GOVERNMENT OF WESTERN AUSTRALIA

Environmental Protection Authority

[redacted]

Referral of a Proposal by the Proponent to the Environmental Protection Authority under Section 38(1) of the *Environmental Protection Act 1986*.

PURPOSE OF THIS FORM

Section 38(1) of the *Environmental Protection Act 1986* (EP Act) provides that where a development proposal is likely to have a significant effect on the environment, a proponent may refer the proposal to the Environmental Protection Authority (EPA) for a decision on whether or not it requires assessment under the EP Act. This form sets out the information requirements for the referral of a proposal by a proponent.

Proponents are encouraged to familiarise themselves with the EPA's *General Guide on Referral of Proposals* [see Environmental Impact Assessment/Referral of Proposals and Schemes] before completing this form.

A referral under section 38(1) of the EP Act by a proponent to the EPA must be made on this form. A request to the EPA for a declaration under section 39B (derived proposal) must be made on this form. This form will be treated as a referral provided all information required by Part A has been included and all information requested by Part B has been provided to the extent that it is pertinent to the proposal being referred. Referral documents are to be submitted in two formats – hard copy and electronic copy. The electronic copy of the referral will be provided for public comment for a period of 7 days, prior to the EPA making its decision on whether or not to assess the proposal.

CHECKLIST

Before you submit this form, please check that you have:

	Yes	No
Completed all the questions in Part A (essential).	☑	
Completed all applicable questions in Part B.	☑	
Included Attachment 1 – location maps.	☑	
Included Attachment 2 – additional document(s) the proponent wishes to provide (if applicable).	☑	
Included Attachment 3 – confidential information (if applicable).	-	-
Enclosed an electronic copy of all referral information, including spatial data and contextual mapping but excluding confidential information.	☑	

Office of the Environmental Protection Authority
File: ....
26 FEB 2014
A: ☐ For Info
fa: ☐ For Discussion
Officer: ☐ For Action
Response please:

Following a review of the information presented in this form, please consider the following question (a response is optional).

Do you consider the proposal requires formal environmental impact assessment?		
☐ Yes	☒ No	☐ Not sure
If yes, what level of assessment?		
☐ Assessment on Proponent Information	☐ Public Environmental Review	

PROPONENT DECLARATION (to be completed by the proponent)

I, Gang Xu, declare that I am authorised on behalf of Dragon Energy Limited (being the person responsible for the proposal) to submit this form and further declare that the information contained in this form is true and not misleading.

Signature:	Name: Mr Gang Xu
Position: Managing Director	Company: Dragon Energy Limited
Date: 25/02/2014	

PART A - PROPONENT AND PROPOSAL INFORMATION

(All fields of Part A must be completed for this document to be treated as a referral)

1 PROPONENT AND PROPOSAL INFORMATION

1.1 Proponent

Name	Dragon Energy Limited (Dragon)
Joint Venture parties (if applicable)	n/a
Australian Company Number (if applicable)	ABN 38 119 992 175
Postal Address (where the proponent is a corporation or an association of persons, whether incorporated or not, the postal address is that of the principal place of business or of the principal office in the State)	Dragon Energy Ltd PO Box 1968 West Perth WA 6872
Key proponent contact for the proposal: • name • address • phone • email	Mr Gang Xu Managing Director Suite 8, 1297 Hay St West Perth WA 6005 Tel: 08 9322 6009 Email: gang.xu@dragonenergyltd.com.au
Consultant for the proposal (if applicable): • name • address • phone • email	Neil Dixon Ennovate Environmental Consulting 1 Seivewright St Silver Sands WA 6210 Tel: 0407 263 635 Email: neil@ennovateconsulting.com.au

1.2 Proposal

Title	Rocklea Early Tonnes Iron Ore Project (M47/1471)
Description	Dragon proposes to develop a 2 mtpa open pit mining operation to recover about 6 Mt of iron ore resource restricted to above water table and with a mine life of 3–4 years. The Proposal includes three mining voids, two waste rock dumps, a run-of-mine pad for a mobile crushing and ore screening plant and support facilities. It is proposed that the iron ore product will be hauled from the minesite by road train using existing public roads and/or private rail to a shipping port/point of sale (yet to be determined).

Extent (area) of proposed ground disturbance.	Up to 153 ha
Timeframe in which the activity or development is proposed to occur (including start and finish dates where applicable).	It is proposed that construction and operations will commence in late 2014. The operational life of the Proposal is 3–4 years, with decommissioning and closure commencing in 2017–18.
Details of any staging of the proposal.	The Proposal will not be staged; however, the proponent is investigating the potential development of a full-scale, below-water table mining project that would look to commence in or around 2017, pending finalisation of further studies and receipt of all necessary approvals.
Is the proposal a strategic proposal?	No
Is the proponent requesting a declaration that the proposal is a derived proposal? If so, provide the following information on the strategic assessment within which the referred proposal was identified: • title of the strategic assessment; and • Ministerial Statement number.	No
Please indicate whether, and in what way, the proposal is related to other proposals in the region.	The Proposal is not related to any other proposal in the region.
Does the proponent own the land on which the proposal is to be established? If not, what other arrangements have been established to access the land?	The Proposal is located within Mining Lease M47/1471-I, held by Dragon.
What is the current land use on the property, and the extent (area in hectares) of the property?	The property on which the Proposal is located is a pastoral lease (L 3114 1166), which is 3307 km^2 in extent. The mining lease M47/1471-I is 2825 ha

1.3 Location

Name of the Shire in which the proposal is located.	Shire of Ashburton
For urban areas: • street address; • lot number; • suburb; and • nearest road intersection.	n/a
For remote localities: • nearest town; and • distance and direction from that town to the proposal site.	The Proposal is located 34 km south-west of Tom Price (Attachment 1, Figure 1)
Electronic copy of spatial data - GIS or CAD, geo-referenced and conforming to the following parameters: • GIS: polygons representing all activities and named; • CAD: simple closed polygons representing all activities and named; • datum: GDA94; • projection: Geographic (latitude/longitude) or Map Grid of Australia (MGA); • format: Arcview shapefile, Arcinfo coverages, Microstation or AutoCAD.	Refer to Enclosure 1

1.4 Confidential Information

Does the proponent wish to request the EPA to allow any part of the referral information to be treated as confidential?	No
If yes, is confidential information attached as a separate document in hard copy?	n/a

1.5 Government Approvals

Is rezoning of any land required before the proposal can be implemented? If yes, please provide details.	No
Is approval required from any Commonwealth or State Government agency or Local Authority for any part of the proposal? If yes, please complete the table below.	Yes

Agency/Authority	Approval required	Application lodged Yes / No	Agency/Local Authority contact(s) for proposal
Department of Mines and Petroleum	Mining Proposal	No	Demelza Dravnieks
Department of Mines and Petroleum	Native Vegetation Clearing Permit	No	To be advised
Department of	Works Approval	No	Carmen

Environmental Regulation			Standring
Department of Water	Dewatering licence (5c)	No	Tasnim Poligadu
Main Roads	Concessional loading/RAV permits	No	Dave Pearson

PART B - ENVIRONMENTAL IMPACTS AND PROPOSED MANAGEMENT

2. ENVIRONMENTAL IMPACTS

Describe the impacts of the proposal on the following elements of the environment, by answering the questions contained in Sections 2.1-2.11:

2.1 flora and vegetation;

2.2 fauna;

2.3 rivers, creeks, wetlands and estuaries;

2.4 significant areas and/ or land features;

2.5 coastal zone areas;

2.6 marine areas and biota;

2.7 water supply and drainage catchments;

2.8 pollution;

2.9 greenhouse gas emissions;

2.10 contamination; and

2.11 social surroundings.

These features should be shown on the site plan, where appropriate.

For all information, please indicate:

(a) the source of the information; and

(b) the currency of the information.

2.1 Flora and Vegetation

2.1.1 Do you propose to clear any native flora and vegetation as a part of this proposal?

[A proposal to clear native vegetation may require a clearing permit under Part V of the EP Act (Environmental Protection (Clearing of Native Vegetation) Regulations 2004)]. Please contact the Department of Environment and Conservation (DEC) for more information.

(please tick) ☑ Yes **If yes**, complete the rest of this section.

☐ No **If no**, go to the next section

2.1.2 How much vegetation are you proposing to clear (in hectares)?

Up to 153 ha will be cleared. Refer to Attachment 1, Figures 3 and 4b.

2.1.3 Have you submitted an application to clear native vegetation to the DEC (unless you are exempt from such a requirement)?

☐ Yes ☑ No **If yes**, on what date and to which office was the application submitted of the DEC?

An application to clear native vegetation is in preparation and will be submitted to the DMP in March 2014.

2.1.4 Are you aware of any recent flora surveys carried out over the area to be disturbed by this proposal?

☑ Yes ☐ No **If yes**, please attach a copy of any related survey reports and provide the date and name of persons / companies involved in the survey(s).

If no, please do not arrange to have any biological surveys conducted prior to consulting with the DEC.

A Level 2 flora and vegetation survey was conducted in September 2011. Refer to Dinglebird Environmental (2012) in Attachment 2.

2.1.5 Has a search of DEC records for known occurrences of rare or priority flora or threatened ecological communities been conducted for the site?

☑ Yes ☐ No If you are proposing to clear native vegetation for any part of your proposal, a search of DEC records of known occurrences of rare or priority flora and threatened ecological communities will be required. Please contact DEC for more information.

Refer to pp.11–12 of Dinglebird Environmental (2012) in Attachment 2.

2.1.6 Are there any known occurrences of rare or priority flora or threatened ecological communities on the site?

☐ Yes ☑ No **If yes**, please indicate which species or communities are involved and provide copies of any correspondence with DEC regarding these matters.

There are no known occurrences of rare or priority flora in the disturbance footprint. The flora and vegetation survey located one population of *Ptilotus trichocephalus* (P4) within the survey area; this population is located 58 m outside of the clearing footprint and will be protected from any disturbance from the Proposal (Attachment 1, Figure 4b).

There are no known occurrences of threatened ecological communities (TECs) or priority ecological communities (PECs) in the disturbance footprint. None of the vegetation units identified in the disturbance footprint correspond with any TECs or PECs as listed under the EPBC Act (DSEWPaC 2009) or as defined by DPaW (DPaW 2013a, b)

2.1.7 If located within the Perth Metropolitan Region, is the proposed development within or adjacent to a listed Bush Forever Site? (You will need to contact the Bush Forever Office, at the Department for Planning and Infrastructure)

☐ Yes ☑ No **If yes**, please indicate which Bush Forever Site is affected (site number and name of site where appropriate).

Not applicable

2.1.8 What is the condition of the vegetation at the site?

The vegetation of the disturbance footprint was generally rated as Excellent to Good. The surrounding area was also rated as mostly Excellent to Good, with some areas of degraded vegetation due to the impacts of cattle and weed invasions, particularly around watercourses and drainage lines associated with the Hardey River.

Refer to p.24 and Appendix 3 of Dinglebird Environmental (2012) in Attachment 2.

2.2 Fauna

2.2.1 Do you expect that any fauna or fauna habitat will be impacted by the proposal?

(please tick) ☑ Yes **If yes**, complete the rest of this section.

☐ No **If no**, go to the next section.

2.2.2 Describe the nature and extent of the expected impact.

Vegetation clearing will result in the localised loss of up to 153 ha of fauna habitat. No conservation significant fauna habitats have been identified within the disturbance footprint. Significant fauna habitat is associated with the riparian vegetation along the Hardey River and its associated major tributaries, to the east and south of the disturbance footprint (Attachment 1, Figure 4c).

No SRE species will be significantly impacted by the Proposal. Eight SRE taxa were recorded in the SRE invertebrate survey (Phoenix 2012). Two of these, a land snail Rhagada 'small banded' (confirmed SRE) and an undescribed centipede species *Mecistocephalus* sp. indet., (potential SRE) were recorded in the disturbance footprint. Rhagada 'small banded' was recorded from several other sites across the broader survey area for the SRE survey (refer to Figure 4d of Attachment 1) and it is also possibly conspecific with specimens from Brockman 4 Syncline. The taxonomy is poorly resolved for geophilomorphan centipedes, the order to which *Mecistocephalus* sp. indet. belongs; therefore it is not possible to comment on its distribution or conservation status.

Stygofauna will not be significantly impacted by the proposal as there will be no mining below groundwater table and any groundwater abstraction will be managed so as to minimise drawdown effects. There is potential for vertical siltation to stygofauna habitat directly below the pits; however, the stygofauna assemblage of the survey area is well distributed and extends well outside the pit boundaries (Phoenix 2014, in Attachment 2). The extent of stygofauna habitat within the pit boundaries represents 4.3% of the stygofauna habitat within the survey area (refer to Figure 4e of Attachment 1).

Some loss of troglofauna habitat associated with excavation of the CID iron ore resource will occur. Based on species distributions, there appear to be two discrete troglofauna assemblages in two Robe River Pisolite (Czp) formation outcrops (eastern and western) within the survey area for the subterranean fauna survey (refer to Figure 4f of Attachment 1 and Phoenix (2014) of Attachment 2). The direct loss of habitat for the western assemblage represents 4% of the inferred total habitat extent for this assemblage or approximately 16% of habitat within the survey area. The eastern assemblage, which will not be impacted by the Proposal, has been excluded from these calculations as a precautionary measure.

Twenty four species of troglofauna were collected in the subterranean fauna survey (Phoenix 2014, in Attachment 2) of which 21 were considered potential or likely SRE species. All but three of the troglofauna species were recorded outside of the proposed pit boundaries (defined as the direct impact area for troglofauna); these were all recorded from a single bore only. Based on species records and an assessment of habitat connectivity, no troglofauna species are likely to be restricted to the direct impact area.

Advice was sought from Terrestrial Ecosystems Branch of the OEPA in relation to the investigation and assessment of impacts to troglofauna (refer to memo, dated 4 February 2014 in Attachment 2). The advice received has been incorporated into this assessment and the subterranean fauna technical report Phoenix 2014 in Attachment 2).

2.2.3 Are you aware of any recent fauna surveys carried out over the area to be disturbed by this proposal?

☑ Yes ☐ No **If yes**, please attach a copy of any related survey reports and provide the date and name of persons / companies involved in the survey(s).

If no, please do not arrange to have any biological surveys conducted prior to consulting with the DEC.

The following surveys have been carried out over the disturbance footprint and surrounds:

- Level 2 vertebrate fauna survey in September 2011 (Phoenix 2011)
- Northern Quoll and Pilbara Olive Python targeted survey in May 2012 (Phoenix 2012b)
- Short-range endemic invertebrate fauna survey in October–November 2011 (Phoenix 2012a)
- Subterranean fauna survey in July–October 2012 (Phoenix 2014).

2.2.4 Has a search of DEC records for known occurrences of Specially Protected (threatened) fauna been conducted for the site?

☑ Yes ☐ No (please tick)

Refer to Phoenix (2011) in Attachment 2 for results of searches of DPaW records for known occurrences of Specially Protected (threatened) Fauna.

2.2.5 Are there any known occurrences of Specially Protected (threatened) fauna on the site?

☐ Yes ☑ No **If yes**, please indicate which species or communities are involved and provide copies of any correspondence with DEC regarding these matters.

There are no known occurrences of Specially Protected (threatened) fauna in the disturbance footprint. The Pilbara Olive Python (Schedule 1) was recorded in the targeted fauna survey (Phoenix 2012b) outside of the disturbance footprint in habitat associated with the Hardey River (Figure 4c of Attachment 1).

Field surveys (Phoenix 2012b) also confirmed the presence of two priority species and one migratory species (Figure 4c in Attachment 1). Most of these records were in the riparian habitat associated with the Hardey River which is outside the disturbance footprint.

2.3 Rivers, Creeks, Wetlands and Estuaries

2.3.1 Will the development occur within 200 metres of a river, creek, wetland or estuary?

(please tick) ☑ Yes **If yes**, complete the rest of this section.

☐ No **If no**, go to the next section.

The Proposal maintains a minimum 100 m buffer to the Hardey River. The Proposal also does not interfere with the 1 in 100 year flood level for the Hardey River but does include a crossing of a minor tributary (refer to Figure 3 in Attachment 1). In most areas of the site, the 1 in 100 year buffer is greater than the 100 m buffer.

2.3.2 Will the development result in the clearing of vegetation within the 200 metre zone?

☑ Yes ☐ No **If yes**, please describe the extent of the expected impact.

Clearing of vegetation will occur within the 200 m zone but not within 100 m of the Hardey River. Riparian vegetation (vegetation unit Eco.Ac.Ass.Ml.*Cc) will not be cleared (refer to Figure 4b in Attachment 1).

2.3.3 Will the development result in the filling or excavation of a river, creek, wetland or estuary?

☐ Yes ☑ No **If yes**, please describe the extent of the expected impact.

2.3.4 Will the development result in the impoundment of a river, creek, wetland or estuary?

☐ Yes ☑ No **If yes**, please describe the extent of the expected impact.

2.3.5 Will the development result in draining to a river, creek, wetland or estuary?

☐ Yes ☑ No **If yes**, please describe the extent of the expected impact.

2.3.6 Are you aware if the proposal will impact on a river, creek, wetland or estuary (or its buffer) within one of the following categories? (please tick)

Conservation Category Wetland	☐ Yes	☑ No	☐ Unsure
Environmental Protection (South West Agricultural Zone Wetlands) Policy 1998	☐ Yes	☑ No	☐ Unsure
Perth's Bush Forever site	☐ Yes	☑No	☐ Unsure
Environmental Protection (Swan & Canning Rivers) Policy 1998	☐ Yes	☑No	☐ Unsure
The management area as defined in s4(1) of the *Swan River Trust Act 1988*	☐ Yes	☑No	☐ Unsure
Which is subject to an international agreement, because of the importance of the wetland for waterbirds and waterbird habitats (e.g. Ramsar, JAMBA, CAMBA)	☐ Yes	☑No	☐ Unsure

2.4 Significant Areas and/ or Land Features

2.4.1 Is the proposed development located within or adjacent to an existing or proposed National Park or Nature Reserve?

☐ Yes ☑ No **If yes**, please provide details.

2.4.2 Are you aware of any Environmentally Sensitive Areas (as declared by the Minister under section 51B of the EP Act) that will be impacted by the proposed development?

☐ Yes ☑ No **If yes**, please provide details.

2.4.3 Are you aware of any significant natural land features (e.g. caves, ranges etc) that will be impacted by the proposed development?

☐ Yes ☑ No **If yes**, please provide details.

2.5 Coastal Zone Areas (Coastal Dunes and Beaches)

2.5.1 Will the development occur within 300metres of a coastal area?

(please tick) ☐ Yes **If yes**, complete the rest of this section.

☑No **If no**, go to the next section.

2.5.2 What is the expected setback of the development from the high tide level and from the primary dune?

n/a

2.5.3 Will the development impact on coastal areas with significant landforms including beach ridge plain, cuspate headland, coastal dunes or karst?

☐ Yes ☑ No **If yes**, please describe the extent of the expected impact.

2.5.4 Is the development likely to impact on mangroves?

☐ Yes ☑ No **If yes**, please describe the extent of the expected impact.

2.6 Marine Areas and Biota

2.6.1 Is the development likely to impact on an area of sensitive benthic communities, such as seagrasses, coral reefs or mangroves?

☐ Yes ☑No **If yes**, please describe the extent of the expected impact.

2.6.2 Is the development likely to impact on marine conservation reserves or areas recommended for reservation (as described in *A Representative Marine Reserve System for Western Australia*, CALM, 1994)?

☐ Yes ☑No **If yes**, please describe the extent of the expected impact.

2.6.3 Is the development likely to impact on marine areas used extensively for recreation or for commercial fishing activities?

☐ Yes ☑No **If yes**, please describe the extent of the expected impact, and provide any written advice from relevant agencies (e.g. Fisheries WA).

2.7 Water Supply and Drainage Catchments

2.7.1 Are you in a proclaimed or proposed groundwater or surface water protection area?

(You may need to contact the Department of Water (DoW) for more information on the requirements for your location, including the requirement for licences for water abstraction. Also, refer to the DoW website)

☐ Yes ☑ No **If yes**, please describe what category of area.

2.7.2 Are you in an existing or proposed Underground Water Supply and Pollution Control area?

(You may need to contact the DoW for more information on the requirements for your location, including the requirement for licences for water abstraction. Also, refer to the DoW website)

☐ Yes ☑ No **If yes**, please describe what category of area.

2.7.3 Are you in a Public Drinking Water Supply Area (PDWSA)?

(You may need to contact the DoW for more information or refer to the DoW website. A proposal to clear vegetation within a PDWSA requires approval from DoW.)

☐ Yes ☑No **If yes**, please describe what category of area.

2.7.4 Is there sufficient water available for the proposal?

(Please consult with the DoW as to whether approvals are required to source water as you propose. Where necessary, please provide a letter of intent from the DoW)

☑Yes ☐ No (please tick)

2.7.5 Will the proposal require drainage of the land?

☐ Yes ☑ No **If yes**, how is the site to be drained and will the drainage be connected to an existing Local Authority or Water Corporation drainage system? Please provide details.

Mining activities will not intersect with groundwater, and as such no mine dewatering is required.

2.7.6 Is there a water requirement for the construction and/ or operation of this proposal?

(please tick) ☑ Yes **If yes**, complete the rest of this section.

☐ No **If no**, go to the next section.

Water is required for construction and operations for use in dust management, ore processing and ablution facility activities.

2.7.7 What is the water requirement for the construction and operation of this proposal, in kilolitres per year?

It is estimated that up to 360,000 kL per year will be required per annum, with the majority of demand for dust suppression during mining, crushing and screening, and stockpiling of ore. Lesser amounts will be required for vehicle and equipment washdown, and camp facilities.

The water demand for dust suppression is currently uncertain as there may be a regulatory requirement to undertake dust suppression along the unsealed section of the Nanutarra Road[1] that occurs near the proposed mine (see Figure 3 in Attachment 1). This issue is currently being considered by the Proponent and Main Roads.

2.7.8 What is the proposed source of water for the proposal? (e.g. dam, bore, surface water etc.)

It is expected that water supplies can be obtained from groundwater present within the CID deposit on M47/1471. Raw water would be treated to potable water standards at the camp. Borefield abstraction will be conducted in accordance with the *Rights in Water and Irrigation Act 1914* licence.

2.8 Pollution

2.8.1 Is there likely to be any discharge of pollutants from this development, such as noise, vibration, gaseous emissions, dust, liquid effluent, solid waste or other pollutants?

(please tick) ☑ Yes **If yes**, complete the rest of this section.

☐ No **If no**, go to the next section.

2.8.2 Is the proposal a prescribed premise, under the Environmental Protection Regulations 1987?

(Refer to the EPA's *General Guide for Referral of Proposals to the EPA under section 38(1) of the EP Act 1986* for more information)

☑ Yes ☐ No **If yes**, please describe what category of prescribed premise.

Category 5 – processing or beneficiation of metallic or non-metallic ore at a rate greater than 50,000 tonnes per year.

It is intended to dispose of solid putrescible waste at an existing approved facility.

The proposed waste water treatment plant is below the threshold for a prescribed premise.

[1] Also referred to as Nanutarra-Munjina Road.

2.8.3 Will the proposal result in gaseous emissions to air?

☐ Yes ☑ No **If yes**, please briefly describe.

2.8.4 Have you done any modelling or analysis to demonstrate that air quality standards will be met, including consideration of cumulative impacts from other emission sources?

☐ Yes ☑No **If yes**, please briefly describe.

2.8.5 Will the proposal result in liquid effluent discharge?

☑ Yes ☐ No **If yes**, please briefly describe the nature, concentrations and receiving environment.

An onsite package waste water treatment plant will be installed to treat all waste water generated by camp facilities for disposal to land.

2.8.6 If there is likely to be discharges to a watercourse or marine environment, has any analysis been done to demonstrate that the State Water Quality Management Strategy or other appropriate standards will be able to be met?

☐ Yes ☑ No **If yes**, please describe.

2.8.7 Will the proposal produce or result in solid wastes?

☑Yes ☐ No **If yes**, please briefly describe the nature, concentrations and disposal location/ method.

Putrescible, inert, recyclable and controlled wastes will be stored on site in designated areas that will avoid potential inundation by storm water. All solid wastes will be stored, used, transported and disposed of in accordance with relevant legislation and guidelines. All solid wastes will be collected and disposed of by a licensed waste contractor to appropriately licenced facilities.

2.8.8 Will the proposal result in significant off-site noise emissions?

☐ Yes ☑ No **If yes**, please briefly describe.

2.8.9 Will the development be subject to the Environmental Protection (Noise) Regulations 1997?

☑ Yes ☐ No **If yes**, has any analysis been carried out to demonstrate that the proposal will comply with the Regulations?

Please attach the analysis.

The closest potential sensitive receptor is Rocklea homestead, 8.6 km from the disturbance footprint (Attachment 1, Figure 2) which is considerably greater than the separation distance for open cut mining operations (3 km; Appendix 1 of the EPA's *Separation distances between industrial and sensitive land uses* (EPA 2005). Noise impacts from the proposal are expected to be negligible. Consultation will be maintained with Rocklea homestead with regard to noise emissions.

2.8.10 Does the proposal have the potential to generate off-site, air quality impacts, dust, odour or another pollutant that may affect the amenity of residents and other "sensitive premises" such as schools and hospitals (proposals in this category may include intensive agriculture, aquaculture, marinas, mines and quarries etc.)?

☐ Yes ☑ No **If yes**, please describe and provide the distance to residences and other "sensitive premises".

2.8.11 If the proposal has a residential component or involves "sensitive premises", is it located near a land use that may discharge a pollutant?

☐ Yes ☑ No ☐ Not Applicable

If yes, please describe and provide the distance to the potential pollution source

2.9 Greenhouse Gas Emissions

2.9.1 Is this proposal likely to result in substantial greenhouse gas emissions (greater than 100 000 tonnes per annum of carbon dioxide equivalent emissions)?

☐ Yes ☑No **If yes**, please provide an estimate of the annual gross emissions in absolute and in carbon dioxide equivalent figures.

The proposal will not result in substantial (greater than 100 000 tonnes per annum) greenhouse gas emissions. Annual greenhouse gas emissions for the Proposal are estimated to be approximately 11,000 tonnes CO_2-e.

2.9.2 Further, if yes, please describe proposed measures to minimise emissions, and any sink enhancement actions proposed to offset emissions.

2.10 Contamination

2.10.1 Has the property on which the proposal is to be located been used in the past for activities which may have caused soil or groundwater contamination?

☐ Yes ☑ No ☐ Unsure **If yes**, please describe.

2.10.2 Has any assessment been done for soil or groundwater contamination on the site?

☐ Yes ☑ No **If yes**, please describe.

2.10.3 Has the site been registered as a contaminated site under the *Contaminated Sites Act 2003*? (on finalisation of the CS Regulations and proclamation of the CS Act)

☐ Yes ☑ No **If yes**, please describe.

2.11 Social Surroundings

2.11.1 Is the proposal on a property which contains or is near a site of Aboriginal ethnographic or archaeological significance that may be disturbed?

☐ Yes ☐ No ☑Unsure **If yes**, please describe.

The proponent has a land access agreement in place with the Yinhawangka people (Native Title applicants for the site).

The Proposal avoids impact to all the places of aboriginal heritage value that have been identified by the Yinhawangka people, based on preliminary site visits.

There are no aboriginal heritage sites, as listed on the Department of Aboriginal Affairs heritage sites register (DAA 2014), within or adjacent to the disturbance footprint (Attachment 1, Figure 2).

A site clearance survey is yet to be undertaken and will be coordinated and assessed through the Yinhawangka people, via the Yamatji Marlpa Aboriginal Corporation (YMAC). Necessary authorisations under the *Aboriginal Heritage Act 1972* will be sought, pending the survey outcomes.

2.11.2 Is the proposal on a property which contains or is near a site of high public interest (e.g. a major recreation area or natural scenic feature)?

☐ Yes ☑ No **If yes**, please describe.

The property does not contain and is not near a site of high public interest.

2.11.3 Will the proposal result in or require substantial transport of goods, which may affect the amenity of the local area?

☑ Yes ☐ No **If yes**, please describe.

Although the Proponent is yet to finalise a transfer/unloading point for the iron ore product, it is estimated that the proposal will result in an additional 50 to 60 truck movements per day (each way) along the Nanutarra Road (Attachment 1, Figure 1). The road is part of the Main Roads WA (MRWA) RAV (Restricted Access Vehicle) network and is pre-approved for RAV10 vehicle configurations. The Proponent is looking to utilise quad road trains on a Concessional Loading Scheme (CLS) with a maximum payload of 115 t.

The Proponent will enter into a road maintenance agreement with MRWA regarding the upkeep of the Nanutarra Road, as well as any conditions of use, such as prior upgrades, dust suppression and minimising truck movements in wet conditions.

3. PROPOSED MANAGEMENT

3.1 Principles of Environmental Protection

3.1.1 Have you considered how your project gives attention to the following Principles, as set out in section 4A of the EP Act? (For information on the Principles of Environmental Protection, please see EPA Position Statement No. 7, available on the EPA website)

1. The precautionary principle.	☑ Yes	☐ No
2. The principle of intergenerational equity.	☑ Yes	☐ No
3. The principle of the conservation of biological diversity and ecological integrity.	☑ Yes	☐ No
4. Principles relating to improved valuation, pricing and incentive mechanisms.	☑ Yes	☐ No
5. The principle of waste minimisation.	☑ Yes	☐ No

3.1.2 Is the proposal consistent with the EPA's Environmental Protection Bulletins/Position Statements and Environmental Assessment Guidelines/Guidance Statements (available on the EPA website)?

☑ Yes ☐ No

3.2 Consultation

3.2.1 Has public consultation taken place (such as with other government agencies, community groups or neighbours), or is it intended that consultation shall take place?

☑ Yes ☐ No **If yes**, please list those consulted and attach comments or summarise response on a separate sheet.

A Land Access Deed has been entered into with the Yinhawangka People. The agreement includes access protocols and the establishment of a Monitoring and Liaison Committee.

Consultation has been undertaken with the following agencies:

- DER, regarding works approvals and licences
- DoW, regarding licences for water abstraction
- OEPA, regarding the anticipated approvals pathway for the Proposal and key environmental factors
- DMP, regarding the mining proposal and native vegetation clearing permit
- Shire of Ashburton regarding traffic, matters relating to local bylaws and utilisation of local landfill

- MRWA – traffic and road maintenance, access to MRWA bores
- Rocklea Pastoral Station Manager RTIO – information exchange re the proposal and future mine plans (no authorisation necessary as no pastoral infrastructure will be encroached or affected.

Attachment 1 – location maps

Fig 1: Proposal location
Fig 2: Locality plan – broad scale, also showing registered Aboriginal sites
Fig 3: Site plan – proposal details
Fig 4a: Existing environment – Beard vegetation
Fig 4b: Existing environment – vegetation and priority flora
Fig 4c: Existing environment – vertebrate fauna
Fig 4d: Existing environment – SRE invertebrate fauna
Fig 4e: Existing environment – stygofauna
Fig 4f: Existing Environment – troglofauna

Attachment 2 – supporting information

Level 2 flora & vegetation survey, Rocklea project area, Dinglebird Environmental (2012)
Vertebrate fauna survey of the Rocklea Iron Ore Project, Phoenix (2011)
Targeted Northern Quoll and Pilbara Olive Python survey for the Rocklea Iron Ore Project, Phoenix (2012b)
Short-range endemic invertebrate fauna survey for the Rocklea Iron Ore Project, Phoenix (2012a)
Subterranean fauna survey for the Rocklea Iron Ore Project, Phoenix (2014)
Memo to Terrestrial Ecosystems Branch (OEPA) regarding subterranean fauna, dated 4 February 2014

Enclosure 1 – GIS
All required GIS data (as per EPA referral guidelines)

References

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DPaW. 2013b. *Priority Ecological Communities for Western Australia*. Department of Parks and Wildlife.

DSEWPaC. 2009. *EPBC Act list of threatened fauna. In: Species Profile and Threats Database*. Australian Government Department of Sustainability, Environment, Water, Populations and Communities. Available at: http://www.environment.gov.au/cgi-bin/sprat/public/publicthreatenedlist.pl (accessed 26 Jul 2010).

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Phoenix. 2012a. *Short-range endemic invertebrate fauna survey for the Rocklea Iron Ore Project*. Phoenix Environmental Sciences Pty Ltd. Unpublished report prepared for Dragon Energy Ltd.

Phoenix. 2012b. *Targeted Northern Quoll and Pilbara Olive Python survey for the Rocklea Iron Ore Project*. Phoenix Environmental Sciences Pty Ltd. Unpublished report prepared for Dragon Energy Ltd.

Phoenix. 2014. *Subterranean fauna survey for the Rocklea Iron Ore Project*. Phoenix Environmental Sciences Pty Ltd. Unpublished report prepared for Dragon Energy.

Figure 1
Proposal location

Mining developments

Railway

Principal and secondary roads

Minor road

Major creeks and rivers

Nationally important wetland

National Parks and Nature Reserves

0 10 20 40 Kilometres

1:1,500,000

Client: Ennovate Consulting
Project: Rocklea Early Tonnes Iron Ore Project

Author: G. Bouteloup
Date: 24/02/2014

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

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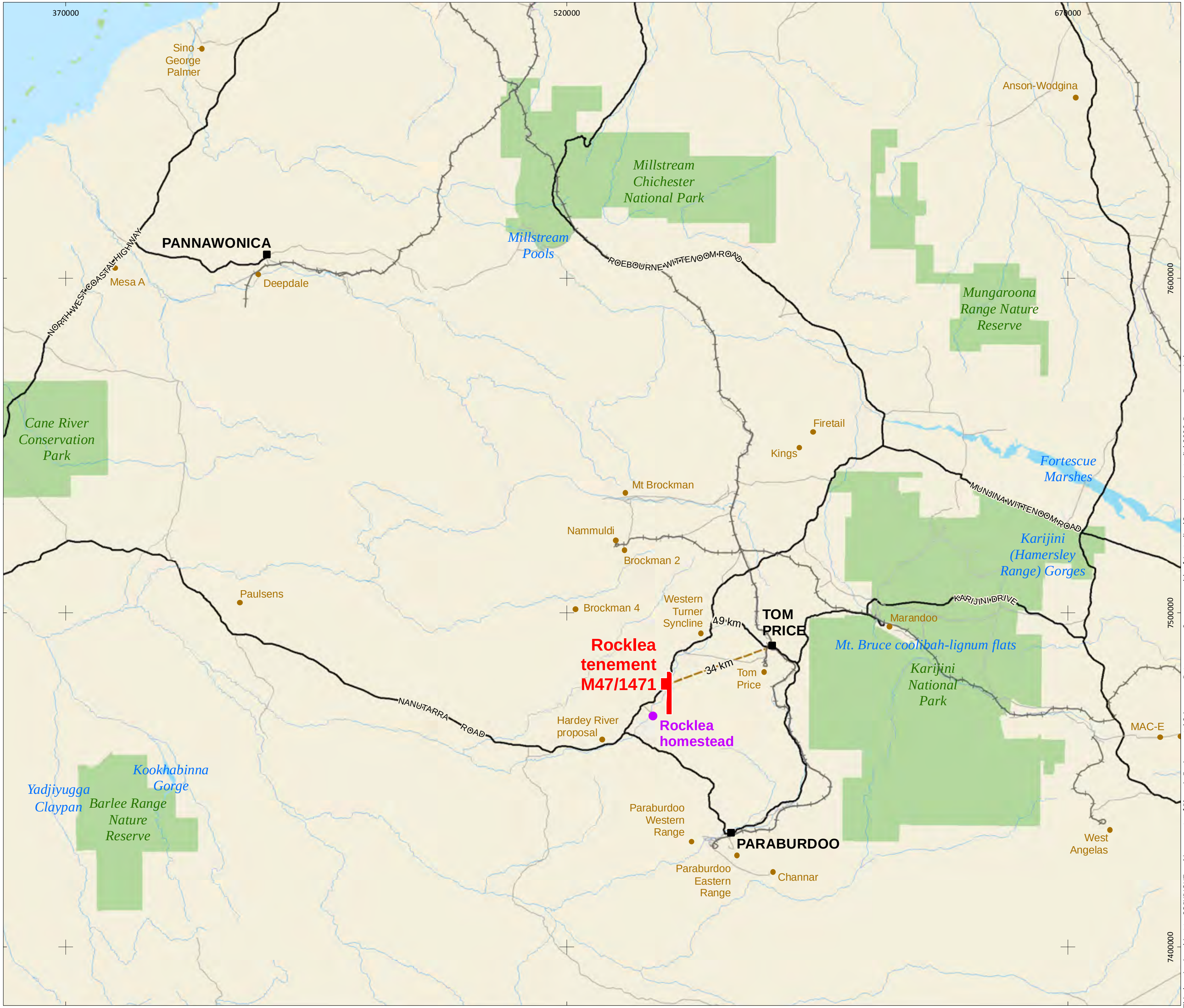

Figure 2
Locality plan — broad scale, also showing registered Aboriginal sites

Tenement M47/1471
Disturbance footprint
Indicative mine layout
Registered Aboriginal sites
Road reserve
Homesteads
Common boundaries (Lease)
Road
Track
Major creeks and rivers

0 0.5 1 2 Kilometres
1:80,000

Client: Ennovate Consulting
Project: Rocklea Early Tonnes Iron Ore Project

Author: G. Bouteloup
Date: 24/02/2014

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

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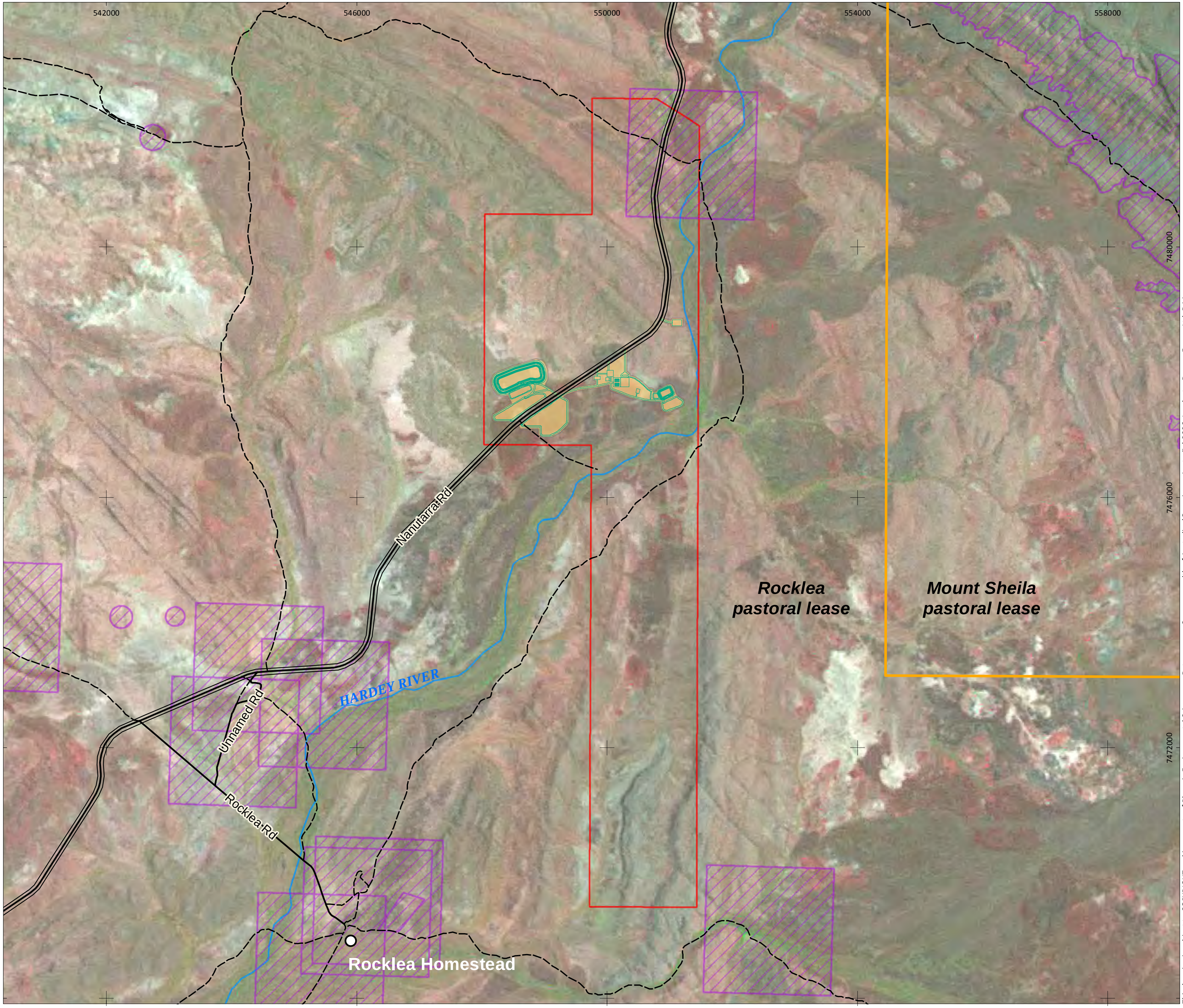

Figure 3
Site plan — proposal details

Tenement M47/1471

Disturbance footprint

Indicative mine layout

Pit

All infrastructure

Road reserve

Main road

Track

Major creeks and rivers

Flood boundary

5m contour

0 125 250 500 Metres

1:15,000

Client: Dragon Energy / Ennovate Consulting
Project: Rocklea Early Tonnes Iron Ore Project

Author: G. Bouteloup
Date: 24/02/2014

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

Western Australia

PERTH

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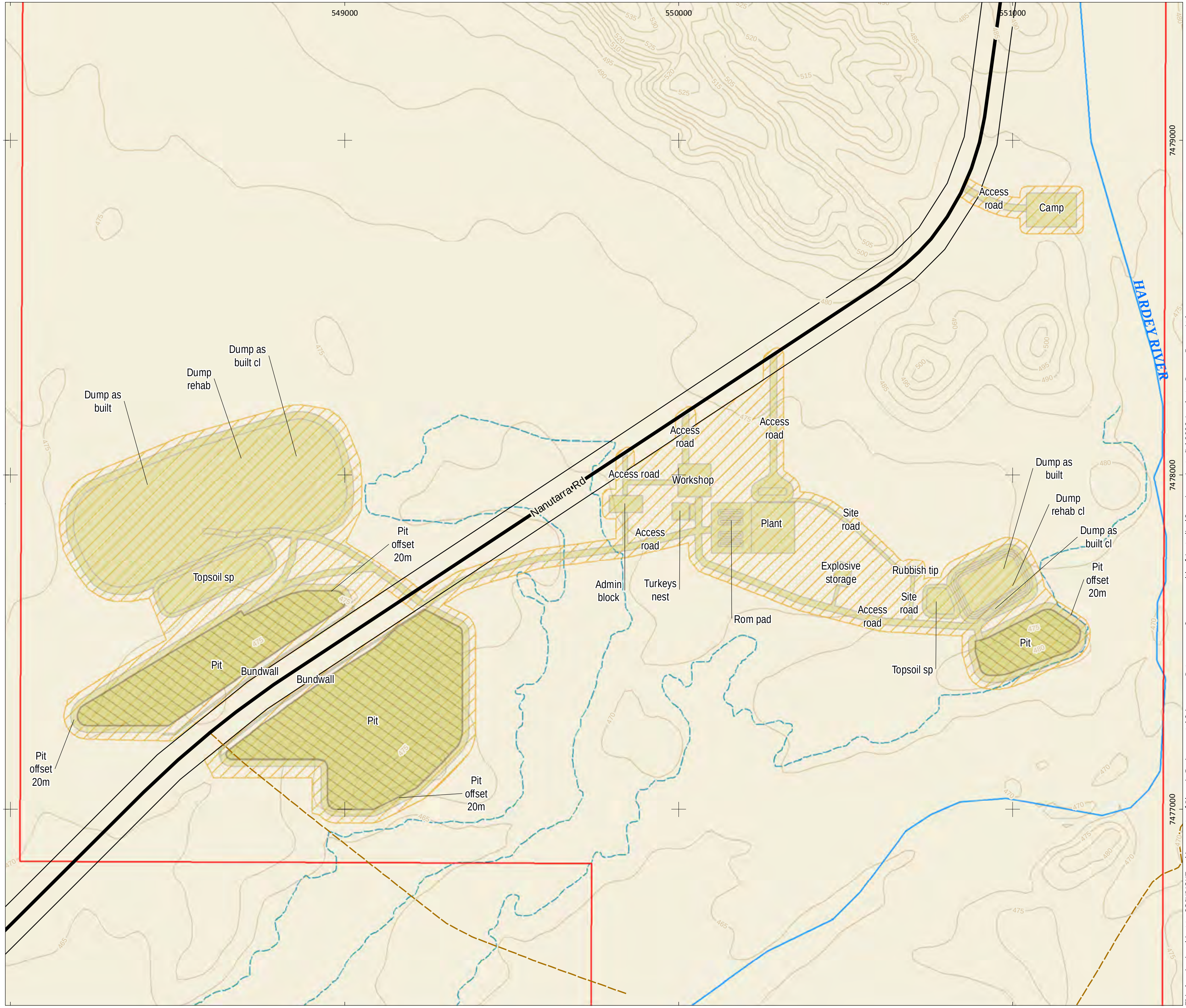
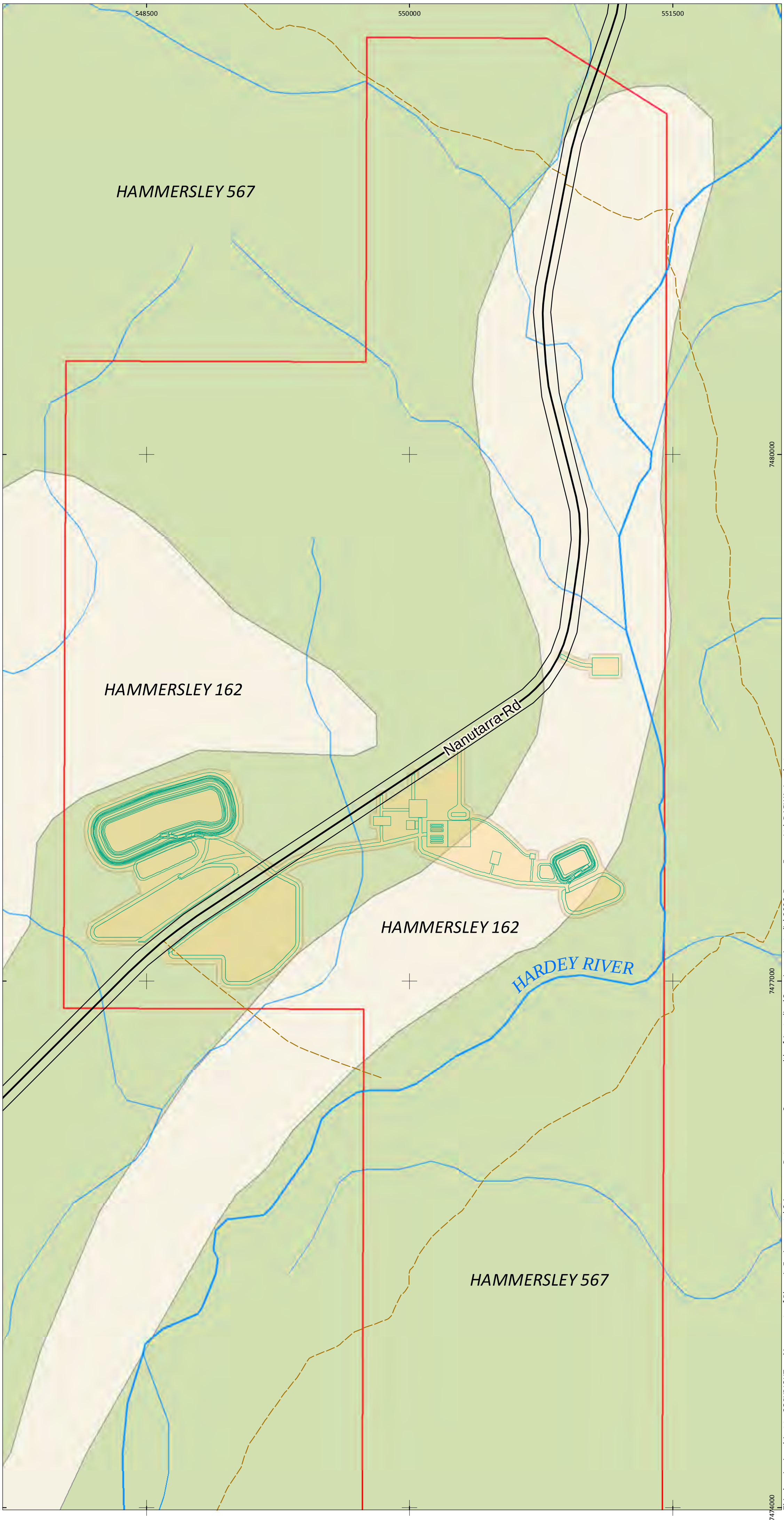


Figure 4a
Existing environment — Beard vegetation associations (1975)



Tenement M47/1471
Indicative mine layout
Disturbance footprint
Road reserve
Road
Track
River
Minor watercourse

Beard (1975) vegetation associations

HAMMERSLEY 162 — Shrublands; snakewood scrub

HAMMERSLEY 567 — Hummock grasslands, shrub steppe; mulga and kanji over soft spinifex and *Triodia basedowii*

0 250 500 1,000 Metres

1:30,000

Client: Dragon Energy Ltd / Ennovate Consulting
Project: Rocklea Early Tonnes Iron Ore Project

Author: G. Bouteloup
Date: 24/02/2014

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

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Figure 4b
Existing environment — vegetation and priority flora

Tenement M47/1471
Study area
Disturbance footprint
Indicative mine layout
Road
Track
Road reserve
Ptilotus trichocephalus population boundary
River
Minor watercourse

Vegetation units

Aa.Apr.Epo.Te
Aap.Aan.Ec.Ef.Ta
Aap.Ax.Epo.Sgch.Tb
Ax.Av.Aap.Tw.Ta
Ax.Sgch.Ec.Ss.Sa.Tw
Ch.Ta
Eco.Ac.Ass.Ml.*Cc
El.Aan.Te
El.Ap.Ta

0 250 500 1,000 Metres
1:30,000

Client: Dragon Energy Ltd / Ennovate Consulting
Project: Rocklea Early Tonnes Iron Ore Project

Author: G. Bouteloup
Date: 24/02/2014

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

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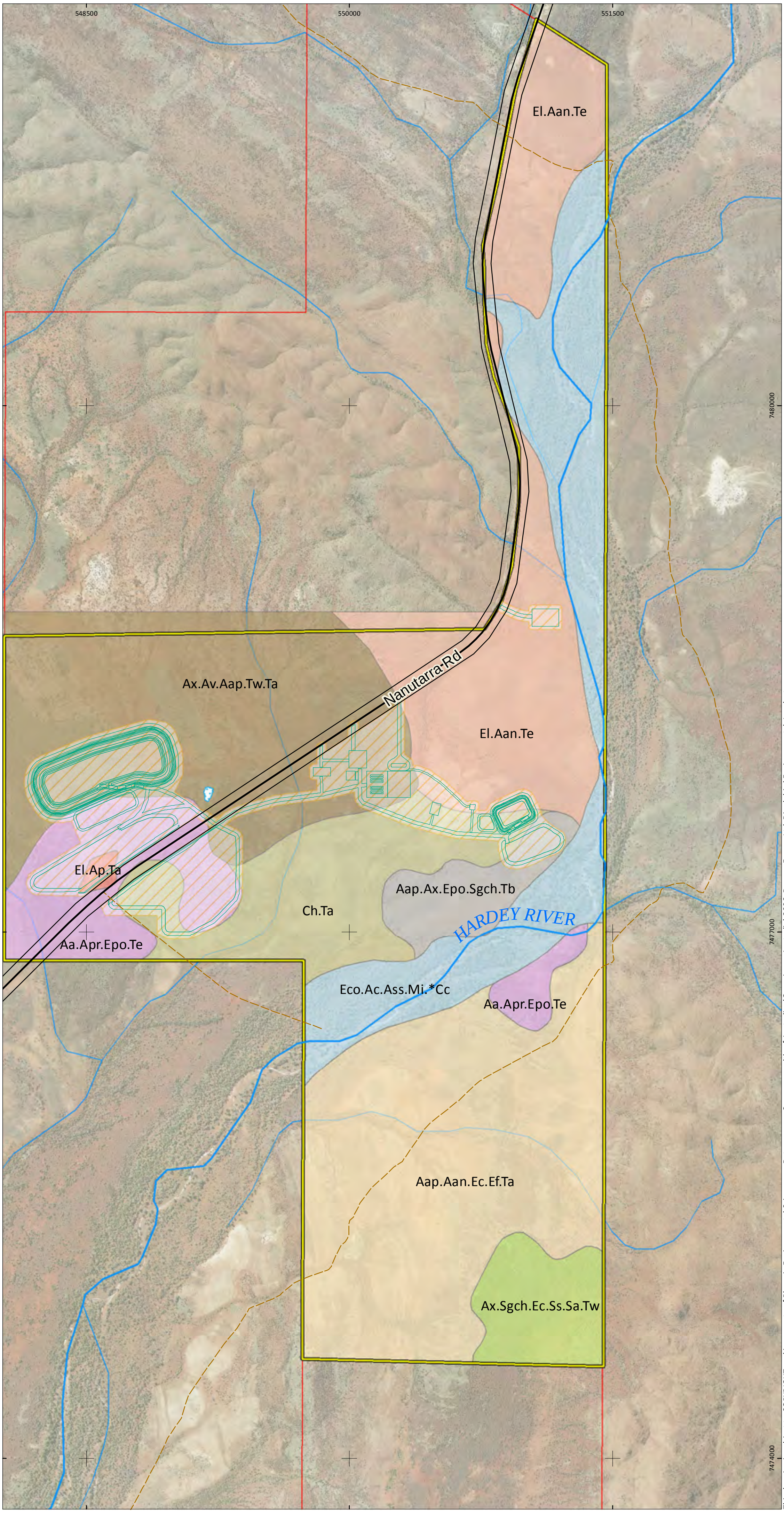

Figure 4b
Existing environment — Vegetation units (legend)

Vegetation units

- **Aa.Apr.Epo.Te**: *Acacia aptaneura* and *A. pruinocarpa* Open Low Woodland over *Acacia* spp. and *Eremophila phyllopoda* subsp. *obliqua* Shrubland to Open Shrubland over *Triodia epactia* Hummock Grassland
- **Aap.Aan.Ec.Ef.Ta**: *Acacia aptaneura* and *A. ancistrocarpa* Low Woodland over *Eremophila cuneifolia* and *E. fraseri* subsp. *fraseri* Open Shrubland over *Triodia angusta* Hummock Grassland (and **Cenchrus ciliaris* where condition is poor) in drainage lines; and *Acacia xiphophylla* Open Low Woodland over *Acacia victoriae*, *Senna glutinosa* subsp. *pruinosa* and *Eremophila cuneifolia* Open Shrubland over *Triodia angusta* Hummock grassland on stony lower slopes
- **Aap.Ax.Epo.Sgch.Tb**: *Acacia aptaneura* Low Open Woodland on upper gentle stony slopes and *Acacia xiphophylla* on lower stony slopes over *Eremophila phyllopoda* subsp. *obliqua* and *Senna glutinosa* subsp. *chatelainiana* Low Open Shrubland over *Triodia brizoides* Hummock Grassland with patches of *Sporobolus australasicus* Tussock Grassland
- **Ax.Av.Aap.Tw.Ta**: *Acacia xiphophylla* and *A. victoria* Tall Shrubland to Tall Open Shrubland, with *A. aptaneura* in drainage lines, over *Eremophila* spp. and *Senna* spp. over mixed low shrubs over annual grasses and *Triodia wiseana* and/or *T. angusta* Hummock Grassland
- **Ax.Sgch.Ec.Ss.Sa.Tw**: *Acacia xiphophylla* Tall Shrubland to Tall Open Shrubland over patches of *Senna glutinosa* subsp. *chatelainiana* and *Eremophila cuneifolia* and *Scaevola spinescens* over *Sporobolus australasicus* Open Tussock Grassland and patches of *Triodia wiseana* on stony plains
- **Ch.Ta**: Scattered to Low Open Woodland of *Corymbia hamersleyana* over *Acacia* spp., *Eremophila* spp. and *Senna* spp. Open Shrubland over *Triodia angusta* Hummock Grassland
- **Eco.Ac.Ass.Ml.*Cc** : *Eucalyptus camaldulensis* subsp. *obtusa*; Open Woodland over patches of *Acacia citrinoviridis*, *A. sclerosperma* subsp. *sclerosperma* and *Melaleuca lasiandra* over **Cenchrus ciliaris*; Open Tussock Grassland
- **El.Aan.Te**: Scattered *Eucalyptus leucophloia* over *Acacia ancistrocarpa* Open Shrubland over *Triodia epactia* Hummock grassland on stony hilltops, and *Acacia aptaneura* and other *Acacia* spp. over *Triodia* spp. Hummock Grassland on slopes
- **El.Ap.Ta**: Scattered *Eucalyptus leucophloia* over patches of *Acacia pruinocarpa* over *Triodia angusta* greater than *T. wiseana* Closed Hummock Grassland

Figure 4c
Existing environment — vertebrate fauna

Tenement M47/1471
Study area
Disturbance footprint
Indicative mine layout
Road reserve
Road
Track
River
Minor watercourse

Conservation significant species

Bush Stone-curlew (slight offset for display)
Rainbow Bee-eater
Western Pebble-mound Mouse (inactive mounds)
Pilbara Olive Python

Vertebrate fauna habitats

Cleared habitat
Grass plain
Grassland on rocky slope
Woodland on rocky slope
Non riparian mulga woodland
Riparian woodland
Minor drainage line
River bed

0 250 500 1,000 Metres
1:30,000

Client: Dragon Energy Ltd / Ennovate Consulting
Project: Rocklea Early Tonnes Iron Ore Project

