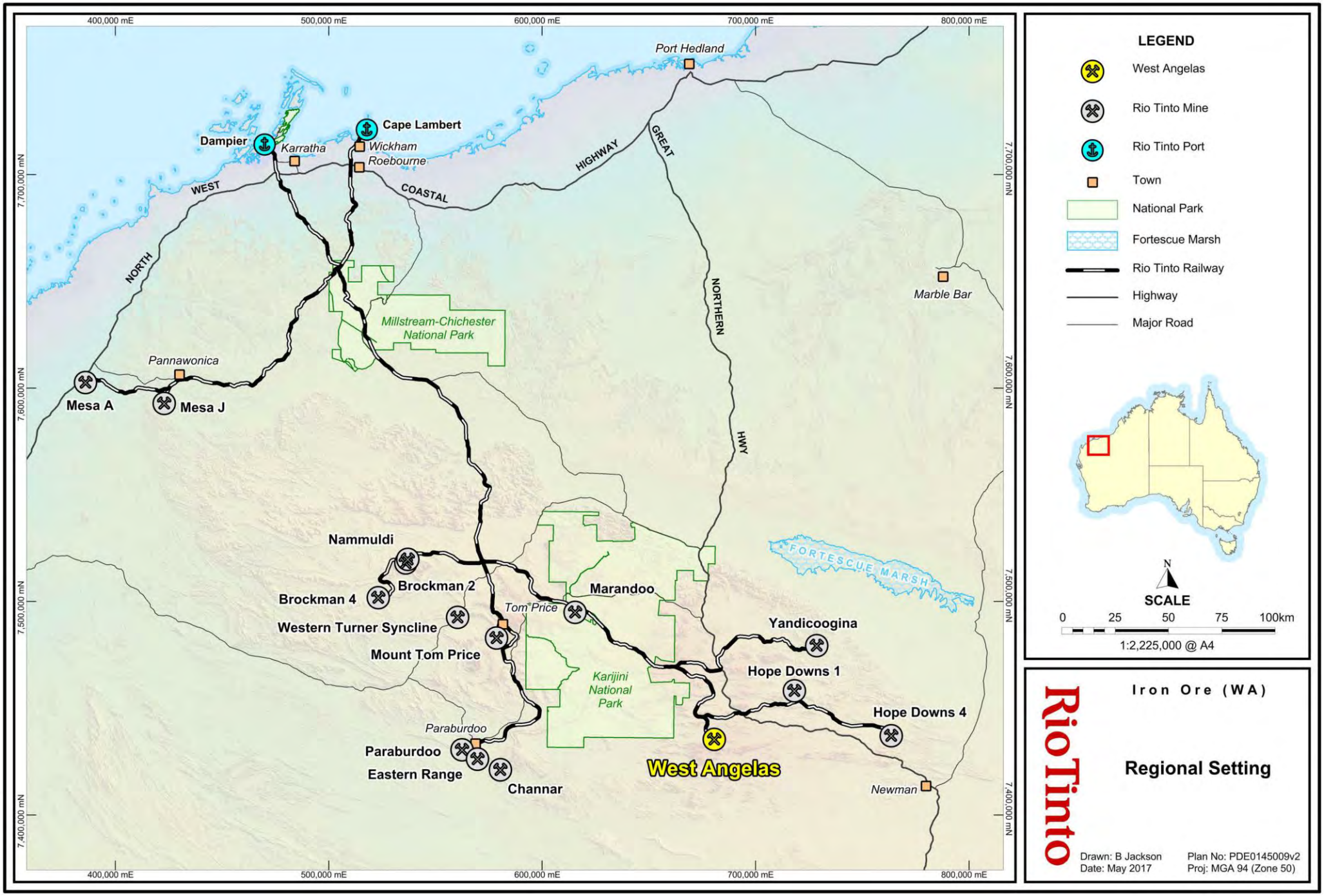
Schedule 2

Geographic spatial data coordinates

Coordinates defining the following are held by the Office of the Environmental Protection Authority:

1. Mine and Linear Infrastructure Development Envelopes
2. Ghost Bat Cave AA1 Exclusion Zone
3. Indicative layout (pits, waste dumps and stockpiles)
4. Conservation significant vegetation communities, subject to offsets (West Angelas Cacking Clay PEC and riparian vegetation)
5. Ghost bat (*Macroderma gigas*) roosts
6. Surplus dewatering water surface discharge extent

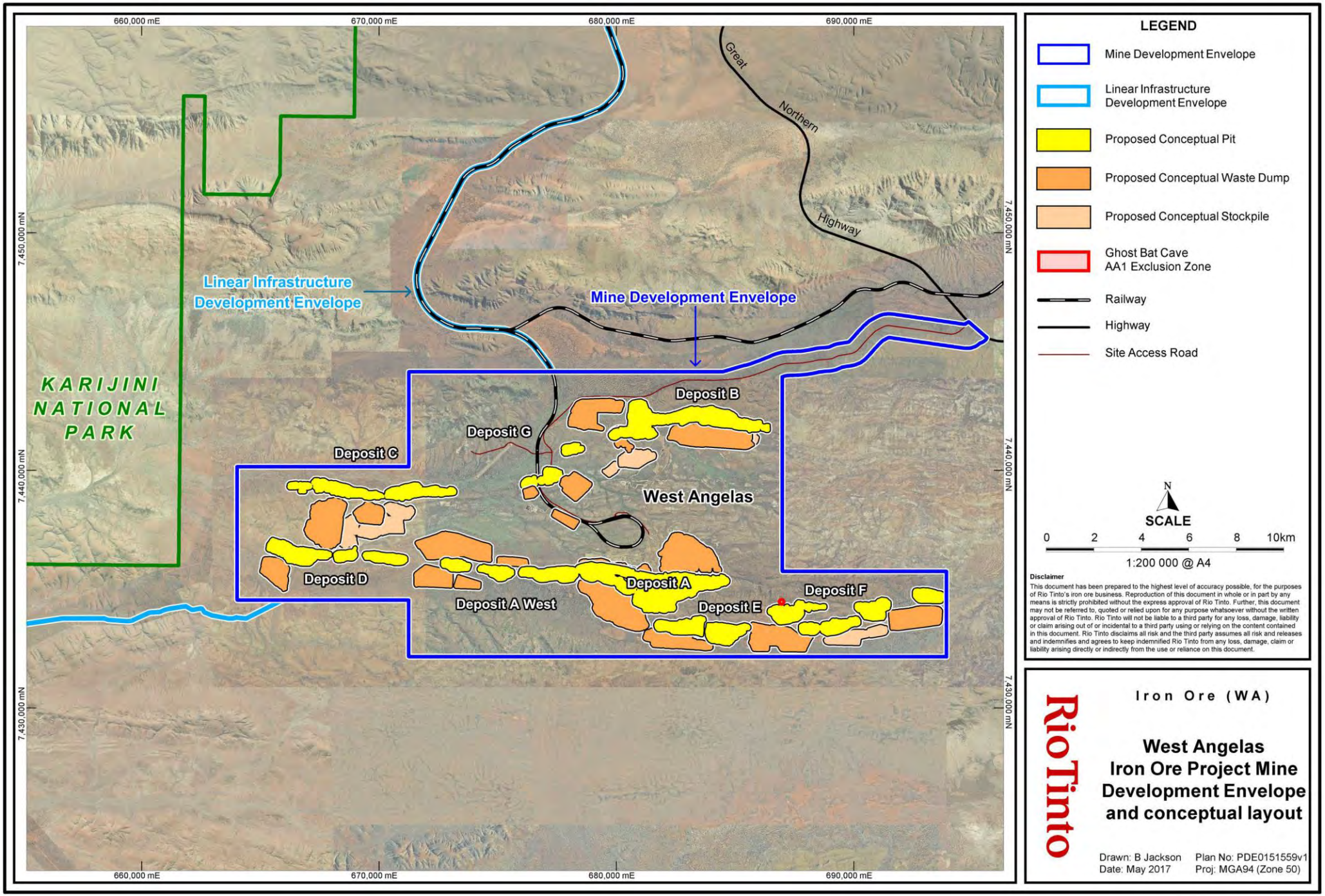


Iron Ore (WA)

Regional Setting

Drawn: B Jackson
Date: May 2017

Plan No: PDE0145009v2
Proj: MGA 94 (Zone 50)



LEGEND

- Mine Development Envelope
- Linear Infrastructure Development Envelope
- Proposed Conceptual Pit
- Proposed Conceptual Waste Dump
- Proposed Conceptual Stockpile
- Ghost Bat Cave AA1 Exclusion Zone
- Railway
- Highway
- Site Access Road

N

SCALE

0 2 4 6 8 10km

1:200 000 @ A4

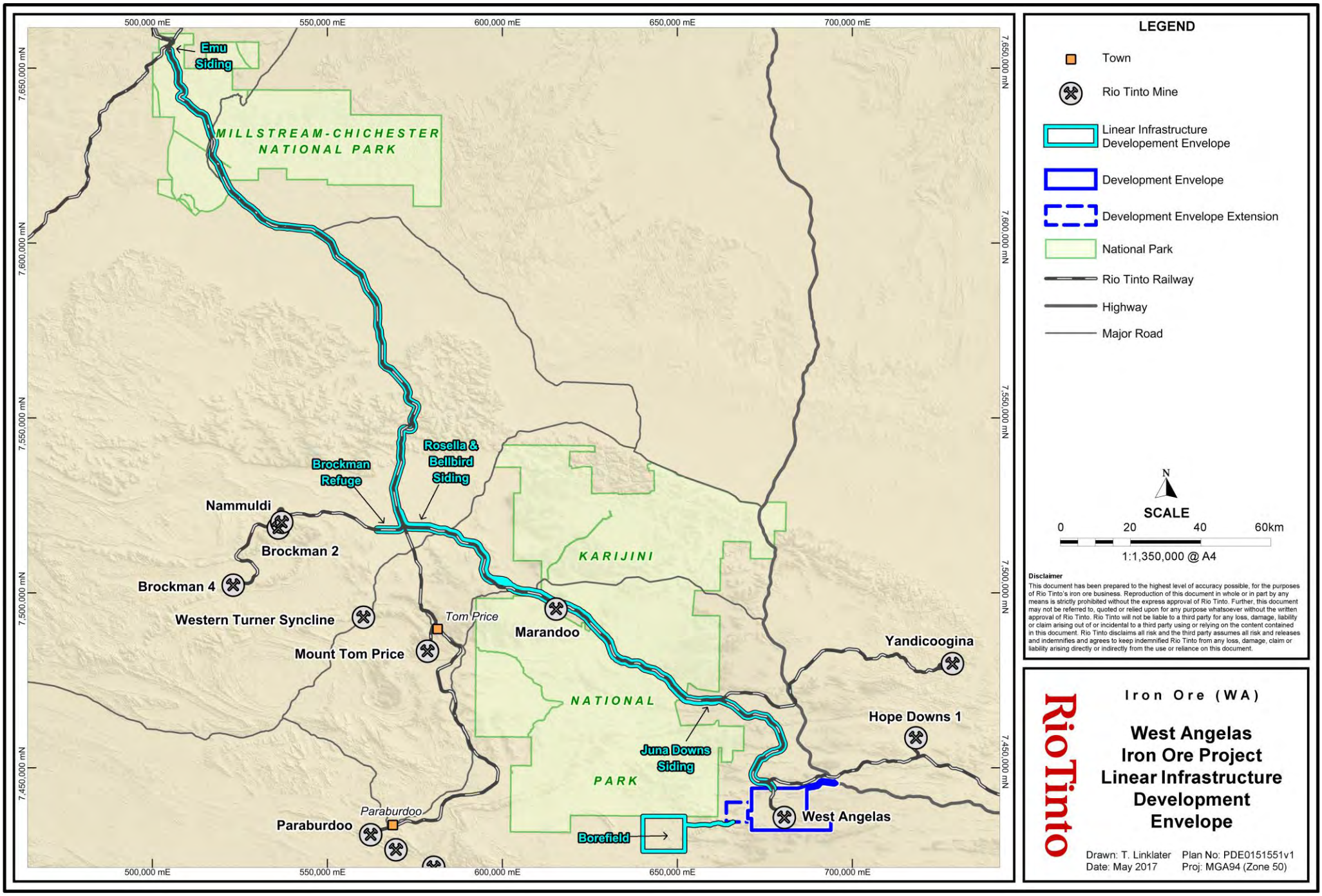
RioTinto

Iron Ore (WA)

West Angelas Iron Ore Project Mine Development Envelope and conceptual layout

Drawn: B Jackson
Date: May 2017

Plan No: PDE0151559v1
Proj: MGA94 (Zone 50)



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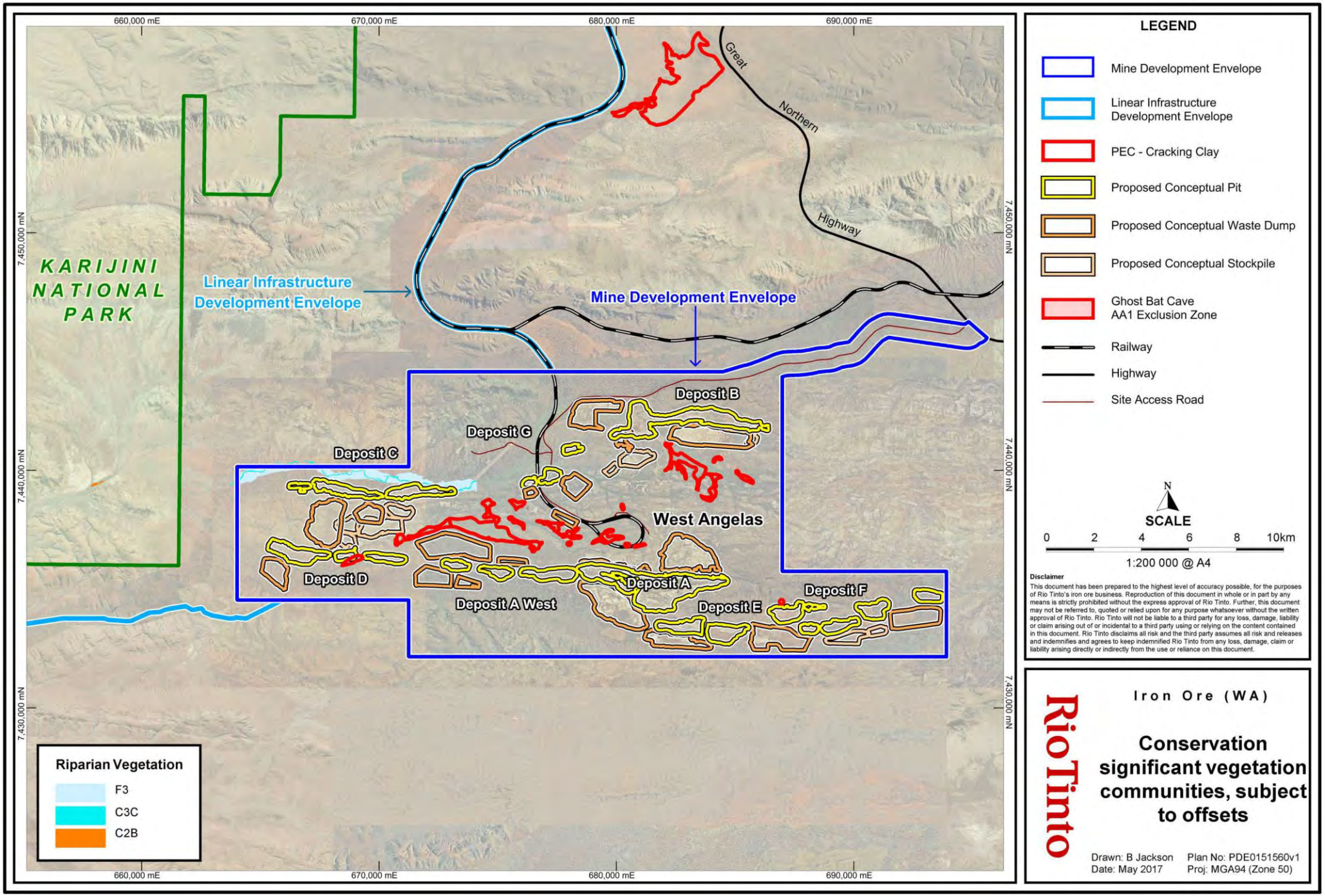
Rio Tinto

Iron Ore (WA)

West Angelas Iron Ore Project Linear Infrastructure Development Envelope

Drawn: T. Linklater
Date: May 2017

Plan No: PDE0151551v1
Proj: MGA94 (Zone 50)



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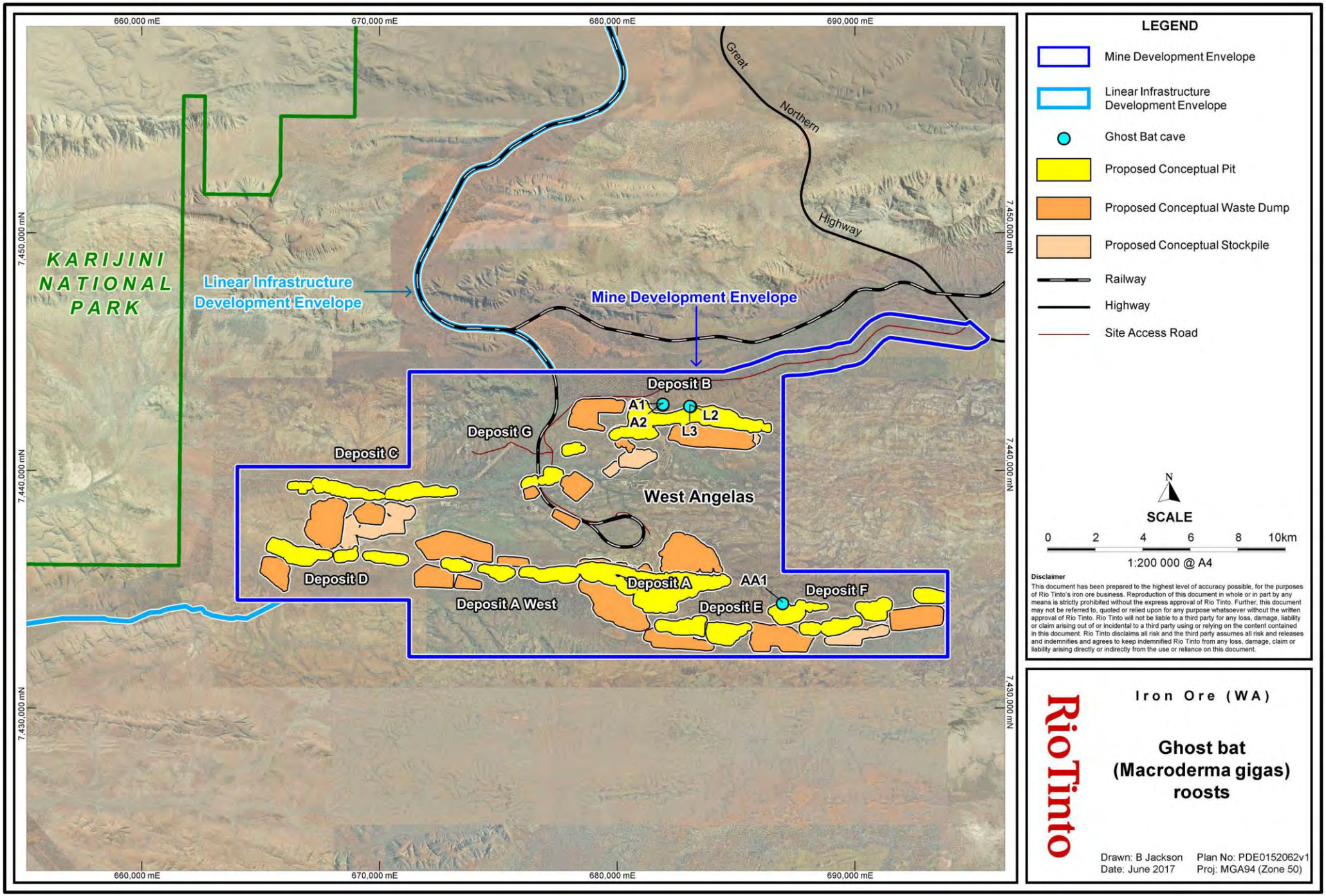
Rio Tinto

Iron Ore (WA)

Conservation significant vegetation communities, subject to offsets

Drawn: B Jackson
Date: May 2017

Plan No: PDE0151560v1
Proj: MGA94 (Zone 50)



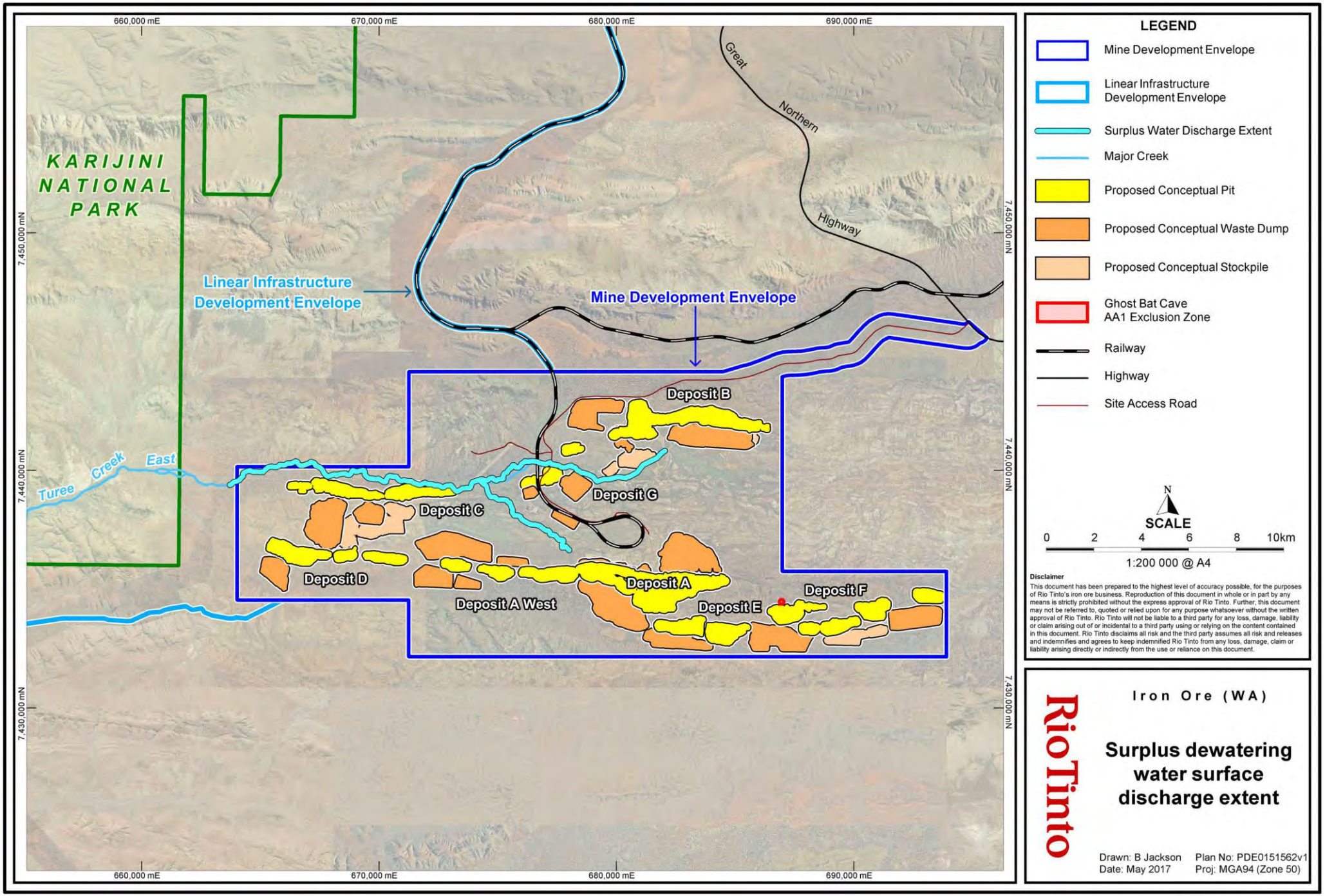
Rio Tinto

Iron Ore (WA)

Ghost bat (Macroderma gigas) roosts

Drawn: B Jackson
Date: June 2017

Plan No: PDE0152062v1
Proj: MGA94 (Zone 50)



LEGEND

- Mine Development Envelope
- Linear Infrastructure Development Envelope
- Surplus Water Discharge Extent
- Major Creek
- Proposed Conceptual Pit
- Proposed Conceptual Waste Dump
- Proposed Conceptual Stockpile
- Ghost Bat Cave AA1 Exclusion Zone
- Railway
- Highway
- Site Access Road

N

SCALE

0 2 4 6 8 10km

1:200 000 @ A4

Rio Tinto

Iron Ore (WA)

Surplus dewatering water surface discharge extent

Drawn: B Jackson
Date: May 2017

Plan No: PDE0151562v1
Proj: MGA94 (Zone 50)

Rio Tinto

Environmental Management Plan

West Angelas Iron Ore Project

RTIO-HSE-0311343

Robe River Mining Co. Pty. Ltd.

152-158 St Georges Terrace, Perth

GPO Box A42, Perth WA 6837

June 2017

Disclaimer and Limitation

This Environmental Management Plan has been prepared by Rio Tinto's Iron Ore group (Rio Tinto), on behalf of Robe River Mining Co. Pty. Ltd. (the Proponent), specifically for the West Angelas Iron Ore Project. Neither the report nor its contents may be referred to without the express approval of Rio Tinto, unless the report has been released for referral and assessment of proposals.

Document Status					
Rev	Author	Reviewer/s	Date	Approved for Issue	
				To Whom	Date
A-E	Equinox Rio Tinto	Rio Tinto	August 2016		
1	Rio Tinto		June 2017	OEPA	June 2017

SUMMARY

This West Angelas Iron Ore Project (West Angelas Project) Environmental Management Plan (EMP) is submitted by Rio Tinto on behalf of Robe River Mining Co. Pty. Ltd. (the Proponent) in accordance with condition 5 of MS xxxx. Table S 1 below presents the environmental criteria to measure achievement of the environmental outcome that must be met through implementation of this EMP.

Table S 1: Environmental criteria to measure achievement of environmental outcome

Proposal title	West Angelas Iron Ore Project
Proponent	Robe River Mining Co. Pty. Ltd.
Ministerial Statement	MS xxxx
Purpose of this EMP	This EMP fulfils the requirements of conditions 6, 7 and 8 of MS xxxx.
Hydrological Processes and Flora and Vegetation – Dewatering, surface water discharge and riparian vegetation **EPA Objective:** *To maintain the hydrological regimes of groundwater and surface water so that environmental values are protected.*	
Condition environmental outcome	• The Proponent shall ensure that dewatering is managed so that there is no irreversible impact to potentially groundwater dependent vegetation within Karijini National Park. • The Proponent shall ensure that discharge of excess water is managed so as to maintain the health of riparian vegetation of Turee Creek East. • The Proponent shall ensure that no new species of declared / environmental weeds are introduced along the surface water discharge extent, and that the abundance and distribution of existing weeds within the surface water discharge extent is not increased as a result of implementation of the West Angelas Project.
Trigger criteria	Potential GDE within Karijini National Park: 1. The mean vegetation index for the upper canopy (*E. victrix / E. camaldulensis*) declines >2 standard deviations (SD) from baseline[1].
	Surface water discharge and riparian vegetation: 2. Surface water discharge reaches within 2km of the boundary of Karijini National Park under natural no-flow conditions. 3. Significant upward trend in number of introduced species relative to baseline.
Threshold criteria	Potential GDE within Karijini National Park: 1. The mean vegetation index for the upper canopy (*E. victrix / E. camaldulensis*) declines >2 SD from baseline over two consecutive monitoring events.

[1] Baseline surveys of the Potential GDE are still to be undertaken therefore the response in natural variation is not yet fully understood.

	Surface water discharge and riparian vegetation: 2. Surface water discharge reaches the boundary of Karijini National Park under natural no-flow conditions. 3. Significant upward trend in number of introduced species with a notable decline in native species richness compared to baseline.
Flora and Vegetation – West Angelas Cracking Clay Priority Ecological Communities **EPA Objective:** *To maintain representation, diversity, viability and ecological function at the species, population and community level.*	
Condition environmental outcome	• The Proponent shall ensure that there is no disturbance to the West Angelas Cracking Clay Priority Ecological Community (PEC-2015-5). • The Proponent shall ensure no more than 20 ha of disturbance to other representations of the West Angelas Cracking Clay Priority Ecological Community.
Trigger criteria	1. Disturbance (direct or indirect) within 100 m of West Angelas Cracking Clay Priority Ecological Community (PEC-2015-5). 2. Disturbance within other representations of West Angelas Cracking Clay PEC exceeds 15.5 ha.
Threshold criteria	1. Disturbance (direct or indirect) within the West Angelas Cracking Clay Priority Ecological Community (PEC-2015-5). 2. Disturbance within other representations of West Angelas Cracking Clay PEC exceeds 20 ha.
Terrestrial Fauna – Conservation significant fauna species; Ghost Bat (*Macroderma gigas*) **EPA Objective:** *To maintain representation, diversity, viability and ecological function at the species, population and assemblage level.*	
Condition environmental outcome	• The Proponent shall ensure that there is no disturbance to the Ghost Bat roost; Cave AA1. • The Proponent shall minimise disturbance to other Ghost Bat roosts; Caves A1, A2, L2 and L3.
Trigger criteria	1. Disturbance within 150 m of Ghost Bat roost; Cave AA1. 2. Vibration levels exceed 40mm/s peak particle velocity (Cave AA1) or 75mm/s peak particle velocity (Caves A1, A2, L2 and L3).
Threshold criteria	1. Disturbance within 100 m of Ghost Bat roost; Cave AA1. 2. Significant damage to Ghost Bat roosts; Caves AA1, A1, A2, L2 and L3. 3. Permanent Ghost Bat abandonment of caves.

Corporate endorsement

I hereby certify that to the best of my knowledge, the provisions within this West Angelas Environmental Management Plan are true and correct and address the legal requirements of MS xxxx.

Name: Bhuvanesh Malhotra **Signed:** 

Designation: GM, West Angelas and Robe Valley **Date:** 07.07.2017.

Contents Page

Tables

Figures

1. CONTEXT, SCOPE AND RATIONALE

1.1 West Angelas Project

The Proponent (Robe River Mining Co. Pty. Ltd.) manages and operates the West Angelas Project, as approved by MS 970 and MS 1015, under Part IV of the *Environmental Protection Act 1986* (EP Act).

The West Angelas Project is located approximately 130 km northwest of Newman in the Pilbara region of Western Australia on Mineral Lease 248SA (ML248SA) which was granted in 1976 under the *Iron Ore (Robe River) Agreement Act 1964 (WA)* (Figure 1-1). The West Angelas Project consists of the following (as depicted in Figure 1-2):

- Open cut above and below water table (AWT and BWT) mining of iron ore from deposits A, A west, B, C, D, E, F and G by conventional drill, blast, and load and haul techniques.
- Ore processing in central processing facilities.
- Surface waste dumps which are used in backfilling of the mine pits as far as practicable.
- Infrastructure including but not limited to the following:
    - Dewatering and surplus water management infrastructure, including the Turee Creek B borefield which provides potable water to the mine and camp facilities (and, when required, water for operational purposes) and the mine dewatering borefield which dewaters the ore bodies to allow below water table mining. Dewatering water is used onsite in the first instance to supply water for operational purposes. Surplus dewatering water, exceeding the operational requirement, is discharged to a local ephemeral tributary of Turee Creek East.
    - Surface water management infrastructure, including diversions to direct surface water flows around deposits.
    - Linear infrastructure, including the 413 km rail network which transports processed ore approximately to port facilities located at Cape Lambert, the Turee Creek B borefield, pipeline and powerline and the 35 km mine access road which links the mine with the Great Northern Highway.
    - Support facilities, including the accommodation village which is located approximately 9 km west of the mine.

1.2 Key Environmental Factors

Management of the following key aspects of the West Angelas Project are incorporated in this Environmental Management Plan (EMP):

- Hydrological processes - dewatering of groundwater; surface discharge of surplus dewatered water; and riparian vegetation.
- Flora and vegetation – the West Angelas Cracking Clay Priority Ecological Community (PEC).
- Terrestrial Fauna – conservation significant fauna species (Ghost Bat).

This EMP will be implemented subject to approval by the EPA and will replace the existing approved management plan associated with the West Angelas Project (RTIO-HSE-0210871, November 2013).

