsaturated profile as a water resource (Rio Tinto 2011a). The effect of drawdown on riparian vegetation therefore depends on the distribution of the differing dominant tree species in areas where substantial drawdown associated with the Expansion Proposal has been predicted. Riparian vegetation communities dominated by *Melaleuca argentea* and *Eucalyptus camaldulensis* are likely to be affected but vegetation communities dominated by *Eucalyptus victrix are* considered unlikely to be affected by drawdown.

Table 36 Groundwater dependence of dominant riparian tree species within the Greater Nammuldi Area

Species	Classification	Requirements
Melaleuca argentea	Obligate phreatophyte	Only occurs in permanently inundated pools and springs and must have access to groundwater.
Eucalyptus camaldulensis	Facultative phreatophyte	Accesses groundwater for part of its requirements.
Eucalyptus victrix	Vadophyte	Relies mostly on soil water in the unsaturated profile (vadose zone).

Source: Rio Tinto 2011a

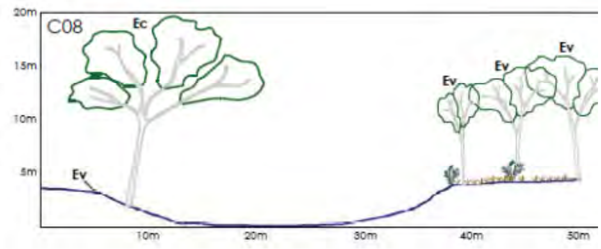
Indicators of change

Comparison of creek surveys undertaken in 2010 and 2011 suggest that the 2011 survey generally recorded high values for:

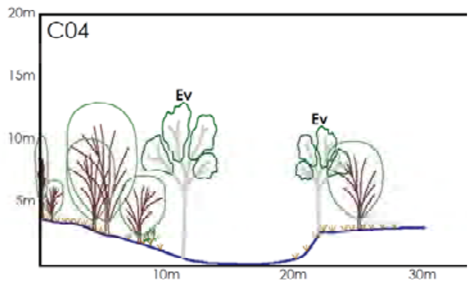
- total number of native species
- mean number of native species within reaches
- total number of weed species.

The higher number of native and weed species was generally attributed to higher rainfall prior to the 2011 survey, which encourages translocation and germination of seed, and plant growth (Biota 2011b). Creek morphology, dominant species, community structure and results of floristic analysis (MDS plots) remained similar between years.

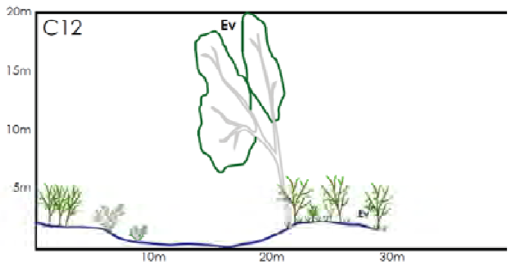
Although the surveys monitored the relationship of the tree height and Diameter at Breast Height (DBH [stem diameter at 1.3 m above ground level]) of the three dominant tree species during both the 2010 and 2011 surveys, the differences of the DBH between the two surveys were not considered a sufficient period of time to detect changes.



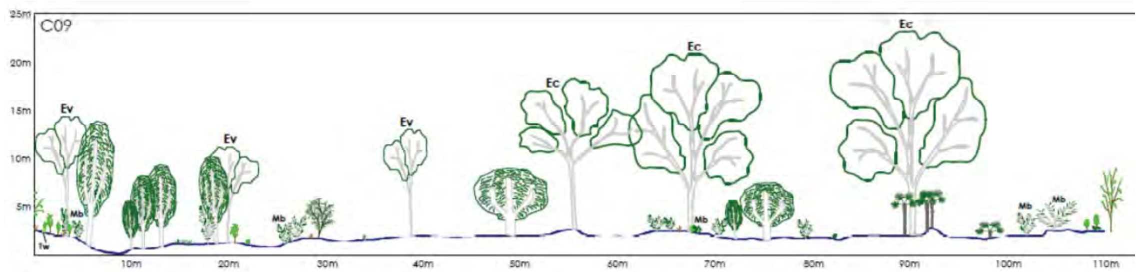
a) Upper Caves



b) Silvergrass



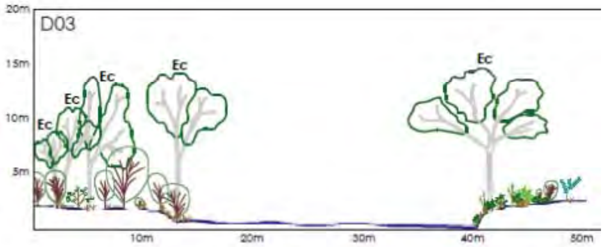
c) Homestead



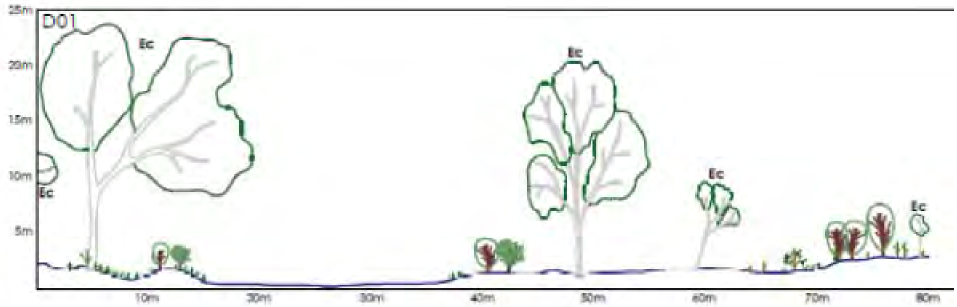
d) Palms Spring

Ma = *Melaleuca argentea,* Ec = *Eucalyptus camaldulensis,* Ev = *Eucalyptus victrix*