Author: G. Bouteloup
Date: 24/02/2014

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

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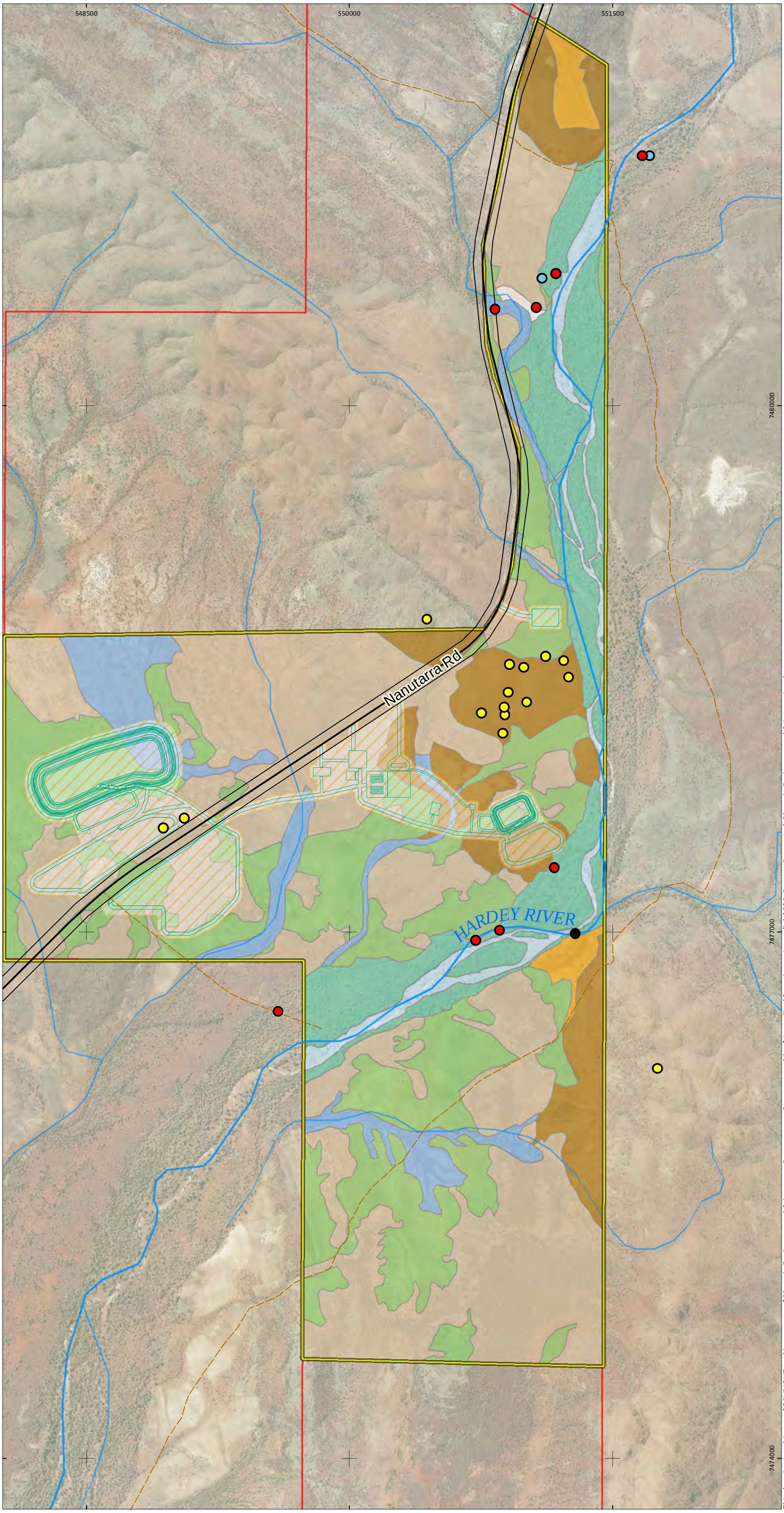
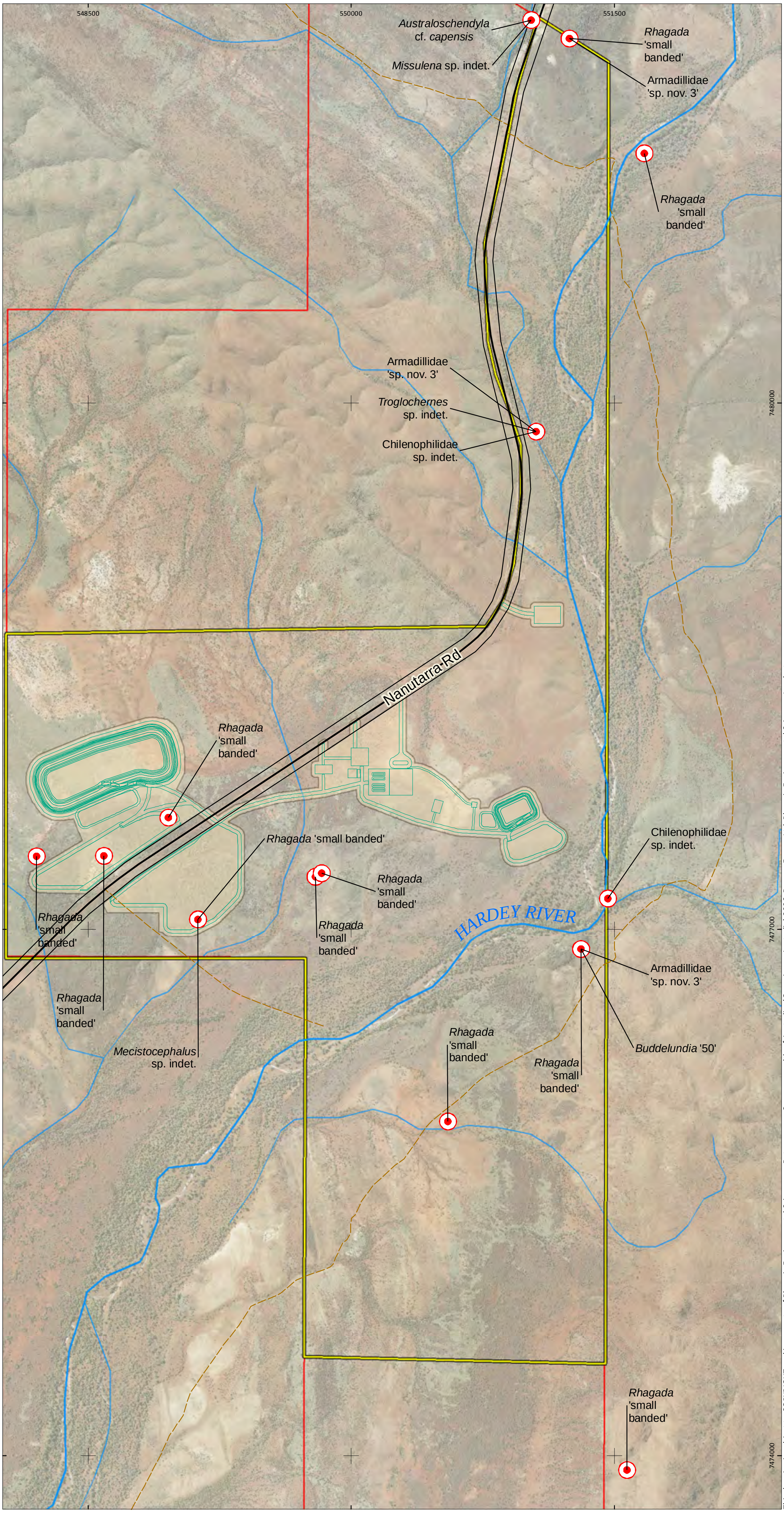


Figure 4d
Existing environment — SRE invertebrate fauna



Tenement M47/1471
Study area
Indicative mine layout
Disturbance footprint
Road reserve
Road
Track
River
Minor watercourse
Short-range endemic species records

0 250 500 1,000 Metres
1:30,000

Client: Dragon Energy Ltd / Ennovate Consulting
Project: Rocklea Early Tonnes Iron Ore Project

Author: G. Bouteloup
Date: 24/02/2014

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

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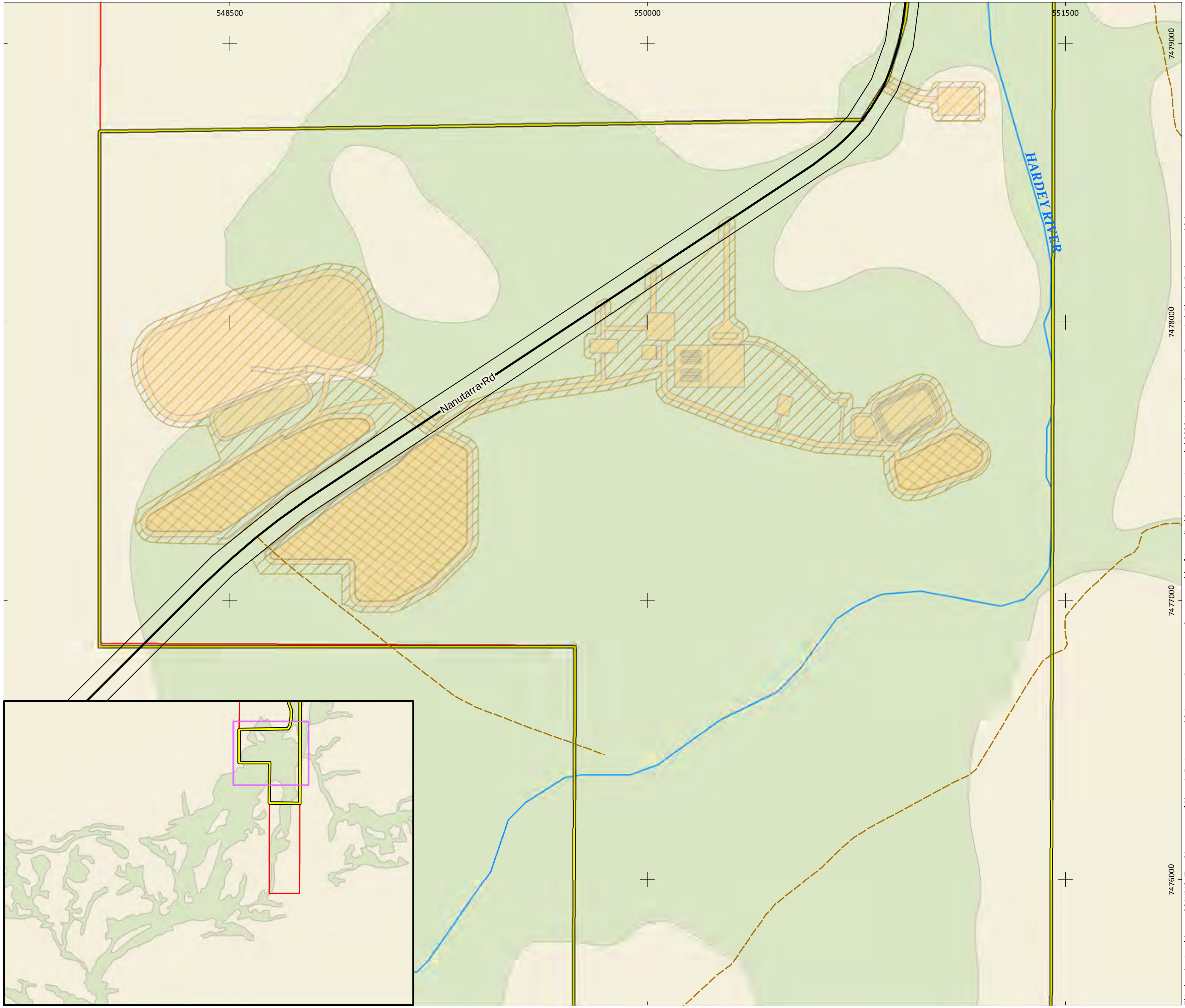
Figure 4e
Existing environment — stygofauna



Tenement M47/1471

Study area

Disturbance footprint

Indicative mine layout

Pit

All infrastructure

Stygofauna habitat

Road reserve

Main road

Track

Major creeks and rivers

0 175 350 700 Metres

1:18,000

Client: Dragon Energy / Ennovate Consulting
Project: Rocklea Early Tonnes Iron Ore Project

Author: G. Bouteloup
Date: 24/02/2014

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

PHOENIX ENVIRONMENTAL SCIENCES

Figure 4f
Existing environment — troglofauna

- Bores not yielding any species
- Bores yielding species outside the pits
- Bores yielding species in the pits
- Tenement M47/1471
- Study area
- Disturbance footprint

Indicative mine layout

- Pit
- All infrastructure
- Road reserve
- Main road
- Track
- Major creeks and rivers
- Western Robe River pisolite outcrop
- Eastern Robe River pisolite outcrop

Surface geology

- Czk: Calcrete
- Czp: Robe River Pisolite
- Qa: Alluvium
- Qc: Colluvium

0 250 500 1,000 Metres

1:35,000

Client: Dragon Energy / Ennovate Consulting
Project: Rocklea Early Tonnes Iron Ore Project

Author: G. Bouteloup
Date: 24/02/2014

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

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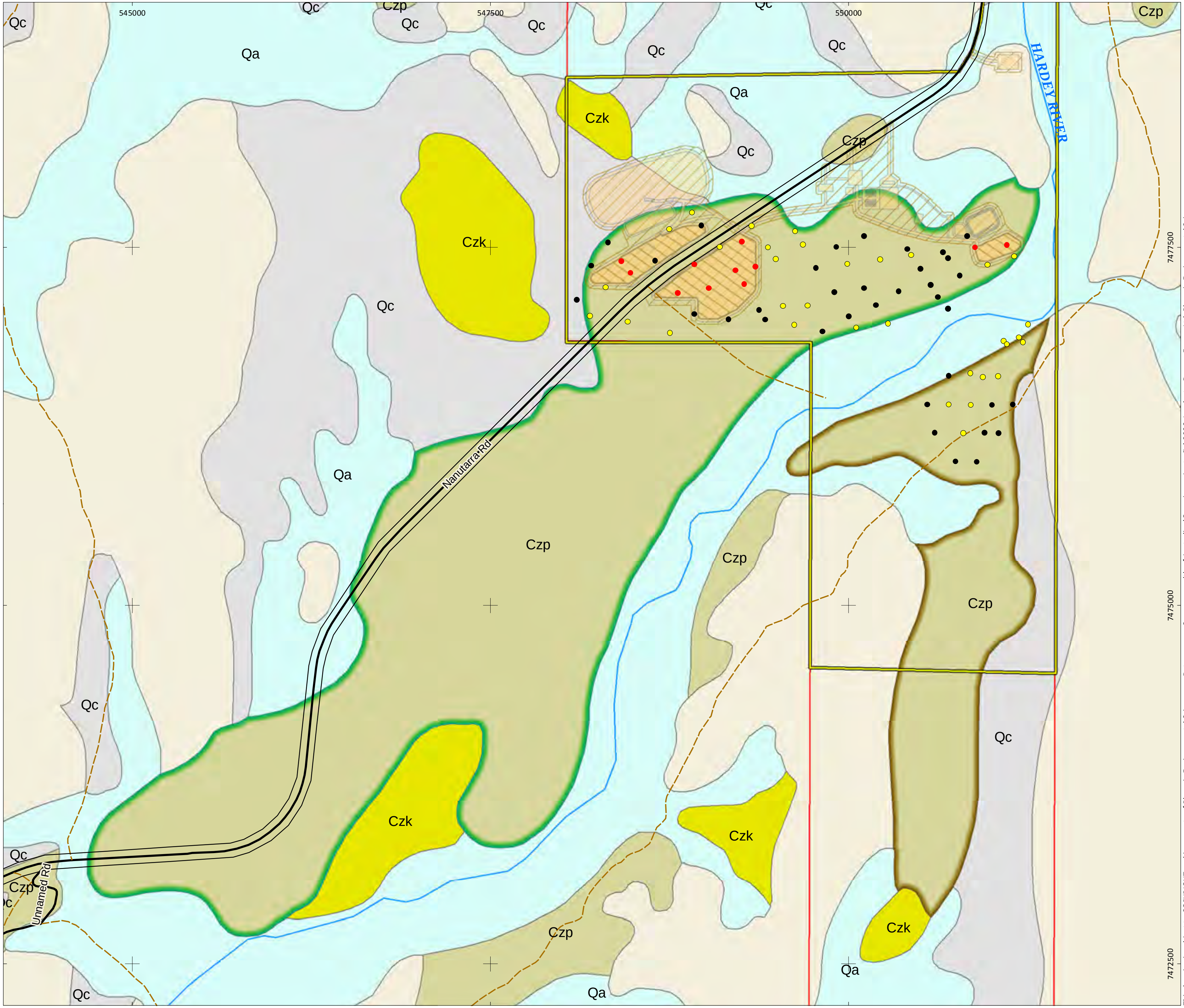

PHOENIX
ENVIRONMENTAL SCIENCES

Targeted Northern Quoll and Pilbara Olive Python survey for the Rocklea Iron Ore Project

Prepared for Dragon Energy Ltd

December 2012

Final Report

Targeted Northern Quoll and Pilbara Olive Python surveys of the Rocklea Iron Ore Project

Prepared for Dragon Energy Ltd

Final Report

Author: Ryan Ellis

Reviewers: Karen Crews, Jarrad Clark

Date: 21 December 2012

Submitted to: Tim Williams

Chain of authorship and review			
Name	Task	Version	Date
Ryan Ellis	Draft for technical review	1.0	15.06.2012
Karen Crews	Technical review	1.1	20.06.2012
Jarrad Clark	Draft submitted to client	1.2	27.06.2012
Mark Hafer	Client comments on draft	1.3	03.07.2012
Tim Williams	Client comments on draft	1.4	23.11.2012
Karen Crews	Final submitted to client	2.1	21.12.2012

Phoenix Environmental Sciences Pty Ltd

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Project code: 996-ROC-DE-VERT

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EXECUTIVE SUMMARY

In May 2012 Phoenix Environmental Sciences Pty Ltd was commissioned by Dragon Energy Ltd Limited to undertake a targeted fauna survey for the Northern Quoll (*Dasyurus hallucatus*) and Pilbara Olive Python (*Liasis olivaceus barroni*), for the Rocklea Iron Ore Project (the Project).The survey was undertaken in response to recommendations from an earlier baseline fauna survey undertaken for the Project (Phoenix 2011). Suitable habitat for both target species was identified in the study area during this earlier survey.

The Northern Quoll is listed as Endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The species is considered to be facing a very high risk of extinction in the wild in the near future due to several threatening processes.

The Pilbara Olive Python is listed as Vulnerable under the EPBC Act. The species is considered to be facing a high risk of extinction in the wild in the medium term.

The main objective of the survey was to determine if the target species are present in the study area and if so, estimate population size, distribution and any movement across the study area. The survey was required to determine if the Project would be likely to have a significant impact on either of the two species.

The field survey took place from 16 to 24 May 2012 in accordance with relevant survey guidelines. Four Northern Quoll trapping sites were installed in areas of potential habitat for the species. Three active search sites represented the extent of Pilbara Olive Python habitat within the study area.

No specimens of Northern Quoll or secondary evidence of species presence were recorded during the survey. It is considered unlikely Northern Quolls are present within the study area due to the limited habitat with suitable structure; only one site with suitable habitat is present within the Rocklea tenement.

No evidence of the species occurring in potential habitat that borders the south-east edge of the Rocklea tenement was recorded. It is unlikely that quolls are using riparian habitat along the Hardey River within the study area as a corridor to this habitat as overgrazing of riparian and woodland vegetation along has resulted in open areas of vegetation between the sites.

Based on the low likelihood of Northern Quoll occurring in the study area, it is unlikely the Project will impact this species.

One specimen of the Pilbara Olive Python was recorded on the survey during spotlighting at Pilbara Olive Python site 1. Suitable habitat is present in the study area and species presence has been confirmed. It is considered likely that the relatively small area of habitat permanently supports only small numbers of the species (<3). The species is known to move widely throughout the year and therefore it is likely that the area supports more individuals and vagrants from time to time, when conditions are favourable.

A detailed impact assessment for the Pilbara Olive Python cannot be undertaken until the project footprint has been defined (currently only resource boundaries are exist); however, potential impacts may include habitat loss and degradation, increased risk of road mortality, increased risk of predation, animals killed due to misidentification and habitat fragmentation.

Disturbance to the recorded Pilbara Olive Python habitat within the study area should be avoided as far as practicable. Mine infrastructure should be sited away from this habitat. Abundance of feral animals should be monitored and controlled to prevent risk of predation on Pilbara Olive Pythons. Education of all personnel should be undertaken increase awareness and knowledge of the species. Management of impacts to Pilbara Olive Python should be incorporated into a fauna management plan for the Project.

1 INTRODUCTION

In May 2012 Phoenix Environmental Sciences Pty Ltd (Phoenix) was commissioned by Dragon Energy Ltd Limited (Dragon) to undertake a targeted fauna survey for the Rocklea Iron Ore Project (the Project; Figure 1-1). The survey targeted two species of conservation significance; Northern Quoll (*Dasyurus hallucatus*) and Pilbara Olive Python (*Liasis olivaceus barroni*).

The main objective of the survey was to determine if the target species are present in the study area (Figure 1-2) and if so, estimate population size, distribution and any movement across the study area. The study area is broadly defined as tenement E47/1024; however, two Northern Quoll sites were installed approximately 100m to the east of the tenement boundary.

The survey was required to determine if the Project would be likely to have a significant impact on either of the two species. This report presents the results of the survey.

1.1 BACKGROUND

The Project is located 34 km southwest of Tom Price in the Pilbara region of WA The Project comprises a channel iron deposit (CID).

Mining is proposed to commence in 2014 in a staged format, with (under current plans) up to 2-4 million tonnes per annum of ore transported to a Pilbara port via road. The anticipated level of assessment is a mining proposal via the Department of Mines and Petroleum. No detailed mapping of the project layout (location of the main pit, waste dump, accommodation village, etc.) has been provided so the study area was expanded to incorporate areas of potential habitat in which an inhabiting population may be impacted. Currently, only resource boundaries based on an iron ore grade of 50% projected to the surface exist (Figure 1-2). Impacts and recommendations are based on this information

In September 2011, Phoenix undertook a Level 2 vertebrate fauna survey for the Project (Phoenix 2011). The survey recorded potential habitat for Northern Quoll and Pilbara Olive Python within the Rocklea tenement. Habitat for quolls was identified along the Hardey River which flows through the study area. Additional potential habitat for quolls was identified in a rocky ridge, extending south of the study area and it was considered possible that quolls may use the creekline habitats as a movement corridor to the ridgeline.

The Northern Quoll and Pilbara Olive Python are classified as Endangered and Vulnerable respectively, under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Both species are therefore matters of national environmental significance (NES) under the act. Actions that have, or are likely to have a significant impact on a matter of NES require approval from the Australian Government Minister for Sustainability, Environment, Water, Population and Communities.

Insufficient information was available from the Level 2 vertebrate fauna survey to determine if the Project would have a significant impact on either of these species. A follow up targeted survey was therefore undertaken to collect additional information to inform the impact assessment.

For an overview of the existing environment of the study area please refer to the baseline vertebrate fauna report (Phoenix 2011).

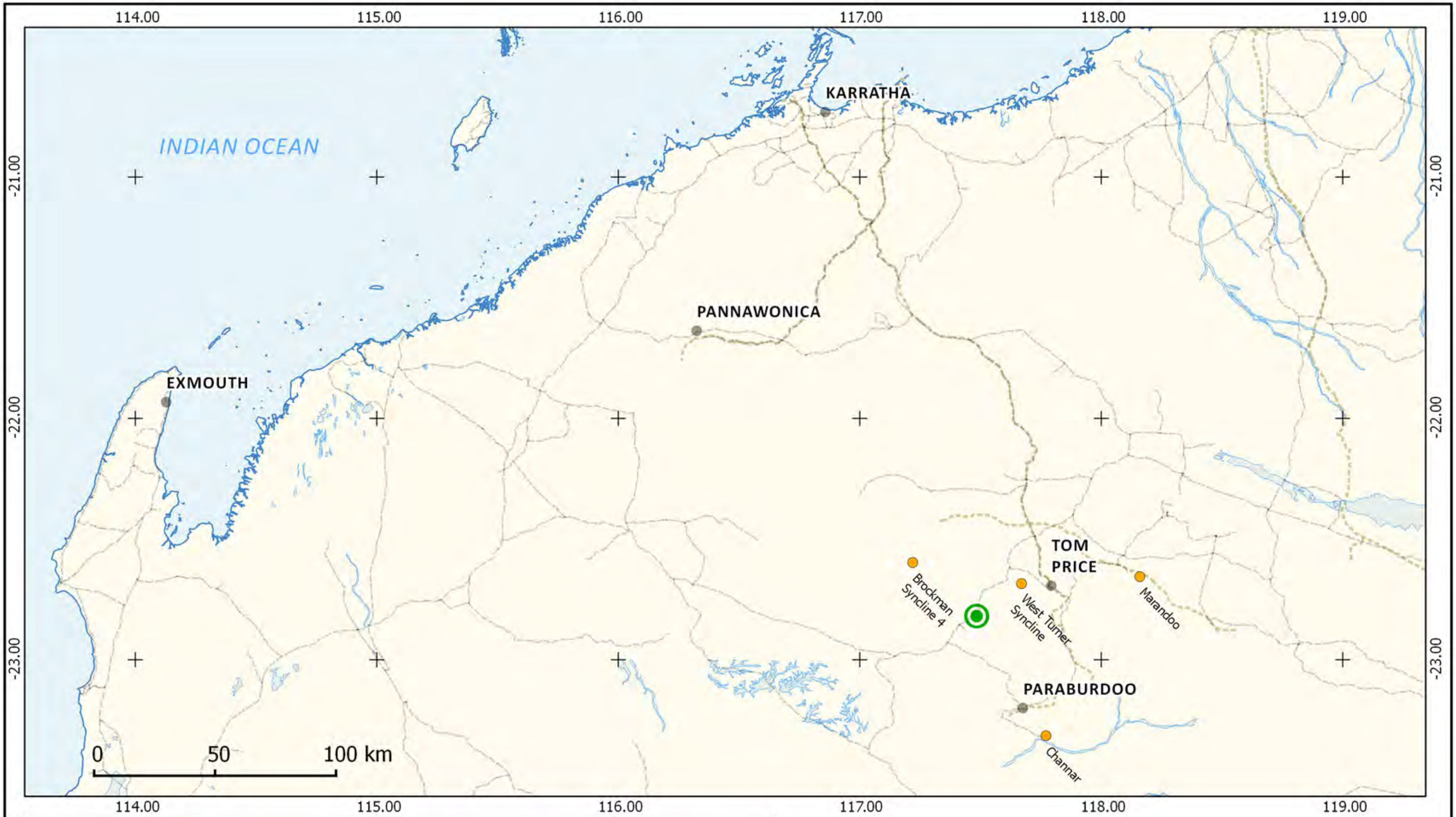


Figure 1-1
Location of the Rocklea Iron Ore Project

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR: G. Bouteloup	CLIENT: Dragon Energy Ltd.
DATE: November 2011	Scale: 1:1746870
Coordinate System: Projection: Transverse Mercator; Datum: WGS84	

PROJECT: Rocklea Iron Ore Project

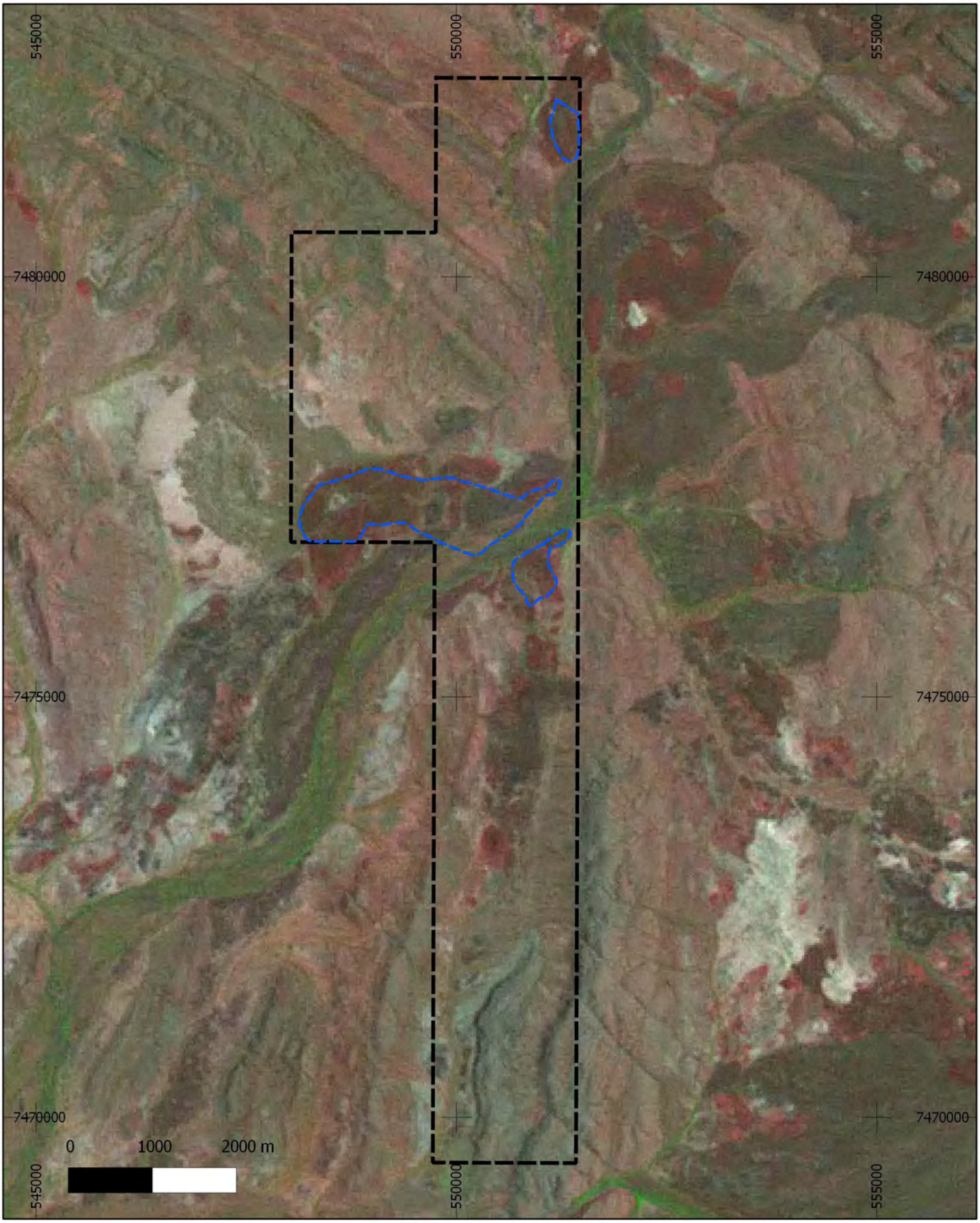


Figure 1-2 Study area for the targeted fauna survey of the Rocklea Iron Ore Project

Legend

Resource boundaries based on 50% Fe grade projected to surface

Study area boundary (Tenement E47/1024)

AUTHOR:J.CLARK	CLIENT: Dragon Energy Ltd
DATE:12.07.2012	Scale: 1:60000
Coordinate System: Projection: Transverse Mercator; Datum: WGS84	

PROJECT: ROCKLEA IRON ORE PROJECT

PHOENIX ENVIRONMENTAL SCIENCES

1.2 Scope of work and survey objectives

The scope of work for the survey was as follows:

- conduct a targeted field survey (trapping) for the Northern Quoll in areas of suitable habitat within the study area.
- conduct targeted searches for the Pilbara Olive Python in areas of suitable habitat within the study area
- prepare maps showing Northern Quoll and Pilbara Olive Python records and habitats in the study area
- prepare a technical report outlining survey methods and results including:
    - an assessment of the Northern Quoll occurrence and local distribution within the study area
    - an assessment of the Pilbara Olive Python occurrence and local distribution within the study area
    - an assessment of the potential impacts of these species from the Project and recommendations for management and mitigation of impacts.

Where practicable, survey design, methodology and report-writing adhere to relevant principles and guidelines, including:

- Environmental Protection Authority (EPA) Position Statement No. 3: Terrestrial biological surveys as an element of biodiversity protection (EPA 2002)
- EPA Guidance Statement No. 56: Terrestrial fauna surveys for environmental impact assessment in Western Australia (EPA 2004b)
- Department of Sustainability Environment, Water, Population and Communities (DSEWPC) Survey guidelines for Australia's threatened mammals (DSEWPC 2010).
- DSEWPC EPBC Act 1999 referral guidelines for the endangered Northern Quoll, Dasyurus hallucatus (DSEWPC 2011a).
- DSEWPC Survey guidelines for Australia's threatened reptiles (DSEWPC 2011c).

1.3 NORTHERN QUOLL LIFE HISTORY AND ECOLOGY

1.3.1 General biology and identification

The Northern Quoll is a medium sized terrestrial and arboreal dasyurid marsupial. It is the largest native marsupial predator in Western Australia; however, it is the smallest of the four Australian quoll species. It can be identified by its kitten like size with a finely pointed muzzle, prominent large ears and eyes. It has a brown coloured back, rump and head that is covered white spots and a creamy grey underbelly. The tail is brown with occasional white spots at the base to dark brown or black with no spots at the tip (Menkhorst & Knight 2011; Van Dyck & Strahan 2008).

Males and females are significantly dimorphic in size, with males being larger than females in length (body and tail) and weight, with potential overlap. Adult males can reach sizes of up to 370 mm in body length with tail reaching up to 245 mm and weights ranging from 340 to 1120 g. Females are often smaller with maximum adult sizes recorded showing up to 310 mm in body length, 300 mm tail length and up to 690 g (Van Dyck & Strahan 2008).

Northern Quolls are solitary and predominantly nocturnal; however, they may occasionally be active during the day in the mating season or on overcast days.

The species is short-lived and reaches maturity at approximately 11 months. Males typically die off shortly after mating (Oakwood 1997). The oldest female recorded in the wild was three years; however, most females often survive only one breeding season (Oakwood 1997; Van Dyck & Strahan 2008).

1.3.2 Taxonomy and nomenclature

The Northern Quoll, *Dasyurus hallucatus* or Yirryiwarru as known by aboriginals in the Pilbara region, was originally described by J. Gould in 1842. Three subspecies of the Northern Quoll are listed in the Zoological Catalogue of Australia 5 Mammalia (1988) (Mahoney & Ride 1988); however, these descriptions were based on geographic and morphological data with limited consideration given to variation within the species and are therefore not commonly referred to (Hill & Ward 2010).

Further recent genetic analysis has shown disjunction within the species between populations in Queensland, the Northern Territory and Western Australia (Hill & Ward 2010). Variation within WA populations have also been recorded showing Kimberley and Pilbara populations differed from each other genetically (How *et al.* 2009).

1.3.3 Habitat and distribution

The former distribution of the Northern Quoll included most of the northern third of Australia from the Pilbara and Kimberley, through northern NT to south-eastern Queensland. During the past century it has dramatically declined across the northern portion of Australia (Braithwaite & Griffiths 1994) due to a number of threatening processes. Its distribution has now contracted to several disjunct populations in WA (Pilbara and Kimberley), Northern Territory and Queensland. Within WA Northern Quolls have been recorded from many areas across the Kimberley (including offshore islands) and several areas across the Pilbara (Hill & Ward 2010; Van Dyck & Strahan 2008).

Northern Quolls occur in a variety of habitats and vegetation types across their range with a preference for rocky areas, such as dissected rocky escarpments, mesas, boulder fields and slopes or rock piles and creek lines. They can also inhabit eucalypt forest and woodlands (often associated with rocky terrain) and occasionally around human settlement (Oakwood 1997; Pollock 1999; Van

Dyck & Strahan 2008). Surveys in Queensland found the most abundant populations were associated with sites containing large boulders (Hill & Ward 2010).

Daytime den sites provide Northern Quolls with shelter and protection. They often include a variety of sites including rock crevices, caves, tree hollows, logs, termite mounds, burrows of other species (such as larger varanid burrows) and even human dwellings (Oakwood 1997; Van Dyck & Strahan 2008; Woinarski *et al.* 2008). Individuals may use a number of dens and records show individuals utilising different dens nightly (Oakwood 1997). The species does not appear to create or enlarge den entrances, instead using existing holes, or crevices in rock. During the mating season females will deposit their young at nursery dens while foraging (Oakwood 1997).

1.3.4 Diet

Northern Quolls are opportunistic omnivores with a varied diet consisting of primarily invertebrates, particularly insects. Other food sources include mammals (including rodents, dasyurids and rabbits), birds (including eggs), frogs and various reptiles. Their diet is also known to include fruits of some species of plants and the nectar of eucalypt and grevillea flowers (Oakwood 1997; Pollock 1999; Van Dyck & Strahan 2008). Analysis of scats and stomach contents has indicated the diet of the Northern Quoll shows seasonal trends when particular food sources are abundant (Oakwood 1997). Northern Quolls have also been recorded scavenging from road-kills and garbage bins (Van Dyck & Strahan 2008).

Northern Quolls will drink freely from water sources when available; however, they often obtain sufficient moisture from their variable diet when water is not available (Van Dyck & Strahan 2008).

1.3.5 Home range size

Surveys on a savannah population in Kakadu (NT) recorded females occupying territories averaging 35 ha with some overlap of foraging range when at high densities (3-4 females/km^2) and no overlap when densities were low (1-2 females/km^2) (Oakwood 1997). Slight shifts in habitat were recorded during the mating season leading to a reduction in range sizes. Adult male ranges were recorded to average over 100 ha during the mating season with some evidence showing male ranges may be similar in size prior to the mating season. Male ranges will overlap with several female territories and numerous other male territories. Dissected escarpments supported higher density populations with greater overlap and smaller ranges (Oakwood 1997; Van Dyck & Strahan 2008) .

1.3.6 Breeding biology

The Northern Quoll reproduces once per year and the timing is often synchronised within a population. Timing of mating between populations across Australia varies but typically occurs between July and September. Sexual maturity is reached at approximately 11 months. During the mating season the range of activity for males has been shown to expand to overlap with several females. Males will move between female ranges in rapid succession to monitor the onset of oestrus and a single female may be visited by up to four males in one night.

Most males die off within two weeks of mating which is believed to be related to the intense physical effort males dedicate to breeding (Oakwood 1997). Recent studies in the Pilbara have recorded male individuals over two consecutive seasons, suggesting that males of some Pilbara populations may have a longer life span (C. Jackson 2012, pers. comm.).

Once copulation has taken place the female will give birth to between five and nine young (on average seven) after a gestation period of 21 to 26 days. After eight to nine weeks the young are deposited in nursery dens while the mother forages, but will return regularly to allow young to suckle. The survival rate of young is high but once young were of age and left in nursery dens survival is relatively poor. Juveniles are fully weaned at around six months, but will start to forage and eat insects at four months (Oakwood 1997).

1.3.7 Conservation status and threatening processes

The Northern Quoll is federally listed as Endangered (EN) under the EPBC Act. Species classified as Endangered under the EPBC Act are considered to be facing a very high risk of extinction in the wild in the near future.

The Northern Quoll has declined significantly over the past century and is now only found in segregated populations across northern Australia with scattered populations recorded in the Kimberley and Pilbara regions of Western Australia (Hill & Ward 2010). A number of threatening processes are impacting the Northern Quoll; many threats coincide with each other increasing scale of impacts. Threatening processes for the Northern Quoll include:

- Cane Toads
- feral predators
- inappropriate fire regimes
- habitat degradation and destruction
- population isolation
- disease.

The primary threat to the Northern Quoll is the Cane Toad (*Bufo marinus*) which has significantly impacted quolls since its introduction. Toxins produced by the Cane Toad kill the quolls once eaten. Within the next 10-20- years Cane Toads are predicted to reach all of the Northern Quoll's range, with the exception of the Pilbara and western Kimberley regions. This makes any populations remaining in the Pilbara of particular importance (Hill & Ward 2010; Van Dyck & Strahan 2008; Woinarski *et al.* 2008).

In the Pilbara region introduced predators such as the Red Fox (*Vulpes vulpes*), Cat (*Felis catus*) and to a lesser extent the Dog (*Canis lupus*) are present and impacting the Northern Quoll through predation and competition for resources (Hill & Ward 2010; Van Dyck & Strahan 2008).

Threats from fire are linked to habitat degradation and destruction through removal of suitable habitat and vegetation cover and the introduction of weeds. Fire also increases competition between other introduced species for food and can result in easier predation on quolls (Hill & Ward 2010).

Habitat degradation and destruction has impacted a number for native species resulting in population decline across Australia. Degradation of habitat includes the introduction of weeds and other factors reducing the quality of habitat within an area such as clearing. Reduction of habitat quantity or quality poses a significant threat to Northern Quolls in the Pilbara region in particular due to increased mining activities (Hill & Ward 2010).

Population isolation poses a threat to the Northern Quoll due to their slow reproductive rate and susceptibility to disease in populations with little genetic diversity (Hill & Ward 2010; How *et al.* 2009). With short life spans in both sexes and post mating die off in males, populations can dramatically decrease if breeding is disrupted, or survival rate of offspring is low. Survivability of a population relies heavily on the survival of offspring each mating season. Reduced genetic diversity has been observed in populations isolated by threatening processes. Such populations are at greater risk of disease, population decline and localised extinction (Hill & Ward 2010).

In addition to the factors listed above, other factors directly impacting Northern Quoll populations include disease, hunting and baiting, and population isolation (Hill & Ward 2010).

1.3.8 Previous survey records

Northern Quolls have not previously been recorded within the study area. The nearest record is located approximately 46 km to the south south-east (Figure 1-3).

Potential habitat for the Northern Quoll was identified during the Level 2 vertebrate fauna survey in September 2011 (Phoenix 2011); however, no specimens were recorded during the survey. Two types of potential habitat were identified during the L2 vertebrate fauna survey, riparian vegetation and rocky range.

The riparian vegetation occurs alongside the Hardey River. Large areas have been overgrazed; however, scattered sections of healthy vegetation occur. The rocky range forms to the east of the Rocklea tenement following a southwest direction where it borders and dissects the south eastern border of the tenement. Three areas of potential habitat were identified, one within the Rocklea tenement and two on the south-eastern boundary of the tenement. A possible linkage between the sites using the vegetated areas along the Hardey River was identified also.

Desktop habitat mapping was subsequently undertaken to provide an indication of the spatial extent of potential habitat (Figure 1-4).

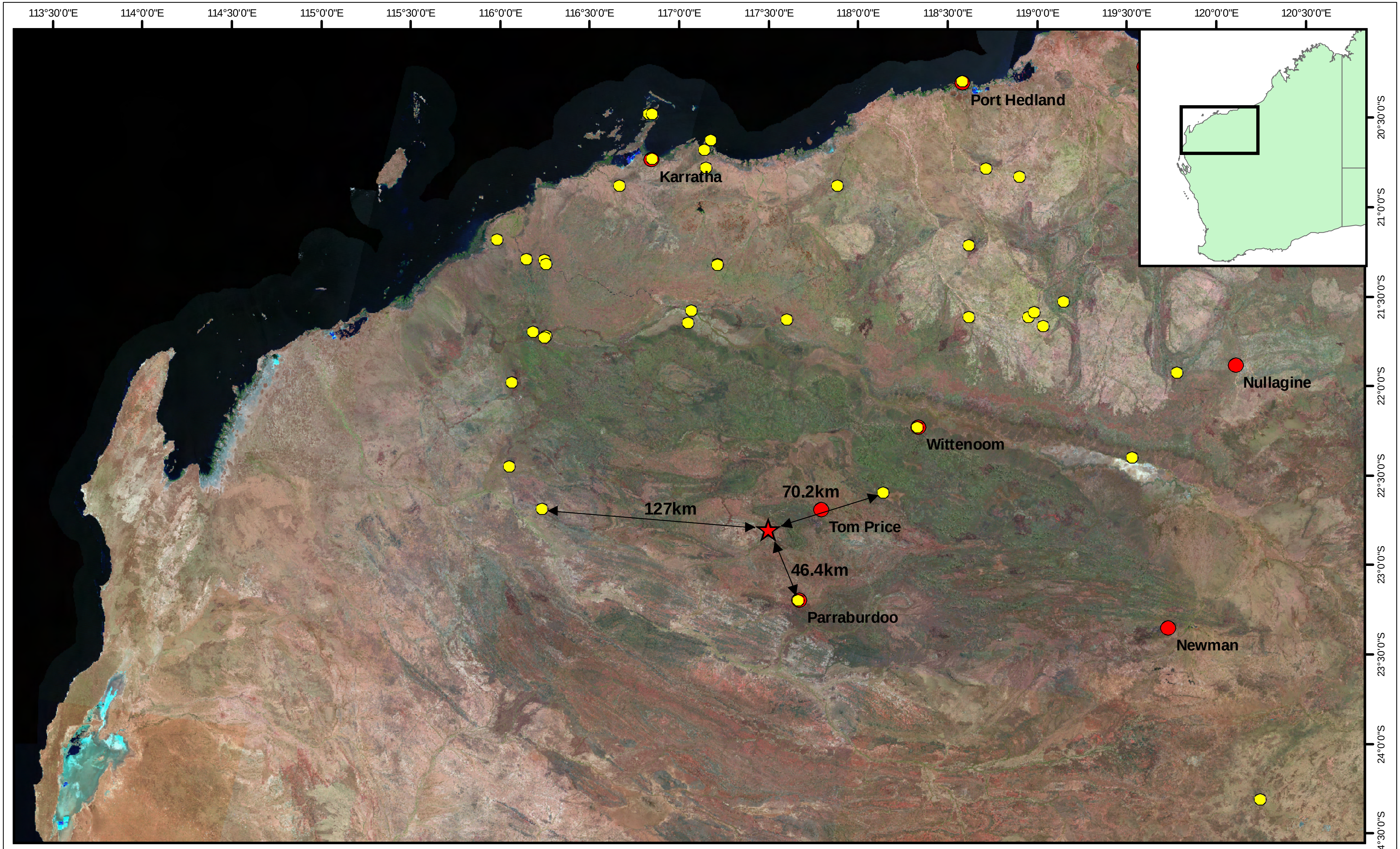


Figure 1-3 Distribution of Northern Quoll records relative to Rocklea Iron Ore Project

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR: ES Volschenk	CLIENT: Dragon Energy Ltd
DATE: 15 June 2012	Scale: 1:2,995,162

PROJECT: Rogklea Iron Ore Project

Coordinate System: Projection: Transverse Mercator; DATUM: GDA94

0 20 40 80 120 160 Kilometres

Dasyurus hallucatus — Rocklea Iron Ore Project — Town

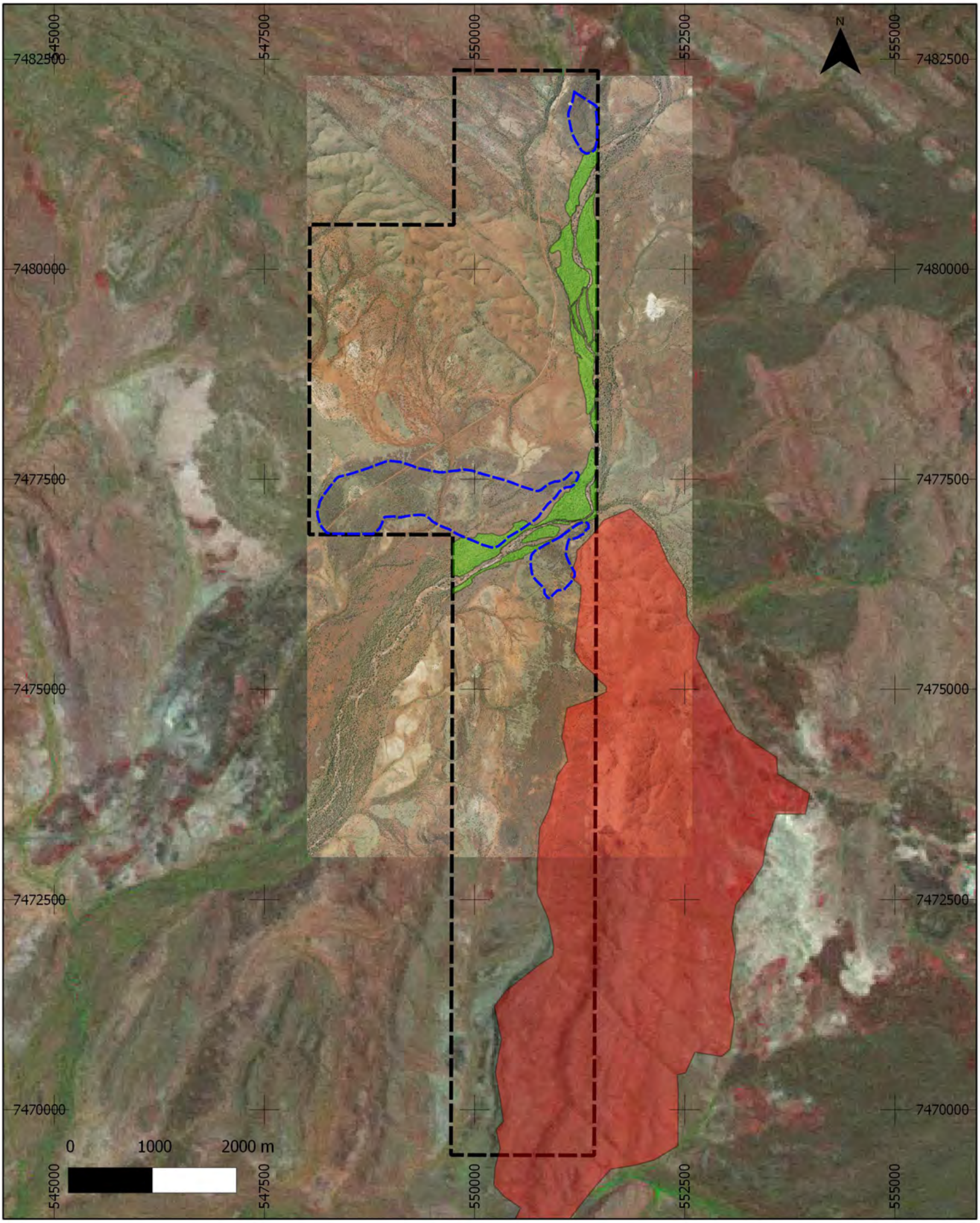


Figure 1-4 Potential habitat for Northern Quoll in the study area, based on desktop mapping

Potentially significant rocky ridgeline habitat
Potentially significant linear creekline habitat
Possible pit locations based on 50% Fe grade projected to surface
Study area boundary (Tenement E47/1024)

AUTHOR:J.CLARK	CLIENT: Dragon Energy Ltd
DATE:12.07.2012	Scale: 1:60000
Coordinate System: Projection: Transverse Mercator; Datum: WGS84	

PROJECT: ROCKLEA IRON ORE PROJECT

PHOENIX ENVIRONMENTAL SCIENCES

1.4 PILBARA OLIVE PYTHON LIFE HISTORY AND ECOLOGY

1.4.1 General biology and identification

The Pilbara Olive Python is a large and robust python found only in the Pilbara region of Western Australia. Average length of adults is 2.5 to 3 m; with records of specimens ranging from 4.5 to 6.5 m. Average adult weight is approximately 10 kg. As the name suggests the species is generally a uniform olive colour with no patterning, although specimens can show some slight variation with brown, reddish brown to dark brown coloration also recorded. The underbelly is a pale cream to white colour (Barker & Barker 1994; Smith 1981).

Distinguishing the two subspecies can be determined from location records (the two subspecies don't overlap in distribution), length and differences in scale characteristics and counts. Pilbara Olive Pythons show slight differences in head scales and body scales, with lower mid-body row and higher ventral scale counts compared to the other subspecies, *Liasis olivaceus olivaceus (Barker & Barker 1994; Cogger 2000; Smith 1981)*.

1.4.2 Taxonomy and nomenclature

The Pilbara Olive Python, *Liasis olivaceus barroni* was described in 1981 by L. A. Smith of the Western Australian Museum. Prior to the description of the sub species it was part of the *Liasis olivaceus* species-group which included the other olive python sub species *Liasis olivaceus olivaceus*, found in the Kimberley and other parts of northern Australia (Cogger *et al.* 1983). The Pilbara Olive Python is also commonly known as the Rock Python, Western Olive Python and bargumyji or pslkunyji to the Yindjibarndi and Kurrama aboriginal people (Pearson 2007).

1.4.3 Habitat and distribution

The Pilbara Olive Python is endemic to WA with most records located in the Pilbara and northern Ashburton regions (Figure 1-5). A specimen reportedly collected from Cue in the Murchison district in 1957 is believed to have come from the Pilbara region. Within the Pilbara the species has been recorded in a number of areas across the region, including some offshore islands (Barker & Barker 1994; Pearson 2007; Smith 1981).

Habitat for the Pilbara Olive Python is often associated with watercourses and drainage lines that dissect various ranges throughout the Pilbara. It is commonly found in rocky areas in association with watercourses and pools. Often associated with areas of permanent of pooling water near to rocky habitats such as gullies, gorges and rocky ranges or boulder sites but have also been recorded in riparian vegetation along major rivers such as the Fortescue (Barker & Barker 1994; DSEWPC 2011c; Pearson 2003, 2007).

1.4.4 Diet

The Pilbara Olive Python is an opportunistic predator with a varied diet including mammals, birds and potentially frogs and reptiles. It predates fauna of various sizes from small rodents, bats and birds through to large rock wallabies and euros. Olive Pythons will often wait in an ambush position on rock ledges, at cave entrances or at water sources for prey to come within striking distance.

Studies suggest sites near water are important predation sites for Olive Pythons (Pearson 2003). They are often found in the water on the edge of pools or creeklines waiting for birds and mammals to come to the site to drink; prey are often concentrated to such sites during drier times of the year (Barker & Barker 1994; Pearson 2007).

1.4.5 Home range size

The results of a study of Pilbara Olive Pythons on the Burrup Peninsula, where four individuals (one male and three females) were radio-tracked, showed the home ranges of the individuals ranged from 87 to 449 ha. The lone male recorded a larger range than the females (Tutt *et al.* 2004; Tutt *et al.* 2002). This range is much larger than any other Australian pythons; however, the sample size in this study was too small to make definitive interpretations about the range of the subspecies. The home range of the Pilbara Olive Python is likely to be dependent on resource availability, such as habitat and prey species.

1.4.6 Breeding biology

Pilbara Olive Pythons breed during the cooler months from June to August, when males will move long distances of up to three km in search of females. As with many other species of python, it is likely the female leaves a pheromone (scent) trail which males follow to locate mature females. When a male has found a female they will often retreat to a cave where they may remain together for up to three weeks. During this time it is likely they mate a number of times. The male soon returns to its original range and leaves the female to lay and incubate the eggs. Eggs are laid around October within or under large rocky areas. There is limited data available on clutch sizes and incubation due to the difficulty of locating incubating females. Eggs hatch in January and hatchlings will disperse in search of food and refuges. Survival rates of Pilbara Olive Pythons are unknown, although they are likely to be dependent on threatening processes existing in an area, such as habitat condition and abundance of predators (Pearson 2003, 2007).

1.4.7 Conservation status and threatening processes

The Pilbara Olive Python is listed as Vulnerable (VU) under the EPBC Act. Under the act, Vulnerable species are considered to be facing a high risk of extinction in the wild in the medium term.

The Pilbara Olive Python has not been shown to be declining dramatically; however, its Vulnerable listing is linked to its endemism to the Pilbara region and threatening processes that are likely to impact the species. Threatening processes for the Pilbara Olive Python include:

- habitat degradation and destruction
- feral predators
- increased human and mining presence.

Degradation of habitat includes the introduction of weeds and other factors reducing the quality of habitat within an area, such as clearing. Destruction or removal of habitat is often linked to increased human presence in the region. Reduction of habitat quantity or quality poses a significant threat to Pilbara Olive Python in the Pilbara region in particular due to increased mining activities which often target areas of potential habitat for the species (DSEWPC 2008).

Introduced predators such as the Red Fox (*Vulpes vulpes*), Cat (*Felis catus*) and to a lesser extent the Dog (*Canis lupus*) are present within the Pilbara region and pose a threat to the Pilbara Olive Python primarily through predation, and to a lesser extent, competition for prey species. Decline in prey species such as small wallabies and quolls will directly affect large Pilbara Olive Pythons and a reduction in smaller vertebrate species preyed upon by introduced species are likely to significantly impact hatchling and juvenile pythons (DSEWPC 2008; Pearson 2007).

Human presence is growing at a fast rate in the Pilbara region, due to increased mining and tourism activity. More people living in and moving through the region pose increasing pressure on the

Pilbara Olive Python, particularly in relation to impacts on habitat. Direct road mortalities also occur (Pearson 2007).

1.4.8 Previous survey records

No Pilbara Olive Pythons have previously been recorded within the study area. There are two records from within 50 km with the nearest record located approximately 33 km south south-east of the study area (Figure 1-5).

Potential habitat for the Pilbara Olive Python was identified during the Level 2 vertebrate fauna survey in September 2011 (Phoenix 2011); however, no specimens or evidence of the species presence were recorded during the survey.

A single site within the study area was identified as suitable habitat for the species during the Level 2 survey. The site was positioned along the Hardey River and contained rock piles and fallen boulders with a pool of water present below. It was not known if the pool at this identified site and other pools in the section of the Hardey River are permanent or not as 386.2 mm of rain had fallen at the Paraburdoo weather station (BOM 2012) between the Level 2 and targeted survey.

Studies suggest sites near water are important predation sites for Olive Pythons (Pearson 2003).

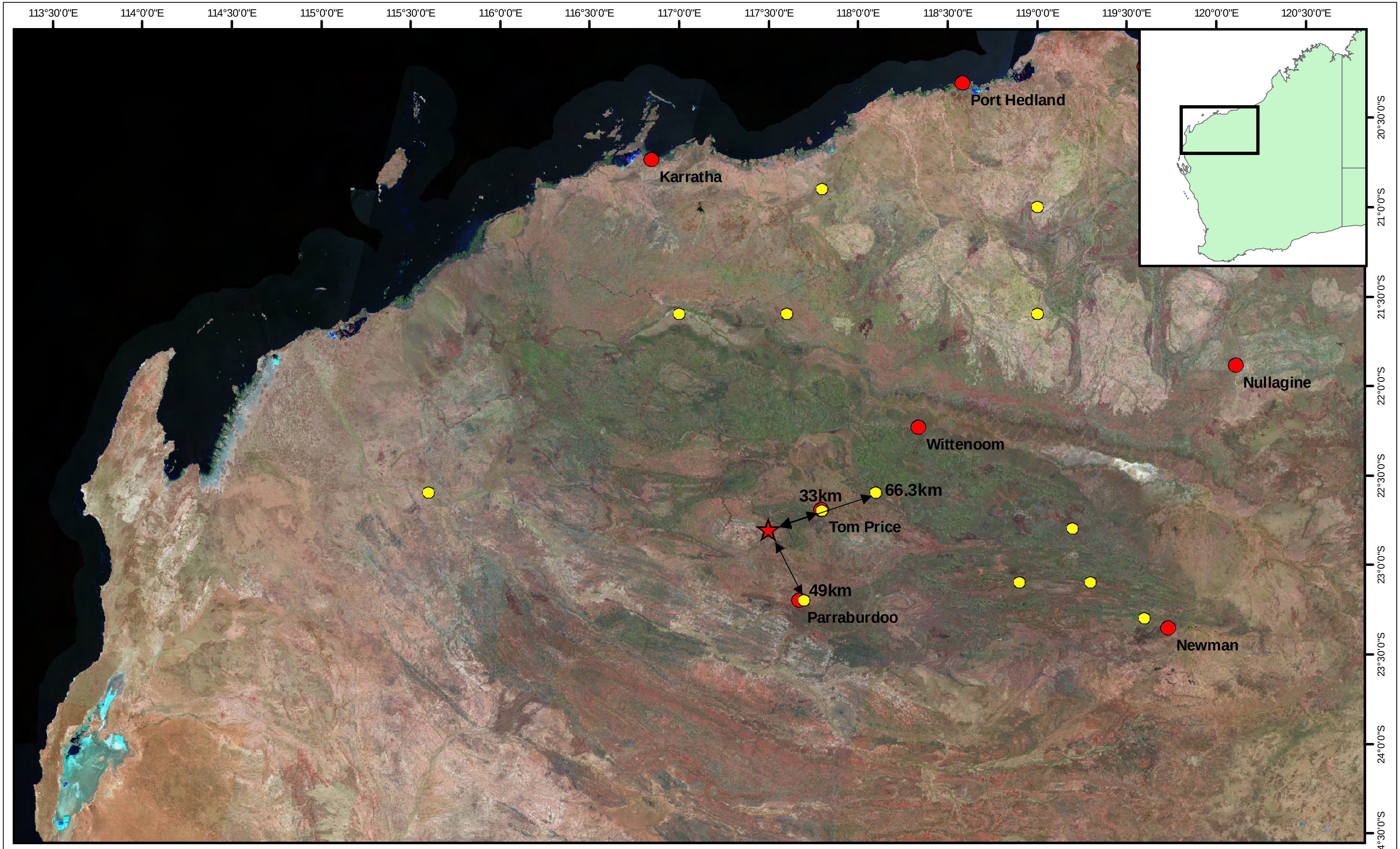


Figure 1-5 Distribution of Pilbara Olive Python records relative to the Rocklea Iron Ore Project

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR: ES Volschenk	CLIENT: Dragon Energy Ltd
DATE: 15 June 2012	Scale: 1:2,995,162

PROJECT: Rogklea Iron Ore Project

Coordinate System: Projection: Transverse Mercator; DATUM: GDA94

Kilometres: 0, 20, 40, 80, 120, 160

Liasis olivaceus barroni records | Rocklea Iron Ore Project | Town

2 METHODS

2.1 HABITAT ASSESSMENT AND SITE SELECTION

Habitats with the potential to support Northern Quoll and Pilbara Olive Python were identified during the Level 2 vertebrate fauna survey (refer to section 1.3.8 and 1.4.8).