This EMP has been developed in accordance with the *Environmental Impact Assessment (Part IV Divisions 1 and 2) Administrative Procedures 2016 and Environmental Impact Assessment (Divisions 1 and 2) Procedures Manual 2016.*

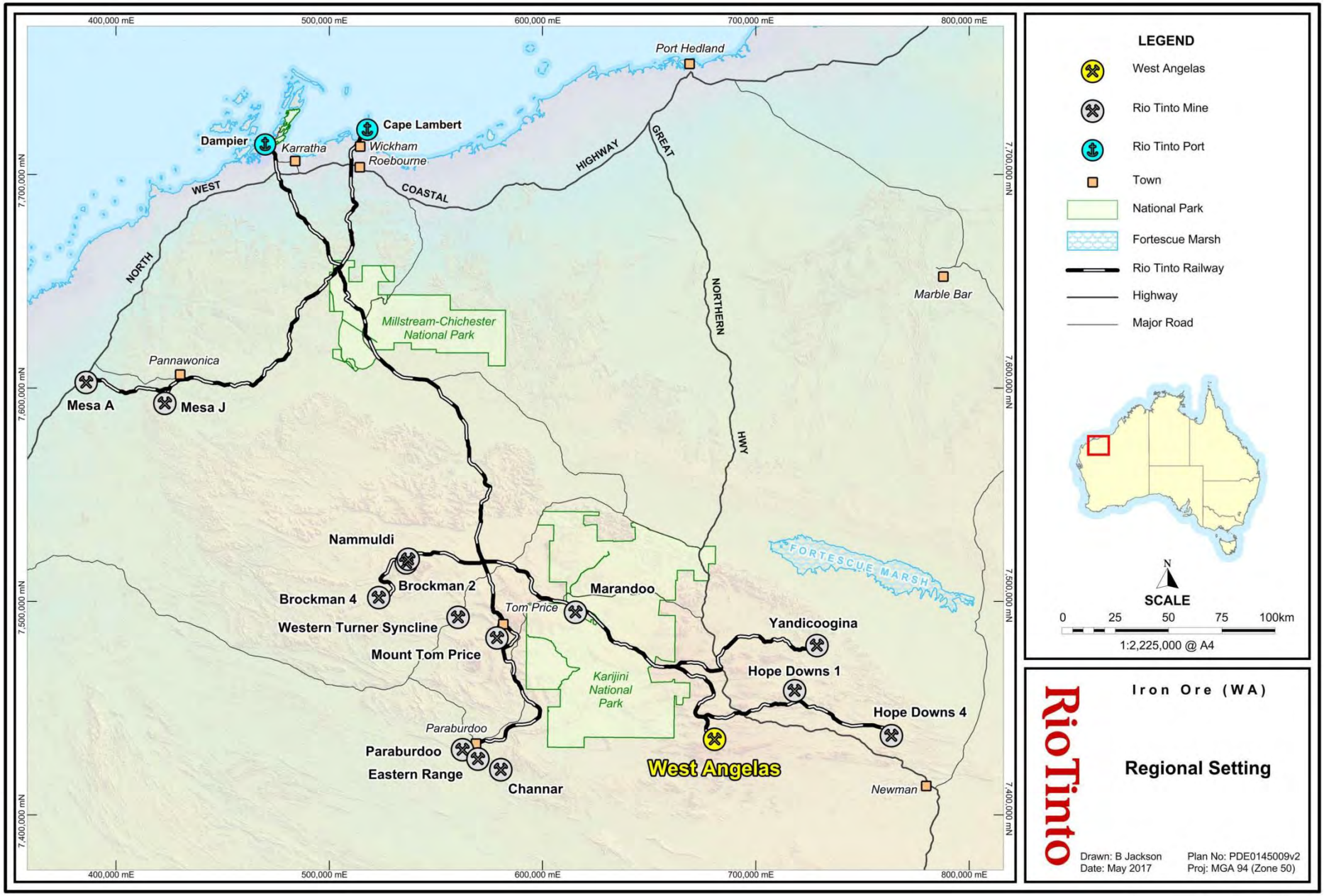


Figure 1-1: Regional Setting of the West Angelas Iron Ore Project

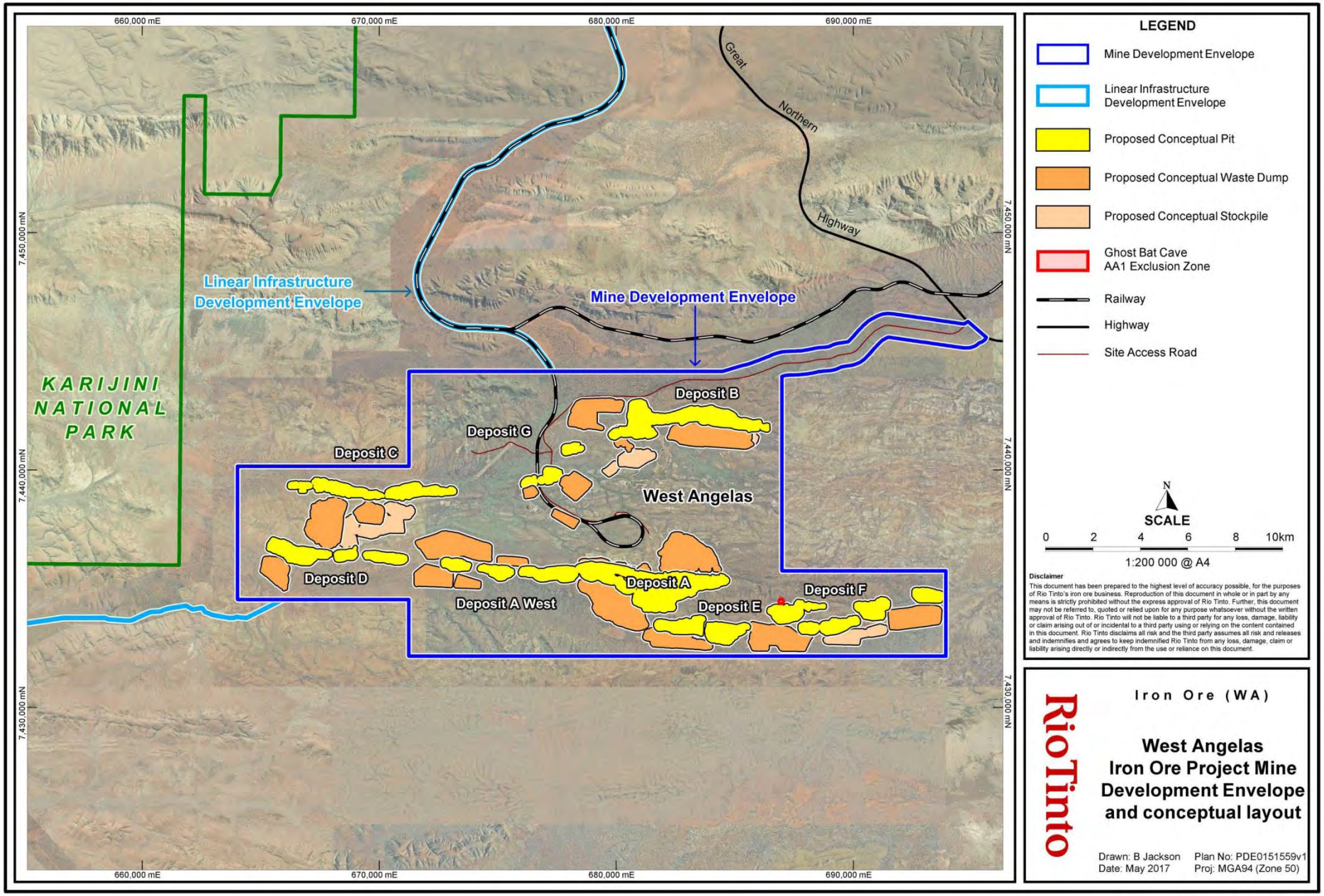


Figure 1-2: West Angelas Iron Ore Project Mine Development Envelope and conceptual layout

1.3 Condition Requirements

The proposed conditions and the associated proposed environmental objectives for the West Angelas Project are detailed below in Table 1-1.

Table 1-1: Proponent proposed condition for the West Angelas Project

Condition	
5	**Condition Environmental Management Plans**
5-1	The proponent shall prepare and implement a Condition Environmental Management Plan to the satisfaction of the CEO. This plan shall demonstrate that the **environmental outcomes** specified in in condition 6-1, condition 7-1 and condition 8-1 will be met.
5-2	The Condition Environmental Management Plan shall: (1) specify the environmental outcomes to be achieved, as specified in condition 5-1; (2) specify trigger criteria that must provide an early warning that the threshold criteria may not be met; (3) specify threshold criteria to demonstrate compliance with the environmental outcomes specified in condition 5-1. Exceedance of the threshold criteria represents non-compliance with these conditions; (4) specify monitoring to determine if trigger criteria and threshold criteria are exceeded; (5) specify trigger level actions to be implemented in the event that trigger criteria have been exceeded; (6) specify threshold contingency actions to be implemented in the event that threshold criteria are exceeded; and (7) provide the format and timing for the reporting of monitoring results against trigger criteria and threshold criteria to demonstrate that condition 5-1 has been met over the reporting period in the Compliance Assessment Report required by condition 3-6.
5-3	After receiving notice in writing from the CEO that the Condition Environmental Management Plan satisfies the requirements of condition 5-2 the proponent shall: (1) implement the Condition Environmental Management Plan, or any subsequent approved versions; and (2) continue to implement the Condition Environmental Management Plan until the CEO has confirmed by notice in writing that the proponent has demonstrated the objectives specified in condition 5-1 have been met.
5-4	In the event that the monitoring indicates an exceedance of the threshold criteria specified in the Condition Environmental Management Plans, the proponent shall: (1) report the exceedance in writing to the CEO within seven (7) days of the exceedance being identified; (2) implement the threshold level contingency actions specified in the Condition Environmental Management Plans within 24 hours and continue implementation of those actions until the CEO has confirmed by notice in writing that it has been demonstrated that the threshold criteria are being met and the implementation of the threshold contingency actions is no longer required; (3) investigate to determine the cause of the threshold criteria being exceeded; (4) investigate to provide information for the CEO to determine potential environmental harm that occurred due to the threshold criteria being exceeded; and (5) provide a report to the CEO within twenty one (21) days of the exceedance being reported as required by condition 5-6(1). The report shall include; a. details of threshold contingency actions implemented; b. the effectiveness of the threshold contingency actions implemented, against the threshold criteria;

Condition	
	c. the findings of the investigations required by condition 5-5(3) and 5-5(4); d. measures to prevent the threshold criteria being exceeded in the future; e. measures to prevent, control or abate the environmental harm which may have occurred; and f. justification of the threshold remaining, or being adjusted based on better understanding, demonstrating that outcomes would continue to be met.
5-5	The proponent: (1) may review and revise the Condition Environmental Management Plan, or (2) shall review and revise the Condition Environmental Management Plan as and when directed by the CEO.
6	**Hydrological Processes and Flora and Vegetation – Dewatering, discharge and riparian vegetation**
6-1	The proponent shall manage implementation of the Proposal to meet the following environmental outcomes: (1) The proponent shall ensure that dewatering is managed so that there is no irreversible impact to potentially groundwater dependant vegetation within Karijini National Park. (2) The proponent shall ensure that discharge of excess water is managed so as to maintain the health of riparian vegetation of Turee Creek East.
7	**Flora and Vegetation – Conservation significant vegetation communities; West Angelas Cracking Clay Priority Ecological Communities**
7-1	The proponent shall manage implementation of the Proposal to meet the following environmental outcomes: (1) The proponent shall ensure that there is no disturbance to the West Angelas Cracking Clay Priority Ecological Community (PEC-2015-5). (2) The proponent shall ensure no more than 20 ha of disturbance to other representations of the West Angelas Cracking Clay Priority Ecological Community.
8	**Terrestrial Fauna – Conservation significant fauna species; Ghost Bat (*Macroderma gigas*)**
8-1	The proponent shall manage the implementation of the Proposal to meet the following environmental outcomes: (1) The proponent shall ensure that there is no disturbance to the Ghost Bat roost; Cave AA1. (2) The proponent shall minimise disturbance to other Ghost Bat roosts; Caves A1, A2, L2 and L3.

1.4 Rationale and Approach

This EMP addresses environmental factors (and relevant environmental objectives) which were determined by the EPA as being relevant to the appropriate management of dewatering, surface water discharge, conservation significant vegetation communities and fauna species associated with the West Angelas Project. The EMP achieves this by:

- Identifying the environmental criteria that the Proponent will use to monitor performance of the measures proposed to address the requirements of condition 5 of MS xxxx for the West Angelas Project.
- Defining the management actions that the Proponent will take in response to monitoring results.

Results of baseline surveys, monitoring and a number of assumptions and uncertainties inform the management approach for meeting the condition environmental outcomes stated in conditions 6, 7, and 8 of MS xxxx.

The identified trigger criteria, threshold criteria, trigger level actions and threshold contingency actions are aligned with the overall management approach.

Monitoring data is used to evaluate compliance with the trigger and threshold criteria to achieve the relevant condition environmental outcomes.

1.4.1 Survey and Study Findings

a) Potential GDE within Karijini National Park

An ecological assessment has been undertaken to determine the presence of any potentially Groundwater Dependent Species and Groundwater Dependent Vegetation likely to represent a potential Groundwater Dependent Ecosystem (GDE).

Three common Pilbara species are known to be groundwater dependant (phreatophytic): *Melaleuca argentea* (obligate phreatophyte)*; Eucalyptus camaldulensis* subsp. *refulgens* (facultative phreatophyte); and *E. victrix* (facultative phreatophyte or vadophyte). Riparian vegetation along Turee Creek East supports two of these species: *E victrix* and *E. camaldulensis*.

Melaleuca argentea and other moisture indicating or mesic species such as *Melaleuca glomerata, Melaleuca bracteata* and *Acacia ampliceps* which often indicate shallow groundwater were not recorded in the survey area. Semi-mesic species like *Acacia pyrifolia* and *Androcalva luteiflora* were recorded but these species are common in creeks in the Pilbara and are not generally recognised as dependent on or indicative of shallow groundwater.

E. victrix were common at variable densities within riparian vegetation communities of Turee Creek East. However, groundwater elevation beneath the riparian vegetation communities of Turee Creek East within the West Angelas area is typically between 20m and 70m bgl, and therefore inaccessible to *E. victrix* such that the potential for groundwater dependence is considered 'negligible'.

Groundwater elevation below the riparian vegetation communities of Turee Creek East within Karijini National Park is typically between 2m and 6.5m bgl, and therefore accessible to riparian vegetation such that the potential for groundwater dependence is elevated.

Approximately 22 ha of relatively dense riparian vegetation within Karijini National Park was found to contain *E. victrix* (the C3B community) at densities which could indicate the potential for groundwater dependence. Based on the stand density, approximately 22 ha of relatively dense riparian vegetation communities of Turee Creek East within Karijini

National Park (the C3B community) is assumed to represent a potential GDE, considered to be at 'low to medium' risk of impact as a result of groundwater drawdown (Figure 1-3).

Approximately 4.8 ha of riparian vegetation within Karijini National Park is co-dominated by *E. victrix* and *E. camaldulensis* (the C2B community) at densities which could indicate the potential for groundwater dependence. Based on the structure and stand density, approximately 4.2 ha of relatively dense riparian vegetation communities of Turee Creek East within Karijini National Park (the C2B community) is assumed to represent a potential GDE considered to be at 'medium' risk of impact as a result of groundwater drawdown (Figure 1-3). Approximately 0.6 ha of the C2B community is considered to be at 'low' risk of impact as groundwater drawdown is expected to be limited beneath this community.

The Proponent proposes to monitor the health of potentially groundwater dependant species; *E. victrix* and *E. camaldulensis,* within Karijini National Park at 'low' to 'medium' risk of impact as a result of groundwater drawdown utilising Digital Multi Spectral Imagery (DMSI) to ensure there are no significant changes to health beyond natural variation.

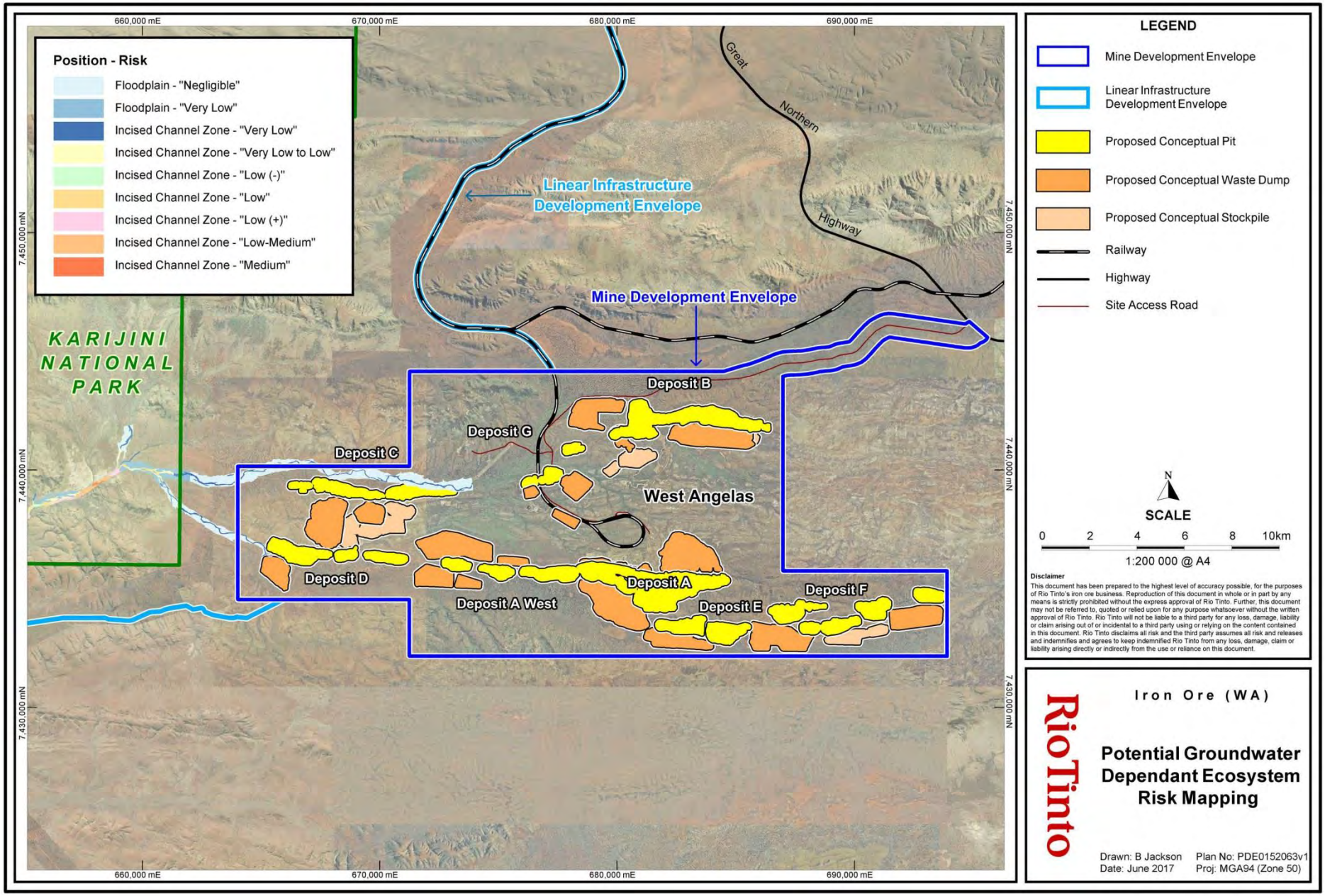


Figure 1-3: Potential groundwater dependant ecosystem risk mapping

b) Surface water discharge

The West Angelas Project is located in the upper reaches of the Turee Creek Catchment immediately west of the regional catchment divide separating Ashburton River catchment from the Fortescue River catchment. The regional Turee Creek Catchment is approximately 7,400 km². The upper catchment has a complex drainage pattern characterised by intermittent flow and infrequent wide-spread flooding, depending on the occurrence of high intensity rainfall events.

Turee Creek, an ephemeral tributary of the Ashburton River, represents the most significant named watercourse in the region.

The east branch of Turee Creek (Turee Creek East) is an ephemeral watercourse which flows depending on the occurrence of high intensity rainfall events, typical of Pilbara watercourses. Turee Creek East flows generally westward across the West Angelas Project, continuing west south-westerly through Karijini National Park , before merging with Turee Creek (Turee Creek merges with the Hardey River, which flows into the Ashburton River). Immediately upstream of the confluence with Turee Creek, Turee Creek East has a catchment area of approximately 2,050 km^2.

West Angelas has historically been considered a water neutral site; whereby operational water demand is roughly equivalent to dewatering requirements. As below water table resources are developed, dewatering volumes are expected to exceed operational water demand. Dewatering water is used onsite in the first instance to supply water to meet operational water demand. Any surplus dewatering water, exceeding the operational requirement is discharged into a local ephemeral tributary of Turee Creek East.

The cumulative balance of surplus dewatering water from Deposits B, C and D requiring management is up to approximately 12 GL/a. Based on discharge of up to 12 GL/a, the maximum surface discharge extent is modelled to extend up to 22 km. Figure 1-4 presents the modelled extent of surface water discharge. The surface discharge extent will not extend as far as Karijini National Park.

The banks of Turee Creek East are fringed by scattered trees and shrubs (mostly *Acacia* spp. with a few patchily distributed *E. victrix* trees).

An extensive baseline riparian vegetation monitoring program was established in 2011. Vegetation community structure, species diversity, cover and abundance have been monitored annually at 48 permanent quadrats across eight transect test sites. This EMP proposes a more targeted monitoring program with riparian monitoring only being undertaken at sites within the actual surface discharge extent within the relevant reporting period (and control sites to contextualise any trends).

The structure, cover and health of both native and introduced species within the surface discharge extent will be recorded during riparian vegetation monitoring surveys.

Discharge is expected to result in inevitable changes to the structure, cover and health riparian vegetation within the surface discharge extent including the following:

- changes in riparian vegetation community structure;
- changes in the health of the dominant riparian tree species *E. victrix* and *E. camaldulensis* (if present), which may include:
    - declining health (decreasing biomass / abundance and / or cover) or death of species susceptible to waterlogging stress (*E. victrix*); and
    - increasing biomass / abundance and / or cover or artificial recruitment of species tolerant to waterlogging (*E. camaldulensis*).

- establishment or increasing biomass / abundance and / or cover of other species which are tolerant to waterlogging (particularly sedges and rushes); and
- enhanced potential for weed ingress / proliferation.

It is expected that species which are currently present but not yet detected in baseline surveys, due to low abundance and / or cover, are likely to be detected during future surveys as their abundance and / or cover increases commensurate to water availability.

Vegetation cover in areas downstream of the surface discharge extent may also increase due to a larger upstream source of seed, which is mobilised during rainfall-induced flow events, though it is unknown whether the recruitment in ephemeral reaches are driven by seed supply or water availability.

Despite the expected changes the structure, cover and health of riparian vegetation communities (both native and introduced species) within the extent of surface water discharge, the health of the riparian vegetation can be maintained by monitoring the relationship between native and introduced taxa. Increased cover of introduced species as a result of perennial hydrologic regime is likely to be mirrored by native species, and hence seedbank for recruitment will be maintained, minimising the risk of future loss of native vegetation at the cessation of discharge. Accordingly, trends in the presence of native species throughout the surface discharge extent shall be analysed in parallel to the presence of introduced species, to detect any threats which weeds may pose to native vegetation. The presence of introduced species will be monitored in isolation as an early warning indicator, though the threshold criteria take into account the balance of all species, to ensure that the increased productivity as a result of perennial water supply is not misinterpreted as a negative impact to the health of riparian vegetation.

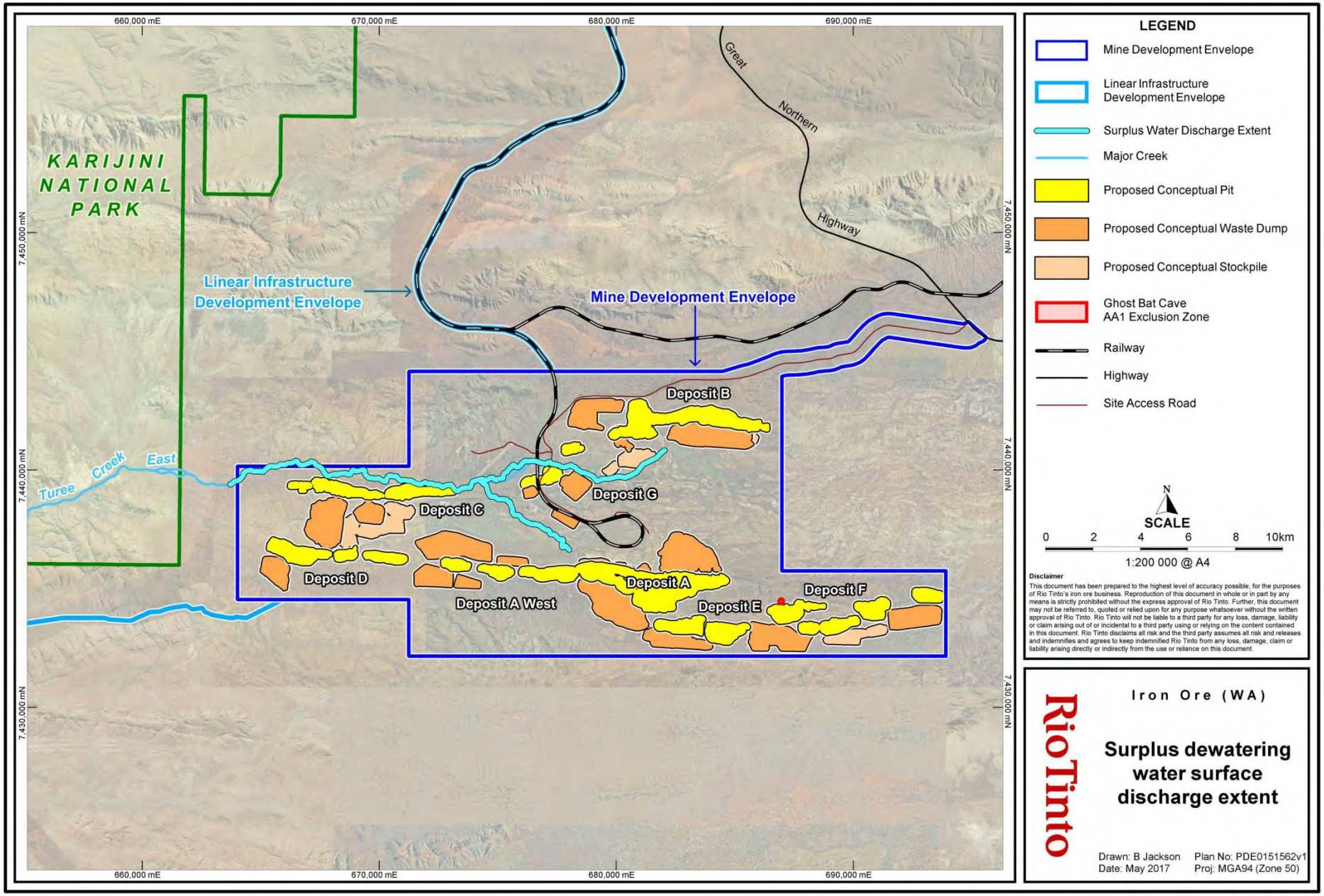


Figure 1-4: Surplus dewatering water surface discharge extent

c) Flora and Vegetation

Several ecosystems are considered locally significant in relation to the West Angelas Project, including:

- The Priority 1 West Angelas Cracking Clay Priority Ecological Community (PEC) occurs extensively within the West Angelas region with approximately 440 ha of this community mapped. Figure 1-5 depicts the extent of mapped PECs within the West Angelas Mine Development Envelope.

  These communities are considered significant because they are relatively uncommon in the Pilbara and because they are in very good condition, attributed to the absence of historic cattle grazing. This community is defined as 'open tussock grasslands of *Astrebla pectinata*, *A*. *elymoides*, *Aristida latifolia* in combination with *Astrebla squarrosa* and low scattered shrubs of *Sida fibulifera*, on basalt derived cracking-clay loam depressions and flowlines'.

  Threats to this community include: clearing for mining; changes in hydrological regimes; changes in fire regimes and weed invasion.

- Communities which are characterised by mulga species are common in the West Angelas region. Only groved Mulga communities are considered significant, deemed to be an '*ecosystem at risk*' (Kendrick 2003).

  The formation of a mosaic pattern of mulga groves with relatively bare areas in between (intergroves) and the retention of mulga groves is directly dependent upon patterns of surface water (sheet) flows. Groved mulga communities are susceptible to shadowing effects when sheet flow is disrupted or water logging effects when sheet flow is concentrated within the landscape.

  These communities occur relatively extensively throughout the Hamersley Ranges however, groved mulga communities in the West Angelas region are in very good condition, attributed to the absence of historic cattle grazing.

  Threats to groved Mulga communities include: clearing for mining; changes in fire regimes; grazing and trampling; and weed ingress, particularly by Ruby Dock. These communities are also sensitive to changes to the hydrological regime.

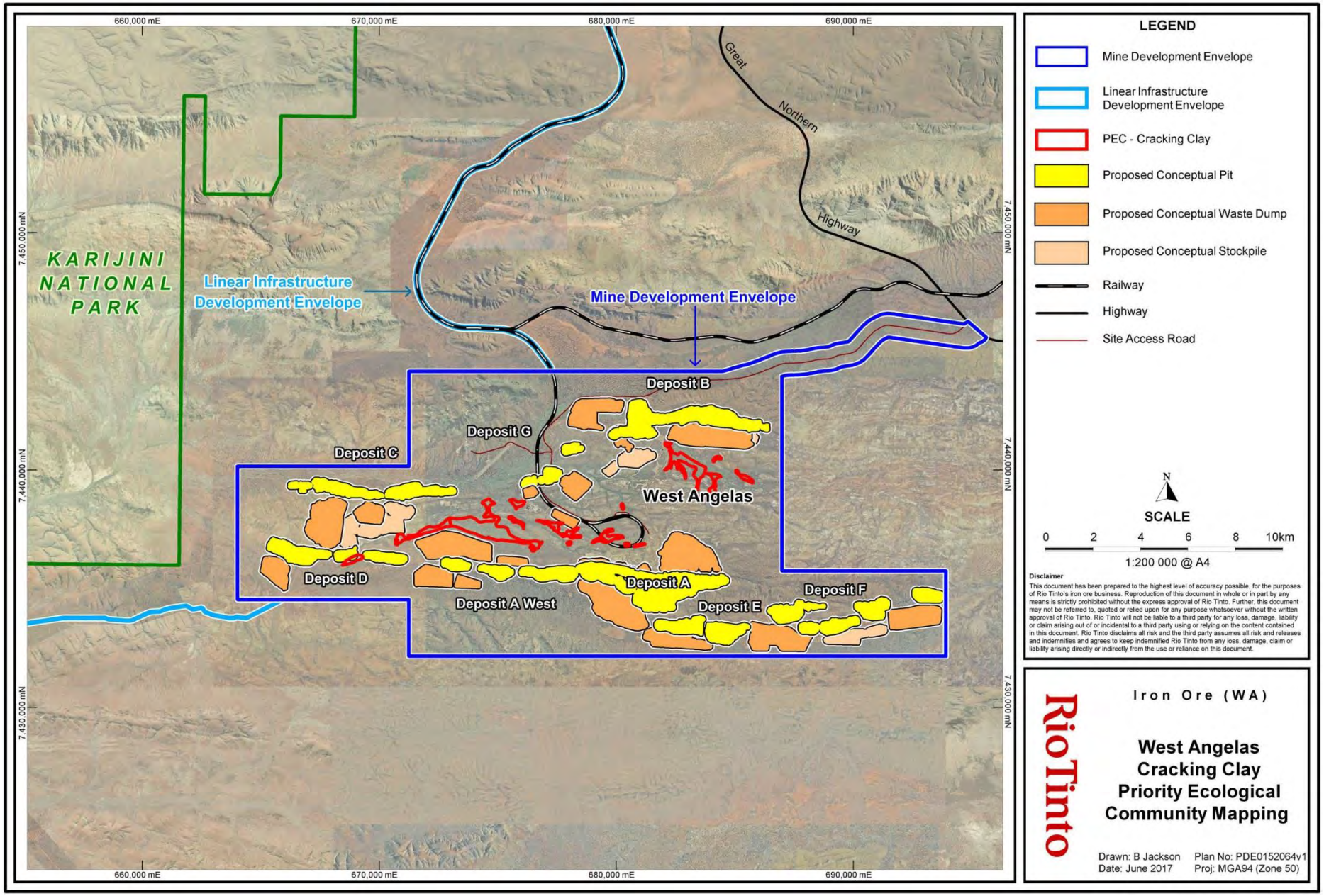


Figure 1-5: West Angelas Cracking Clay Priority Ecological Community mapping

d) Terrestrial Fauna

West Angelas is acknowledged to support diverse fauna for its size due to the great diversity of habitats it provides.