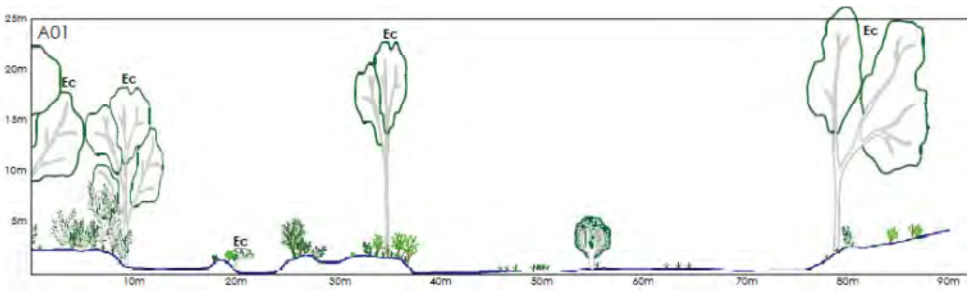
STRATEGEN	Nammuldi-Silvergrass Expansion Proposal Riparian vegetation profiles of Caves Creek	Figure 52



a) Upper Duck Creek



b) Lower Duck Creek



c) Confluence between Caves Creek and Duck Creek

Ma = *Melaleuca argentea,* Ec = *Eucalyptus camaldulensis,* Ev = *Eucalyptus victrix*

9.3 Potential sources of impact

The following aspects of the Expansion Proposal may affect flora and vegetation values:

- **clearing of vegetation** for the mining area, infrastructure, channel re-alignment at Caves Creek and the Irrigated Agriculture Area will directly reduce the extent of vegetation communities (including vegetation communities of local conservation significance) and potentially disturb Priority Flora species
- **disruption of sheet flows** through extension of mine pits, and construction of additional waste dumps, infrastructure and diversion structures has the potential to have an impact on vegetation communities that are sustained by sheet flow
- **dewatering at Silvergrass** will lower groundwater levels in proximity to the pits and therefore may affect groundwater-dependent vegetation
- **discharge of surplus water** may alter the composition of vegetation communities downstream of the discharge
- **increased vehicle movements and earthworks** have the potential to introduce and spread weed species
- **dust generation** (similar to the Original Proposal) due to earthworks, mining, processing and vehicle movements has the potential to smother vegetation.

As discussed in Section 8.4.3, after the application of mitigation measures (including energy dissipation structures, if required) the proposed re-alignment to Caves Creek is considered unlikely to alter flows downstream and thus changes to the flow regime will not have an impact on downstream riparian vegetation.

9.4 Assessment of likely direct and indirect impacts

9.4.1 Clearing of vegetation

The Expansion Proposal will require clearing of approximately 3900 ha for mine pits, waste dumps, associated mine infrastructure and facilities (including the re-alignment of Caves Creek), and 2500 ha for irrigated agriculture out of a Proposal area of approximately 26 680 ha, which was in a mapped area of 58 600 ha.

Clearing of vegetation will directly reduce the local extent of vegetation communities and potentially disturb some Priority Flora species. The majority of vegetation communities recorded in the Greater Nammuldi Area are well represented across the Pilbara region and clearing is considered unlikely to significantly affect regional diversity. Clearing will mostly occur within vegetation associations of low conservation significance (Table 28) with the layout being shown in Figure 47.

The Expansion Proposal does not include any clearing of vegetation in the Themeda grassland TEC. Of the remaining vegetation communities, no more than 10% of vegetation units of high conservation significance will be affected within the Greater Nammuldi Area (Table 37).

A section (up to approximately 2.5 km) of riparian vegetation community CD1 (High conservation significance) along Caves Creek will be cleared to allow widening of Pit 1 and the diversion of Caves Creek. This section represents approximately 9% of the mapped distribution of this vegetation community (Figure 47). This vegetation community is considered to be wide-spread along Caves Creek within the 160 km extent of riparian vegetation sampled by Biota (2011b). This clearing is not expected to reduce the local or regional abundance or diversity as these vegetation associations have been recorded outside of the area affected and are likely to persist along the creek systems in the region.

The impact to the Astrebla tussock grassland PEC will be minimal. Of the two major vegetation units that represent this PEC only approximately 8% of PC6 will be disturbed and there will be no impact on PC7 (Table 37). When considered on a regional scale (Figure 15), there will no impact to *Astrebla* tussock grassland PEC in good or marginal representation and the impact to the *Astrebla* tussock grassland mosaic PEC will be only approximately 1% (Table 29).