Prior to the targeted field survey, further refinement of potential habitat extent for the target species was undertaken. In particular, the initial habitat mapping for Northern Quoll (section 1.3.8) was refined, as this data set was determined to be considerably too broad in extent.

2.2 FIELD SURVEY

The field survey took place from 16 to 24 May 2012. Survey work was undertaken over 10 consecutive days. The survey components are described in more detail in Sections 2.2.1 to 2.2.4.

2.2.1 Trapping for Northern Quolls

Trapping for Northern Quolls followed survey guidelines detailed in the EPBC Act referral guidelines for the species (DSEWPC 2011a) and DSEWPC survey guidelines for Australia's threatened mammals (DSEWPC 2011b). Four trap sites were selected, three rocky sites (NQ1, NQ2 and NQ3) and one transect along a section of the Hardey River (NQ4) that passed site NQ1 (Appendix 1).

Large Elliott traps and Cage traps were used during with additional remote camera traps deployed across the four sites. A total of 86 large Elliotts (type B), 11 Sheffield cage traps and eight camera traps were deployed during the survey period (Table 2-1).

Elliott and cage traps were placed in areas of likely quoll movement or near potential den sites at all four trapping sites. Traps at sites NQ1, NQ2 and NQ3 were spaced across the sites targeting areas quolls were likely to use more often such as cleared pathways from other fauna and potential den entrances. Elliott and cage traps were shrouded with reflective closed cell insulation (R2.5 rated) to provide shade and protection for any captured animals. All traps were given as much shade as possible, including leaf litter cover if necessary.

The trap site at the rocky ridge located within the Rocklea tenement was trap saturated with the same quantity of traps placed at the site even though it was a smaller area of habitat. A higher density of traps were deployed at this site because being the only site located within the tenement, it is the only site that may be directly impacted by the Project.

NQ4 was a creekline site which was used to determine if quolls present in NQ1 (if any) were using the vegetation along the creekline as a movement pathway. The site consisted of 11 traps placed 100 m apart evenly along the river evenly on either side of NQ1 totalling 0.5 km either side of site NQ1. All traps remained open for seven consecutive nights and were checked within three hours of sunrise each morning.

Traps were baited using a universal bait mix consisting of rolled oats, peanut butter and sardines. Traps were rebaited with freshly made bait every second day.

Camera traps were set to take ten consecutive pictures every time a movement was detected, 24 hours a day. The area in front of the cameras was scent-marked with smeared universal bait in order to attract animals to the camera. Cameras were deployed for seven consecutive nights in areas Northern Quolls were likely to move through.

Table 2-1 Summary of survey effort

Site number	# large Elliott	# cage	# camera traps	# nights	Total
NQ1	25	3	3	7	217
NQ2	25	3	3	7	217
NQ3	25	3	2	7	217
NQ4 (River)	11	2	0	7	91
					742

2.2.2 Active searches for secondary evidence of Northern Quoll

Daily active searches targeting Northern Quoll were undertaken in potential habitat for the species (mostly rocky areas with caves, rock piles and boulders). Searches consisted of transect lines with two observers, approximately 5 m apart, looking for secondary evidence, including scats and larine sites, tracks, fur from predation or combat, evidence of feeding and potential den sites or pathways.

2.2.3 Spotlighting for Pilbara Olive Python

Spotlighting for Pilbara Olive Pythons was undertaken five nights during the survey, totalling 20 person hours. Spotlighting occurred from dusk into the night when the species is most likely to be out basking on rocks or foraging. Potential habitat (primarily rocky sites near water and surrounding pools close by were targeted. Two survey staff targeted areas of potential habitat spotlighting for individuals foraging or basking on warm rocks.

2.2.4 Active Searches for specimens and secondary evidence of Pilbara Olive Python

Active searches targeting Pilbara Olive Pythons were undertaken in potential habitat for five days during the survey, totalling 30 person hours. The searches were undertaken from mid-late afternoon to sunset, when the species is typically active. Searches for secondary evidence (tracks, scats and sloughs) took place throughout the day in potential habitat.

The main area searched for evidence of Olive Pythons was the rocky ridge with the pool at the base; however, a number of surrounding pools and sites with fringing riparian vegetation were also targeted during the survey.

2.3 SURVEY PERSONNEL

The field survey was conducted by experienced zoologists (Table 2-2).

Table 2-2 Field team

Name	Qualifications	Role/s
Ryan Ellis	Dip. (CALM)	Field survey, reporting, GIS
Tom Parkin	BSc. (Env. Mgt.)	Field survey

3 Results

3.1 Environmental parameters

The nearest Bureau of Meteorology (BOM) weather station is located at Paraburdoo Airport (no. 007185; 23°10'21"S 117°44'58"E, alt. 423 m) approx. 30 km to the south south-east of the study area. Records from Paraburdoo Airport during January 2011 and 2012 show higher rainfall (205.0 and 205.2 mm) than normal compared with the long term average (52.0 mm). February recorded below average rainfall levels (66.0 and 73.6 mm vs. 78.3 mm on average). Annual mean rainfall for 2011 was still above average (393.0mm vs. 319.0 on average) (BOM 2012). Above average rainfall in January both years was mainly attributed to successive cyclones.

During the survey, daily temperatures were similar to annual long-term averages from Paraburdoo Airport (13.3°C and 29.4°C vs. 14.6°C and 29.1°C) (Figure 3-1). The minimum temperature recorded during the survey was 11.3°C on 22 May and the maximum recorded temperature was 32.4°C on 15 May. No rain was recorded during the survey period (Figure 3-2).

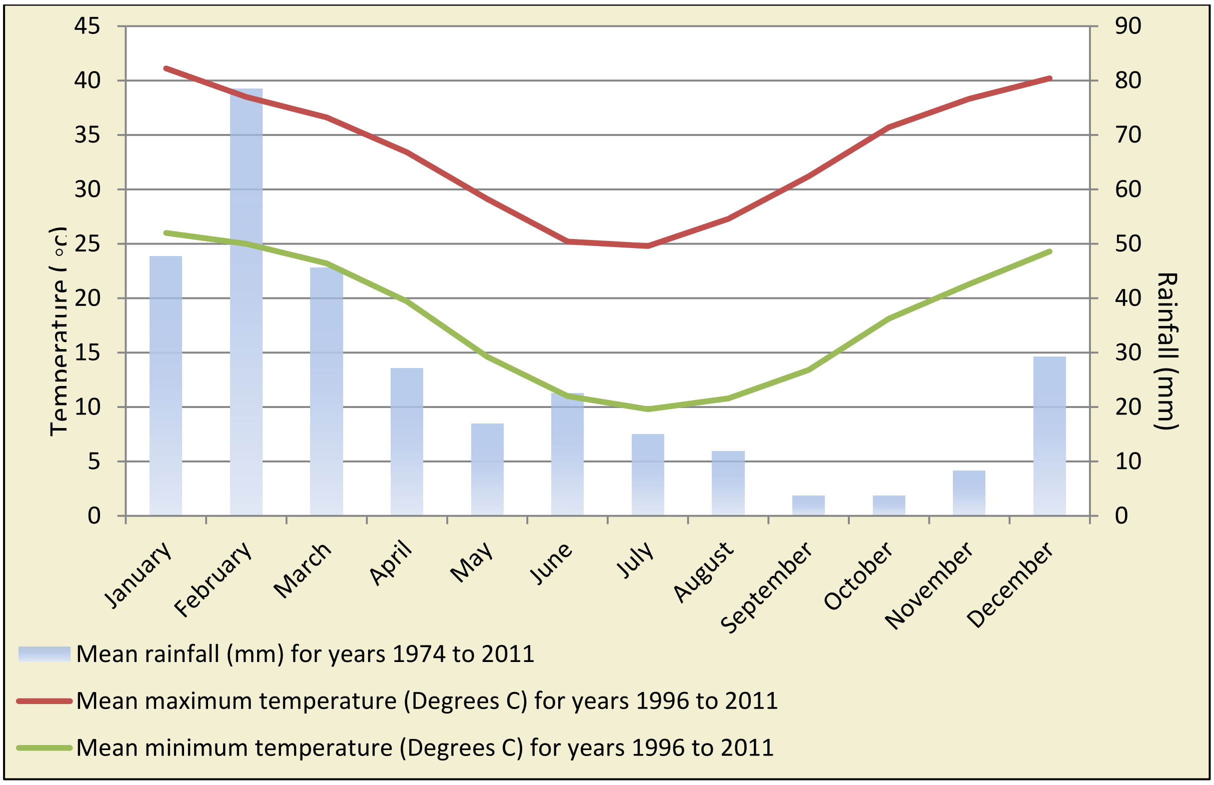


Figure 3-1 Temperature and rainfall variables, annual means (data courtesy BOM June 2012)

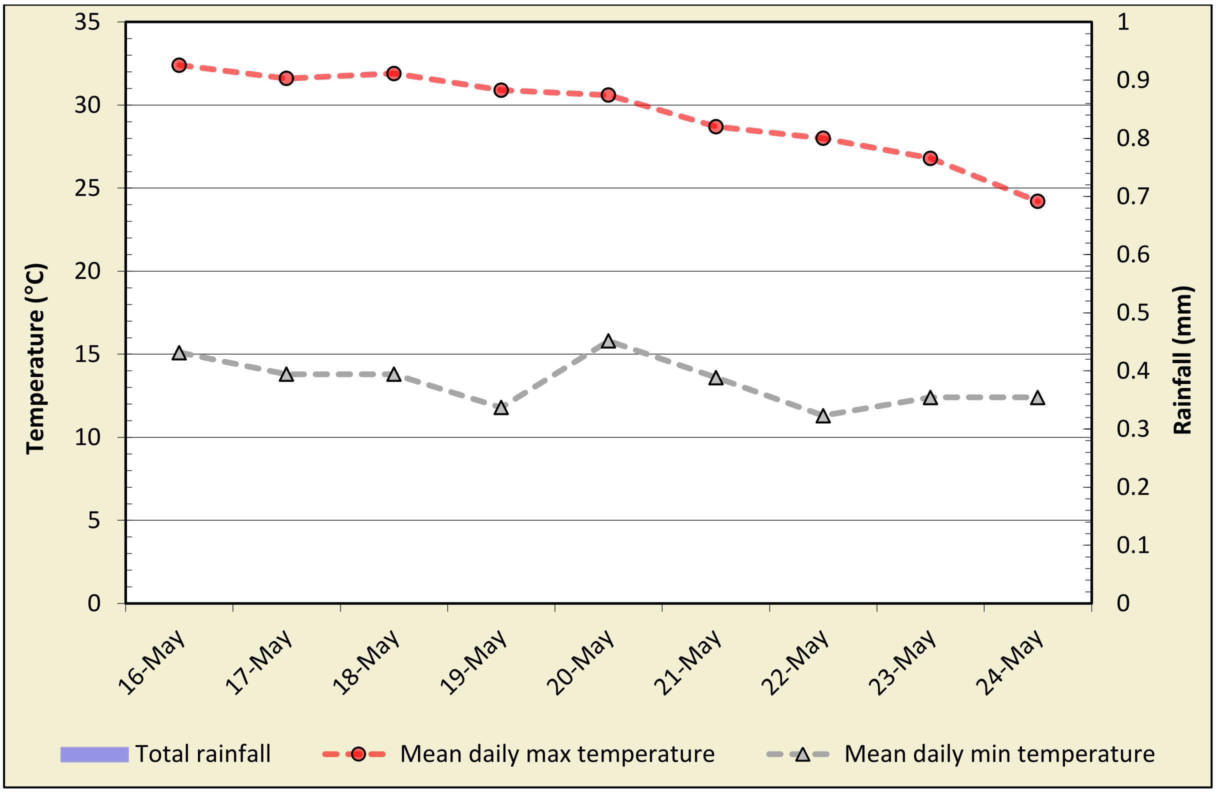


Figure 3-2 Temperature and rainfall variables collected during the targeted survey

3.2 SURVEY SITES AND HABITAT MAPPING

Four Northern Quoll trapping sites were installed in areas of potential habitat for the species (Figure 3-3 and Figure 3-4). The extent of suitable habitat for Northern Quoll is considerably smaller in extent than the initial desktop assessment (section 1.3.8).

Three active search sites represented the extent of Pilbara Olive Python habitat within the study area (Figure 3-3). Habitat descriptions and site photographs are provided in Table 3-1.

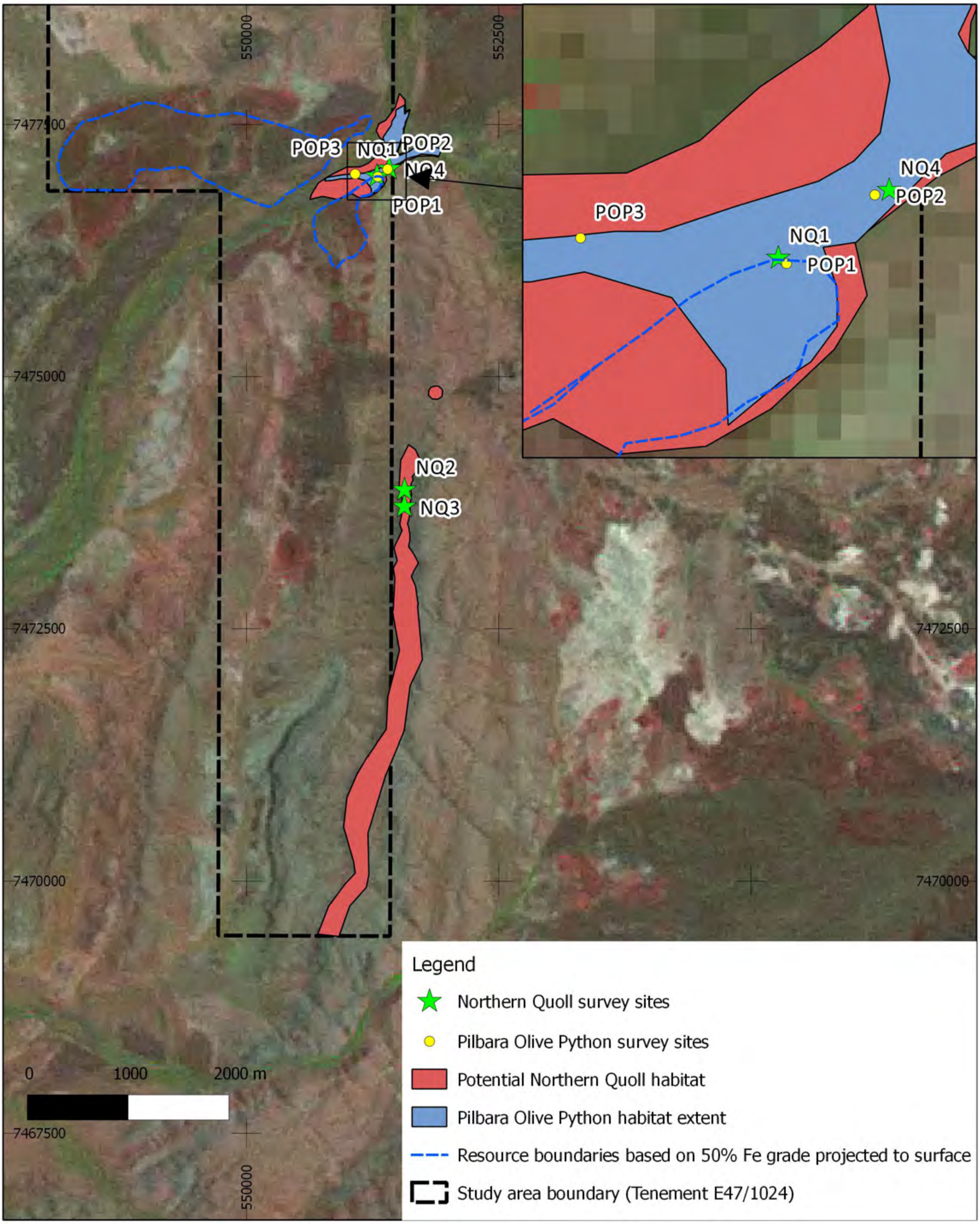


Figure 3-3 Survey site locations and suitable habitat for Northern Quoll and Pilbara Olive Python

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR: J.CLARK	CLIENT: Dragon Energy Ltd
DATE: 12.07.2012	Scale: 1:50000

Coordinate System: Projection: Transverse Mercator; Datum: WGS84

PROJECT: ROCKLEA IRON ORE PROJECT

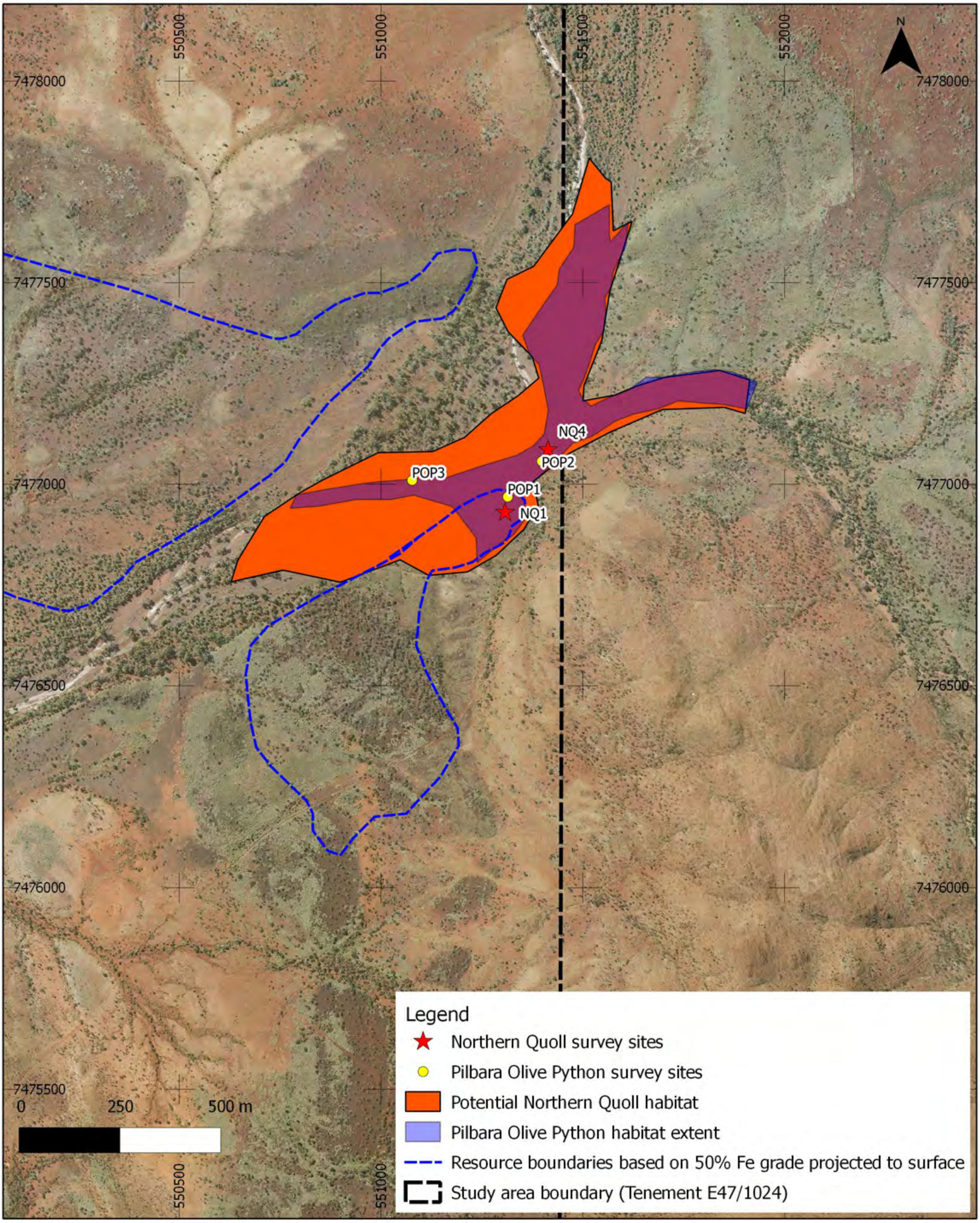


Figure 3-4 Suitable habitat for Northern Quoll and Pilbara Olive Python near resource boundaries

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR:J.CLARK	CLIENT: Dragon Energy Ltd
DATE:12.07.2012	Scale: 1:12500
Coordinate System:	Projection: Transverse Mercator; Datum: WGS84

PROJECT: ROCKLEA IRON ORE PROJECT

Table 3-1 Site descriptions

NQ1			
Latitude	-22.813958°	**Longitude**	117.499823°
Dominant tree	*Eucalyptus / Corymbia*		
Tree cover	26-50		
Dominant shrub	Various		
Shrub cover	26-50		
Dominant grass	Buffelgrass		
Grass cover	26-50		
Slope	Steep		
Soil texture			
Soil colour			
Surface	Coarse Gravel; Boulders; Stones;		
Rock cover	>90% cover		
Leaf litter distribution	0-25%		
Litter distribution	Concentrated under vegetation;		
Dead wood	Sparse		
Disturbance details	Drill pads; Cattle Grazing		
Fire history	None Evident		
Fire intensity			
Description: Small ridge with exposed rocky area fringing Hardey River, not flowing at time of survey. Large boulders and fallen rocks and various small caves into rocks present. Numerous pools of water at base and nearby in river bed.			

NQ2			
Latitude	-22.842053°	**Longitude**	117.502586°

Dominant tree	*Acacia*
Tree cover	0-25
Dominant shrub	Spinifex
Shrub cover	26-50
Dominant grass	Hill Slope
Grass cover	Spinifex Grassland
Slope	Steep
Soil texture	Sandy Clay
Soil colour	Red
Surface	Coarse Gravel; Boulders; Stones;
Rock cover	>90% cover
Leaf litter distribution	0-25%
Litter distribution	Concentrated under vegetation;
Dead wood	Sparse
Disturbance details	None evident;
Fire history	>5 years
Fire intensity	Medium

Description:
Steep rocky ridge with large areas of exposed rock, rock piles and boulders. Vegetated with spinifex *Triodia* sp. with scattered *Acacia* sp. across site. Scattered open areas with little vegetation amongst areas with large exposed rocks.

NQ3			
Latitude	-22.843552°	**Longitude**	117.502582°
Dominant tree	*Acacia*		
Tree cover	0-25		
Dominant shrub	Spinifex		
Shrub cover	26-50		
Dominant grass	Hill Slope		
Grass cover	Spinifex Grassland		
Slope	Steep		
Soil texture	Sandy Clay		
Soil colour	Red		
Surface	Coarse Gravel; Boulders; Stones;		
Rock cover	>90% cover		
Leaf litter distribution	0-25%		
Litter distribution	Concentrated under vegetation;		
Dead wood	Sparse		
Disturbance details	None evident;		
Fire history	>5 years		
Fire intensity	Medium		

Description:
Similar to NQ2. Steep rocky ridge slope with exposed rock, rock piles and large boulders. Spinifex *Triodia* sp dominant, with *Acacia* sp. sparsely scattered. Large areas of exposed rock and minimal vegetation.

NQ4			
Latitude	-22.813286°	**Longitude**	117.500999°
Dominant tree	*Eucalyptus/Corymbia*		
Tree cover	26-50		
Dominant shrub	Acacia		
Shrub cover	51-75		
Dominant grass	Buffel grass		
Grass cover	0-25		
Slope	Negligible		
Soil texture	Sand		
Soil colour	Brown		
Surface	Coarse Gravel; Stones		
Rock cover	50-90% cover		
Leaf litter distribution	25-50%		
Litter distribution	Evenly distributed		
Dead wood	Dense		
Disturbance details	Grazing - Med		
Fire history	None evident		
Fire intensity			

Description:
Riparian vegetation alongside the Hardey River. Vegetation relatively thick in patches on river edge where soil is moist. Large pools extending along vegetation edge. Large amount of debris in creek bed from past floods providing habitat structure.

POP1			
Latitude	-22.814012°	**Longitude**	117.499911°
Dominant tree	*Eucalyptus / Corymbia*		
Tree cover	26-50		
Dominant shrub	Various		
Shrub cover	26-50		
Dominant grass	Buffelgrass		
Grass cover	26-50		
Slope	Steep		
Soil texture	Sandy Loam		
Soil colour	Brown		
Surface	Coarse Gravel; Boulders; Stones;		
Rock cover	>90% cover		
Leaf litter distribution	0-25%		
Litter distribution	Concentrated under vegetation;		
Dead wood	Sparse		
Disturbance details	Drill pads; Grazing - Med		
Fire history	None Evident		
Fire intensity			

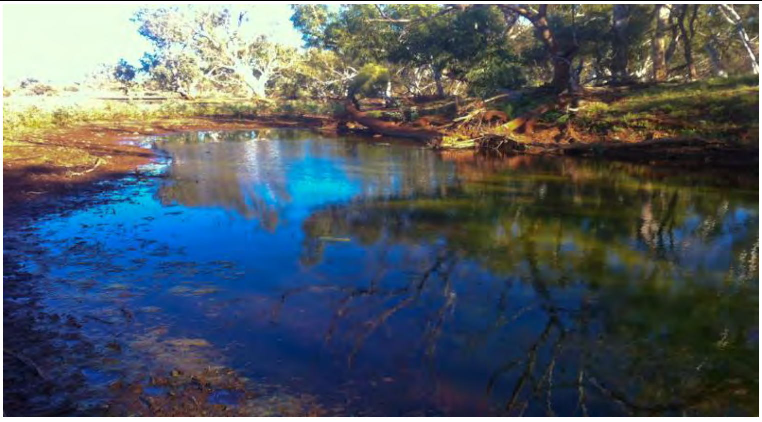
Description:
Small ridge with exposed rocky area fringing Hardey River, not flowing at time of survey. Large boulders and fallen rocks and various small caves into rocks present. Numerous pools of water at base and nearby in river with fringing rocks and vegetation. Vegetation and rock consenting to pool at base of ridge.

POP2			
Latitude	-22.813333°	**Longitude**	117.500847°
Dominant tree	*Eucalyptus/Corymbia*		
Tree cover	26-50		
Dominant shrub	Acacia		
Shrub cover	26-50		
Dominant grass	Buffel grass		
Grass cover	26-50		
Slope	Negligible		
Soil texture	Sandy Loam		
Soil colour	Brown		
Surface	Coarse Gravel; Stones		
Rock cover	50-90% cover		
Leaf litter distribution	25-50%		
Litter distribution	Evenly distributed		
Dead wood	Scattered		
Disturbance details	Grazing - High		
Fire history	None evident		
Fire intensity			

Description:
Hardey River bed and fringing riparian vegetation. Large pools present with abundant aquatic fauna. Large eucalypts to 7 m, mixed tall shrubs to 4m over mixed medium and small shrubs. Reduced ground cover in areas where overgrazing evident with plenty of debris and leaf litter.

POP3			
Latitude	-22.813768°	**Longitude**	117.497719°
Dominant tree	*Eucalyptus/Corymbia*		
Tree cover	26-50		
Dominant shrub	Acacia		
Shrub cover	26-50		
Dominant grass	Buffel grass		
Grass cover	0-25		
Slope	Negligible		
Soil texture	Sandy Loam		
Soil colour	Brown		
Surface	Coarse Gravel; Stones		
Rock cover	50-90% cover		
Leaf litter distribution	25-50%		
Litter distribution	Evenly distributed		
Dead wood	Dense		
Disturbance details	Grazing - Med		
Fire history	None evident		
Fire intensity			

Description:
Hardey River riparian zone/floodplain. Large eucalypts up to 9 m over acacia trees to 5 m over mixed shrubs 0.5-1.5 m and Buffel grass. Large pools present with fringing riparian vegetation. Debris build up in areas from previous flooding in area, providing habitat structure.



3.3 NORTHERN QUOLL RECORDS

No specimens of Northern Quoll were recorded during the survey. No secondary evidence of the species was collected either.

3.4 PILBARA OLIVE PYTHON RECORDS

Targeted searches for the Pilbara Olive Python recorded one specimen within the Rocklea tenement (Figure 3-5). The single specimen was recorded at 22°48'50.18"S, 117°29'59.21"E during targeted spotlighting at site POP1 at 8pm the evening of 19 May (Figure 3-6 and Figure 3-7). The specimen was observed sitting on rocks amongst dense grasses approximately 3 m from the pool at the base of the ridge. The site is on the edge of the defined resource boundary (Figure 3-5).

The specimen was positioned in a partial ambush position facing a pathway across the slope caused by cattle and kangaroos in the area. It is likely the individual was waiting for a prey item to move past along the track. The specimen measured just under 2.5 m and weighed 3.750 kg. The overall condition of the specimen was good; however, a fair amount of scarring was present on the back of the individual.

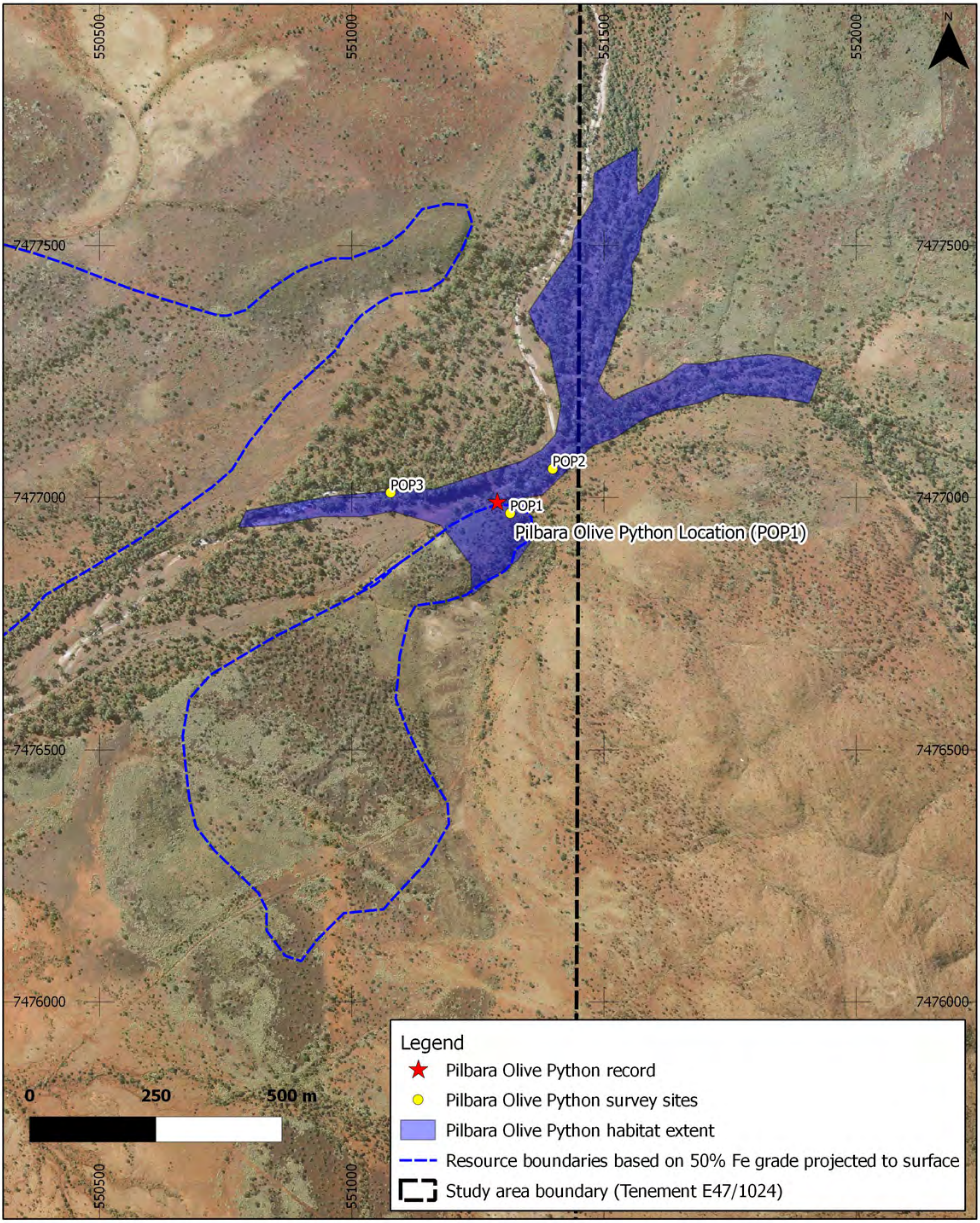


Figure 3-5 Location of Pilbara Olive Python recorded during the survey and projected habitat extent

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR:J.CLARK	CLIENT: Dragon Energy Ltd
DATE:12.07.2012	Scale: 1:10000
Coordinate System: Projection: Transverse Mercator; Datum: WGS84	

PROJECT: ROCKLEA IRON ORE PROJECT

Figure 3-6 Pilbara Olive Python recorded during the survey

Figure 3-7 Pilbara Olive Python recorded during the survey in approximate positioning to when located

3.5 NON-TARGET RECORDS

Non target, 'bycatch' species recorded during the targeted Northern Quoll survey included five species not previously recorded during the Level 2 vertebrate fauna survey (Phoenix 2011). A total of 14 records of six species were recorded during the survey, four mammal and two reptile species (Table 3-2). Species not previously recorded during the Level 2 survey were Woolley's Pseudantechinus (*Pseudantechinus woolleyae*), Common Rock-rat (*Zyzomys argurus*), House Mouse (*Mus musculus*), Goldfields Crevice-skink (*Egernia formosa*) and Pilbara Rock Monitor (*Varanus pilbarensis*). No non-target records from the current survey represent species of conservation significance.

Table 3-2 Non-target species captured at Northern Quoll trap sites

Species	Common Name	Site			
		NQ1	NQ2	NQ3	NQ4 (River)
Mammals					
Pseudantechinus woolleyae	Woolley's Pseudantechinus	1	2	1	
Zyzomys argurus	Common Rock-rat		1	2	
Mus musculus	House Mouse				3
Planigale sp.	Planigale sp.				1
Reptiles					
Egernia formosa	Goldfields Crevice-skink	2			
Varanus pilbarensis	Pilbara Rock Monitor			1	

3.6 LIMITATIONS

Guidance Statement 56 (EPA 2004a) identifies potential limitations that may be encountered during fauna surveys. In relation to the guidance, there was only one possible limitation encountered during the current survey. Between the Level 2 vertebrate fauna survey (Phoenix 2011)and the current survey, additional drilling has taken place (in mid-December 2011) near targeted Northern Quoll site NQ1 and to the south of Pilbara Olive Python site POP1 (Figure 3-8).

The drilling and associated activities, such as pre-drill clearing, that took place in these locations in mid-December 2011 may have caused temporary, localised displacement of some animals. It is unlikely however, that the drilling has affected the results of the Northern Quoll survey; no secondary evidence was recorded for the species at site NQ1, suggesting that quolls were not present at this site prior to the drilling.

The Pilbara Olive Python was recorded at site POP1; it is unknown if the python has occupied the site prior to drilling.

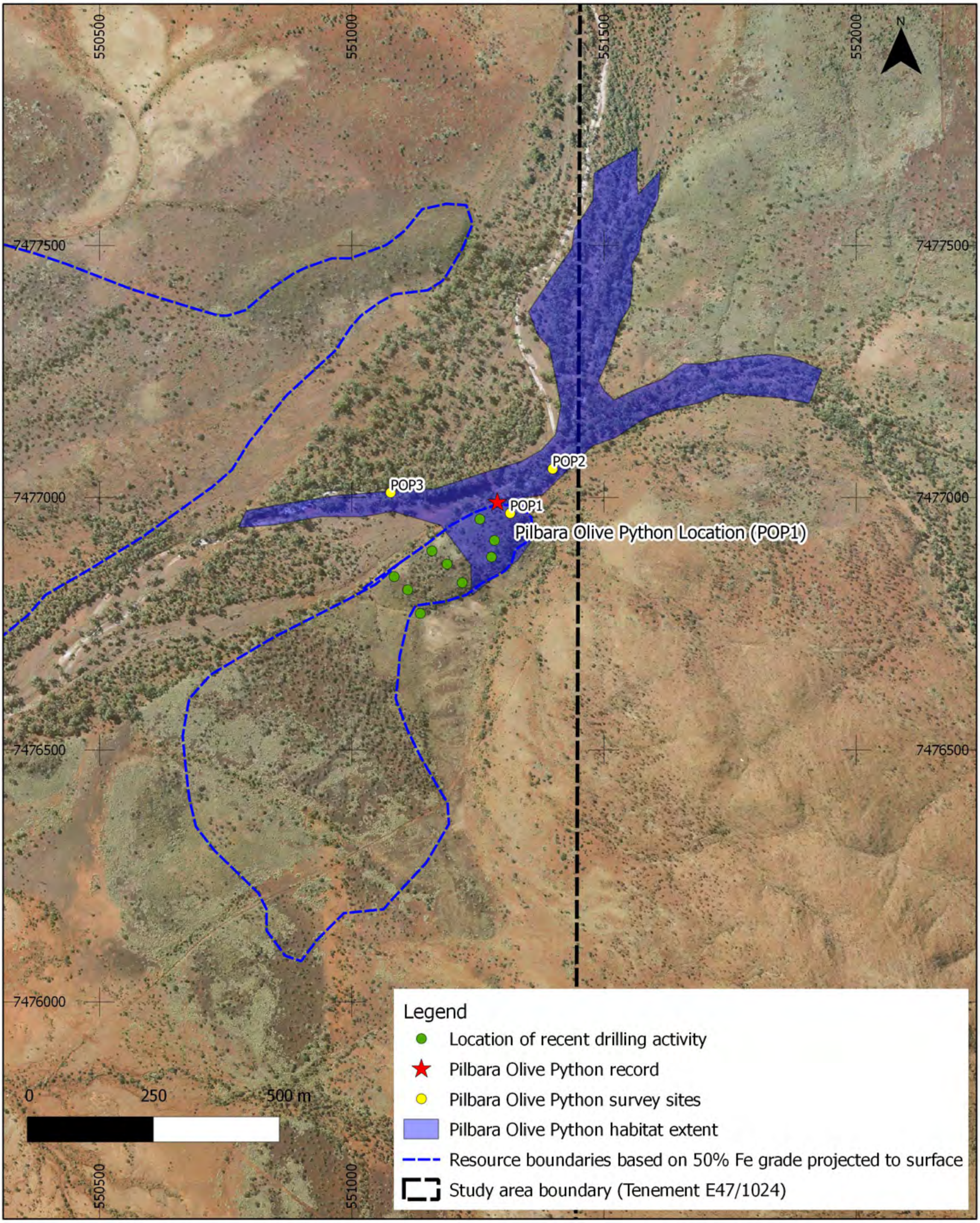


Figure 3-8 Location of drilling near Pilbara Olive Python record

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR:J.CLARK	CLIENT: Dragon Energy Ltd
DATE:12.07.2012	Scale: 1:10000
Coordinate System: Projection: Transverse Mercator; Datum: WGS84	

PROJECT: ROCKLEA IRON ORE PROJECT

4 Discussion

4.1 Northern Quoll

No Northern Quolls were captured during the targeted survey, despite targeting all areas of potential habitat with a sufficient number of traps, operating camera traps throughout and intensive targeted searches for secondary evidence.

It is therefore considered unlikely Northern Quolls are present within the study area. This is likely to be due to the limited areas of habitat containing suitable structure within the study area; only one site with suitable habitat is present within the Rocklea tenement (site NQ1).

No evidence of the species occurring in the areas of potential habitat that border the south-east edge of the Rocklea tenement was recorded. If quolls do occupy this area, movement into the study area would be hazardous due to a buffering area of rolling stony slope with little or no vegetative cover to provide protection from predators.

Based on field investigations during the targeted survey, it is unlikely that quolls are using riparian habitat along the Hardey River as a corridor to potential habitat sites south-east of the study area. Overgrazing of riparian and woodland vegetation along the Hardey River has resulted in open areas of vegetation between the sites, which would increase chances of predation of any fauna moving through the area.

Recent drilling close to Northern Quoll site one (NQ1) may have disturbed any inhabiting quolls forcing them to abandon the site in search of replacement habitat; however, this is unlikely as no evidence of the species occurring in the area was recorded during this survey or the previous Level 2 vertebrate fauna survey.

Based on the low likelihood of Northern Quoll occurring in the study area, it is unlikely the Project will impact this species.

4.2 Pilbara Olive Python

A single Pilbara Olive Python was recorded during the survey on 19 May during targeted spotlighting at site POP1 (22°48'50.18"S, 117°29'59.21"E). The specimen was sitting in a partial ambush position near a track along the ridge made by cattle, though likely to be used by other species such as kangaroos. The location, positioning and activity of the python indicate it was likely to be waiting for prey to move along the track.

Limited areas of potential habitat for the Pilbara Olive Python exist within the Rocklea tenement (Figure 3-3). A small rocky ridge with various small caves and fallen boulders located close to pools of water was identified during the Level 2 vertebrate fauna survey (Phoenix 2011) and intensely surveyed during the targeted survey. Situated alongside the Hardey River a number of large pools were located around the rocky site with one pool located at the base of the rocky ridge. It is unknown if these pools are permanent or intermittent, but they were also present during the level 2 survey in spring 2011 (Phoenix 2011).

It is considered likely that the relatively small area of habitat permanently supports only small numbers of the species. The species is known to move widely and therefore it is also likely that the area supports more individuals and vagrants from time to time, when conditions are favourable.

In the absence of detailed data on the mining proposal (i.e. location of the main pit, waste dump, accommodation village, modification of water regimes) potential impacts to the Pilbara Olive Python cannot be assessed in detail. While it is unlikely the Project will significantly impact the species at a regional scale; there may be some localised impacts. These are discussed below and should be given consideration during mine infrastructure design process. A more detailed impact assessment for the Pilbara Olive Python should be undertaken once the impact footprint has been defined.

Mortality and displacement of individuals may be be caused by habitat loss and degradation, increased predation and increased human presence. Singly these threats pose a low risk to the species; however, these threats combined may pose a significant threat to Pilbara Olive Pythons occurring within the tenement.

Degradation and destruction of potential Olive Python habitat may have a significant local impact on the species if the impact footprint overlaps the habitat for the species within the study area; the current resource boundary (50 % Fe grade projected to surface) overlaps a small portion of habitat for the species and borders location where the individual was recorded. Disturbance to this habitat should be avoided as far as practicable.

Other potential impacts may include increased risk of road mortality, increased risk of predation, animals killed due to misidentification and fragmentation of habitats. Mine camps can result in an increase in introduced scavenger species, in particular house mice and black rats. These prey animals are likely to attract pythons to the area where they can easily be mistaken by untrained personnel for venomous species and killed. Increased abundance of mice and rats often attracts larger introduced species such as cats and foxes. These predators can significantly reduce impact Pilbara Olive Python populations, with localised extinction possible where feral animal control is not undertaken.

Mine infrastructure should be sited away from Pilbara Olive Python habitat. Placement of roads and other infrastructure should avoid suitable habitat within the study area, as well as potential corridors for movement. Abundance of feral animals should be monitored and controlled to prevent risk of predation on Pilbara Olive Pythons. Education of all personnel should be undertaken increase awareness and knowledge of the species.

Management of impacts to Pilbara Olive Python should be incorporated into a fauna management plan for the Project.

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Appendix 1 Survey site coordinates (Datum, GDA94)

Site number	Coordinates in Decimal Degrees		Coordinates in UTM		
	Latitude	Longitude	Northing	Easting	Zone
Northern Quoll sites					
NQ1	-22.813958°	117.499823°	551293.50	7476988.92	50k
NQ2	-22.842053°	117.502586°	551566.28	7473877.90	50k
NQ3	-22.843552°	117.502582°	551565.14	7473711.85	50k
NQ4 (River)	-22.813286°	117.500999°	551414.91	7477062.93	50k
Pilbara Olive Python sites					
POP1	-22.814012°	117.499911°	551302.00	7476982.00	50k
POP2	-22.813333°	117.500847°	551398.33	7477056.92	50k
POP3	-22.813768°	117.497719°	551077.16	7477009.80	50k

Short-range endemic invertebrate fauna survey for the Rocklea Iron Ore Project

Prepared for Dragon Energy Ltd

March 2012

Final Report

Short-range endemic invertebrate fauna survey for the Rocklea Iron Ore Project

Prepared for Dragon Energy Ltd

Final report

Authors: Peter Langlands, Volker Framenau

Reviewers: Karen Crews

Date: 10 March 2012

Submitted to: Mark Hafer (Dragon Energy Ltd)

Chain of authorship and review			
Name	**Task**	**Version**	**Date**
Peter Langlands	Draft for technical review	0.1	13 February 2012
Volker Framenau	Draft for editorial review	0.2	14 February 2012
Karen Crews	Editorial review	0.3	15 February 2012
Volker Framenau	Draft for client comments	1.0	17 February 2012
Volker Framenau	Final submitted to client	2.0	10 March 2012

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EXECUTIVE SUMMARY

In September 2011, Dragon Energy Ltd (Dragon) commissioned Phoenix Environmental Sciences Pty Ltd (Phoenix) to undertake a short-range endemic (SRE) invertebrate fauna survey for the Rocklea Iron Ore Project (the Project), located 34 km southwest of Tom Price in the Pilbara region of WA. The Project comprises a channel iron deposit (CID) with a current JORC inferred resource of 63.1 Mt@ 53.4% Fe (60.4% caFe).

This report documents the results of the survey was conducted in October and November 2011.

The key objective of the SRE survey was to provide information on the presence of SREs in the study area, in particular within a preliminary footprint of the proposed pit.

The scope of work included the following components:

- desktop review of databases and literature to determine potential SRE invertebrates in the study area
- conduct of an SRE field survey for the Project
- specimen identifications and data analysis
- identification of potential impacts on SRE fauna and habitat and recommendations to minimise or mitigate these impacts
- preparation of a technical report based on survey data for inclusion in environmental approvals documentation, including assessment of potential impacts on fauna and recommendations.

There are uncertainties in determining the range-restrictions of many invertebrates in the Pilbara due to lack of surveys in the region, lack of taxonomic resolutions within the target taxa and problems in identifying certain life stages. In that context, SRE taxa collected from the study area were grouped into three different categories: confirmed SRE, likely SRE and potential SRE.

The desktop review identified a total of 28 invertebrate taxa in the three SRE categories to occur within a 100 km radius around the Project, but only one potential SRE was previously recorded from within the study area, a juvenile scorpion in the genus *Urodacus* (potential SRE). Only one of the confirmed and likely SREs identified in the desktop review was also collected during our survey, the camaenid land snail *Rhagada* ‘small banded’.

Our survey recovered a total of 775 individual specimens in the SRE target groups from the study area, representing 40 individually-recognised taxa from seven orders, 19 families and at least 22 genera. A total of eight taxa in at least eight genera from seven families and five orders comprising 92 individuals (11.9% of total catch) are considered to include species from the three SRE categories.

Two taxa are considered confirmed SREs:

- the land snail *Rhagada* ‘small banded’ (family Camaenidae)
- the pseudoscorpion *Troglochernes* sp. indet. (juv.) (Chernetidae).

Three species represent likely SREs:

- the mouse spider *Missulena* ‘sp. indet.’ (Actinopodidae)
- the slater *Buddelundia* ‘sp. 50’ (Armadillidae)
- the slater New Genus ‘sp. 3’ (Armadillidae).

A further three taxa include potential SREs:

- the centipede genus *Sepedonophilus* (Geophilomorpha: Chilenophilidae)
- the centipede family Mecistocephalidae (Geophilomorpha)
- all centipede *Australoschendyla* cf. *capensis* (Lithobiomorpha: Schendylidae)

The pseudoscorpion, *Troglochernes*, the mouse spider, *Missulena*, and the two species of slaters, *Buddelundia* 'sp. 50' and New Genus 'sp. 3' are currently only known from the study area at Rocklea necessitating consideration of conservation measures. The land snail *Rhagada* 'small banded' is well represented inside and outside the study area, therefore impacts of the Project on the species are considered negligible.

The taxonomy of the three potential SRE centipedes is unresolved and no comment can be made on their distribution and conservation status. Likewise, the *Urodacus* specimen from the desktop review cannot be identified to species level and therefore no recommendations can be made regarding this record.

The records of the four SRE taxa only known from the study area concentrate along the Hardey River well outside the currently proposed main pit. With respect to the future footprint of mining infrastructure, including overburden area, processing facilities and transport infrastructure, it is recommended to avoid the areas where these species were found. Specifically, it is recommended to

- create an environmental buffer of 300 m along the Hardey River and its major tributary in the north to maintain ecological functionality of the river with respect to SRE invertebrates (habitat and migration corridor). These can be implemented by:
    - signpost the environmental buffer in appropriate intervals to avoid accidental disturbance
    - staff and contractor education on the value of the environmental buffer
    - create some exclusion zones for cattle along the Hardey River
    - avoid waste disposal into the river
- further mitigate any long-term effects of the mining operation on the creekline habitat (e.g. excessive dust) by sealing tracks or implementing dust management measures.

Additional measurements that can support the conservation of SRE taxa are:

- support research into the taxonomy and systematics of SREs
- reduce livestock grazing levels or protect river areas from cattle (although it is recognised that this is not the responsibility of the Client).

In summary, four SRE invertebrates identified in this survey are currently known only from the study area and these were mainly recorded from woodlands along the Hardey River and a major tributary in the north. An environmental exclusion buffer along the Hardey River is recommended to protect its ecological functionality, in particular to provide habitat for SREs and a migration route for their dispersal.

1 INTRODUCTION

In September 2011 Phoenix Environmental Sciences Pty Ltd (Phoenix) was commissioned by Dragon Energy Ltd to undertake a short-range endemic (SRE) invertebrate fauna survey for the Rocklea Iron Ore Project (the Project). This report presents the results of the survey, which was conducted in October and November 2011.

1.1 BACKGROUND

The project is located 34 km southwest of Tom Price in the Pilbara region of WA (Figure 1-1). The Project comprises a channel iron deposit (CID) with a current JORC inferred resource of 63.1 Mt@ 53.4% Fe (60.4% caFe).

Mining is proposed to commence in mid-2013 in a staged format, with (under current plans) up to two million tonnes per annum of ore transported to a Pilbara port near Onslow via road. The anticipated level of assessment is a Mining Proposal via the Department of Mines and Petroleum (DMP). No detailed mapping of the project layout was provided prior to the survey and therefore the survey design was based on an indicative footprint of the iron ore deposit (Figure 1-2), representative habitats present and habitat condition therein.

1.2 SCOPE OF WORK AND SURVEY OBJECTIVES

The key objective of the SRE survey was to provide information on the presence of SREs in the study area, in particular within an indicative mining footprint limited to the main pit which is the subject of the Mining Proposal.

The scope of work was to:

- conduct a desktop review of databases and literature to determine potential SRE invertebrate species in the study area
- conduct an SRE field survey for the Project
- undertake specimen identifications and data analysis
- identify potential impacts on SRE fauna and habitat and make recommendations to minimise or mitigate these impacts
- prepare a technical report outlining survey methods, results, significant fauna habitat and species records, assessment of potential impacts and recommendations.

This SRE survey adhered to the principles and practices of the Environmental Protection Authority's (EPA) Guidance Statement No. 20: *Sampling of short-range endemic invertebrate fauna for environmental impact assessment in Western Australia* (EPA 2009), which outlines preferred methods for the surveying and assessment of SREs in the context of environmental impact assessment.

The survey has also been designed in accordance with EPA Guidance Statement No. 56: *Terrestrial fauna surveys for environmental impact assessment in Western Australia* (EPA 2004) and EPA Position Statement No. 3: *Terrestrial biological surveys as an element of biodiversity protection* (EPA 2002).

The limitations of the surveys with respect to Guidance Statement 56 (EPA 2004) are discussed in Section 3.5.

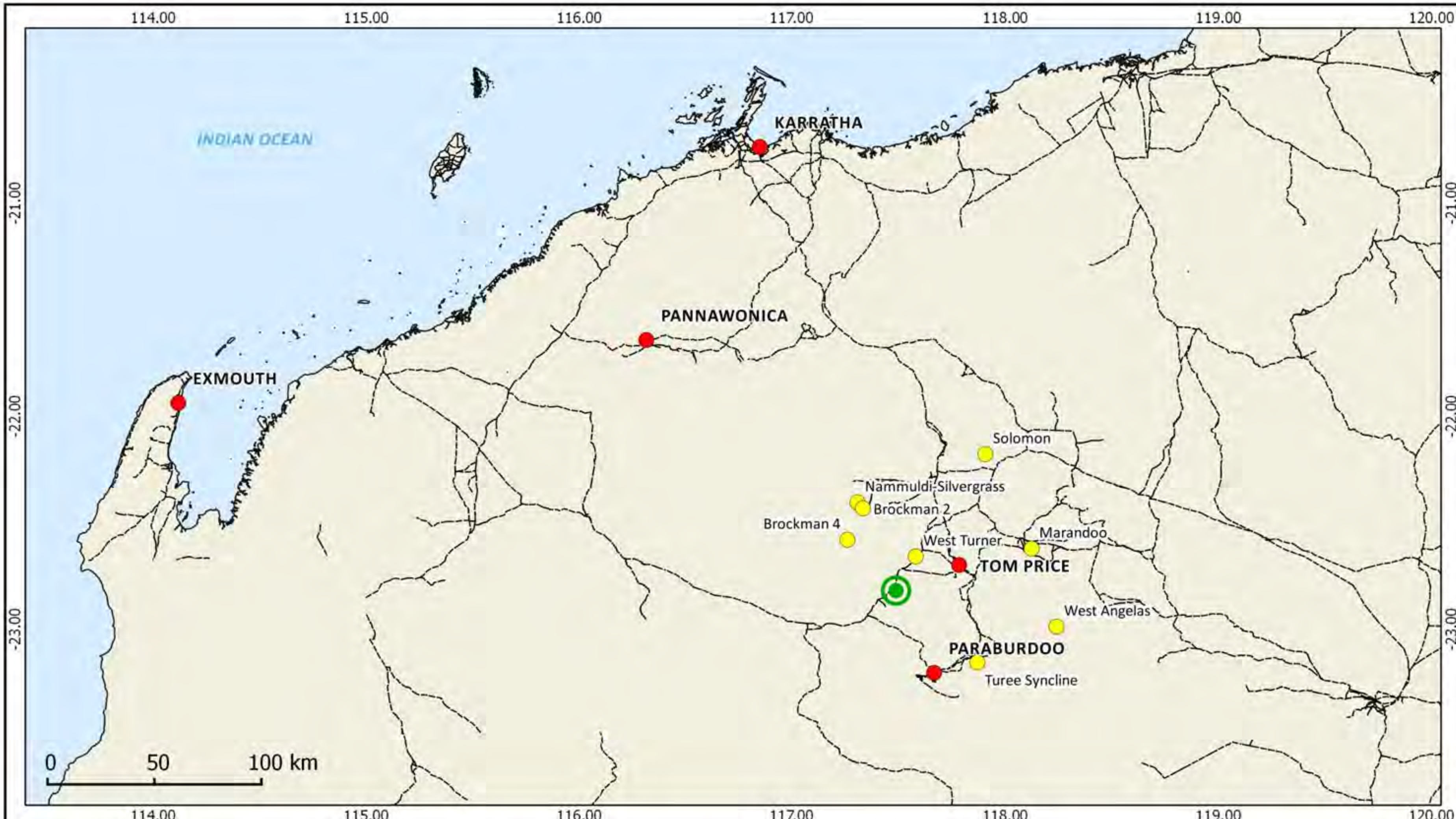

Figure 1-1
Location of the Rocklea Iron Ore Project

PHOENIX ENVIRONMENTAL SCIENCES

Survey Area
Mining projects
Towns
Roads

N

AUTHOR: P. Langlands	**CLIENT:** Dragon Energy Ltd.
DATE: Feb 2012	**Scale:** 1:2000000
Coordinate System: Projection: Transverse Mercator; Datum: WGS84	

PROJECT: Rocklea Iron Ore Project

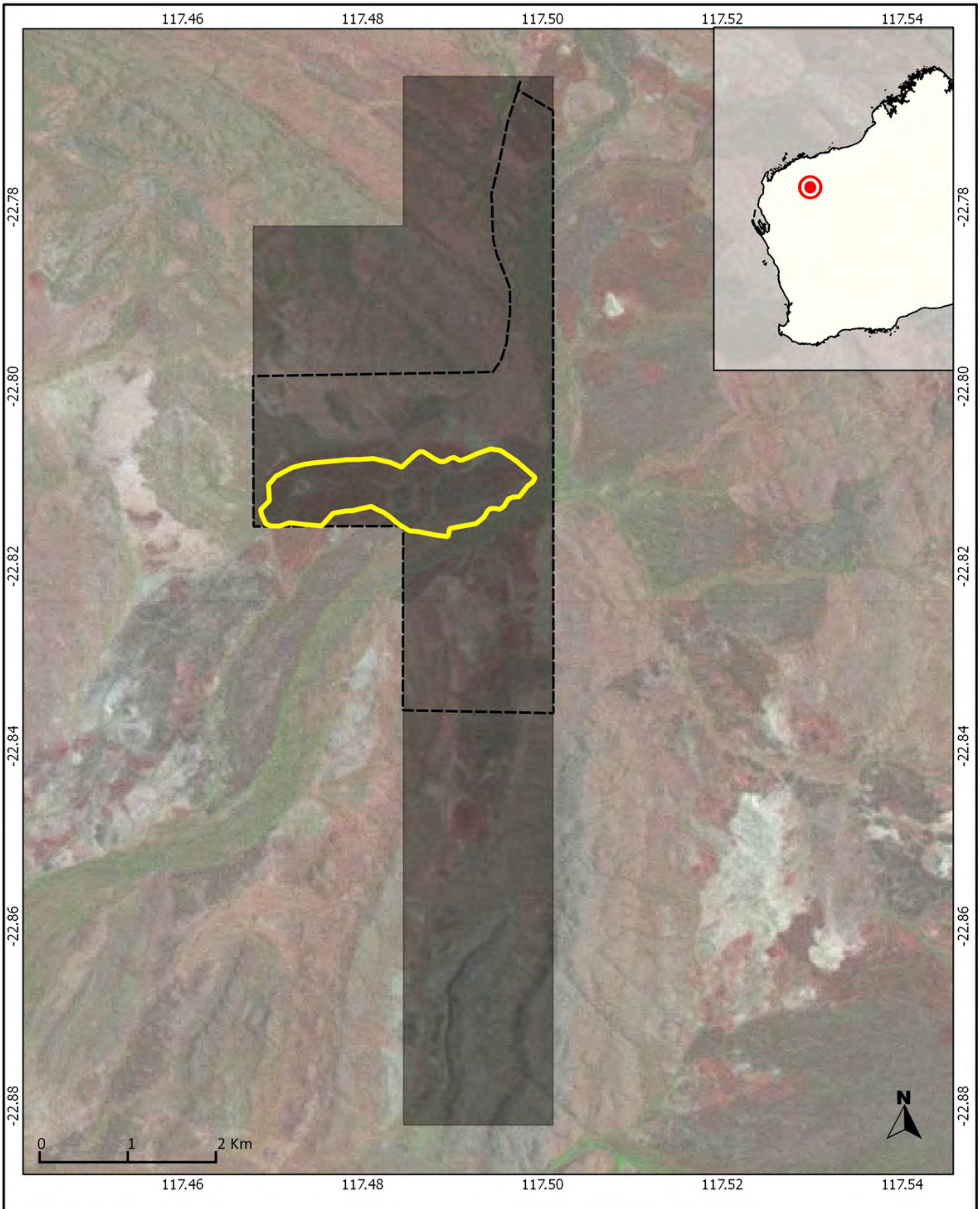

Figure 1-2
Study area for the short-range endemic survey of the Rocklea Iron Ore Project, including indicative footprint of the proposed main pit

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR: P.R. Langlands	**CLIENT:** Dragon Energy Ltd
DATE: February 2012	**Scale:** 1:45000
Coordinate System: Projection: Transverse Mercator; Datum: WGS84	

PROJECT: Rocklea Iron Ore Project

2 EXISTING ENVIRONMENT

2.1 INTERIM BIOGEOGRAPHIC REGIONALISATION OF AUSTRALIA (IBRA)

The Interim Biogeographic Regionalisation of Australia (IBRA) defines 'bioregions' as large land areas characterised by broad, landscape-scale natural features and environmental processes that influence the functions of entire ecosystems (DSEWPC 2011; Thackway & Cresswell 1995). Their purpose is to record and categorise the large-scale geophysical patterns that occur across the Australian continent. The identified patterns in the landscape are linked to fauna and flora assemblages and processes at the ecosystem scale. They are a useful means for simplifying and reporting on more complex patterns of biodiversity (Thackway & Cresswell 1995).