A total of nine broad-scale habitats have been identified within the West Angelas area: 'footslope or plain'; 'hilltop, hillslope; ridge or cliff'; 'mixed Acacia woodland'; 'mulga woodland'; 'mesa top'; 'cracking clay'; 'major gorge and gully'; 'major drainage'; and 'cleared area'. Most of these habitats are considered to be of low conservation significance, representing units that are relatively common in the region. However, the 'mulga woodland' and 'cracking clay' habitats are considered to be of moderate conservation significance.

In addition to these habitats of elevated conservation significance, caves that are utilised by ghost bats for roosting or foraging represent significant habitat features.

Ghost bats are known to require a number of suitable caves throughout their home ranges (i.e. night / feeding roosts for feeding throughout the duration of the night, day roosts for resting and maternity roosts). The presence of day roosts and / or maternity roosts in an area is considered the most important indicator of habitat for ghost bats, and these caves are generally the primary focus of conservation and / or monitoring (Department of Environment 2015 in Biologic 2016).

The first sightings of ghost bats in the West Angelas region were documented in 1978 (Integrated Environmental Services 1979). Monitoring surveys were undertaken between 1997 and 2003 and then annually since 2012 (except for 2016).

Ghost bats have been recorded roosting in five caves within from 'gorge and gully' habitat in the West Angelas region; four roosts: Caves A1, A2, L2 and L3 to the north of Deposit B and one cave to the north of Deposit F; Cave AA1 (Figure 1-6). The monitoring surveys identified a pattern of consistent intermittent use of the monitoring caves by Ghost bats:

Cave A1 has consistently shown evidence of recent ghost bat use throughout all surveys and is classified as a day roost. Owing to its high ongoing record of use, the possibility of it being a maternity roost is difficult to rule out; therefore it is considered of moderate to high importance to the Ghost Bat population.

Cave A2 has shown evidence of recent ghost bat use during three out of four years of monitoring (no evidence of Ghost Bat use recorded during the 2014 survey however, scats were recorded during the 2015 survey) and is a feeding / night roost. Despite its relatively frequent use, this cave's relatively open, shallow structure would limit its use as a day roost or maternity roost, therefore it is considered of moderate importance to the local ghost bat population.

Cave L2 has only shown reliable evidence of recent ghost bat use once (scats recorded in 1998) and potential evidence of a Ghost Bat call in 2015 and is classified as a feeding / night roost. This cave's collapsed entrance and relatively open, shallow structure would limit its use as a day roost or maternity roost, therefore it is considered only of low to moderate importance to the local Ghost Bat population.

Cave L3 has shown evidence of recent Ghost Bat use during all surveys except for 2014 (no evidence of Ghost Bat use recorded during the 2014 survey however, scats were recorded during the 2015 survey) and is classified as a potential day roost. Owing to its relatively frequent use and the larger size and structure of this cave (particularly the presence of deeper rear passages), it is also difficult to rule out the cave's potential as a maternity roost, therefore it is considered to be of moderate to high importance to the local Ghost Bat population.

Cave AA1 has shown evidence of recent Ghost Bat use or presence throughout all surveys and is considered to have the highest conservation value of all the caves in the West Angelas region because it is a suspected maternity roost (Biologic 2016), in 1997/98 a female was captured that was considered to be pregnant. Maternity roosts are uncommon with only eleven recorded in the Pilbara bioregion and therefore, Cave AA1 is also considered to have regional significance. A 100m exclusion zone has been, and will continue to be, maintained, preventing direct or indirect disturbance to Cave AA1.

Foraging habitat favoured by the Ghost Bat is diverse. This carnivorous predator typically requires a relatively large foraging area (usually containing riparian vegetation), within 2 km of day roosts for hunting of small mammals, birds, reptiles and insects that are common and widespread in the Pilbara.

Recognised threats to the Ghost Bat include loss of roosting and foraging habitat, either directly (removal of roosts or vegetation during clearing) or indirectly as a result of mining (noise and / or vibrations resulting in damage to roosts or abandonment, and degradation of foraging habitat from dust deposition or weed incursion).

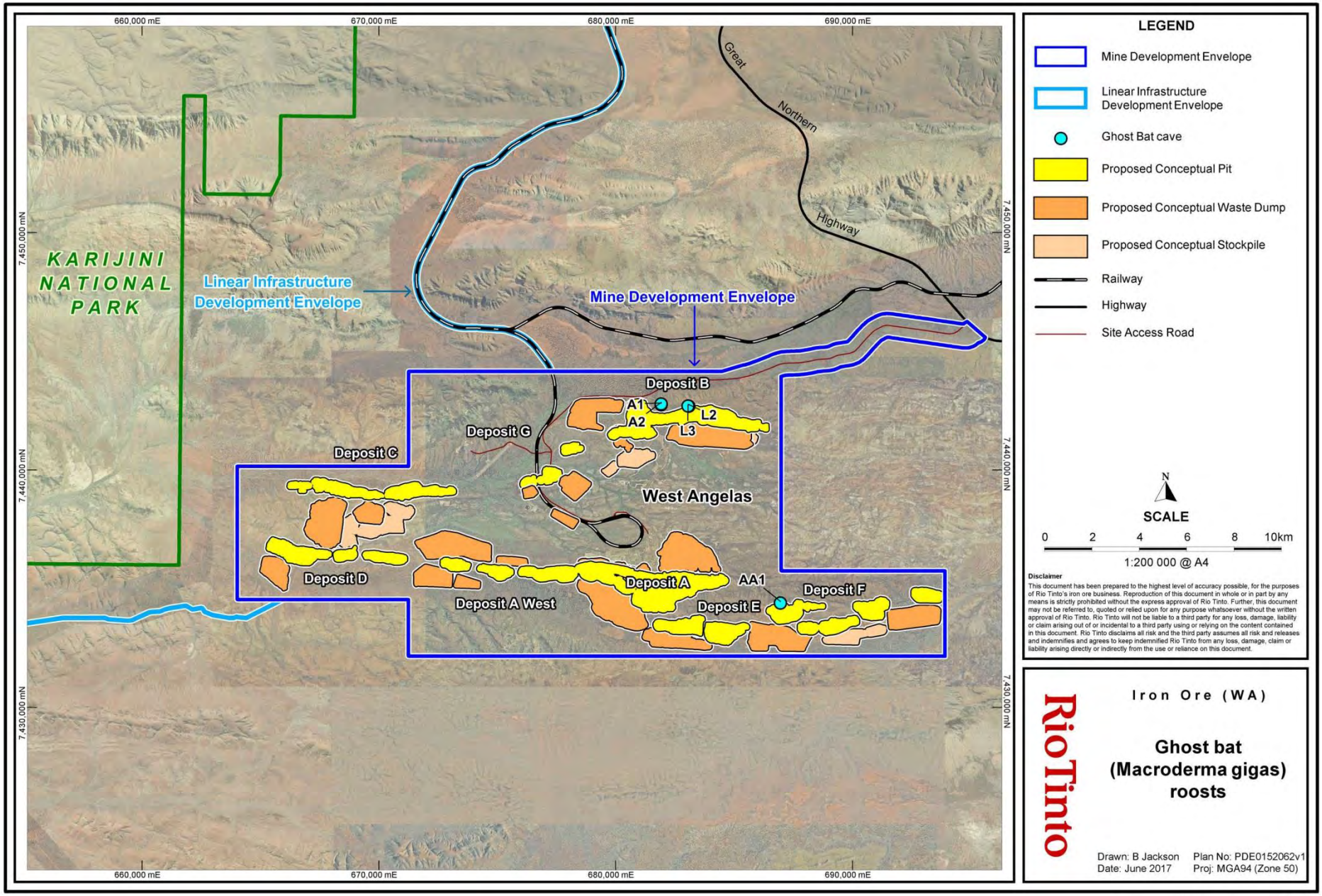


Figure 1-6: Ghost Bat (*Macroderma gigas*) roosts

1.4.2 Key Assumptions and Uncertainties

The key assumptions relating to this EMP are:

- Turee Creek East and its tributaries are ephemeral and thus dry for most of the year. Based on modelling, it is predicted that permanent surface water flows from discharge of excess water (assuming no natural flows at time of discharge) may reach within 2 km of the boundary of Karijini National Park.
- Prolonged / permanent inundation of ephemeral creeks as a result of discharge is expected to result in inevitable changes to riparian vegetation community structure, the health of the dominant riparian tree species *E. victrix* and *E. camaldulensis* and establishment or increasing abundance of other species which are tolerant to waterlogging.

  Riparian ecosystems are characterised by the presence of phreatophytic species. Three common Pilbara species are known to be phreatophytic: *M. argentea* (obligate phreatophyte)*, E. camaldulensis* (facultative phreatophyte) and *E. victrix* (facultative phreatophyte or vadophyte).

  Riparian vegetation along Turee Creek East supports two of these species: *E. victrix* and potentially *E. camaldulensis*. *M. argentea* is not present along Turee Creek East.

  M. argentea, which most often occurs in permanently inundated pools and springs, are adapted to a perennial hydrologic regime. *E. victrix* and *E. camaldulensis* are adapted to an ephemeral hydrologic regime. Trees are subjected to flooding following high intensity rainfall events and then potentially waterlogging for several months afterwards. These eucalypt species are also able to tolerate extended periods of draught.

  These characteristics influence the patterning and abundance of these species within the creek system and also their response to impacts such as dewatering and discharge. For example, dewatering may have a significant impact on the health of *M. argentea* but not at all on *E. victrix* or *E. camaldulensis*. Discharge creates a perennial hydrologic regime which may favour *M. argentea*, resulting in increased recruitment but may have a significant impact on the health of *E. victrix* and *E. camaldulensis*.

  Given the absence of *M. argentea* Turee Creek East, *E. victrix* and *E. camaldulensis* will be treated as a functional group for detecting impact to riparian trees.

  After cessation of discharge, riparian vegetation is expected to gradually revert to a pre-impact condition (e.g. structural composition, functional behaviour, habitat elements and recruitment dynamics).
- Baseline weed surveys will provide a representative weed species inventory as well as collect abundance and distribution data.
- Weed distribution and abundance in the Pilbara fluctuates considerably depending on seasonal conditions. The Proponent assumes that the seasonal conditions during the baseline weed survey will be typical, where rainfall is sufficient to trigger weed germination and growth. However, a level of uncertainty exists when comparing monitoring results to baseline i.e. determining whether changes in weed distribution and abundance may be due to seasonal variances rather than attributable to the West Angelas Project or effectiveness of control actions.
- Due to the presence of dormant seeds, weeds are expected to persist over a number of years irrespective of control actions.

- A 100 m exclusion zone around Cave AA1 and controlled blasting and vibration monitoring will be undertaken for blasts located within 300 meters all Ghost Bat roosting habitats will protect the roosting habitat for this species.
- Protection of roosting habitat for species of conservation significance will enable the persistence of these species.

1.4.3 Management Approach

This EMP has been developed to address the key environmental factors (and relevant EPA environmental objective) of Hydrological Processes, Flora and Vegetation, and Terrestrial Fauna and the specific outcomes stated in condition 6, 7 and 8 of MS xxxx.

Weeds within the West Angelas Development Envelopes are managed through a comprehensive annual weed control program, completed between April and October. Weed control measures include the use of both selective and non-selective herbicides. In some cases, physical removal of weeds is undertaken where appropriate.

This EMP includes the trigger and threshold criteria and associated management contingency actions that the Proponent will undertake if the environmental outcomes are exceeded.

1.4.4 Rationale for choice of provisions

Environmental criteria have been developed based on consideration of:

- threatening processes and risks associated with each environmental factor
- the availability of suitable monitoring methods; and
- relevance to the condition environmental outcomes sought for each environmental factor.

The specific trigger and threshold criteria and actions defined in Table 2-1 have been chosen as they provide a basis for detecting and avoiding or otherwise managing potential impacts, such that the condition environmental outcomes stated in conditions 6, 7 and 8 of MS xxxx can be achieved.

The potential for the trigger criteria to be detected due to natural variability in vegetation communities must be accounted for in the management response. Therefore, exceedance of the trigger criteria will not be treated as a non-compliance to the condition environmental objectives.

The potential for the threshold criteria to be detected due to natural variability in vegetation communities must also be accounted for in the management response.

Exceedance of the threshold criteria will be treated as a non-compliance of the West Angelas Project to the environmental objective if the exceedance is attributable to the West Angelas Project.

2. EMP PROVISIONS

This section of the EMP identifies the legal provisions that the Proponent will implement to ensure that the environmental outcomes of conditions 6, 7 and 8 are met during implementation of the West Angelas project.

It identifies the environmental criteria that will be used to measure performance and monitoring that will be undertaken in relation to these environmental criteria. Finally, it defines the response actions (trigger level and contingency actions) that will be undertaken if the environmental criteria are exceeded. Table 2-1 details the provisions of this EMP.

2.1 Outcomes

- No irreversible damage to potentially groundwater dependant vegetation within Karijini National Park.
- Maintain the health of riparian vegetation of Turee Creek East.
- No disturbance to the West Angelas Cracking Clay PEC (PEC-2015-5).
- Minimise disturbance to other representations of the West Angelas Cracking Clay Priority Ecological Community.
- No disturbance to the Ghost Bat roost; Cave AA1.
- Minimise disturbance to other Ghost Bat roosts; Caves A1, A2, L2 and L3.

2.2 Performance Indicators (Environmental Criteria)

Two levels of criteria, which vary in function, have been developed for this EMP.

2.2.1 Trigger Level Criteria

Trigger criteria measures are set at a conservative level to ensure management actions are implemented well in advance of the environmental objective being compromised. Thus, trigger criteria are set at a level below the threshold criteria to signal the need to focus and investigate and where applicable, mitigate the impact further or increase the level of production or rehabilitation.

Potential GDE within Karijini National Park:

1. The mean vegetation index for the upper canopy (*E. vitrix / E. camuldulensis*) declines >2 SD from baseline.

Surface water discharge and riparian vegetation:

2. Surface water discharge reaches within 2 km from the boundary of Karijini National Park under natural no-flow conditions.
3. Significant upward trend in number of introduced species relative to baseline.

West Angelas Cracking Clay PEC:

4. Disturbance (direct or indirect) within 100 m of West Angelas Cracking Clay Priority Ecological Community (PEC-2015-5).
5. Disturbance to other representations of West Angelas Cracking Clay PEC exceeds 15.5 ha.

Ghost Bat:

6. Disturbance is within 150 m of Ghost Bat roost; Cave AA1.
7. Vibration levels exceed 40 mm/s peak particle velocity (Cave AA1) or 75 mm/s peak particle velocity (Caves A1, A2, L2 and L3).

2.2.2 Threshold Level Criteria

Threshold criteria measures are framed to measure achievement of the environmental objective. A failure to meet the threshold criterion, if deemed attributable to the implementation of the West Angelas Project, signals that the environmental objective is not being met.

Potential GDE within Karijini National Park:

1. The mean vegetation index for the upper canopy (*E. vitrix / E. camaldulensis*) declines >2 SD from baseline over two consecutive monitoring events.

Surface water discharge and riparian vegetation:

2. Surface water discharge reaches the boundary of Karijini National Park under natural no flow conditions.
3. Significant upward trend in number of introduced species with a notable decline in native species richness compared to baseline.

West Angelas Cracking Clay PEC:

4. Disturbance (direct or indirect) within West Angelas Cracking Clay PEC (PEC-2015-5).
5. Disturbance to other representations of West Angelas Cracking Clay PEC exceeds 20 ha.

Ghost Bat:

6. Disturbance within 100 m of Ghost Bat roost; Cave AA1.
7. Significant damage to Ghost Bat roosts; Caves AA1, A1, A2, L2 and L3.
8. Permanent Ghost Bat abandonment of caves.

2.3 Response Actions

The Proponent has developed a number of trigger level actions that would be implemented if the associated trigger criterion signals the need to increase mitigation or protection (Table 2-1). These trigger level actions will be implemented by the Proponent to mitigate and manage impacts so they once again will meet trigger and safeguard the threshold criteria.

The Proponent has developed a number of threshold contingency actions that would be implemented if the associated threshold criterion signals that the environmental outcome is exceeded (Table 2-1). The threshold contingency actions will be implemented to manage aspects of the proposal and achieve the condition environmental outcome and manage the impact to below threshold and trigger criteria again and hence bring the Proponent back into compliance.

2.4 Monitoring

The purpose of monitoring is to inform, through the environmental criteria, if the conditioned environmental outcome is being achieved and when trigger level actions or threshold contingency actions will be implemented.

Monitoring provisions for each environmental factor and how these will determine performance against the environmental criteria are presented in Table 2-1.

Missed monitoring events will not be treated as a non-compliance as long as the Proponent can validate that the required environmental outcome has still be achieved, for example through the use of alternative data to assess performance against the environmental criteria.

a) Potentially Groundwater Dependent Vegetation Monitoring

Approximately 4.2 ha of the riparian vegetation of Turee Creek East, within Karijini National Park, is co-dominated by *E. victrix* and *E. camaldulensis* at elevated densities and is assumed to represent a potential GDE considered to be at 'medium' risk of impact as a result of groundwater drawdown.

Whilst it's inherently difficult to interpolate the local groundwater table elevation from limited data, and hence to predict the groundwater dependence of local eucalypt assemblages, monitoring the cover and health of the upper canopy may provide an indicator of stress related to groundwater drawdown and reduced water availability.

Digital Multi-Spectral Imagery (DMSI) has been selected as an appropriate monitoring technique, to examine the spectral vegetation index of the upper canopy. Vegetation indices provide a representation of the cover and photosynthetic vigour of vegetation, by assessing the ratio of red and near-infra red radiation wavelengths. Changes to spectral vegetation can provide a meaningful indication of condition and stress.

Prior to groundwater drawdown extending beneath the potential GDE within Karijini National Park, remote sensing will collect DMSI over the area from which a baseline vegetation index will be established.

Changes to the vegetation index of the canopy for both *E. camaldulensis* and *E. victrix* within the potential GDE within Karijini National Park will be monitored over time, concurrently with groundwater elevation observations. A two standard deviation (2 SD) change from baseline is the same approach used for other monitoring programs in the East Pilbara.

As detailed in Table 2-1, part of the actions to complete in response to exceeding the trigger criteria will be field-based observations of the community within Karijini National Park.

b) Riparian Vegetation Monitoring

Monitoring of diversity, cover and abundance of both native and introduced species within riparian vegetation of Turee Creek East has been undertaken annually since 2011.

The condition, cover and health of riparian vegetation within the observed surface water discharge extent shall continue to be monitored annually by qualitative in-field assessment.

Whilst it's predicted that increased water availability may increase the biomass / abundance and / or cover of other species which are tolerant to waterlogging (including weeds) within the surface discharge extent, the triggers have been selected to ensure that during times of discharge, weed coverage does not cause a reduction of native species diversity or cover. It's also noted that once discharge ceases, the trigger would effectively ensure that the ratio of native and introduced species coverage is maintained, which aligns with the environmental outcome of condition 6.

c) West Angelas Cracking Clay PEC Monitoring:

Annual land clearing reconciliation shall be compared against West Angelas Cracking Clay PEC mapping.

d) Blast Vibration Prediction and Monitoring:

Blast vibration shall be predicted using a 'scaled distance' blast vibration model for every blast within 300m of Caves AA1, A1, A2, L2 and L3. Blasts shall not proceed where predicted blast vibration exceeds criteria to ensure that the caves are protected from significant damage.

Blast vibration monitoring shall be implemented for all blasts within 300m of Caves AA1, A1, A2, L2 and L3 to confirm blast vibration predictions are met, to ensure that blast vibration does not exceed criteria and that the caves are protected from significant damage.

A set of photographs shall be prepared as reference for damage assessment. Quarterly visual inspection shall identify any significant damage (change from reference). Additional visual inspection shall be required where blast vibration levels exceed criteria.

e) Ghost Bat Presence / Absence Monitoring:

Monitoring of Ghost Bat presence / absence within Caves AA1, A1, A2, L2 and L3 has been undertaken annually since 2012.

The use of a monitoring cave by Ghost Bats shall continue to be confirmed annually by a visual sighting and / or the presence of scats and / or middens. The Ghost Bat is distinctive in being very much larger than any other cave dwelling bat in the region, and is easily identified. Scats and middens are also distinctive for this species.

Sheets of black cotton shall be placed on scat piles or middens and shall be searched for fresh scat material. Presence of scats or middens on the sheets indicates use of the caves by Ghost Bats over a known time period, and enables acquisition of scat samples should further studies be undertaken (e.g. pregnancy detection and dietary analysis).

Categorisation of each of the monitoring caves shall be reassessed based on the results of the most recent survey, and where appropriate shall be re-categorised using the following definitions:

- Feeding Cave / Night Roost – no individuals, only a small number of scats observed.
- Feeding Cave / Possible Day Roost – no individuals, large scat piles observed.
- Day Roost – individuals are or have been observed within a cave during the day. The cave can be visually inspected for the presence of juveniles, no juveniles are observed.
- Day Roost / Possible Maternity Roost – individuals are observed within a cave during the day but flush or hide before a full inspection of individuals possibly carrying juveniles can be made.
- Maternity Roost – juveniles are observed attached to females within a cave. (Note that all maternity roosts are day roosts, but not all day roosts are maternity roosts).

The use of a monitoring cave by Ghost Bats can also be confirmed by remote detection. Ultrasonic bat detectors, recording continuously, shall be placed in the entrance of all monitoring caves. Ultrasonic bat detectors contain omnidirectional microphones and record calls (including inaudible calls, which are often made by Ghost Bats when exiting caves, thus providing an additional method of detecting this species) in high quality audio formats. Digital cameras, taking photos at 30 minute intervals, shall also be placed at locations with scat piles, facing towards the roof to visually detect Ghost Bats returning to roosts.

Table 2-1: West Angelas EMP Provisions

EPA objectives:

- To maintain the hydrological regimes of groundwater and surface water so that environmental values are protected.
- To maintain representation, diversity, viability and ecological function at the species, population and community level.

Outcomes:

- No irreversible impact to potentially groundwater dependent vegetation within Karijini National Park.
- Maintain the health of riparian vegetation of Turee Creek East.
- No disturbance (direct or indirect) to the West Angelas Cracking Clay Priority Ecological Community; PEC-2015-5.
- Minimised disturbance (direct or indirect) to other representations of the West Angelas Cracking Clay Priority Ecological Community.
- No disturbance (direct or indirect) to the Ghost Bat roost; Cave AA1.
- Minimise disturbance (direct or indirect) to other Ghost Bat roosts; Caves A1, A2, L2 and L3.
- Avoid the use of barbed wire in the Proposal area, except where there is a statutory requirement to do so, to minimise the impact of barbed wire on Ghost Bats.

Key environmental values: Karijini National Park, Turee Creek East, West Angelas Cracking Clay PEC, riparian vegetation, Ghost Bats.

Key impacts and risks: potential adverse impacts on riparian vegetation, conservation significant vegetation and conservation significant fauna species as a result of clearing, dewatering, surface water discharge, and blasting and loss of habitat.

Environmental criteria	Response Actions	Monitoring	Reporting
Hydrological Processes – Potential GDE within Karijini National Park			
Trigger criterion: 1. The mean vegetation index for the upper canopy (*E. victrix / E. camaldulensis*) declines >2SD from baseline.	• Review reference sites data to ascertain if change has also occurred at reference sites. • Review degree of exposure of impacted sites relative to dewatering via review of: site specific observations; dewatering volumes and extent; hydrogeological model and other natural factors (i.e. seasonal rainfall data) to determine if attributable to implementation of the project. • Complete in-field inspection of the area.	Annual assessment of vegetation condition using DMSI at established monitoring regions containing *E. victrix* and *E. camaldulensis* within Karijini National Park along with suitable reference site/s (Figure 1-3).	• The environmental outcome will be reported against the trigger criteria for each calendar year by 30 April in the ACAR for MS xxxx. • If trigger criterion was exceeded during the reporting period, the ACAR will include a description of the effectiveness of trigger level.

Environmental criteria	Response Actions	Monitoring	Reporting
Threshold criterion: 1. The mean vegetation index for the upper canopy (*E. victrix / E. camaldulensis*) declines >2SD from baseline over two consecutive monitoring events.	As for trigger criteria with addition of the following: • Notify the OEPA within 7 days of that non-compliance being known. • Within 21 days of confirmation of this threshold criteria being exceeded, provide a report to the OEPA in accordance with Ministerial Condition. If threshold criteria exceedance is considered likely to be due to discharge, report to include proposed remedial action/s identified during trigger investigations. • Implement remedial action/s, as agreed with the OEPA. • Submit a report to the OEPA within 12 months after the notification, detailing the: o Effectiveness of contingency actions implemented. o Analysis of trends. o Schedule for ongoing reporting.	• Annual assessment of vegetation condition using DMSI at established monitoring regions containing *E. victrix* and *E. camaldulensis* within Karijini National Park along with suitable reference site/s (Figure 1-3). • Assessment of condition and cover of understorey flora. • Quarterly groundwater levels, physiochemical and hydrochemical parameters.	• Notify the OPEA within 7 days of that non-compliance being known with a report provided within 21 days. • The environmental outcome will be reported against the threshold criterion for each calendar year in the ACAR. The ACAR will include a description of the effectiveness of threshold contingency actions that have been implemented to manage the potential impact, as well as a summary of analysis of trends.
Surface water discharge – riparian vegetation			
Trigger criterion: 1. Surface water discharge reaches within 2km of the boundary of Karijini National Park under natural no-flow conditions. 2. Significant upward trend in number of introduced species relative to baseline.	• Review correlative environmental parameters, including discharge volumes and extent; hydrological model; and other natural factors (i.e. seasonal rainfall data etc.) to determine if permanent surface water flow beyond 2km of the boundary of Karijini National Park / significant upward trend in number of introduced species is attributable to implementation of the project. • If other causal environmental factors for permanent surface water flow beyond 2km of the boundary of Karijini National Park / significant upward trend in number of introduced species (other than discharge) cannot be identified:	• Monthly permanent surface water flow at established monitoring point along the proposed surface water discharge extent (Figure 1-4). • Annual condition, cover and health of riparian vegetation within the observed (or predicted) surface water discharge extent (Figure 1-4).	• The environmental outcome will be reported against the trigger criteria for each calendar year by 30 April in the ACAR for MS xxxx. • If trigger criterion was exceeded during the reporting period, the ACAR will include a description of the effectiveness of trigger level.

Environmental criteria	Response Actions	Monitoring	Reporting
	• undertake expanded on-ground assessment (if appropriate, expand the extent and frequency of permanent surface water flow monitoring, expand the extent of riparian vegetation monitoring to include reference sites). • investigate potential remediation strategies (such as modified surplus water management strategy, discharge regime or alternative discharge location, weed control).		
Threshold criterion: 1. Surface water discharge reaches the boundary of Karijini National Park under natural no-flow conditions. 2. Significant upward trend in number of introduced species with a notable decline in native species richness compared to baseline.	As for trigger criteria with addition of the following: • Notify the OEPA within 7 days of that non-compliance being known. • Within 21 days of confirmation of this threshold criteria being exceeded, provide a report to the OEPA in accordance with Ministerial Condition. If threshold criteria exceedance is considered likely to be due to discharge, report to include proposed remedial action/s identified during trigger investigations. • Implement remedial action/s, as agreed with the OEPA. • Submit a report to the OEPA within 12 months after the notification, detailing the: o Effectiveness of contingency actions implemented. o Analysis of trends. o Schedule for ongoing reporting.	• Monthly permanent surface water flow at established monitoring point along the proposed surface water discharge extent (Figure 1-4). • Annual condition, cover and health of riparian vegetation within the observed (or predicted) surface water discharge extent (Figure 1-4).	• Notify the OPEA within 7 days of that non-compliance being known with a report provided within 21 days. • The environmental outcome will be reported against the threshold criterion for each calendar year in the ACAR. The ACAR will include a description of the effectiveness of threshold contingency actions that have been implemented to manage the potential impact, as well as a summary of analysis of trends.

Environmental criteria	Response Actions	Monitoring	Reporting
Flora and Vegetation - West Angelas Cracking Clay PEC			

Trigger criterion:
1. Disturbance (direct or indirect) within 100 m of West Angelas Cracking Clay Priority Ecological Community (PEC-2015-5).
2. Disturbance within other representations of West Angelas Cracking Clay PEC exceeds 15.5 ha.
	• Complete hydrological assessment to determine whether the disturbance will impact surface water drainage to the West Angelas Cracking Clay PEC
	• Review mine plan to ensure:
	  ○ Disturbance will not occur within West Angelas Cracking Clay Priority Ecological Community (PEC-2015-5); and
	  ○ Disturbance within other representations of West Angelas Cracking Clay PEC will not exceed 20 ha.
	• Investigate potential remediation strategies
		• Annual land clearing reconciliation against West Angelas Cracking Clay PEC mapping (Figure 1-5).	• The environmental outcome will be reported against the trigger criteria for each calendar year by 30 April in the ACAR for MS xxxx.
			• If trigger criterion was exceeded during the reporting period, the annual report will include a description of the effectiveness of trigger level.

Threshold criterion:
1. Disturbance (direct or indirect) within the West Angelas Cracking Clay Priority Ecological Community (PEC-2015-5).
2. Disturbance within other representations of West Angelas Cracking Clay PEC exceeds 20 ha.
	As for trigger criteria with addition of the following:
	• Notify the OEPA within 7 days of that non-compliance being known.
	• Within 21 days of confirmation of this threshold criteria being exceeded, provide a report to the OEPA in accordance with Ministerial Condition.
	If threshold criteria exceedance is considered likely to be due to operations, report to include proposed remedial action/s identified during trigger investigations.
	• Implement remedial action/s, as agreed with the OEPA.
	• Submit a report to the OEPA within 12 months after the notification, detailing the:
	  ○ Effectiveness of contingency actions implemented.
	  ○ Schedule for ongoing reporting.
		• Annual land clearing reconciliation against West Angelas Cracking Clay PEC mapping (Figure 1-5).	• Notify the OPEA within 7 days of that non-compliance being known with a report provided within 21 days.
			• The environmental outcome will be reported against the threshold criterion for each calendar year in the ACAR. If the threshold criterion was exceeded during the reporting period, the ACAR will include a description of the effectiveness of threshold contingency actions that have been implemented to manage the potential impact, as well as a summary of analysis of trends.

Environmental criteria	Response Actions	Monitoring	Reporting
Terrestrial fauna – Ghost Bat			
Trigger criterion: 1. Disturbance within 150 m of Ghost Bat roost; Cave AA1. 2. Vibration levels exceed 40mm/s peak particle velocity (Cave AA1) or 75mm/s peak particle velocity (Caves A1, A2, L2 and L3).	• Complete in-field inspection of the area. • Review site specific observations; clearing extent; blast vibration predictions / blast vibration monitoring levels; and other natural factors (i.e. seasonal rainfall data etc.) to determine if disturbance / significant damage is attributable to implementation of the project. • If other causal environmental factors for disturbance / significant damage cannot be identified, undertake expanded on-ground assessment (if appropriate, expand the frequency of monitoring). • Investigate potential remediation strategies (such as modified blast management strategy).	• Annual land clearing reconciliation against Ghost Bat roost, Cave AA1 Exclusion Zone (Figure 1-6). • Blast vibration monitoring for all blasts within 300m of Caves AA1, A1, A2, L2 and L3 (Figure 1-6). • Quarterly visual inspection where blast vibration levels exceed criteria. • Annual assessment of presence / absence of evidence of Ghost Bat use within Caves AA1, A1, A2, L2 and L3 (Figure 1-6).	• The environmental outcome will be reported against the trigger criteria for each calendar year by 30 April in the ACAR for MS xxxx. • If trigger criterion was exceeded during the reporting period, the annual report will include a description of the effectiveness of trigger level.
Threshold criterion: 1. Disturbance within 100 m of Ghost Bat roost; Cave AA1. 2. Significant damage to Ghost Bat roosts; Caves AA1, A1, A2, L2 and L3. 3. Permanent Ghost Bat abandonment of caves.	As for trigger criteria with addition of the following: • Notify the OEPA within 7 days of that non-compliance being known. • Within 21 days of confirmation of this threshold criteria being exceeded, provide a report to the OEPA in accordance with Ministerial Condition. If threshold criteria exceedance is considered likely to be due to operations, report to include proposed remedial action/s identified during trigger investigations. • Implement remedial action/s, as agreed with the OEPA. • Submit a report to the OEPA within 12 months after the notification, detailing the: o Effectiveness of contingency actions implemented. o Analysis of trends. o Schedule for ongoing reporting.	• Annual land clearing reconciliation. • Blast vibration monitoring for all blasts within 300m of Caves AA1, A1, A2, L2 and L3 (Figure 1-6). • Quarterly visual inspection where blast vibration levels exceed criteria. • Annual assessment of presence / absence of evidence of Ghost Bat use within Caves AA1, A1, A2, L2 and L3 (Figure 1-6).	• Notify the OPEA within 7 days of that non-compliance being known with a report provided within 21 days. • The environmental outcome will be reported against the threshold criterion for each calendar year in the ACAR. If the threshold criterion was exceeded during the reporting period, the ACAR will include a description of the effectiveness of threshold contingency actions that have been implemented to manage the potential impact, as well as a summary of analysis of trends.