Table 37 Area of high conservation significance vegetation communities that will be cleared within the Greater Nammuldi Area.

Integrated Vegetation Code	Habitat	Vegetation community	Location	Amount (ha)	Amount cleared (ha)	Extent cleared (%)
CD1	Major creeklines	*Eucalyptus camaldulensis, E. victrix* open woodland over *Acacia citrinoviridis* tall shrubland over mixed open tussock grassland.	Duck Creek and Caves Creek, Silvergrass West (Caves Creek)	520	45	9
PC6	Clay plains	*Astrebla elymoides* tussock grassland.	Silvergrass cracking clay	415	34	8
PC7	Clay plains	*Astrebla lappacea, A. pectinata* tussock grassland.	Silvergrass cracking clay	149	0	0
PC8	Clay plains	*Themeda* sp. Hamersley Station (M.E. Trudgen 11431) tussock grassland.	Silvergrass cracking clay	204	0	0
PC9	Clay plains	*Eriachne benthamii* tussock grassland.	Silvergrass cracking clay	55	4	7
PC10	Clay plains	*Aristida latifolia, Chrysopogon fallax, (Eragrostis xerophila, Astrebla elymoides)* tussock grassland.	Silvergrass cracking clay	539	9	2
			Total	**1882**	**92**	

The Expansion Proposal is therefore not expected to significantly affect the regional extent of any vegetation community or affect the conservation significant.

Priority Flora

As summarised in Table 38, clearing associated with the Expansion Proposal may directly affect four Priority 3 flora species:

- *Eremophila magnifica* subsp. *velutina*
- *Gymnanthera cunninghamii*
- *Rhagodia* sp. Hamersley (M. Trudgen 17794)
- *Rostellularia adscendens* var. *latifolia*.

Table 38 Predicted impact on flora species of conservation significance recorded in the Greater Nammuldi Area

Species	Priority	Habitat	Likely of occurrence within Proposal Boundary	Predicted Impact
Calotis squamigera	Priority 1	Rocky creeks, hillsides and floodplains	Recorded on a tributary of Duck Creek upstream of the proposed discharge location.	Unlikely that any occurrences will be disturbed by the Expansion Proposal. As the only potential habitat that could be affected by the Expansion Proposal occurs in the section of the creek diversion. The species has not been recorded in this section and the majority of the potential habitat will not be affected by the Expansion Proposal.
Sida sp. Hamersley Range	Priority 1	Rocky slopes	Occurs within the Greater Nammuldi Area on the rocky slopes south of the Proposal Boundary.	Unlikely that any occurrences will be disturbed by the Expansion Proposal. As the Proposal Boundary does not include disturbance to rocky slopes habitat, the Expansion Proposal is unlikely to affect potential habitat.
Abutilon sp. Quobba	Priority 2	Rocky slopes	Occurs within the Greater Nammuldi Area on the rocky slopes south of the Proposal Boundary.	Unlikely that any occurrences will be disturbed by the Expansion Proposal. As the Proposal Boundary does not include disturbance to rocky slopes habitat, the Expansion Proposal is unlikely to affect potential habitat.
Spartothamnella puberula	Priority 2	Rocky loam, sandy, skeletal soils or clay on sand plains and hills	Occurs within the Greater Nammuldi Area west of Silvergrass. However, potential habitat considered unlikely to occur within the Proposal Boundary given due to the absence of appropriate soil types.	Unlikely that any occurrences will be disturbed by the Expansion Proposal. As the Proposal Boundary does not include potential habitat the local distribution is considered unlikely to be affected.
Vigna ? Sp. Central (M.E. Trudgen 1626)	Priority 2	Edge of flats and alluvial outwash areas	Recorded in three vegetation communities in IAA.	The Expansion Proposal is unlikely to affect the local and regional distribution of this species. Species has a relatively broad distribution within the IAA and the majority of this habitat will not be cleared. It is unlikely that any occurrences of this species will be disturbed by the Expansion Proposal.
Astrebla lappacea	Priority 3	Clayey plains	Restricted to the Silvergrass occurrence of the Themeda Grassland TEC and unlikely to occur within the Proposal Boundary.	The Expansion Proposal is unlikely to affect the local and regional distribution of this species.
Dampiera anonyma	Priority 3	Rocky slopes	Occurs within the Greater Nammuldi Area on the rocky slopes south of the Proposal Boundary.	Unlikely that any occurrences will be disturbed by the Expansion Proposal. As the Proposal Boundary does not include disturbance to rocky slopes habitat, the Expansion Proposal is unlikely to affect potential habitat.
Eremophila magnifica subsp. *velutina*	Priority 3	Rocky hills	Occurs within the Greater Nammuldi Area on the rocky slopes south of the Proposal Boundary.	Unlikely that any occurrences will be disturbed by the Expansion Proposal. As the Proposal Boundary does not include disturbance to rocky slopes habitat, the Expansion Proposal is unlikely to affect potential habitat.
Glycine falcata	Priority 3	Black clayey sand along drainage depressions in crabhole plains on river floodplains.	Restricted to creeklines and occurs west of the Proposal Boundary on Caves Creek,	Unlikely that any occurrences will be disturbed by the Expansion Proposal. As the only potential habit that could be affected by the Expansion Proposal occurs in the section of the creek diversion. The species has not been recorded in this section and the majority of the potential habitat will not be affected by the Expansion Proposal.
Gymnanthera cunninghamii	Priority 3	Sandy soil along inland watercourses	Recorded along Caves Creek and at Mt Brockman during surveys for the CER but has not been subsequently recorded.	The Expansion Proposal is unlikely to affect the local and regional distribution of this species. Species has not been recorded within the Proposal Boundary during recent surveys but has previously been recorded in the area that will be disturbed for the Caves Creek diversion. If the species does occur in this area then it is possible that there may be some loss of individuals. However, the loss of some individuals is not expected to affect the regional distribution of the species given that the majority of the potential habitat will not be affected by the Expansion Proposal.