Western Australia contains 26 IBRA bioregions and 53 subregions. The nature and scale of threatening processes varies across the bioregions, as does the extent of intact vegetation and the extent protection under the State reserve system.

The study area falls within the Pilbara bioregion, which covers an area of 178,500 km^2. The Pilbara bioregion contains four main geological components (subregions) (DSEWPC 2011):

- **Hamersley (PIL 3):** mountainous area of ranges and plateaux dissected by gorges, vegetation is mostly comprised of Mulga woodland over grasses on fine texture soils
- **Fortescue Plains (PIL 2)**: alluvial plains and river frontages, northern limit of Mulga, permanent springs fed by an extensive calcrete aquifer, supports large permanent wetlands
- **Chichester (PIL 1)**: undulating granite and basalt plains supporting shrub steppe of *Acacia pyrifolia* over *Triodia pungens* hummock grasslands
- **Roebourne (PIL 4):** alluvial and older colluvial coastal and sub-coastal plains with a grass savannah.

The study area is situated within the Hamersley subregion (Figure 2 1). The Hamersley subregion is characterised by a semi-desert tropical climate (average of 300 mm annual rainfall) and represents 34% of the Pilbara bioregion. Several features are distinctive of the Hamersley subregion (Kendrick 2001):

- rare features: gorges of the Hamersley range, Palm spring, Duck Creek, *Themeda* grasslands, Red Hill Station mulga stands
- centres of endemism (calcrete deposits for troglofauna)
- refugia (gorges of the Hamersley Range, calcrete deposits, mountain tops of the Hamersley Range, permanent spring systems)
- high species and ecosystem diversity (*Acacia*, *Triodia*, *Ptilotus*, *Corymbia* and *Sida* sp., crustacean stygofauna within the calcrete environment).

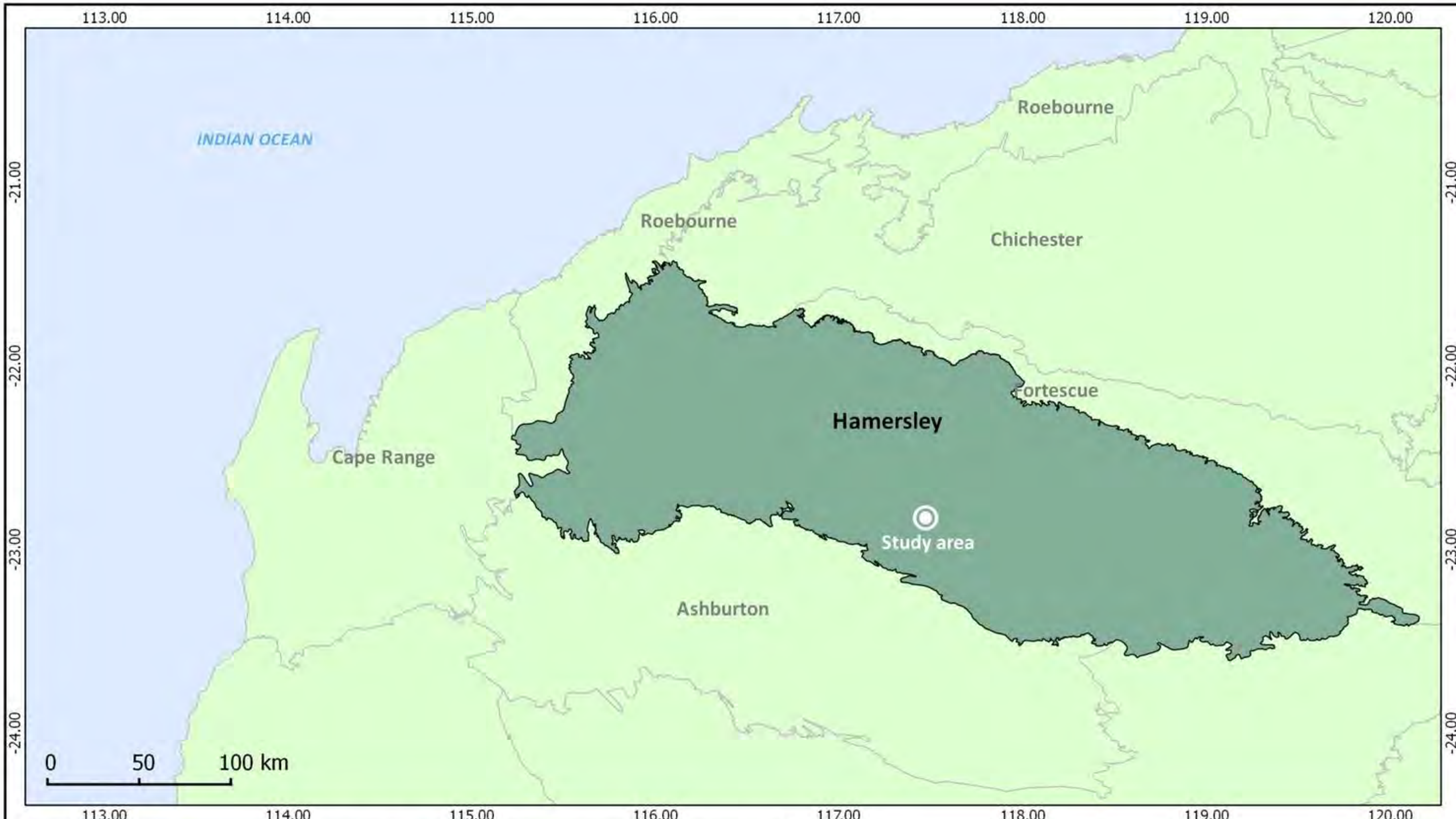

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Figure 2-1 **Biogeographic subregions of the study area**	PHOENIX ENVIRONMENTAL SCIENCES
AUTHOR: G. Bouteloup / **CLIENT:** Dragon Energy Ltd.	
DATE: / **Scale:** 1:2310495	**PROJECT:** Rocklea Iron Ore Project
Coordinate System: Projection: Transverse Mercator; Datum: WGS84	

2.2 LAND SYSTEMS

The Department of Agriculture and Food Western Australia (Van Vreeswyk *et al.* 2004) has mapped the land systems of the Hamersley sub-region from aerial photography, providing the largest-scale interpretation of vegetation units for the study area. The study area traverses six land systems (Figure 2-2):

- **Robe**: low limonite mesas and buttes supporting soft spinifex (and occasionally hard spinifex) grasslands
- **Boolgeeda**: stony lower slopes and plains below hill systems supporting hard and soft spinifex grasslands and mulga shrublands
- **Rocklea**: basalt hills, plateaux, lower slopes and minor stony plains supporting hard spinifex (and occasionally soft spinifex) grasslands
- **Paraburdoo**: basalt derived stony gilgai plains and stony plains supporting snakewood and mulga shrublands with spinifex and tussock grasses
- **River**: active flood plains and major rivers supporting grassy eucalypt woodlands, tussock grasslands and soft spinifex grasslands
- **Table**: low calcrete plateaux, mesas and lower plains supporting mulga and cassia shrublands and minor spinifex grasslands.

The dominant land systems present in the study area are the Robe, Boolgeeda, Rocklea and Paraburdoo land systems. The rocky habitats present in (particularly) the Rocklea, Boolgeeda and Robe land systems, and the riparian habitats of the River land system, can potentially support conservation significant SRE invertebrate species. The Table and Paraburdoo land systems are less likely to support species of conservation significance.

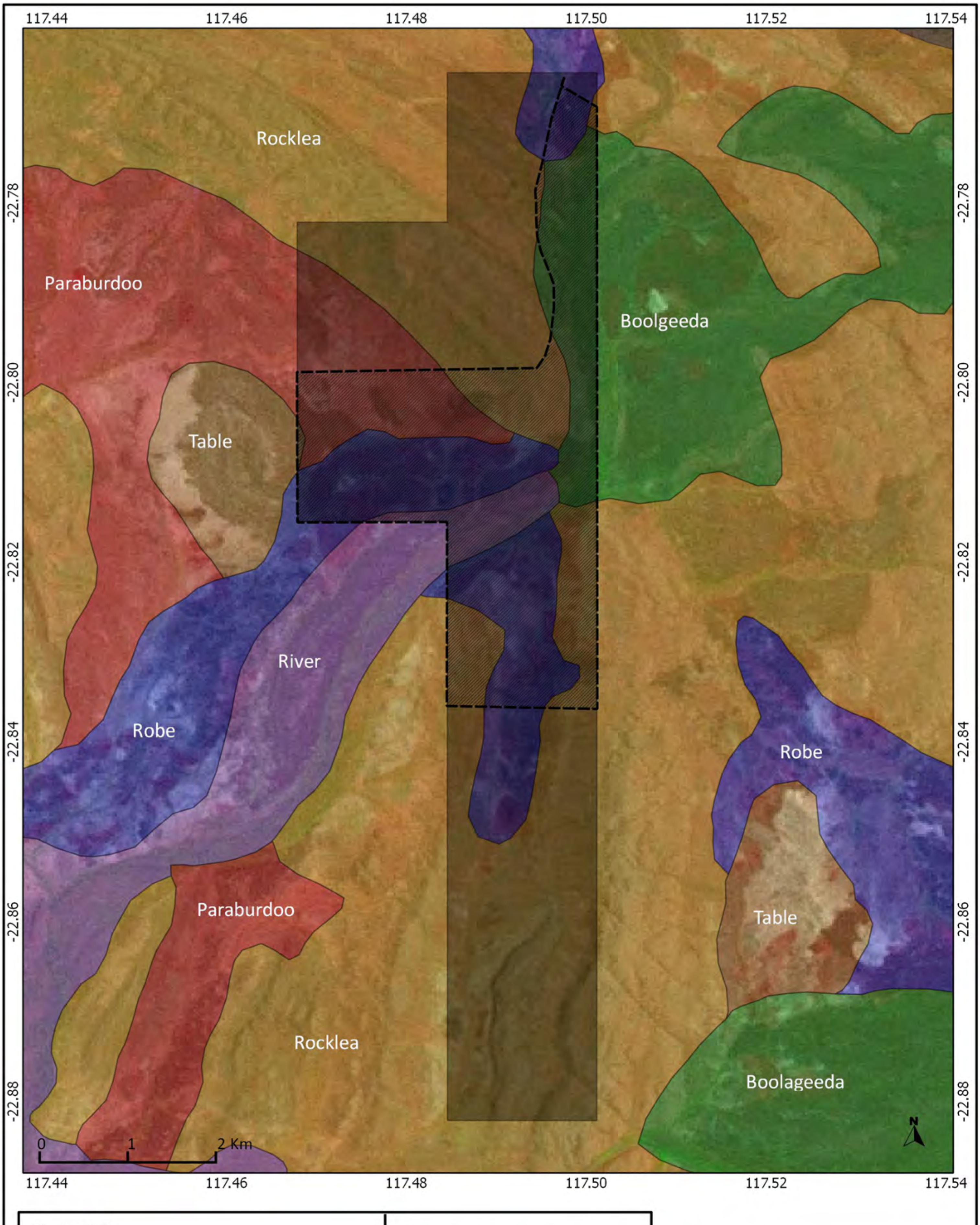


Figure 2-2
Land systems of the Rocklea Iron Ore Project

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR: P.R. Langlands	**CLIENT:** Dragon Energy Ltd
DATE: February 2012	**Scale:** 1:45000
PROJECT: Rocklea Iron Ore Project	
Coordinate System: Projection: Transverse Mercator; Datum: WGS84	

2.3 Climate and weather during survey period

The Pilbara bioregion has an arid climate with average maximum temperatures over 40°C from November to February and an average of 25°C during the winter months. Rainfall is highly variable but is more prevalent in summer. The average rainfall over the broader Pilbara region is about 290 mm, ranging from a monthly average of approximately 2 mm in September to 66 mm in February. Rainfall patterns are driven by highly variable, year-to-year cyclonic activity that accounts for half of the yearly precipitation (McKenzie *et al.* 2009).

One of the nearest Bureau of Meteorology (BOM) weather stations is located at Paraburdoo Airport (no. 7185; 23.17°S 117.75°E, alt. 424 m), approx. 50 km south-east of the Project. Paraburdoo Airport has its highest mean maximum monthly temperature (41°C) in January and the lowest mean maximum temperature (24.3°C) in July (Figure 2-3) (BOM 2012). The highest mean minimum temperature is recorded for January (26°C) and the lowest mean minimum temperature for July (9.8°C). The area has an average annual rainfall of 309.9 mm and January and February are the wettest months (Figure 2-3) (BOM 2012).

Average annual (pan) evaporation in the area is approximately 3,600 mm per year (Department of Agriculture 2003), which greatly exceeds annual rainfall and consequently contributes to the arid environment.

Average temperatures over the SRE survey period (October and November 2011; Figure 2-3) matched the long term means recorded for these months. Rainfall for the survey period was also consistent with long-term averages, although very high precipitation was recorded in the month of January before the surveys (Figure 2-3).

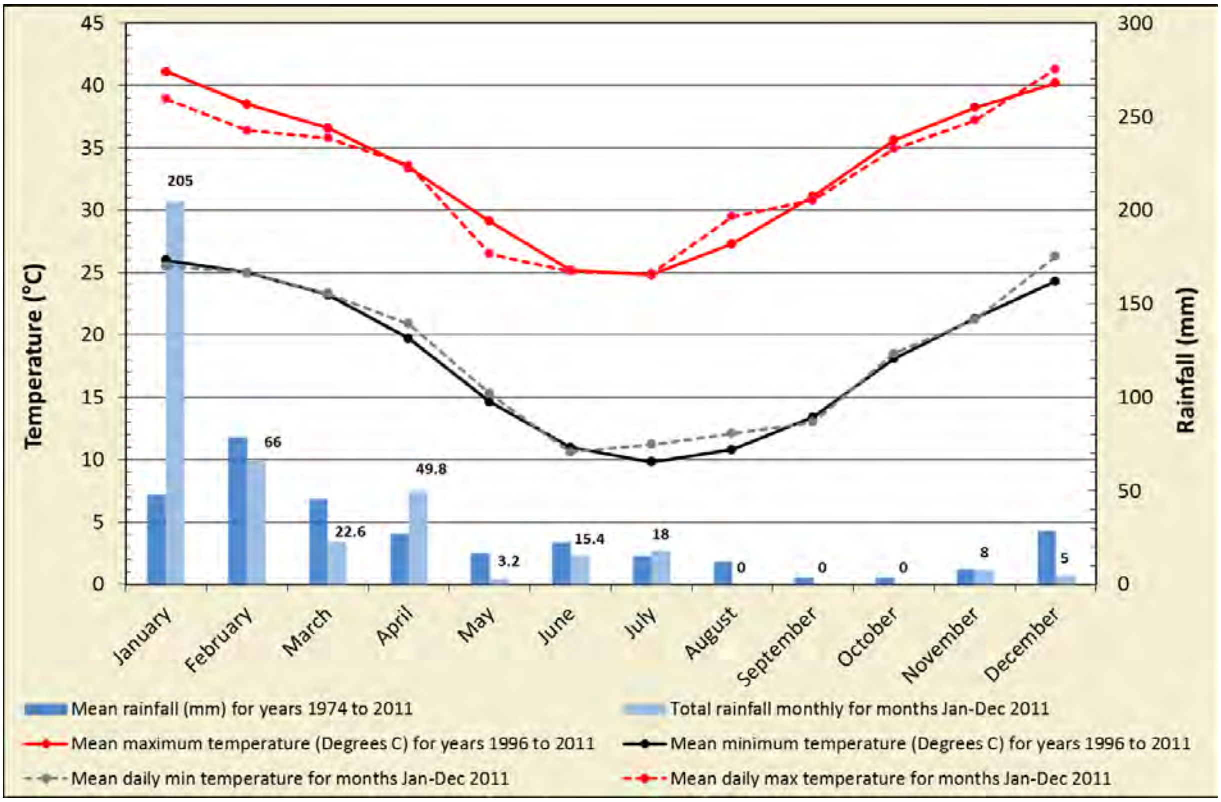


Figure 2-3 Climate and weather data for Paraburdoo Airport (BOM 2012)

2.4 LAND USE

The study area lies within the broader region of the Pilbara, an area distinct from (but including) the Pilbara IBRA bioregion. The Pilbara region was historically dominated by native grazing and pastoral activities. Current land use in this region is more diverse, comprising pastoral grazing; mineral exploration and mining activities; and dedication of land to Crown Reserves (e.g. Jigalong Aboriginal Reserve, Karijini National Park and Millstream National Park (Van Vreeswyk *et al.* 2004). In 2009, land tenure in the broader Pilbara region was approximately 60% pastoral lease, 10% conservation reserve, 5% Aboriginal Reserve and 25% unallocated Crown land (McKenzie *et al.* 2009). Within the Hamersley subregion, dominant land uses are grazing, UCL and crown reserves, native pastures, conservation, mining and urban (Kendrick 2001).

Grazing is prevalent across the study area. Stocking rates appear high on Rocklea station, especially in the low-lying, shadier portions of the study area.

2.5 BIOLOGICAL CONTEXT

2.5.1 Short-range endemic invertebrates

Short-range endemic fauna are defined as animals that display restricted geographic distributions, nominally less than 10,000 km^2, that may also be disjunct and highly localised (Harvey 2002). The most appropriate analogy is that of an island, where the movement of fauna is restricted by the surrounding marine waters, therefore isolating the fauna from other terrestrial populations. Isolating mechanisms and features such as roads, urban infrastructure, large creek lines and ridges can act to prevent the dispersal and gene flow of the less mobile invertebrate species.

Short-range endemism in terrestrial invertebrates is believed to have evolved through two primary processes (Harvey 2002):

- **Relictual short-range endemism**: relictual SREs are thought to have had wider distributions during more mesic geological periods. Australia's aridification over the last 60 million years resulted in a contraction of the ranges of these species into relatively small habitat pockets where moist conditions persist (relictual Gondwanan habitats). Evolutionary processes over long periods of isolation typically resulted in each population developing into a distinctive species. Millipedes and slaters are typical relictual SREs and they are generally found in deep gullies often on the south-facing slopes of mountains, hills and ridges. Relictual SREs often inhabit areas with: high rainfall, areas where topography induces fog, areas with permanent water (swamps, creek lines and river systems) or deep litter beds. Sometimes habitats have various combinations of these features.
- **Habitat specialisation**: habitat specialist SREs may have settled in particular isolated habitat types by means of dispersal or phoresy (transport of one organism by another) and evolved in isolation into distinct species. Such habitat islands include rocky outcrops (pseudoscorpions in the genus *Synsphyronus* or selenopid spiders are typical examples) or salt lakes (e.g. wolf spiders of the genus *Tetralycosa*). Unlike relictual SREs in mesic habitats, habitat specialist SREs are restricted by environmental parameters other than humidity and are often found in arid environments such as the Pilbara.

Invertebrate groups that contain SRE taxa are generally well distributed across the Australian landscape and well adapted to semi-arid environments due to a variety of behavioural and morphological features that have developed to avoid desiccation and predation. They generally possess (Harvey 2002):

- poor powers of dispersal
- confinement to discontinuous habitats
- seasonality, i.e. only active in cooler or wetter months
- slow growth
- low levels of fecundity.

In the Pilbara, the current knowledge of SREs is relatively poor and the rarity of collections from certain areas makes it difficult to assess the distribution and likely occurrence of SRE species. Habitats such as mountains containing gullies/gorges and south-facing slopes (principally within the Hamersley and Chichester Ranges), wetlands and rivers often include unique habitat attributes set amongst a relatively homogeneous surrounding landscape. These unique, isolated microhabitats often harbour SRE taxa. Potential SRE taxa of the Pilbara include the following groups that represent the target invertebrates of this survey (EPA 2009):

- spiders and relatives (Arachnida)
    - spiders (Araneae), in particular trapdoor spiders (Mygalomorphae) and selected modern spiders (Araneomorphae) (here mainly Flat Rock Spiders, family Selenopidae)
    - harvestmen (Opiliones)
    - false scorpions (Pseudoscorpiones)
    - true scorpions (Scorpiones)
    - whip spiders (Schizomida) (although the majority of SREs in this order are troglobites (Harvey *et al.* 2008; Harvey *et al.* 2011)
- multipedes (Myriapoda)
    - centipedes (Chilopoda), mainly the order Geophilomorpha and the Cryptopidae in the order Scolopendromorpha; other Scolopendromorpha are generally widespread and are not considered target taxa (e. g. Colloff *et al.* 2005; Koch 1982, 1983a, b, c)
    - millipedes (Diplopoda)
- crustaceans (Crustacea)
    - slaters (Isopoda)
- snails and relatives (Mollusca)
    - land snails (Eupulmonata, Gastropoda)
- earth worms (Oligochaeta).

Whilst other invertebrate groups have recently been proposed to contain a substantial proportion of range-restricted species in the Pilbara, e.g. epigaeic (ground-dwelling), often wingless beetles (Guthrie *et al.* 2010), these are currently not targeted in SRE invertebrate surveys (EPA 2009).

2.5.2 Categories of short-range endemism

Currently, there is no accepted system to define the varying probabilities of a species to be an SRE. The uncertainty in categorising a specimen as SRE originates in a number of factors including:

- **Poor regional survey density** (sometimes taxon-specific): A regional fauna is simply not known well enough to assess the distribution of species. This factor also considers the fact that, simply because a species has not been found regionally, does not mean it is really absent; this confirmation ('negative proof') is almost impossible to obtain ("absence of proof is not proof of absence").
- **Lack of taxonomic resolution**: many potential SRE taxa (based on preferences for typical SRE habitats, SRE status of closely related species, or morphological peculiarities such as troglomorphism) have never been taxonomically treated and identification to species level is very difficult or impossible as species-specific character systems have not been defined. Good taxonomic resolution does not necessarily require a published revision, but generally requires a taxonomist to be actively working on this group or a well-established, preferably publicly available, reference collection (i.e. museum collection).
- **Problems of identification**: SRE surveys often recover life stages of potential SRE taxa that cannot be confidently identified based on morphological characters, even if revisions exist. These include, for example, juvenile or female millipedes, mygalomorph spiders and scorpions. Molecular techniques are increasingly being employed to overcome these identification problems (see chapter 3.4.2).

Considering these factors of uncertainty, Phoenix currently employs a simple three-tier system to categorise the different probabilities of short-range endemism: confirmed, likely or potential SRE (Table 2-1). The assignment of taxa to these categories is dynamic and can change with every single survey, as knowledge of SRE status is updated. For example, the millipede *Austrostrophus stictopygus* Hoffman, 2003 (order Spirobolida) has been shown widespread in the Pilbara based on material collected as part of environmental assessment studies following its initial description from few localities (Harvey *et al.* 2011; Hoffman 2003).

Life stages of species that cannot be identified at the species level, e.g. some females and juveniles, are assessed based on the knowledge of the higher taxon they belong to, i.e. family or genus. For example, all juvenile or female *Antichiropus* millipedes would be classified as 'confirmed SRE' as all but two of the 120+ known species in this genus are considered SREs (Wojcieszek *et al.* 2011).

Although the different categories of 'SRE-likelihood' may help to set conservation priorities, SRE taxa of all categories should be assessed on their merit, in order to determine appropriate conservation measures that adhere to the Precautionary Principle within environmental impact assessments. That is, "*where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason to postpone measures to prevent environmental degradation*" (EPA 2002).

Table 2-1 SRE categories reflecting survey, taxonomic and identification uncertainties

SRE category	Criteria	Typical representative
(Confirmed) SRE	Confirmed or almost certainly SRE; taxonomy of the group is well known (but not necessarily published); group is well represented in collections, in particular from the region in question; high levels of endemism exists in documented species; inference is often possible from immature specimens	*Antichiropus* millipedes and araneomorph spiders in the genus *Karaops* (Selenopidae)
Likely	Taxonomically poorly resolved group; unusual morphology for the group (e.g. some form of troglomorphism); often singleton in survey and few, if any, regional records	Opiliones, some pseudoscorpions and slaters
Potential	Taxonomically poorly resolved group; often common in certain microhabitats in SRE surveys (i.e. litter dwellers), but no other regional records; congeners (= species in the same genus) often widespread	Cryptopidae, Geophilomorpha

2.5.3 Threatening processes

The restricted ranges of SREs in combination with often very specific habitat preferences make them particularly vulnerable to adverse effects caused by some of the land uses mentioned above (section 2.5) (Harvey 2002). Several threats confront the flora and fauna across the Pilbara bioregion, in particular:

- **Wildfire and alteration of fire regimes**: over 72% of the Pilbara region was burnt between 1993 and 2006 (van Leeuwen *et al.* 1995). For example, the extent of mulga woodland in the Central Hamersley Range is decreasing as a consequence of too-frequent fires. These woodlands support assemblages of species, including SREs, which do not persist in the spinifex scrublands that are replacing the mulga.
- **Habitat alteration through grazing** (Figure 2-4): livestock grazing started depleting the native grass cover along the main river channels in the early 1900s, resulting in increasingly occluded drainage systems with substantial bed loads. Simultaneously, the introduced Buffel Grass (*Cenchrus ciliaris*) rapidly colonised alluvial surfaces via these river systems. Subsequently, it has displaced indigenous shrubs and grasses from a variety of Pilbara environments (McKenzie *et al.* 2009).

Figure 2-4 Evidence of heavy impact by grazing cattle at Rocklea survey site 6: trampled grass and cattle droppings (inset bottom left)

- **Spread of introduced fauna including unmanaged livestock and feral bees:** twelve introduced mammals compete with and/or prey on indigenous species in the Pilbara, including house mice, black rats, feral dogs and cats, red fox, European rabbit, brumbies, feral pigs and camels (see also McKenzie & Burbidge 2002).
- **Spread of weeds**: a total of 103 weed species are currently established in the Pilbara comprising 6.3% of the region's flora. Fourteen of these species alter the region at a landscape scale by altering fire patterns, modifying soil characteristics or competing directly with native species. Another 15 species significantly modify particular habitats such as wetlands, six are major threats to islands and a further 16 have potential threat to Pilbara environments (Keighery 2010).

- **Habitat destruction through mining and associated infrastructure:** several large-scale mining developments are present in the area (e.g. Paraburdoo, Tom Price). The cumulative effects of these projects are not well understood. Large scale projects such as these and associated infrastructure developments such as railways also potentially impact surface and sub-surface hydrology which in turn may affect surface vegetation and therefore dependent fauna species and assemblages.
- **Climate change**: current predictions suggest that the Pilbara region may become warmer with more hot days and fewer cold nights and may experience less annual rainfall. Droughts may be more severe and storm events become more common (McKenzie *et al.* 2009). These effects may enhance the effects of other threatening processes, in particular the likelihood of fire and the introduction of more species from the tropics.

2.5.4 Previous surveys

The Pilbara has very diverse flora and fauna, however, its biota remain poorly documented despite a considerable amount of localised surveys by government and tertiary institutions as well as mining companies and their environmental consultants (Harvey *et al.* 2011; McKenzie *et al.* 2009). A comprehensive biological survey of the Pilbara was conducted by the Department of Environment and Conservation (DEC) from 2002–2007. This survey provided a benchmark for environmental assessment studies in the Pilbara, as it comprehensively surveyed the biota and summarised faunistic and floristic data for the region for many groups of plants and animals (Baynes & McDowell 2010; Durrant *et al.* 2010; Gibson & McKenzie 2009; Guthrie *et al.* 2010; Heterick *et al.* 2010; Keighery 2010; McKenzie *et al.* 2009; Pinder *et al.* 2010; Volschenk *et al.* 2010).

Survey data for a number of SRE target taxa were analysed during the DEC Pilbara survey including those of spiders (Durrant *et al.* 2010) and scorpions (Volschenk *et al.* 2010). These studies provided the much-needed regional context to interpret species distributions for these groups. However, survey data for other SRE target taxa, such as millipedes, pseudoscorpions, isopods and molluscs, have so far not been published.

Short-range endemic invertebrate surveys have been conducted in the vicinity of the study area for mining developments such as Brockman 4, Turee Syncline, Nammuldi-Silvergrass, and the FMG Solomon project (see Figure 1-1), but reports for some of these were not accessible for comparison with this survey. However, if specimens from these surveys were deposited at the WA Museum, these records were accessed as part of the desktop review (see 3.1 and 4.1).

Lack of biological data in the Pilbara severely hampers environmental impact assessment for many economically important industrial projects and pastoral diversification proposals, and limits the development of a comprehensive, adequate and representative reserve system in the Pilbara (McKenzie *et al.* 2009). The importance of a comprehensive regional biodiversity framework for impact assessment and sustainable natural resource development has been stressed in the advice provided to governments by the EPA for a number of Pilbara development proposals (McKenzie *et al.* 2009). A regional context is particularly important for the interpretation of distribution data of SREs. An evaluation of a species' distribution and therefore a confirmation of its range-restricted status are only possible if regional data are available.

Distribution data for many SRE species in WA is mainly available through the collection databases of the WA Museum, but is restricted to those groups for which these collections have been taxonomically evaluated. Interpretation of distribution data of SREs for the Pilbara, most of which are undescribed, generally rests with the respective experts and is impossible without consulting these scientists.

3 METHODS

3.1 DESKTOP REVIEW AND DATABASE SEARCHES

WA Museum Arachnology and Myriapodology, WA Museum Mollusca and WA Museum Crustacea database searches were requested to gain distribution data for potential SRE taxa. The rectangular search grid was determined by the proposed maximum range of short-range endemism, i.e. 100 km x 100 km (Harvey 2002). Therefore, the search grid extended approx. 100 km from the centre of the study area (NW corner 21°87'S/116°52"E and SE corner 23°72'S/118°45’E).

A number of mining developments are being progressed in the vicinity of Rocklea, mainly to the north-east of the study area (Figure 1-1). However, SRE survey reports were not accessible for all of them:

- Brockman 2 (Hamersley Iron, subsidiary of Rio Tinto Ltd) (RTIO 2010; Strategen 2011); SRE survey report currently not available
- Brockman 4 (Hamersley Iron, subsidiary of Rio Tinto Ltd)(Hamersley Iron *et al.* 2005); SRE assessment by Biota (2005)
- Marandoo (Rio Tinto Ltd) (EPA 2010)); SRE assessment by Biota (2008a)
- Nammuldi-Silvergrass (Hamersley Iron, subsidiary of Rio Tinto Ltd) (e.g. EPA 2000); SRE survey report currently not available
- Solomon (Fortescue Metals Group, FMG); one of the largest mining developments in the vicinity of Rocklea and surveys have been conducted in three distinct areas: Firetail – mining of the Firetail North and Firetail South areas; rail – construction of a 127 km railway from FMG’s existing north-south rail line to the proposed Firetail mining area; and Kings – mining of the Zion, Valley of the Kings, Valley of the Queens and Trinity iron ore deposits and a 15 km extension of the proposed railway (as above) to these deposits (EPA 2011; GHD 2010); SRE survey reports by Ecologia (2010) and Phoenix (2010)
- Turee Syncline (Hamersley Iron, subsidiary of Rio Tinto Ltd); SRE assessment by Phoenix (2008).
- West Angelas (Rio Tinto Ltd); SRE survey report currently not available
- West Turner Syncline (Rio Tinto Ltd); SRE survey reports by Biota (2008b) and Biota (2009).

3.2 HABITAT ASSESSMENT AND SITE SELECTION

Two habitat types that potentially harbour SRE invertebrates were identified in the study area (Table 3-1), namely: rocky hills (some with south facing slopes) and creeklines (mainly the floodplain of the Hardey River).

Within these habitats, a total of seven potential SRE sites were surveyed (Table 3-1, Figure 3-1). Two of these were located in the proposed main pit and five represented reference sites in the wider study area (Table 3-1; Figure 3-1). Two opportunistic sites within the proposed main pit were visited with much lower survey effort (Table 3-1; Figure 3-1). Six sites of the concurrent vertebrate survey were opportunistically surveyed and also recovered some SRE target specimens; site descriptions for those sites can be found in Phoenix (2011). Detailed site descriptions for the SRE sites list geography, vegetation, soil, rockiness, litter, disturbance with a site photograph (Appendix 1).

Table 3-1 Short-range endemic survey sites and sampling effort for the Rocklea Iron Ore Project

(Collecting techniques: wPT – wet pitfall trap (propylene glycol), FO – foraging, LS – litter and soil sieve

Site	Habitat	Proposed main pit	Easting (50K)	Northing (50K)	Collecting techniques	Time spent foraging (mins)	Number of litter sifts
SRE survey sites							
1	rocky hill	Yes	549125	7477057	wPT, FO, LS	125	7
2	rocky hill	No	551308	7476888	wPT, FO, LS	120	6
3	creekline	No	551462	7477177	wPT, FO, LS	120	6
4	rocky hill	No	551242	7482078	wPT, FO, LS	120	6
5	creekline	No	551024	7482182	wPT, FO, LS	120	7
6	creekline	No	551052	7479839	wPT, FO, LS	120	7
7	rocky hill	Yes	548588	7477419	wPT, FO, LS	120	6
Opportunistic sites							
SRE Opp 1		Yes	551195	7477375	FO	40	-
SRE Opp 2		Yes	548205	7477416	FO	40	-
Vert 1		No	550547	7475905	FO	-	-
Vert 4		Yes	548953	7477639	FO	-	-
Vert 5		Yes	549830	7477321	FO	-	-
Vert 7		No	551667	7481423	FO	-	-
VertOpp 1		Yes	549795	7477301	FO	-	-
VertOpp 4		No	551570	7473920	FO	-	-

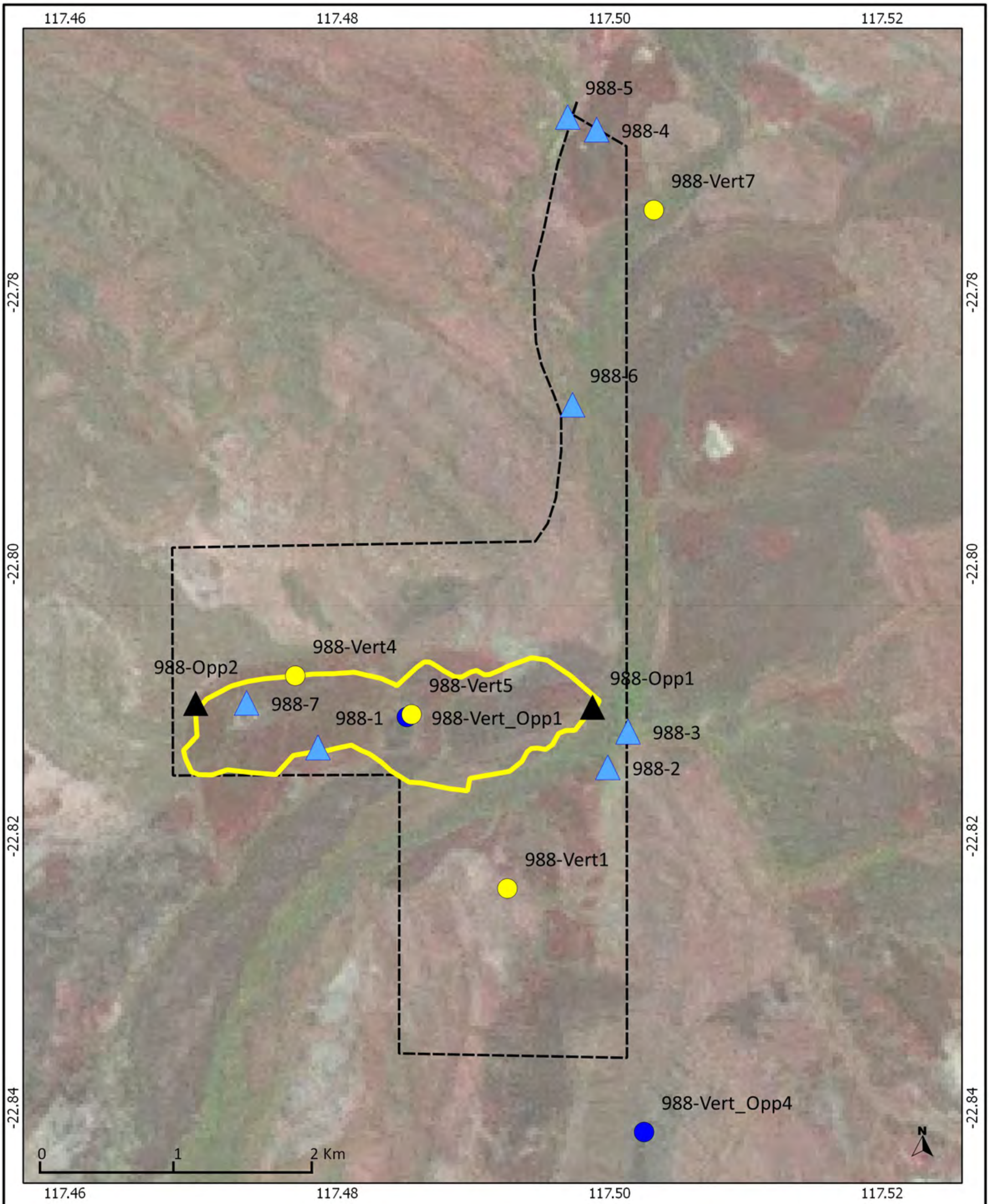


Figure 3-1
Collection sites for the SRE survey (n = 7), opportunistic (n = 2) and vertebrate survey sites that recovered SRE target taxa (n = 6)

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR: P.R. Langlands	CLIENT: Dragon Energy Ltd
DATE: February 2012	Scale: 1:30000
Coordinate System:	Projection: Transverse Mercator; Datum: WGS84

PROJECT: Rocklea Iron Ore Project

Proposed main pit
Study area

Study sites
SRE
SRE Opportunistic
Vertebrate
Vertebrate Opportunistic

3.3 SURVEY METHODS

The collecting methods consisted of three proven, industry-recognised sampling techniques to target SRE taxa: wet pitfall trapping (propylene glycol), active searches (foraging) and the sieving of combined leaf litter and soil samples (see Table 3-1 for total survey effort).

3.3.1 Foraging

Foraging incorporated the systematic inspection of logs, larger plant debris, the underside of bark of larger trees and the underside of rocks. Methodical searches were conducted amongst the leaf litter of shade-bearing tall shrubs and trees and spinifex bases were inspected thoroughly. Rocks and rock crevices were inspected, particularly for pseudoscorpions. A temporally standardised approach was undertaken, whereby each site was sampled for a minimum of 1.5 person hours. Trap door spider burrows identified during the searches were excavated if they were considered to be inhabited. Excavation involved removing soil from around the burrow to carefully expose the burrow chamber and remove the spider.

3.3.2 Litter/soil sieving

A variable number of combined leaf litter and soil samples were taken at each of the seven SRE sites, depending on the amount of deep leaf litter present. At least three combined litter/soil sifts were undertaken at each site. The collection of leaf litter samples were standardised volumetrically by the diameter and height (310 mm x 50 mm = 1.55 L) of the sieves which were completely filled with compressed litter and the upper layers of underlying soil.

Samples were sieved through three stages of decreasing mesh size over a round tray and invertebrates were picked from the sieves and tray with forceps or an aspirator. These samples particularly targeted small spiders (Araneomorphae), pseudoscorpions, buthid scorpions, millipedes, centipedes (in particular Geophilomorpha and Cryptopidae), smaller species of molluscs (e.g. Pupillidae) and slaters.

In situ collecting and sieving was preferred over transporting litter samples to the laboratory. Small invertebrates are best detected when moving and transport to the laboratory can kill a large proportion of the catch. In addition, if litter sieves in the field contain groups of interest, more extensive searches can be conducted, providing greater flexibility in the sampling protocol.

3.3.3 Wet pitfall traps

Five wet pitfall traps were dug in flush with the surface in suitable microhabitats at each site. The traps comprised one litre plastic containers with a 70 mm diameter that were half-filled with a solution of propylene glycol. All traps were covered with a plastic lid elevated 25 mm above the trap with wooden blocks to minimise by-catch of vertebrates. Pitfall traps were installed from 3 to 5 October 2011 and collected from 7 to 9 November 2011 resulting in a trapping period of approximately five weeks.

3.4 IDENTIFICATION, TAXONOMY AND NOMENCLATURE

3.4.1 Morphological species identification

Phoenix has considerable in-house expertise in the identification of SRE target groups. Senior staff involved in the identification are also Research Associates with a longstanding taxonomic research history at the WA Museum (Table 3-2).

In all cases, identifications relied on direct comparison with reference material from the WA Museum. WA Museum staff were engaged to identify groups in which Phoenix does not have the appropriate expertise (e.g. some pseudoscorpions and all snails). The single exception was slaters (Isopoda) which were identified by Dr Simon Judd who is the Western Australian authority on slaters (e.g. Judd 2004; Judd & Horwitz 2003), having extensive experience in the identification of isopods from the Pilbara and other regions of the state.

Comparison of the survey specimens with the WA Museum reference collections provides the important regional context in the assessment of short-range endemism for unpublished taxa (McKenzie *et al.* 2009).

Most material collected during the SRE survey, in particular SRE species, was lodged with the WA Museum, the exception being some representative specimens that remain in the Phoenix reference collection.

Table 3-2 Specialist taxonomists that identified the short-range endemic invertebrates from the Rocklea Iron Ore Project

Person	Title	Taxon
Dr Volker W. Framenau	Manager, Terrestrial Invertebrates, Phoenix; Research Associate, WA Museum	Araneae (Mygalomorphae, Araneomorphae), Opiliones, Diplopoda, Chilopoda
Dr Erich S. Volschenk	Manager, Subterranean Fauna, Phoenix; Taxonomic consultant, ScorpionID; Research Associate, WA Museum	Scorpiones, Pseudoscorpiones
Ms Anna Leung	Invertebrate Zoologist, Phoenix	Geophilomorpha, Pseudoscorpiones
Dr Peter Langlands	Invertebrate Zoologist, Phoenix	Araneae (Mygalomorphae, Araneomorphae)
Dr Mark S Harvey	Head of Department of Terrestrial Zoology, WA Museum	Pseudoscorpiones
Mr Corey Whisson	Assistant Curator – Department of Aquatic Zoology, WA Museum	Mollusca
Dr Simon Judd	Taxonomic consultant	Isopoda

3.4.2 Molecular species identification

The survey in the study area recovered a juvenile *Missulena* trapdoor spider, which could not be identified to species level with morphological methods. Identification of this specimen was desirable as the genus is a target of SRE surveys and therefore molecular analysis of these specimens was undertaken.

Molecular methods of species identification have become increasingly common recent years. The identification of species based on comparisons between DNA sequences is referred to as DNA barcoding. Any gene can be used for barcoding purposes; however, the primary gene targeted by researchers is Cytochrome Oxidase Subunit I (COI or COXI), the 'Barcoding Gene' (Hebert *et al.* 2003).

Hebert *et al.* (2003) examined the percentage differences of over 13,000 species pairs. That study found a mean divergence of 11.3% between species pairs and with the majority of species showing 8% or more sequence divergence. Chelicerata were found to have an average sequence divergence of 14.4% and more than 97% had divergences greater than 8%. For this reason 8% sequence difference was used as the threshold for discrimination of species.

3.4.2.1 DNA extraction

Fourteen specimens of spiders belonging to the genus *Missulena* were sequenced for variation at the mitochondrial gene cytochrome oxidase unit I (COI), including the one collected during the Phoenix SRE survey at Rocklea. The 13 remaining were from the tissue collection of the WA Museum and were collected from localities in the vicinity of the study area in the south-eastern Pilbara region (Table 3-3). No tissue of the *Missulena* specimens that were identified from near Rocklea in the desktop review (see Figure 4-1, Table 4-1) was available for sequencing and therefore no test of conspecifity could be conducted.

COI sequences of two WA specimens of *Conothele* (family Ctenizidae) (WAM T112453, T71237) were included in the analysis. *Conothele* was sister group to *Missulena* in an extensive higher phylogenetic study on trapdoor spiders (Hedin & Bond 2006). The Nearctic *Euagrus chisoseus* Gertsch, 1939 (family Dipluridae) (COI sequence FJ607564; obtained from the National Center for Biotechnology Information (NCBI) (http://www.ncbi.nlm.nih.gov/genbank/) was used as outgroup for the analysis.

Genomic DNA was extracted from all specimens using the Quiagen DNeasy Blood & Tissue Kit (Valencia, CA, USA). Extraction was achieved by incubating approximately 1.0 g of leg muscle tissue in lysis buffer overnight at 56˚C.

Initial test PCR's using four primer combinations were run to determine which primers could amplify the gene consistently across all species. Polymerase chain reaction (PCR) amplification of a 827 bp fragment of the COI gene was achieved using the primers LCO 1490 (Folmer *et al.* 1994) and HCOoutout (Prendini *et al.* 2005). The alternative forward primer CI-J-1718 (Simon *et al.* 1994) was used for samples where LCO 1490 failed, resulting in a slightly shorter fragment of 628 bp in length.

PCR conditions for all runs were:

- initial denaturation at 95˚C for 2 min
- denaturation at 95˚C for 30 sec
- annealing 42˚C for 1 min (40 cycles)
- extension 72˚C for 5 min
- final extension 72˚C for 10 min.

The PCR products were sequenced for both DNA strands at the AGRF node in Perth (Western Australian Institute of Medical Research, WA, Australia) using the supplied sequencing primers.

Sequences were edited using the software SEQUENCHER (Gene Codes Corporation, Ann Arbor, MI, USA) and, following an initial alignment with Clustal X (Thompson *et al.* 1997), cropped to an identical length in order to allow precise homology statements and objective analysis across all base pairs. Final multiple sequence alignment was performed using MUSCLE (Edgar 2004) as incorporated into the program Geneious (Drummond *et al.* 2011) using the default parameters.

All sequence data was communicated to the WA Museum (M.S. Harvey).

3.4.3 Nomenclature

The nomenclature of described invertebrates and higher taxa follows a number of taxon-specific references, most of which are available online (Table 3-4). However, many SRE invertebrate species are currently unnamed and morphospecies designations listed in this report were adopted from the nomenclatural systems developed by the respective taxonomic authorities.

Reference collections generally reside with WA Museum and morphospecies designations generally follow listings developed by the WA Museum (Table 3-4), as expected by the EPA (EPA 2004).

Table 3-3 Spider specimens (family Actinopodidae) sequenced for molecular identification of *Missulena* specimens from Rocklea

Species	WA Museum registration	Locality	Latitude	Longitude
Missulena sp. indet.[a]	T118178	Rocklea, SRE site 05	-22.767044	117.497034
Missulena occatoria-grp	T62264	47.4 km SE of Roy Hill homestead, site FML01	-22.6544°S	120.4100°E
Missulena \`MYG044\`	T91911	Hamersley Range, Weeli Wolli Creek region, Area C, site 09-9C	-22.92583°S	119.0379°E
Missulena \`MYG044\`	T91914	Hamersley Range, Weeli Wolli Creek region, Area C, site 15-15E	-22.93161°S	119.0473°E
Missulena \`MYG044\`	T112076	Wonmunna, ~73 km W of Newman	-23.1192	119.0643
Missulena sp. indet. (fem.)	T95395	Jimblebar minesite, 35 km E of Newman	-23.37889°S	120.2575°E
Missulena \`MYG003\`	T97017	Jinayri, approx. 65 km NW. of Newman	-22.96783	119.2672
Missulena sp. indet. (fem.)	T97637	Murray Hills, Mulga Downs Station	-22.12782	118.5153
Missulena sp. indet. (fem.)	T99600	Bellbird Siding to Juna Downs, 76.4 km E. of Tom Price	-22.8750	118.5039
Missulena sp. (male)	T113598	Southern Flank, 72 km NW of Newman	-23.0031	119.1392
Missulena sp. indet. (juv.)	T113626	113.8km NW of Newman	-22.6565	118.9182
Missulena sp. indet. (juv.)	T113653	110.6km NW of Newman	-22.7423	118.8806
Missulena sp. indet. (juv.)	T113660	119.1km NW of Newman	-22.6336	118.8698
Missulena sp. indet. (fem.)	T102165	Davidson Creek, ~75 km E. of Newman	-23.42878	120.4466

[a] Specimen collected in the study area is shaded grey.

Table 3-4 Nomenclatural references, morphospecies designations and reference collections for SRE invertebrates of the Rocklea Iron Ore Project

Taxonomic group	Taxonomic reference for described species and higher taxa	Morphospecies designation and reference collection
Araneae (Mygalomorphae)	Platnick (2012)	"MYG"-numbering system developed by V.W. Framenau (WAM, Phoenix), reference collection at WAM
Araneae (Araneomorphae: Selenopidae)	Platnick (2012)	Morphospecies designations developed by M. Harvey (WAM) and V.W. Framenau (WAM, Phoenix), reference collection at WAM
Pseudoscorpiones	Harvey (2009)	"PSE"-morphospecies designations developed by M. Harvey (WAM), reference collection at WAM
Scorpiones	Rein (2011)	Morphospecies designation developed by E.S. Volschenk (WAM, Phoenix), reference collection at WAM
Diplopoda (Polydesmida: *Antichiropus*)	Mesibov (2006)	Morphospecies designations developed by M. Harvey (WAM) and V.W. Framenau (WAM, Phoenix), reference collection at WAM
Chilopoda (Geophilomorpha, Cryptopidae only)	Colloff *et al.* (2005)	Taxonomically poorly studied groups, no reference collection available
Gastropoda	Smith (Smith 1992); C. Whisson (pers. comm.)	Morphospecies designations developed by C. Whisson and S. Slack-Smith (WAM), reference collection at WAM
Isopoda	Schotte *et al.* (2008 onwards)	Morphospecies designations developed by S. Judd, reference material at WAM

3.5 STATISTICAL ANALYSES

Species estimation curves were compiled to obtain an estimate of survey completeness, i.e. whether the collection adequately represents the SRE invertebrate fauna of the study area. Individual-based taxon accumulation curves were plotted in favour of sample-based curves, as they assess species richness rather than density (Gotelli & Colwell 2001).

Analyses were limited to SRE target taxa for the survey that were collected in sufficient numbers to allow for statistically meaningful analyses, i.e. pseudoscorpions, slaters and land snails (see 2.5.1). Centipedes were not analysed as they could not be identified to species level due to a lack of taxonomic resolution. The analysis was conducted with the lowest identified taxon rank, i.e. species or morphospecies.

Taxon richness from Mao Tau estimates (Colwell *et al.* 2004) was calculated using the software package EstimateS v8.2 (Colwell 2009) with 999 randomizations. In addition, the abundance based, non-parametric species estimators ACE, Chao1 and Jack Knife1 were used to estimate the total number of each taxa group within the study area. These estimators were chosen as they are insensitive to pooling collection data ("grain size") and perform well when tested against real data (Hortal *et al.* 2006; Walther & Moore 2005).

A number of important limitations must be considered when interpreting the species accumulation results. The above analyses do not extrapolate the total species numbers within the study area, but provide estimates for the circumstances under which the data were collected. They reflect potential results for more comprehensive surveys (i.e. more samples), but with the same methods in the same habitats at the same time of the year. Total species numbers for the survey area may be higher.

Our species accumulation data is based on all SRE target taxa, not those that are here considered to actually belong to the three SRE categories. It is impossible to provide statistically reliable estimates on actual SREs in the study are due to the low number of individuals collected. The likelihood of finding more SREs must be based on the estimate for each group and their likelihood to contain SREs.

3.6 SURVEY LIMITATIONS

Limitations of the survey are outlined (Table 3-5) in compliance with EPA Guidance Statement 56 (EPA 2004).

Table 3-5 Limitations of short-range endemic survey for the Rocklea Iron Ore Project

Limitations	Relevant to this survey? Yes/no	Comments
Competency/experience of the consultant carrying out the survey	No	Phoenix has extensive experience in SRE surveys throughout the Pilbara, Midwest, Southwest, Kimberley and Goldfields regions of WA; senior staff are leading taxonomists for SRE target groups; identifications of other groups were outsourced to relevant leading experts (e.g. WA Museum) (Table 3-2)
Scope (what faunal groups were sampled and were some sampling methods not able to be employed because of constraints such as weather conditions, e.g. pitfall trapping in waterlogged soils or inability to use pitfall traps)	No	The survey targeted all groups known to include SREs. Extensive foraging and litter/soil sieving effort supplemented the pitfall trapping program, to ensure that groups such as pseudoscorpions were represented in the survey; opportunistic records were provided through a concurrent vertebrate survey (Phoenix 2011)
Proportion of fauna identified, recorded and/or collected	No	Species accumulation curves suggested most taxa were collected for snails and isopods (Figure 4-8). Few individuals of some groups (mygalomorphs, millipedes) were collected, not allowing a statistical analysis of survey effectiveness.
Sources of contextual information, e.g. previously available information (whether historic or recent) as distinct from new data	Yes	There is little historic data concerning invertebrates in the region. The DEC Pilbara Biological Survey provided some data for SRE groups (spiders, scorpions) but not for many others. WAM databases identified some species that may occur in the survey area and some of these were recorded.

(continued next page)

(Table 3-5 continued)

Limitations	Relevant to this survey? Yes/no	Comments
Timing/weather/season/cycle	No	The survey was conducted mainly in October and November, inside the period recommended by EPA Guidance Statement 20 (EPA 2009).
The proportion of the task achieved and further work which might be needed	No	The program was implemented as planned at seven sites that potentially harbour SREs, plus two opportunistic sites.
Disturbances (e.g. fire, flood, accidental human intervention etc.) which affected results of survey	No	There was minimal, if any evidence of these disturbances at any sample site.
Intensity (in retrospect, was the intensity adequate?)	No	Species accumulation curves suggested most taxa were collected for snails and isopods (Figure 4-8). Few individuals of some groups (mygalomorphs, millipedes) were collected, not allowing a statistical analysis of survey effectiveness.
Completeness (was relevant area fully surveyed?)	No	All habitats with the greatest potential for facilitating short-range endemism were sampled across the survey area.
Remoteness and/or access problems	No	Access was possible to all SRE sites.
Availability of contextual (e.g. biogeographic) information on the region	No	The Pilbara is fairly well known from a floristic and vertebrate faunal context. Faunistic surveys in the vicinity of the study area, mainly for environmental impact assessment, provide very good data.

3.7 SURVEY AND LABORATORY PERSONNEL

Scientific personnel that were involved in the SRE field survey and laboratory work are listed in Table 3-6.

Table 3-6 Scientific personnel

Person	Title	Qualification
Dr Volker W. Framenau	Manager, Terrestrial Invertebrates	M.Sc. (Cons. Biol.), Ph.D. (Zool.)
Dr Erich S. Volschenk	Manager, Subterranean Fauna	Ph.D. (Zool.)
Dr Peter Langlands	Invertebrate Zoologist	B.Sc. (Env. Biol.) (Hons) Ph.D. (Zool.)
Ms Anna Leung	Invertebrate Zoologist	B.Sc. (Env. Sci.) (Hons)
Ms Kate Penwarden	Invertebrate Zoologist	B.Sc. (Zool.) (Hons)
Mr Danilo Harms	Invertebrate and Molecular Zoologist	M.Sc. (Zool.)

4 RESULTS

4.1 DESKTOP REVIEW

A total of 28 confirmed, likely or potential SRE invertebrate taxa were identified through database searches, in particular those of the WA Museum (Table 4-1; Appendix 2; Figure 4-1; Figure 4-2; Figure 4-3; Figure 4-4). The majority of these were collected during recent surveys of mining developments in the region and where therefore also listed in the respective reports (Biota 2005, 2008a; Ecologia 2010; Phoenix 2008, 2010) (see also Table 4-1).

Records of a single SRE invertebrate identified in the database search were from within the study area, a juvenile scorpion in the genus *Urodacus* (potential SRE) (Figure 4-2).

The confirmed (five taxa) and likely (five taxa) SREs identified during the desktop review (Table 4-1) are of conservation interest. Only one of these was also collected during the field survey, a camaenid land snail *Rhagada* ‘small banded’.

A critical review of the available reports show that some of the taxa previously reported as SREs are now considered more widespread. The survey of the Firetail mining area (Solomon Project) revealed a single confirmed SRE, the pseudoscorpion *Synsphyronus gracilis* Harvey, 1987 (Ecologia 2010). However, this species has subsequently been found to be more widespread in the Pilbara and is now not considered an SRE (M.S. Harvey personal communication). Similarly, the assessment for the scorpion *Urodacus* ‘firetail’, a potential SRE reported by Ecologia (2010) and Phoenix (2010) was downgraded recently (E.S. Volschenk unpublished data).