2.5 Reporting

The environmental outcome will be reported against trigger and threshold criteria (Table 2-2) for each calendar year in the Annual Compliance Assessment Report (ACAR) for the West Angelas Project against MS xxxx.

The annual report will also include a summary of analysis of monitoring data to facilitate adaptive management.

In the event that trigger and threshold criteria are exceeded during the reporting period, the annual report will include a description of the effectiveness of any management contingency actions that have been implemented to manage the impact.

Table 2-2: West Angelas Environmental Management Plan Reporting Table

Key environmental factor: Conservation significant vegetation, riparian vegetation and conservation significant terrestrial fauna	
Condition environmental outcome, trigger and threshold criteria as per MS xxxx	**Reporting periods 1 January-31 December**
Trigger criteria:	**Status report:** Environmental outcome achieved Environmental outcome not achieved
1. The mean vegetation index for the upper canopy *(E. victrix / E. camaldulensis*) declines >2SD from baseline.	
2. Surface water discharge reaches within 2 km from the boundary of Karijini National Park under natural no-flow conditions.	
3. Significant upward trend in number of introduced species relative to baseline.	
4. Disturbance (direct or indirect) within 100 m of West Angelas Cracking Clay Priority Ecological Community (PEC-2015-5).	
5. Disturbance (direct or indirect) to other representations of West Angelas Cracking Clay PEC exceeds 15.5 ha.	
6. Disturbance within 150 m of Ghost Bat roost; Cave AA1.	
7. Vibration levels exceed 25mm/s peak particle velocity (Cave AA1) or 50mm/s peak particle velocity (Caves A1, A2, L2 and L3).	
Threshold criteria:	**Status report:** Environmental outcome achieved Environmental outcome not achieved
1. The mean vegetation index for the upper canopy (E. victrix / E. camaldulensis) declines >2SD from baseline over two consecutive monitoring events.	
2. Surface water discharge reaches the boundary of Karijini National Park under natural no-flow conditions.	
3. Significant upward trend in number of introduced species with a notable decline in native species richness compared to baseline.	
4. Disturbance (direct or indirect) within the West Angelas Cracking Clay PEC (PEC-2015-5).	
5. Disturbance (direct or indirect) to other representations of West Angelas Cracking Clay PEC exceeds 20 ha.	
6. Disturbance within 100 m of Ghost Bat roost; Cave AA1.	
7. Significant damage to Ghost Bat roosts; Caves AA1, A1, A2, L2 and L3.	
8. Permanent Ghost Bat abandonment of caves.	

3. ADAPTIVE MANAGEMENT AND REVIEW OF THIS EMP

The Proponent will implement adaptive management to learn from the implementation of mitigation measures, monitoring and evaluation against trigger and threshold criteria, to more effectively meet the conditioned environmental outcome.

The following approach will apply:

- Monitoring data will be systematically evaluated and compared to baseline and reference site data on a regular basis in a process of adaptive management to verify whether riparian vegetation responses to the impact are the same or similar to predictions.
- The effectiveness and relevance of trigger level and threshold contingency actions will be evaluated on an annual basis to determine if any changes to management actions are required.
- Increased understanding of the hydrological and ecohydrological regimes based on additional internal and external studies will be incorporated into the monitoring and management approach when newer relevant information becomes available and where applicable.

This EMP will also be reviewed annually to ensure it is consistent with and informed by existing strategies and licences, including (but not limited to) the following:

- Licence L7774/2000, issued under Part V of the EP Act for processing of ore, dewatering (discharge), screening, power generation, sewage facility, landfill and bulk storage of chemicals;
- Groundwater Licence GWL98740, issued under the RiWI Act for abstraction of 5,380,000 kL from the mine for dewatering and water supply purposes;
- Groundwater Licence GWL103136, issued under the RiWI Act for abstraction of 3,102,500 kL from the Turee B Borefield for water supply purposes;
- West Angelas Operations Groundwater Operating Strategy; and
- West Angelas Turee B Borefield Groundwater Operating Strategy.

4. STAKEHOLDER CONSULTATION

Consistent with the EPA's expectations for this EMP to align with the principles of EIA, the Proponent consulted with stakeholders, including but not limited to the Department of Park and Wildlife, OEPA, and the Department of Water during the environmental impact assessment of the West Angelas Deposits C, D and G Project (2017) and the information is captured in the supporting Environmental Review Document.

Any add consultation regarding this EMP will be captured in subsequent revisions.

5. REFERENCES

Biologic Environmental Survey (Biologic) 2016, West Angelas Iron Ore Mine – Deposit B and F Ghost Bat Monitoring 2015, unpublished report prepared for Rio Tinto Iron Ore by Biologic, Perth

ecologia Environmental Consultants (ecologia) 2013, Greater West Angelas Vegetation and Flora Assessment, unpublished report prepared for Rio Tinto by ecologia, Perth

ecologia Environmental Consultants (ecologia) 2014, Greater West Angelas Terrestrial Fauna Assessment, unpublished report prepared for Rio Tinto by ecologia, Perth.

EPA 2013, Environmental Assessment Guideline for Environmental factors and objectives (EAG 8), Environmental Protection Authority, Perth

EPA 2015, Environmental Assessment Guideline for Preparation of Management Plans (EAG 17), Environmental Protection Authority, Perth

Rio Tinto 2013, West Angelas Operations Environmental Management Program, prepared by Rio Tinto Iron Ore on behalf of Robe River Mining Co. Pty. Ltd.

Rio Tinto 2017, West Angelas Iron Ore Project, Deposit C, D and G Proposal, prepared by Rio Tinto Iron Ore on behalf of Robe River Mining Co. Pty. Ltd.

APRIL 2013

Providing sustainable environmental strategies,
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ACRONYMS

AIR	Ashburton Regional Inventory
ARRP Act	*Agriculture and Related Resources Protection Act 1976*
BIF	Banded Ironstone Formation
CALM	Department of Conservation and Land Management (now DEC)
DAFWA	Department of Agriculture and Food Western Australia
DEC	Department of Environment and Conservation
DEFL	Department of Environment and Conservation Endangered Flora Database
EIA	Environmental Impact Assessment
EPA	Environmental Protection Authority
EP Act	*Environmental Protection Act 1986*
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
RT	Rio Tinto
Opp col	Opportunistic collection
PRI	Pilbara Regional Inventory
TEC	Threatened Ecological Community
PEC	Priority Ecological Community
UCL	Unallocated Crown Land
WAHERB	Western Australian Herbarium
WC Act	*Wildlife Conservation Act 1950*
WONS	Weeds of National Significance

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EXECUTIVE SUMMARY

Rio Tinto (RT) commisioned *ecologia* Environment (*ecologia*) to undertake a two phase assessment of the Greater West Angelas Study Area. Greater West Angelas is located approximatley 105 km north-west of Newman and comprises of three disjointed areas covering a total of 17,596 ha. Deposits C, D, D extension, G, F, H and Mt Ella were surveyed.

Methods

The vegetation and flora of the Study Area was surveyed in two phases over two separate trips totalling 60 person days. Survey timing was as follows:

- Phase 1; 9th to 18th of July 2012 (36 person days); and
- Phase 2; 21st-26th August 2021 (24 person days).

Seasonal conditions were favorable, with higher than average rainfall recorded in the months preceding the survey.

One hundred and fifty quadrats (2,500 m^2 each) were surveyed, distributed throughout the Study Area. Locations were selected using aerial photography, topographic features and field observations to represent the diversity of vegetation present. Additional opportunistic collections were made of taxa not already located within the quadrats. Locations of any introduced flora and known or potentially conservation significant taxa encountered were also recorded.

Flora

A total of 441 taxa were recorded from the West Angelas Study Area. Ten taxa could not be fully identified due to lack of reproductive material. The pattern of families and genera represented are considered typical for the Pilbara during favourable seasonal conditions. The high number of taxa within the family Scrophulariaceae and genus *Eremophila* reflects the abundance of mulga woodlands and shrublands. The relatively high representation of Asteraceae, Amaranthaceae and Goodeniaceae is a reflection of the optimal timing of the survey when many ephemeral species were flowering.

Flora sampling adequacy was estimated using species accumulation curve analysis and extrapolation of the curve to the asymptote using Michaelis-Menten modelling. Using this analysis it is estimated that between 86% and 88 % of the taxa present were recorded.

Species richness within quadrats varied from seven to 67 taxa, with a mean species richness of 35.7± 1.0 (n= 150). Vegetation units with the lowest species overall richness include *ApTssp* (*Acacia aptaneura* and *A. pruinocarpa* open woodland over *A. tetragonophylla, Senna glutinosa* subsp. *glutinosa* and *S. artemisioides* subsp. *oligophylla* isolated shrubs over *Triodia wiseana* and *T. pungens* open hummock grassland), and *Tp* (*Eucalyptus leucophloia* subsp. *leucophloia* and *Acacia pruinocarpa* isolated trees over *Senna glutinosa* subsp. *glutinosa, A. bivenosa* and *Ptilotus rotundifolius* isolated shrubs over *Triodia pungens* or *T. basedowii* or *T.* sp. Mt Ella hummock grassland.), both of which are typical of rocky midslopes, with a mean species richness of 15.8 and 16.8, respectively. The most consistently diverse vegetation unit was *AaPoTt* (*Acacia aptaneura* open woodland over *Ptilotus obovatus* sparse shrubland over *Themeda triandra* open tussock grassland), which occurs along sandy floodplains, with mean species richness of 50.1.

Four specimens of *Lepidium catapycnon,* listed under the *Environment Protection and Biodiversity Conservation Act, 1999* (EPBC Act) and the *Wildlife Conservation Act, 1950* (WC Act) (Declared Rare

Flora) were collected opportunistically from four locations within Greater West Angelas. A total of 29 individuals were recorded. Vegetation and landforms consistent with this species' habitat occur within the Study Area and it is possible that more individuals could be present given that access to some areas was limited during the survey.

Thirteen Threatened and Priority Flora taxa were recorded during the survey: one Threatened (*Lepidium catapycnon*); three Priority 1 species (*Aristida jerichoensis* var. *subspinulifera, Brachyscome* sp. Wanna Munna Flats (S. van Leeuwen 4662) and *Brunonia* sp. long hairs (D.E. Symon 2440); two Priority 2 species (*Aristida lazaridis* and *Eremophila forrestii* subsp. Pingandy (M.E. Trudgen 2662)); six Priority 3 species (*Acacia* aff. *subtiliformis, Indigofera* sp. Gilesii (M.E. Trudgen 15869)*, Rhagodia* sp. Hamersley (M. Trudgen 17794), *Sida* sp. Barlee Range (S. van Leeuwen 1642), *Themeda* sp. Hamersley Station (M.E. Trudgen 11431) and *Triodia* sp. Mt Ella (M.E. Trudgen 12739) and one Priority 4 species (*Goodenia nuda*). Seven of these species have previously been recorded within the Study Area. Five of the recorded priority taxa are not represented within conservation estates (*Aristida jerichoensis* var. *subspinulifera*, *Brachyscome* sp. Wanna Munna Flats (S. van Leeuwen 4662), *Brunonia* sp. long hairs (D.E. Symon 2440), *Indigofera* sp. Gilesii (M.E. Trudgen 15869) and *Triodia* sp. Mt Ella (M.E. Trudgen 12739). Current advice form the Western Australian Herbarium is that *Brunonia* sp. long hairs and *Brunonia australis* are likely to be amalgamated in the future (Hislop 2012, *pers. comm.*), but as this change has not yet been adopted by the Western Australian Herbarium, *Brunonia* sp. long hairs is regarded as a priorty taxon in this report.

No Weeds of National Significance (WONS) or Declared Plants were recorded. Nine weeds were recorded within the Study Area, all of which have been assessed within the Department of Environment and Conservation (DEC) classification of Environmental Weeds within the Pilbara. Three species are ranked as a high threat; **Cenchrus ciliaris*, **Cenchrus setiger* and **Vachellia farnesiana*. **Bidens bipinnata* is by far the most abundant weed species recorded in the Study Area.

Vegetation

The West Angelas Study Area is not located within a pastoral lease and, as a result, is not actively grazed by livestock. Overall the vegetation condition was found to be excellent, with 51% and 36% assessed as being in excellent or very good condition, respectively. The disturbance most commonly observed was the presence of weed species, with a small number of areas subject to disturbance from previous exploration activities. The majority of the Study Area has not been recently burnt, with 50% of quadrats assessed as burnt more than five years ago or with no evidence of fire and 44% burnt two to five years ago. The pattern of burning appears sporadic and localised, which is typical of fires arising during the early wet season from lightning strikes that are extinguished relatively rapidly, rather than larger scale fires that burn an extensive area before being extinguished.

Based on multivariate analysis, interpretation of aerial imagery and ground truthing, 22 vegetation communities were described and mapped within the Study Area.

One Priority 1 PEC, West Angelas Cracking-Clays, occurs extensively within the Study Area. This community is further defined as open tussock grasslands of *Astrebla pectinata*, *A. elymoides*, *Aristida latifolia* in combination with *Astrebla squarrosa* and low scattered shrubs of *Sida fibulifera*, on basalt derived cracking-clay loam depressions and flowlines. Threats to this community include; clearing for further mining expansion and future infrastructure development, weed invasion and changes in fire regimes. The vegetation unit *AlAp* was determined to be equivalent to the PEC with the species compositions found to be a good match, despite the lack of *A. elymoides* which was not recorded during the current survey. It is thought that the survey timing for tussock grasses may not have been optimal with reproductive material often being absent and identifications problematic for this group.

Assessment of the significance of the vegetation of the Study Area is constrained by the lack of mapping across the state conducted at a scale comparable to the mapping conducted during the current survey. At a scale of 1: 1,000,000 the vegetation units described by Beard (1975) within the Study Area are well represented elsewhere, and extensively represented for some vegetation types.

The vegetation units mapped in the current survey were compared to those identified in the Biota (2006) survey, in which 12 vegetation types were identified and ME Trudgen & Associates (1998) in which 54 vegetation types were identified.

The mapping boundaries of the ME Trudgen & Associates survey extended beyond that of the current survey resulting in just 29 of the 54 communities defined by ME Trudgen & Associates represented within the current Study Area.

Approximately 50% of the area surveyed by Biota falls outside of the current Study Area, although, of the 12 units described by Biota, 10 identified in the current survey match well and have been interpreted to be equivalent.

Vegetation is also of conservation significance if it has "a role as a key habitat for threatened species" (EPA 2004, page 30). *Lepidium catapycnon* (T) appears to have a high specificity to the vegetation unit *SggIrTw,* rocky hillslopes, which supports 100% of all plants recorded. Although present in 10 vegetation units, *Aristida jerichoensis* var. *subspinulifera* (P1) demonstrates a higher specificity to unit *AaSlTp* (sandy undulating plains) with 40.9% of locations and 57.9% of individuals recorded within this unit. *Indigofera* sp. Gilesii (M.E. Trudgen 15869) demonstrates specificity for the vegetation unit *SggTp,* rocky midslopes, with 47.8% of all locations and 31.9% of individuals recorded within this unit.

Vegetation communities that are groundwater dependent are regionally important and also of conservation significance. Vegetation unit *AaPoTt* supports variable densities of *E. victrix* and therefore may represent a vadophytic ecosystem (i.e. supporting plants that rely on moisture in the upper soil profile) or occasionally phreatophytic (dependent on groundwater), and on this basis has been qualified as a GDE.

In a local context vegetation can be considered significant if it is locally uncommon or provides habitats of local significance. Vegetation of local significance is not legislatively protected but is of conservation value if areas are restricted and have not been identified to occur outside the Study Area, and such conservation significance is typically a consideration for environmental impact assessments. The least extensive vegetation units locally are *AaEffTp* (141.54 ha) and *AmTw* (108.7 ha), which represent 0.80 % and 0.62% of the Study Area, respectively.

Conclusions

Of the 13 threatened and priority taxa recorded, *Lepidium catapycnon*, *Aristida jerichoensis* var. *subspinulifera*, *Brachyscome* sp. Wanna Munna Flats (S. van Leeuwen 4662), *Brunonia* sp. long hairs (D.E. Symon 2440) and *Aristida lazaridis* appear to be the most restricted in distribution, with only 14, six, ten, three and three other West Australian Herbarium records, respectively. Only *Lepidium catapycnon* and *Aristida lazaridis* have one record each within Conservation Reserves, and therefore all of the remaining significant taxa are poorly represented within the Conservation Estate, which adds to their vulnerability.

Vegetation unit *SggIrTw* (rocky hilltops) supports *Lepidium catapycnon* (T) and is therefore of conservation significance and could be the focus of further targeted surveys.

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1 INTRODUCTION

Rio Tinto (RT) requires a series of biological surveys in order to support a strategic assessment of the Greater West Angelas Project, which includes a series of iron ore deposits in the Pilbara region of Western Australia.

RT is currently conducting preliminary feasibility studies for the development of ore deposits C, D, D extension, G, F, H and Mt Ella, collectively termed the Greater West Angelas Study Area (herein referred to as 'the Study Area') located approximately 105 km north-east of Newman (Figure 1.1). The Study Area comprises of three disjointed areas covering a total of 17,565 ha, is situated on RT exploration leases and encompasses the borefield supplying water to West Angelas Mine. The Survey Area does not support any pastoral leases.

As part of the series of biological surveys, *ecologia* was commissioned to conduct a two phase, Level 2 survey of the flora and vegetation of the Survey Area. This survey will provide baseline data which may be supplemented with additional studies, should approval to mine be sought in the future.

1.1 LEGISLATIVE FRAMEWORK

Commonwealth and State legislation applicable to the conservation of native flora and fauna in Western Australia includes, but is not limited to, the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), the Western Australian *Wildlife Conservation Act 1950* (WC Act) and the*Environmental Protection Act 1986* (EP Act).

Section 4a of the EP Act requires that developments take into account the following principles applicable to native flora and fauna:

- The 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.

- The Principles of Intergenerational Equity

  The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.

- The Principle of the Conservation of Biological Diversity and Ecological Integrity

  Conservation of biological diversity and ecological integrity should be a fundamental consideration of the project.

Furthermore, floristic surveys undertaken as part of the Environmental Impact Assessment (EIA) process are required to address the following:

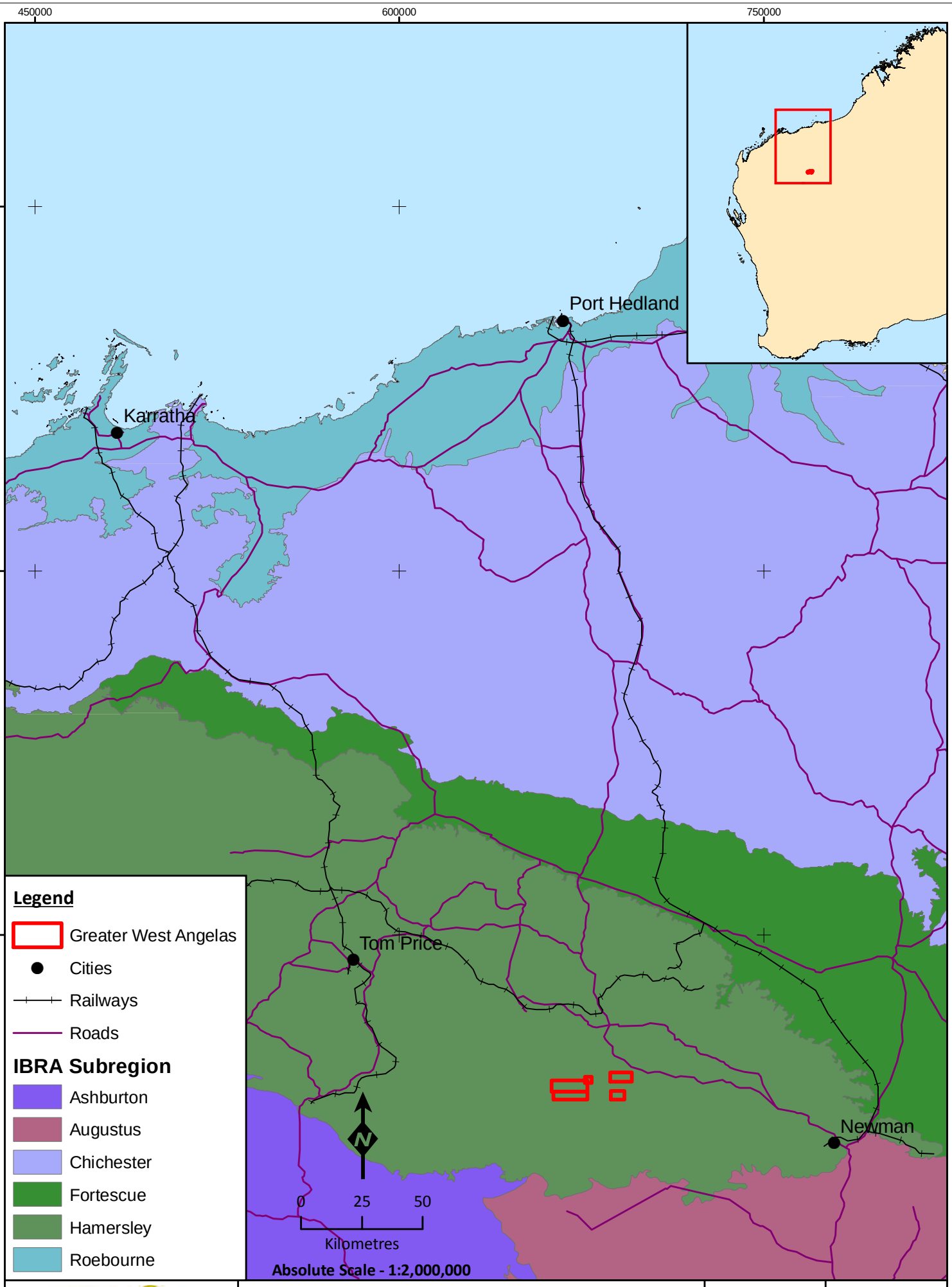
- Environmental Protection Authority's (EPA's) Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection (Environmental Protection Authority 2002); and

- Guidance Statement No. 51: Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia (Environmental Protection Authority 2004).

The EPBC Act was developed to provide for the protection of the environment, especially those aspects of the environment that are matters of National Environmental Significance, to promote

ecologically sustainable development through the conservation and ecologically sustainable use of natural resources; and to promote the conservation of biodiversity. The EPBC Act includes provisions to protect native species (in particular to prevent the extinction and promote the recovery of threatened species) and to ensure the conservation of migratory species. In addition to the principles outlined in Section 4a of the EP Act, Section 3a of the EPBC Act includes the principle of ecologically sustainable development; that decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equity considerations.

The WC Act was developed to provide for the conservation and protection of wildlife in Western Australia. Under Section 14 of this Act, all fauna and flora within Western Australia are protected; however, the Minister may, via a notice published in the Government Gazette, declare a list of flora taxa identified as likely to become extinct, or as rare, or otherwise in need of special protection. The current listing was gazetted on 17 February 2012.



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Location of West Angelas and IBRA Subregions

Figure: 1.1	**Drawn: CP**
Project ID: 1457	**Date:04/09/2012**

Coordinate System
Name: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Unique Map ID: CP098

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1.2 SURVEY OBJECTIVES

The EPA's objectives with regard to the management of native flora and vegetation are to:

- Avoid adverse impacts on biological diversity comprising the different plants and animals and the ecosystems they form, at the levels of genetic, species and ecosystem diversity.
- Maintain the abundance, species diversity, geographic distribution and productivity of vegetation communities.
- Protect Threatened flora (formerly DRF, Declared Rare Flora) consistent with the provisions of the WC Act.
- Protect other flora species of conservation significance.

The primary objective of the surveys is to provide sufficient information to the EPA to assess the impact of the development on the vegetation, flora and fauna of the Study Area, thereby ensuring that the EPA objectives can be upheld.

Specifically, this survey was to satisfy the requirements documented in the EPA's Guidance Statement 51 and Position Statement No. 3, thus providing:

- A review of background information (including literature and database searches).
- An inventory of vegetation types and flora species occurring in the Study Area, incorporating recent published and unpublished records.
- An inventory of flora species of biological and conservation significance recorded or likely to occur within the Study Area and surrounds.
- A map and detailed description of vegetation types occurring in the Study Area.
- An appraisal of the current knowledge base for the area, including a review of previous surveys conducted in the area relevant to the current.
- A review of regional and biogeographical significance, including the conservation status of species recorded in the Study Area.
- A risk assessment to determine likely impacts of threatening processes on vegetation and flora within the Study Area.

2 EXISTING ENVIRONMENT

2.1 CLIMATE

The Study Area is located in the Pilbara region of Western Australia. The Pilbara experiences an arid-tropical climate with two distinct seasons; a hot summer from October to April and a mild winter from May to September. Temperatures are generally high, with summer temperatures frequently exceeding 40°C. Light frosts occasionally occur inland during July and August.

Rainfall is generally localised and unpredictable (some years have recorded zero rainfall), and temperatures are high, resulting in annual evaporation exceeding rainfall by as much as 500 mm per year. The majority of the Pilbara has a bimodal rainfall distribution; from December to March rains result from tropical storms producing sporadic thunderstorms. Tropical cyclones moving south also bring heavy rains. From May to June, extensive cold fronts move eastwards across the state and occasionally reach the Pilbara. These fronts usually produce only light rains. Surface water can be found in some pools and springs in the Pilbara all year round, although watercourses generally flow intermittently due to the short wet season (Beard 1975).

The nearest Bureau of Meteorology (BOM) station for which both rainfall and temperature data is available is Paraburdoo Aero (Site No. 007185), 85 km west from the western boundary of the Study Area. The location has a typical inland Pilbara climate of hot summers with sporadic summer storms and warm dry winters (Figure 2.1).

Rainfall data is available from Turee Creek Station (Site No 007083) located 45.5 km south of the southern boundary of the Study Area. Rainfall from November 2011 to March 2012 was considerably higher than the long term average at this site and occurred earlier in the season, with February the only month to record slightly below average rainfall. The rainfall received in the months preceding the first and second phases of the survey were below the monthly averages (Table 2.1). Paraburdoo received the majority of its rain later in the season (January to March 2012) with the surrounding months receiving below average rainfall (Table 2.1). Given the proximity to West Angelas, it is probable that rainfall recorded at Turee Creek is a more accurate reflection of the rainfall received by the Study Area than is rainfall at Paraburdoo. The higher than average rainfall earlier in the season and the light but continual rainfall in the months leading up to the survey determined that the survey timing was suitable.

Table 2.1 – Rainfall at Turee Creek and Paraburdoo meteorological stations

Total rainfall (mm)	Turee Creek		Paraburdoo Aero	
	Monthly total	Monthly average (1920-2012)	Monthly total	Monthly average (1974-2012)
August 2011	2	8.3	0	11.6
September 2011	0	2.9	0	3.6
October 2011	2.6	4	0	3.6
November 2011	30.2	8.5	8	8.3
December 2011	27.7	22.6	5	28.5
January 2012	126.3	41	205.2	52
February 2012	42	56.7	73.6	78.3
March 2012	72.5	34.7	77	46.4
April 2012	1.8	18.5	17.4	26.8
May 2012	0	21.6	0	16.4
June 2012	8.6	18.8	10.4	22.2
July 2012	1	10.9	1	14.6

(BOM 2011)

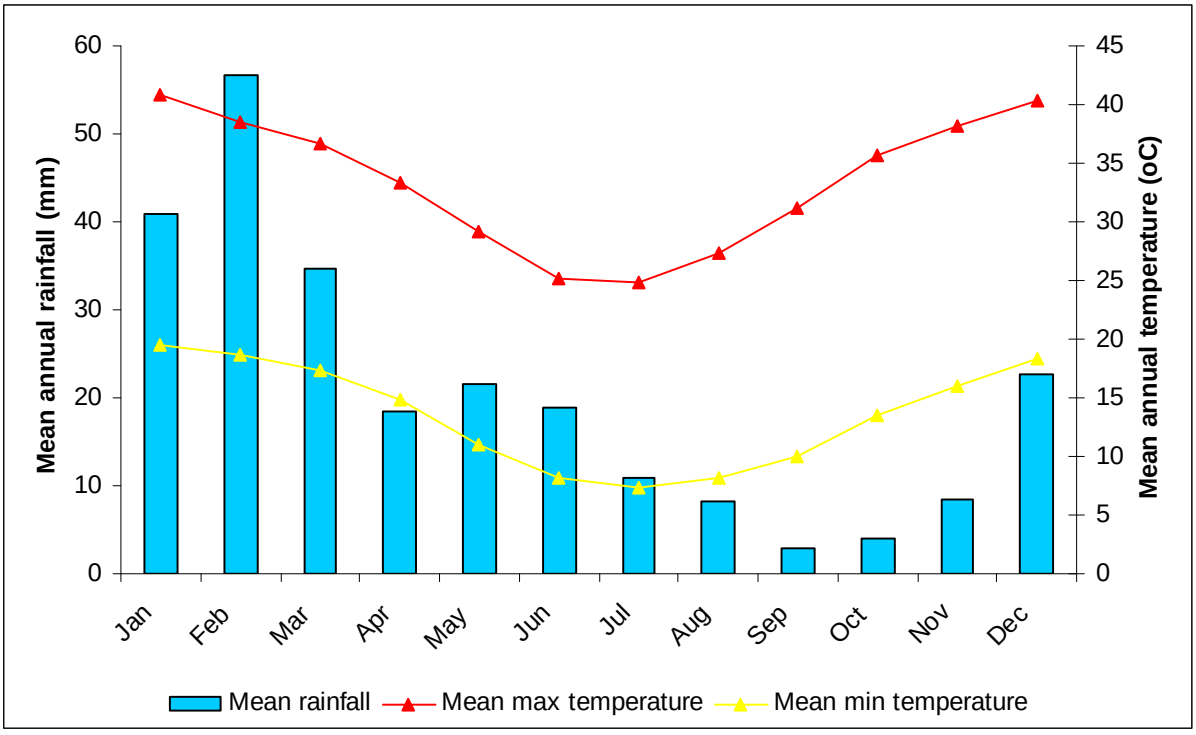


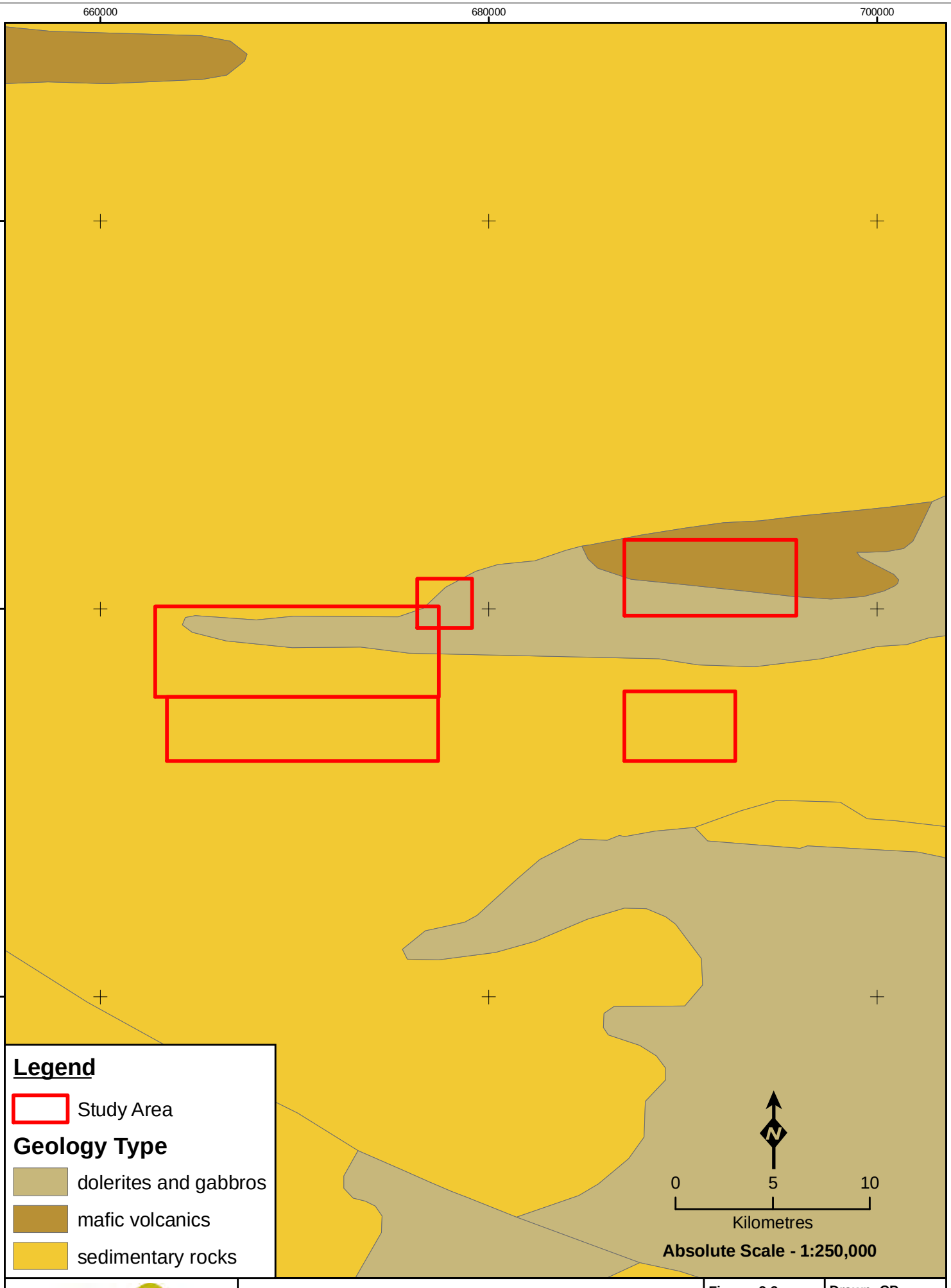
Figure 2.1 – Mean monthly climate data for Turee Creek (temperature from Paraburdoo Aero)

2.2 GEOLOGY, LAND SYSTEMS AND SOILS

2.2.1 Geology

The majority of the Pilbara is comprised of the granite terrain of the Pilbara Block in the north with the rugged sedimentary Hamersley Basin in the south and the sedimentary rocks overlain by Aeolian sands of the Canning Basin to the east. Drainage is mostly via major river catchments of the De Grey, Turner and Yule rivers in the north, and the Fortescue and Robe rivers in the west. All rivers are exoreic (i.e. flow into the ocean) with the exception of Savory Creek, which drains eastwards into Lake Disappointment (Van Vreeswyk *et al*. 2004). The geological stratigraphy in the Pilbara region is relatively continuous, with similar geological processes occurring across the region which have resulted in the enrichment of the iron deposits (Van Vreeswyk *et al.* 2004).