Species	Priority	Habitat	Likely of occurrence within Proposal Boundary	Predicted Impact
Indigofera gilesii subsp. gilesii	Priority 3	Rocky slopes	Occurs within the Greater Nammuldi Area on the rocky slopes south of the Proposal Boundary.	Unlikely that any occurrences will be disturbed by the Expansion Proposal. As the Proposal Boundary does not include disturbance to rocky slopes habitat, the Expansion Proposal is unlikely to affect potential habitat.
Indigofera sp. Bungaroo Creek (S. van Leeuwen 4301)	Priority 3	Creekline and drainage areas	Occurs within the Greater Nammuldi Area at a number of locations to the west of the Proposal Boundary. But not recorded within the Proposal Boundary.	Unlikely that any occurrences will be disturbed by the Expansion Proposal. As the only potential habit that could be affected by the Expansion Proposal occurs in the section of the creek diversion. The species has not been recorded in this section and the majority of the potential habitat will not be affected by the Expansion Proposal.
Ptilotus subspinescens	Priority 3	Stony plains and gentle, rocky slopes with a fine calcareous substrate	Occurs within the Greater Nammuldi Area on the calcrete soils west of the Proposal Boundary.	Unlikely that any occurrences will be disturbed by the Expansion Proposal. As the Proposal Boundary does not include disturbance to calcrete soil habitat, the Expansion Proposal is unlikely to affect potential habitat.
Rhagodia sp. Hamersley (M. Trudgen 17794)	Priority 3	Minor drainage area	This widespread species was recorded in a widespread distribution to the east of the IAA in spinifex grassland that fringes a drainage zone and has also been recorded within the Proposal Boundary in an area covered by the existing approval.	The Expansion Proposal is unlikely to affect the local and regional distribution of this species. The loss of some individuals associated with the existing approval is not expected to affect the regional distribution of the species given that the majority of occurrences and potential habitat occur to the east of the IAA and will not be affected by the Expansion Proposal.
Rostellularia adscendens var. *latifolia*	Priority 3	Creekline vegetation	Restricted to creeklines and occurs west of the Proposal Boundary on Caves Creek.	Unlikely that any occurrences will be disturbed by the Expansion Proposal. As the only potential habit that could be affected by the Expansion Proposal occurs in the section of the creek diversion. The species has not been recorded in this section and the majority of the potential habitat will not be affected by the Expansion Proposal.
Sida sp. Barlee Range	Priority 3	Rocky slopes	Occurs within the Greater Nammuldi Area on the rocky slopes south of the Proposal Boundary.	Unlikely that any occurrences will be disturbed by the Expansion Proposal. As the Proposal Boundary does not include disturbance to rocky slopes habitat, the Expansion Proposal is unlikely to affect potential habitat.
Swainsona sp. Hamersley Station (A.A. Mitchell 196)	Priority 3	Cracking clay plains	Restricted to the Silvergrass TEC.	Unlikely that any occurrences will be disturbed by the Expansion Proposal. As the Proposal Boundary does not include disturbance to cracking clay habitat, the Expansion Proposal is unlikely to affect potential habitat.
Themeda sp. Hamersley Station (M.E Trudgen 11431)	Priority 3	Cracking clay plains	Restricted to the Silvergrass TEC.	Unlikely that any occurrences will be disturbed by the Expansion Proposal. As the Proposal Boundary does not include disturbance to cracking clay habitat, the Expansion Proposal is unlikely to affect potential habitat.
Goodenia nuda	Priority 4	Alluvial plains	Occurs within the Greater Nammuldi Area at numerous sites east of the IAA.	Unlikely that any occurrences will be disturbed by the Expansion Proposal. As the occurrences are east of the Proposal Boundary, the Expansion Proposal is unlikely to affect potential habitat.
Ptilotus mollis	Priority 4	Stony hills and screes	Occurs within the Greater Nammuldi Area on the rocky hills north of the Proposal Boundary.	Unlikely that any occurrences will be disturbed by the Expansion Proposal. As the Proposal Boundary does not include disturbance to rocky hills habitat, the Expansion Proposal is unlikely to affect potential habitat.