Table 4-1 Short-range endemic invertebrates identified through the desktop review for the Rocklea Iron Ore Project (WAM database searches and survey reports)

Family	Genus	Species	Locality	Source	SRE category
Araneae (spiders)					
Actinopodidae	*Missulena*	'MYG045?'	Nammuldi-Silvergrass, NW of Tom Price	WAM[a] database	Potential SRE
	Missulena	sp. (juv.)	Recorded from Serenity Valley	WAM database; Phoenix (2010)	Potential SRE
	Missulena	'*occatoria* grp'	Only known from Marandoo minesite (possibly *Missulena* 'MYG045?')	WAM database	Potential SRE
Barychelidae	*Synothele*	'MYG237'	Only known from Zion, 63 km N of Tom Price	WAM database	Potential SRE
	Barychelidae	sp. (juv.)	8.9 km S. of Tom Price, Tom Price Mine, site BLF# MMF100 6	WAM database	Potential SRE
Nemesiidae	*Aname*	'marae'	Only known from Tom Price powerlines, approx. 4.9 km NW Tom Price	WAM database; Harvey *et al.* (submitted)	Likely SRE
	Aname	'MYG168'	Only known from Valley of the Kings, 61 km N Tom Price	Phoenix (2010)	Potential SRE
	Kwonkan	'MYG169'	Only known from Valley of the Kings, 61 km N Tom Price	Phoenix (2010)	Potential SRE
	Kwonkan	sp. indet.	Tom Price, possibly *Kwonkan* 'MYG169'	WAM database	Potential SRE
	Yilgarnia	sp. indet.	Serenity Valley, site 7, approx. 93 km N. of Tom Price	Phoenix (2010)	Potential SRE
Selenopidae	*Karaops*	sp. indet.	Recorded from Serenity Valley, Nammuldi-Silvergrass and Tom Price	WAM database, Ecologia (2010)	Likely SRE

[a] WAM – WA Museum

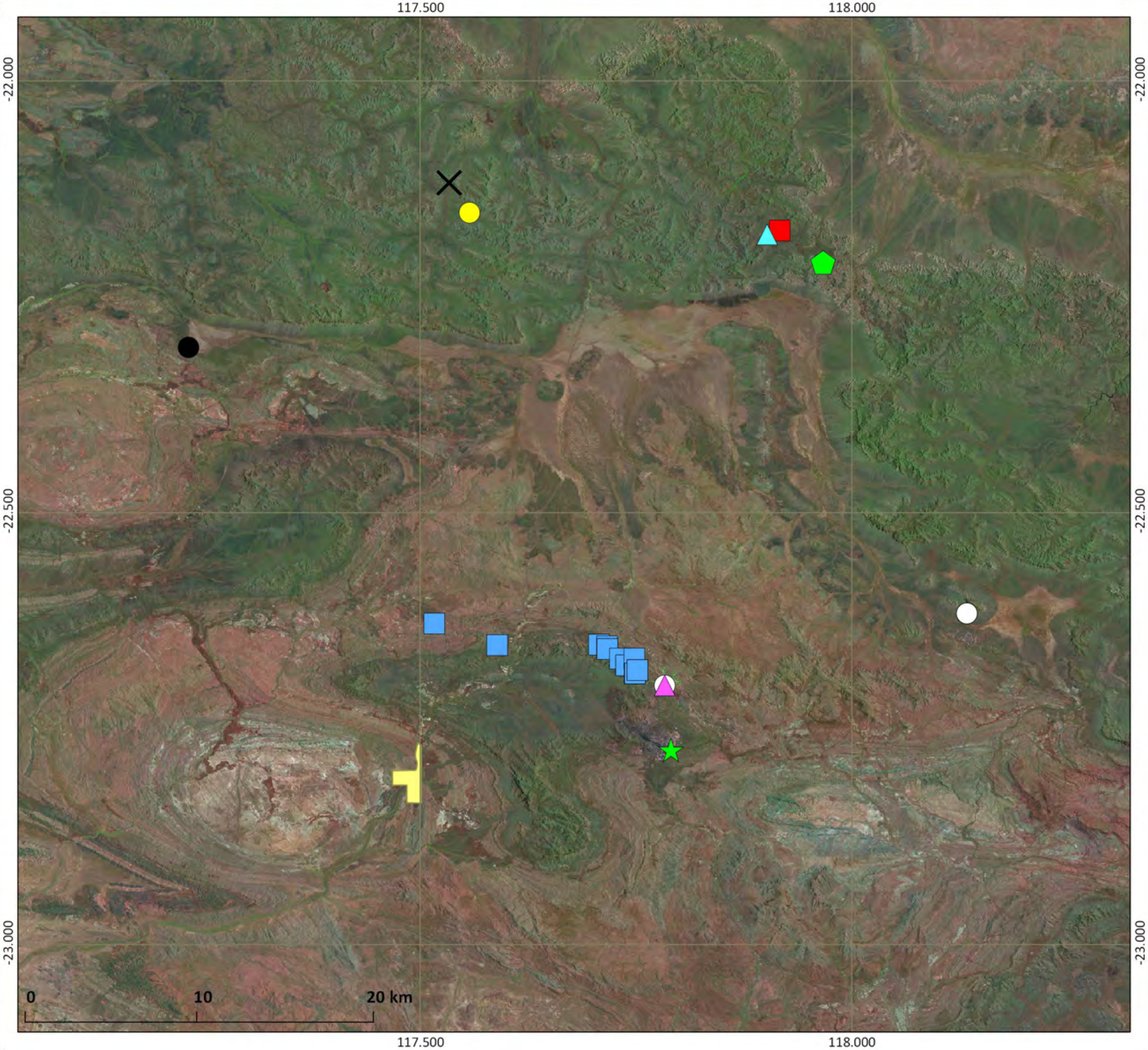
Family	Genus	Species	Locality	Source	SRE category
Opiliones (harvestmen)					
	Opiliones	sp. indet.	West Angelas, only Harvestmen recorded in desktop review; order rarely found in the Pilbara	WAM[a] database	Likely SRE
Scorpiones (scorpions)					
Buthidae	*Lychas*	'gracillimus'	Only known from 8 km S of Coolawanyay	WAM database	Potential SRE
	Lychas	'kings'	Only known from Valley of the Kings, approx. 61 km N of Tom Price	Phoenix (2010)	Potential SRE
	Lychas	'marandoo 1'	Only known from Marandoo minesite	WAM database; (Biota 2008a)	Potential SRE
	Lychas	'scottae'	Mt Brockman, Nammuldi mine (Hamersley Iron), site 33	WAM database	Potential SRE
Urodacidae	*Aops*	'solomon'	Only known from a single specimen from Valley of the Kings, approx. 61 km N of Tom Price; genus otherwise only known from Barrow Island (Volschenk & Prendini 2008) and Abydos.	WAM database; (Phoenix 2010)	Confirmed SRE
	Urodacus	'cf. mckenziei'	Brockman, 3.5 km W of Mt Brockman, site BRO32	WAM database	Potential SRE
	Urodacus	sp. indet.	Recorded 35 km WSW of Tom Price and 47.5 km ESE of Paraburdoo	WAM database	Potential SRE

[a] WAM – WA Museum

Family	Genus	Species	Locality	Source	SRE category
Diplopoda (millipedes)					
Paradoxosomatidae	*Antichiropus*	sp. indet.	Recorded 10 km W of Tom Price and approx. 25 km ESE Mt De Courcey; all *Antichiropus* from the Pilbara a currently considered confirmed SREs.	WAM[a] database	Confirmed SRE
Paradoxosomatidae		sp. indet.	approx. 9.9 km NW of Tom Price	WAM database; Ecologia (2010)	Likely SRE
Craspedosomatida		sp. indet.	Only known from Anketell Rail Corridor, NW Tom Price; only record of this millipede order in Pilbara	WAM database	Confirmed SRE
Chilopoda (centipedes)					
Mecistocephalidae	*Mecistocephalus*	sp. indet.	Recorded from 35 km E of Paraburdoo	WAM database	Potential SRE
Geophilomorpha		sp. indet.	Recorded from approx. 25 km NE of Hamersley Homestead	WAM database; Ecologia (2010)	Potential SRE
Gastropoda (land snails)					
Camaenidae	*Rhagada*	'small banded'	Only recorded from "central Pilbara", Mt Brockman and Nammuldi-Silvergrass	WAM database (possibly *Rhagada* 'Mt Brockman' of Biota (2005); C. Whisson personal communication)	Confirmed SRE
Camaenidae	*Rhagada*	sp. indet.	Recorded from Hamersley station, Mt Turner, Mt Bruce and Tom Price	WAM database; Biota (2005)	Potential SRE
Camaenidae	*Quistrachia*	'cancellate'	Only known from Hamersley Range, Tom Price, Millers Gorge, Kangeenamarina Gorge and Serenity valley	WAM database	Confirmed SRE
Camaenidae	*Quistrachia*	sp. indet.	Only known from Ashburton Downs, Marandoo minesite, Tom Price and Millers Gorge	WAM database; Biota (2005)	Likely SRE

[a] WAM – WA Museum

Figure 4-1
Records of short-range endemic trapdoor spiders (Mygalomorphae) from the desktop review



Study area
Missulena `MYG045?`
Missulena sp. (juv.)
Missulena `occatoria group`
Synothele `MYG237`
Barychelidae sp. (juv.)
Aname `marae`
Aname `MYG168`
Kwonkan `MYG169`
Kwonkan sp. indet.
Yilgarnia sp. indet.

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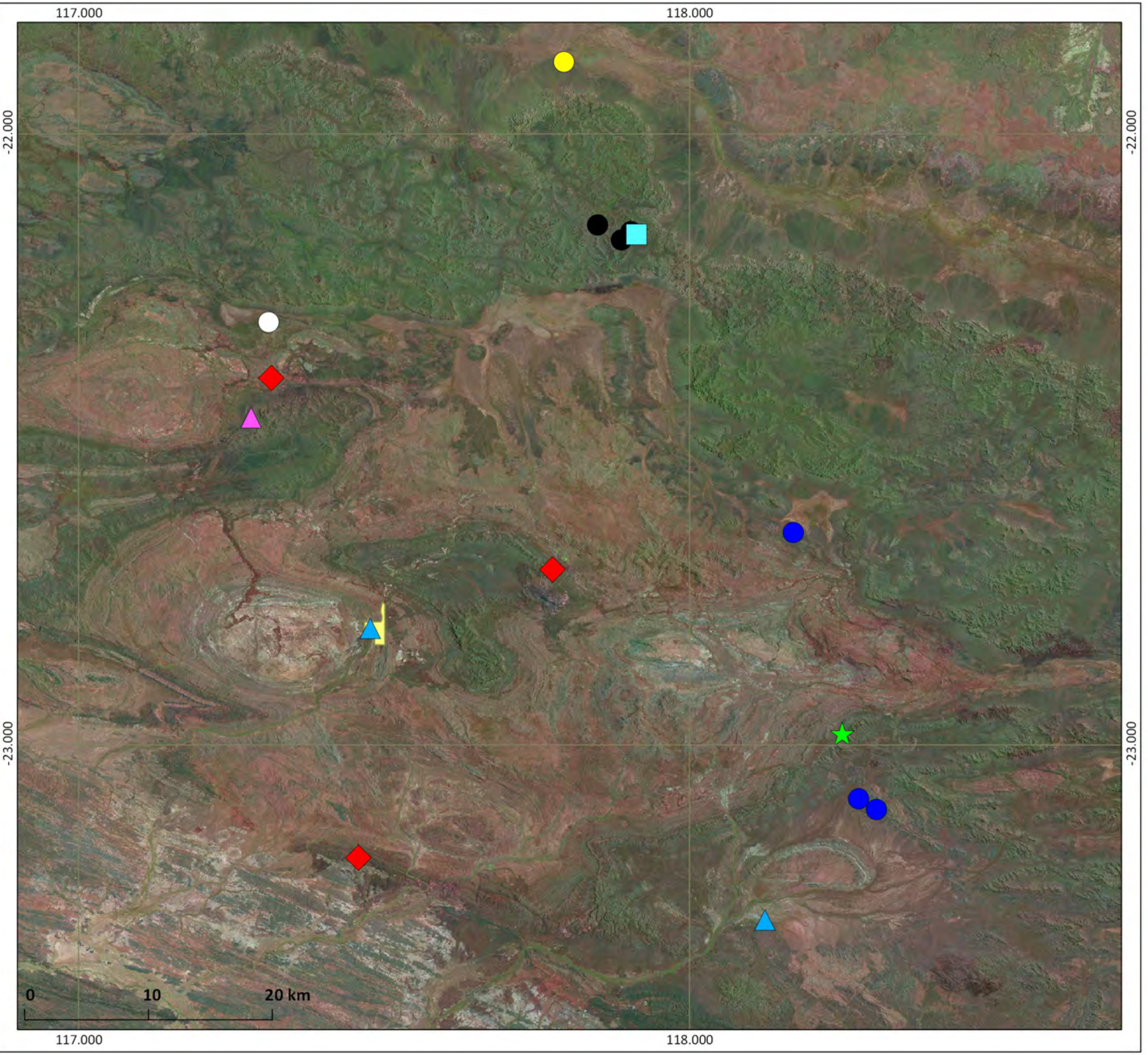
AUTHOR: P.R. Langlands	CLIENT: Dragon Energy Ltd
DATE: February 2012	Scale: 1:500000

Coordinate System: Projection: Transverse Mercator; Datum: WGS84

Figure 4-2
Records of short-range endemic modern spiders (Araneomorphae), harvestmen (Opiliones) and scorpions (Scorpiones) from the desktop review



Study Area

Karaops sp. (juv.)
Opiliones sp. indet.
Lychas `gracilimanus`
Lychas `kings`
Lychas `marandoo 1`
Lychas `scottae`
Aops 'solomon'
Urodacus `cf. mckenziei`
Urodacus sp. indet.

N

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Figure 4-3
Records of short-range endemic millipedes (Diplopoda) and centipedes (Chilopoda) from the desktop review

Study area

Antichiropus sp. indet.
Paradoxosomatidae sp. indet.
Craspedosomatida sp. indet.
Mecistocephalus sp. indet.
Geophiliida sp. indet.

N

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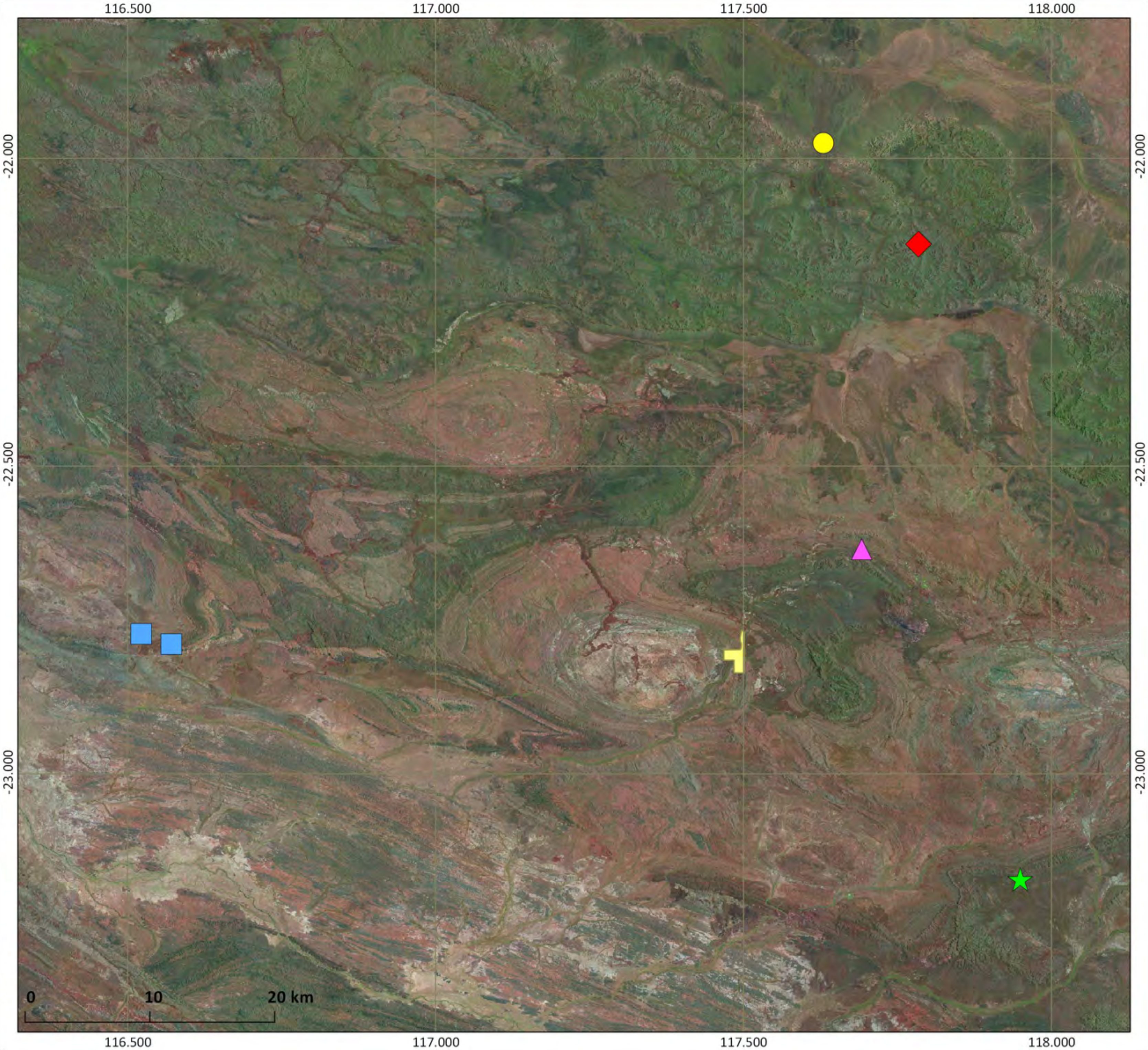
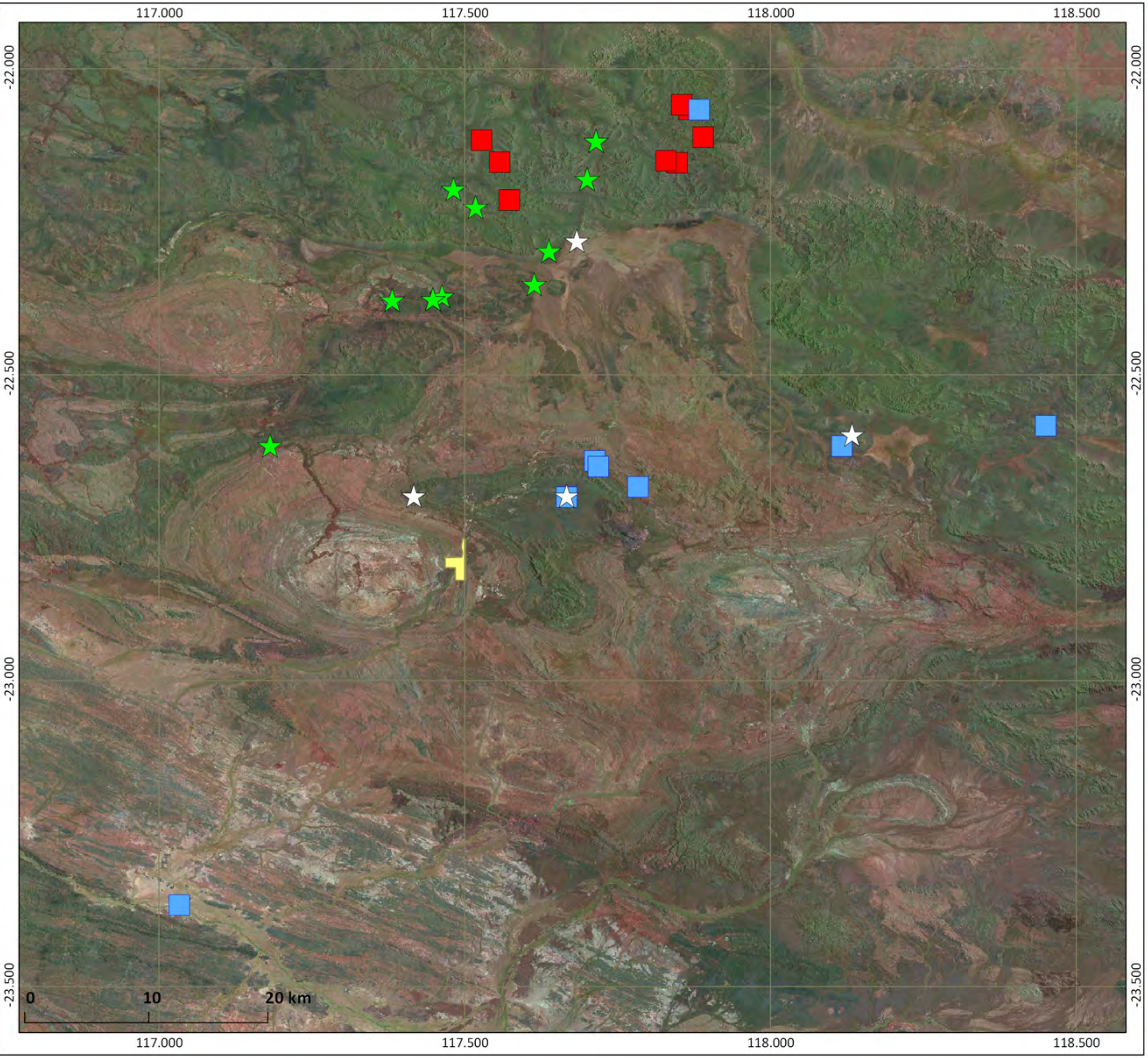


Figure 4-4
Records of short-range endemic snails (Mollusca) from the desktop review



Study area
Rhagada 'small banded'
Rhagada sp. indet.
Quistrachia 'cancellate'
Quistrachia sp. indet.

N

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PROJECT: Rocklea Iron Ore Project	
AUTHOR: P.R. Langlands	CLIENT: Dragon Energy Ltd
DATE: February 2012	Scale: 1:700000

Coordinate System: Projection: Transverse Mercator; Datum: WGS84

4.2 SURVEY RESULTS

4.2.1 Survey summary

A total of 775 individual specimens in the SRE target groups (see 2.5.1) were identified from the study area, representing 40 individually-recognised taxa from seven orders, 19 families and at least22 genera (Appendix 3). Of these, collections from the seven SRE survey sites recovered a total of 725 individuals, the SRE opportunistic sites recovered 12 specimens and the vertebrate survey sites added a further 38 specimens in the SRE target groups (Appendix 3).

A total of eight taxa in at least eight genera from seven families and five orders comprising 92 individuals (11.9% of total catch) are considered to include species from the three SRE categories (Table 4-2).

Two taxa are considered confirmed SREs:

- the pseudoscorpion, *Troglochernes* sp. indet. (Chernetidae) (Figure 4-5c)
- the snail, *Rhagada* 'small banded' (Camaenidae) (Figure 4-10).

Three species represent likely SREs:

- the mouse spider, *Missulena* sp. indet. (Actinopodidae) (Figure 4-9)
- the slater, *Buddelundia* 'sp. 50' (Armadillidae) (Figure 4-5b)
- the slater, New Genus 'sp. 3' (Armadillidae) (Figure 4-5a).

A further three taxa are rated as potential SREs:

- the centipede family Chilenophilidae (Figure 4-5d)
- the centipede genus *Mecistocephalus* (Mecistocephalidae) (Figure 4-5f)
- the centipede, *Australoschendyla* cf. *capensis* (Schendylidae) (Figure 4-5e).

Four of these SREs are exclusively known from the study area and therefore deserve conservation consideration: the confirmed SRE pseudoscorpion *Troglochernes*, and the three likely SREs (*Missulena* mouse spider and the two slaters Buddelundia 'sp. 50' and New Genus 'sp. 3'). The confirmed SRE land snail *Rhagada* 'small banded' was not only found at almost all survey sites (Figure 4-6) but has also been identified to occur commonly outside the study area through the desktop review.

The taxonomy and therefore distribution patterns of the SRE centipedes of this survey are poorly resolved limiting a discussion of their conservation status. While Chilenophilidae sp. indet. and *Australoschendyla* cf. *capensis* were only found outside the proposed main pit area, *Mecistocephalus* sp. indet. was found on the edge of the proposed pit. However, this genus was identified in the desktop review and has been collected from near Paraburdoo and many other places throughout the Pilbara region. Given the current poor taxonomic knowledge of this group, no further comment can be made in relation to these taxa.

Table 4-2 Short-range endemic invertebrate taxa recorded during the Rocklea Iron Ore Project survey

Higher Taxon	Species	SRE status	Sites outside proposed pit	Sites in proposed pit (see Fig. 3-1)	Habitat
Mygalomorphae (trapdoor spiders)	*Missulena* sp. indet. (Actinopodidae)	Likely	5	-	Creekline
Pseudoscorpiones (pseudoscorpions)	*Troglochernes* sp. indet. (Chernetidae)	Confirmed	6	-	Creekline
Chilopoda (centipedes)	Chilenophilidae sp. indet. (Chilenophilidae)	Potential	3, 6	-	Creekline
	Mecistocephalus sp. indet. (Mecistocephalidae)	Potential	-	1	Rocky hill
	Australoschendyla cf. *capensis* (Schendylidae)	Potential	5	-	Creekline
Isopoda (slaters)	*Buddelundia* 'sp. 50' (Armadillidae)	Likely	2	-	Rocky hill
	New Genus 'sp. 3' (Armadillidae)	Likely	2, 4, 6	-	Rocky hill, creekline
Gastropoda (snails)	*Rhagada* 'small banded' (Camaenidae)	Confirmed	2, 4, vert1, vert7, vertopp4	1, 7, opp2, vert4-5, vertopp1,	Rocky hill

Figure 4-5 Short-range endemic invertebrates from the study area: a, New Genus 'sp. 3' (Armadillidae) from site 4; b, *Buddelundia* sp. '50' (Armadillidae) from site 2; c, *Troglochernes* sp. indet. (Chernetidae) from site 5; d, Chilenophilidae sp. indet. (Chilenophilidae) from site 3; e, *Australoschendyla* cf. *capensis* (Schendylidae) from site 5; f, *Mecistocephalus* sp. indet. from site 1.

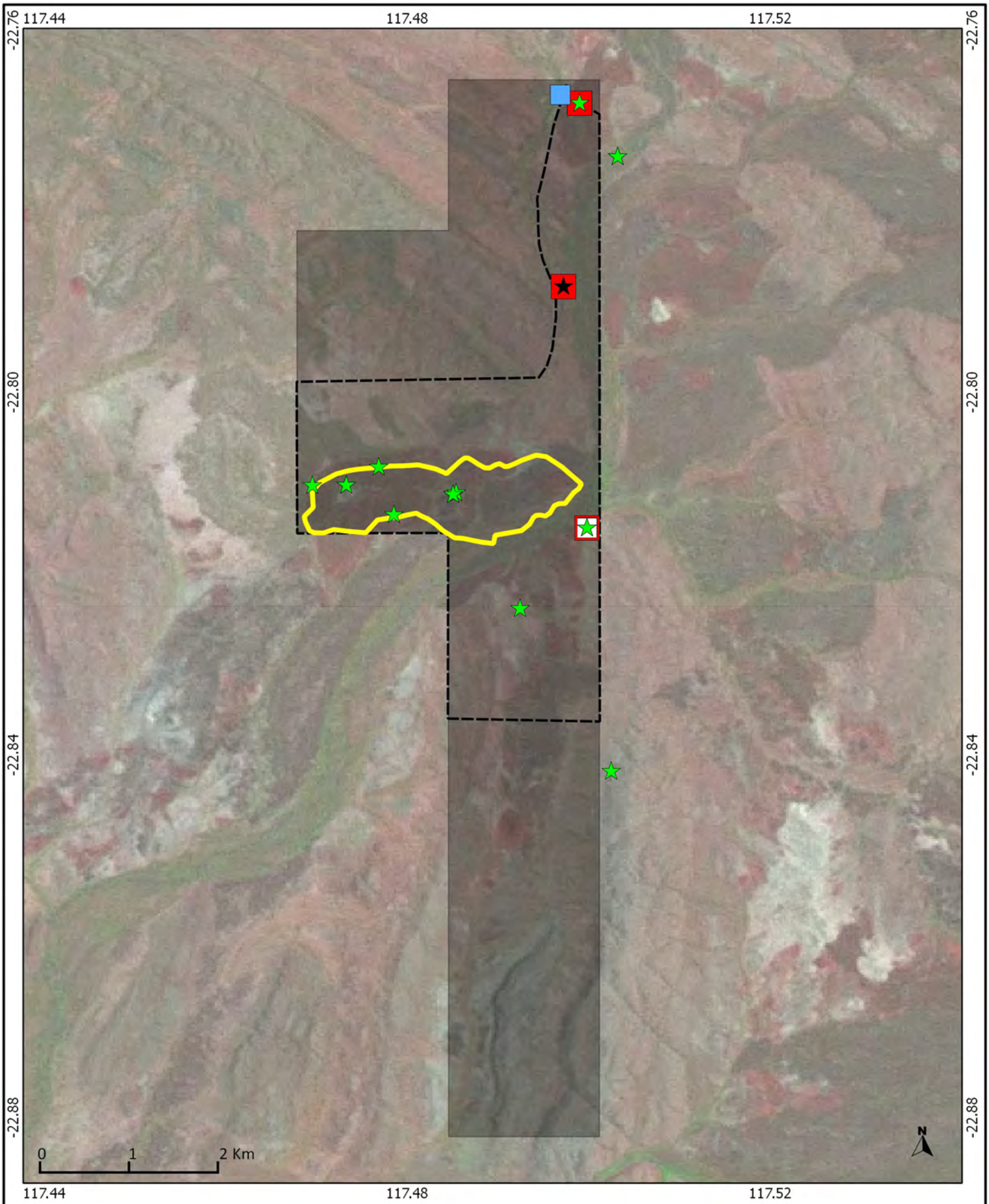

Figure 4-6: Confirmed (stars) and likely (squares) short-range endemic invertebrates recorded during the survey of the Rocklea Iron Ore Project

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DATE: February 2012	Scale: 1:45000
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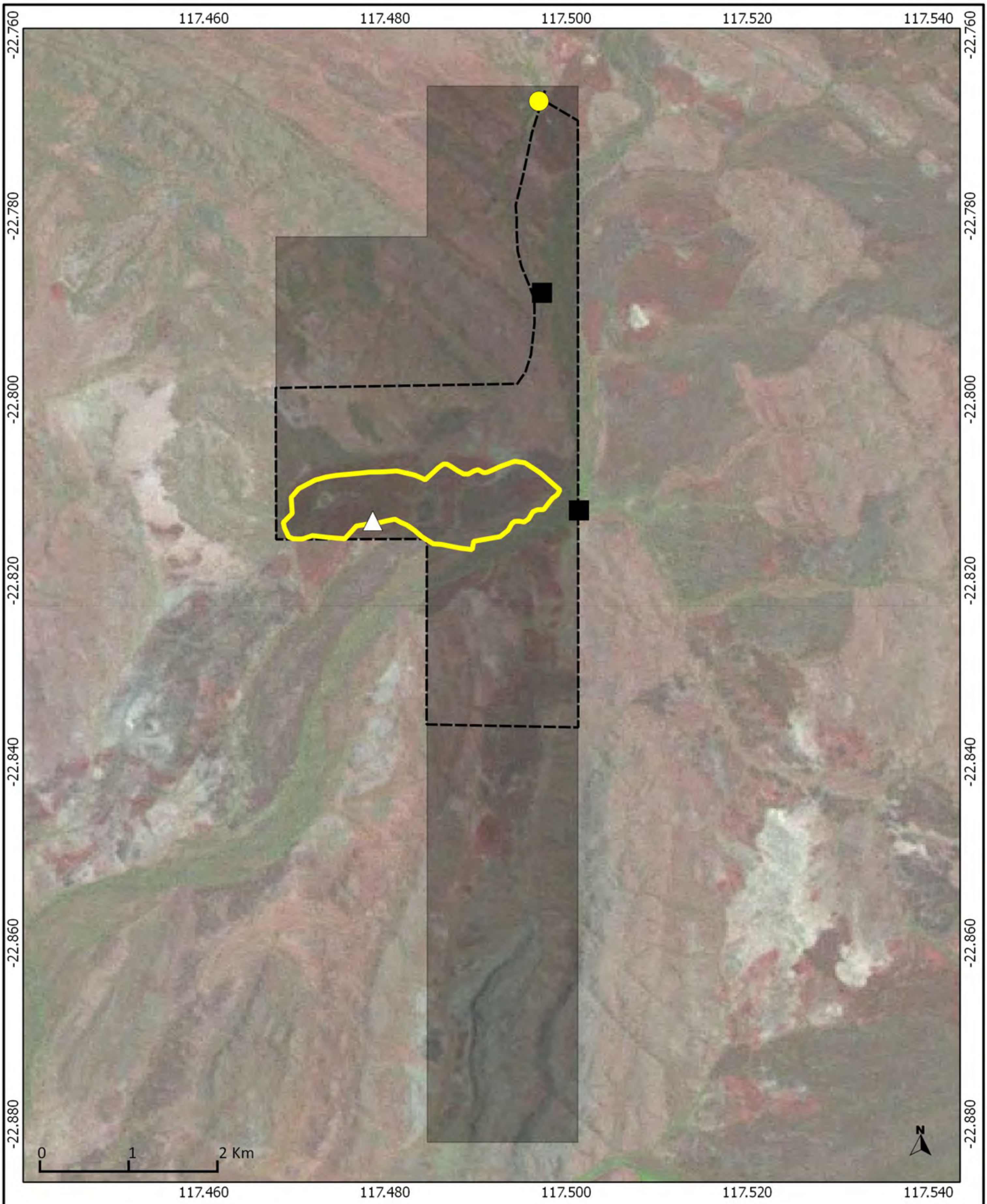
PROJECT: Rocklea Iron Ore Project

Proposed main pit
Study area
Tenement
New Genus 'sp. 3'
Buddelundia 'sp. 50'
Missulena sp. indet.
Rhagada 'small banded'
Troglochernes sp. indet.



Proposed main pit
Study area
Tenement

Australoschendyla cf. capensis
Chilenophilidae sp. indet.
Mecistocephalus sp. indet.

Figure 4-7
Potential short-range endemic species recorded during the survey of the Rocklea Iron Ore Project

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR: P.R. Langlands	CLIENT: Dragon Energy Ltd
DATE: February 2012	Scale: 1:45000

PROJECT: Rocklea Iron Ore Project

Coordinate System: Projection: Transverse Mercator; Datum: WGS84

4.3 SURVEY EFFECTIVENESS

The species accumulation data indicated that for slaters and snails a majority of species were collected (Table 4-3; Figure 4-8). In contrast, the survey may have missed approximately three to four species of pseudoscorpions, dependent on which estimator is used. However, it should be acknowledged that estimators generally underestimate 'true' species diversity and these should therefore be considered minimum species richness estimates.

Species estimation was not performed for mygalomorph spiders, scorpions or millipedes due to the small number of specimens collected. A minimum of 20 individuals is recommended for such estimates (Gotelli & Colwell 2001). Centipedes were not analysed due to a lack of taxonomic resolution.

Table 4-3 Survey data and species estimators (ACE, Chao1, Jack Knife1 rounded to nearest whole number) for short-range endemic target groups

Taxon[a]	Survey data				Species estimators		
	Number of individuals	Number of singletons per species	Number of doubletons per species	Number of species collected	ACE mean	Chao1 mean	Jack Knife1 mean
Pseudoscorpions	95	4	1	11	15	14	15
Slaters	242	0	1	9	9	9	13
Snails	410	0	0	8	8	8	9

[a] Mygalomorph spiders, Scorpions and Millipedes were not analysed due to a lack of specimens (< 20 individuals). Centipedes were not analysed due to lack of taxonomic resolution.

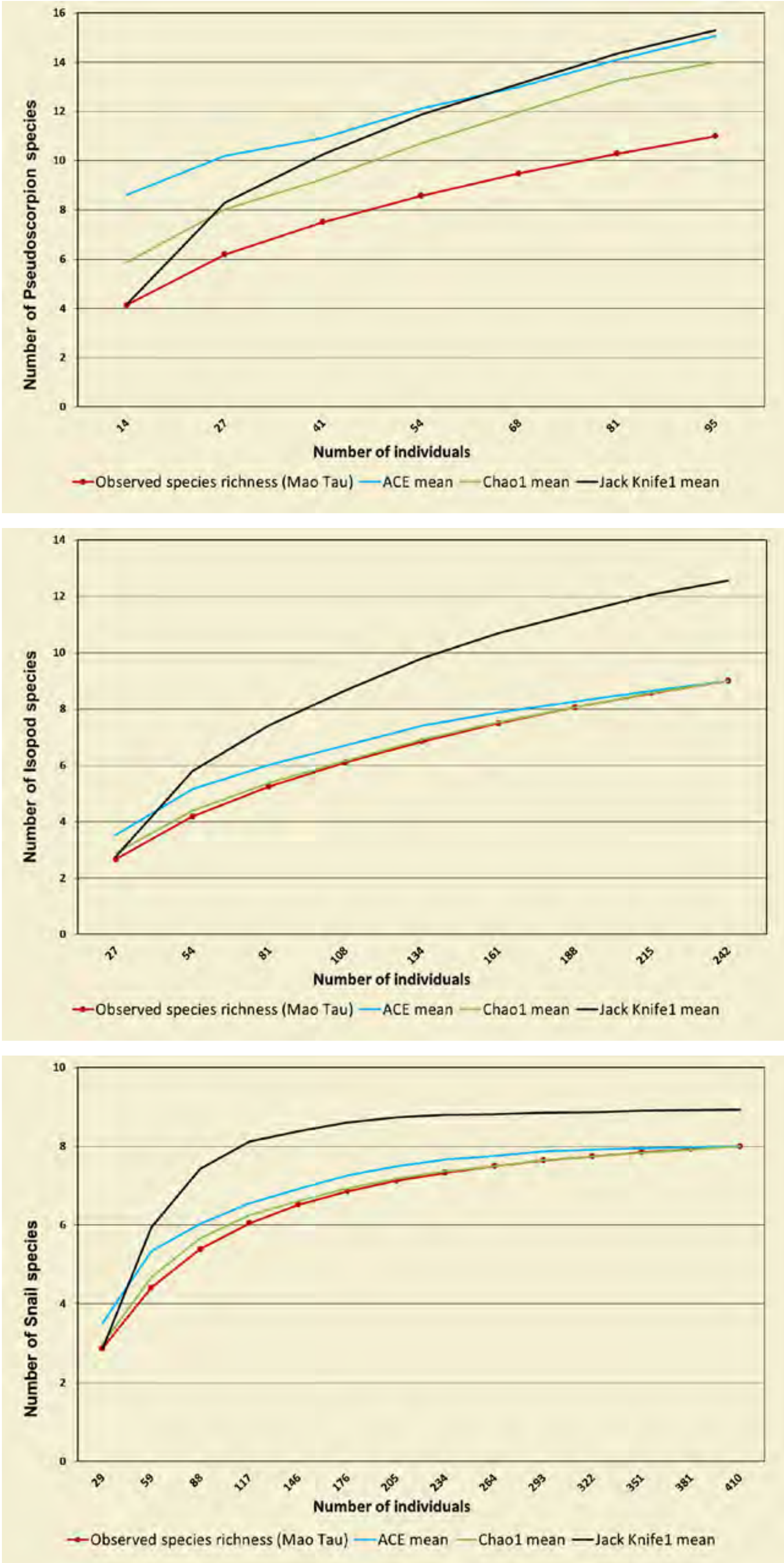


Figure 4-8 Individual based species accumulation curves, with observed species richness, as well as species estimators (ACE, Chao1 and Jack Knife1) for pseudoscorpions, slaters and snails

4.4 ARANEAE – MYGALOMORPHAE (TRAPDOOR SPIDERS)

Trapdoor spiders represent one of the focal groups in surveys of short-range endemic taxa (Harvey 2002). A number of mygalomorph spiders, e.g. *Idiosoma nigrum*, *Kwonkan eboracum* and *Moggridgea tingle* are listed on Schedule 1 of the *Wildlife Conservation (Specially Protected Fauna) Notice 2010(2)* (Western Australian Government 2010). The Western Australian mygalomorph fauna is vast and many families and genera remain taxonomically poorly known (e.g. Barychelidae: *Idiommata*; Idiopidae: *Aganippe*; Nemesiidae: *Aname*, *Chenistonia*, *Kwonkan*).

A total of two specimens of mygalomorph spiders representing two species in two genera and two families were recovered in the survey (Table 4-4). This low number of mygalomorph spiders does not allow for a statistical extrapolation of species richness in the survey area.

Only the juvenile *Missulena* belongs to one of the SRE categories within the mygalomorph spiders (Table 4-2; Table 4-4). In contrast *Aname* 'mellosa' (family Nemesiidae) belongs to one of the most commonly collected species of trapdoor spiders in the Pilbara region and also occurs into the Midwest region of WA (Harvey *et al.* submitted).

Table 4-4 Trapdoor spiders (Araneae: Mygalomorphae) collected during the short-range endemic survey of the Rocklea Iron Ore Project, by site

Taxon	Site 1[a]	Site 5	Sum
Actinopodidae			
Missulena sp. indet.[a]		1	**1**
Nemesiidae			
Aname 'mellosa'	1		**1**
Sum	**1**	**1**	**2**

[a] Site located in the proposed main pit area and species categorised as likely or potential short-range endemics are shaded grey.

4.4.1 Family Actinopodidae (Mouse Spiders)

The trapdoor spider family Actinopodidae, commonly known as Mouse Spiders, is only represented by the genus *Missulena* in Australia. Spiders within this family are medium to large spiders with an extremely raised head region and widely spaced eyes (in contrast to most other trapdoor spider families in which the eyes are grouped closely together) (Figure 4-9). Mouse spiders can be found in a variety of habitats from open-forest to semi-arid shrubland.

4.4.1.1 Genus *Missulena*

With the exception of a single species from Chile, the genus *Missulena* is restricted to the Australian mainland, where currently 10 species are described (Faulder 1995b). Western Australia is the centre of diversity for the genus with seven named species; however, many more undescribed species are present in the WA Museum morphospecies collection, in particular from the arid northern and central parts of the state.

Whilst females and juveniles are generally uniformly black or brown in colour (Figure 4-9), males are often strikingly coloured with a distinctly red cephalic area and chelicerae, contrasting against a black thoracic part and abdomen. The abdomen itself often has a velvety shine. The entrance of the burrow of *Missulena* is ovoid in shape and equipped with two neighbouring doors (Main 1956). Emergent juveniles of some *Missulena* species have been reported to disperse via ballooning (Faulder 1995a); however, this may only happen over a few metres, therefore limiting long-distance dispersal (R. J. Raven personal communication).

***Missulena* sp. indet.**

A single *Missulena* juvenile was found in the study area (Table 4-2; Table 4-4; Figure 4-9). Molecular identification showed that the specimen was not closely related to any other *Missulena* from the Pilbara that was sequenced (Table 4-5). The closest related specimen (divergence = 16.5%) was *Missulena* 'MYG003', found at Jinayri, approximately 190 km west of the study area. Other specimens from the Pilbara were more distantly related with CO1 divergence between 16.8–17.9 % (Table 4-5). Unfortunately there was no tissue available for those *Missulena* specimens recorded from the desktop review, i.e. those that are known from within 100 km of the study area (Table 4-1). Based on its distinct genetic sequence data and the known distribution of other Mouse Spiders in WA, the juvenile *Missulena* is considered a likely SRE.

Figure 4-9 Mouse Spider *Missulena* sp. indet. (juvenile) from site 5

Table 4-5 Percentage similarity of COI sequences for *Missulena* DNA barcoding

Location	Registration (WA Museum)	species	T97637	T118178	T97017	T112076	T62264	T91911	T91914	T113598	T99600	T102165	T113660	T113653	T113626	T95395
Mulga Downs	T97637	sp. indet. (fem.)	0													
Rocklea[a]	T118178	sp. indet. (juv.)	31.6	0												
Jinayri	T97017	\`MYG003\`	30.8	16.5	0											
Wonmunna	T112076	\`MYG044\`	28.3	17.3	16.9	0										
Roy Hill Station	T62264	sp. indet. (male)	28.7	18	17.1	14.1	0									
Area C	T91911	\`MYG044\`	28.5	17.5	16.9	8.7[b]	12.2	0								
Area C	T91914	\`MYG044\`	28.3	17.4	16.8	8.9	12.7	8.2	0							
Southern Flank	T113598	sp. indet. (male)	30.1	16.8	18	16.8	16.5	16.8	16.5	0						
Juna Downs	T99600	sp. indet. (fem.)	22.8	17.3	16.3	14.9	15.2	15.2	15	2.4[b]	0					
Davidson Creek	T102165	sp. indet. (fem.)	22.9	17.9	16.5	17	16.4	16.2	15.9	6.8	6.4	0				
119.1 km NW Newman	T113660	sp. indet. (juv.)	21.7	17.9	16.7	15.6	15.5	15.6	15.3	7.1	6.4	7.7	0			
110.6 km NW Newman	T113653	sp. indet. (juv.)	23.1	17.5	16.5	15.9	15.3	15.7	15.5	3.5	3.5	5.8	6.9	0		
113.8 km NW Newman	T113626	sp. indet. (juv.)	21.6	17.6	16.5	15.5	15.3	15.3	15.1	6.9	6.2	7.5	0.2	6.6	0	
Jimblebar	T95395	sp. indet. (fem.)	22.9	17.9	16.9	16.3	16.3	16.1	15.8	6.8	6.6	2.4	7.6	6	7.6	0

[a] The specimen from the study area is shaded in grey.

[b] Percentage sequence difference: 0.0–7.9% - green; 8.0–10.0 – blue; > 10.0% white. 8.0% divergence difference is here considered the threshold at the species level, see 4.4.1.1.

4.5 PSEUDOSCORPIONES (FALSE SCORPIONS OR PSEUDOSCORPIONS)

The Western Australian pseudoscorpion fauna is fairly diverse with representatives of 17 different families (M. Harvey personal communication). They are found in a variety of biotopes, but can be most commonly collected from the bark of trees, from the underside of rocks, or from leaf litter habitats (Harvey 1992).

A total of 95 specimens of pseudoscorpions representing at least eleven species in eight genera and four families were collected in the study area (Table 4-6). Species accumulation estimators suggest that between three to four species were missed during the survey (Table 4-3; Figure 4-8). This is not surprising because these animals are very small with cryptic biology. Most of the recognised morphospecies from the survey are considered widespread in the Pilbara region, although the taxonomy in most families is poorly resolved (e.g. Atemnidae, Olpiidae and Sternophoridae). A single specimen collected at site 6, a juvenile in the genus *Troglochernes* (Chernetidae) represents the only SRE of the collection.

4.5.1 Family Chernetidae

Chernetidae are the most diverse of all pseudoscorpion families with 113 named genera and 652 named species worldwide. The Australian fauna is quite extensive, with 37 described species (Harvey 2009). Chernetid pseudoscorpions are generally found under bark of trees and unlikely to include many SRE species.

4.5.1.1 Genus *Troglochernes*

Troglochernes currently contains six species in Australia and Papua New Guinea, of which two are known from WA: the type species *T. imitans* Beier, 1969 from caves on the Nullarbor Plain and *T. dewae* (Beier, 1967) from bird nests in NSW, Qld and WA (Harvey & Volschenk 2007).

***Troglochernes* sp. indet. (juv.)**

Troglochernes are often troglobitic and the record of a surface-dwelling species in a pitfall trap at site 6 (woodland along creekline) is noteworthy (Figure 4-6; Table 4-6). This new species probably inhabits leaf litter environments. *Troglochernes* are rarely collected in the Pilbara region and here only known from Mt Dove and Roy Hill Station (WA Museum database). Based on our current knowledge of the habitat preferences of *Troglochernes* species and the rarity of these pseudoscorpions in museum collections, the specimen from the survey area must be considered a confirmed SRE (M. S. Harvey personal communication).

Table 4-6 Pseudoscorpions (Pseudoscorpiones) collected during the short-range endemic survey of the Rocklea Iron Ore Project, by site

	Site 1[a]	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Sum
Atemnidae								
Oratemnus sp. indet.	1	1	5			1		**8**
Chernetidae								
Haplochernes sp. indet.						1		**1**
Troglochernes sp. indet.[a]						1		**1**
Olpiidae								
Austrohorus sp. indet.		2				2		**4**
Beierolpium '8/2'	7	6		2	1	13	3	**32**
Beierolpium '8/3'						1		**1**
Beierolpium '8/4'		1	1	1		2		**5**
Beierolpium '8/4 small'			1					**1**
Euryolpium sp. indet.		3						**3**
Indolpium sp. indet.	4	12	1	5		1	14	**37**
Sternophoridae								
Afrosternophorus sp. indet.			1			1		**2**
Sum	**12**	**25**	**9**	**8**	**1**	**23**	**17**	**95**

[a] Sites located in the proposed main pit area and species categorised as potential short-range endemics are shaded grey.

4.6 SCORPIONES (SCORPIONS)

Scorpions are characterised by the presence of chelate pedipalps, pectines and an elongate metasoma furnished with a sting. Scorpions are important components of arid ecosystems because their levels of diversity and abundance contribute significantly to the biomass of animal assemblages and they are important predators and prey for other species (Volschenk *et al.* 2010).

The DEC Pilbara Biological Survey recovered two families of scorpions, Buthidae and Urodacidae. The buthids were represented by two genera, *Lychas* (10 species) and *Isometroides* (2 species). The family Urodacidae was represented by 10 species in the single genus *Urodacus* (Volschenk *et al.* 2010). However, the regional scorpion fauna is clearly more diverse both at the species and the genus level, than was recorded in this comprehensive survey. For example, the urodacid genus *Aops* was recently described from Barrow Island (Volschenk & Prendini 2008) and has since also be found on the mainland in the Pilbara, including at a site within the desktop review .

The SRE survey of the study area recovered three species of scorpions in the Buthidae (Table 4-7). There were insufficient specimens to provide meaningful estimations of the potential total number of scorpions present in the area.

None of the species collected are currently considered SREs. For example, *Lychas bituberculatus* has been recorded widely throughout the Midwest, Pilbara and Kimberley regions and *Lychas* 'multipunctatus' has been found throughout the Pilbara, where it is one of the most common scorpion species.

In contrast, the desktop review recovered a record of a juvenile in the genus *Urodacus* from the study area, which is here considered a potential SRE.

Table 4-7 Scorpions (Scorpiones) collected during the short-range endemic survey of the Rocklea Iron Ore Project, by site

Taxon	Site 5	Site 7[a]	Site Vert1	Sum
Buthidae				
Lychas bituberculatus Pocock, 1891	4	1		**5**
Lychas 'multipunctatus'			3	**3**
Lychas 'pilbara1'			1	**1**
Sum	**4**	**1**	**4**	**9**

[a] Site located in the proposed main pit area is shaded grey.

4.6.1 Family Urodacidae

The family Urodacidae is endemic to Australia (Fet 2000; Prendini 2003; Volschenk *et al.* 2000) where it is represented by the genera *Urodacus* Peters, 1861 and *Aops* Volschenk and Prendini, 2008.

4.6.1.1 Genus *Urodacus*

Urodacus has been considered a member of the family Scorpionoidea for many years, but in a revision of the superfamily Scorpionoidea, Prendini (2000) placed *Urodacus* in its own family. Unlike the species designations for Buthidae, Koch's (1977) species of *Urodacus* have been mostly supported by subsequent authors (Harvey & Volschenk 2002; Volschenk & Prendini 2008; Volschenk *et al.* 2000). The biggest issue confronting *Urodacus* taxonomy is the number of undescribed species being uncovered through current revisionary work (E. S. Volschenk unpublished data). Currently 22 species of *Urodacus* are described; however, this may represent as little as 20% of the real diversity of this genus in Australia. *Urodacus* appears to be most diverse in Western Australia and few species are recorded east of the Great Dividing Range in eastern Australia. *Urodacus* contains both widespread and SRE species. During a large-scale survey of the Pilbara fauna, Volschenk *et. al.* (2010) recorded nine undescribed species and only one formerly describes species were reported in that study.

***Urodacus* sp. indet. (juv.)**

No *Urodacus* scorpion was found during the survey at Rocklea, but the database search of the WA Museum recovered a record of a juvenile specimen from the study area (Table 4-1; Figure 4-2). It is not possible to identify immature *Urodacus* to species level. Based on the occurrence of range-restricted species in the Pilbara (some of which were identified in the desktop review), *Urodacus* sp. indet. (juv.) is considered a potential SRE.

4.7 CHILOPODA (CENTIPEDES)

The centipedes represent a diverse group of predatory arthropods. Each pair of legs is attached to a separate body segment which distinguishes this class from the millipedes (Diplopoda; two pairs of legs per segment) (Colloff *et al.* 2005). Adult body length ranges from 4 to 300 mm, with most species measuring 10 to 100 mm long. In most cases, they feed on small live arthropods and other invertebrates, although large scolopendrids can take vertebrate prey (Edgecombe & Giribet 2007).

All five orders of centipedes can be found in Australia, of which one, the Craterostigmorpha, only occurs in Tasmania and New Zealand (Colloff *et al.* 2005). Scolopendromorpha and Scutigeromorpha (house centipedes) are the most commonly encountered centipedes in WA. Most species are very fast runners and are highly mobile and therefore, widespread (e. g. Edgecombe & Barrow 2007; Edgecombe & Giribet 2009; Koch 1982, 1983a, b, c). Therefore, they are not considered target groups for SRE surveys.

In contrast, Geophilomorpha, Lithobiomorpha and the Cryptopidae (within the Scolopendromorpha) may include Gondwanan refugial SREs based on the habitat preference for moist and deep leaf litter. Geophilomorpha and Cryptopidae have been found in subterranean environments in the Pilbara where they are limited to very small ranges (e. g. Edgecombe 2005).

4.7.1 Geophilomorpha

Nine specimens of geophilomorphan centipedes in at least four families were collected in the study area (Figure 4-3; Table 4-8). The taxonomy of these groups is poorly resolved and, with the exception of *Australoschendyla* cf. *capensis* (see below), it is currently not possible to further comment on their distribution and conservation status, other than that three of these are potential SREs. The single described species, *Orphnaeus brevilabiatus*, is cosmopolitan and possibly introduced to Australia and not uncommon in WA (DSEWPC).

Australoschendyla* cf. *capensis

The schendylid centipede *Australoschendyla capensis* is currently known only from a single locality at Cape Range, approx. 360 km to the west of the study area (Jones 1996). The survey recovered a very similar species that may be conspecific, but this cannot be established with certainty until more specimens are collected to enable an assessment of intraspecific variation, in particular in the area between the currently known locations. Currently, the *Australoschendyla* from Rocklea is considered a different species to the Cape Range species, designated ‘cf.’ (= close form). It is considered a potential SRE.

Table 4-8 Centipedes (Chilopoda) collected during the short-range endemic survey of the Rocklea Iron Ore Project, by site

Taxon	Site 1[a]	Site 2	Site 3	Site 5	site6	Sum
Chilenophilidae						
Chilenophilidae sp. indet.[a]			1		1	**2**
Mecistocephalidae						
Mecistocephalus sp. indet.	4					**4**
Oryidae						
Orphnaeus brevilabiatus (Newport, 1845)	1	1				**2**
Schendylidae						
Australoschendyla cf. *capensis*				1		**1**
Sum	**5**	**1**	**1**	**1**	**1**	**9**

[a] Site located in the proposed main pit area and species categorised as potential short-range endemics are shaded grey.

4.8 DIPLOPODA (MILLIPEDES)

The Australian millipedes are poorly studied and biogeographic patterns remain largely unresolved (Black 1997; Shelley & Golovatch 2011). At least eight orders of millipedes are native to Australia; all species in the order Julida are introduced (Mesibov 2006). Millipedes belong to one of the main target groups of SRE surveys. Short-range endemism is particularly common within the orders Sphaerotheriida (rolling millipedes), Polydesmida, and Chordeumatida (not known from WA) (EPA 2009; Harvey 2002). A recent review of Australian *Atelomastix* (order Spirostreptida) found almost all of the 29 species treated were SREs (Edward & Harvey 2010).

The SRE survey of the Rocklea Iron Ore Project found four specimens of millipedes, all in the order Spirobolida. Although some of these could not be identified beyond order level, it appears that they all belong to the common species *Austrostrophus stictopygus* (family Trigoniulidae) (Table 4-9, Appendix 3). This species was initially thought to have restricted distributions, but intensive collections of invertebrates as part of environmental assessment studies in the Pilbara have shown it to be a wide-spread species in the region (Harvey *et al.* 2011; Hoffman 2003). Species estimations were not performed due to the small number of specimens.

Table 4-9 Millipedes (Diplopoda) collected during the short-range endemic survey of the Rocklea Iron Ore Project, by site

Taxon	Site 2	Site 4	Site 7[a]	Sum
Pachybolidae				
Austrostrophus stictopygus Hoffman, 2003			1	**1**
Spirobolida				
Spirobolida sp. indet.	1	1	1	**3**
Sum	**1**	**1**	**2**	**4**

[a] Site located in the proposed main pit area is shaded grey.

4.9 ISOPODA (SLATERS)

Almost 200 described species of Oniscidea, a suborder of the Isopoda containing the supralittoral, terrestrial and secondarily aquatic slaters (or woodlice), have been recorded from Australia (DSEWPC 2010). The WA fauna is comparatively poorly known with many undescribed species (Judd

& Horwitz 2003). Slaters are an ideal biological model for faunistic and biogeographical studies, due to their reduced dispersal ability and narrow habitat preferences (e.g. Taiti & Argano 2009).

A total of 244 specimens representing at least nine species in three genera and two families were collected in the study area (Table 4-10). The accumulation curve (Jack Knife1) suggests that two additional species might have been present at the time of sampling (Figure 4-8). Most of the species collected, in particular those of the genus *Buddelundia*, are widespread in the Pilbara region and beyond (S. Judd personal communication). Two of the species from the study area are considered likely or potential SRE respectively (Table 4-10).

Table 4-10 Slaters (Isopoda) collected during the short-range endemic survey of the Rocklea Iron Ore Project, by site

Taxon	Site 1[a]	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Opp1	Vert7	Sum
Armadillidae										
Buddelundia 'sp. 13'	5	5		1	5	1	15			**32**
Buddelundia 'sp. 14'							47			**47**
Buddelundia 'sp. 15'					13	14				**27**
Buddelundia 'sp. 16'	21	9	11		5	30		4	1	**81**
Buddelundia 'sp. 19'					1	5				**6**
Buddelundia 'sp. 20'		2								**2**
Buddelundia 'sp. 50'[a]		27								**27**
New Genus 'sp. 3'		1		3		1				**5**
Armadillidae indet.							2			**2**
Philosciidae										
Philosciidae indet.			15							**15**
Sum	**26**	**44**	**26**	**4**	**24**	**51**	**64**	**4**	**1**	**244**

[a] Sites located in the proposed main pit area and species categorised as likely or potential short-range endemics are shaded grey.

4.9.1 Family Armadillidae

Armadillidae typically have a convex dorsal surface and the animal can roll up into a ball. The family is diverse in Australia, currently 24 genera are described; many species live in litter or under wood and stones in forest or woodland or near the coast (Green *et al.* 2010).

4.9.1.1 Genus *Buddelundia*

Members of the genus *Buddelundia* belong to the most common terrestrial isopods in WA and the genus was well represented in the study area at Rocklea. The genus is currently under taxonomic revision by S. Judd. Species of *Buddelundia* often have a very wide distribution and are not expected to have many SRE species (S. Judd personal communication). For example, the most common species from our survey, *Buddelundia* 'sp. 13' and *Buddelundia* 'sp. 16.' are very widespread throughout the Pilbara region (S. Judd personal communication).

***Buddelundia* 'sp. 50'**

Buddelundia 'sp. 50' is only tentatively included in *Buddelundia*; probably all species of this group represent a new genus (Figure 4-5; Table 4-10). *Buddelundia* 'sp. 50' has been recorded only once before at the Turee Syncline approximately 50 km south of the study area (S. Judd personal communication). Based on the currently known distribution within a comparatively well studied region, *Buddelundia* 'sp. 50' is considered a likely SRE.

4.9.1.2 New Genus

This new genus is considered intermediate between *Barrowdillo* and *Buddelundia* and all species within this genus are believed to be SREs (S. Judd personal communication). Species in this group are generally found in small numbers which compromises a judgement of intra- versus interspecific variation.

New Genus 'sp. 3'

The specimens from Rocklea are notable for their relatively large size and distinctive pattern in their dorsal ornamentation, which may be markedly more pronounced in juvenile specimens. The species from Rocklea is currently only known from the north of the study area and therefore New Genus 'sp. 3' is considered a likely SRE (Figure 4-6; Table 4-10).