The main source of the magnetic mineralisation in the Pilbara is the Pincunah Formation, which is one of the prominent Banded Ironstone Formations (BIF) within the greenstone belts of the Pilbara Craton. The Study Area supports three different geological formations and these, along with the geology of the surrounding region is presented in Figure 2.2 (Hickman and Kranendonk 2008) with definitions of the geological unit codes provided in Table 2.2. The Study Area is comprised of 12.4% maffic volcanics, 66.4% sedimentary rock and 21.1% dolerites and gabbros geological units (Hickman and Kranendonk 2008).



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Geology of West Angelas Study Area

Figure: 2.2
Project ID: 1457

Drawn: CP
Date: 04/09/2012

Coordinate System
Name: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Unique Map ID: CP099

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Table 2.2 – Geology of West Angelas Study Area

Geological Code	Lith Association	Area within Study Area (km^2)	Definition of code
Ap	Mafic volcanics	21.7	Archaean period
Ab	Sedimentary rocks	116.9	Archaean – palaeoproterozoic period
Ad	dolerites and gabbros	37.0	Archaean period

2.2.2 Soils

Twenty-one broad soil groups have been identified by Van Vreeswyk *et al*. (2004) within their study defining land systems within the Pilbara. Soils are predominantly red and shallow with stony mantles.

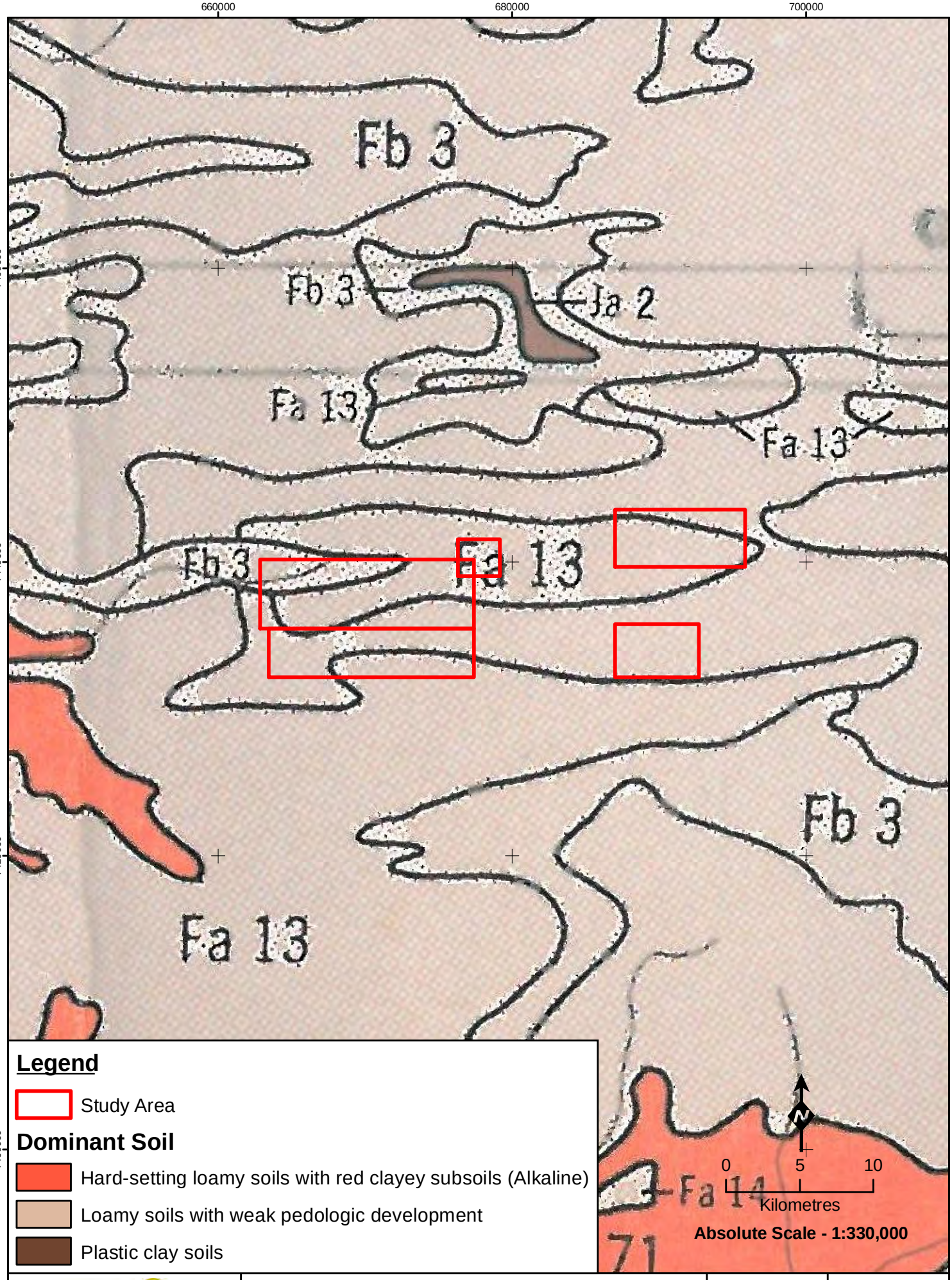
The most extensive soils in the Pilbara are shallow, stony soils on hills and ranges and sands on sandplains. In the south, the soils are predominantly red earths overlying hardpan on level to gently inclined plains. Lower flood plains have cracking and non-cracking clay soils. Duplex (texture-contrast) soils occur in localised areas on saline alluvial plains and elsewhere. These soils support the most preferentially grazed vegetation and are highly susceptible to erosion (Van Vreeswyk *et al*. 2004).

Within the Study Area, the dominant soil type is loamy soils with weak pedology (Figure 2.3) (Bettenay *et al*, 1967), which has been further classified as the following units:

Fa13: Ranges of banded jaspilite and chert along with shales, dolomites, and iron ore formations; some areas of ferruginous duricrust as well as occasional narrow winding valley plains and steeply dissected pediments. This unit is largely associated with the Hamersley and Ophthalmia Ranges. The soils are frequently stony and shallow and there are extensive areas without soil cover: chief soils are shallow stony earthy loams (Um5.51) along with some soils on the steeper slopes (Uc5.11). Associated are soils on the limited areas of dissected pediments, while (Um5.52) and (Uf6.71) soils occur on the valley plains.

Fa14: Steep hills and steeply dissected pediments on areas of banded jaspilite and chert along with shales, dolomite, and iron ore formations; some narrow winding valley plains: chief soils are shallow stony earthy loams (Um5.51) along with some (Uc5.11) soils on the steeper slopes. The (Dr2.33) and (Dr2.32) soils which occur on the pediments are more extensive than unit Fa13, while (Um5.52) and (Uf6.71) soils occur on the valley plains.

Fb3: High-level valley plains set in extensive areas of unit Fa13. There are extensive areas of pisolitic limonite deposits: ptoncipal soils are deep earthy loams (Um5.52) along with small areas of Gn2.12) soils.



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Soils of West Angelas Study Area

Figure: 2.3
Project ID: 1457
Drawn: CP
Date: 04/09/2012

Coordinate System
Name: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Unique Map ID: CP100

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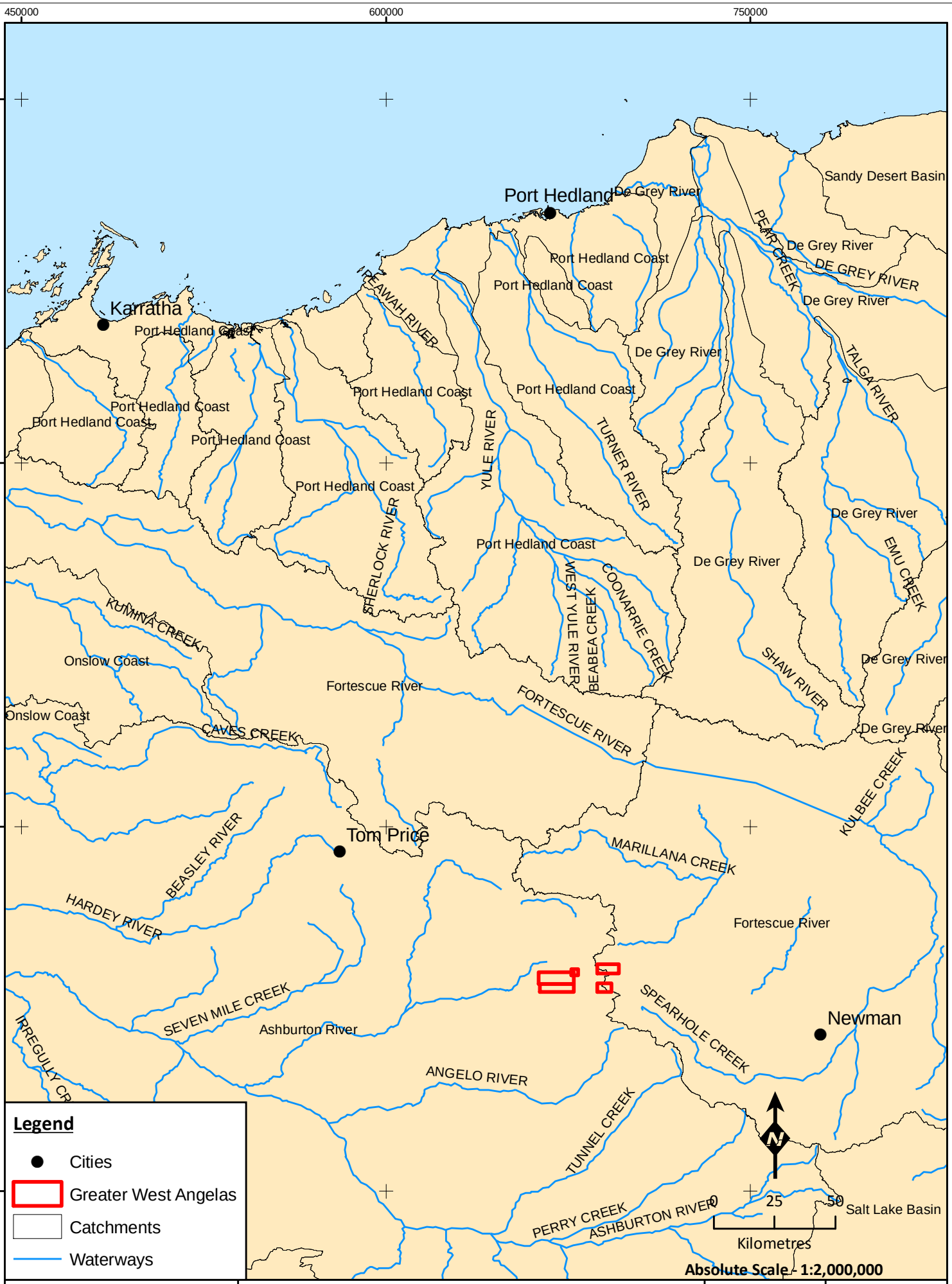
2.3 HYDROGEOLOGY

Central Pilbara groundwater occurs in the Archaean/Proterozoic basement rocks and the Cainozoic deposits. It originates from direct rainfall recharge into basement rock outcrops and indirect recharge through runoff (Johnson and Wright 2001).

The Study Area is located in the Hamersley Range, and is a part of both the Ashburton and the Fortescue Catchments. The closest creek to the Study Area is Turee Creek, a sub-tributary of the Ashburton River. Turee Creek flows west along a 4 km wide valley before turning sharply to exit the Hamersley Range (Johnson and Wright 2001). The West Angelas mine and Study Area are situated in the East Turee Creek catchment (Figure 2.4). The Turee Creek East drainage is fed by a number of smaller creeks originating in the hills to the west (Johnson and Wright 2001). The creek system is ephemeral and does not support any permanent surface-water features (Johnson and Wright 2001). The main aquifer in the area is the vuggy pisolite (Robe Pisolite) which overlies fractured basement rocks of the Woongarra volcanics and Boolgeeda Iron Formations (Johnson and Wright 2001). This aquifer lies within tertiary paleochannels and the aquifer zone varies between 50 and 80 m in thickness and has an estimated permeability of 40-80 m per day (Johnson and Wright 2001).


450000
600000
750000
7800000
7650000
7500000
7350000
Port Hedland
Karratha
Tom Price
Newman
Sandy Desert Basin
De Grey River
Port Hedland Coast
REAWIAH RIVER
PEAR CREEK
DE GREY RIVER
TALGA RIVER
YULE RIVER
TURNER RIVER
SHERLOCK RIVER
WEST YULE RIVER
BEABEA CREEK
COONARRIE CREEK
EMU CREEK
SHAW RIVER
KUMINA CREEK
Onslow Coast
Fortescue River
FORTESCUE RIVER
CAVES CREEK
KULBEE CREEK
BEASLEY RIVER
HARDEY RIVER
MARILLANA CREEK
SEVEN MILE CREEK
Ashburton River
SPEARHOLE CREEK
IRREGULLY CR
ANGELO RIVER
TUNNEL CREEK
PERRY CREEK
ASHBURTON RIVER
Salt Lake Basin
0
25
50
Kilometres
N
Legend
Cities
Greater West Angelas
Catchments
Waterways
Absolute Scale - 1:2,000,000
ecologia
ENVIRONMENT
Location of West Angelas and Regional Hydrology
Figure: 2.4
Project ID: 1457
Drawn: CP
Date:13/06/2012
Coordinate System
Name: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
Unique Map ID: CP085
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2.4 LAND USE HISTORY

2.4.1 Overview

Pastoralism is the most extensive land use in the Pilbara bioregion with 812 different pastoral leases encompassing 109,285 km^2 (61.4%) of the region. Areas set aside for conservation account for 14,763 km^2 (8.3%), consisting of the Cane River Conservation Park, Karijini and Millstream Chichester National Parks, Mungaroona Range and an unnamed Nature Reserve (LandGate, 2012). In addition, the pastoral leases of Mt Minnie and Nanutarra (adjoining the Cane River Conservation Park), Mt Florence (adjoining Karijini NP) and Meentheena have been purchased by the DEC and destocked. Although currently of informal status, these areas will ultimately be incorporated into the conservation estate, contributing a further 1.9%.

The Aboriginal reserves of Abydos, Jigalong, Woodstock and Yandeyarra, and the special lease for Aboriginal use, Callawa, occupy 10,655 km^2 (6%) of the bioregion.

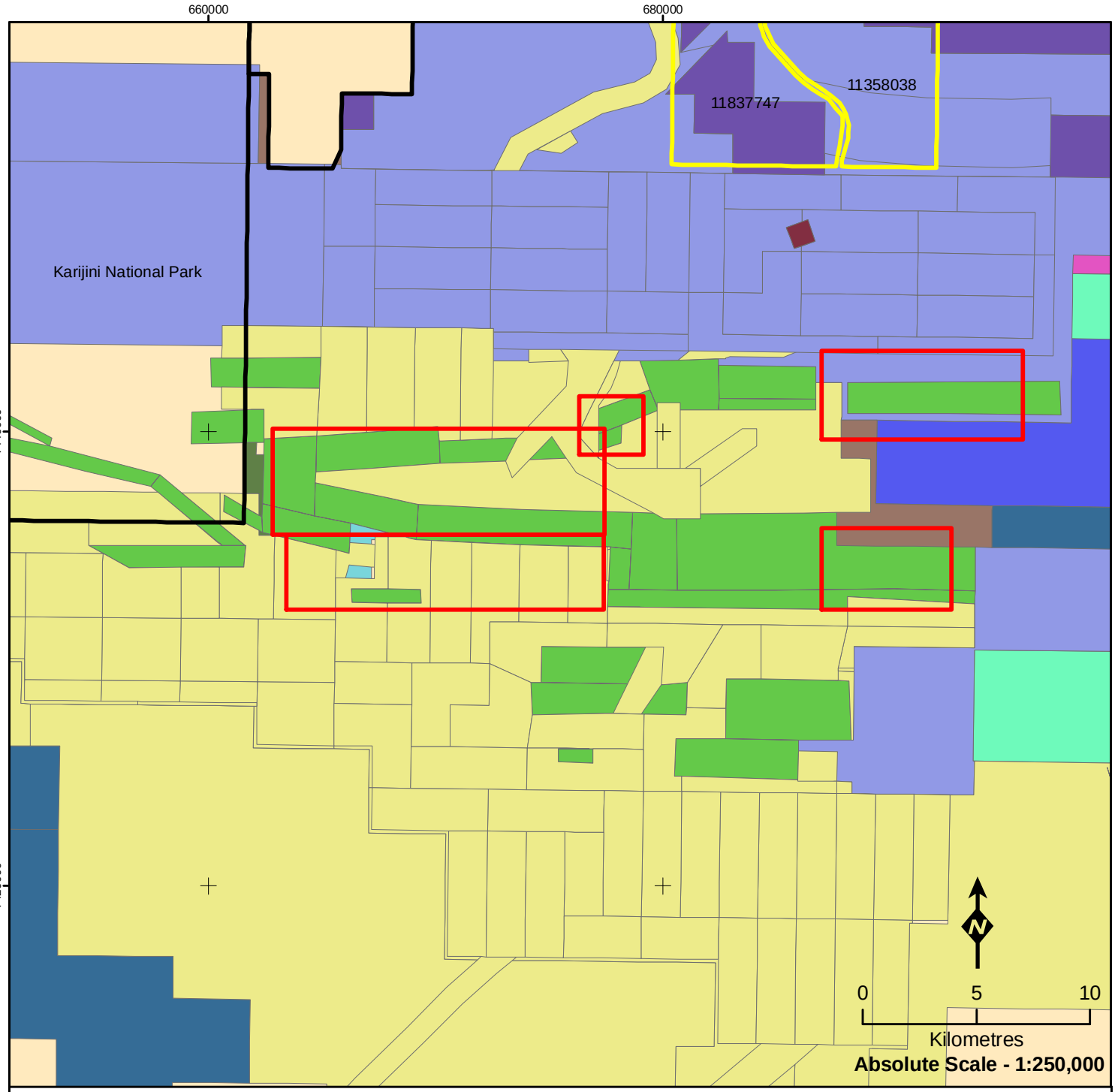
The total area of unallocated Crown land within the Pilbara bioregion is 496 km^2 (0.28%).

Mining is an important land use of ironstone ranges and greenstone belts throughout the bioregion, with development of the iron ore rich deposits accelerated in the 1960s after the Commonwealth lifted the 1938 export embargo on iron ore. Mining and exploration leases encompass 4.1% and 86% of the region, respectively. The development of the iron ore industry has resulted in activity within the Pilbara increasing from cattle and sheep stations and small coastal ports to a large mining economic base with a commensurate increase in population. In 2009, the Pilbara Development Commission reported that the Pilbara was at that time producing approximately 95% of Australia's iron ore exports, estimated at 157 Mtpa and with a value of over $5.1 billion per year (Pilbara Development Commision 2009).

Approximately 1% of the bioregion consists of town, commons and various reserves.

2.4.2 Local Land Use

The Study Area is not bound by, nor does it form part of any pastoral lease in the area. Exploration and mining leases owned by RT encompass 100% of the Study Area. As a result, the site is not subject to grazing pressure from cattle or other livestock. The Study Area (Particularly Deposit G) intersects the active West Angelas mine and infrastructure and these areas are subject to clearing and heavy vehicle traffic. All deposits in the Study Area have been subject to varying levels of clearing due to extensive resource exploration in the past during the feasibility and extent evaluation processes.



Legend

- Study Area
- Conservation Reserves
- Pastoral Lease Boundaries

Mining Tenements

- BHP BILLITON MINERALS PTY LTD
- FMG PILBARA PTY LTD
- HAMERSLEY RESOURCES LTD
- HAMERSLEY WA PTY LTD
- HOPE DOWNS IRON ORE PTY LTD
- ILMENITE RESOURCES PTY LTD
- MAMBA RESOURCE MANAGEMENT PTY LTD
- MULGA MINERALS PTY LTD
- ROBE RIVER LTD
- ROBE RIVER MINING CO. PTY LTD
- TALISMAN MINING LTD
- UNITED IRON PTY LTD
- WEST AUSTRALIAN MINISTER FOR STATE DEVELOPMENT
- WESTMAG LTD

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Local Land Use of West Angelas Study Area

Figure: 2.5
Project ID: 1457
Drawn: CP
Date: 05/09/2012

Coordinate System
Name: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Unique Map ID: CP101

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2.5 PILBARA BIOGEOGRAPHIC REGION

The Study Area is situated within the Pilbara Region of the Interim Biogeographic Regionalisation of Australia, IBRA 7 (Australian Government Department of Sustainability 2012). The Pilbara biogeographic region comprises four subregions: Hamersley, RT Plains, Chichester and Roebourne, and the Study Area lies within the Hamersley subregion (Figure 1.1). The Hamersley subregion encompasses 6,215,092 ha of the southern section of the Pilbara Craton. It is comprised of mountainous areas of Proterozoic sedimentary ranges and plateauxs, dissected by gorges (basalt, shale and dolerite). Mulga low woodland over bunch grasses on fine textured soils in valley floors, and *Eucalyptus leucophloia* over *Triodia brizoides* occur on the skeletal soils of the ranges. The climate is Semi-desert tropical, with an average 300 mm annual rainfall, usually in summer cyclonic or thunderstorm events, while winter rain is not uncommon. Drainage flows into either the Fortescue (to the north), the Ashburton to the south, or the Robe to the west (Kendrick and McKenzie 2001).

2.6 LAND SYSTEMS

The Study Area crosses the northern boundary of the area surveyed by Payne *et al* (1982) in the Regional Inventory of the Ashburton Rangelands and into the area surveyed by Van Vreeswyk *et al*. (2004) in the Regional Inventory of the Pilbara Rangelands. Both surveys documented the land systems present and their condition. Because the Survey Area intersects both Regional Inventory surveys, they will be discussed collectively for the purpose of the report. The Ashburton Regional Inventory (AIR) and Pilbara Regional Inventory (PIR) collectively cover an area of approximately 275,323 km^2, encompassing the Ashburton River and Rous Creek, part of the Yannarie River catchment, as well as the costal strip from and including Marrilla Station in the south, extending to Broome in the north-east.

Seven land systems mapped by Payne *et al* (1982) within the AIR and by Van Vreeswyk *et al*. (2004) in the PRI are present within the Study Area, each of which has been further classified by landform, soil, vegetation and drainage patterns (Table 2.3, Figure 2.6). The seven land systems within the Study Area include the Boolgeeda, Egerton, Elimunna, Newman, Platform, Rocklea and Wannamunna, with the Newman (71.4 km^2) and Boolgeeda (56.2 km^2) land systems being the most extensive.

The condition of vegetation of each land system within the AIR and PIR were also assessed. Regionally the majority of the area within each of these land systems was assessed to be in very good condition due to their inaccessibility and lack of palatable vegetation. The Elimunna and Wannamunna Land Systems are the exception, with only 39% and 44% assessed regionally as being in good or very good condition, respectively. The remaining percentage was assessed as either; fair, poor or very poor. The condition assessment for both Land Systems is due to the presence of vegetation that is attractive to grazing animals and prone to degradation if grazing pressure is excessive. The Wannamunna Land System is regionally restricted, comprising only 0.22% of the combined ARI and PRI areas surveyed by Payne *et al* (1982) and Van Vreeswyk *et al*. (2004). Within the Study Area it is also restricted, comprising only 0.3% of the total area. The area of each land system within the Study Area represents less than one percent of their individual regional distribution.

Given the aim of assessing the pastoral value of rangelands, the presence of the introduced grass **Cenchrus ciliaris* (Buffel grass) was not considered a negative indicator of condition, due to its perceived foraging value to pastoralists. However, this species is a serious environmental weed and the proportion of land systems in poor condition within an environmental context is therefore likely to be significantly higher, particularly for those land systems which support extensive stands of this species. Conversely the value of areas in which this species is not widespread is likely to be higher.

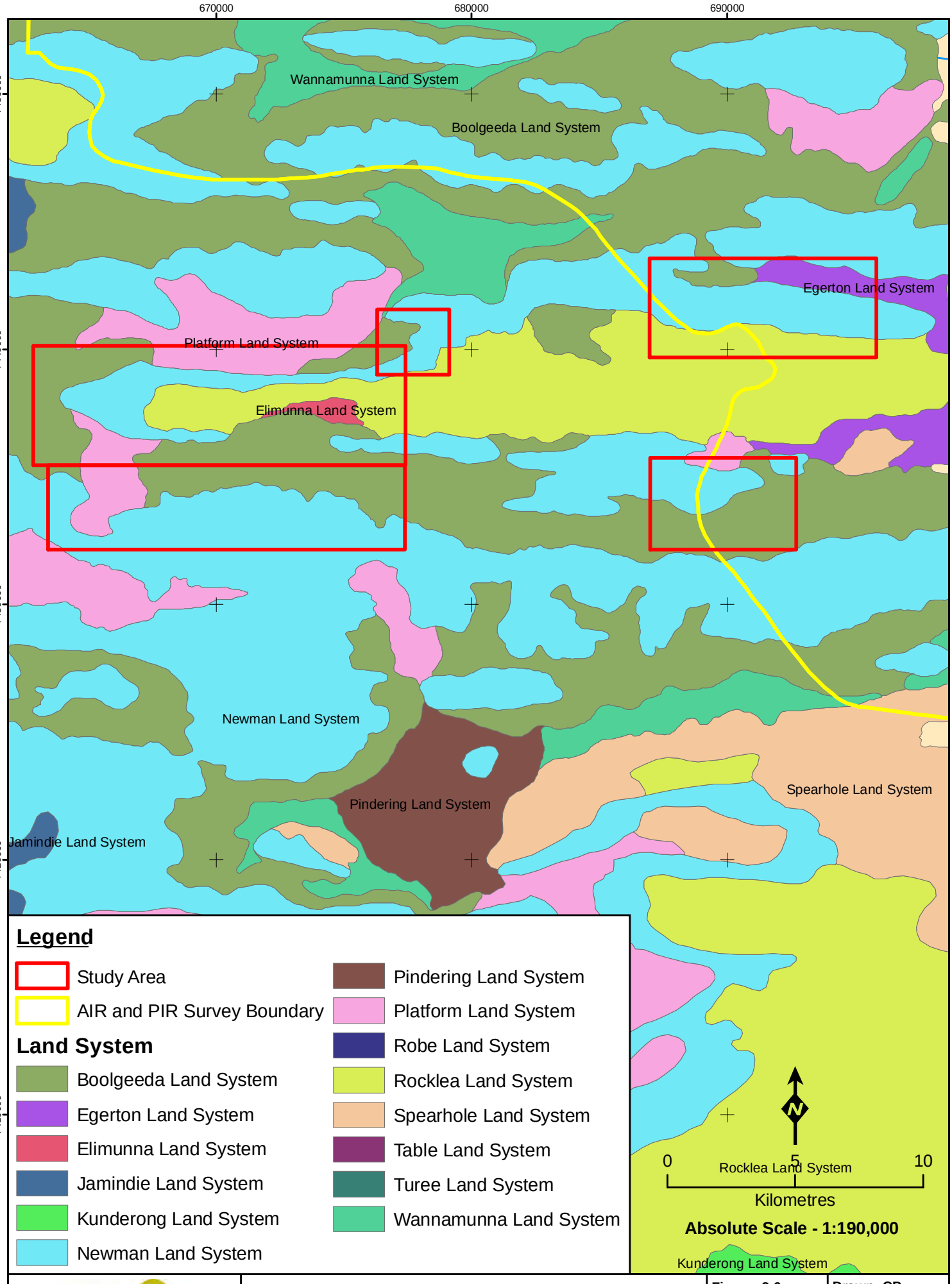
Table 2.3 – Extent of land systems present within the Study Area

Land System (% of Study Area)	Area (% of PIR and AIR combined)	Area within West Angelas Study Area (% of Land System)	Description	Vegetation Condition Assessment	Landform (and % of Land system)	Vegetation Community
Boolgeeda (32.01%)	10337 km^2 (3.8%)	56.2 km^2 (0.54%)	Stony lower slopes and plains below hill systems supporting hard and soft spinifex grasslands and mulga shrublands.	Very good 82%, good 13%, fair 4%, poor 1%. Hard spinifex grasslands not preferred by livestock.	Low hill and rises (4%)	Hummock grasslands of *T. wiseana* and other *Triodia* spp. with very scattered *Acacia* spp. Shrubs.
					Stony slope and upper plain (20%)	Hummock grasslands of *T. lanigera*, *T. wiseana* or scattered tall shrublands of *A. aneura*, *A. ancistrocarpa*, *A. atkinsiana* and other *Acacia* spp., with occasional *Eucalyptus* trees.
					Stony lower plain (65%)	Hummock grasslands of *T. wiseana*, *T. lanigera* or *T. pungens*. Also scattered to moderately close tall shrublands of *A. aneura* and other *Acacia* spp. with hard and soft *Triodia* spp. ground layer.
					Grove (small drainage foci) (1%)	Moderately closed woodlands or tall shrublands of *A. aneura* with sparse low shrubs and tussock or hummock grasses.
					Narrow drainage floor and channel (10%)	Scattered to closed tall shrublands or woodlands of *A. aneura*, *A. atkinsiana* and *C. hamersleyana* with sparse low shrubs and hummock and tussock grasses. Occasionally hummock grasslands of *T. pungens*.
Egerton (2.52%)	3868 km^2 (1.40%)	4.4 km^2 (0.11%)	Dissected hardpan plains supporting mulga shrublands and hard spinifex hummock grasslands.	Very good 89%, good 11%. Vegetation not preferred by livestock.	Hardpan plains (10%)	Very scattered to scattered tall shrublands of *Acacia aneura* and other *Acacia* spp. with prominent ground layer of *Triodia* spp.
					Dissected slopes (75%)	Hummock grasslands of *Triodia brizoides*, *T. wiseana* with isolated *Acacia* shrubs and *Eucalypt*s.
					Calcrete drainage margins (6%)	Hummock grasslands of *T. wiseana* with sparse *Eucalyptus socialis* trees or mallees and isolated low shrubs.
					Drainage floors and channels (9%)	Moderately close woodlands/tall shrublands of *A. aneura* with other shrubs including *Senna* spp., *Ptilotus obovatus* and *Eremophila forrestii* with *Triodia* spp. ground layer.
Elimunna (1.15%)	656.6 km^2 (0.24%)	2.0 km^2 (0.30%)	Stony plains on basalt supporting	Very good 14%, good 25%, fair 35%, poor	Hills and low rises (10%)	Hummock grasslands of *Triodia wiseana* (hard spinifex) or very scattered shrublands of *Acacia* and *Senna* spp.