The Priority 2 taxon *Vigna* ?sp. central was recorded within the proposed IAA (although fruiting material is required to verify the presence of this taxon) and recorded within vegetation communities M1, T2 and C2. The layout of the pivots and clearing within the IAA will be planned so as avoid as far as practicable impacts on these vegetation units.

Of these species, *Eremophila magnifica* subsp. *velutina* is widespread to the southwest of Silvergrass and the majority of occurrences are outside the area of disturbance. The species located along Caves Creek, *Gymnanthera cunninghamii* and *Rostellularia adscendens* var. *latifolia*, have been recorded at a number of locations along the creek. The disturbance to Caves Creek is limited to less than 10% of the surveyed area and therefore the possible disturbance of some occurrences of these species is considered unlikely to materially affect the extent of the local population.

Rhagodia sp. Hamersley (M. Trudgen 17794) was recorded at one location in a spinifex grassland community that fringes a drainage zone which will be disturbed. This species is expected to be widely distributed in the local area. Although poorly vouchered, this species is common across the central-eastern Hamersley subregion, occurring primarily within Mulga woodlands. The conservation status is likely to be a product of the species being poorly vouchered, rather than not being widely represented (Biota 2010b).

The Priority 4 species *Goodenia nuda* was recorded within vegetation communities M1, T2 and has a wide occurrence in the Pilbara. The Expansion Proposal will not affect the distribution of this flora (Mattiske 2011). The layout of the pivots and clearing within the IAA will be planned so as to minimise impacts on these vegetation units.

On this basis, the Expansion Proposal is unlikely to materially affect the conservation status of any Priority Flora species.

9.4.2 Disruption of sheet flow

Construction of mine pits and associated infrastructure (in particular, linear infrastructure) has the potential to change surface water run-off patterns and can affect downstream vegetation communities that are dependent on sheetflow (particularly Mulga woodlands). Barriers to surface water flow up-gradient of Mulga woodlands can reduce the volume of water delivered to the area, while down-gradient barriers can increase flood inundation time; both conditions may potentially have detrimental impacts on the Mulga communities. Ineffective drainage management may also channel surface flow that would have otherwise been sheetflow, thereby reducing the volume of water that Mulga woodlands are able to intercept away from the channel, leading to increased erosion in and around the channel.

The Expansion Proposal includes a haulroad between Nammuldi and BS4, and a network of roads between new mine pits and/or waste dumps. The network of roads between the mine pits and waste dumps are not situated near any Mulga woodlands and are therefore unlikely to affect sheetflow-dependent communities.

Vegetation mapping of the heavy vehicle road between Nammuldi and BS4 is still to be undertaken. Monitoring of Mulga woodlands along other Rio Tinto linear infrastructure (railway lines at Marandoo, East Angelas and Yandicoogina) does not indicate that the presence of linear infrastructure and associated drainage has had any substantial negative effect on the survival of existing Mulga woodlands (Hick et. al. 1997; Muller 2005; Nickolls 2006; Batini 2008). The new haulroad is therefore considered unlikely to affect any sheetflow-dependent communities that are potentially nearby, given the results from previous Rio Tinto studies and proposed mitigation measures including design measures.

9.4.3 Dewatering

The only vegetation communities in the Greater Nammuldi Area that are considered to be potentially groundwater-dependent are the riparian vegetation communities along major creeklines (Duck and Caves creeks). Groundwater drawdown at Nammuldi is expected to be confined to the Nammuldi valley (Section 7.4.1) which does not contain any major creeklines or groundwater-dependent riparian vegetation in proximity to the watertable. Dewatering at Silvergrass will result in at least 2 m drawdown for approximately 15 km along Caves Creek where riparian vegetation is present (Figure 34). In this section, the pre-mining depth to watertable is generally at least 5 m below the surface and this watertable is known to fluctuate by at least 5 m in response to rainfall particularly large rainfall events [typically cyclone (Rio Tinto 2010d)]. This is supported by groundwater investigations, which identified that groundwater samples from below Caves Creek had depleted isotopic values, indicating that it was predominantly recharged from intense rainfall events (Rio Tinto 2010c). groundwater investigations have also identified an extensive clay layer approximately 15 to 20 m thick, which is aquitard separating the alluvial surface water fed shallow aquifer and the deeper basement and lower detritals aquifer.

The extent of the increase in drawdown compared with the Original Proposal and characteristics of the riparian vegetation along this section of Caves Creek (Biota 2010e, 2011b) were investigated to determine the potential effect of drawdown on vegetation from the Expansion Proposal.

The 2 m drawdown contour (at 2024 for Figure 34) was used as a threshold for potential adverse environmental effects on groundwater-dependent vegetation at Caves Creek. The 2 m drawdown contour is also considered appropriate given the margin of error associated with the groundwater modelling (Rio Tinto 2010b).

The results from the creekline surveys for dominant riparian tree species (*Melaleuca argentea*, *Eucalyptus camaldulensis* and *E. victrix*) are presented Table 39. The transect sites within the 2 m drawdown contour recorded *Eucalyptus victrix* as the overstorey species, which indicates that the riparian vegetation in this section of the creek accesses soil moisture from the vadose zone (unsaturated zone) and is unlikely to be associated with the watertable. On this basis, the increase in the extent of drawdown over that predicted for the Original Proposal is unlikely to affect the riparian vegetation along Caves Creek.