4.10 MOLLUSCA (SNAILS)

Molluscs are one of the most diverse groups of invertebrates and the Australian fauna is characterised by a high degree of endemism (Beesley *et al.* 1998). Lands snails belong to the target groups for SRE surveys due to their limited dispersal capabilities, in combination with often strict dependencies on particular soils (EPA 2009; Harvey 2002). These characteristics have also resulted in a significant global decline of non-marine molluscs (Lydeard *et al.* 2004).

The 412 specimens contained in the survey samples belong to eight species in at least six genera in the pulmonate families Camaenidae, Helicodiscidae, Planorbidae, Pupillidae, Subulinidae (Figure 4-6; Table 4-11). Species estimators suggest that all species present during the survey, except possibly one, were recovered (Table 4-3).

Table 4-11 Land snails (Gastropoda) collected during the short-range endemic survey of the Rocklea Iron Ore Project, by site

Taxon	Site 1[a]	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7[a]	Site Opp2[a]	Site Vert1	Site Vert4[a]	Site Vert5[a]	Site Vert7	Site Vert Opp1[a]	Site Vert Opp4	Sum
Camaenidae															
Rhagada 'small banded'[a]	2	5		1			2	8	1	3	2	8	16	3	**51**
Helicodiscidae															
Stenopylis coarctata			7		1	8									**16**
Planorbidae															
Gyraulus sp. indet.			4												**4**
Pupillidae															
Gastrocopta larapinta		3	10		2	2									**17**
Gastrocopta mussoni	1	54	17	4	2	9	36								**123**
Pupoides beltianus	1	1	11	3	6	2	120								**144**
Pupoides pacificus	1	9	23			2	17								**52**
Pupillidae indet.		1		1											**2**
Subulinidae															
Eremopeas interioris			1			2									**3**
Sum	**5**	**73**	**74**	**9**	**11**	**24**	**175**	**8**	**1**	**3**	**2**	**8**	**16**	**3**	**412**

[a]Sites located in the proposed main pit area and species categorised as potential SREs are shaded grey.

Most of the species are known to be widespread. For example, the known distribution of *Pupoides beltianus* ranges from the Northern Territory and South Australia in the east to Barrow Island in the west, and similar ranges are reported for *Gastrocopta mussoni* Pilsbry, 1917 and *Gastrocopta larapinta* (Tate, 1896) (Whisson 2012). A single snail species collected in the survey is considered to be a potential SRE, the camaenid *Rhagada* 'small banded' (Table 4-11; Figure 4-5).

4.10.1Camaenidae

The Camaenidae is one of the most diverse land snail families in Australia both in species richness and morphology. Shell diameter ranges between 5 to 70 mm and shell shapes vary from discoidal and lenticular to globose, trochoidal, conical and elongate (Stanisic *et al.* 2010). The family is found Australia-wide with the exception of Tasmania and south-west WA (Stanisic *et al.* 2010).

In northern WA, the Camaenidae are the dominant group of land snails, with greatest diversity in the Kimberley region, where 19 of the 25 camaenid genera include SREs (Harvey *et al.* 2011; Solem 1997). In the Ningbing Ranges east of Kununurra, for example, the median geographical range of the 26 species occupying the area is less than one square-kilometre (Cameron 1992). Many of these ranges are shrinking, due to grazing and fire (Solem 1997) which resulted in the listing of 31 camaenid species under the *Wildlife Conservation Act 1950* (Western Australian Government 2010).

Based on the latest taxonomic revision, the Pilbara camaenid fauna comprised 27 species from six genera, distributed in latitude between Port Hedland and Cape Range, with no evidence of sympatry between congeneric species (Solem 1997). However, recent targeted sampling of camaenid land snails in the region has shown that many forms are parapatric, allowing direct genetic tests of reproductive isolation. This has revealed that some species have broader distributions than formerly thought, while other described species are actually complexes of multiple species, some with very narrow distributions. The molecular analyses have also shown the unreliability of shell characteristics on their own for assessing species taxonomy in many of these snails (Harvey *et al.* 2011).

4.10.1.1 Genus *Rhagada*

The genus *Rhagada* is endemic to WA and, with 29 species, the second most diverse genus of the Camaenidae in the state (Johnson *et al.* 2004; Solem 1997). Solem (1997) has reported 18 species from the northern tip of Dampier Land through Bernier Island, Shark Bay.

As in other camaenid land snails in northern WA, recent molecular studies have revealed that there are taxonomic uncertainties when species are assessed based on morphology alone (Harvey *et al.* 2011). For example, detailed molecular and morphological analyses have shown continuity among morphologically diverse forms of *Rhagada* on Rosemary Island (Dampier Archipelago), suggesting that they represent a single species (Harvey *et al.* 2011). In contrast, other populations of *Rhagada* from the central Pilbara with no apparent morphological differences are highly divergent lineages.

***Rhagada* 'small banded'**

The specimens collected during this survey belong to an undescribed banded form of *Rhagada* that is known from the Mt Brockman and Tom Price areas (Whisson 2012); (Figure 4-10; Table 4-1). This species is possibly the same that was reported from the Brockman 4 Syncline by Biota (2005) (C. Whisson personal communication). Solem (1997) recorded a single, variable and widespread species, *Rhagada radleyi*, within this area. However, the survey specimens clearly differ in size (smaller) and umbilicus (widely open) from those of typical smaller *R. radleyi* specimens. Therefore, this undescribed banded form of *Rhagada* is considered an SRE in lack of evidence against its species status (Whisson 2012).

Figure 4-10 ***Rhagada*** **'small banded' (family Camaenidae) from site Vert7.**

5 DISCUSSION

The survey of the study area at Rocklea recovered eight potentially range-restricted species (confirmed, likely or potential SREs) in addition to the juvenile *Urodacus* scorpion that was identified from the study area through the WA Museum database search. Four of these, the mouse spider *Missulena* sp. indet., the pseudoscorpion *Troglochernes* sp. indet. and two species of slaters, *Buddelundia* 'sp. 50' and New Genus 'sp. 3' warrant conservation consideration within the Project, as they are currently known only from the study area at Rocklea.

These four species are all known from the vicinity of the Hardey River or its tributaries along the northern and eastern border of the study area. They appear to be restricted to creekline habitats, with the exception of the slater New Genus 'sp. 3', that has also been collected on a rocky hill. Although low capture rates do not allow a statistically meaningful habitat analysis, it appears that all species inhabit woodlands along the river. This habitat was initially identified as most prospective for the occurrence of SREs. None of the four 'study area endemics' were found in the footprint of the proposed main pit.

The survey confirmed the faunistic importance of the Hardey River and its woodlands as refuge for potentially range-restricted invertebrates and impacts to these habitats should be avoided and/or minimised as far as practicable. Hydrological connectivity should be maintained as much as possible as the river is assumed to present a corridor for the migration and dispersal of some of the SREs present. For example, the mouse spider *Missulena* may be restricted to riparian habitats similar to other species in the genus in other areas of the Pilbara, e.g. *Missulena* 'MYG044' along Weeli Wolli Creek (WA Museum database). The role of the riparian woodland along the Hardey River as important fauna habitat appears to persist despite heavy impact by grazing and the introduction of invasive weeds, such as Buffel Grass.

The collection of a pseudoscorpion in the genus *Troglochernes* is noteworthy. The genus was previously known from only two localities in the Pilbara, Mt Dove (approx. 220 km NE of Rocklea) and Roy Hill Station (approx. 250 km W) (WA Museum database). Based on their cryptic biology it is unlikely that these records represent the same species.

The two isopod species have also not been reported from outside the study area. This is not surprising as the knowledge of slaters in the Pilbara region is poor and may be an artefact of poor sampling density. Specifically, the isopod material from the DEC Pilbara Biological Survey (McKenzie *et al.* 2009) has not been analysed (S. Judd personal communication) in contrast to other groups such as spiders and scorpions (Durrant *et al.* 2010; Volschenk *et al.* 2010), and therefore the desktop review returned only a few unidentified records of the group.

Whilst considered a confirmed SRE, i.e. the known distribution is smaller than that nominally given by Harvey (2002), the land snail *Rhagada* 'small banded' is common throughout and beyond the study area and the proposed mining development at Rocklea is not expected to impact on the species as a whole. Due to their unresolved taxonomy, the distribution of the three centipede taxa, Chilenophilidae, *Mecistocephalus* and *Australoschendyla* cf. *capensis*, all considered potential SREs, cannot be determined and it is impossible to comment on their conservation status. Likewise, the juvenile *Urodacus* scorpion cannot be identified further.

It is desirable to increase the knowledge on the taxonomy and distribution of many of the SRE target groups in WA to inform proponents of the impact of their developments on these species. The molecular identification of the *Missulena* juvenile forms part of research programs currently developed between research staff at the School of Animal Biology (University of Western Australia), the Queensland Museum and Phoenix. This project will be designed to establish the ranges of most species of *Missulena* in the Pilbara, including that of the juvenile *Missulena* from survey site 5. The genetic COI sequence derived for this specimen of *Missulena* will allow its wider distribution to be established when further collections of these spiders are available in the vicinity of Rocklea.

5.1 RECOMMENDATIONS FOR MANAGEMENT

One of the survey objectives and scope of works was the assessment of potential impacts on fauna and advice on management and mitigation of these impacts. The recommendations for an impact management may either be driven by the presence of single conservation significant species, such as *Missulena* sp. indet. and *Troglochernes* sp. indet. and/or based on habitats or specific sites with a high number of confirmed, likely or potential SREs. As all conservation significant SREs at Rocklea were predominantly found in the same habitat along the Hardey River and its tributaries, taxon-specific and habitat-specific recommendations for management and mitigation are here presented together.

To avoid impacts on the SRE invertebrates currently only known from the study area, it is recommended:

- to create an environmental buffer along the Hardey River and avoid any disturbance within this buffer to protect the woodland habitats along river and maintain its connectivity as a potential migration route for invertebrate fauna. A 300 m wide corridor along the river and its northern tributary (where the *Missulena* mouse spider was found) is considered sufficient to maintain ecological functionality of the river (Figure 5-1). Impact by the intersecting proposed main pit should be minimised and any mining infrastructure should be constructed outside this buffer (for example to the north of the proposed main pit where no habitat for SREs was identified). To implement this buffer, the following measures are recommended:
    - signpost the environmental buffer in appropriate intervals to avoid accidental disturbance
    - staff and contractor education on the value of the environmental buffer
    - create some exclusion zones for cattle along the Hardey River
    - avoid waste disposal into the river
- to further mitigate any long-term effects of the mining operation on the creekline habitat (e.g. excessive dust) by sealing tracks or implementing dust management measures.

Additional measurements that can support the conservation of SRE taxa are:

- Support research into the taxonomy and systematics of SREs
- Reduce livestock grazing levels or protect river areas from cattle (although it is recognised that this is not the responsibility of the Client).

In summary, four SRE invertebrates identified in this survey are currently solely known from the study area and these were mainly recorded from woodlands along the Hardey River and a major tributary in the north. An environmental exclusion buffer along the Hardey River is recommended to protect its ecological functionality, in particular to provide habitat for SREs and a migration route for their dispersal.

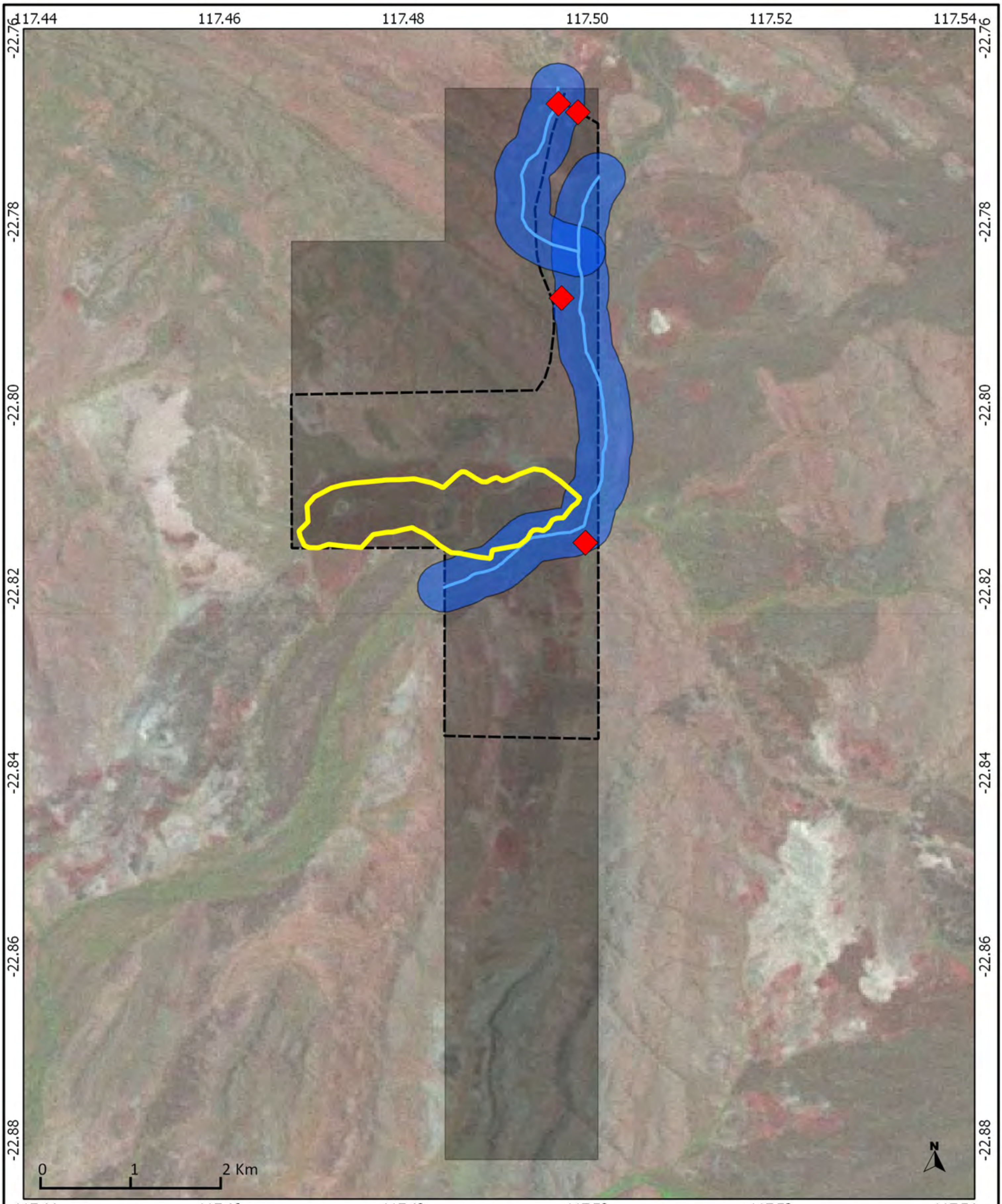


Figure 5-1: Recommended 300 m environmental buffer along the Hardey River and tributary, with indication of sites where short-range endemics were collected that are currently only known from the study area

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AUTHOR: P.R. Langlands	CLIENT: Dragon Energy Ltd
DATE: February 2012	Scale: 1:45000
PROJECT: Rocklea Iron Ore Project	
Coordinate System: Projection: Transverse Mercator; Datum: WGS84	

Proposed main pit
Short-range endemics
Hardey River
Hardey River buffer 300 m
Tenement
Study area

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APPENDIX 1 SITE DESCRIPTIONS

Site number: 1

Coordinates (WGS84): -22.813402 S 117.478695 E; UTM, 7477057 N, 549125 E, Zone 50K

Impact area: Yes

Habitat

Type: Rocky hill

Geography: topography, midslope; slope, moderate; slope direction, S

Vegetation: tree count within 10 m, 6; dominant tree, *Eucalyptus*; shrub count within 10 m, 30; herb count within 10 m, 20; dominant grass, spinifex

Soil: texture, sand; colour, brown; surface type, fine gravel, coarse gravel, stones/boulders

Rockiness: rock abundance, continuous >90% cover; rock type/s, ferrous: other than BIF

Litter: leaf litter distribution, sparse; leaf litter depth, <1 cm; wood litter distribution, sparse

Disturbance and fire: weeds, not evident; fire history, 10–15; other disturbance/s, none evident

Site number: 2

Coordinates (WGS84): -22.814858 S 117.499969 E; UTM, 7476888 N, 551308 E, Zone 50K

Impact area: No

Habitat

Type: Rocky hill

Geography: topography, midslope; slope, moderate; slope direction, SW

Vegetation: tree count within 10 m, 9; dominant tree, mulga; shrub count within 10 m, 9; herb count within 10 m, 9; dominant grass, Spinifex

Soil: texture, sand; colour, Red-brown; surface type, fine gravel, coarse gravel

Rockiness: rock abundance, continuous >90% cover; rock type/s, ferrous: other than BIF

Litter: leaf litter distribution, sparse; leaf litter depth, <1cm; wood litter distribution, sparse

Disturbance and fire: weeds, not evident; fire history, 20+; other disturbance/s, livestock tracks; livestock dung

Site number: 3

Coordinates (WGS84): -22.812247 S 117.501462 E; UTM, 7477177 N, 551462 E, Zone 50K

Impact area: No

__Habitat__

Type: Creekline

Geography: topography, plain; slope, negligible; slope direction, S

Vegetation: tree count within 10 m, 7; dominant tree, *Eucalyptus*; shrub count within 10 m, 28; herb count within 10 m, 5; dominant grass, buffel grass

Soil: texture, sandy clay; colour, brown; surface type, coarse gravel, loose soil

Rockiness: rock abundance, common: 30–50% cover; rock type/s, ferrous: other than BIF

Litter: leaf litter distribution, concentrated in drifts; leaf litter depth, 1–5cm; wood litter distribution, sparse

Disturbance and fire: weeds, common; fire history, 20+; other disturbance/s, major erosion channels; livestock tracks; livestock dung; surface dust from livestock

Site number: 4

Coordinates (WGS84): -22.76798 S 117.499156 E; UTM, 7482078 N, 551242 E, Zone 50K

Impact area: Yes

Habitat

Type: Rocky hill

Geography: topography, ridgetop; slope, negligible

Vegetation: tree count within 10 m, 10; dominant tree, mulga; shrub count within 10 m, 45; herb count within 10 m, 3; dominant grass, spinifex

Soil: texture, sand; colour, red-orange; surface type, fine gravel, coarse gravel

Rockiness: rock abundance, continuous >90% cover; rock type/s, ferrous: other than BIF

Litter: leaf litter distribution, sparse; leaf litter depth, 1–5cm; wood litter distribution, widespread

Disturbance and fire: weeds, not evident; fire history, 20+; other disturbance/s, livestock tracks; livestock dung

Site number: 5

Coordinates (WGS84): -22.767044 S 117.497034 E; UTM, 7482182 N, 551024 E, Zone 50K

Impact area: No

__Habitat__

Type: Creekline

Geography: topography, gully base; slope, negligible

Vegetation: tree count within 10 m, 30; dominant tree, mulga; shrub count within 10 m, 4; herb count within 10 m, 0; dominant grass, buffel grass

Soil: texture, sandy clay; colour, red-brown; surface type, coarse gravel, loose soil

Rockiness: rock abundance, few: 5–30% cover; rock type/s, mudstone; quartz

Litter: leaf litter distribution, concentrated in drifts; leaf litter depth, 1–5 cm; wood litter distribution, widespread

Disturbance and fire: weeds, common; fire history, 20+; other disturbance/s, major erosion channels; livestock tracks; livestock dung; surface dust from livestock

Site number: 6

Coordinates (WGS84): -22.788216 S 117.497384 E; UTM, 7479839 N, 551052 E, Zone 50K

Impact area: No

Habitat

Type: Creekline

Geography: topography, plain; slope, negligible

Vegetation: tree count within 10 m, 12; dominant tree, *Eucalyptus*; shrub count within 10 m, 1; herb count within 10 m, 0; dominant grass, buffel grass

Soil: texture, sandy clay; colour, red-brown; surface type, coarse gravel; loose soil

Rockiness: rock abundance, negligible <5% cover; rock type/s, mudstone; quartz

Litter: leaf litter distribution, concentrated in drifts; leaf litter depth, <1 cm; wood litter distribution, sparse

Disturbance and fire: weeds, abundant; fire history, 20+; other disturbance/s, minor erosion channels; livestock tracks; livestock dung

Site number: 7

Coordinates (WGS84): -22.810148 S 117.473454 E; UTM, 7477419 N, 548588 E, Zone 50K

Impact area: Yes

Habitat

Type: Rocky hill

Geography: topography, midslope; slope, gentle; slope direction, E

Vegetation: tree count within 10 m, 5; dominant tree, *Acacia* (not mulga); shrub count within 10 m, 10; herb count within 10 m, 5; dominant grass, spinifex

Soil: texture, sandy clay; colour, yellow-brown; surface type, coarse gravel, loose soil

Rockiness: rock abundance, many: 50–90% cover; rock type/s, calcrete, chirt

Litter: leaf litter distribution, concentrated under shrubs/trees; leaf litter depth, 1–5 cm; wood litter distribution, sparse

Disturbance and fire: weeds, not evident; fire history, 10–15; other disturbance/s, livestock dung

APPENDIX 2 DESKTOP REVIEW: SHORT-RANGE ENDEMIC INVERTEBRATES

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude	Longitude
Araneae (spiders)							
100065	Araneae	Actinopodidae	*Missulena*	`MYG045?`	Nammuldi-Silvergrass, NW of Tom Price	-22.308610	117.231700
94/1402	Araneae	Actinopodidae	*Missulena*	`*occatoria* group`	Tom Price	-22.7000	117.7833
94/650	Araneae	Actinopodidae	*Missulena*	`*occatoria* group`	Marandoo Minesite	-22.6166	118.1333
94/395	Araneae	Actinopodidae	*Missulena*	`*occatoria* group`	Marandoo	-22.6166	118.1333
94/396	Araneae	Actinopodidae	*Missulena*	`*occatoria* group`	Marandoo	-22.6166	118.1333
94/393	Araneae	Actinopodidae	*Missulena*	`*occatoria* group`	Marandoo	-22.6166	118.1333
94/394	Araneae	Actinopodidae	*Missulena*	`*occatoria* group`	Marandoo	-22.6166	118.1333
94/392	Araneae	Actinopodidae	*Missulena*	`*occatoria* group`	Marandoo	-22.6166	118.1333
94/391	Araneae	Actinopodidae	*Missulena*	`*occatoria* group`	Marandoo	-22.6166	118.1333
102133	Araneae	Actinopodidae	*Missulena*	sp. (juv.)	Serenity Valley, approx. 93 km N of Tom Price, Serenity site 3	-22.152640	117.557200
89232	Araneae	Barychelidae		sp. (juv.)	8.9 km S of Tom Price, Tom Price Mine, site BLF# MMF100 6	-22.7761	117.7906
103010	Araneae	Barychelidae	*Synothele*	`MYG237`	Zion, site 6, approx. 63 km N of Tom Price	-22.211600	117.966700
98355	Araneae	Nemesiidae	*Aname*	`marae`	c. 30 km WNW. of Tom Price	-22.628330	117.516400
98437	Araneae	Nemesiidae	*Aname*	`marae`	West Turner Syncline, 21.5 km WNW of Tom Price (WTS17)	-22.653330	117.589200
98431	Araneae	Nemesiidae	*Aname*	`marae`	Tom Price powerlines, 9 km NW of Tom Price	-22.652780	117.707200
98426	Araneae	Nemesiidae	*Aname*	`marae`	Tom Price powerlines, 9 km NW of Tom Price	-22.652780	117.707200

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude	Longitude
98429	Araneae	Nemesiidae	*Aname*	\`marae\`	Tom Price powerlines, 9 km NW of Tom Price	-22.652780	117.707200
98436	Araneae	Nemesiidae	*Aname*	\`marae\`	Tom Price powerlines, 8 km NW of Tom Price	-22.654720	117.716400
98433	Araneae	Nemesiidae	*Aname*	\`marae\`	Tom Price powerlines, 8 km NW of Tom Price	-22.657780	117.716900
98434	Araneae	Nemesiidae	*Aname*	\`marae\`	Tom Price powerlines, 8 km NW of Tom Price	-22.657780	117.716900
112542	Araneae	Nemesiidae	*Aname*	\`marae\`	Tom Price Powerlines, 6.1 km NW of Tom Price	-22.668890	117.731400
98423	Araneae	Nemesiidae	*Aname*	\`marae\`	Tom Price powerlines, 5 km NW of Tom Price	-22.676670	117.738600
98425	Araneae	Nemesiidae	*Aname*	\`marae\`	Tom Price powerlines, 5 km NW of Tom Price	-22.676670	117.738600
98430	Araneae	Nemesiidae	*Aname*	\`marae\`	Tom Price powerlines, 6 km NW of Tom Price	-22.668890	117.748100
112543	Araneae	Nemesiidae	*Aname*	\`marae\`	Tom Price Powerlines, 4.1 km WNW of Tom Price	-22.686110	117.748600
112544	Araneae	Nemesiidae	*Aname*	\`marae\`	Tom Price Powerlines, 4.1 km WNW of Tom Price	-22.686110	117.748600
98424	Araneae	Nemesiidae	*Aname*	\`marae\`	Tom Price powerlines, 4 km NW of Tom Price	-22.686110	117.748900
98427	Araneae	Nemesiidae	*Aname*	\`marae\`	Tom Price powerlines, 4 km NW of Tom Price	-22.686110	117.748900
98435	Araneae	Nemesiidae	*Aname*	\`marae\`	Tom Price powerlines, 4 km NW of Tom Price	-22.682220	117.751700
98432	Araneae	Nemesiidae	*Aname*	\`marae\`	Tom Price powerlines, 4 km NW of Tom Price	-22.682220	117.751700

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude	Longitude
98428	Araneae	Nemesiidae	*Aname*	\`marae\`	Tom Price powerlines, 4 km NW of Tom Price	-22.682220	117.751700
100158	Araneae	Nemesiidae	*Aname*	\`MYG168\`	Valley of the Kings, approx. 61 km N of Tom Price, site 949-KNG-09	-22.173320	117.916500
100159	Araneae	Nemesiidae	*Kwonkan*	\`MYG169\`	Valley of the Kings, approx. 61 km N of Tom Price, site 949-KNG-11	-22.177840	117.901900
44348	Araneae	Nemesiidae	*Kwonkan*	sp. indet.	Tom Price	-22.7000	117.7833
103006	Araneae	Nemesiidae	*Yilgarnia*	sp. (juv.)	Serenity Valley, site 7, approx. 93 km N of Tom Price	-22.118060	117.533600
100075	Araneae	Selenopidae	*Karaops*	sp. (juv.)	Nammuldi-Silvergrass, 584 km NW of Tom Price	-22.399440	117.315600
97943	Araneae	Selenopidae	*Karaops*	sp. (juv.)	Hamersley Range, Western Ranges, approx. 22 km WNW of Paraburdoo	-23.184500	117.458100
92503	Araneae	Selenopidae	*Karaops*	sp. (juv.)	Tom Price, 2 km S of Tom Price, A20080815.CH23-01	-22.712780	117.775800
Opiliones (harvestmen)							
87/1260	Opiliones				West Angelas	-22.9833	118.2500
Scorpiones (Scorpions)							
100606	Scorpiones	Urodacidae	*Aops*	‘solomon’	Valley of the Kings, approx. 61 km N of Tom Price, site no. 949-KNG-14	-22.164420	117.913300
78458	Scorpiones	Urodacidae	*Urodacus*	‘cf. mckenziei’	Brockman, 3.5 km W of Mt Brockman, site BRO32	-22.4644	117.2825
80237	Scorpiones	Urodacidae	*Urodacus*	sp. indet.	47.5 km ESE of Paraburdoo (site TCMBC11)	-23.2863	118.1236
80235	Scorpiones	Urodacidae	*Urodacus*	sp. indet.	35 km WSW of Tom Price (site TCMBW03)	-22.8091	117.4775
79774	Scorpiones	Buthidae	*Lychas*	‘gracillimus’	8 km S of Coolawanyay (site PE02)	-21.8821	117.7945

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude	Longitude
80303	Scorpiones	Buthidae	*Lychas*	'gracillimus'	8 km S of Coolawanyay (site PE02)	-21.8821	117.7945
100601	Scorpiones	Buthidae	*Lychas*	'kings'	Valley of the Kings, approx. 61 km N of Tom Price, site no. 949-KNG-20	-22.148940	117.849600
100607	Scorpiones	Buthidae	*Lychas*	'kings'	Valley of the Kings, approx. 61 km N of Tom Price, site no. 949-KNG-20	-22.148940	117.849600
100604	Scorpiones	Buthidae	*Lychas*	'kings'	Valley of the Kings, approx. 61 km N of Tom Price, site no. 949-KNG-15	-22.159830	117.904200
100992	Scorpiones	Buthidae	*Lychas*	'kings'	Valley of the Kings, approx. 61 km N of Tom Price, site 949-KNG-17 REF	-22.173460	117.888500
80306	Scorpiones	Buthidae	*Lychas*	'marandoo1'	Marandoo Mine expansion, 35 km ENE of Tom Price	-23.1055	118.3061
80307	Scorpiones	Buthidae	*Lychas*	'marandoo1'	Marandoo Mine expansion, 35 km ENE of Tom Price	-22.6522	118.1700
80303	Scorpiones	Buthidae	*Lychas*	'marandoo1'	Marandoo Mine expansion, 35 km ENE of Tom Price (MAR05)	-23.0880	118.2769
60450	Scorpiones	Buthidae	*Lychas*	'scottae'	Mt Brockman, Nammuldi mine (Hamersley Iron), site 33	-22.3080	117.3111
Diplopoda (millipedes)							
113056	Craspedosomatida				Anketell Rail Corridor, NNW Tom Price	-21.975280	117.629600
113055	Craspedosomatida				Anketell Rail Corridor, NNW Tom Price	-21.975280	117.629600
73501	Polydesmida	Paradoxosomatidae			approx. 9.9 km NW of Tom Price, site TP555	-22.635280	117.691900
76059	Polydesmida	Paradoxosomatidae	*Antichiropus*	indet.	22.5 km ESE of Mt De Courcey, Pilbara Biological Survey site WYE02 (CHECK?)	-22.772720	116.522000
76080	Polydesmida	Paradoxosomatidae	*Antichiropus*	indet.	27 km ESE of Mt De Courcey, Pilbara	-22.789220	116.570900

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude	Longitude
					Biological Survey site WYE01		
Chilopoda (centipedes)							
93373	Geophilida	Mecistocephalidae	*Mecistocephalus*		Paraburdoo, approx. 35 km E	-23.173380	117.949300
92258	Geophilida				Hamersley Range, c. 25 km NE of Hamersley Homestead, site VQSRE2	-22.139530	117.784100
Gastropoda (land snails)							
	Eupulmonata	Camaenidae	*Quistrachia*	`cancellate`	Serenity valley	-22.1114761	117.8897119
	Eupulmonata	Camaenidae	*Quistrachia*	`cancellate`	Serenity valley	-22.1535389	117.8471972
	Eupulmonata	Camaenidae	*Quistrachia*	`cancellate`	Serenity valley	-22.1502361	117.8293278
	Eupulmonata	Camaenidae	*Quistrachia*	`cancellate`	Serenity valley	-22.06625	117.867
	Eupulmonata	Camaenidae	*Quistrachia*	`cancellate`	Tom Price	-22.05883	117.85493
	Eupulmonata	Camaenidae	*Quistrachia*	`cancellate`	Tom Price	-22.21442	117.57306
	Eupulmonata	Camaenidae	*Quistrachia*	`cancellate`	Kangeenamarina gorge	-22.21442	117.57306
	Eupulmonata	Camaenidae	*Quistrachia*	`cancellate`	Millers Gorge	-22.11672	117.52766
	Eupulmonata	Camaenidae	*Quistrachia*	`cancellate`	Hamersley range	-22.1526361	117.5572056
	Eupulmonata	Camaenidae	*Quistrachia*	indet.	Ashburton downs	-22.61667	118.11667
	Eupulmonata	Camaenidae	*Quistrachia*	indet.	12 km West of Tom Price	-22.7	117.66667
	Eupulmonata	Camaenidae	*Quistrachia*	indet.	Tom Price	-22.06667	117.88333
	Eupulmonata	Camaenidae	*Quistrachia*	indet.	Tom Price	-22.64083	117.7125
	Eupulmonata	Camaenidae	*Quistrachia*	indet.	Tom Price	-23.36667	117.03333
	Eupulmonata	Camaenidae	*Quistrachia*	indet.	Millers Gorge	-22.58333	118.45
	Eupulmonata	Camaenidae	*Quistrachia*	indet.	Marandoo minesite	-22.68333	117.78333
	Eupulmonata	Camaenidae	*Quistrachia*	indet.	Marandoo minesite	-22.6500556	117.7185
	Eupulmonata	Camaenidae	*Rhagada*	`small banded`	Mt Brockman	-22.22806	117.51778

WAM reg. no.	Order	Family	Genus	Species	Location	Latitude	Longitude
	Eupulmonata	Camaenidae	*Rhagada*	`small banded`	Nammuldi-Silvergrass	-22.61778	117.18167
	Eupulmonata	Camaenidae	*Rhagada*	`small banded`	Nammuldi-Silvergrass	-22.29972	117.63778
	Eupulmonata	Camaenidae	*Rhagada*	`small banded`	Nammuldi-Silvergrass	-22.19861	117.48167
	Eupulmonata	Camaenidae	*Rhagada*	`small banded`	Nammuldi-Silvergrass	-22.18235	117.7001889
	Eupulmonata	Camaenidae	*Rhagada*	`small banded`	Nammuldi-Silvergrass	-22.12	117.7147194
	Eupulmonata	Camaenidae	*Rhagada*	`small banded`	Nammuldi-Silvergrass	-22.12	117.7147194
	Eupulmonata	Camaenidae	*Rhagada*	`small banded`	Central Pilbara	-22.3541778	117.6136417
	Eupulmonata	Camaenidae	*Rhagada*	`small banded`	Central Pilbara	-22.3786861	117.4481028
	Eupulmonata	Camaenidae	*Rhagada*	`small banded`	Nammuldi-Silvergrass	-22.3799333	117.3814889
	Eupulmonata	Camaenidae	*Rhagada*	`small banded`	Central Pilbara	-22.3734694	117.4630917
	Eupulmonata	Camaenidae	*Rhagada*	`small banded`	Central Pilbara	-22.3786861	117.4481028
	Eupulmonata	Camaenidae	*Rhagada*	`small banded`	Central Pilbara	-22.3786861	117.4481028
	Eupulmonata	Camaenidae	*Rhagada*	`small banded`	Central Pilbara	-22.3786861	117.4481028
	Eupulmonata	Camaenidae	*Rhagada*	indet.	Mt Turner	-22.28333	117.68333
	Eupulmonata	Camaenidae	*Rhagada*	indet.	Tom Price	-22.7	117.41667
	Eupulmonata	Camaenidae	*Rhagada*	indet.	Hamersley station	-22.6	118.13333
	Eupulmonata	Camaenidae	*Rhagada*	indet.	Mt Bruce	-22.7	117.66667

APPENDIX 3 NUMBER OF SPECIMENS OF SRE TARGET TAXA COLLECTED DURING SURVEY

Order	Family	Species	1	2	3	4	5	6	7	Opp1	Opp2	vert1	vert4	vert5	vert7	vertOpp1	vertOpp4	Total
Araneae	Actinopodidae	*Missulena* sp. indet.					1											**1**
	Nemesiidae	*Aname* 'MYG001'	1															**1**
Pseudoscorpiones	Atemnidae	*Oratemnus* sp. indet.	1	1	5			1										**8**
	Chernetidae	*Haplochernes* sp. indet.						1										**1**
		Troglochernes sp. indet.						1										**1**
	Olpiidae	*Austrohorus* sp. indet.		2				2										**4**
		Beierolpium '8/2'	7	6		2	1	13	3									**32**
		Beierolpium '8/3'						1										**1**
		Beierolpium '8/4'		1	1	1		2										**5**
		Beierolpium '8/4 small'			1													**1**
		Euryolpium sp. indet.		3														**3**
		Indolpium sp. indet.	4	12	1	5		1	14									**37**
	Sternophoridae	*Afrosternophorus* sp. indet.			1			1										**2**
Scorpiones	Buthidae	*Lychas bituberculatus*					4		1									**5**
		Lychas 'multipunctatus'										3						**3**
		Lychas 'pilbara1'										1						**1**
Geophilomorpha	Chilenophilidae	Chilenophilidae sp. indet.			1			1										**2**
	Mecistocephalidae	*Mecistocephalus* sp. indet.	4															**4**
	Oryidae	*Orphnaeus brevilabiatus*	1	1														**2**
	Schendylidae	*Australoschendyla* cf. *capensis*					1											**1**
Spirobolida	Pachybolidae	*Austrostrophus stictopygus*							1									**1**
	Spirobolida*	Spirobolida sp. indet.		1		1			1									**3**

Order	Family	Species	1	2	3	4	5	6	7	Opp1	Opp2	vert1	vert4	vert5	vert7	vertOpp1	vertOpp4	Total
Isopoda	Armadillidae	Armadillidae sp. indet.							2									**2**
		New Genus 'sp. 3'		1		3		1										**5**
		Buddelundia '13'	5	5		1	5	1	15									**32**
		Buddelundia '14'							47									**47**
		Buddelundia '15'					13	14										**27**
		Buddelundia '16'	21	9	11		5	30		4					1			**81**
		Buddelundia '19'					1	5										**6**
		Buddelundia '20'		2														**2**
		Buddelundia '50'		27														**27**
	Philosciidae	Philosciidae sp. indet.			15													**15**
Eupulmonata	Camaenidae	*Rhagada* 'small banded'	2	5		1			2		8	1	3	2	8	16	3	**51**
	Helicodiscidae	*Stenopylis coarctata*			8		1	7										**16**
	Planorbidae	*Gyraulus* sp. indet.			4													**4**
	Pupillidae	*Pupoides beltianus*	1	1	11	3	6	2	120									**144**
		Gastrocopta larapinta		3	10		2	2										**17**
		Gastrocopta mussoni	1	54	17	4	2	9	36									**123**
		Pupoides pacificus	1	9	23			2	17									**52**
		Pupillidae sp. indet.		1		1												**2**
	Subulinidae	*Eremopeas interioris*			1			2										**3**
Total			**49**	**144**	**110**	**22**	**42**	**99**	**259**	**4**	**8**	**5**	**3**	**2**	**9**	**16**	**3**	**775**

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ENVIRONMENTAL SCIENCES

Subterranean fauna survey for the Rocklea Iron Ore Project

Prepared for Dragon Energy Ltd

February 2014

Final Report

Subterranean fauna survey for the Rocklea Iron Ore Project

Prepared for Dragon Energy Ltd

Final Report

Authors: Erich S. Volschenk and Anna Leung

Reviewer: Volker Framenau and Karen Crews

Date: February 2012

Submitted to: Gang Xu

Chain of authorship and review			
Name	Task	Version	Date
Erich S. Volschenk Anna Leung	Draft for technical review	0.1	15 February 2013
Volker Framenau	Technical review	0.2	17 February 2013
Erich Volschenk	Draft for editorial review	0.3	19 February 2013
Karen Crews	Editorial review	0.4	24 February 2012
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EXECUTIVE SUMMARY

In September 2011, Phoenix Environmental Sciences Pty Ltd (Phoenix) was commissioned by Dragon to undertake a baseline subterranean fauna survey for the Rocklea Iron Ore Project . The Project area is located approximately 34 km southwest of Tom Price in the Pilbara region of WA. The Project aims to develop a CID (channel iron deposit) with a current JORC inferred resource of 182.6 Mt@ 52.7% Fe (59.5% caFe). The study area for the subterranean fauna survey was restricted to the area that had exploration drill holes suitable for sampling on tenement E47/1024.

This report documents the results of the subterranean survey, conducted during July and October 2012, representing two seasons.

The key objective of the subterranean fauna survey was to provide information on the presence of subterranean fauna species in the study area, and an assessment of their conservation status.

The scope of work included the following components:

- conduct a desktop review of technical reports and relevant databases to determine the potential subterranean species and respective habitats within the study area
- conduct field surveys for subterranean fauna within the study area
- undertake data analysis, sample processing and species identifications for samples collected during the field surveys
- prepare maps showing significant species records and fauna habitats in the study area
- prepare a technical report outlining the survey methods used, results, assessment of significant species and habitats.

Subterranean fauna are fauna (usually invertebrates) that live underground. They are usually divided into two types on the basis of the medium in which they live: troglofauna, living in air filled void networks, and stygofauna, living in water filled void networks. Animals living in these environments are categorised on the basis of their level of ecophysiological specialisation to their respective habitats:

- Troglobites and Stygobites are obligate subterranean fauna living in air and water filled void networks respectively. These species are so specifically adapted to their environments that they cannot survive on the surface. This level of specialisation often leads these species to be short-range endemics.
- Troglophiles and stygophiles facultatively use subterranean air filled and water filled void networks respectively. They are often not specifically adapted to live in these subterranean habitats and move freely between these and connected surface habitats.

There are uncertainties in determining the extent of range-restriction of many invertebrates species in the Pilbara due to lack of surveys in the region, lack of taxonomic resolutions within the target taxa and problems in identifying certain life stages. In that context, subterranean fauna collected from the study area were grouped into two different categories: likely SRE and potential SRE.

The desktop review identifies 139 unique subterranean invertebrate fauna species, and morphospecies within a 100 km radius search from the survey area. Of the 139 species, 39 (28%) were represented by SRE troglofauna, 66 (47.5%) are represented by stygofauna. The area supports a rich diversity of subterranean SREs.

This survey uncovered 24 troglofauna species, of which 21 are considered to be SREs. The 24 species could also not be matched with known species on the basis of their morphology and genomic comparisons with reference specimens from the Pilbara found three of the 24 troglobites to be widespread. Troglofauna SREs comprised the following species, sorted by order ranking:

- Araneae: *Anapistula* 'D1' (Symphytognathidae) and Trochanteriidae 'D1' (Trochanteriidae),
- Palpigradi: Palpigradi sp. indet.,
- Pseudoscorpiones: *Tyrannochthonius* 'D1' and *Indohya* 'D1',
- Schizomida: *Draculoides* 'D1',
- Scolopendromorpha: *Cryptops* 'D1',
- Polydesmida: Haplodesmidae 'D1' and Haplodesmidae 'D2',
- Diplura: Japygidae 'D1', Japygidae 'D2', Parajapygidae 'D1', Projapygidae 'D1' and Projapygidae 'D2',
- Thysanura: Atelurinae 'D1' and *Trinemura* sp. indet.,
- Pauropoda: Pauropoda 'D1' and Pauropoda 'D2',
- Symphyla: Symphyla 'D1a', Symphyla 'D1b' and Symphyla 'D2'.

A total of 19 stygofauna species were discovered; however, only eight of these represent stygofauna SREs. Stygobitic SRE's are listed, sorted by order ranking:

- Amphipoda: Bogidiellidae 'D4', Melitidae 'D1', Melitidae 'D2' and Paramelitidae 'D2'
- Syncarida: *Atopobathynella* 'D1',
- Isopoda: *Haptolana* 'D1', *Pygolabis eberhardi*
- Ostracoda: *Areacandona atomus*.

The troglofauna richness estimation indicated that between 30 and 160 species were predicted to occur within the study area and indicating that this survey recovered between 14% to 79% species richness. The troglofauna data matrix was dominated by singleton records, a factor that is likely to have resulted in such a wide range of extrapolations. Stygofauna species richness was extrapolated to between 21 and 47 species. The recorded species richness of 19 species represents between 73% and 87% of the extrapolated species richness.

Troglofauna species distributions were largely partitioned in two areas of the Central CID deposit of the Rocklea Project on E47/1024. These areas are separated by a narrow strip of Alluvium. Ten troglofauna SREs appear to be restricted to the western area: *Tyrannochthonius* 'D1' Japygidae 'D1', Japygidae 'D2', Parajapygidae 'D1', Projapygidae 'D2', Atelurinae 'D1', *Trinemura* 'D1', Haplodesmidae 'D1', Pauropoda 'D1' and Symphyla 'D1a'. Five troglofauna SREs were restricted to the eastern outcrop: *Indohya* 'D1', Haplodesmidae 'D2', Pauropoda 'D2', Symphyla 'D1a', Symphyla 'D2'. Only two SRE troglobites were found in both eastern and western areas, *Draculoides* 'D1' and *Cryptops* 'D1'; however, the identity of the specimens in the latter species will need to be verified. Both the eastern and western outcrops extend outside of the survey area and it seems likely the extent of these outcrops will reflect the distribution of the troglofauna living in them.

Stygofauna SRE species were evenly distributed between eastern and western areas. One of the SRE stygofauna, *Pygolabis eberhardi*, was first collected from the Hardey bore field, approximately 16 km south west of the survey area. The type locality and the present survey records indicate that tis species is likely to be present in the flooded alluvial deposits of the Hardey River. It is therefore also possible that the other stygofauna species share this distribution; however, this hypothesis needs confirmation by sampling for remaining stygofauna SRE species from the Hardey River bore field.

In summary, 21 troglofauna SREs and eight stygofauna SREs were discovered. Evidence based on the distribution of *Pygolabis eberhardi* suggests that these stygofauna may occur up to 16 km to the south-west of the survey area. The troglofauna SREs appear to be restricted to two outcrops (above water table) of the central Robe Pisolite deposit, both of which extend outside of the survey area. Further survey work may be needed in order to substantiate these distributions.

1 INTRODUCTION

In September 2011, Phoenix Environmental Sciences Pty Ltd (Phoenix) was commissioned by Dragon Energy Ltd (Dragon) to undertake a baseline subterranean fauna survey for the Rocklea Iron Ore Project (the Project). This report describes the subterranean fauna surveys undertaken in July and October 2012.

1.1 BACKGROUND

The Project area is located 34 km southwest of Tom Price in the Pilbara region of WA (Figure 1-1). The Project aims to develop a CID (channel iron deposit) with a current JORC inferred resource of 182.6 Mt@ 52.7% Fe (59.5% caFe). The study area for the subterranean fauna survey is defined in Figure 1-2; however, the area surveyed was restricted to the western portion of the study area as only this area had drill holes suitable for sampling.

1.2 SCOPE OF WORK AND SURVEY OBJECTIVES

The scope of work is as follows:

- conduct a desktop review of technical reports and relevant databases to determine the potential subterranean species and respective habitats within the study area
- conduct field surveys for subterranean fauna within the study area
- undertake data analysis, sample processing and species identifications for samples collected during the field surveys
- prepare maps showing significant species records and fauna habitats in the study area
- prepare a technical report outlining the survey methods used, results, assessment of significant species and habitats.

Where practicable, survey design, methodology and report-writing adhere to relevant principles and guidelines, including:

- EPA Guidance Statement No. 54: Consideration of Subterranean Fauna in Groundwater and Caves during Environmental Impact Assessment in Western Australia (EPA 2003)
- EPA Guidance Statement No. 54a: *Sampling methods and survey considerations for subterranean fauna in Western Australia* (EPA 2007).

An impact footprint has not been clearly defined and this survey is therefore intended to provide baseline data to support future development of the resource.

Figure 1-1 Location of the Rocklea Iron Ore Project	
AUTHOR: E.S. Volschenk	CLIENT: Dragon Energy Ltd.
DATE: February 2013	Scale: 1:350,332
Coordinate System: Projection: Transverse Mercator; DATUM: GDA94	

PHOENIX ENVIRONMENTAL SCIENCES

Rocklea Iron Ore Project

0 3.5 7 14 21 Kilometers

Study Area
Tenement E47/1024
Towns
Roads

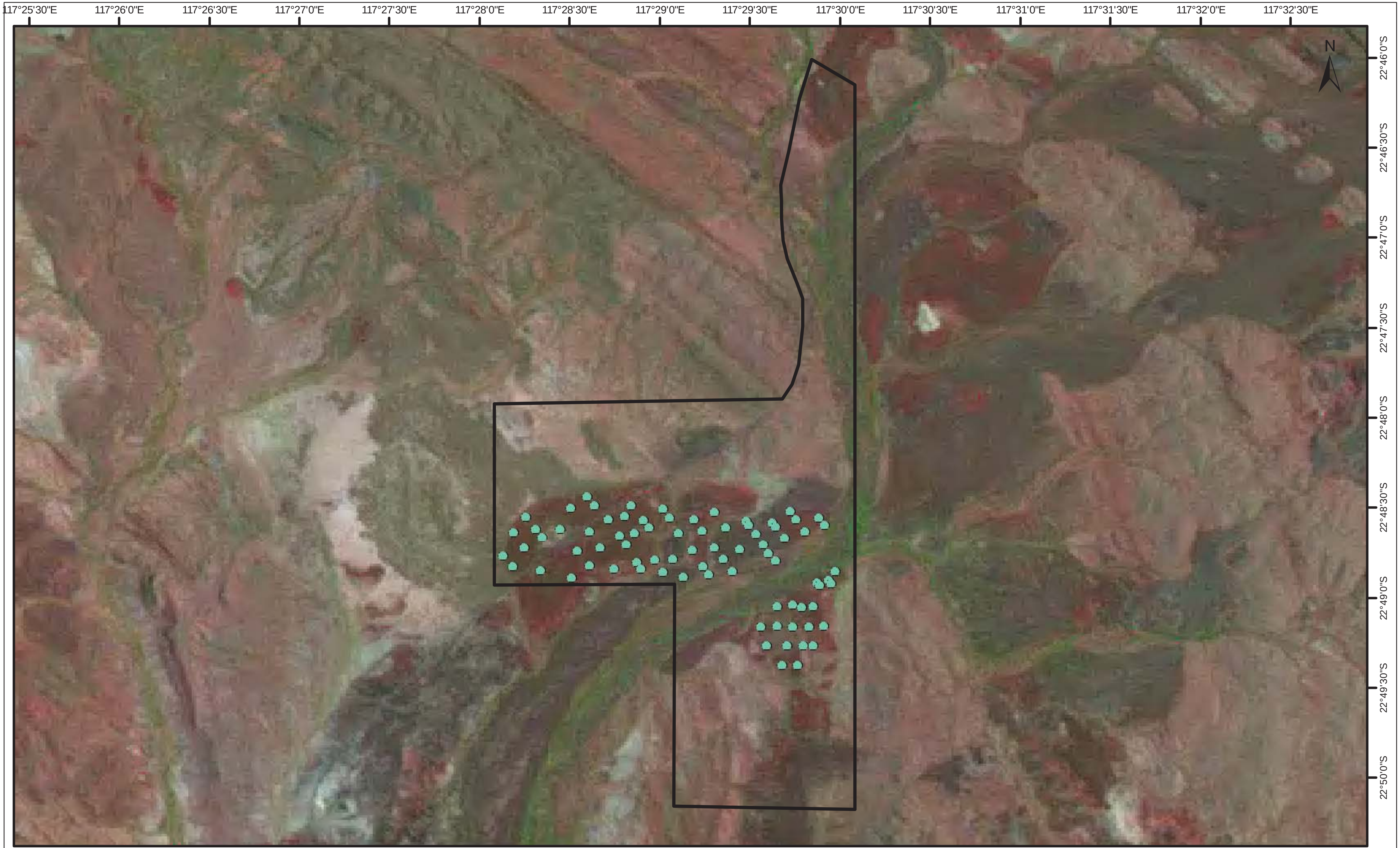

Figure 1-2 Study area for the subterranean fauna survey of the Rocklea Iron Ore Project

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR: E.S. Volschenk | CLIENT: Dragon Energy Ltd.

DATE: February 2013 | Scale: 1:49,679

Rocklea Iron Ore Project

Coordinate System: Projection: Transverse Mercator; DATUM: GDA94

0 0.45 0.9 1.8 2.7 Kilometers

Study Area

Subterranean fauna survey bores

2 EXISTING ENVIRONMENT

2.1 GEOLOGY AND HYDROLOGY

The geology of the study area and surrounds is comprised of the following:

- **Quaternary Alluvium (Qa):** unconsolidated silt, sand, and gravel; in drainage channels and adjacent floodplains.
- **Quaternary Colluvium (Qc):** unconsolidated quartz and rock fragments in soil.
- **Cainozoic Alluvium (Cza):** partly consolidated silt, sand, and gravel; old alluvium dissected by present-day drainage.
- **Cainozoic Colluvium (Czc):** partly consolidated quartz and rock fragments in silt and sand matris; old valley-fill deposits, locally derived.
- **Cainozoic Calcrete (Czk):** sheet carbonate, found along major drainage lines.
- **Robe Pisolite (Czp):** pisolitic limonite deposits developed along river channels.
- **Hardey Formation (AFh):** pelite, metasandstone, metaconglomerate, metabasalt, metamorphosed volcanic sandstone, and metabasaltic breccia.
- **Layered sills intruded into Fortescue Group (AFl):** sills generally consist of a coarse-grained metapyroxenite base, overlain by leucocratic metage.
- **Boongal Formation (AFo):** pillowed and massive metabasaltic flows, metabasaltic breccia, pelite, and minor chert.
- **Pyradie Formation (AFp):** metamorphosed pyroxene spinifex-textured basaltic flows and pillow lava; metamorphosed volcanic sandstone and minor chert.
- **Bunjinah Formation (AFu):** pillowed and massive metabasaltic flows, metabasaltic breccia, metamorphosed volcanic sandstone, and minor chert; amygda.

Data obtained from the Geological Survey of WA, (Geological Survey of Western Australia 1996).

The study area contains three types of geology known to support subterranean fauna: Quaternary Alluvial, Robe Pisolite and Cainozoic Calcrete (Figure 2-1) (EPA 2003, 2007; Phoenix 2011). Two Robe Pisolite Formation outcrops (above the water table) are present in the study area. Dragon has confirmed that these two outcrops are surface expressions of the larger Central Deposit and merge below the water table. Only the northern portion of the eastern outcrop is within the study area, the majority of this outcrop lies outside of the study area. In a similar manner, only the northern portion of the western outcrop is within the study area and most of this outcrop lies outside of the study area, and is within tenement E47/952, held by Murchison Metals at the time of commissioning this report. The western outcrop is separated from the eastern outcrop by Quaternary Alluvial deposits from the Hardey River. The western outcrop is also in direct contact with the northern limit of a large Cainozoic Calcrete deposit (Figure 2-1).

The study area is relatively flat and low lying. It is intersected by the Hardey River, a tributary of the Ashburton River. The Alluvial deposits surrounding the Hardey River are generally coarse and highly transmissive of water; the standing water level is likely to be highly variable, particularly after heavy rainfall events.

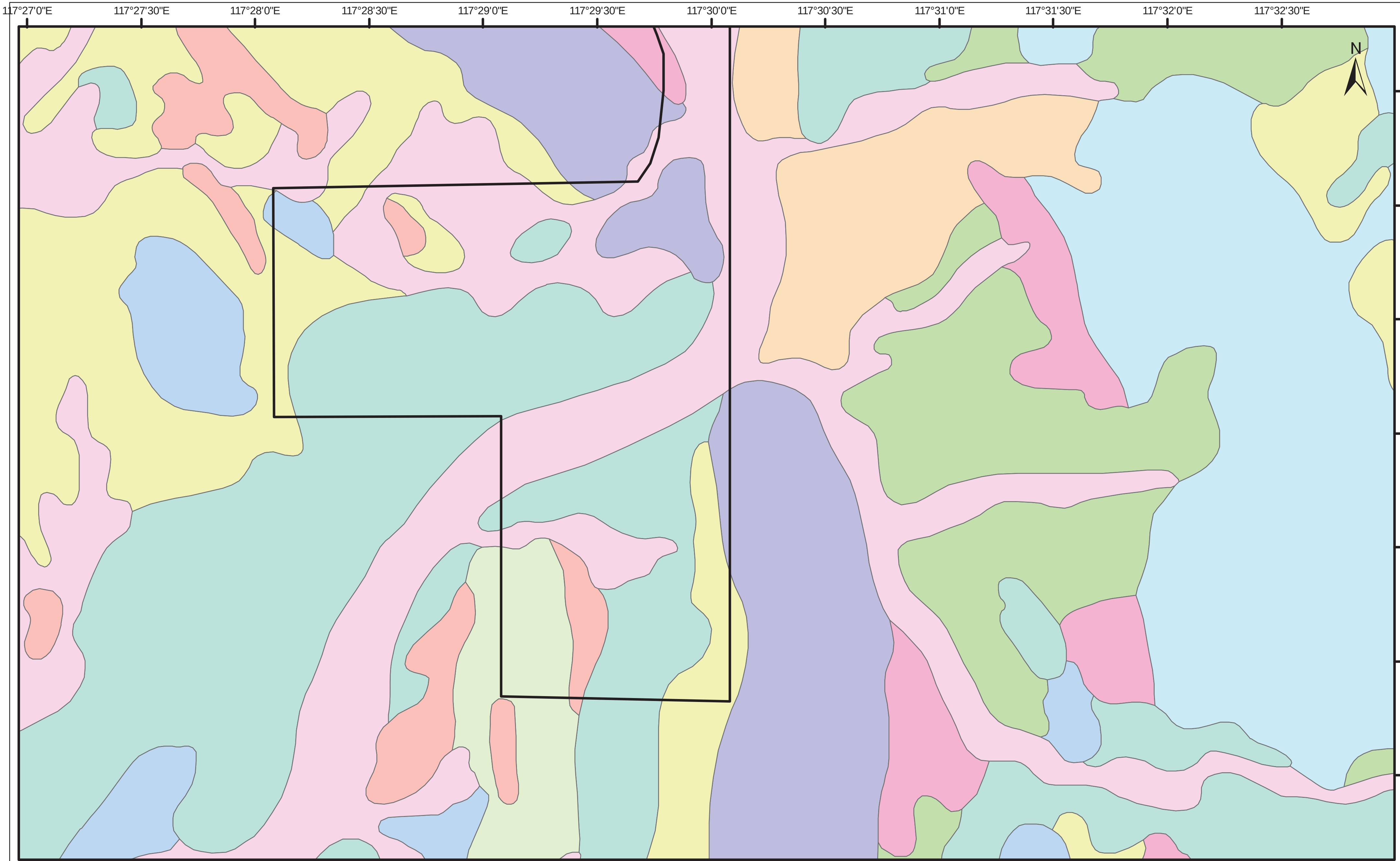

Figure 2-1 Location of the Rocklea Iron Ore Project in relation to surface geology

AUTHOR: E.S. Volschenk	CLIENT: Dragon Energy Ltd.
DATE: February 2013	Scale: 1:39,774

Coordinate System: Projection: Transverse Mercator; DATUM: GDA94

PHOENIX ENVIRONMENTAL SCIENCES

Rocklea Iron Ore Project

0 0.35 0.7 1.4 2.1 Kilometers

Study Area

Surface Geology

- AFu: Bunjinah formation
- AFp: Pyradie formation
- Czc: Colluvium
- Cza: Alluvium
- AFo: Boongal formation
- AFl: Layered sills
- HFh: Hardey formation
- Qa: Alluvium
- Qc: Colluvium
- Czp: Robe Pisolite
- Czk: Calcrete

2.2 CLIMATE AND WEATHER

Rainfall is considered to be an influential climatic parameter for troglofauna and stygofauna since both of these groups are dependent on groundwater and are thought to respond to the influx of nutrients carried into the subterranean void networks after heavy rain (EPA 2003, 2007).

The Project is located in the Pilbara bioregion which has a semi-arid, tropical climate. McKenzie *et al.* (2009) classified the area in which the Project is situated, as 'hot-persistently dry grassland'. Daily temperatures in summer can exceed 45°C. The region also experiences thunderstorms and cyclones during the summer months. Rainfall in the region is variable between years and unpredictable throughout the year. Winter is temperate and rainfall is significantly lower than summer.