Land System (% of Study Area)	Area (% of PIR and AIR combined)	Area within West Angelas Study Area (% of Land System)	Description	Vegetation Condition Assessment	Landform (and % of Land system)	Vegetation Community
			Sparse *Acacia* and cassia shrublands and patchy tussock grasslands.	21%., very poor, 5% Vegetation attractive to grazing animals and prone to degradation if grazing pressure is excessive.	Stony plains (45%)	Very scattered to scattered mixed height shrublands with *Acacia aneura* (mulga) other *Acacia*s, *Senna* spp. (cassias) and *Eremophila* spp Occasionally with patchy *Triodia* spp. (hard spinifex) understorey.
					Gilgai plains (26%)	Patchy tussock grasslands with *Eragrostis xerophila* (Roebourne Plains grass), *E. setifolia* (neverfail), *Astrebla pectinata* (barley Mitchell grass) with isolated shrubs mainly *Eremophila* and *Senna* spp.
					Hardpan plains (6%)	Very scattered tall shrublands of *A. aneura* and other *Acacia*s.
					Groves (1%)	Moderately close to close tall shrublands of *A. aneura* with numerous other shrubs and patchy perennial grasses.
					Drainage floors (12%)	Tussock grasslands with *Astrebla* and *Eragrostis* spp. or very scattered to moderately close tall shrublands of *Acacia* spp. with various low shrubs and patchy tussock and/or hummock grasses.
Newman (40.66%)	21109 km^2 (7.7%)	71.4 km^2 (0.34%)	Rugged jaspilite plateaux, ridges and mountains supporting hard.	Very good 91%, good 7%, fair 1%, poor 1%. Inaccessible or poorly accessible and is unsuitable for pastoral purposes.	Plateaux, ridges, mountains and hills (70%)	Hummock grasslands of *Triodia wiseana*, *T. brizoides*, *T. plurinervata* with very scattered to scattered shrubs and trees including *Acacia* and *Senna* spp., *Grevillea wickhamii*, *Eucalyptus leucophloia* and other eucalypts. Occasionally hummock grass is *Triodia biflora*.
					Lower slopes (20%)	Similar to the vegetation community above.
					Stony plains (5%)	Hummock grasslands of *Triodia wiseana*, *T.* spp. (hard spinifex) with isolated to very scattered shrubs of *Acacia* and *Senna* spp. and occasional eucalypt trees. Occasionally hummock grasslands of *Triodia pungens* (soft spinifex).
					Narrow drainage floors with channels (5%)	Smaller floors support hummock grassland of *Triodia pungens* with very scattered shrubs. Larger floors and channel support tall shrublands/woodlands of *Acacia* spp. and *Eucalyptus victrix* with tussock grass or hummock grass understoreys.

Land System (% of Study Area)	Area (% of PIR and AIR combined)	Area within West Angelas Study Area (% of Land System)	Description	Vegetation Condition Assessment	Landform (and % of Land system)	Vegetation Community
Platform (9.75%)	2552 km^2 (0.9%)	17.1 km^2 (0.67%)	Dissected slopes and raised plains supporting hard spinifex grasslands.	Very good 97%, good 3%. Vegetation on this system is not preferred by livestock and is of Very little use for pastoralism. The system is not susceptible to erosion.	Stony upper plains (25%)	Hummock grasslands of *Triodia wiseana* and other *Triodia* spp. (hard spinifex) with isolated to very scattered *Acacia* spp. shrubs
					Dissected slopes (60%)	Hummock grasslands of *Triodia wiseana*, *T. plurinervata* (hard spinifex) with isolated to very scattered *Acacia* spp. shrubs or *Eucalyptus leucophloia* (snappy gum)
					Drainage floors (15%)	Scattered to close tall shrublands/woodlands with *Acacia citrinoviridis* (black mulga), *A. tumida* (pindan wattle) and other *Acacia*s, occasional eucalypt trees, numerous low shrubs including *Senna* spp. (cassias), *Ptilotus obovatus* (cotton bush), *Corchorus walcottii* (grey Corchorus) and *Triodia pungens* (soft spinifex)
Rocklea (13.89%)	31089 km^2 (11.3%)	24.4 km^2 (0.08%)	Basalt hills, plateaux, lowers slopes and minor stony plains supporting hard spinifex (and occasionally soft spinifex) grasslands.	Very good 89%, good 7%, fair 2%, poor 2% Spinifex grasslands inaccessible and not preferred by livestock.	Hills, ridges, plateaux and upper slopes (65%)	Hummock grasslands of *T. wiseana*, *Triodia* spp. or less frequently, of *T. pungens* with isolated to very scattered shrubs such as *A. inaequilatera* and *Senna* spp.
					Lower slopes (15%)	Hummock grasslands of *T. wiseana*, *Triodia* spp. Or less frequently, of *T. pungens* with isolated to very scattered shrubs such as *A. inaequilatera* and *Senna* spp.
					Stony plains and interfluves (10%)	Hummock grasslands of *T. wiseana* or less frequently *T. pungens* with isolated to very scattered shrubs such as *A. inaequilatera*. Occasionally grassy shrublands with *Acacia*, *Senna* and *Eremophila* spp.
					Gilgai plains (1%)	Tussock grasslands with *Astrebla pectinata*, *E. xerophila* and other perennial grasses.
					Upper drainage lines (4%)	Hummock grasslands of *T. wiseana* or *T. pungens* with very scattered to scattered *Acacia* shrubs and occasional *C. hamersleyana* trees.
					Drainage floors and channels (5%)	Scattered to moderately close tall shrublands or woodlands of *Acacia* and *Eucalyptus* spp. with numerous undershrubs and hummock grass understoreys or tussock grass understoreys.

Land System (% of Study Area)	Area (% of PIR and AIR combined)	Area within West Angelas Study Area (% of Land System)	Description	Vegetation Condition Assessment	Landform (and % of Land system)	Vegetation Community
Wannamunna (0.03%)	630.1 km^2 (0.22%)	0.04 km^2 (0.006%)	Hardpan plains and internal drainage tracts supporting mulga shrublands and woodlands (and occasionally eucalypt woodlands).	Very good 19%, good 25%, fair 19%, poor 21%., very poor, 16% The system supports low shrubs and tussock grasses which are highly preferred by grazing animals and are prone to degradation if grazing pressure is excessive.	Stony plains (8%	Very scattered to scattered tall shrublands of *Acacia aneura* (mulga) with sparse low shrubs and *Triodia* sp. (hard spinifex) understorey
					Hardpan plains (56%)	Very scattered tall or low shrublands of *Acacia aneura*, *Eremophila* spp., *Ptilotus obovatus* (cotton bush), *Maireana villosa*.
					Calcrete platforms (1%)	Scattered shrublands with *Acacia aneura* and other *Acacia*s, *Senna* spp. and *Triodia wiseana* (hard spinifex)
					Groves (15%)	Moderately close to closed woodlands of *Acacia aneura* with numerous undershrubs and tussock grasses such as *Chrysopogon fallax* (ribbon grass) and *Themeda triandra* (kangaroo grass).
					Internal drainage plains (20%)	Moderately close to closed woodlands of *Acacia aneura* and *Eucalyptus victrix* (coolibah) with sparse undershrubs such as *Muehlenbeckia florulenta* (lignum) and *Chenopodium auricomum* (swamp bluebush) and patchy tussock grasses. Also grasslands of *Eriachne* sp. with isolated *Eucalyptus victrix* trees and shrubs such as *M. florulenta* or grassy scattered woodlands of *E. victrix*



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Land Systems of West Angelas Study Area

Figure: 2.6	**Drawn: CP**
Project ID: 1457	**Date: 05/09/2012**

Coordinate System
Name: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Unique Map ID: CP103

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2.7 THREATENED ECOLOGICAL COMMUNITIES

2.7.1 Commonwealth Threatened Ecological Communities

Ecological communities are naturally occurring biological assemblages associated with a particular type of habitat. At a commonwealth (national) level, flora and Threatened Ecological Communities (TECs) are protected under the EPBC Act. An ecological community may be categorised into one of three sub-categories:

- Critically endangered if it is facing an extremely high risk of extinction in the wild in the immediate future.
- Endangered if it is not critically endangered and is facing a very high risk of extinction in the wild in the near future.
- Vulnerable if it is not critically endangered or endangered, and is facing a high risk of extinction in the wild in the medium-term future.

No Commonwealth listed TECs occur in the vicinity of the Study Area.

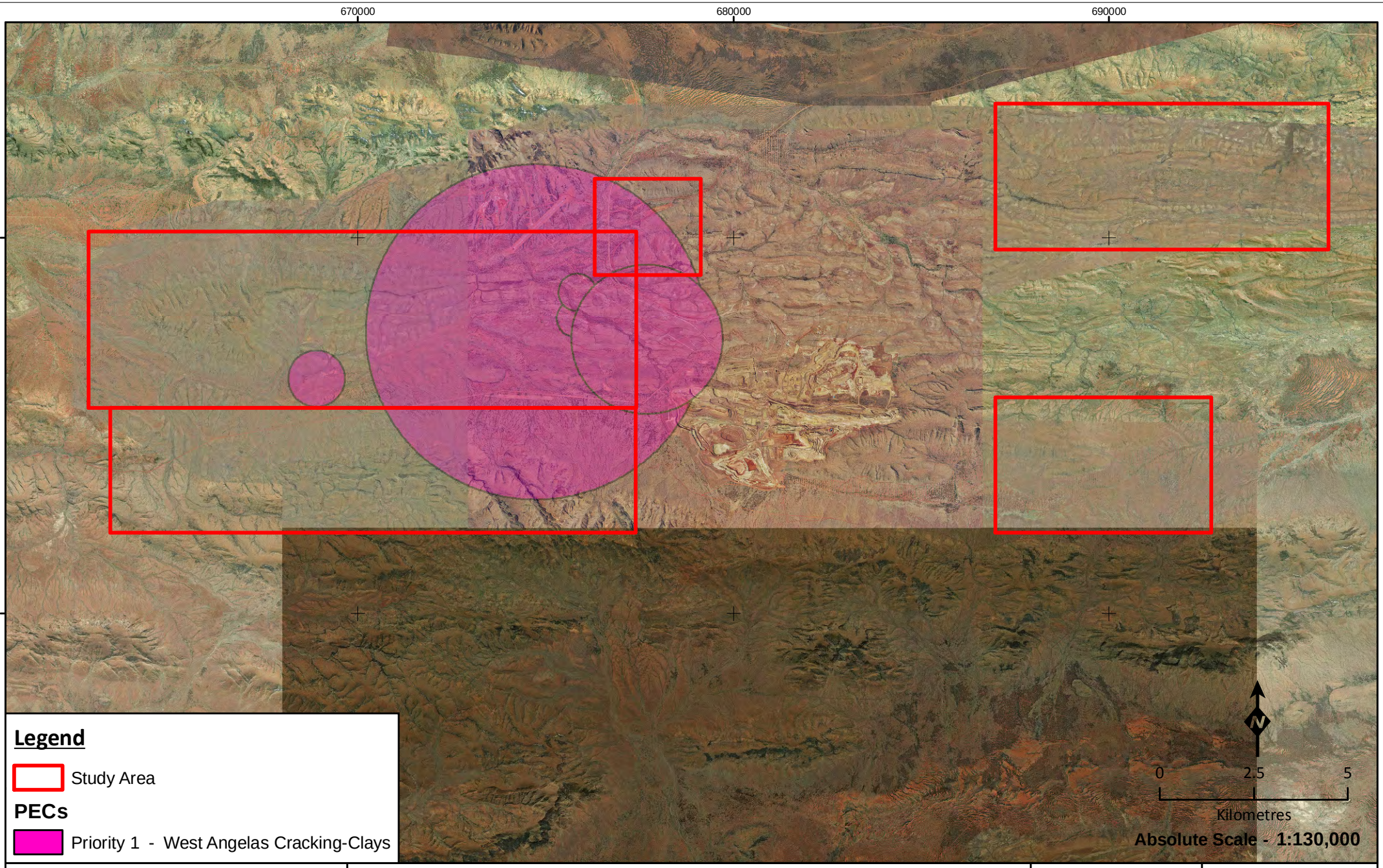
2.7.2 State Threatened Ecological Communities

The Western Australian DEC maintains a list of TECs which are further caterorised into three subcategories which replicate those of the EPBC Act, but with further definition of the threatening processes as detailed in Appendix D.

No state threatened ecological communities are located within a 40 km radius of the Study Area

2.7.3 State Priority Ecological Communities

The DEC also maintains a list of Priority Ecological Communities (PECs) which includes potential TECs that do not meet survey criteria, or that are not adequately defined. As at 13 April 2012 (Department of Environment and Conservation 2012), one Priority 1 PEC; West Angelas Cracking-Clays, has been identified to occur extensively within the Study Area (Figure 2.7). This community is further defined as open tussock grasslands of *Astrebla pectinata*, *A. elymoides*, *Aristida latifolia* in combination with *Astrebla squarrosa* and low scattered shrubs of *Sida fibulifera*, on basalt derived cracking-clay loam depressions and flowlines. Threats to this community include clearing for further mining expansion and future infrastructure development, weed invasion and changes in fire regimes.



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PECs of the West Angelas Study Area

Figure: 2.7
Project ID: 1457

Drawn: CP
Date: 20/09/2012

Coordinate System
Name: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Unique Map ID: CP138

A4

2.8 PREVIOUS VEGETATION SURVEYS

2.8.1 Beard Vegetation Descriptions

The Study Area lies within the area mapped by Beard (1975) within the Pilbara region of the Eremaean Botanical Province. The vegetation mapping was subsequently reinterpreted to reflect the National Vegetation Information System (NVIS) (Department of Environment and Water Resources 2012) standards, taxonomy revised where required and digitised (Shepherd *et al*. 2001). Two vegetation units have been mapped within the Study Area, the distributions and features of which are detailed in Figure 2.8 and Table 2.4, respectively.

Table 2.4 – Vegetation association codes.

Code	Structure	Vegetation Association	Species
18	Low woodland; mulga (*Acacia aneura*)	*Acacia* open shrubland / *Ptilotus* mixed open forbland	*Acacia aneura*, *Acacia pru*inocarpa, *Acacia aneura* var. *aneura Eremophila fraseri*, *Eremophila foliosissima*, *Eremophila exilifolia Senna* sp., *Solanum lasiophyllum*, *Ptilotus obovatus*.
82	Open hummock grassland	Hummock grasslands, low tree steppe; snappy gum over *Triodia wiseana*	*Eucalyptus leucophloia*, *Eucalyptus gamophylla*, *Senna artemisioides subs*p. x *sturtii*, *Dodonaea viscosa*, *Grevillea wickhamii*, *Triodia wiseana*, *Ptilotus rotundifolius*, *Acacia lycopodiifolia* and *Triodia wiseana*.

2.8.2 Finer Scale Vegetation Surveys

In recent history, strong iron ore prices have resulted in a boom in resource development projects in the Pilbara which has resulted in a significant increase in biological survey effort for the Bioregion. *ecologia* has reviewed previous survey data ranging from 1979 to the present day. During this period, the Greater West Angelas area has been subject to a series of previous vegetation, targeted flora and monitoring surveys. Infrastructure triggering previous vegetation surveys included: railway lines, gas pipelines, power stations, borefields and viable ore deposits. The most relevant spatial and temporal surveys to the current study are summarised in table Table 2.5.

Table 2.5 – Previous Vegetation Surveys at Greater West Angelas

Author	Survey	Year
ENV. Australia	Flora, Vegetation and Fauna Assessment of the Re-Aligned Gas Pipeline Corridor at West Angelas	2011
Rio Tinto	Flora and Vegetation Assessment of the West Angelas water pipeline Study Area	2011
Rio Tinto	Statement Addressing the 10 CP for West Angelas Power Station and Borrow Pits	2011
Biota Environmental Sciences	A Flora and Vegetation Survey of the Proposed West Angelas Gas-Fired Power Station and Pipeline Corridor	2010
Rio Tinto	Flora and Vegetation Assessment of the Proposed West Angelas Discharge Creekline Corridor (WADCC)	2009
ecologia Environment	West Angelas Multiple Areas Flora and Vegetation Survey & Desktop Fauna Assessment	2008
Biota Environmental Sciences	Vegetation and Flora Survey of West Angelas Deposits E and F	2006
Biota Environmental Sciences	Vegetation and Flora Survey of West Angelas Deposits E & F	2005
ME Trudgen & Associates	Flora & Vegetation Surveys of Orebody A & B in the West Angelas Hill Area	1998 (1995)

Of the surveys summarised in Table 2.5, the vegetation mapping conducted by Biota Environmental Sciences in 2006 and 2010 (Biota 2006, Biota 2010) and ME Trudgen & Associates (1998) are of particular relevance. These three are also quadrat based flora and vegetation assessments that encompass areas within and adjacent to the current Study Area.

The Biota survey, "Flora and Vegetation Survey of the Proposed West Angelas Gas-Fired Power Station" (Biota 2010), was a single phase Level Two flora and vegetation survey. A total of 262 taxa from 93 genera and 35 families were recorded from a combination of 37, 50 x 50 m bound quadrats and targeted searches.

Earlier, in 2006 Biota completed; "Flora Survey of West Angelas Deposits E and F" (Biota 2006), where 24 detailed flora quadrats and 17 releves, as well as observations in the field were used to record a total of 429 taxa of native vascular flora from 143 genera belonging to 53 families.

ME Trudgen & Associates (1998) mapped a large proportion of the current Study Area in "Flora & Vegetation Surveys of Orebody A & B in the West Angelas Hill Area" where 635 taxa were recorded.

Table 2.6 summarises the vegetation units of the three surveys mapped within the current Study Area. The most abundant unit from the ME Trudgen & Associates (1998) survey was vegetation unti *5edb,* covering 2,536.25 ha of the Study Area. In the 2006 survey conducted by Biota the most abundant vegetation unit was *H1*, *Eucalyptus leucophloia* low open woodland over *Acacia maitlandii*, *A*. *hamersleyensis* shrubland over *Triodia pungens* (*T*. *wiseana*) mid-dense hummock grassland, covering an area of 206.08 ha.

The most restricted vegetation units within the Study Area were units *6adb212* (0.06 ha) and *6adb213* (0.35 ha) from the ME Trudgen & Associates (1998) survey and unit *CdAanAprTsTp* (0.91 ha), *Corymbia deserticola*, *Acacia aneura*, *A. pruinocarpa* low open woodland over *Triodia sch*inz*ii*, *T. pungens* hummock grassland, from the Biota (2010) survey.

Table 2.6 – Summary of Vegetation Units of Previous Studies Within the Study Area

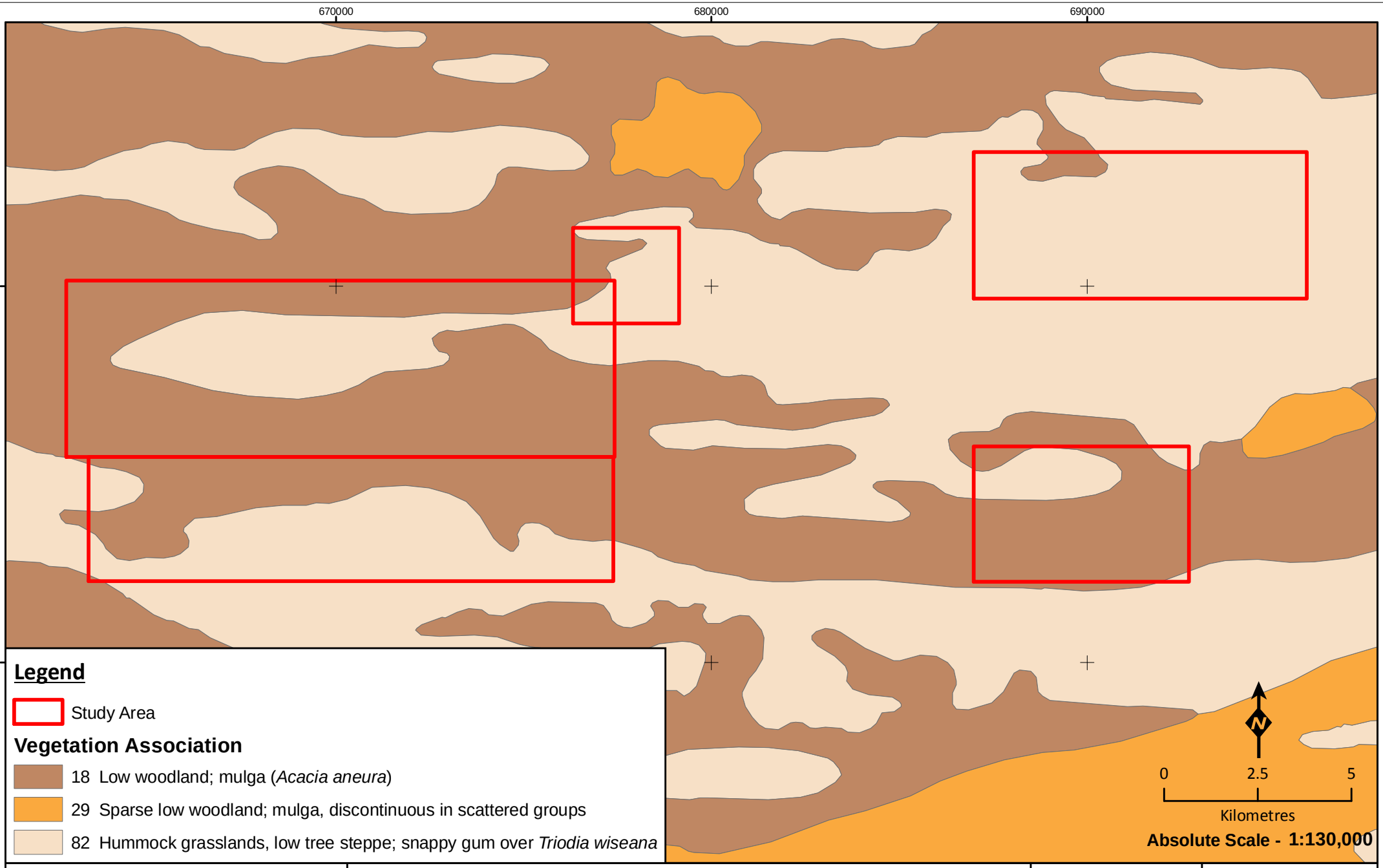
Biota (2010)			Biota (2006)			ME Trudgen & Associates(1998)		
Unit	**Description**	**Area (ha)**	**Unit**	**Description**	**Area (ha)**	**Unit**	**Description**	**Area (ha)**
AanAprRHeE RfoTHtTlo	*Acacia aneura*, *A. pruinocarpa* low woodland over *Rhagodia eremaea*, *Eremophila forrestii* open shrubland over *Themeda triandra* open *tussock* grassland, *Triodia longiceps* scattered hummock grasses	34.28	*C1*	*Eucalyptus* spp. scattered low trees over *Acacia maitlandii*, *Gossypium robinsonii*, *Petalostylis labicheoides* shrubland over *Triodia pungens* open hummock grassland *and Eriachne mucronata*, *Themeda triandra* open *tussock* grassland	40.38	*2cab*	*Eucalyptus xerothermica* low open woodland over *Acacia pruinocarpa* scattered tall shrubs over *Maireana* spp. Scattered low shrubs over *Triodia pungens* open hummock grassland with *Themeda triandra* scattered tussock grass	576.73
AanAprTbrTp	*Acacia aneura*, *A. pruinocarpa* tall open shrubland over *Triodia brizoides*, *T. pungens* hummock grassland	32.48	*C2*	*Eucalyptus xerothermica* low open woodland over *Acacia maitlandii*, *Petalostylis labicheoides*, *Rulingia luteiflora* shrubland to tall shrubland over *Triodia pungens* open hummock grassland	10.09	*2cac*	*Eucalyptus xerothermica* scattered low trees over *Acacia aneura* var. *longicarpa* and *Acacia* aff. *aneura* high shrubland over *Themeda triandra* and *Chrysopogon fallax* very open tussock grassland with *Triodia pungens* and *Triodia wiseana* scattered hummock grass	272.04
AanAprTp/AanTp	*Acacia aneura*, *A. pruinocarpa* tall open *scrub* over *Triodia pungens very* open hummock grassland; occurring in mosaic with groves of *Acacia aneura* low open *forest* over *Triodia pungens* hummock grassland	10.79	*H1*	*Eucalyptus leucophloia* low open woodland over *Acacia maitlandii*, *A. hamersleyensis* shrubland over *Triodia pungens (T. wiseana)* mid-dense hummock grassland	206.08	*5eda*	*Corymbia deserticola* scattered low trees over *Acacia bivenosa*, *Acacia pruinocarpa* and *Hakea chordophylla* scattered tall shrubs over *Cassia prunosa* scattered shrubs over *Triodia* aff. *basedowii* and *Triodia pungens* open hummock grassland	1,798.74
AanApyTHt	*Acacia aneura* low open woodland over *A. pyrifolia* scattered tall *shrubs* over *Themeda triandra tussock* grassland	21.88	*H2*	*Acacia catenulata* low woodland over *Triodia pungens* mid-dense hummock grassland	4.54	*5edac*	*Eucalyptus gamophylla* scattered low trees over *Acacia bivenosa*, A. pyrifolia scattered tall shrubs over *Triodia pungens* open hummock grassland	132.06
AanArERfoTp	*Acacia aneura* low woodland over *A. rhodophloia*, *Eremophila forrestii*, open shrubland over *Triodia pungens* open hummock grassland	8.23	*H3*	*Corymbia ferriticola*, *Eucalyptus leucophloia* low open woodland over *Triodia* sp. *Mt Ella*, *T. pungens* hummock grassland *and Eriachne mucronata* open *tussock* grassland	45.18	*5edacl*	*Eucalyptus gamophylla* scattered low trees over *Acacia bivenosa* scattered tall shrubs over *Triodia pungens* and *Triodia longiceps* open hummock grassland.	47.95

Biota (2010)			Biota (2006)			ME Trudgen & Associates(1998)		
Unit	**Description**	**Area (ha)**	**Unit**	**Description**	**Area (ha)**	**Unit**	**Description**	**Area (ha)**
AanArGbERf oERpCAsTp	*Acacia aneura* low woodland over *A. rhodophloia*, *Grevillea berryana* scattered tall *shrubs* over *Eremophila phyllopoda*, *E.* sp., *Cassia stricta* low open shrubland over *Triodia pungens very* open hummock grassland	21.31	*H4*	*Eucalyptus leucophloia* low open woodland over *Triodia wiseana* mid-dense hummock grassland *and Themeda triandra tussock* grassland	1.09	*5edad*	*Eucalyptus gamophylla* scattered low trees over *Acacia bivenosa* and *Acacia pyrifolia* scattered tall shrubs over *Triodia pungens* and *Triodia longiceps* open hummock grassland	665.01
AbApyTp	*Acacia bivenosa*, *A. pyrifolia* shrubland over *Triodia pungens* hummock grassland	1.50	*H5*	*Eucalyptus gamophylla* low woodland over *Triodia* aff. *basedowii (T. pungens)* mid-dense hummock grassland	111.44	*5edae*	*Scaervola acacioides* open shrubland over *Triodia pungens* open hummock grassland	296.24
AciTHtTp	*Acacia citrinoviridis* tall shrubland over *Themeda triandra* open *tussock* grassland over *Triodia pungens* scattered hummock grasses	38.86	*M1*	*Acacia aneura* low open woodland over *Acacia bivenosa*, *Gossypium robinsonii*, *Sida* aff. *cardiophylla*, *Scaevola parvifolia* shrubland to low open shrubland over *Triodia pungens*, *T. schinzii* mid-dense hummock grassland	184.02	*5edaf*	*Acacia aneura* var. *longicarpa* and *Acacia rhondophloia* high shrubland over *Eremophila fraseri* ssp. *fraseri*, *Eremophila lachnocalyx* and *Eremophila exilifolia* shrubland over *Triodia pungens* open hummock grassland	194.01
AiTbrTw	*Acacia* in*aequilatera* tall shrubland over *Triodia brizoides*, *T. wiseana* hummock grassland	60.56	*M2*	*Acacia aneura* low open woodland over *Triodia pungens*, *T.* aff. *basedowii* mid-dense hummock grassland	22.81	*5edag*	*Corymbia ferriticola* ssp. *ferriticola* low open woodland over *Acacia pruinocarpa* and *Acacia aneura* var. *aneura/ intermedia* high open shrubland over *Harneria kempeana* ssp. *muelleri* and *Ptilotus obovatus* shrubland over *Triodia pungens* and *Plectrachne melvillei* very open hummock grassland with *Themeda triandra* scattered tussock grassland.	24.22
AprAanAwTp	*Acacia pru*inocarpa, *A. aneura* tall open *scrub* over *A. wanyu* scattered *shrubs* over *Triodia pungens* hummock grassland	47.20	*M3*	*Acacia aneura* woodland over *Maireana villosa*, *Ptilotus obovatus*, *Rhagodia* sp. *Hamersley* open to low open shrubland over *Triodia* sp. *Mt Ella* open hummock grassland	129.84	*5edb*	*Acacia ayersiana*, *Acacia* aff. *aneura* (narrow green), *Acacia* Aff. *catenulata*, *Acacia* aff. *aneura* (grey, bushy form) and *Acacia* aff. *aneura* (scythe-shaped) high open shrubland over *Maireana* spp. low scattered shrubs over *Triodia pungens* very open hummock grassland	2,536.25
AprAciApyTp	*Acacia pru*inocarpa, *A. citrinoviridis*, *A.*	17.64	*M4*	*Acacia aneura*, *A. pruinocarpa* low *closed forest*	66.28	*5edbw*	*Eucalyptus leucophloia, Corymbia*	913.81

Biota (2010)			Biota (2006)			ME Trudgen & Associates(1998)		
Unit	**Description**	**Area (ha)**	**Unit**	**Description**	**Area (ha)**	**Unit**	**Description**	**Area (ha)**
	pyrifolia open shrubland over *Triodia pungens* hummock grassland			to low woodland over *Eremophila forrestii*, *E. longifolia*, *Ptilotus obovatus*, *Rhagodia* sp. *Hamersley* low open shrubland to open shrubland over *Triodia pungens* open hummock grassland			*hamersleyana* and *Eucalyptus pilbarensis* scattered low trees over *Acacia pruinocarpa* and *Acacia rhodophloia* scattered tall shrubs over *Ptilotus obovatus* scattered shrubs over *Triodia wiseana* and *Triodia pungens* hummock grassland	
AprAiTw	*Acacia pruinocarpa*, *A.* in*aequilatera* open shrubland over *Triodia wiseana* hummock grassland	50.13	*M5*	*Acacia aneura* low *closed forest* over *Triodia pungens* mid-dense hummock grassland	32.32	*5kd3r*	*Eucalyptus leucophloia* low open woodland over *Acacia pruinocarpa* scattered tall shrubs over *Triodia pungens* open hummock grassland.	885.70
ApyAciTp	*Acacia pyrifolia*, *A. citrinoviridis* tall shrubland over *Triodia pungens* open hummock grassland	2.46				*5kd3w*	*Eucalyptus leucophloia* low open woodland over *Triodia wiseana* open hummock grassland with *Eriachne mucronata* scattered tussock grass	15.50
AteTbr	*Acacia tenuissima* scattered *shrubs* over *Triodia brizoides* hummock grassland	17.78				*5kdm1*	*Eucalyptus leucophloia* scattered low trees over *Triodia* aff. *basedowii* and *Triodia pungens* open hummock grassland	687.41
CdAanAprTsTp	*Corymbia deserticola*, *Acacia aneura*, *A. pruinocarpa* low open woodland over *Triodia schinzii*, *T. pungens* hummock grassland	0.91				*5kdm2*	*Eucalyptus leucophloia* and *Corymbia hamersleyana* low open woodland over *Acacia maitlandii* scattered shrubs over *Triodia wiseana* open hummock grassland	1.16
ChAciGwRUlTp	*Corymbia hamersleyana*, *Acacia citrinoviridis* low woodland over *Grevillea wickhamii*, *Rulingia luteifolia* shrubland over *Triodia pungens* hummock grassland	23.19				*5kdm3*	*Eucalyptus leucophloia* scattered low trees over *Acacia pruinocarpa* scattered tall shrubs over *Triodia pungens* open hummock grassland	36.71
Disturbed	Cleared of native vegetation	4.53				*5kdmaf*	*Eucalyptus leucophloia* and *Corymbia ferriticola* low woodland over *Acacia pruinocarpa* and *Acacia anuran* var. *longicarpa* high open shrubland over *Ptilotus obovatus* and *Olearia stuartii* low open shrubland over *Triodia pungens* open hummock grassland	30.84

Biota (2010)			Biota (2006)			ME Trudgen & Associates(1998)		
Unit	**Description**	**Area (ha)**	**Unit**	**Description**	**Area (ha)**	**Unit**	**Description**	**Area (ha)**
EgAiAprAbTp	*Eucalyptus gamophylla*, *Acacia* in*aequilatera*, *A. pruinocarpa*, *A. bivenosa* open shrubland over *Triodia pungens* hummock grassland	19.26				*6/2ef*	*Eucalyptus victrix* open woodland over *Acacia aneura* var. *longicarpa* scattered tall shrubs over *Enneapogon* sp. and *Eriachne benthamii* tussock grassland over *Eragrostis pergracilis* and *Aristida contorta*	508.84
ElCdAiTbrTp	*Eucalyptus leucophloia*, *Corymbia deserticola* scattered trees over *Acacia* in*aequilatera* open shrubland over *Triodia brizoides*, *T. pungens* hummock grassland	8.00				*6adb212*	*Acacia* aff. *aneura* (narrow, green; M.E.T. 15,850), *Acacia* aff. *catenulata, Acacia* aff. *ayersiana* (narrow form; M.E.T. 15,786) and *Acacia ayersiana* high shrubland over *Plectrachne melvillei* and *Triodia pungens* scattered hummock grassland	0.06
EvAciTHtEUaCYaTp	*Eucalyptus victrix*, *Acacia citr*inoviridis low woodland over *Themeda triandra*, *Eulalia aurea*, *Cymbopogon ambiguus* open *tussock* grassland, *Triodia pungens* hummock grassland	3.76				*6adb213*	*Acacia* aff. *aneura* (scythe-shaped; MET 15,743), *A. pruinocarpa*, A. aff. *aneura* (grey, bushy form; MET 15,732 high shrubland over *Eremophila forrestii* subsp. *forrestii* scattered shrubs over *Triodia pungens* very open hummock grassland	0.35
						6adb215	*Aristida contorta* open annual tussock grassland	13.17
						6adb231	*Acacia* aff. *aneura* (grey, bushy form; M.E.T. 15,732) and *Acacia aneura* var. *longicarpa* high open shrub land over *Triodia pungens* very open hummock grassland	627.79
						6adb232	*Acacia aneura* var. *longicarpa* high shrubland over *Rhagodia* sp. Hamersley, *Ptilotus obovatus* open shrubland over *Digitaria brownii* scattered tussock grassland	1.09
						6adb26	*Acacia* aff. *aneura* and *Acacia pruinocarpa* scattered tall trees over *Maireana* spp. scattered low shrubs	167.00

Biota (2010)			Biota (2006)			ME Trudgen & Associates(1998)		
Unit	**Description**	**Area (ha)**	**Unit**	**Description**	**Area (ha)**	**Unit**	**Description**	**Area (ha)**
							over *Triodia pungens* open hummock grassland with *Themeda triandra* scattered tussock grass	
						8bj	*Acacia aneura* var. *longicarpa* and *Acacia pruinocarpa* high open shrubland over *Acacia pyrifolia* and cassia *oligophylla* scattered shrubs over *Triodia wiseana* and *Triodia pungens* open hummock grassland	947.73
						8bja	*Eremophila fraseri spp. fraseri* and *Acacia pyrifolia* scattered shrubs over *Triodia wiseana* open hummock grassland	3.12
						8db/8dc	*Astrebla pectinata*, *Astrebla elymoides* and *Aristida latifolia* open tussock grassland	239.13
						8dd	*Sida fibulifera* low scattered shrubs over *Astrebla squarrosa* tussock grassland	11.12
						11kb	*Acacia* sp., *Acacia pyrifolia* and *Acacia bivenosa* scattered shrubs over *Triodia wiseana* open hummock grassland	139.81



ecologia ENVIRONMENT

Shepherd *et al.* (2001) Vegetation Units of West Angelas Study Area

Figure: 2.8
Project ID: 1457

Drawn: CP
Date: 16/10/2012

Coordinate System
Name: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Unique Map ID: CP104

A4

2.8.3 Previous Records of Priority Flora at West Angelas

Searches of the DEC database, the Department's Threatened Flora Database (DEFL) and the Western Australian Herbarium's specimen database were conducted for all records within a polygon encompassing the West Angelas Study Area and a 40 km buffer zone. In addition, the published Threatened and Priority Taxa listing was searched for records for which the named location is within the search area. The latter search is less precise as no coordinates are provided for records retrieved.