Neither the PEC nor TEC use groundwater and will not be affected.

Table 39 The distribution of the dominant tree species along different reaches of the creek system of the Greater Nammuldi Area, and the likelihood that they will be affected by groundwater drawdown

Reach	Within extent of 2 m drawdown	*Melaleuca argentea*	*Eucalyptus camaldulensis*	*Eucalyptus victrix*	Likelihood of being affected by > 2 m ground water drawdown
Caves Creek					
Upper Caves (Figure 52 a)			✓	✓	Unlikely to be affected as not within predicted 2 m drawdown contour.
Silvergrass (Figure 52 b)	✓			✓	Unlikely to be affected as species and vegetation communities unlikely to be reliant on groundwater.
Homestead (Figure 52 c)			✓	✓	Unlikely to be affected as not within predicted 2 m drawdown contour.
Palm Springs (Figure 52 d)			✓	✓	Unlikely to be affected as not within predicted 2 m drawdown contour.
Duck Creek					
Upper Duck (Figure 53 a)			✓		Unlikely to be affected as not within predicted 2 m drawdown contour.
Lower (Figure 53 b)			✓	✓	Unlikely to be affected as not within predicted 2 m drawdown contour.
New Duck		✓	✓	✓	Unlikely to be affected as not within predicted 2 m drawdown contour.

Reach	Within extent of 2 m drawdown	*Melaleuca argentea*	*Eucalyptus camaldulensis*	*Eucalyptus victrix*	Likelihood of being affected by > 2 m ground water drawdown
Confluence					
Caves / Duck creeks (Figure 53 c)			✓		Unlikely to be affected as not within predicted 2 m drawdown contour.
Tributaries to Duck Creek					
Control			✓	✓	Unlikely to be affected as not within predicted 2 m drawdown contour.
Donkey Pool			✓	✓	Unlikely to be affected as not within predicted 2 m drawdown contour.

Adapted from Biota (2011b)

9.4.4 Discharge of surplus water

The discharge of surplus water into Duck Creek will saturate the alluvium and modify the hydrological regime for a distance downstream of the discharge. The riparian ecosystems may experience increased water availability and ponding/inundation during the period of discharge, potentially resulting in altered composition abundance of those riparian vegetation communities. Those species that can tolerate or prefer wetter conditions in the creek systems will be favoured by the discharge depending on the timing, period and magnitude of discharge.

Statement 558 includes the provision to discharge up to 18 ML/day of surplus water over the life of the mine to either Duck Creek or Caves Creek. The Expansion Proposal will increase the volume and change the frequency that surplus water is discharged (expected volumes are shown in Figure 44); however, discharges above 20 ML/day are unlikely to significantly increase the length of the discharge footprint (Section 8.4.2).

Ponding and inundation of some riparian vegetation causing changes in community structure may occur during periods of surplus water discharge associated with the Expansion Proposal. The three dominant tree species within the riparian vegetation; *Eucalyptus camaldulensis, Eucalyptus victrix* and *Melaleuca argentea*, are all considered tolerant of water logging conditions (Rio Tinto 2011a). However, the overall growth, transpiration rate and net photosynthesis of *Eucalyptus victrix* may be negatively affected by prolonged waterlogged conditions.

Rio Tinto currently discharges surplus water into creeks at other operations in the Pilbara. Monitoring of riparian vegetation to detect changes in vegetation community structure and composition is carried out along 10 creeks (Bungaroo, Caves, Duck, Southern Fortescue, Paraburdoo, Weeli Wolli, Marillana, Yandicoogina, Coondiner, and Kalgan creeks) and two wetland systems (Mt Bruce and Coondewanna Flats) using several different methods (remote sensing, digital cover photography and transects). The results of this monitoring have indicated that the riparian eucalypts, including *Eucalyptus victrix*, are relatively resilient to the effects of prolonged surplus water discharge (Rio Tinto 2011a).

The experience of Rio Tinto in monitoring and managing the effects of discharging to natural watercourses will be applied to discharges to Duck Creek as follows:

- gathering baseline information for at least three years prior to planned discharge
- comprehensive studies on flora, vegetation, channels, fauna and water quality within the discharge footprints and within reference sites
- adoption of a periodic discharge strategy by reusing water on site, at BS4 and transferring water to the IAA
- consideration of a number of potential receiving creeks; with decisions based on the comparison of natural conditions, geology and relative values at Caves, Duck and Boolgeeda creeks
- using a conservative approach to modelling by adopting steady state for greater than maximum predicted discharge volumes, and adopting baseline survey coverage for the entire potential footprint.

The use of these methods in monitoring downstream changes is described in detail in the Surface Water Management Plan (Appendix 3).

Any potential effect on riparian ecosystems will be reduced by managing the volume of water to be released in the first place by limiting the frequency of discharges to creeks, and ensuring that water is discharged into the most suitable watercourse in the area (Section 3.3.10). Discharge is most likely to occur in summer during substantial rainfall, as required during emergencies and during winter, in periods when the surplus water generation exceeds agricultural area irrigation capacity. As described in Section 4.2, Duck Creek is considered better suited to accept discharge than the surrounding creeks (Boolgeeda and Caves creeks) because below the confluence with Caves Creek, Duck Creek contains large sections that are wetter and the vegetation more adapted to wetter conditions.