The nearest Bureau of Meteorology (BOM) weather station is located at Paraburdoo (23.18°S, 117.75°E) approximately 50 km south-east of the Project. Paraburdoo records the highest maximum mean monthly temperature (41.1°C) in January, the lowest minimum mean annual temperature (13.6°C) in July and an average annual rainfall of (313.4) mm (BOM 2012) (Figure 2-2).

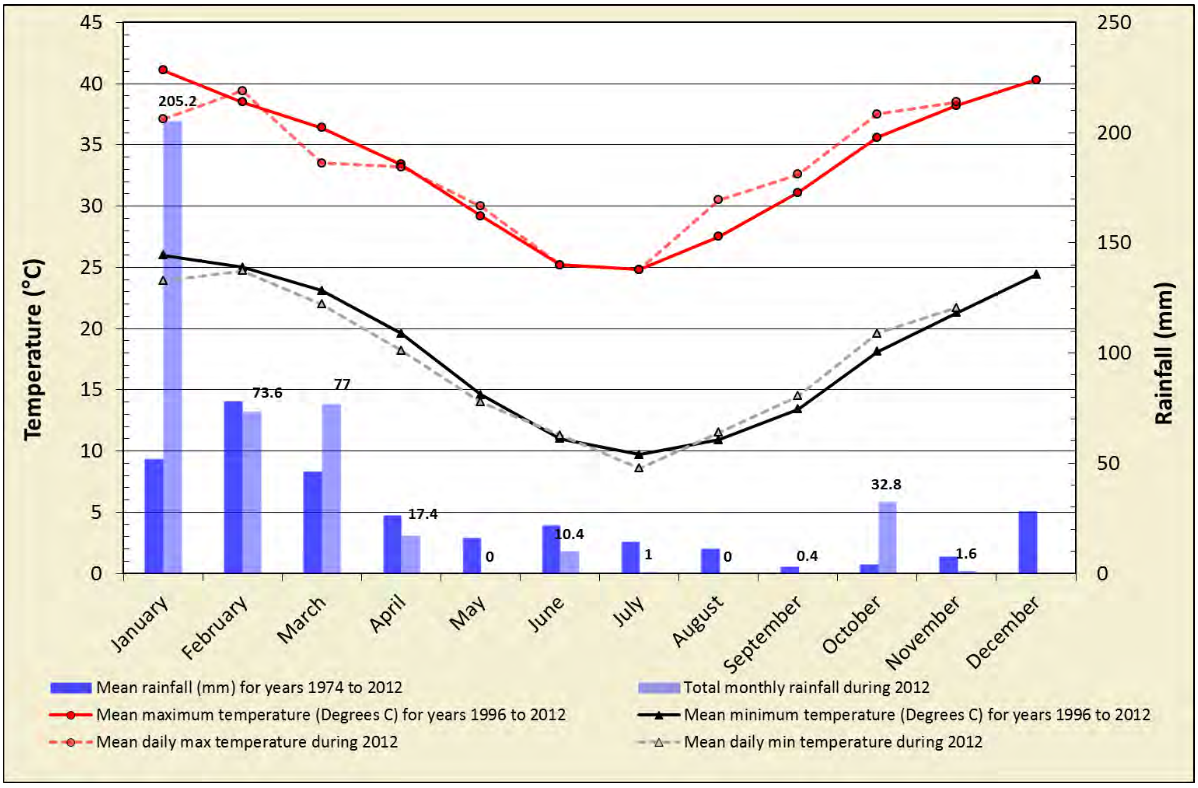

Figure 2-2 **Average monthly temperatures (maximum and minimum) and rainfall records from Paraburdoo**

Records from Paraburdoo weather station during the survey period from July to October show below average rainfall compared with the long term average. October experienced far above average rainfall for that month; however, this occurred in one event after the final phase of the survey (Figure 2-2). During July to October, mean daily maximum temperatures were above average (Figure 2-2).

The rainfall data suggest that 2012 may have had suboptimal rainfall for subterranean surveys owing to the below average rainfall observed from May to September. Temperature is thought to be less influential than rainfall on subterranean fauna sampling outcomes.

2.3 BIOLOGICAL CONTEXT

2.3.1 Subterranean fauna and habitats

Subterranean fauna are organisms (almost exclusively invertebrates) that live beneath the surface of the ground. Surface-dwelling species are generally referred to as epigean (Howarth 1983; Humphreys 2000) and subterranean species are named to reflect their eco-physiological specialisation to subterranean habitat. Subterranean organisms can exist within a variety of subterranean void networks, including solution cavities within calcrete and karst; fractured rock and coarse sediments such as cobble or gravel strata (Howarth 1983; Humphreys 2008; Phoenix 2011).

Subterranean habitats are perpetually dark, are extremely constant in temperature and humidity (air-filled networks) and very low in nutrients and energy that are required to support organisms (Howarth 1993). Evolution under such conditions has resulted in very specialised organisms that are restricted to the void networks in which they have evolved (Harvey 2002; Holsinger 2000; Howarth 1993; Ponder & Colgan 2002; Volschenk & Prendini 2008). Such species are obligated to living in subterranean networks and cannot live in epigean (surface) environments. For this reason, organisms specialised to live in subterranean networks are likely to represent SREs (Harvey 2002; Ponder & Colgan 2002; Volschenk & Prendini 2008). Short-range endemics are species with naturally small distributions; nominally defined by Harvey as less than 10,000 km^2. It is these subterranean SRE species that are considered to be of conservation significance because they are at greatest risk of extinction from development projects (Eberhard *et al.* 2009). Subterranean systems are also characterised by having higher levels of endemism than epigean environments (Eberhard *et al.* 2009). Categories of short-range endemism are discussed in section 2.3.3.

In Western Australia, and particularly in the Pilbara region, there has been a renaissance in the study of subterranean biodiversity (Humphreys 2008) driven by the growth of the mineral resources industry and mining environmental impact assessment (EPA 2003, 2007). Despite the extensive survey work undertaken in the Pilbara, relatively little knowledge on SRE diversity and biology, whether subterranean or epigean, has emerged from the primary literature. The biology, diversity and distributions of most of Western Australia's subterranean fauna are so poorly understood that most species have not even been named yet.

Subterranean fauna have been traditionally split into two groups based on their primary habitat (Humphreys 2000):

- Troglofauna, air breathing species inhabiting air filled void spaces
- Stygofauna, water breathing species inhabiting water filled void spaces.

Within each of these groups, several levels of ecological classification have been used to identify the level of specialisation to subterranean habitats.

Troglofauna are typically divided into three categories:

- **troglobites**, that are restricted to subterranean habitats and usually perish on exposure to the surface environment (Barr 1968; Howarth 1983; Humphreys 2000)
- **troglophiles**, which facultatively use subterranean habitats but are not reliant on them for survival (Barr 1968; Howarth 1983; Humphreys 2000)
- **trogloxenes**, which use subterranean systems for specific purposes, such as roosts for reproduction (bats and swiftlets).

Stygofauna are typically divided into three categories:

- **stygobites**, that are restricted to subterranean habitats and usually perish on exposure to the surface environment
- **stygophiles**, which facultatively use subterranean habitats but are not reliant on them for survival
- **stygoxenes**, which can inhabit both surface and subterranean systems, they move between systems depending on biological requirements (Humphreys 2008).

Species in all of these categories may be SREs and may therefore be of conservation significance; however, it is the troglobites and stygobites that are most likely to be restricted owing to their dependency on subterranean habitats. Troglobites and stygobites are organisms that have evolved to exploit the special characteristics of subterranean networks. They are often characterised by much specialised adaptations to subterranean life, such as:

- lack or reduction of eyes
- lack or reduction of wings (for species that are normally winged)
- lack or reduction of body pigmentation
- elongation of appendages
- heightened chemosensory and mechanosensory systems
- loss of circadian rhythms
- very low metabolic rate.
- elongation of the body (especially in stygofauna).

These adaptations allow troglobites to exploit the perpetually dark, and nutrient-poor subterranean networks (Howarth 1983, 1993; Humphreys 2000; Poulson & Lavoie 2000). Several hypogean and litter dwelling invertebrate taxa are also blind and pale (i.e. cryptopid and geophylid centipedes, atelurine thysanurans, palpigrades etc.), making determination of troglobitic status extremely difficult without extensive research into the ecophysiology of each putative troglobite species. While their troglobitic nature may be uncertain, the important question of whether these species are SREs can still be investigated. In these instances, DNA sequencing can be used to obtain regional context for the species in question (Phoenix 2011) to determine if any records are conspecific with other sequenced specimens.

Troglophiles are species that can live and reproduce in subterranean networks, but are not restricted to them. These species are usually very tiny and exist within the soil. Some troglophiles appear to be widespread species, while others, like diplurans and cryptopids, are often SREs (Phoenix 2011; Subterranean Ecology 2010). Aquifers may be connected to surface water bodies and some surface species may also be able to freely move from surface to subterranean systems and back. Such species may be either stygoxenes or stygophiles (Humphreys 2000).

2.3.2 Identifying subterranean fauna

The ecological classification of subterranean fauna is largely based on an understanding of species' habitat and ecophysiological limitations (Humphreys 2000). Most of the troglofauna species encountered during surveys of the Pilbara are new to science, and therefore knowledge of their physiological limitations or ecology is unknown. In the absence of physiological or ecological data, the recognition and identification of obligatory subterranean species is usually dependant on the presence of troglomorphies, such as reduction or loss of eyes or wings etc. Troglomorphies are used to infer species that have become specialised to subterranean existence over many generations of confinement to subterranean habitats.

A noted above (2.3.2), some taxa, (subterranean or epigean) exhibit characteristics that appear to be troglomorphic. Determining if these taxa are troglobites is extremely difficult.

Taxonomic resolution is also difficult to achieve in taxa for which there is no regional context or expertise. The apparently strong evolutionary pressure of subterranean habitats has resulted in highly convergent, morphologically-similar species (Finston *et al.* 2004; Finston & Johnson 2004; Finston *et al.* 2007). Molecular techniques such as 'barcoding' (Hebert *et al.* 2003a; Hebert *et al.* 2003b) are routinely employed to overcome these identification problems (Finston *et al.* 2004; Phoenix 2011; Subterranean Ecology 2010). Barcoding methods can also resolve specimen identification where specimens represent taxonomically uninformative life stages or sexes (Hebert *et al.* 2003a; Hebert *et al.* 2003b).

2.3.3 Categories of short-range endemism

Short-range endemic fauna are defined as animals that display restricted geographic distributions, nominally less than 10,000 km^2, that may also be disjunct and highly localised (Harvey 2002; Ponder & Colgan 2002). Species restricted to subterranean void systems may have considerably smaller distributions and therefore represent extreme SREs (Eberhard *et al.* 2009; Harvey 2002). The most appropriate analogy is that of an island, where the movement of fauna is restricted by the surrounding marine waters, therefore isolating the fauna from other terrestrial populations.

Short-range endemism in subterranean invertebrates is believed to have evolved through two primary processes (Harvey 2002):

- **Relictual short-range endemism**: relictual SREs are thought to have had wider distributions during more mesic geological periods. Australia's aridification over the last 60 million years resulted in a contraction of the ranges of these species into relatively small habitat pockets where moist conditions persist (relictual Gondwanan habitats). Evolutionary processes over long periods of isolation result in each population developing into a distinctive species. Relictual SREs often inhabit areas with high rainfall or humidity, a feature of most subterranean habitats.
- **Habitat specialisation**: habitat specialist SREs may have colonised particular isolated habitat types through dispersal, and subsequently evolved in isolation into distinct species. Unlike relictual SREs in mesic habitats, habitat specialist SREs are restricted by environmental parameters other than humidity and are often found in arid environments such as the Pilbara.

In Australia, troglobites and stygobites are, largely thought to be relictual SREs that became 'trapped' in mesic subterranean habitats following the aridification of the continent.

Phoenix and the WA Museum have developed a system of categorising SREs that considers several determining factors. The recognition of SREs is often hampered by the following factors:

- **Poor regional survey density** (sometimes taxon-specific): A regional fauna is simply not known well enough to assess the distribution of species. This factor also considers the fact that, simply because a species has not been found regionally, does not mean it is really absent; this confirmation ('negative proof') is almost impossible to obtain ('absence of proof is not proof of absence').

- **Poor of taxonomic resolution**: many potential SRE taxa (based on habitat constraints, SRE status of closely related species, or morphological peculiarities such as troglomorphism) have never been taxonomically treated and identification to species level is very difficult or impossible as species-specific character systems have not been defined. Good taxonomic resolution does not necessarily require a published revision, but generally requires a taxonomist to be actively working on this group or a well-established, preferably publicly available, reference collection (i.e. museum collection).
- **Problems of identification**: SRE surveys often recover life stages of potential SRE taxa that cannot be confidently identified based on morphological characters, even if revisions exist. These include, for example, juvenile or female millipedes, mygalomorph spiders and scorpions. Molecular techniques are increasingly being employed to overcome these identification problems.

Considering these factors of uncertainty, Phoenix and the WA Museum employ a three-tier system to categorise the different probabilities of short-range endemism: confirmed, likely or potential SREs. These categories are dynamic and can change with the inclusion of new taxonomic or survey information, as knowledge of determining factors is updated.

Although the different categories of 'SRE-likelihood' may help to set conservation priorities, SRE species of all categories should be assessed on their merit in order to determine appropriate conservation measures that adhere to the Precautionary Principle within EIA. That is, "*where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason to postpone measures to prevent environmental degradation*" (EPA 2002).

Table 2-1 SRE categories reflecting survey, taxonomic and identification uncertainties

SRE category	Criteria	Typical subterranean representative
Confirmed	Confirmed or almost certainly SRE; taxonomy of the group is well known (but not necessarily published); group well represented in collections, in particular from the region in question; high levels of endemism in documented species; identification is often possible from immature specimens.	Troglobitic Pseudoscorpiones, Araneae and Isopoda Stygobitic Amphipoda and Isopoda Some copepods, Parastenocarididae (Harpacticoida)
Likely	Taxonomically poorly resolved group; unusual morphology for the group (i.e. some form of troglomorphism); often singleton in survey and few, if any, regional records.	Symphyla, Palpigradi, Diplura, Chilopoda (Cryptopidae) Syncarida and stygobitic Ostracoda
Potential	Taxonomically poorly resolved group; often common in certain microhabitats in SRE surveys (i.e. litter dwellers), but no other regional records; congeners are often widespread; identification often dependent on mature specimens of specific sex.	Species within the genus *Nocticola* (Blattaria) and representatives of the families Meenoplidae (Hemiptera) and Polyxenidae (Diplopoda). Stygobitic Copepoda and Oligochaeta.

2.3.4 Threatening processes

Impacts to subterranean fauna can be classed as:

- **primary impacts:** impacts that physically destroy the subterranean void networks
- **secondary impacts:** impacts that change the subterranean habitat without physically destroying the void networks.

Primary impacts are obvious, whereas secondary impacts tend to be cumulative and may affect a far greater area than that being developed (Hamilton-Smith & Eberhard 2000). There are commonly two key threatening processes from mining activities that impact subterranean fauna through the direct loss of habitat:

- **Development of mine pits:** the most obvious primary impact to subterranean habitats occurs as a result of their physical removal during mining. Troglofauna require air-filled void networks and most of this habitat exists in the overburden, which is typically destroyed during pit construction/excavation. Similarly, direct loss of stygofauna habitat may be caused by the removal of geological formations if any aquifers are associated with these formations.
- **Depletion of an aquifer leading to loss of stygofauna habitat:** depletion of an aquifer that is identified as suitable for stygofauna represents a direct loss of stygofauna habitat. The significance of the impact is dependent on the depth of drawdown, the size and extent of the aquifer and the connectivity of the aquifer with adjacent habitat for stygofauna. The EPA typically considers a lowering of the water table by more than 10 m to be a significant impact.

Secondary impacts are those that affect the physicochemical properties of subterranean habitats. The nature of these changes can be difficult to measure and there is limited empirical evidence to support or refute these putative impacts. There are four secondary impacts that are often relevant to projects:

- **Depletion of an aquifer leading to altered relative humidity:** troglofauna are dependent on high relative humidity (Barr 1968; Humphreys 2000; Humphreys 1991). Dewatering may impact troglofauna habitat in unsaturated strata above the water table by lowering relative humidity.
- **Nutrient starvation:** surface vegetation is the primary source of nutrients entering subterranean systems. Large-scale clearing of vegetation may result in the localised nutrient starvation of underlying subterranean habitat. Smothering of these nutrient sources on which subterranean systems depend, in the form of waste and overburden stockpiles and tailings ponds, may reduce inflow of nutrients to subterranean systems and lead to nutrient deficient habitats.
- **Vibration:** propagation of shock waves through subterranean strata from blasting or heavy vehicle traffic may result in the collapse of less-consolidated void spaces and also impact physically on subterranean fauna. There is little data to challenge or corroborate these observations and impacts would generally be localised rather than critically threatening.
- **Contamination:** contamination of subterranean habitats from spills, such as diesel fuel, may degrade the quality of subterranean habitats. Such impacts would generally be highly localised and minor in scale; however, major contamination of subterranean habitats may have significant impacts.
- **Siltation:** vertical siltation of stygofauna habitat may occur from dislodgement of fine particles in substrates directly beneath the mining pit as a result of percussion disturbances

from heavy machinery and explosive blasting. The impact on stygofauna from vertical siltation fauna is not well understood.

3 METHODS

3.1 DESKTOP REVIEW

The following database searches were requested or undertaken:

- WA Museum Crustacea database, Arachnology/Myriapodology database and Subterranean Fauna database - search grid for each search extended ca. 100 km beyond the study area boundaries (21.87°S, 116.52°E; 23.72°S, 118.45°E; Datum, WGS84)
- DEC Pilbara Stygofauna Survey (PSS) – search grid the same as WA Museum searches

A literature review of published journal articles and EIA documents from surveys in the vicinity of the Project was undertaken to identify any subterranean fauna species records that may not be captured in the databases:

- West Turner Syncline Section 10 potential short range endemic fauna species risk assessment (Biota 2008c).
- Brockman Syncline 4 Project baseline stygofauna assessment (Biota 2005)
- Nammuldi stygofauna assessment programme (Biota 2003a)
- Turee Syncline troglofauna survey (Bennelongia 2012)
- Marandoo Mine Phase 2 subterranean fauna assessment (Biota 2008a)
- West Angelas stygofauna survey (Biota 2008b, 2003b; Ecologia 2002, 1998)
- Solomon Project Kings Deposit subterranean fauna survey and assessment (Subterranean Ecology 2010).

3.2 FIELD METHODS

Bores were selected from a list provided by the client. All bores sampled were greater than six months old in accordance with EPA (2007). Bores were evenly spread across the full extent of the study area drilled in order to maximise sample coverage. In the field, all bores found to contain oil or other obvious contaminants were rejected for sampling. The locations of all of the bores surveyed are listed in Appendix 1.

During this survey, three survey methods were employed at each bore: troglofauna trapping, troglofauna bore scraping and stygofauna netting. At each bore, the sampling tasks were carried out in the following succession:

1. a water sample was taken using a disposable bailer and water quality parameters were recorded (section 3.2.2)
2. a bore scrape sample was taken (section 3.2.3)
3. a stygofauna netting sample was taken (section 3.2.5)
4. a troglofauna trap was set in the bore (section 3.2.4).

Karaman-Chappuis sampling was undertaken at creek line locations; this is a method of sampling hyporheic fauna from creeks (see section 3.2.6).

3.2.1 Survey effort

Two survey trips were conducted, representing two seasons:

- trip 1 (T1), 2–9 July 2012
- trip 2 (T2), 15–21 October 2012.

The survey effort for two survey dates and each sampling method is summarised (Table 3-1; Appendix 2).

Table 3-1 Summary of survey effort

Trip number	Number of samples collected			
	Bore scraping	Stygofauna netting	Troglofauna trapping	Regional Karaman-Chappuis sampling
T1	80	60	0	2
T2	80	60	74	0
TOTAL	160	120	74	2

3.2.2 Water quality sampling

Water quality was recorded by lowering a disposable bailer into the bore to obtain a water sample. The following water quality parameters were recorded for each bore: temperature, pH, salinity (ppt), conductivity (ms/cm), oxygen (as both percentage and parts per million), and oxygen reduction potential (OPR) (mV) (Appendix 3). Water quality was recorded using a YSI Pro Plus Water Quality Meter.

3.2.3 Bore scraping

While Guidance Statement 45a (EPA 2007) does not provide specific guidance on this survey method, bore scraping has been clearly demonstrated as a superior method to trapping (Phoenix 2011; Subterranean Ecology 2010).

Scrapes were taken from 80 bores in the study area (Figure 3-1). Samples were collected using a 150 µm plankton net, with a 'tickler device' positioned *ca*. 40 cm above the net. The assembly of net and 'tickler' is referred to as a 'scraper'. The design of the tickler device is described in Phoenix (2011) and closely follows that employed by Subterranean Ecology (2010). The effect of the 'tickler' was to gently agitate the sides of the bore and dislodge any fauna present. Dislodged troglofauna are likely to drop into the net on either lowering or retrieval of the scraper.

Scrape samples were obtained using the following methodology:

- Each bore was scraped four times along four sides: north, south, east and west. For the first scrape, the scraper was lowered and retrieved along one side of the bore, but subsequent scrapes were lowered along the side previously scraped and retrieved along the side intended for sampling.
- Where the bore intercepted the water table, the scraper was allowed to sink into the water to a depth of approximately 1 m before being retrieved, in an attempt to net any troglofauna that may have missed the net after being dislodged. In dry bores, the scraper was lowered to the bottom of the bore prior to retrieval.

- Between each scrape, the sample contents were emptied into a jug of clean water.
- After four scrapes were collected, the combined net samples were elutriated to consolidate fauna and remove sediment. Samples were then cold-fixed. Cold fixing involved the following methodology:
    - each sample was fixed with cold (~0°C) 95+% ethanol and was maintained at a constant temperature within a cooler bag or cooler box filled with ice
    - the sample was stored in the same ice bag as the ethanol for the remainder of the day
    - at the end of the day, samples were transferred and stored in a refrigerator (approximately 2°C) for at least 48 hours prior to transport to the laboratory for processing.

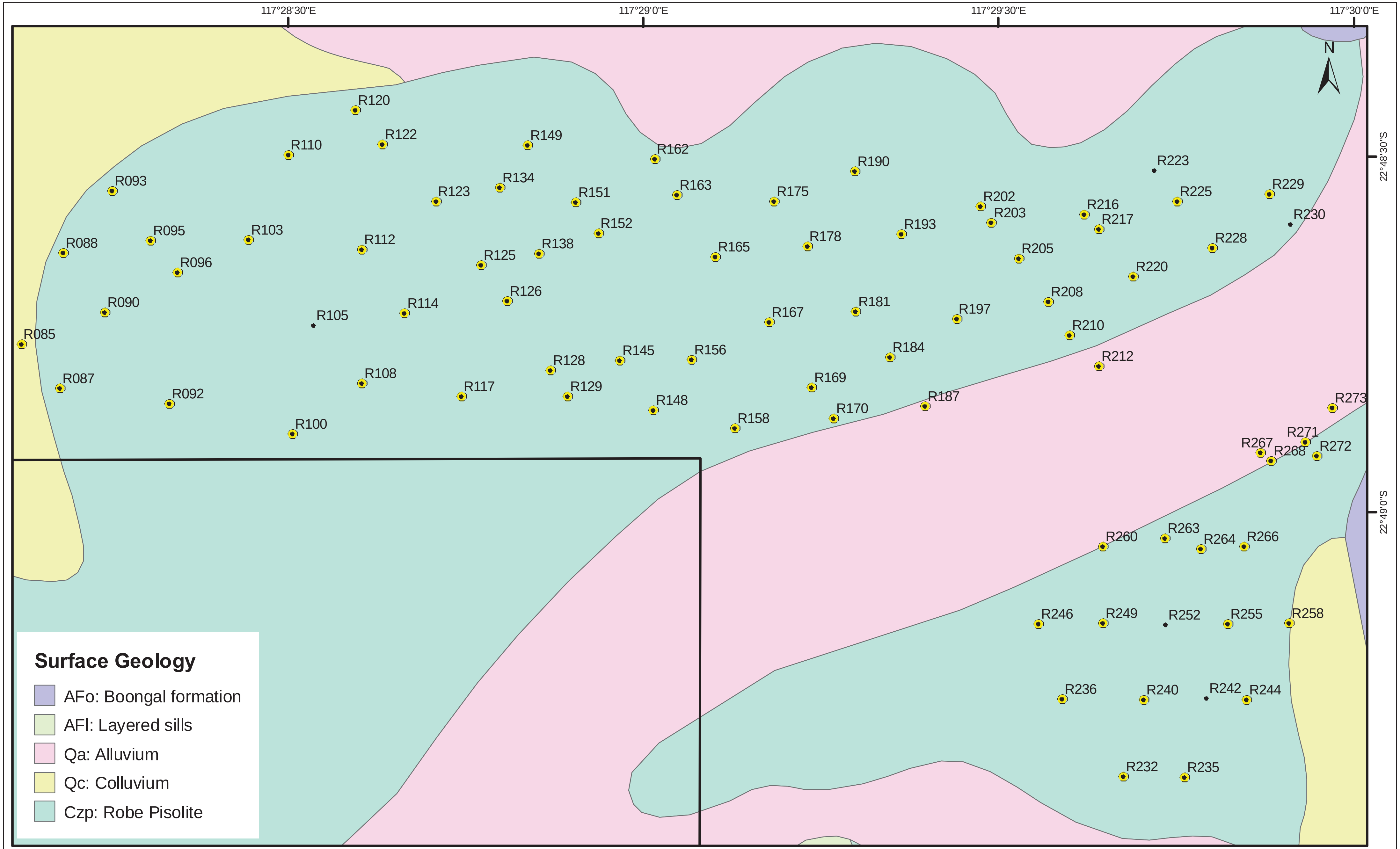

Figure 3-1 Locations of bores sampled for troglofauna

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR: E.S. Volschenk	CLIENT: Dragon Energy Ltd.
DATE: February 2013	Scale: 1:12,569

Rocklea Iron Ore Project

Coordinate System: Projection: Transverse Mercator; DATUM: GDA94

0 0.1 0.2 0.4 0.6 Kilometers

• Bore scrape Troglofauna trap Study area

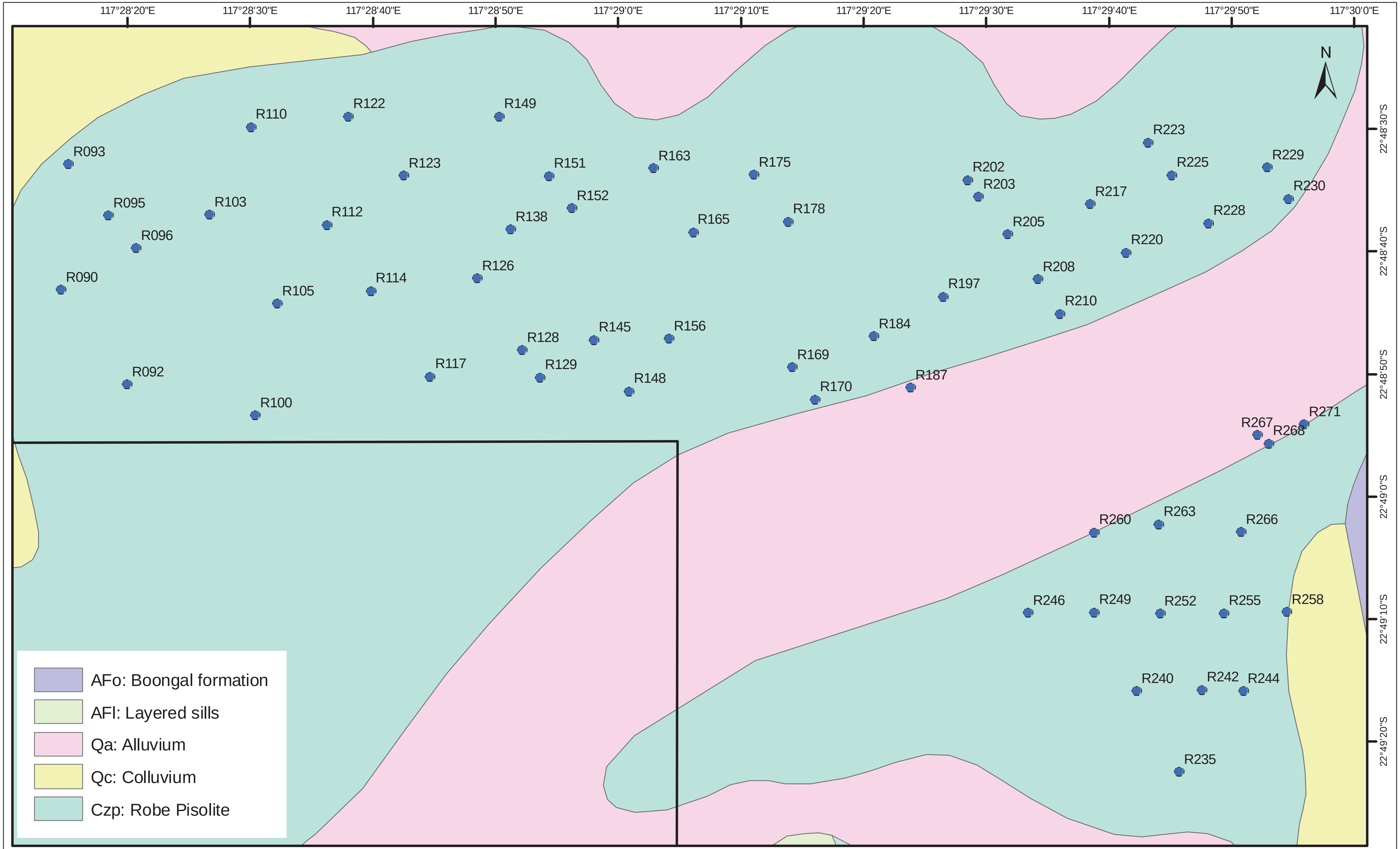

Figure 3-2 Locations of bores sampled for stygofauna

AUTHOR: E.S. Volschenk	CLIENT: Dragon Energy Ltd.
DATE: March 2013	Scale: 1:12,135

Coordinate System: Projection: Transverse Mercator; DATUM: GDA94

PHOENIX ENVIRONMENTAL SCIENCES

Rocklea Iron Ore Project

0 0.1 0.2 0.4 0.6 Kilometers

Stygofauna sampling sites

Study Area

3.2.4 Troglofauna trapping

The methodology employed for troglofauna trapping closely followed that recommended by the EPA (2007) for the surveying of troglofauna. Troglofauna trapping was conducted at 74 bores within the study area (Figure 3-1). Traps were comprised of PVC cylinders of dimensions 20 cm long and 5 cm diameter. The top end of each trap was left open to allow access by troglobites. The bottom of each trap was capped with a PVC end-cap, with a small drain hole to allow water to drain out. Traps were filled with aged and wetted spinifex litter. Approximately three days prior to deployment, the 'litter loaded' traps were flooded with boiling water, and left in the water until cooled (approximately 3 hours), in order to kill any potentially-contaminating arthropods, and to saturate the samples. After cooling, the traps were drained and packed for shipping.

At deployments, each trap was lowered into its bore until it reached the bottom of the bore, or the water table. The trap was then lifted and tied off at approximately 2-3 m above the water table or bottom of the bore.

Traps were retrieved from their bores approximately three months after initial trap placement. Each trap was placed directly into a brown paper bag, and then sealed in plastic snap lock bags prior to being placed into cooler boxes. Samples were transported to Perth in the same boxes. Traps were placed into Phoenix's custom Tullgren extractors with a programmed temperature ramp-up from 25°C to 50°C over 12 hours and were then maintained at 50°C for an additional 12 hours. If the leaf litter was still damp afterwards, the samples were re-run in the Troglofauna Extractor with the same 24 hour cycle. The process was repeated until all the leaf litter in all of the samples was completely dry.

3.2.5 Stygofauna netting

The methodology employed for stygofauna netting closely followed that recommended by the EPA (2007) for the surveying of stygofauna. Stygofauna netting was conducted at sixty bores within the study area (Figure 3-2). Six net hauls were collected from each bore using a 150 µm plankton net (three hauls), followed by a 50 µm plankton net (three hauls). Each netting assembly was fitted with a tickler device (see section 3.2.3) placed *ca.* 40 cm above the sampling net to dislodge crawling taxa from the sides of the bore. Each haul sampled the entire water column of the bore.

The six samples were elutriated in a 2 L jug to consolidate fauna and to remove excess sediments, producing a single sample for each bore. Excess water was removed from the sample and samples were cold-fixed (see section 3.2.3) to maximize DNA yields from tissues, should sequencing be required.

3.2.6 Karaman-Chappuis sampling

The Karaman-Chappuis method was used to provide regional data for interstitial fauna in accessible creeks. These samples help to evaluate the habitat constraints of fauna that were collected from bores in the 'impact area', and therefore provide regional context. The method targets interstitial fauna beneath gravel banks of rivers and streams. Some of these fauna are also likely to be present within the superficial aquifer and therefore appear in bore samples.

Karaman-Chappuis sampling was conducted at two locations along the Hardey River (Figure 3-3). A hole was dug into the gravel bank of a creek until the water table was reached. Then, as water flowed into the hole, it was scooped out and filtered through a 50 µm stygofauna net. Approximately 60 L of water was sampled per site. After filtering through the stygofauna net, the samples were elutriated and preserved following the cold fixing method (see section 3.2.3).

3.3 Taxonomy

Phoenix applies a phylogenetic species approach to taxonomy, whereby morphospecies are defined by the presence of consistent morphological characteristics Cracraft (1983). Specialist taxonomists were consulted for groups that were targeted in the survey (Table 3-2).

The morphospecies naming system used here involves the use of the highest level of taxon identification possible (genus, family, order or even class), with a naming code. The numbering code involves a letter ("D") representing the project, and a number, representing the species. For some taxa, these codes are replaces with respective WA Museum codes subsequent to lodgement.

Table 3-2 Taxonomic specialists

Personnel	Taxonomic group/s
Dr Erich S. Volschenk[1]	Arachnida (non-spiders), Amphipoda, Syncarida, Myriapoda, Insecta
Ms Anna Leung[1]	Amphipoda, Insecta
Dr Mark Harvey[2]	Arachnida, Myriapoda
Dr Michael Rix[2]	Araneae
Dr Volker Framenau[1]	Araneae
Dr Bill Humphreys[2]	Isopoda
Mr Mike Scanlon[3]	Oligochaeta
Ms Jane McRae[3]	Copepoda

[1] Phoenix Environmental Sciences; [2] Western Australian Museum; [3] Bennelongia Environmental Services

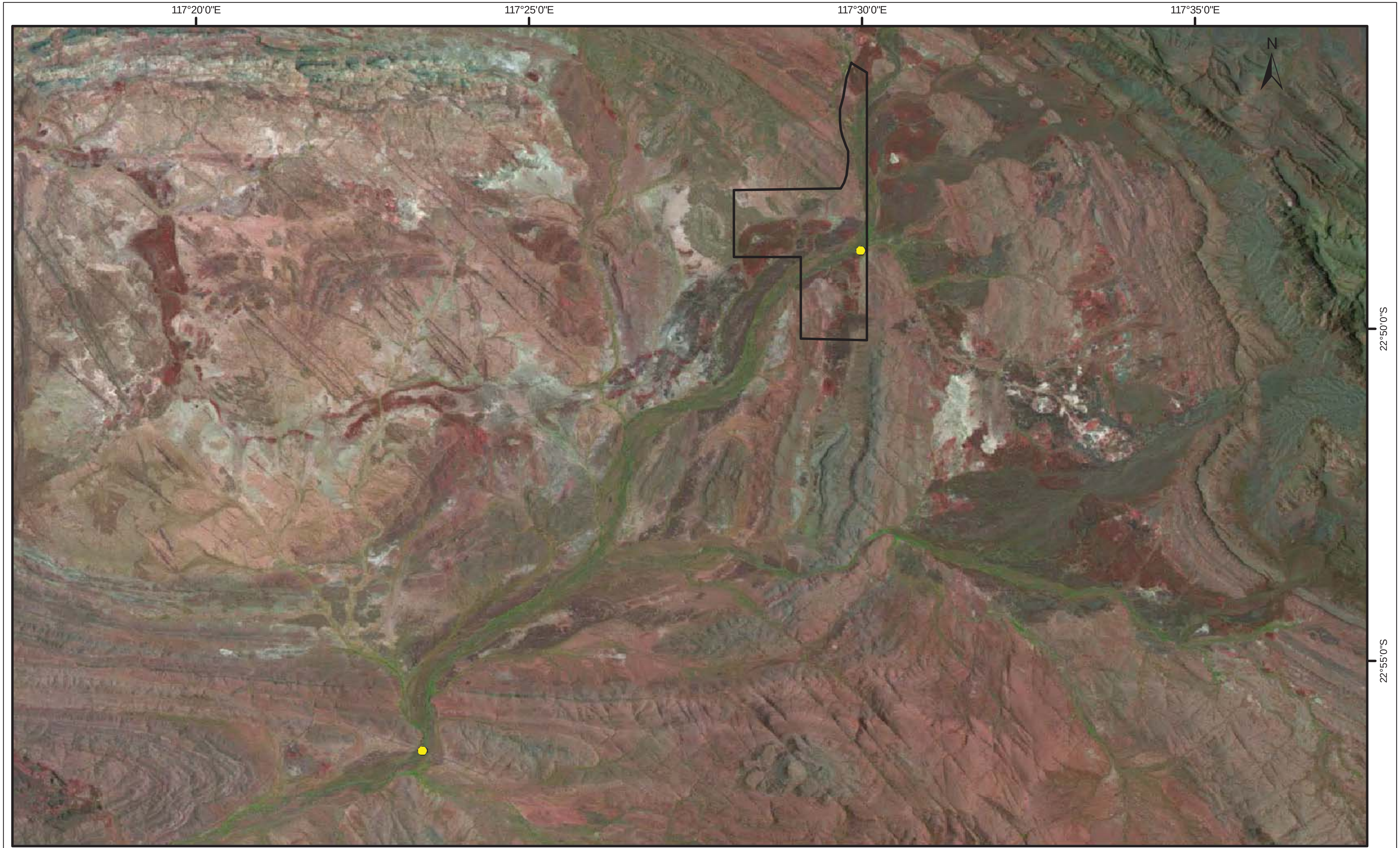

Figure 3-3 Locations of regional Karaman-Chappuis samples

AUTHOR: E.S. Volschenk	CLIENT: Dragon Energy Ltd.
DATE: February 2013	Scale: 1:134,176
Coordinate System: Projection: Transverse Mercator; DATUM: GDA94	

PHOENIX ENVIRONMENTAL SCIENCES

Rocklea Iron Ore Project

0 1.25 2.5 5 7.5 Kilometers

Study Area   Karaman-Chappuis samples

3.4 GENOMIC ANALYSES

The WA fauna collection licence (Regulation 17 *Licence to take fauna for scientific purposes*, under the *Wildlife Conservation Act 1950*) requires lodgement of voucher specimens with the WA Museum.

In some cases, the DNA of specimens representing difficult taxa is sequenced and the sequences compared with the database of Helix Molecular Solutions (Helix) to obtain regional context for species. Genomic analyses were used for specimens collected from the survey that were suspected to be SREs.

Genomic analyses were also undertaken to evaluate potentially separate communities within the study area by targeting specimens representing each community or population. The variation between these sequences was analysed at the same time as broader scale sequence comparisons at the regional (Pilbara) level.

Sequencing usually targets the gene COI (Cytochrome C Oxidase Subunit 1), also referred to as the 'barcoding gene' (Hebert *et al.* 2003b). Hebert *et*. *al* (2003b) found sequence differences of 10.1% or more between 1,400 different arthropod species, and more than 50% of these comparisons showed more than 8% sequence divergence.

Species within groups for which morphological taxonomy is not available, can be assessed by comparing the pairwise COI sequence divergences. Species with COI sequence divergences of 8%, or greater, are likely to represent different species and those with less than 8% divergence are likely to be members of the same species. In instances where COI sequences could not be obtained, the ribosomal genes 12S and 18S were targeted and used in a similar way.

Helix Molecular Solutions methodologies are described in Appendix 4.

3.5 STATISTICAL ANALYSES

The efficiency of the survey effort was evaluated by comparing the observed species richness of both troglofauna and stygofauna against the predicted species richness of seven widely used species richness estimators. Species accumulation curves and richness estimation were calculated with EstimateS (v8.2.0) using the default settings, with the following exceptions:

- species accumulation curves were smoothed using 10,000 repetitions rather than the default setting of 50 to provide greater accuracy to extrapolations
- a variety of richness estimators were used: ACE, ICE, Chao 1, Chao 2, Jack 1, Jack 2 and Bootstrap
- the coverage estimator value was set to two rather than 10, so as to more reliably treat 'rare' taxa, since troglobites are often sampled in very low numbers.

The methods used by Colwell and Coddington (1994) and Moir *et al*. (2009) were followed to examine the complementarity of sample methods. Extrapolations were performed on the abundance data; however, troglofauna data have high incidence of singletons which are essentially incidence data. For this reason we use both incidence- and abundance optimised species richness estimators.

3.6 Survey personnel and acknowledgements

The survey personnel involved in the survey are presented in (Table 3-3).

Table 3-3 Project team

Name	Role/s
Dr Erich S. Volschenk	Project Manager, field surveys, taxonomy, report writing
Ms Anna Leung	Field surveys, laboratory work, taxonomy, GIS, report writing
Ms Leanda Mason	Field surveys, laboratory work
Mr Xavier Leenders	Laboratory work
Mrs Karen Crews Dr Volker Framenau	Report review

4 RESULTS

4.1 DESKTOP REVIEW

A total of 139 unique subterranean invertebrate fauna species, morphospecies and unidentified taxa were identified in the desktop review (Appendix 5). The true species richness is likely to be higher as some of the identifications were not made to species level, i.e. “Amphipod sp.” may represent several species or a new unidentified species belonging to that order, or an unidentified species already known to occur in the area.

Of the 139 subterranean species, 39 (28.05 %) are represented by SRE troglofauna and are comprised of the following groups: Arachnida, Myriapoda, Isopoda and Insecta

Of the 139 subterranean species, 66 (47.5%) are represented by stygofauna. The stygofauna SREs are comprised of the following groups: Amphipoda, Isopoda, Syncarida, Copepoda (Harpacticoida) and Ostracoda.

The majority of subterranean fauna found in the desktop review were collected in the DEC PSS (Pilbara Stygofauna Survey) and surveys completed by environmental consultancies. The PSS surveyed over 300 bores, many of which occur within the search area (within 100 km of the study area).

4.2 FIELD SURVEY RESULTS

4.3 SURVEY SUMMARY

This field survey produced a rich sample of subterranean invertebrates. Twenty-four putative troglobites and 22 putative stygofauna species were recorded from this survey (Table 4-1).

Twenty-one species of troglofauna are thought to be either likely or potential SREs: *Anapistula* 'D1', Trochanteriidae 'D1', Palpigradi sp. indet., *Tyrannochthonius* 'D1', *Indohya* 'D1', *Draculoides* 'D1', *Cryptops* 'D1', Haplodesmidae 'D1', Haplodesmidae 'D2', Japygidae 'D1', Japygidae 'D2', Parajapygidae 'D1', Projapygidae 'D1', Projapygidae 'D2', Atelurinae 'D1', *Trinemura* sp. indet., Pauropoda 'D1', Pauropoda 'D2', Symphyla 'D1a', Symphyla 'D1b' and Symphyla 'D2'.

Three species of troglofauna are known to be widespread species and are not SREs (neither likely SRE nor potential SRE): Polyxenidae PXD1', *Nocticola* 'Pilbara1', Meenoplidae 'widespread' (Table 4-1).

Eight species of stygofauna are considered to be either likely SREs or potential SREs: Bogidiellidae 'D4', Melitidae 'D1', Melitidae 'D2', Paramelitidae 'D2', Atopobathynella 'D1', *Haptolana* 'D1', *Pygolabis eberhardi and Areacandona atomus.*

Eleven species of stygofauna were verified as belonging to widespread species and are not SREs (likely SRE or potential SRE): *Enchytraeus* 'Pilbara 1 (PSS)', *Enchytraeus* 'Pilbara 2 (PSS)', Tubificidae stygo type 1A, *Insulodrilus lacustris, Diacyclops humphreysi humphreysi, Diacyclops humphreysi unispinosus, Goniocyclops* nr *uniarticulatus, Orbuscyclops westraliensis, Abnitocrella halsei, Schizopera roberiverensis* and *Aeolosoma* sp. indet. 1 (PSS) (Table 4-1).

Sixteen (66.6%) of the 24 troglobitic species and four (21.05%) of the 19 stygofauna were represented by singletons.

Twelve groups are either partly or completely unresolved taxonomically, owing to inconclusive genomic or morphological data (all. “sp. indet.”; Table 4-1).

Two species of stygofauna (*Diacyclops humphreysi humphreysi* and *Insulodrilus lacustris*) were also obtained in Karaman-Chappuis samples, indicating that they are more likely to be stygophiles than stygobites.

Table 4-1 Subterranean fauna recorded during the surveys over all survey phases and from all sampling sites

Class	Order	Family	Morphospecies	Ecotype	SRE status
Arachnida	Araneae	Symphytognathidae	*Anapistula* 'D1'[2]	Troglobite	Likely SRE
		Trochanteriidae	Trochanteriidae 'D1'[2]	Troglobite	Likely SRE
	Palpigradi	Palpigradi[1]	Palpigradi sp. indet.[3]	Troglobite	Likely SRE
	Pseudoscorpiones	Chthoniidae	*Tyrannochthonius* 'D1'[2]	Troglobite	Likely SRE
		Hyidae	*Indohya* 'D1'[2]	Troglobite	Likely SRE
		Olpiidae	Olpiidae sp. indet.[3]	Epigean	Not an SRE
	Schizomida	Hubbardiidae	*Draculoides* 'D1'[2]	Troglobite	Likely SRE
Chilopoda	Geophilomorpha	Geophilomorpha[1]	Geophilomorpha sp. indet.	Epigean	Potential SRE
	Scolopendromorpha	Cryptopidae	*Cryptops* 'D1'[2]	Troglobite	Potential SRE
Clitellata	Haplotaxida	Enchytraeidae	Enchytraeidae sp. indet.[3]	Stygobite	Potential SRE
			Enchytraeus 'Pilbara 1 (PSS)'	Stygobite	Not an SRE
			Enchytraeus 'Pilbara 2 (PSS)'	Stygobite	Not an SRE
		Naididae	Tubificidae stygo type 1A	Stygobite	Not an SRE
		Phreodrilidae	*Insulodrilus lacustris*	Stygophile	Not an SRE
			Insulodrilus sp. indet.[3]	Stygobite	Not an SRE
			Phreodrilidae 'with dissimilar ventral chaetae'	Stygophile	Undetermined
			Phreodrilidae sp. indet.[3]	Stygophile	Undetermined
			Phreodrilus sp. indet.[3]	Stygophile	Undetermined
	Oligochaeta[1]	Oligochaeta[1]	Oligochaeta sp. indet.[3]	Stygobite	Undetermined
Diplopoda	Polydesmida	Haplodesmidae	Haplodesmidae 'D1'[2]	Troglobite	Likely SRE
			Haplodesmidae 'D2'[2]	Troglobite	Likely SRE
			Haplodesmidae sp. indet.[3]	Troglobite	Potential SRE
	Polyxenida	Polyxenidae	Polyxenidae PXD1'[2]	Troglobite	Not an SRE
Entognatha	Diplura	Japygidae	Japygidae 'D1'[2]	Troglobite	Likely SRE

Class	Order	Family	Morphospecies	Ecotype	SRE status
		Japygidae	Japygidae 'D2'[2]	Troglobite	Likely SRE
		Parajapygidae	Parajapygidae 'D1'[2]	Troglobite	Likely SRE
		Projapygidae	Projapygidae 'D1'[2]	Troglobite	Likely SRE
			Projapygidae 'D2'[2]	Troglobite	Likely SRE
Insecta	Blattaria	Nocticolidae	*Nocticola* 'Pilbara1'[2]	Troglobite	Not an SRE
	Hemiptera	Meenoplidae	Meenoplidae 'widespread'[2]	Troglobite	Not an SRE
	Thysanura	Nicoletiidae	Atelurinae 'D1'[2]	Troglobite	Likely SRE
			Trinemura sp. indet. [3]	Troglobite	Likely SRE
Malacostraca	Amphipoda	Amphipoda[1]	Amphipoda sp. indet. [3]	Stygobite	Undetermined
		Bogidiellidae	Bogidiellidae 'D4'[2]	Stygobite	Likely SRE
		Melitidae	Melitidae 'D1'[2]	Stygobite	Likely SRE
		Melitidae	Melitidae 'D2'[2]	Stygobite	Likely SRE
		Paramelitidae	Paramelitidae 'D2'	Stygobite	Likely SRE
	Bathynellacea	Parabathynellidae	Atopobathynella 'D1'[2]	Stygobite	Likely SRE
	Isopoda	Cirolanidae	*Haptolana* 'D1'[2]	Stygobite	Likely SRE
		Tainisopidae	*Pygolabis eberhardi*	Stygophile	Likely SRE
Maxillopoda	Cyclopoida	Cyclopidae	*Diacyclops humphreysi humphreysi*	Stygophile	Not an SRE
			Diacyclops humphreysi unispinosus	Stygophile	Not an SRE
			Goniocyclops nr *uniarticulatus*	Stygophile	Not an SRE
			Orbuscyclops westraliensis	Stygobite	Not an SRE
			Cyclopoida sp. indet.[3]	Stygobite	Undetermined
	Harpacticoida	Ameiridae	*Abnitocrella halsei*	Stygobite	Not an SRE
		Diosaccidae	*Schizopera roberiverensis*	Stygobite	Not an SRE
Ostracoda	Podocopida	Candonidae	*Areacandona atomus*	Stygobite	Potential SRE
			Candonidae sp. indet.[3]	Stygobite	Potential SRE
Pauropoda	Pauropoda[1]	Pauropoda[1]	Pauropoda 'D1'[2]	Troglobite	Likely SRE

Class	Order	Family	Morphospecies	Ecotype	SRE status
			Pauropoda 'D2'[2]	Troglobite	Likely SRE
			Pauropoda sp. indet. [3]	Troglobite	Likely SRE
Polychaeta	Scolecida[1]	Aeolosomatidae	*Aeolosoma* sp. indet. 1 (PSS)	Stygobite	Not an SRE
Symphyla	Symphyla[1]	Symphyla[1]	Symphyla 'D1a'[2]	Troglobite	Likely SRE
			Symphyla 'D1b'[2]	Troglobite	Likely SRE
			Symphyla 'D2'[2]	Troglobite	Likely SRE
			Symphyla sp. indet.[3]	Troglobite	Potential SRE

[1] represents unresolved classifications; the name of the highest clear taxon rank was used instead.

[2] species identifications confirmed using genomic barcoding.

[3] taxa for which species level identifications were not possible owing to poor specimens or challenging taxonomy

4.4 ASSESSMENT OF SPECIES RICHNESS

4.4.1 Troglofauna species richness estimation and evaluation of survey results

The species accumulation curves for leaf litter traps plateau at three species, whereas scraping data indicate an almost linear increase in species richness without plateauing of the curve (Figure 4-1). Scraping sampled more fauna at a higher rate than other methods used, and is consistent with previous surveys (Phoenix 2011; Subterranean Ecology 2010).

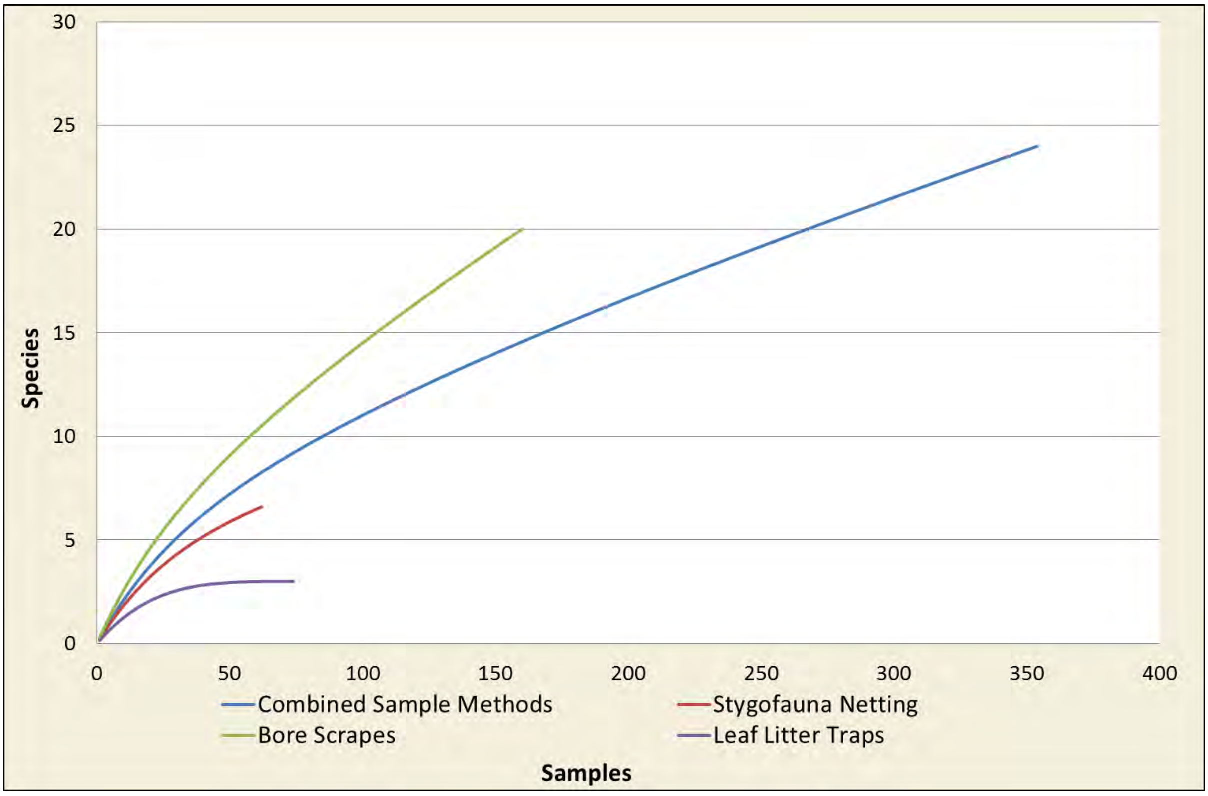

Figure 4-1 Species accumulation curves for troglofauna sampling

The troglofauna richness estimation indicates that between 30 and 160 species were predicted to occur within the study area (Table 4-2, Figure 4-2). With 23 troglofauna species recorded from this survey, the percentage of species sampled relative to extrapolated species richness ranges from 14% to 79% (Figure 4-2).

Table 4-2 Estimation of troglofauna richness using seven commonly used richness estimators

	Observed species richness	ACE mean	ICE mean	Chao 1 mean	Chao 2 mean	Jack 1 mean	Jack 2 mean	Bootstrap mean
Combined (354)	24	129	160	129	152	39.95	54.8	30.11

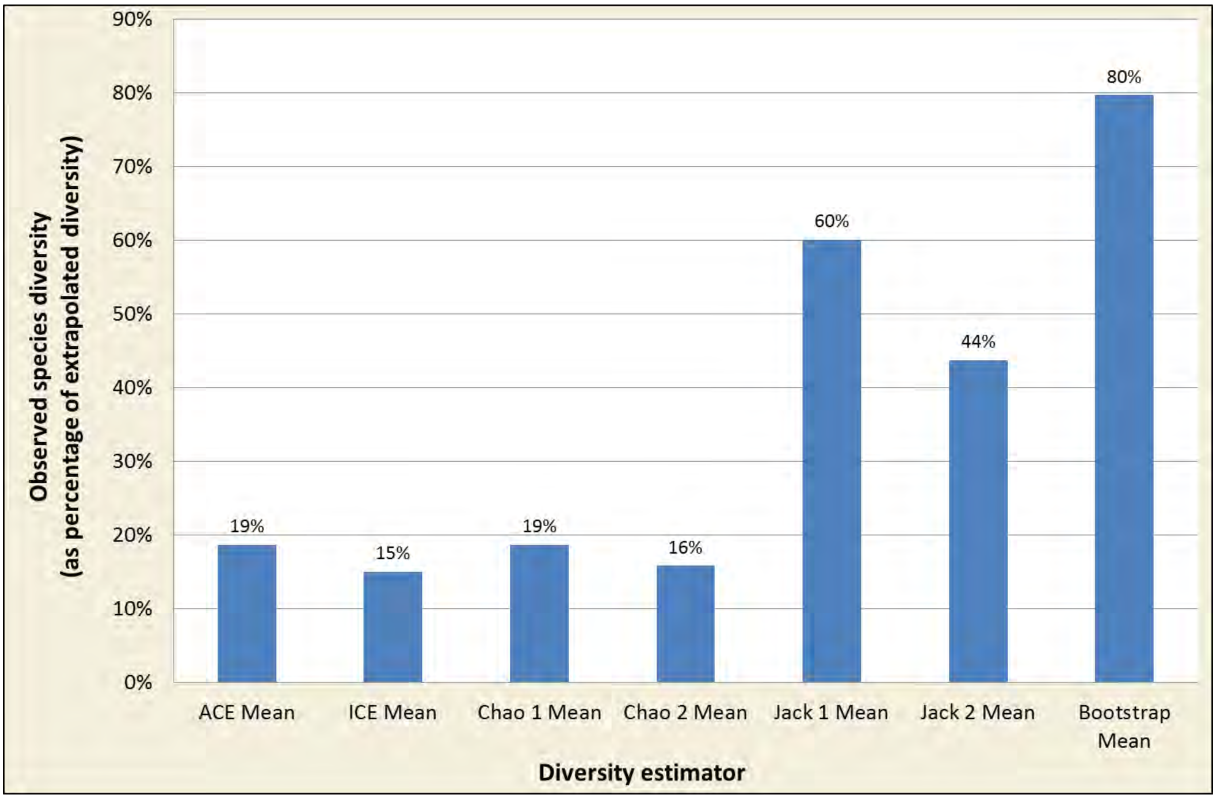

Figure 4-2 **Observed troglofauna species richness as a percentage of extrapolated species richness**

4.4.2 Stygofauna species richness estimation and evaluation of survey results

The species accumulation curves for each sampling method (and combined methods) indicate that the rate of species accumulation is generally in a plateauing trend (Figure 4-3). This trend is supported by the relatively high proportion of species richness relative to the extrapolated species richness values for abundance optimised species richness estimators (Table 4-3 and Figure 4-4).

Stygofauna species richness was extrapolated to between 21 (Bootstrap mean) and 47 (ICE mean) species (Table 4-3). Owing to the low degree (four) of singletons and doubletons in this data matrix, the estimators optimised for abundance data may be more reliable, indicating between 21 and 25 species present. The recorded species richness of 19 species represents between 73% and 87% of the extrapolated species richness (Figure 4-4).