Two EPBC listed, Threatened Flora (Declared Rare Flora) have previously been recorded within the search area: *Thrypt*o*mene wittweri* from the location-based search of the Threatened and Priority listing and *Lepidium catapycnon* from the spatial DEFL and Western Australian Herbarium searches. Twenty nine other Priority flora were also recoded in the location based search and 37 additional records resulted within the 40 km spatial database search area. Thirteen locations of *Lepidium catapycnon* are present within the 40 km search area, with the closest falling within 4 km of the Study Area boundary (Figure 2.9).

A review of RT spatial data and the DEC database revealed that 11 species of Priority flora were observed to occur within the Study Area; *Aristida lazaridis*, *Dampiera me*tall*orum Eremophila forrestii sub*sp. Pingandy (M.E. Trudgen 2662), *Goodenia* sp. East Pilbara (A.A. Mitchell PRP 727), *Indigofera* sp. Gilesii (M.E. Trudgen 15869), *Oldenlandia* sp. Hamersley Station (A.A. Mitchell PRP 1479), *Rhagodia* sp. *Hamersley* (M. Trudgen 17794), *Sida* sp. *Barlee Range* (S. van Leeuwen 1642), *Tetratheca fordiana*, *Themeda* sp. Hamersley Station (M.E. Trudgen 11431) and *Triodia* sp. Mt Ella (M.E. Trudgen 12739).

The likelihood of occurrence of each taxon within the Study Area was assessed based on distribution and known habitat preference (Table 2.8), using the following rankings:

Table 2.7 – Criteria used to Assess Likelihood of Occurrence of Significant Flora at West Angelas.

Likelihood of Occurrence	Criteria
Certain	The taxon has already been recorded within the Study Area.
Probable	Due to the proximity of previous records (<2 km) and the presence of suitable habitat, the taxon is considered highly likely to occur.
Likely	Given the presence of suitable habitat and moderate proximity (2-10 km) of previous records, the taxon is considered likely to occur.
Possible	The habitat specificity of the taxon is only broadly defined, or is not defined and/or there are no current records within 10 km. However there is insufficient information available to exclude the possibility of occurrence.
Unlikely	The habitat specificity of the taxon is well defined from previous records and the habitat is considered unlikely to be present within the Study Area.

Table 2.8 – Priority Flora Previously Recorded in the Vicinity of the West Angelas.

Conservation Status	Taxon	Family	Source	Bio-region	Habitat (WA Herbarium 2012)	Nearest Localities or Towns	Flowering Period	Likelihood of Occurrence
4	*Acacia bromilowiana*	Fabaceae	WAHERB, DRF, DEC	PILB	High in landscape, summit of hill and on steep slope, skeletal red gritty soil over massive basalt type rock	Tom Price, Balfour Downs Stn, West Angelas, Hope Downs, Hamersley Ranges, Marillana Stn, Ophthalmia Range	Jul-Aug	Probable
3	*Acacia daweana*	Fabaceae	DEC	PILB	Very stony red loam, gentle slope	Hamersley Range, Karijini N.P.	Jul	Possible
3	*Acacia effusa*	Fabaceae	WAHERB, DRF, DEC	PILB	Stony red loam. Scree slopes of low ranges	Mt Bruce, Hamersley Ra., Karijini N.P., Juna Downs	May to Aug	Likely
3	*Acacia* aff. *subtiliformis*	Fabaceae	WAHERB, DRF, DEC	PILB	On rocky calcrete plateaus	Hamersley Ranges, Hancock Range, Ophthalmia Range, Hope Down North, Marillana Stn	Jul, Aug	Likely
2	*Adiantum capillus-veneris*	Pteridaceae	DEC	PILB, SWAN	Moist, sheltered sites in gorges and on cliff walls	Hamersley Range, Karijini N.P., Peppermint Grove	-	Unlikely
1	*Aluta quadrata*	Myrtaceae	RT	PILB	Edge of creek beds, base of cliffs, rocky crevices, near crest of ridge	Mt Channar, Paraburdoo	May-Jun	Unlikely
3	*Ampelopteris prolifera*	Thelypteridaceae	DEC	KIMB, PILB	Near water or in wet ground	Barlee Range N.R., Doongan Stn, Karijini N.P., Prince Regent River	-	Unlikely
2	*Aristida calycina* var. *calycina*	Poaceae	DEC	PILB	Red earths, sands, alluvial soils	Karijini N.P., Eastern States	-	Unlikely
2	*Aristida lazaridis*	Poaceae	DEC, RT	PILB	Sand or loam	Karijini N.P., Queensland	Apr	Certain
1	*Barbula ehrenbergii*	Pottiaceae	DEC	PILB	Gorge wall, restricted to a small area where water trickles down the wall. On rock iron rich, weathered conglomerate	Dale's Gorge, Hamersley Range	-	Unlikely
1	*Bothriochloa decipiens* var. *cloncurrensis*	Poaceae	DEC	PILB	On a stony clay plain. Red-brown clay loam with a sparse surface mantle of ironstone	Hamersley Range, Queensland	-	Unlikely

Conservation Status	Taxon	Family	Source	Bio-region	Habitat (WA Herbarium 2012)	Nearest Localities or Towns	Flowering Period	Likelihood of Occurrence
1	*Brachyscome* sp. Wanna Munna Flats (S. van Leeuwen 4662)	Asteraceae	WAHERB	PILB	Plain; deep clay loam with very fine buckshot gravel along with a clay crust on the surface	Tom Price, Newman	July, Sep	Possible
1	*Brunonia* sp. Long hairs (D.E. Symon 2440)	Goodeniaceae	WAHERB	CR, PILB	Along creeklines and floodplains in clay or sandy clay	West Angelas, Newman	Ma	Likely
3	*Calotis latiuscula*	Asteraceae	DEC	GOLD, PILB	Sand, loam. Rocky hillsides, floodplains, rocky creeks or river beds	Giles, Warburton, Blackstone Range, Rawlinson Range, Hamersley Range	Jun to Oct	Possible
1	*Calotis squamigera*	Asteraceae	DEC	PILB	Plain with pebbly red-brown loam with loam surface.	Wittenoom, Hamersley Range	-	Possible
2	*Cladium procerum*	Cyperaceae	DEC	PILB	Perennial pools	Karijini N.P., Millstream-Chichester N.P.	Nov	Unlikely
3	*Dampiera anonyma*	Goodeniaceae	DEC	PILB	High in landscape, summit of hill and on steep slope, skeletal red gritty soil over massive basalt type rock (Jerrinah formation)	Mt Bruce, Mt Nameless, Hamersley Ranges, Mt Sheila, Karijini NP	Jun-Aug	Unlikely
3	*Dampiera metallorum*	Goodeniaceae	WAHERB, DRF, DEC	PILB	Rocky ledges and breakaways with loose scree material in lower section of plot.	Hamersley Range, Mt Meharry, West Angelas, Karijini NP	Sep	Certain
1	*Dicrastylis mitchellii*	Laminaceae	WAHERB, DEC	MWST, PILB	Sand or clay soils around dunes	Killara Stn, Turee Creek	Oct	Possible
1	*Eragrostis* sp. Mt Robinson (S. van Leeuwen 4109)	Poaceae	WAHERB, DRF, DEC	PILB	Red-brown skeletal soils, ironstone. Steep slopes, summits	Hamersley Range	Sep	Likely
2	*Eremophila forrestii* subsp. Pingandy (M.E. Trudgen 2662)	Scrophulariaceae	WAHERB, DRF, DEC, RT	PILB	Flat terrain, low in landscape, base of broad valley, stony gibber plain above shallow drainage line, red clay-loam	Karijini NP, Hamersley Range NP, Turee Creek Stn	May-Jul	Certain
3	*Eremophila forrestii* subsp. *viridis*	Scrophulariaceae	DEC	PILB	Dune. Red [sand]	Hamersley Range, Onslow, Canning Stock Route	Aug	Unlikely
4	*Eremophila magnifica* subsp. *magnifica*	Scrophulariaceae	WAHERB, DEC	PILB	High in landscape, summit of hill, skeletal red brown soil over massive ironstone, Brockam Iron Formation.	Hamersley Ranges, Tom Price, Marandoo, Wittenoom	Jul-Sep	Possible

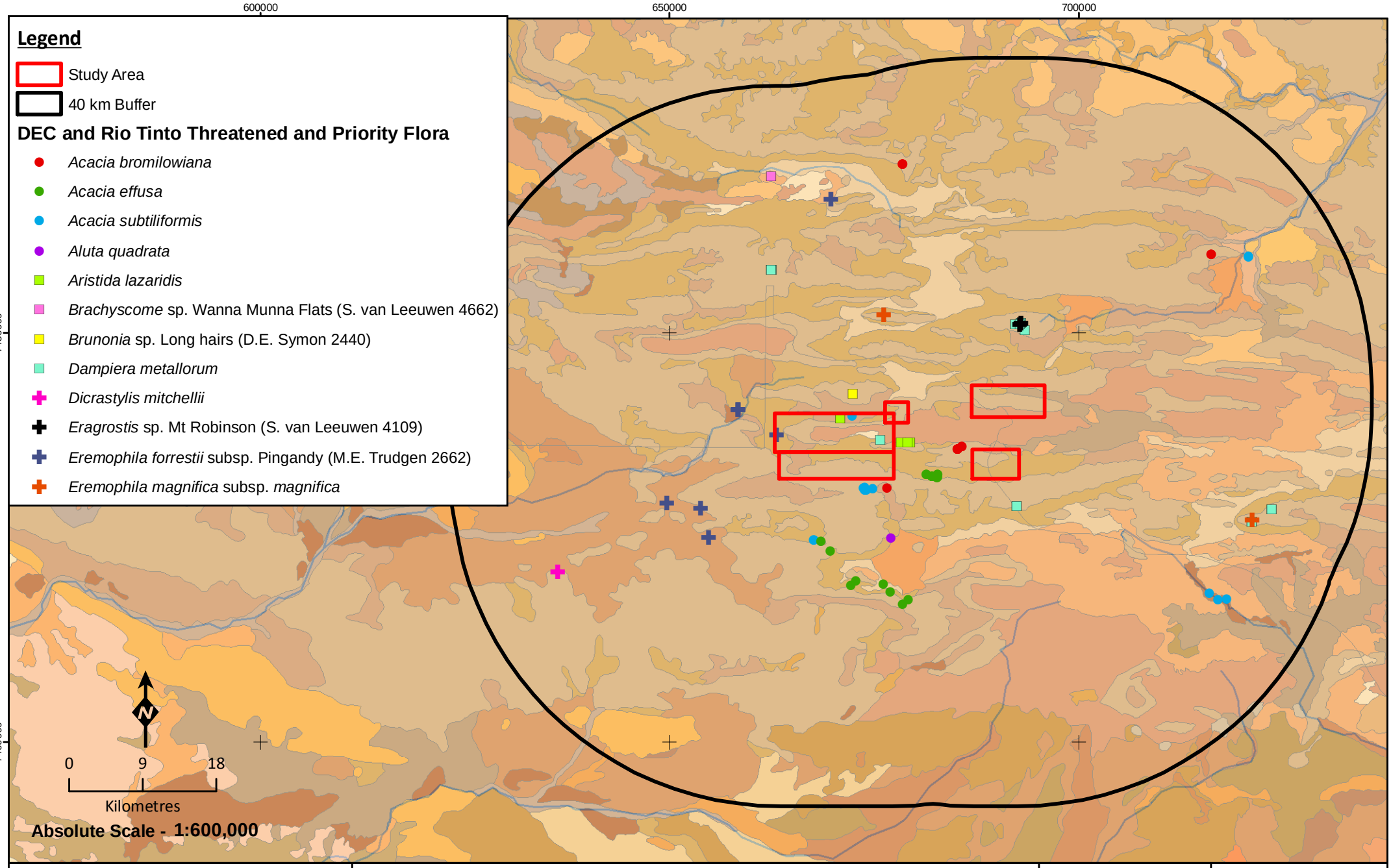
Conservation Status	Taxon	Family	Source	Bio-region	Habitat (WA Herbarium 2012)	Nearest Localities or Towns	Flowering Period	Likelihood of Occurrence
3	*Eremophila magnifica* subsp. *velutina*	Scrophulariaceae	WAHERB, DRF, DEC	PILB	Skeletal soils over ironstone. Summits	Hamersley Ranges, Newman, Marandoo	Jul-Sep	Possible
1	*Eremophila* sp. Hamersley Range (K. Walker KW 136) PN	Scrophulariaceae	DEC	PILB	Summit of hill, high in landscape, steep rock slopes and scree, skeletal brown-red soil over massive banded ironstone of the Brockman Iron Formation	Newman, Hamersley Range	Aug	Likely
1	*Eremophila* sp. Snowy Mountain (S. van Leeuwen 3737)	Scrophulariaceae	DEC	PILB	Summit of hill, high in landscape, skeletal red gritty soil over massive ironstone of the Brockman Iron Formation	Hamersley Range	-	Unlikely
1	*Eremophila* sp. West Angelas (S. van Leeuwen 4068)	Scrophulariaceae	WAHERB, DEC	PILB	High in landscape, summit of hill, gently undulating to steep terrain, skeletal red gritty soil over massive banded iron of the Brockman Iron Formation	West Angela Hill, Opthalmia, Hamersley Range	Sep-Oct	Likely
3	*Eriachne* sp. Dampier Peninsula (K.F. Kenneally 5946)	Poaceae	DEC	KIMB	Plain. Red-brown sandy loam	Karijini N.P., Dampier Peninsula, King Hall Is.	Mar-Apr	Possible
1	*Eucalyptus lucens*	Myrtaceae	DEC	PILB	Rocky mountain top; ironstone.	Hamersley Range	-	Unlikely
2	*Euphorbia clementii*	Euphorbiaceae	DRF	PILB	Sandplains, gravelly hillsides, stony grounds	Ashburton and Yule River	-	Likely
2	*Euphorbia* sp. *Mt Bruce flats (S. van Leeuwen 3861)*	Euphorbiaceae	DEC	PILB	Sump, low in landscape, alluvial cracking clay loamy soil, gritty with ironstone fragments, some sinkholes	Karijini NP	-	Possible
3	*Euphorbia stevenii*	Euphorbiaceae	DEC	KIMB, PILB	Bedrock rise with thin proximal colluvium. Gently inclined slope, cracking black clay plain	Karijini N.P., Kununurra	-	Possible
3	*Fimbristylis sieberiana*	Cyperaceae	DEC	KIMB, PILB	Mud, skeletal soil pockets. Pool edges, sandstone cliffs	Hamersley Range, Millstream, Fitzroy Crossing, King Leopold Range, Halls Creek, Little Sandy Desert	May to Jun	Unlikely

Conservation Status	Taxon	Family	Source	Bio-region	Habitat (WA Herbarium 2012)	Nearest Localities or Towns	Flowering Period	Likelihood of Occurrence
3	*Geijera salicifolia*	Rutaceae	DEC	PILB	Red skeletal sand in massive rock scree, high in landscape.	Mt Samson, Mt Howieson, Tom Price, Hamersley Ranges, Qld, NT	-	Unlikely
1	*Genus* sp. Hamersley Range hilltops (S. van Leeuwen 4345)	Asteraceae	DEC	PILB	Skeletal, brown gritty soil over ironstone. Hill summit	Hamersley Range	-	Unlikely
3	*Goodenia lyrata*	Goodeniaceae	WAHERB, DRF	PILB, GIB, MUR	Red sandy loam. Near claypan	Newman, Gibson Desert Nature Reserve, Coodewonna Flats	Aug	Possible
4	*Goodenia nuda*	Goodeniaceae	RT	PILB	Wide alluvial plain or creek beds. Red-brown clay loam, ironstone.	Dry brown-red sand – loam occasionally in areas of recent burns	Apr to Aug	Likely
3	*Goodenia* sp. East Pilbara (A.A. Mitchell PRP 727)	Goodeniaceae	DRF, RT	PILB, GAS	Red-brown clay soil, calcrete pebbles. Low undulating plain, swampy plains	Tom Price, Newman	Mar, Apr	Certain
1	*Grevillea* sp. Turee (J. Bull & G. Hopkinson ONS JJ 01.01) PN	Proteaceae	DEC	PILB	Breakaways and scree slopes, orange-brown loam soils	Paraburdoo, Tom Price, Karijini, Newman	Feb-Mar	Likely
2	*Hibiscus* sp. Gurinbiddy Range (M.E. Trudgen MET 15708) PN	Malvaceae	DEC	PILB	Near summit of hill, high in landscape, skeletal red-brown stony soil over massive ironstone of the Brockman Iron Formation	Hamersley Range, Karijini N.P.	May, Jul	Probable
1	*Hibiscus* sp. Mt Brockman (E. Thoma ET 1354) PN	Malvaceae	DEC	PILB	Rocky Places and Gorges	Hamersley Range, Tom Price	Aug	Unlikely
3	*Indigofera* sp. Gilesii (M.E. Trudgen 15869)	Fabaceae	WAHERB, DRF, DEC, RT	GOLD, KIMB, PILB	Pebbly loam amongst boulders & outcrops. Hills	Hamersley Range, Meekatharra, West Angelas, Rawlinson Range, Tanami Desert	May, Aug	Certain
2	*Indigofera ixocarpa*	Fabaceae	DEC	PILB	High in landscape, summit of hill, skeletal red brown soil over massive ironstone, Brockam Iron Formation.	Marandoo, Tom Price, Nullagine, Karijini NP	Mar, May	Possible
3	*Indigofera* sp. Bungaroo Creek (S. van Leeuwen 4301)	Fabaceae	DEC	PILB	Cracking loam flat with some flow channels. Soil: red-brown loam, pebbly.	Hamersley Range, Tom Price	Jul	Unlikely
3	*Iotasperma sessilifolium*	Asteraceae	DEC	PILB	Cracking clay, black loam. Edges of waterholes, plains	Ethel Creek Stn, Coolawanya Stn, Juna Downs Stn, Hamersley Range	Jul-Sep	Possible

Conservation Status	Taxon	Family	Source	Bio-region	Habitat (WA Herbarium 2012)	Nearest Localities or Towns	Flowering Period	Likelihood of Occurrence
2	*Isotropis parviflora*	Fabaceae	DEC	KIMB, PILB	Valley slope of ironstone plateau.	East Angelas, Karijini N.P., Tanami Desert	Feb-Mar, May	Possible
1	*Josephinia* sp. Marandoo (M.E. Trudgen 1554)	Pedaliaceae	WAHERB, DRF, DEC	PILB	Outer edge of creek vegetation. Soil: Orange-brown (terracotta) coloured clay-loam	Marandoo, West Angelas	-	Likely
T	*Lepidium catapycnon*	Brassicaceae	WAHERB, DRF, DEC	PILB	Skeletal soils. Hillsides	Wittenoom Gorge, Hamersley Range, Weeli Wolli, Newman	Oct-Jan?	Likely
3	*Nicotiana umbratica*	Solanaceae	DEC	PILB	Shallow soils. Rocky outcrops	Newman, Karijini N.P., Marble Bar, Woodstock, Abydos	Apr, Jun, Sept	Possible
3	*Oldenlandia* sp. Hamersley Station (A.A. Mitchell PRP 1479)	Rubiaceae	WAHERB, DEC	PILB	Cracking clay, basalt. Gently undulating plain with large surface rocks, flat crabholed plain	Millstream-Chichester N.P., Hamersley Range, Caoolawanyah Stn	Mar-May, Jul	Certain
3	*Olearia mucronata*	Asteraceae	WAHERB, DRF, DEC	GOLD, PILB	Schistose hills, along drainage channels	Hamersley and Chichester Range area, West Angelas, Paraburdoo, Mt Margaret, Mt Keith, Wiluna	Aug-Jan	Likely
2	*Oxalis* sp. Pilbara (M.E. Trudgen 12725)	Oxalidaceae	WAHERB, DEC	PILB	Gully. Brown-red loam, cobbles and pebbles	Karijini N.P., Hamersley Range	May	Likely
3	*Phyllanthus aridus*	Phyllanthaceae	DEC	KIMB, PILB	Sandstone, gravel, red sand.	West Kimberley, Chichester Range, West Angelas, Pardoo, Shay Gap, Doongan Homestead, Durack River	May-Jun	Possible
2	*Pilbara trudgenii*	Asteraceae	WAHERB, DRF, DEC	PILB	Skeletal, red stony soil over ironstone. Hill summits, steep slopes, screes, cliff faces	Hamersley Range	Sep-Oct	Likely
4	*Ptilotus mollis*	Amaranthaceae	RT	LSD, PILB	Stony hills and screes	Tom Price, Paraburdoo, Marble Bar, Hamersley Range National Park	May or Sep	Unlikely
3	*Rhagodia* sp. Hamersley (M. Trudgen 17794)	Chenopodiaceae	WAHERB, DRF, DEC, RT	PILB	Broad plain at the base of hills (enclosed on all sides). Red brown clay/ loam. Ironstone pebbles	Hamersley Ranges	May	Certain
1	*Rhodanthe ascendens*	Asteraceae	WAHERB, DRF, DEC	MWST, PILB	Clay	Gascoyne Junction, Middalya Station, Karijini N.P.	Aug	Likely

Conservation Status	Taxon	Family	Source	Bio-region	Habitat (WA Herbarium 2012)	Nearest Localities or Towns	Flowering Period	Likelihood of Occurrence
4	*Rhynchosia bungarensis*	Fabaceae	DEC	MWST, PILB	Pebbly, shingly coarse sand amongst boulders. Banks of flow line in the mouth of a gully in a valley wall.	Hamersley Ranges, Chichester Ranges, Yardie Creek, Robe River, Tom Price, Ashburton, East Lewis Island, Burrup Peninsula, Dampier Archipelago	May-Dec	Unlikely
3	*Rostellularia adscendens* var. *latifolia*	Acanthaceae	WAHERB, DEC	PILB	Ironstone soils. Near creeks, rocky hills	Hamersley Ranges	Apr to May	Likely
2	*Scaevola* sp. Hamersley Range basalts (S. van Leeuwen 3675)	Goodeniaceae	DEC	PILB	Skeletal, brown gritty soil over basalt. Summits of hills, steep hills	Hamersley Range	Jul to Aug	Unlikely
3	*Sida* sp. Barlee Range (S. van Leeuwen 1642)	Malvaceae	WAHERB, DEC, RT	PILB	Skeletal red soils pockets. Steep slope.	Barlee Range, Turee Creek, Paraburdoo, Hamersley Range	Aug	Certain
1	*Sida* sp. Hamersley Range (K. Newbey 10692)	Malvaceae	DEC	PILB	High in landscape, summit of hill, skeletal red stony soil over massive Brockman Iron Formation bedrock	Hamersley Range, Lawloit Range	-	Unlikely
2	*Spartothamnella puberula*	Lamiaceae	WAHERB, DRF, DEC	PILB	Rocky loam, sandy or skeletal soils, clay. Sandplains, hills	Mt Bruce, Hamersley Range, West Angelas, NT	Sep to Nov	Likely
1	*Tetratheca fordiana*	Elaeocarpaceae	WAHERB, DRF, DEC, RT	PILB	Shale pocket amongst ironstone	West Angelas, Hamersley Range	Sep	Certain
1	*Teucrium pilbaranum*	Lamiaceae	WAHERB	PILB	Crab hole plain in a river floodplain, margin of calcrete table	Millstream National Park, Wittenoom	May or Sep	Likely
3	*Themeda* sp. Hamersley Station (M.E. Trudgen 11431)	Poaceae	WAHERB, DEC, RT	PILB	Red clay. Clay pan, grass plain	Karratha, Millstream, Hamersley Stn, West Angelas, Coondewanna Flats	Aug	Certain
T	*Thryptomene wittweri*	Myrtaceae	WAHERB, DRF, DEC	GOLD, MWST, PILB	Skeletal red stony soils. Breakaways, stony creek beds	Hamersley Range, Mt Augustus, Carnarvon Range, White Cliffs Stn, NT	Aug-Oct	Possible
3	*Triodia* sp. Mt Ella (M.E. Trudgen 12739)	Poaceae	WAHERB, DEC, RT	PILB	Light orange-brown, pebbly loam. Amongst rocks & outcrops, gully slopes	Hamersley Range, Mt Ella	-	Certain
3	*Triodia* sp. *Robe River* (M.E. Trudgen et al. MET 12367)	Poaceae	DEC	PILB	Rangeland. Hillside and hill top. Brown/red ironstone gravel	Yarraloola Stn, Yalleen Stn., Red Hill Stn., Mt Stuart Stn., Hamersley Range	-	Unlikely

Conservation Status	Taxon	Family	Source	Bio-region	Habitat (WA Herbarium 2012)	Nearest Localities or Towns	Flowering Period	Likelihood of Occurrence
2	*Vigna* sp. *central* (M.E. Trudgen 1626)	Fabaceae	DEC	PILB	Plain with thin sheet of sand (light orange / brown) over compacted hardpan and limestone rock	Karijini N.P., Nyang Stn, Warrawagine Stn	May-Jun, Oct	Possible
1	*Vittadinia* sp. Coondewanna Flats (S. van Leeuwen 4684)	Asteraceae	WAHERB, DEC	PILB	Flat plain. Red sandy clay-loam.	Hamersley Range	Jul	Probable



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Regional Threatened and Priority Flora of Greater West Angelas - Map A

Figure: 2.9
Project ID: 1457

Drawn: CP
Date: 19/09/2012

Coordinate System
Name: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Unique Map ID: CPXXX

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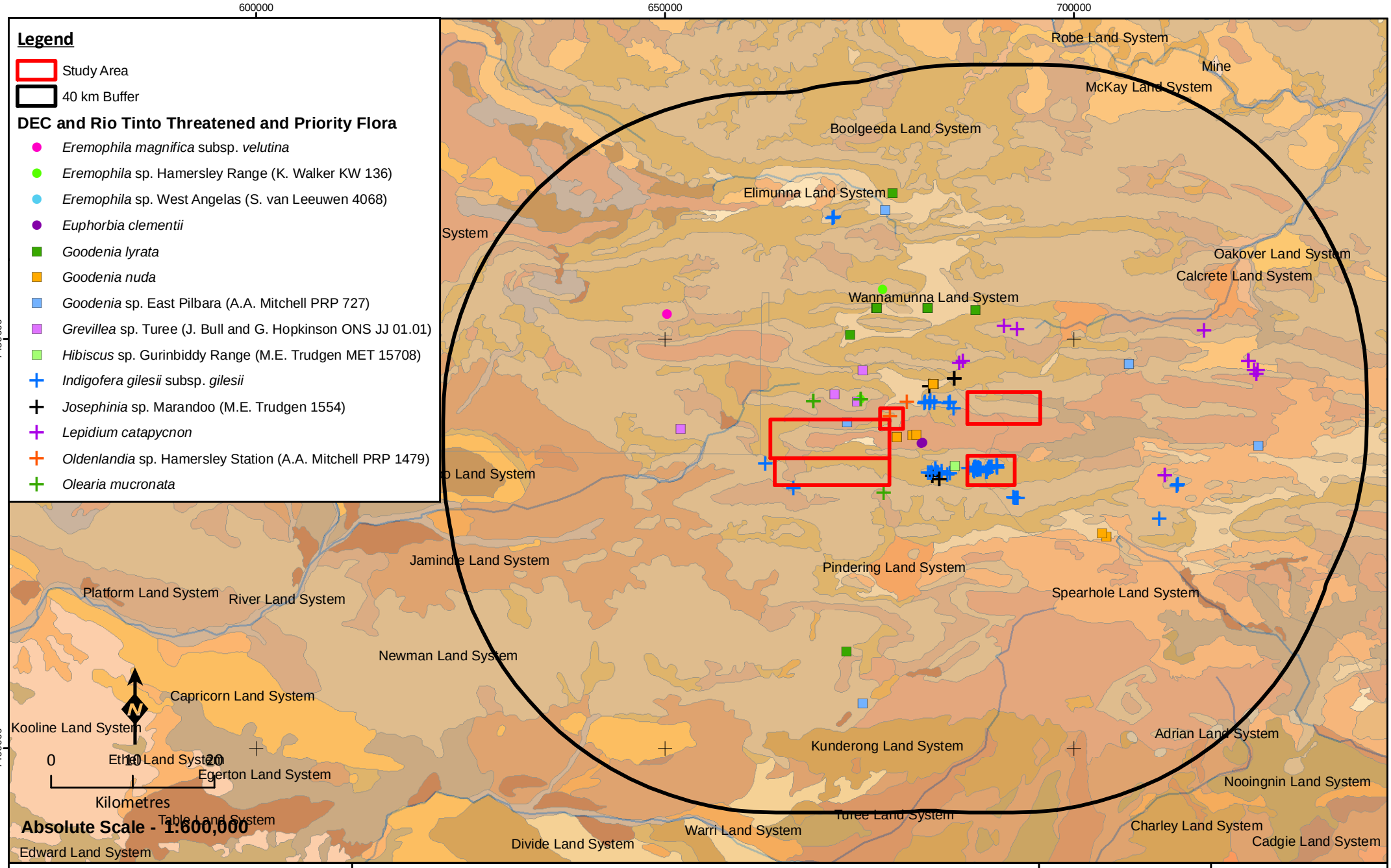