The dominant riparian tree species along Duck Creek downstream of the proposed discharge point (and most of the Pilbara) are *Eucalyptus camaldulensis* and *Eucalyptus victrix* (Figure 53). These species are adapted to intermittent surface water availability where most of the water is delivered by cyclonic events. Trees are naturally subjected to flooding, root scouring, high wind speeds and physical damage from large woody debris during these events and then potentially water logging for several months afterwards. These eucalypt species are also able to tolerate extended periods of drought.

Eucalyptus camaldulensis is a 'facultative phreatophyte' and requires access to groundwater for part of its water requirement, whereas *Eucalyptus victrix* is a 'vadophyte', relying mostly on soil water in the unsaturated profile (Rio Tinto 2011a). These characteristics influence the patterning and abundance of these species within creek systems and also their response to mining-related impacts such as creek discharge. Increased water availability through discharge may favour some aspects of the plant lifecycle such as facilitating seedling recruitment of *Eucalyptus camaldulensis* (this has been evident along Marillana Creek where several mine dewatering discharge outfalls have led to a significant increase in *Eucalyptus camaldulensis*) (Rio Tinto 2011a). However, increased ponding and inundation may contribute to mature tree death in less tolerant species, such as *Eucalyptus victrix*. At the local scale, the effects of excess water will differ depending on the duration of surplus water discharge, the substrate and channel morphology and thus the relative position of trees to available water.

At Rio Tinto's Hope Downs 1 operation, the health of dominant riparian eucalypts (*Eucalyptus camaldulensis* and *Eucalyptus victrix*) has been monitored using digital cover photography (DCP) since October 2006 to monitor changes to foliage cover for both positive and negative changes. Two rounds of monitoring were completed prior to commencement of discharge and monitoring has subsequently been conducted quarterly at points both upstream and downstream of the discharge (Rio Tinto 2011a).

The variability between sampling events is low and has generally remained below the focus trigger value of 10% change in foliage cover downstream of the Hope Downs 1 discharge location. Only one site of the ten monitoring sites that occur with the discharge footprint has lost more than 15% foliage cover and this loss was associated with a fire in late 2008. Since 2009, this site has been recovering, with cover now only 10% less than baseline (Rio Tinto 2011a). During recent monitoring (December 2010), sites at the discharge outlets recorded a foliage cover within 15% of the baseline foliage cover. Control sites demonstrate similar variability to impact sites.

Unlike the Hope Downs 1, the Nammuldi-Silvergrass Expansion Proposal does not involve release of water during the majority of the year but periodically discharged during rainfall events, when surplus water generation exceeds the capacity of the IAA, and during emergencies or due to rainfall.

The natural periodic flow events in Duck Creek are already likely to spread waterweeds, where present. Increased water flow and ponding may promote some growth of weeds, but will not introduce any species that are not already found in permanent waterholes within the catchment.

Riparian eucalypts are relatively resilient to the effects of surplus water discharge across multiple sites subjected to these impacts as indicated by monitoring results to date at the other operations (Rio Tinto 2011a). The discharge of surplus water into Duck Creek or temporary disposal to other local creeks is not anticipated to have a long-term detrimental impact on riparian tree health based on these monitoring results and proposed pattern of discharge.

Downstream of discharge point on Duck Creek the main land use is pastoral, specifically cattle grazing. As indicated in Table 35, a wide range of introduced species have been recorded along the creek. The main vector for the spread of weeds along the creek is considered to be from cattle coming to the creek to drink. It is therefore considered unlikely that the discharge of surplus water will affect the distribution of introduced species along the creek.

9.4.5 Vehicle movements

Vehicle movements and earthworks have the potential to increase the risk of introducing and/or spreading weed species.

Strict weed hygiene measures will be implemented to reduce the risk of weed introduction into adjacent uncleared areas and areas that are largely weed-free. Weed management will be undertaken according to the Weed Management Plan within the EMP (Appendix 3) and the AEMP.

9.4.6 Dust generation

The main sources of dust will be from earthmoving activities, vehicle traffic on dry unsealed access roads and haul roads, from blasting and ore handling during mining and liftoff from dust prone surfaces (Section 15.2). The Pilbara is a naturally dusty environment, with studies indicating that Pilbara vegetation species are unlikely to experience significant loss of plant function as a result of dust exposure (Butler 2009). Periodic rainfall events will naturally mitigate the build up of dust on vegetation.

The preferred option for transport of ore from Silvergrass to Nammuldi is by conveyer which will reduce the potential for dust emissions. Dust emissions from loaded haul trucks between the pits and the conveyor may cause some dust fallout on nearby vegetation. Water trucks will be used for dust suppression along any unsealed access or haul roads and other active dust prone surfaces as required.

Modelling has been undertaken to estimate dust deposition in the vicinity of the *Themeda* grassland TEC. The predicted maximum was found to be significantly lower (<5%) than the Rio Tinto standard for dust deposition and no adverse impacts on the vegetation would be expected (Environmental Alliances 2010).

Various management measures will be implemented to reduce dust generation from other aspects of the mining operations. These are listed in Section 15.2 and further details can be found in the Dust Management Plan in the EMP (Appendix 3).

9.5 Management measures and performance standards

Clearing of vegetation will be minimised, as far as practicable, to allow construction and operation to be undertaken in a safe manner. Management measures will include the use of an internal ground disturbance authorisation procedure and clear demarcation of areas approved for clearing to ensure that clearing is contained, and environmental awareness training is undertaken to ensure that employees are aware of the requirement to minimise ground disturbance.

Disturbance to vegetation and flora of conservation significance within the Proposal Boundary will be avoided wherever practicable. Management measures to protect and manage vegetation and flora will include:

- establishing and demarcating of a 200 m buffer to prohibit disturbance of the *Themeda* grasslands TEC
- modifying infrastructure layout and location to avoid species or vegetation of conservation significance wherever practicable
- plan clearing to avoid or minimise impact on riparian vegetation, where possible, during clearing and construction of the Caves Creek channel re-alignment at Silvergrass
- implementing a surplus water management strategy (described in Section 3.3.11) that reduces discharge and promotes discharge to creek systems more adapted to wetter regimes, as far as practicable
- reuse of surplus water as far as practicable and periodic discharge to creeks during rainfall events and emergencies
- redirection of surface flows around operations and constructed landforms, where practicable, to maintain flow to downstream vegetation
- implementation of vehicle hygiene procedures for earth-moving equipment during the pre-construction and construction phases
- ongoing weed management at the mine sites and through regular weed monitoring and spraying programs as outlined in the Weed Management Plan in the EMP (Appendix 3)
- control of dust fallout on vegetation in accordance with the Dust Management Plan in the EMP (Appendix 3)
- adoption of rehabilitation strategies for disturbed sites which are discussed in further detail in Section 14.3. Measures include the stockpiling of cleared vegetation and topsoil, and use of seedmix containing local provenance seed, to help preserve the biological diversity within the region.

Ongoing studies are being conducted to assess the potential impacts of the Expansion Proposal on surface water flows and groundwater-dependent vegetation; and, to assess options for managing surplus water. A number of Digital Cover Photography (DCP) monitoring sites have been established along Caves Creek at approximately 4 km intervals. These have been monitored annually since 2008. In 2011, sites were also established along Duck Creek. Monitoring at Caves and Duck creek will continue throughout the operation of the Expansion Proposal. The ongoing monitoring results will be compared to baseline imagery captured over Caves Creek and Duck Creek in November 2005.

Monitoring of transects across Caves and Duck creeks will be conducted at intervals during dewatering. As a part of this, the channel cross sections will be resurveyed to detect any changes in morphology. Baseline fine resolution (~ 1 m pixel size) Digital Multispectral Imagery (DMSI) was captured over Caves Creek and much of Duck Creek in November 2005, and additional baseline DMSI imagery has been captured for years from 2007 to 2010. DMSI data capture will be re-run at intervals if deemed appropriate, to identify changes in creek and vegetation cover.

As mentioned in Section 7.5, groundwater monitoring will be undertaken along Caves and Duck creek, and in addition, water level gauges will be used to monitor pool depths at Silvergrass, Homestead and Palm Springs. The data from these monitoring programmes may be compared to vegetation monitoring during dewatering to assist in the interpretation of results.

9.6 Predicted environmental outcomes against environmental objectives, policies, guidelines, standards and procedures

After application of mitigation measures described in Section 9.5, the Expansion Proposal is expected to result in the following outcomes in relation to vegetation and flora:

- clearing of an approximate 3900 ha of native vegetation for the mine expansion and associated infrastructure, and around 2500 ha for the establishment of irrigated agriculture
- proposed clearing will not significantly affect the local or regional distribution of any vegetation community of conservation significance
- no clearing or indirect disturbance will occur in the *Themeda* grasslands TEC at Silvergrass
- no disturbance to the *Astrebla* PEC in good representation, disturbance of the mosaic representation will be reduced as far as practicable and maximum disturbance is expected to be 91 ha (approximately 1% of regional extent)
- based on the distribution of groundwater-dependent species within the 2 m drawdown contour, groundwater drawdown from the Expansion Proposal is unlikely to affect riparian vegetation communities in Caves Creek
- realignment of Caves Creek will result in the loss of approximately 2.5 km section of riparian vegetation (representing approximately 9% of the mapped distribution of vegetation unit CD1 in the Greater Nammuldi Area), which will not affect the local or regional abundance of riparian vegetation
- intermittent discharge of surplus water may result in localised changes to the riparian vegetation within the discharge footprint of Duck Creek; however, these local changes are not expected to affect the regional diversity or abundance of riparian vegetation and that is expected to be able to re-adapt when the discharge ceases in the long-term
- no DRF species will be affected
- there will be a loss in the local abundance of some Priority Flora but no change in the conservation status of these species will occur
- dust emission are not anticipated to adversely affect flora or vegetation
- implementation of the rehabilitation plan will restore some of the previous vegetation values of the pre-existing landscape.