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Regional Threatened and Priority Flora of Greater West Angelas - Map B

Figure: 2.10
Project ID: 1457

Drawn: CP
Date: 19/09/2012

Coordinate System
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Projection: Transverse Mercator
Datum: GDA 1994

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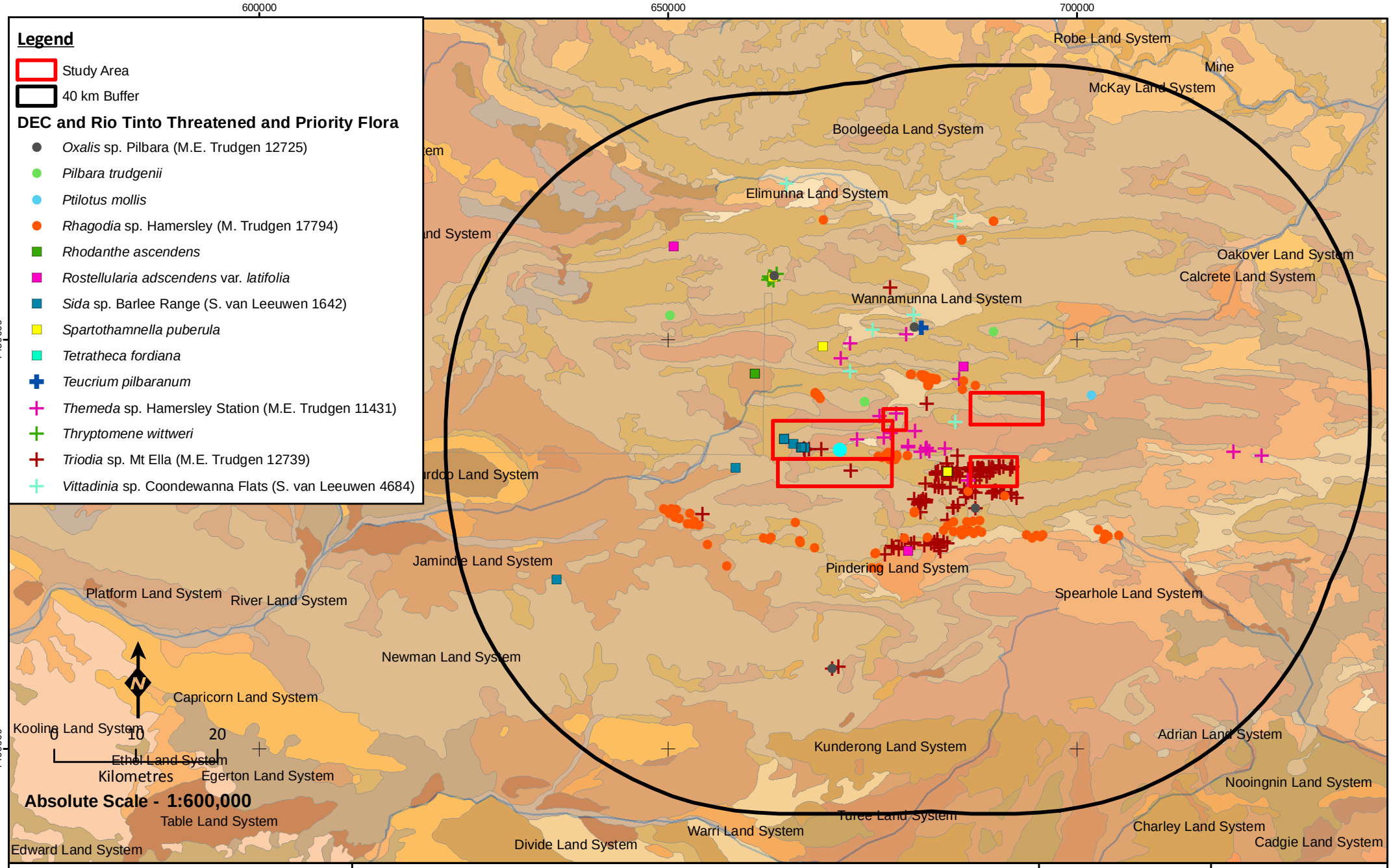

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Regional Threatened and Priority Flora of Greater West Angelas - Map C

Figure: 2.11
Project ID: 1457

Drawn: CP
Date: 19/09/2012

Coordinate System
Name: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Unique Map ID: CP172

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3 SURVEY METHODOLOGY

3.1 GUIDING PRINCIPLES

The survey methods adopted by *ecologia* were formulated using:

- Position Statement 3 (Environmental Protection Authority 2002), Terrestrial Biological Surveys as an Element of Biodiversity Protection;
- Guidance Statement 51 (Environmental Protection Authority 2004) Terrestrial Flora and Vegetation Surveys for nvEironmental Impact Assessment;
- Consultation with DEC personnel;
- Background research to gather background information on the footprint or target area (i.e. search of literature, data and map-based information); and
- A reconnaissance survey, conducted in February 2011, to verify the accuracy of the background information, broadly characterise the flora and range of vegetation units present in the footprint and to identify logistical constraints to survey.

Guidance Statement 51 recommends the following characteristics for a Level 2 surveys which were incorporated into the survey and reporting design:

- One or more visits to the target area in the main flowering season and visits in other seasons;
- Replication of plots in each vegetation unit to thoroughly sample the flora and characterise the vegetation units over their full extent in the target area;
- Multivariate analysis of the vegetation using, at a minimum, presence/absence data and perennial species;
- Mapping of vegetation at an appropriate scale; and
- Tabulation of the area of each vegetation unit mapped and an assessment of the environmental values including such factors as extent, condition and presence or significant flora.

3.2 DATABASE SEARCHES

A search of the following databases were undertaken in May 2012 prior to the field survey, to determine flora species and ecological communities of conservation significance previously recorded in the vicinity of the Study Area:

- DEC Threatened (Declared Rare) Flora Database (DEFL);
- DEC Declared Rare and Priority Flora List;
- DEC Western Australian Herbarium Specimen Database (WAHERB);

- DEC Threatened Ecological Community Database; and
- Department of the Sustainability, Environment, Water, Populations and Communities (DSEPaC) Protected Matters search.

3.3 VEGETATION AND FLORA ASSESSMENT

The two-phase survey involved a combination of sampling within bounded quadrats of 2,500 m^2 in area, in accordance with Guidance Statement 51, supplemented by a series of linked field traverses. Linked traverses assisted in maximising the floristic inventory and thus increasing the probability of locating flora of potential significance. Standardised quadrats allow the vegetation to be consistently characterised and facilitate multivariate analysis. Both methods contributed to the delineation of vegetation units and a comprehensive floristic inventory of the Study Area.

3.3.1 Survey Timing

The vegetation and flora of the Study Area was surveyed in two phases over two separate trips totalling 60 person days. Survey timing was as follows:

- Phase 1; 9 to 18 July 2012 (36 person days); and
- Phase 2; 21 to 26 August 2011 (24 person days).

The objectives of these surveys were to provide:

- Inventory of vascular plant species;
- Description and mapping of plant communities, including an update (Deposits C, D extension and G) and extension (Deposits C, D, F and H) of historical vegetation mapping;
- Review of plant species considered to be rare and endangered, or geographically restricted, which are known to, or may occur, within the Study Area;
- Inventory of exotic plants, including Declared Plantss; and
- Review of the significance of the plant communities within a local, regional, and state context.

3.3.2 Quadrat-Based and Transect Sampling

One hundred and fifty quadrats, distributed throughout the Study Area as detailed in Figure 3.1 were surveyed. Locations were selected using aerial photography, topographic features and field observations to represent the diversity of vegetation present. The majority of quadrats were 50 x 50 m, however the dimensions were modified where necessary to ensure that sampling occurred in homogeneous vegetation. For example, 25 x 100 m quadrats were frequently used for vegetation along drainage lines and other linear features.

Coordinates for all quadrats are detailed in Appendix A.

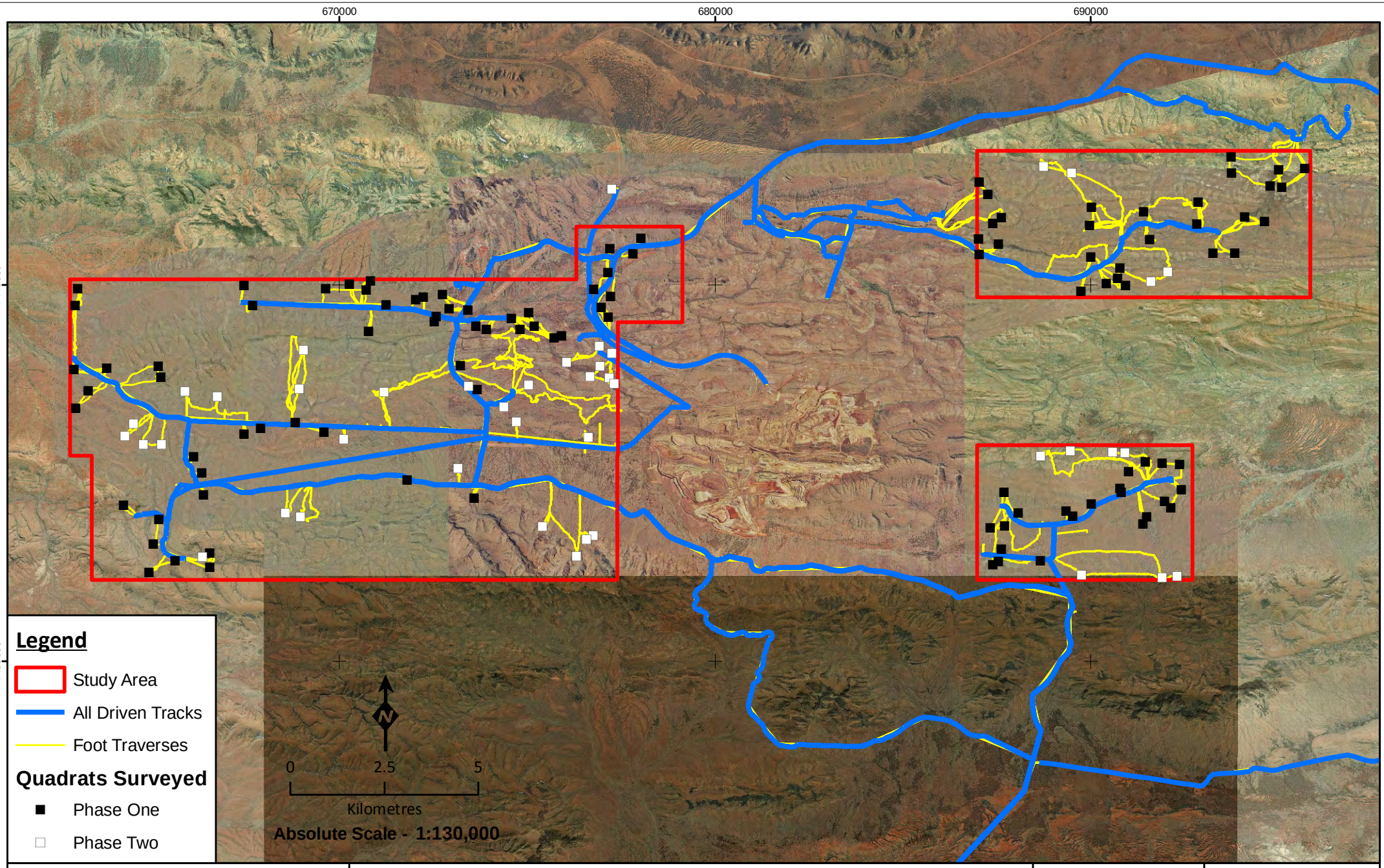
For each quadrat, the following was recorded:

- Coordinates of each corner of the quadrat;
- Site features such as topography, soil and lithology;

- Structure of the vegetation, including the height, cover, habit and dominant species within each stratum;
- Height range and percentage foliage cover for each species within the site (including introduced species);
- Vegetation condition (degree of disturbance); and
- Estimated time since fire.

At least one specimen of all taxa recorded was collected for subsequent verification. Nomenclature and taxonomy follow the conventions currently adopted by the Western Australian Herbarium (Western Australian Herbarium 1998-2013).

While walking between quadrats (Figure 3.1), opportunistic collections were made of taxa not recorded within the quadrats. Locations of any introduced flora, known or potentially conservation significant taxa encountered were also recorded, and notes were made on the boundaries of the vegetation communities to facilitate with the mapping of the vegetation communities.



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Quadrat Locations and Foot Traverses of the Greater West Angelas Study Area

Figure: 3.1
Project ID: 1457

Drawn: CP
Date: 27/09/2012

Coordinate System
Name: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Unique Map ID: CP147

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3.3.3 Vegetation Condition

Vegetation condition was assessed at each quadrat using the condition scale based on Trudgen (1991) based on the criteria described in Table 3.1.

Table 3.1 – Vegetation Condition Scale

Vegetation Condition	Criteria
Excellent	Pristine or nearly so, no obvious sign of damage caused by European man
Very good	Some relatively slight signs of damage caused by the activities of European man. E.g. damage to tree trunks by repeated fires, the presence of some relatively non-aggressive weeds or occasional vehicle tracks.
Good	More obvious signs of damage caused by the activities of European man, including some obvious impact to vegetation structure such as caused by low levels of grazing or by selective logging. Weeds as above, possibly plus some more aggressive ones
Poor	Still retains basic vegetation structure or ability to regenerate it after very obvious impacts of European man such as grazing or partial clearing or very frequent fires. Presence of some more aggressive weeds.
Very poor	Severely impacted by grazing, fire, clearing or a combination of these activities. Scope for some regeneration but not to a state approaching good condition without intensive management. Usually with a number of weeds species including aggressive species.
Completely Degraded	Areas that are completely or almost completely without native vegetation e.g. areas that are cleared or parkland cleared with their flora comprising weed or crop species with isolated native trees or shrubs.

3.3.4 Vegetation Mapping

Vegetation mapping is the delineation of plant communities based on distinctive characteristics of these communities such as the vegetation structure, dominant species, species composition, soil types and position in the landscape.

A combination of multivariate analysis of species composition of quadrats and ground truthing was employed to define communities. Multivariate analysis was conducted using the species matrix data from quadrats completed during both field trips. Cluster analysis was performed on the cover weighted site by species matrix using an association matrix of the Bray-Curtis coefficient with the multivariate program SYSTAT™. The resultant dendrogram was used in the definition of hierarchy of vegetation assemblages. This method provides an objective means of defining vegetation communities and provides insight into the hierarchical relationship between communities based on the degree of similarity in species composition and abundance.

The communities were described to Association level (NVIS level V). The boundaries of communities were then extrapolated to the entire Study Area based on their appearance in aerial imagery.

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4 FLORA RESULTS

A total of 441 taxa were recorded from the West Angelas Study Area in this study. Ten taxa could not be fully identified due to lack of reproductive material, nine of which are likely to be recollections of fully identified taxa. Only the 431 fully identified records were included in the diversity and multivariate analyses, but all 441 taxa are presented in the species list (Appendix C).

The summary of the composition of the fully identified species inventory is summarised in Table 4.1 .

Table 4.1 – Diversity of the Flora of Survey Area

Number of Quadrats Surveyed	Number of Taxa Recorded	Number of Families	Number of Genera	Number of Families Represented by a Single Taxon	Number of Genera Represented by a Single Taxon
149	431	48	163	13	94

The families and genera represented by the greatest number of taxa and the most frequently recorded species in the Study Area are listed in Table 4.2. This pattern of representation is typical of surveys within the Pilbara. The large number of taxa within the family Scrophulariaceae and genus *Eremophila* reflects the abundance of mulga woodlands and shrublands, within which most of these taxa occur. The relatively high representation of Asteraceae, Amaranthaceae and Goodeniaceae is a reflection of the optimal timing of the survey when many ephemeral species were flowering.

Table 4.2 – Most Frequently Recorded Families, Genera and Taxa in the Current Survey

Most Common Families	Most Common Genera	Most Frequently Recorded Taxa
Poaceae (76 taxa)	*Acacia* (33 taxa)	*Triodia pungens* (99 quadrats, 66 %)
Fabaceae (72 taxa)	*Eremophila* (17 taxa)	*Acacia pruinocarpa* (94 quadrats, 63 %)
Malvaceae (46 taxa)	*Ptilotus* (15 taxa)	*Ptilotus nobilis* subsp. *nobilis* (92 quadrats, 61 %)
Asteraceae (27 taxa)	*Senna* (15 taxa)	*Aristida contorta* (85 quadrats, 57 %)
Amaranthaceae (23 taxa)	*Sida* (15 taxa)	*Enneapogon polyphyllus* (85 quadrats, 57 %)
Chenopodiaceae (20 taxa)	*Abutilon* (11 taxa)	*Acacia bivenosa* (74 quadrats, 49 %)
Scrophulariaceae (17 taxa)	*Eragrostis* (9 taxa)	*Pterocaulon sphacelatum* (73 quadrats, 49 %)
Goodeniaceae (14 taxa)	*Aristida* (8 taxa)	*Ptilotus obovatus* (73 quadrats, 49 %)
Myrtaceae (14 taxa)	*Eucalyptus* (8 taxa)	*Themeda triandra* (72 quadrats, 48 %)
	Goodenia (8 taxa)	*Solanum lasiophyllum* (68 quadrats, 45%)

Species richness within quadrats varied from seven to 67 taxa, with a mean species richness of 35.7± 1.0 (n= 150). Vegetation units with the lowest overall species richness include *ApTssp* (*Acacia aptaneura* and *A. pruinocarpa* open woodland over *A. tetragonophylla, Senna glutinosa* subsp. *glutinosa* and *S. artemisioides* subsp. *oligophylla* isolated shrubs over *Triodia wiseana* and *T. pungens* open hummock grassland.), and *Tp* (*Eucalyptus leucophloia* subsp. *leucophloia* and *Acacia pruinocarpa* isolated trees over *Senna glutinosa* subsp. *glutinosa, A. bivenosa* and *Ptilotus rotundifolius* isolated shrubs over *Triodia pungens* or *T. basedowii* or *T.* sp. Mt Ella hummock grassland.), both of which are typical of rocky midslopes, with a mean species richness of 15.8 and 16.8 respectively. The most consistently diverse vegetation unit was *AaPoTt* (*Acacia aptaneura* open woodland over *Ptilotus obovatus* sparse shrubland over *Themeda triandra* open tussock grassland), which occurs along sandy floodplains, with mean species richness of 50.1.

4.1.1 Sampling Adequacy for the Study Area

Species accumulation curves (SAC) provide a theoretical basis for understanding the relationship between sampling effort and the accumulation of species, and therefore provide a means of estimating the survey adequacy. As sampling effort increases, the rate at which new species are recorded is reduced until ultimately the curve representing the number of species recorded becomes asymptotic. At the point where there is a negligible increase in species inventory with continued sampling effort, the survey effort is deemed sufficient.

Flora sampling adequacy was estimated using SAC analysis (Colwell 2009) and extrapolation of the curve to the asymptote using Michaelis-Menten modelling (Figure 4.1). The incidence-based coverage estimators of species richness; ICE Mean, Chao 2 Mean were determined as 462 and 470, respectively. The total number of taxa collected in the study was 441 if all potential duplicates not fully identified to subspecies level (and therefore possibly repeats of other taxa) are excluded. Thus, it is estimated that between 86% and 88 % of the taxa present were recorded.

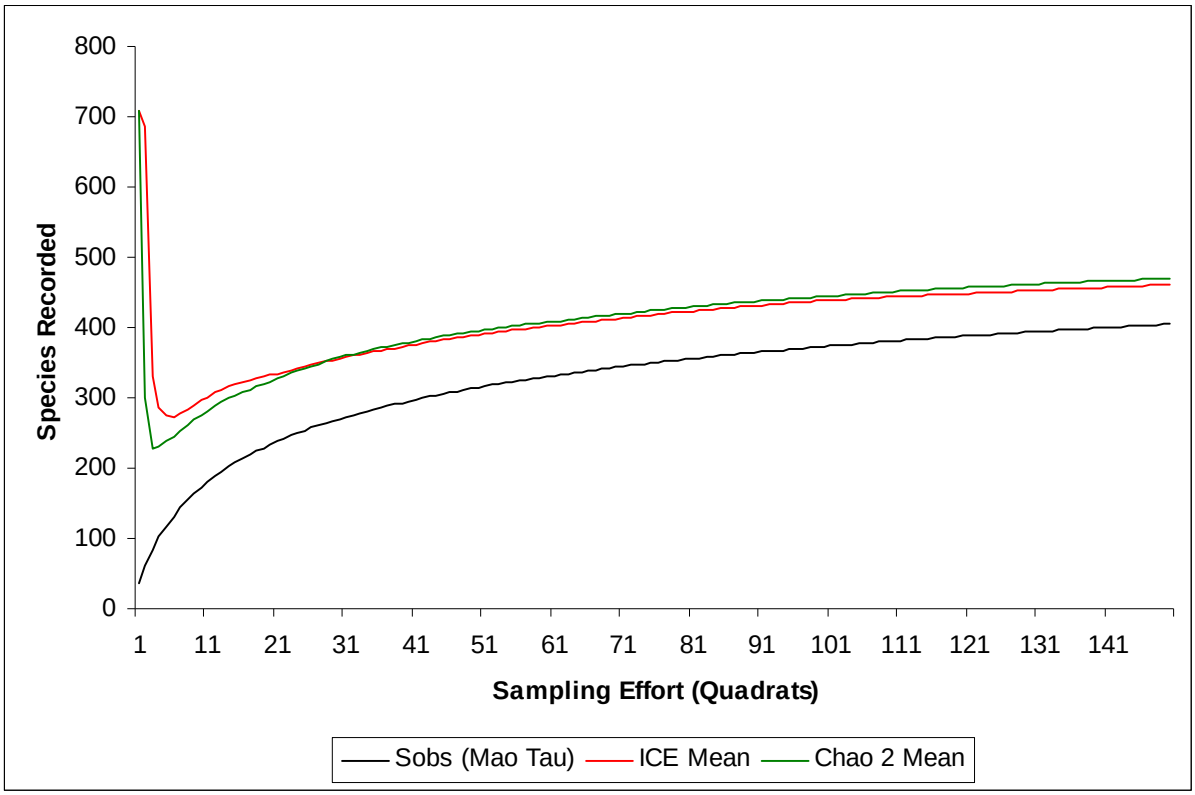


Figure 4.1 – Average Randomised Species Accumulation Curve for Greater West Angelas

4.2 FLORA OF CONSERVATION SIGNIFICANCE

4.2.1 EPCB Act

At a Commonwealth level, flora are protected under the EPBC Act, which lists species that are considered Critically Endangered, Endangered, Conservation Dependant, Extinct, or Extinct in the Wild (Appendix D). Two taxa occurring within the Pilbara bioregion are listed: *Lepidium catapycnon* and *Thryptomene wittweri* (both Vulnerable).

Four specimens of *Lepidium catapycnon* were collected opportunistically from four locations within Greater West Angelas, all within the northern portion of Deposit H. A total of 29 individuals were recorded. Vegetation and landforms consistent with this species habitat occur within the Study Area (Table 4.3) and it is possible that more individuals could be present given that access to some areas was limited during the survey.

The GPS coordinates of each location at which *Lepidium catapycnon* was observed are provided in Appendix E, and the Priority Flora Report Forms for these are presented in Appendix F. The general characteristics of the species and maps showing the locations of all recorded priority taxa are presented in Section 4.2.3.

The nearest record of *Thryptomene wittweri* lies 17 km to the north of the Study Area boundary and this species was not recorded during the survey. However, due to the presence of suitable habitat and its proximity to the Study Area, it is considered possible that this species may occur.

4.2.2 WC Act

Taxa which have been adequately searched for and are deemed to be either rare, in danger of extinction, or otherwise in need of special protection, are gazetted as such (Schedule 1, *WC Act* 1950). Threatened Flora (Schedule 1, December 2010) taxa are further categorised by the Department according to their level of threat using IUCN Red List criteria:

- CR: Critically Endangered – considered to be facing an extremely high risk of extinction in the wild;
- EN: Endangered – considered to be facing a very high risk of extinction in the wild; and
- VU: Vulnerable – considered to be facing a high risk of extinction in the wild.

These taxa are legally protected and their removal or impact to their surroundings cannot be conducted without Ministerial approval, obtained specifically on each occasion for each population (refer to Appendix D for category definitions).

There are two State Listed Threatened taxa known to occur within the Pilbara, *Lepidium catapycnon* and *Thryptomene wittweri* (both Vulnerable). As discussed above, 29 individuals of *Lepidium catapycnon* was collected from four locations within the Study Area, and further results are presented in Section 4.2.3 (species characteristics and distribution maps) and in Appendices E (GPS coordinates of collections) and F (Priority Flora Report Forms).

4.2.3 Priority Flora

The DEC maintains a list of Priority Flora taxa, which are considered poorly known, uncommon or under threat but for which there is insufficient justification, based on known distribution and

population sizes, for inclusion in Schedule 1 of the *WC Act*. A Priority Flora taxon is assigned to one of four priority categories (Appendix D).

Currently, 163 Priority Flora taxa are listed as occurring in the Pilbara region, including 60 Priority 1, 24 Priority 2, 68 Priority 3, and nine Priority 4 taxa (Western Australian Herbarium 1998-2013).

Thirteen Priority taxa were recorded in the Study Area during the current survey (Table 4.3). The distribution of records within the Study Area are illustrated in Figure 4.2 and coordinates of records and Rare Flora Report Forms are provided in Appendices E and F, respectively.

Table 4.3 – Priority Flora Recorded Within the West Angelas Study Area

Conservation Status	Taxon	Family	No. of records in Study Area	Habitat (WA Herbarium 2012)	Distribution	Flower Period	Picture
T	*Lepidium catapycnon* A papilose perennial herb or shrub. Leaves small, linear, ascending, terete succulent - on characteristically zigzag branch tips.	Brassicaceae	4 locations (29 plants)	Outer edge of creek vegetation and on rocky screes. Soil: Orange-brown (terracotta) coloured clay-loam	Marandoo, West Angelas, Tom Price	Oct-Jan	 (*ecologia* 2012)
P1	*Aristida jerichoensis* var. *subspinulifera* A tufted annual grass. Leaf-blade wire-like, round in cross section, surface scabrous.	Poaceae	44 locations (1,948 plants)	Plains with brown-red loam, clay	East Angelas, Sylvania Station, Newman		 (*ecologia* 2012)

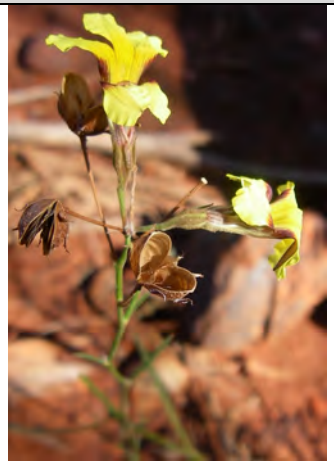
Conservation Status	Taxon	Family	No. of records in Study Area	Habitat (WA Herbarium 2012)	Distribution	Flower Period	Picture
P1	*Brachyscome* sp. Wanna Munna Flats (S. van Leeuwen 4662) PN Erect annual herbaceous daisy with pinnatisect leaves and light purple flower heads.	Asteraceae	2 locations (2 plants)	Plain; deep clay loam with very fine buckshot gravel along with a clay crust on the surface	Tom Price, Newman	July, Sep	 (*ecologia* 2012)
P1	*Brunonia* sp. long hairs (D.E. Symon 2440) PN Rosulate herb with long silvery hairs, especially at the base of the leaves and bright blue flowers in an aggregated head.	Goodeniaceae	10 locations (>20 plants)	Along creeklines and floodplains in clay or sandy clay	West Angelas, Newman	May	 (*ecologia* 2012)

Conservation Status	Taxon	Family	No. of records in Study Area	Habitat (WA Herbarium 2012)	Distribution	Flower Period	Picture
P2	*Aristida lazaridis* A tufted perennial grass. Leaf-blade surface scaberulous; rough on both sides.	Poaceae	3 locations (>23 plants)	Sand or loam	Karijini N.P., Queensland	Apr	 (Western Australia Herbarium 2012)
P2	*Eremophila forrestii* subsp. Pingandy (M.E. Trudgen 2662) Shrub to 50 cm tall, compact tight bush. Flowers pale yellow-cream to pinky-yellow.	Scrophulariaceae	1 location (1 plant)	Flat terrain, low in landscape, base of broad valley, stony gibber plain above shallow drainage line, red clay-loam.	West Angela Hill, Karijini National Park, Turee Creek Homestead	Jun	 (*ecologia* 2012)

Conservation Status	Taxon	Family	No. of records in Study Area	Habitat (WA Herbarium 2012)	Distribution	Flower Period	Picture
P3	*Acacia* aff. *subtiliformis* Erect, spindly, wispy, single-stemmed, glabrous shrubs, the upper branches scarred where phyllodes have fallen.	Fabaceae	3 locations (~250 plants)	On rocky calcrete plateaus	Hamersley Ranges, Hancock Range, Ophthalmia Range, Hope Down North, Marillana Stn	Jul, Aug	 (*ecologia* 2012)
P3	*Indigofera* sp. Gilesii (M.E. Trudgen 15869) An open shrub, to 1.5 m high with purple-pink flowers.	Fabaceae	24 locations (>232 plants)	Pebbly loam amongst boulders & outcrops. Hills	Mt Ella, Newman, Rhodes Ridge, Coondewanna and West Angelas Hill	May or Aug	 (*ecologia* 2012)

Conservation Status	Taxon	Family	No. of records in Study Area	Habitat (WA Herbarium 2012)	Distribution	Flower Period	Picture
P3	*Rhagodia* sp. Hamersley (M. Trudgen 17794) Small erect, open shrub or scrambler to 4 m high with green - cream flowers.	Chenopodiaceae	31 locations (>81 plants)	Gravely silt and sand in sheet-flood fans. Red brown silty clay loam / silty loam on undulating plains.	Tom Price, Paraburdoo, Brockman and Newman	May	 (*ecologia* 2012)
P3	*Sida* sp. Barlee Range (S. van Leeuwen 1642) PN Rounded, densely woolly to velvety somewhat woody shrub, with small ovate ruminate leaves and yellow flowers.	Malvaceae	8 locations (>42 plants)	Skeletal red soils pockets. Steep slope.	Barlee Range, Turee Creek, Paraburdoo, Hamersley Range	Aug	 (*ecologia* 2012)

Conservation Status	Taxon	Family	No. of records in Study Area	Habitat (WA Herbarium 2012)	Distribution	Flower Period	Picture
P3	*Themeda* sp. Hamersley Station (M.E. Trudgen 11431) PN A robust Kangaroo Grass, tall, with a bluish tinge to tussock.	Poaceae	7 locations (>3505 plants)	Red clay. Clay pan, grass plain	Karratha, Millstream, Hamersley Stn, West Angelas, Coondewanna Flats	Aug	 (*ecologia* 2012)
P3	*Triodia* sp. *Mt Ella (M.E. Trudgen 12739)* A diffuse, loose, sprawling rather than rounded, hummock hard spinifex grass, leaves bright mid-green, shiny, very resinous with a distinctive resinous smell.	Poaceae	8 locations (>300 plants)	Rangeland. Hillside and hill top. Brown/red ironstone gravel	Yarraloola Stn, Yalleen Stn., Red Hill Stn., Mt Stuart Stn., Hamersley Range	-	 (*ecologia* 2012)

Conservation Status	Taxon	Family	No. of records in Study Area	Habitat (WA Herbarium 2012)	Distribution	Flower Period	Picture
P4	*Goodenia nuda* An erect herb with yellow flowers with a maroon centre.	Goodeniaceae	2 location (2 plants)	Dry brown-red sand – loam occasionally in areas of recent burns.	Port Headland, Newman, Onslow, Paraburdoo and Tom Price	Apr to Aug	 (*ecologia* 2011)