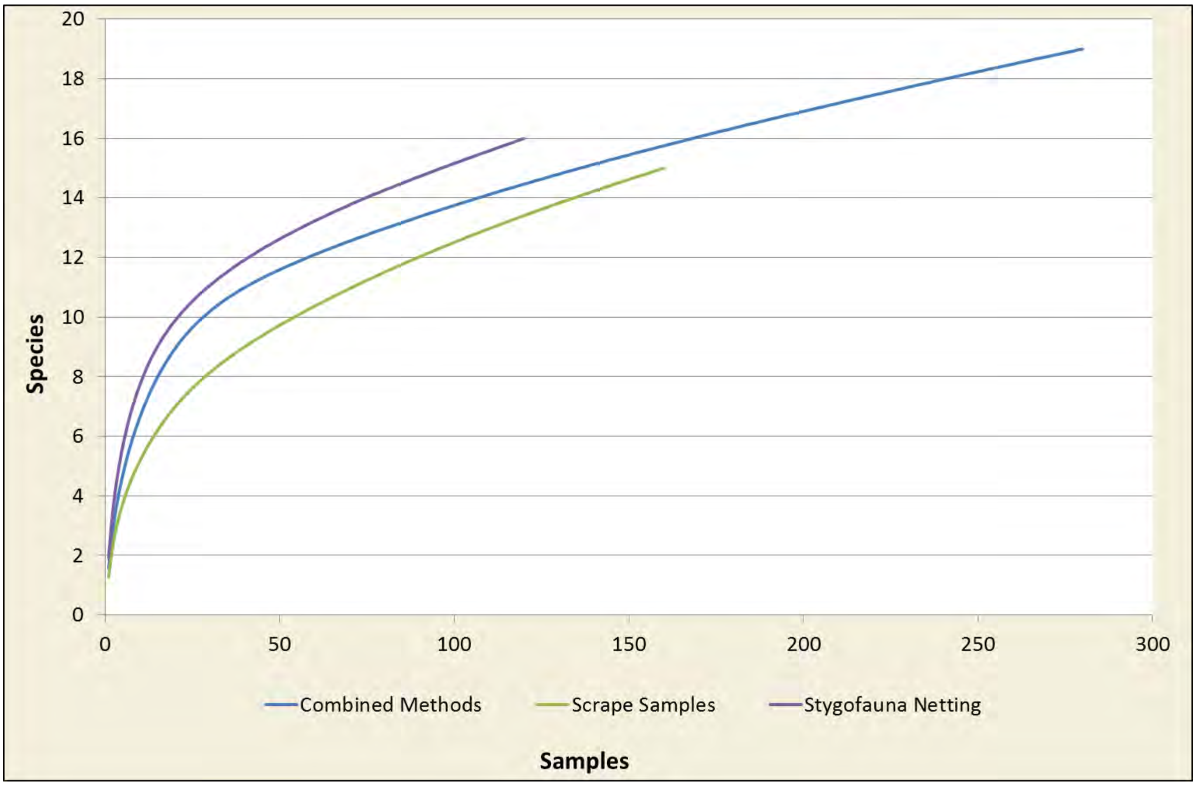

Figure 4-3 **Species accumulation curves for stygofauna sampling**

Table 4-3 **Estimation of stygofauna richness using seven commonly used richness estimators**

	Observed diversity	ACE mean	ICE mean	Chao 1 mean	Chao 2 mean	Jack 1 mean	Jack 2 mean	Bootstrap mean
Combined samples (280)	19	25	47	25	43.5	25.9	31.94	21.74

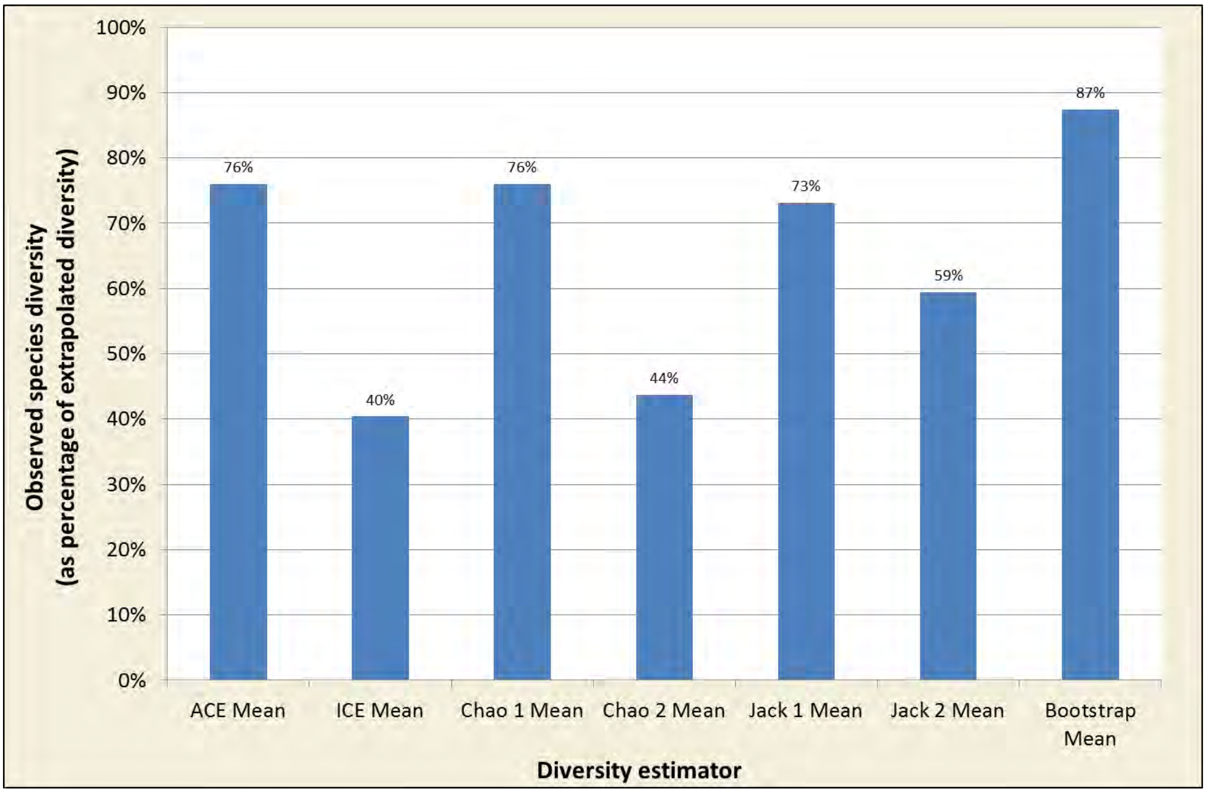

Figure 4-4 **Observed stygofauna species richness as a percentage of extrapolated species richness**

4.5 TROGLOFAUNA RECORDS

Twenty-four putative troglobitic species were recorded from this survey. A total sample effort of 354 samples yielded 194 individuals from the 24 species. Of the troglobitic samples collected, 17 (70.8%) were represented by only one or two specimens (Figure 4-5). Troglobitic species were recorded from 47 bores (Figure 4-6) and all of these sites recorded troglobitic SREs.

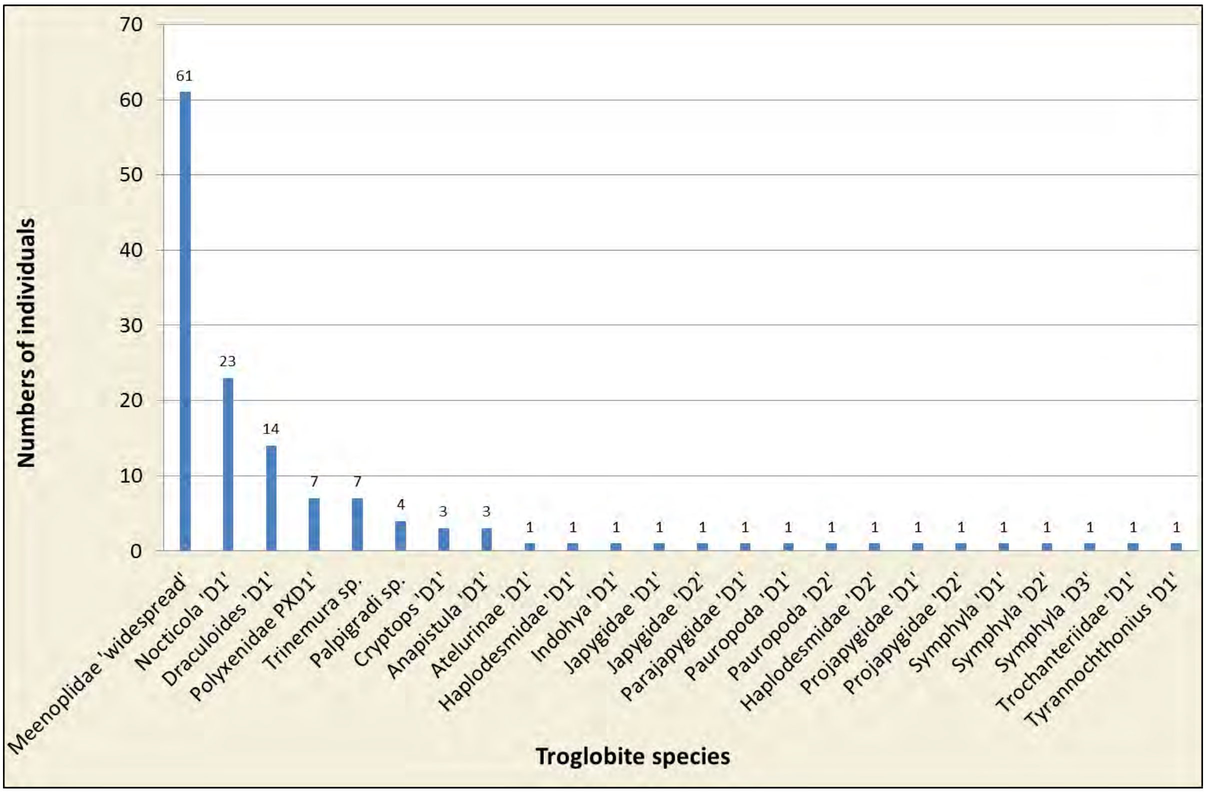

Figure 4-5 Abundance records for troglobitic species

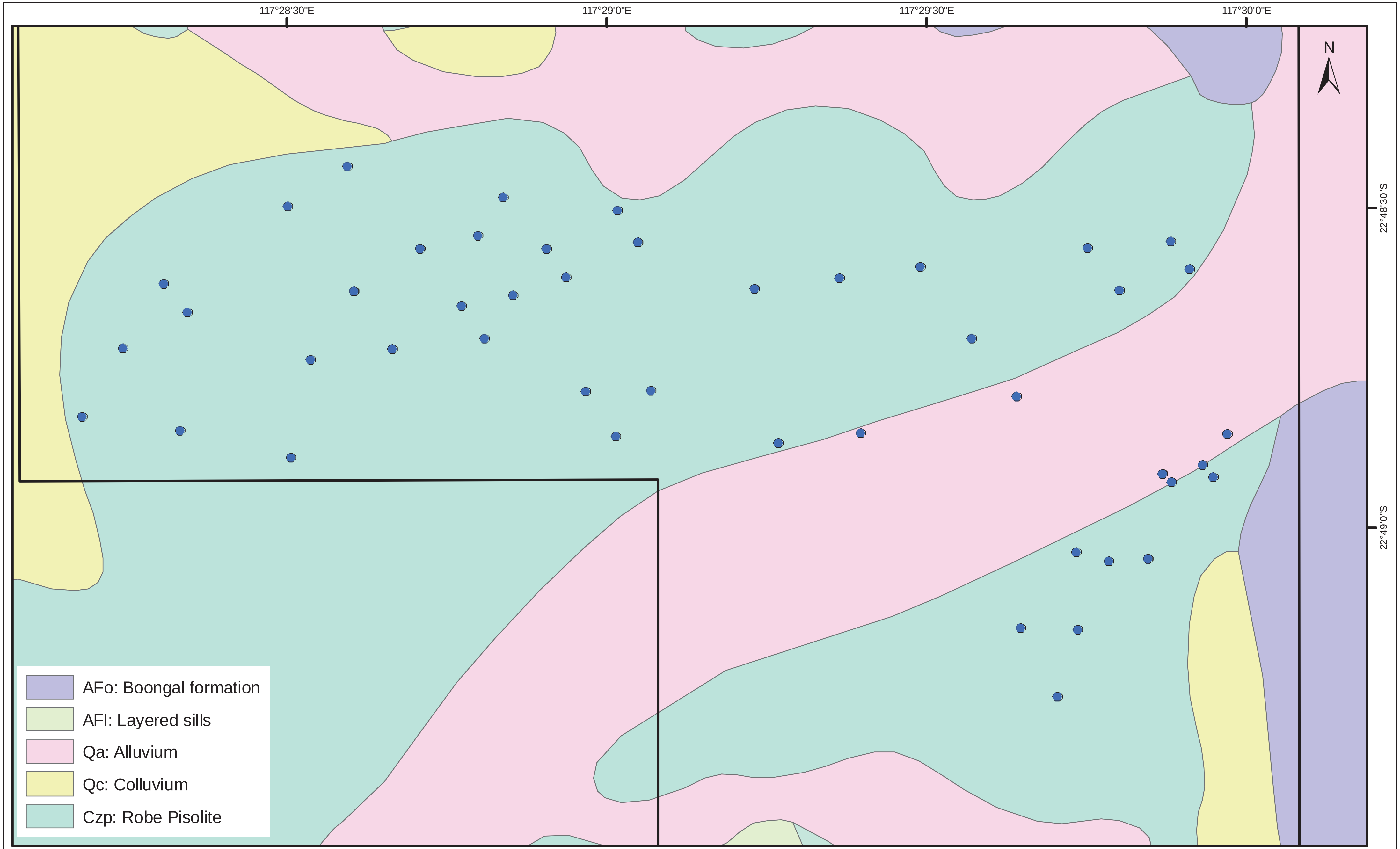

Figure 4-6 Troglofauna species records from the survey

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AUTHOR: E.S. Volschenk	CLIENT: Dragon Energy Ltd.
DATE: February 2013	Scale: 1:13,964

Rocklea Iron Ore Project

Coordinate System: Projection: Transverse Mercator; DATUM: GDA94

0 0.125 0.25 0.5 0.75 Kilometers

4.5.1 Arthropoda: Arachnida: Araneae

The Araneae (spiders) are characterised by a number of unique characters, including abdominal appendages modified as spinnerets, silk glands and associated spigots, cheliceral venom glands and male pedipalp tarsi modified as secondary genitalia from sperm transfer (Coddington & Levi 1991). Spiders are one of the largest and most diverse orders of arachnids with more than 40,000 described species worldwide (Platnick 2013), and approximately 3,400 species named from Australia (Framenau 2012). A small proportion of the Australian fauna are subterranean and those that are appear to have close affinities to epigean taxa, for example in the families Symphytognathidae, Tetrablemmidae and Trochanteriidae (Burger *et al.* 2010; Harvey 1998; Paquin & Dupérré 2009; Platnick 2008). The epigean relatives are often associated with wetter, tropical climates, suggesting that they have evolved from these to live underground and escape desiccation in an aridifying environment (Cardoso & Scharff 2009).

Infraorder Araneomorphae (modern spiders)

Araneomorphae (modern spiders) differ from the Mygalomorphae by the opposing orientation of the fangs (these are striking downwards in the Mygalomorphae) and only one pair of booklungs (two pairs in the Mygalomorphae). In contrast to the Mygalomorphae, modern spiders are rarely targeted in terrestrial SRE surveys. Araneomorphae often disperse very well through a mechanism called ballooning ‘ballooning’ (e.g. Bell *et al.* 2005). Using this method of dispersal, many araneomorph species are dispersed across Australian (Harvey 2002); however, modern spiders have regularly been recovered from subterranean environments where they are usually SREs (Gray 1973, 1992; Harvey 1998; Platnick 2002, 2008).

4.5.1.1 *Anapistula* 'D1' (Symphytognathidae)

Dwarf orb-weaving spiders are extremely small spiders, often less than 1 mm body length in adult males and females (Cardoso & Scharff 2009) Symphytognathids don’t have booklungs; apparently their small size allows them to breathe through their cuticular surface. Other characters of the family includes a fusion of the base of the chelicerae and a reduction of pedipalps in females. The family was originally described from Australia, based on spiders collected in Tasmania (Hickman 1931). At present, eight species of dwarf orb-weavng spiders are described from Australia in the genera *Anapistula* and *Symphytognatha* (Harvey 1992, 1998, 2001).

Anapistula differs from the only other Australian genus of Symphytognathidae, *Symphytognatha*, by the generally lower carapace and a retention of posterior abdominal spiracles (Harvey 1998). They are amongst the smallest spiders with adults approximately 0.5 mm in body length (Cardoso & Scharff 2009). *Anapistula* is a largely tropical genus. Four species are described in Australia; *A. australia* from Queensland, *A. cuttacutta* and *A. bifurctata* the Northern Territory and *A. troglobia* from Cape Range in Western Australia; *A. cuttacutta* and *A. troglobia* have been reported from caves or carst (Harvey 1998). Further undescribed troglobitic species from northern WA are present in the collection of the WA Museum.

Survey records: *Anapistula* 'D1'(Figure 4-7) was represented by three specimens, recorded from the following three bores (Figure 4-9): R240; R268 [DNA]; R267.
Taxonomic resolution: specimens collected were all juveniles and therefore could not be identified to the level of species based on morphology.

[DNA] sites from which sequenced specimens were obtained.

Genomic taxonomy: tissues of one specimen of this species were sequenced in order to obtain genomic comparisons with other WA species. *Anapistula* 'D1' differed from the reference species *Anapistula* species by between 11.1% and 13.0% sequence divergence indicating that it is a different species (Appendix 4).

SRE status: *Anapistula* 'D1' is a likely SRE.

Known distribution: only known from this survey.

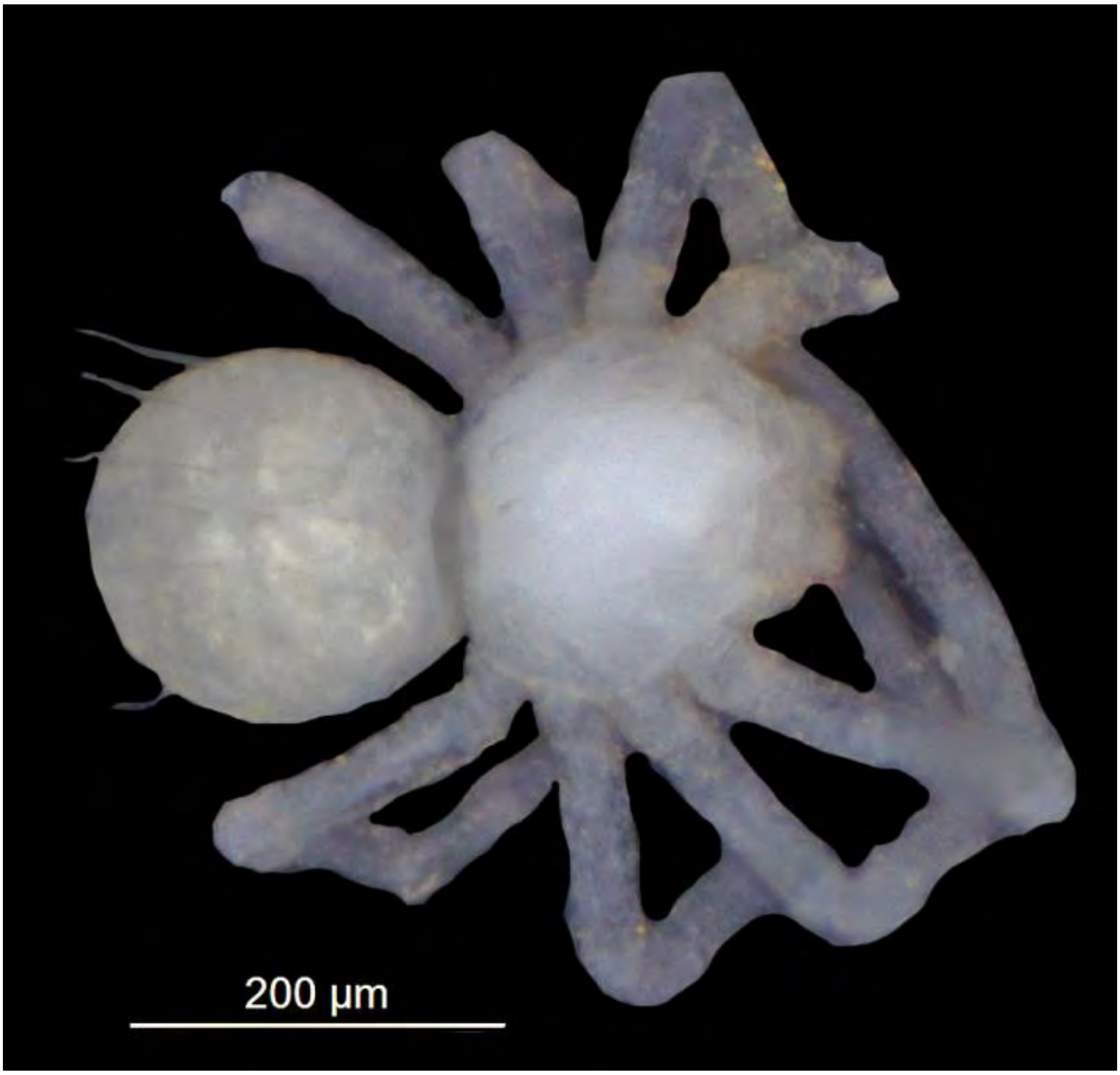

Figure 4-7 Image of *Anapistula* 'D1'

4.5.1.2 Trochanteriidae 'D1'

The spider family Trochanteriidae, the long-jawed ground spiders, includes very small to very large spiders. They generally have a greatly flattened carapace with the eyes occupying most of the carapace width. The family name is derived from a greatly elongated trochanter of the fourth leg which might be more than twice as long as that of the third leg; however, this elongation is found in only a few trochanteriid genera (Platnick 2002). Some 115 species of Trochanteriidae in seventeen genera are known from Australia. A single non-indigenous species, *Platyoides walteri*, has apparently been introduce to Western Australia from Africa (Platnick 2002). Dorso-ventrally flattened trochanteriid morphology reflects their habitat preferences for narrow cracks and crevices such as under bark or slabs of exfoliating rock on rocky outcrops.

Trochanteriidae are known to contain troglobitic species, including *Olin platnicki* from South-east Asia and Christmas Island (Platnick 2002) and *Desognanops humphreysi* from the Mid West region of Western Australia (Platnick 2008).

The Dragon specimen has an elongated trochanter IV and is therefore in all likelihood a trochanteriid.

Survey records: Trochanteriidae 'D1' (Figure 4-8) was represented by a single specimen from the site R178^{DNA} (Figure 4-9).

Taxonomic resolution: morphological examination indicated that it is a sub adult, making identification to species level (requiring adult morphology) impossible. The specimen has an elongated trochanter IV and is therefore in all likelihood a trochanteriid (M. Rix, pers. comm., Research Associate, WA Museum, February 2013).

Genomic taxonomy: the COI sequence from this species differed from other reference spider sequences from the Pilbara by between 19.3% and 27.9% sequence divergence, indicating that it is a different species to the subterranean spiders previously sequenced from the Pilbara (Appendix 4).

Helix also included several other family representatives in the analysis in order to try and better place this species. Helix placed this species near *Dysdera hernadezi* (Dysderidae), a family not closely related to Trochanteriidae; however, the latter data set did not contain representatives of any of the gnaphosoid families (no available sequences), and so the morphological assessment was not properly tested.

SRE status: Trochanteriidae 'D1' is a likely SRE.

Known distribution: the distribution of this species is restricted to the records obtained from this survey. While other subterranean gnaphosoids are known from the Pilbara (M. Harvey pers. comm., Senior Curator Terrestrial Invertebrates, WA Museum, February 2013) none have been sequenced and are thus impossible to compare with the Rocklea specimen as it is a subadult.

Figure 4-8 **Image of Trochanteriidae 'D1'**

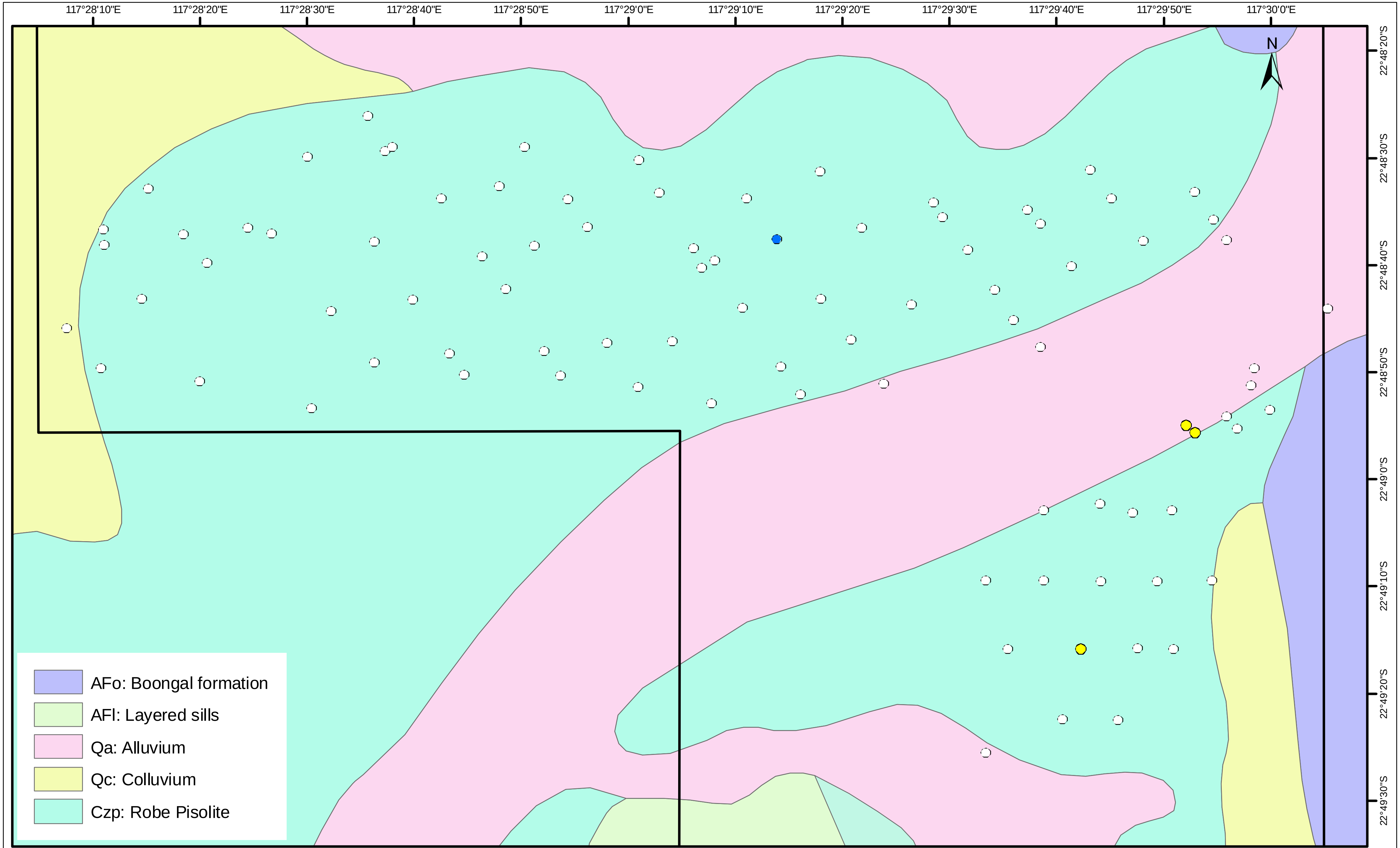

Figure 4-9 Troglobitic spider site records

AUTHOR: E.S. Volschenk	**CLIENT:** Dragon Energy Ltd.
DATE: February 2013	**Scale:** 1:13,906

PHOENIX ENVIRONMENTAL SCIENCES

Rocklea Iron Ore Project

Coordinate System: Projection: Transverse Mercator; DATUM: GDA94

0 0.125 0.25 0.5 0.75 Kilometers

Trochanteriidae 'D1'
Anapistula 'D1'
Survey Sites
Study Area

4.5.2 Arthropoda: Arachnida: Palpigradi

Palpigrades, commonly known as microwhip scorpions, are an order of arachnid and are therefore related to spiders and scorpions; however, their position within the Arachnida is enigmatic with no clear relationship to the other arachnid orders (Shultz 1990; Wheeler & Hayashi 1998). They are very small (usually only a few millimetres), pale and possess a distinctively long articulated tail. The tail is very fragile and typically broken off during the sampling process.

Palpigrades inhabit moist soils and leaf litter (Barranco & Harvey 2008). The order is distributed worldwide including Australia; however, few Australian species have been described. For a long time, it was thought that only two introduced species occurred in Australia (Harvey & Yen 1989) but in recent years, several endemic species have been discovered from the Pilbara region (Phoenix 2011).

4.5.2.1 Palpigradi sp. indet.

Survey records: Palpigradi sp. indet. (Figure 4-10) were represented by four specimens, recorded from the following two bores (Figure 4-11): R271 and R100.

Taxonomic resolution: very little is known about the subterranean Palpigradi of WA and there are no palpigrade experts with knowledge of the Australian palpigrade fauna. Therefore, the only reliable species level identifications depend on genomic assessment. Subterranean palpigrades from the Pilbara are often locally endemic (Phoenix 2011).

Genomic taxonomy: tissues from two specimens were submitted for sequencing; however, neither sample yielded sequences.

SRE status: Palpigradi sp. indet. represents at least one (possibly more) likely SRE species. Without DNA confirmation it is unclear how many species are represented in this sample.

Known distribution: only known from this survey.

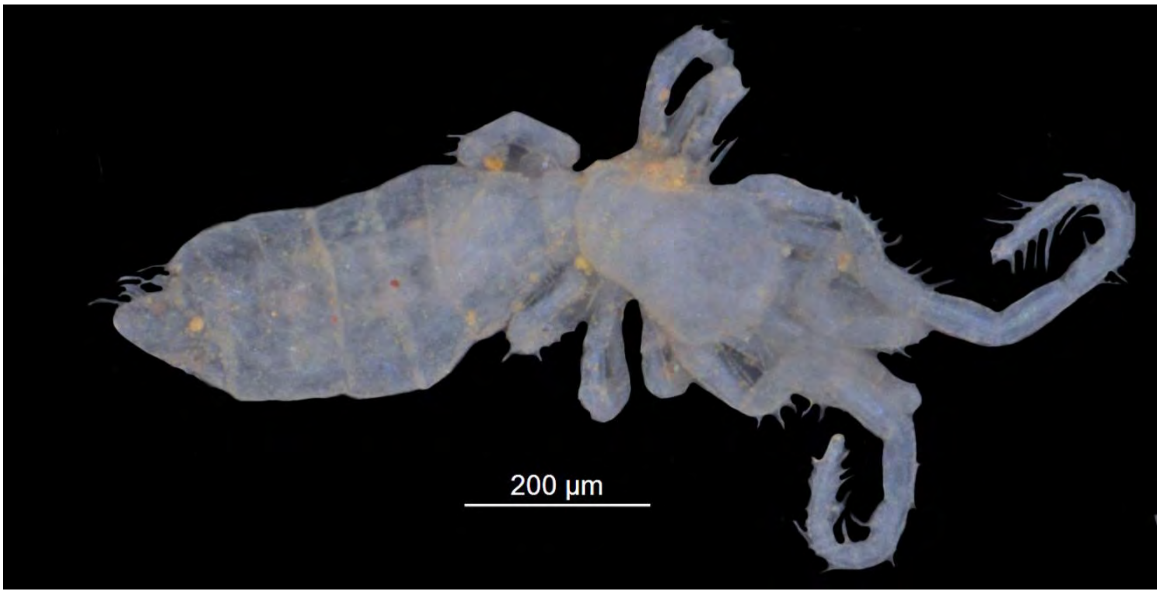

Figure 4-10 Image of Palpigradi sp. indet.

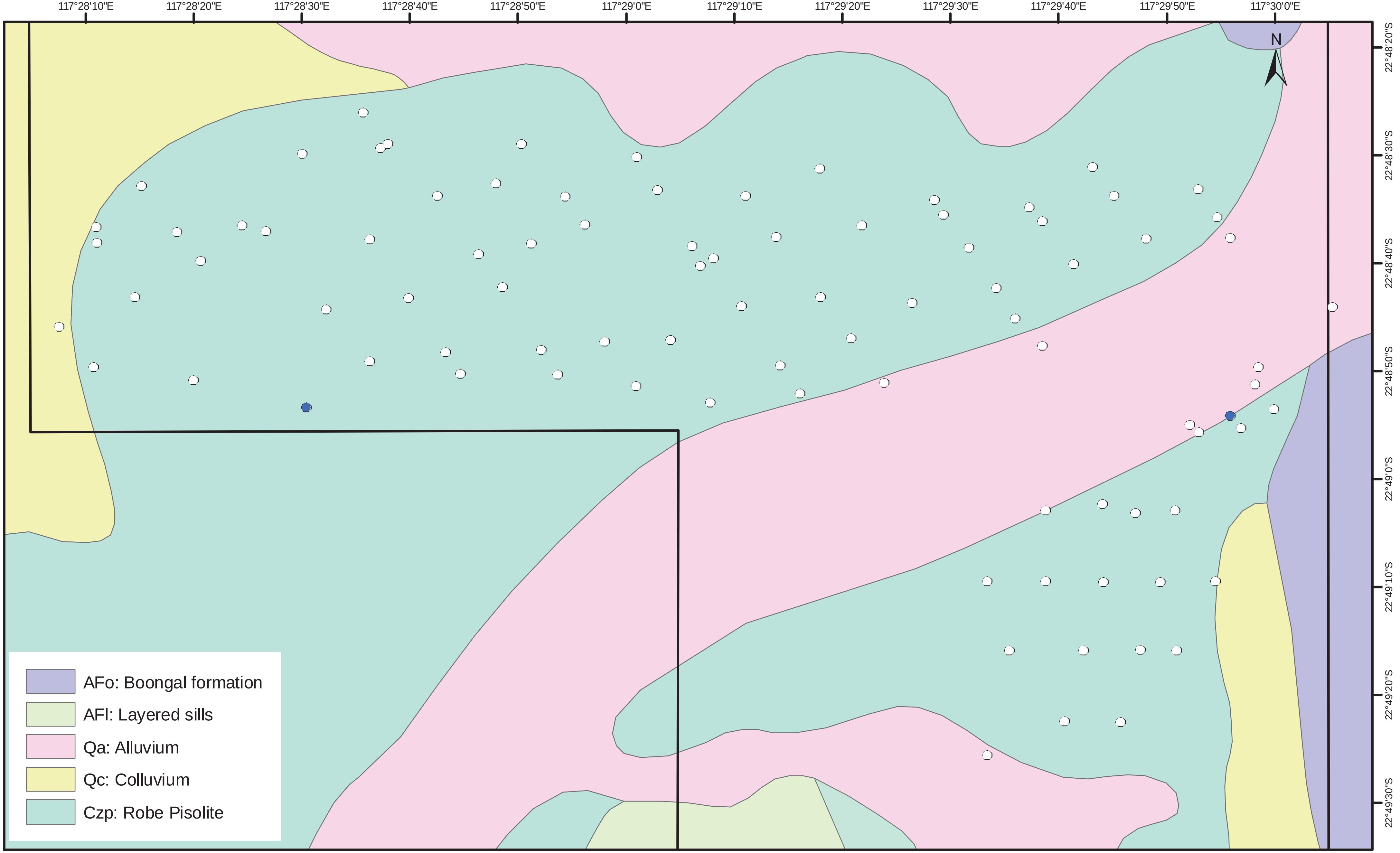

Figure 4-11 Palpigradi site records

AUTHOR: E.S. Volschenk

CLIENT: Dragon Energy Ltd.

DATE: February 2013

Scale: 1:13,906

PHOENIX ENVIRONMENTAL SCIENCES

Rocklea Iron Ore Project

Coordinate System: Projection: Transverse Mercator; DATUM: GDA94

0 0.125 0.25 0.5 0.75 Kilometers

4.5.3 Arthropoda: Arachnida: Pseudoscorpiones

Pseudoscorpions resemble scorpions in that they possess a pair of long pedipalps with pincers which are directed anteriorly of the body; however, they do not possess the tail or a sting of scorpions. Most species are small to very small in size (most species are less than 1cm long) (Rupert & Barnes 1994). Pseudoscorpions can be found inhabiting a wide variety of habitats and are regular faunal elements of subterranean communities (Harvey 2011).

In Western Australia, 17 families of pseudoscorpions have been recorded to date. Pseudoscorpions from the families Hyidae (Harvey 1993; Harvey & Volschenk 2007b), Olpiidae (Harvey 2011), Chernetidae (Harvey & Volschenk 2007a) and Chthoniidae (Edward & Harvey 2008), are also often encountered in subterranean surveys and are nearly always SREs.

4.5.3.1 *Tyrannochthonius* 'D1'

The family Chthoniidae has a global distribution and is represented by 27 genera, including the genus *Tyrannochthonius* (Harvey 2011). Chthoniids are characterised by large chelicerae, squarish carapace shape, the absence of venom apparatus in the chela fingers and a diagnostic arrangement of trichobothria (mechanosensory setae) (Harvey 1992a).

The genus *Tyrannoththonius* is the second most speciose of the chthoniid genera, containing 137 species (Harvey 2011). Members of the genus are recognised by the diagnostic arrangement of setae on the carapace, and diagnostic arrangement of trichobothria on the chela (Harvey 1992a). *Tyrannochthonius* species are globally distributed and in Western Australia, many species are known from subterranean habitats (Edward & Harvey 2008). All subterranean *Tyrannochthonius* species are likely SREs and all of the eyeless subterranean species are considered to be confirmed SREs.

Survey records: *Tyrannochthonius* 'D1' (Figure 4-12) was represented by a single specimen from the site R087 [DNA] (Figure 4-14).

Taxonomic resolution: this species did not conform with any of the species described by Edward and Harvey (2008).

Genomic taxonomy: the specimen was sequenced in order to determine if it represents any species that have not been lodged at the WA Museum, but for which sequences have been obtained. The COI sequence from this species differed from other reference *Tyrannochthonius* sequences by between 16.1% and 23.5% sequence divergence indicating that it is a different species to the reference species (Appendix 4).

SRE status: *Tyrannochthonius* 'D1' is a likely SRE.

Known distribution: only known from this survey.

4.5.3.2 *Indohya* 'MH1'

Hyidae is a family of pseudoscorpions characterised by a basidorsal mound on the femora of legs I and II, 2-3 distinctive setae on the posterior basal margin of the pedipalps femur, and anterior genital operculum of females with very small setae (Harvey 1993).

In the Pilbara, the family is represented by the genus *Indohya*, which is characterised by very small chelal teeth of the fixed finger, carapace with 14–16 setae, distinctive arrangement of trichobothria on the fixed chela finger, and males possessing a distinctive genital morphology (Harvey 1993; Harvey & Volschenk 2007b). With the exception of one widespread species, all subterranean species appear to be SREs. This species is not like any of the other known *Indohya* from the Pilbara (Harvey & Volschenk 2007b) and it is therefore considered it to be a new species.

Survey records: *Indohya* 'D1' (Figure 4-13) was represented by a single specimen, recorded from bore R267[DNA] (Figure 4-14).

Taxonomic resolution: the specimen sampled is a juvenile, making morphology based species level identification impossible.

Genomic taxonomy: the COI sequence from this species differed from other reference hyid sequences by between 17.3% and 28.7% sequence divergence indicating that it is different to the reference species (Appendix 4).

SRE status: *Indohya* 'D1' is a likely SRE.

Known distribution: only known from this survey.

Figure 4-12 Image of *Tyrannochthonius* 'D1'

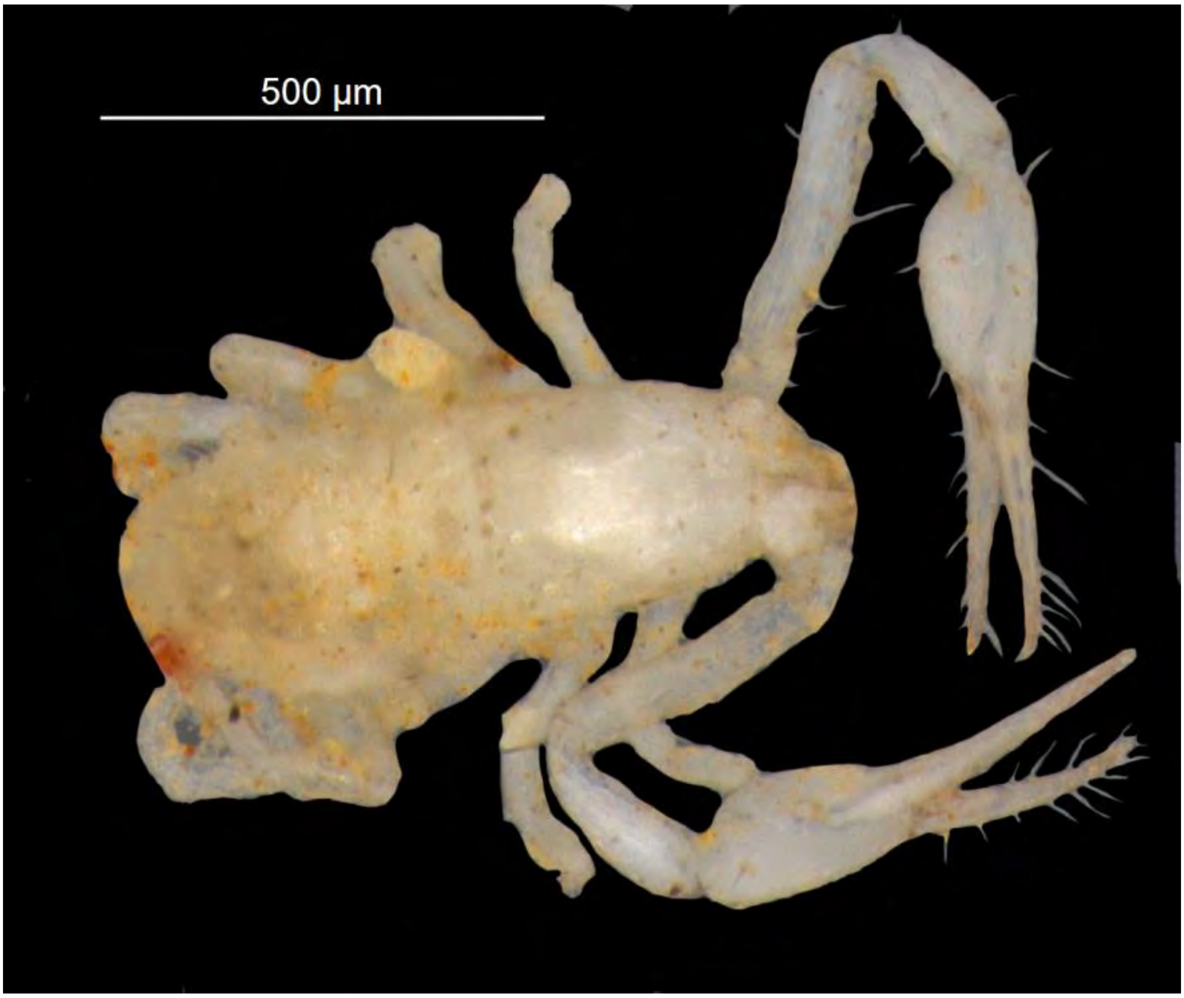

Figure 4-13 Image of *Indohya* 'D1'

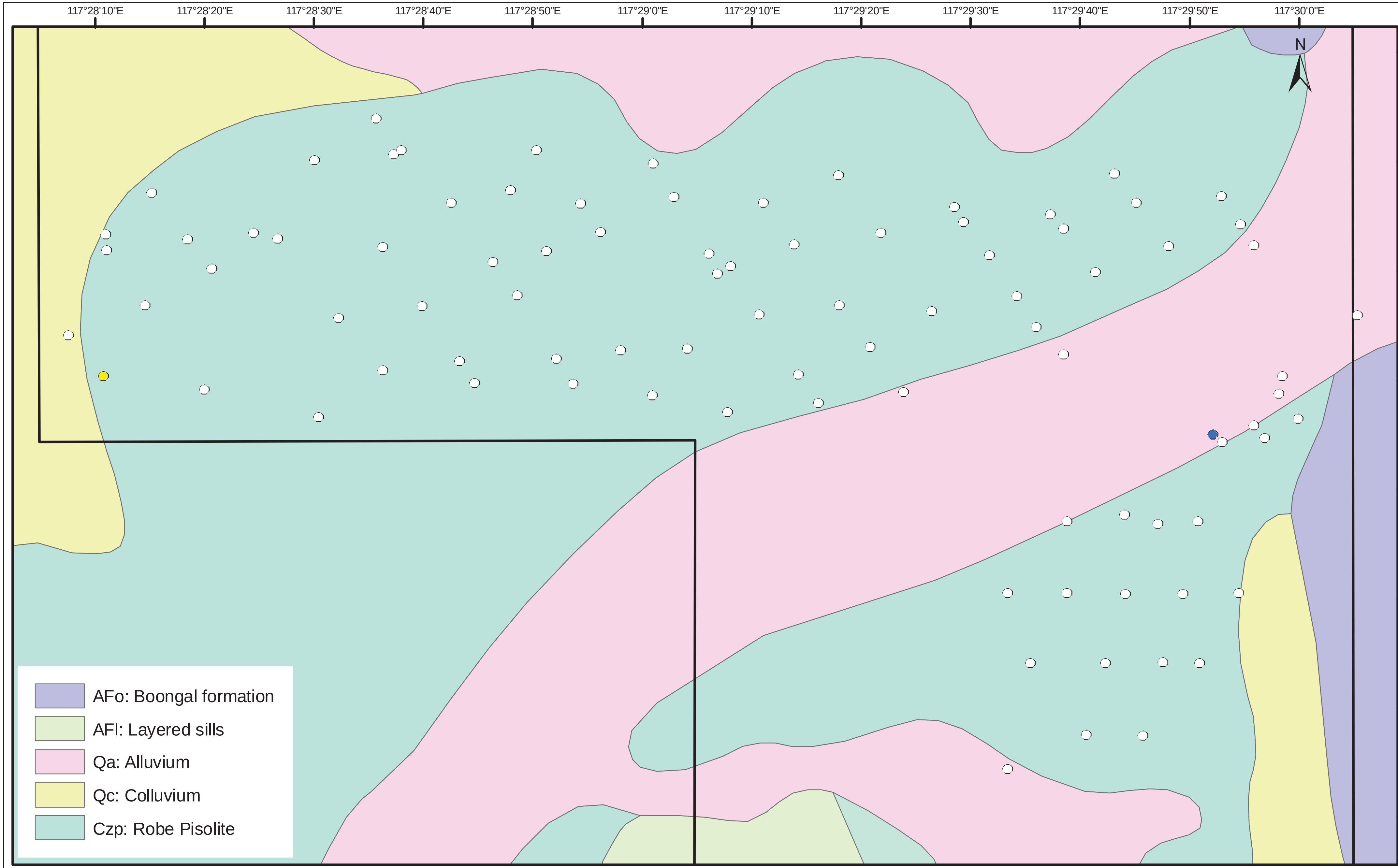

Figure 4-14 Pseudoscorpion site records

AUTHOR: E.S. Volschenk	CLIENT: Dragon Energy Ltd.
DATE: February 2013	Scale: 1:13,906

Coordinate System: Projection: Transverse Mercator; DATUM: GDA94

PHOENIX ENVIRONMENTAL SCIENCES

Rocklea Iron Ore Project

0 0.125 0.25 0.5 0.75 Kilometers

Indohya 'D1'
Tyrannochthonius 'D1'
Survey Sites
Study Area

4.5.4 Arthropoda: Arachnida: Schizomida

The schizomids are an order of arachnida that superficially resemble palpigrades (see 4.5.2.1), however they are not closely related and share closer affinity with the Uropygi (Wheeler & Hayashi 1998) which are not known from Australia. The Australian species are relatively well studied and numerous subterranean species are known from Western Australia, both described and undescribed (Harvey 1992b; Harvey *et al.* 2008).

All of the Australian species belong to the family Hubbardiidae (Harvey *et al.* 2008). In the Pilbara, this family is represented by the genera *Draculoides* and *Paradraculoides*.

Draculoides can be identified from *Paradraculoides* by the presence of two macrosetae on the abdominal tergites, instead of three, and by the possession of a laterally compressed flagellum, as opposed to a dorso-ventrally compressed flagellum in the males. Recent morphological and genomic data indicates that these two genera may be paraphyletic (not originating from a common ancestor and therefore not representing meaningfull genera) (Appendix 4).

Pilbara schizomids show very high levels of endemicity and are all considered likely SREs.

4.5.4.1 *Draculoides* 'D1'

Survey records: *Draculoides* 'D1' (Figure 4-15) was represented by 15 specimens, recorded from the following 12 bores (Figure 4-16): R123 [DNA], R193, R230, R240 [DNA], R272, R151, R272, R228, R267, R273, R266 and R268.

Taxonomic resolution: morphological assessment of species boundaries is largely dependent on characteristics of the adult males and females. The morphology of the male flagellum was compared against described species from the Pilbara (Harvey 1992b; Harvey *et al.* 2008) and could not be matched to any of these species.

Genomic taxonomy: two specimens were sequenced for genomic comparisons. These analyses revealed a single species, differing from other reference schizomids by between 11.5% and 18.5% sequence divergence (Appendix 4).

SRE status: *Draculoides* 'D1' is a likely SRE.

Known distribution: the samples obtained during this study represent the known distribution of this species.

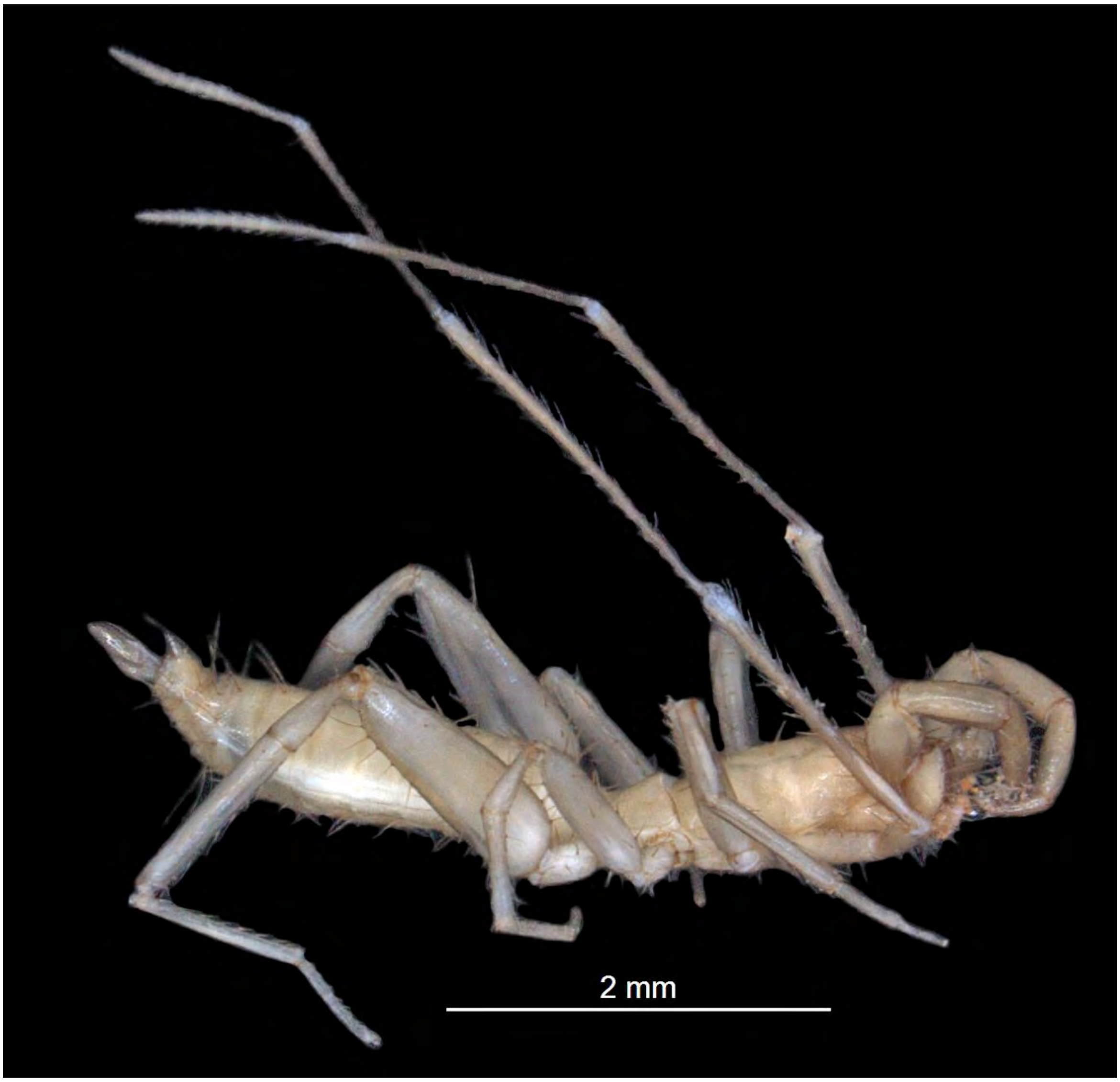

Figure 4-15 Image of *Draculoides* 'D1'

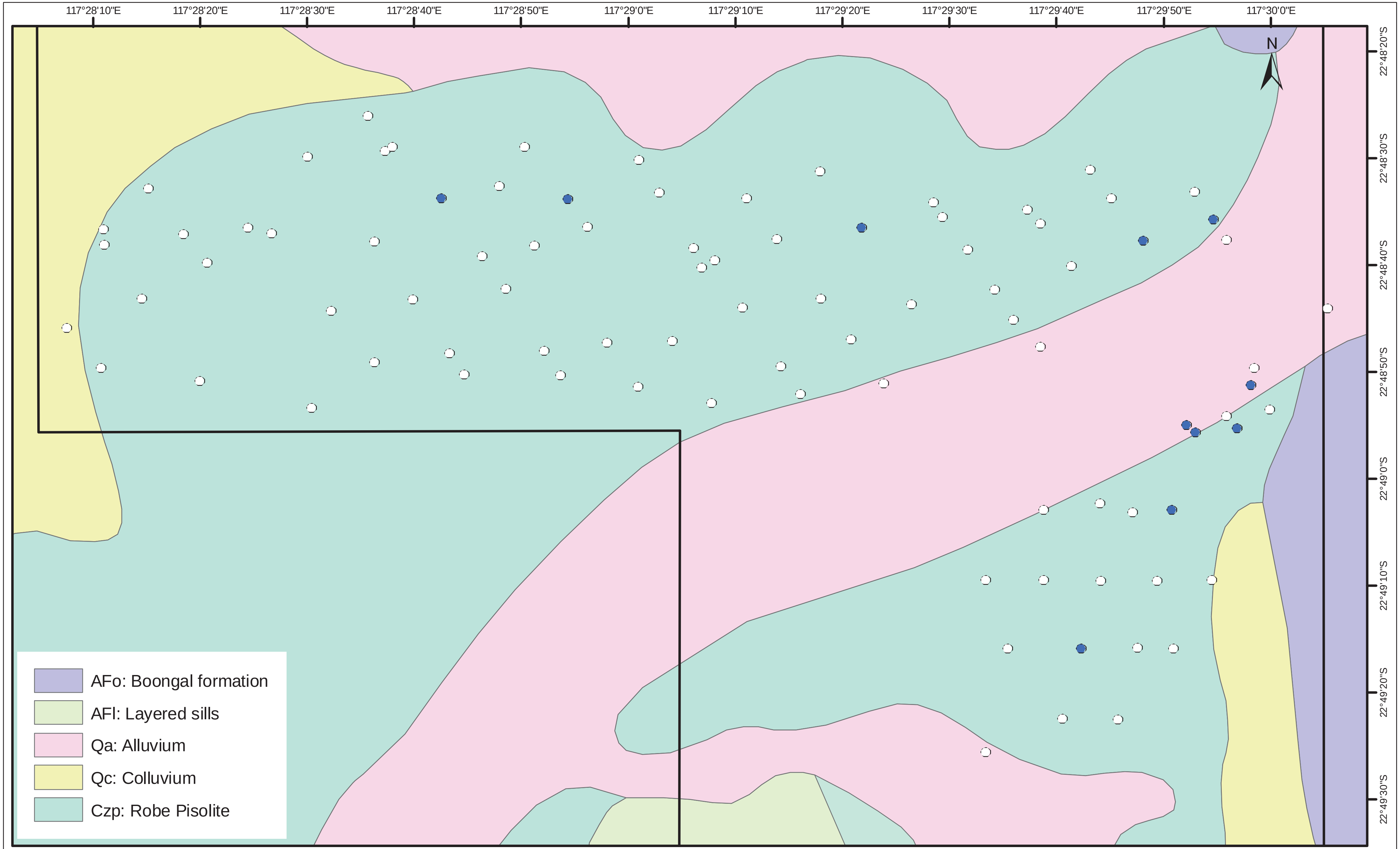

Figure 4-16 *Draculoides* 'D1' site records

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AUTHOR: E.S. Volschenk	CLIENT: Dragon Energy Ltd.
DATE: February 2013	Scale: 1:13,906

Rocklea Iron Ore Project

Coordinate System: Projection: Transverse Mercator; DATUM: GDA94

0 0.125 0.25 0.5 0.75 Kilometers

Draculoides 'D1' Survey Sites Study Area

4.5.5 Arthropoda: Entognatha: Diplura

Diplurans are an ancient group of hexapods, distantly related to the insects and sharing many features with them including three pairs of legs, antennae and a body plan divided into three regions; head, thorax and abdomen. They differ from most insects by the possession of internal mouthparts and possess short abdominal appendages (styles). Diplurans are characterised by the absence of eyes, and body pigment, making it impossible to discern the level of troglobitic specialisation from most specimens (Condé & Pagés 1991). The most notable feature of diplurans is their possession of two pairs of posteriorly directed appendages (cerci) on the last abdominal segment. The cerci can be either filamentous and multi segmented, or they can be heavily sclerotized, forcipulate (tweezer-like) morphology (Condé & Pagés 1991). The ecology of diplurans is poorly known and the limited data on species distribution based on genetics, indicates that they are both diverse and likely SREs (Phoenix 2011).

4.5.5.1 Japygidae 'D1', Japygidae 'D2',

Members of the dipluran family Japygidae can be identified by their possession of well-developed labial palps, antennae with trichobothria restricted to segments 4–6 and the presence of heavily sclerotized forcipulate cerci (Condé & Pagés 1991). The taxonomy of the Pilbara species is unknown and virtually all of the species level identifications and regional context are based on genomic comparisons (Phoenix 2011; Subterranean Ecology 2010) and most species are likely SREs.

Survey records:

- Japygidae 'D1' (Figure 4-17) was represented by one specimen recorded from bore R126^{DNA} (Figure 4-19)
- Japygidae 'D2' was represented by one specimen recorded from bore R110^{DNA} (Figure 4-19)

Taxonomic resolution: morphospecies of Japygidae are usually based on the morphology of the cerci and their setation.

Genomic taxonomy: two specimens were sequenced and differed from each other by 16.1% sequence divergence and from all of the reference lineages of Japygidae by between 14.3% and 16.5% sequence divergence (Appendix 4). These two specimens therefore represent two separate species here identified as Japygidae 'D1' and Japygidae 'D2'.

SRE status: Both Japygidae 'D1' and Japygidae 'D2' are likely SREs.

Known distribution: only known from this survey.

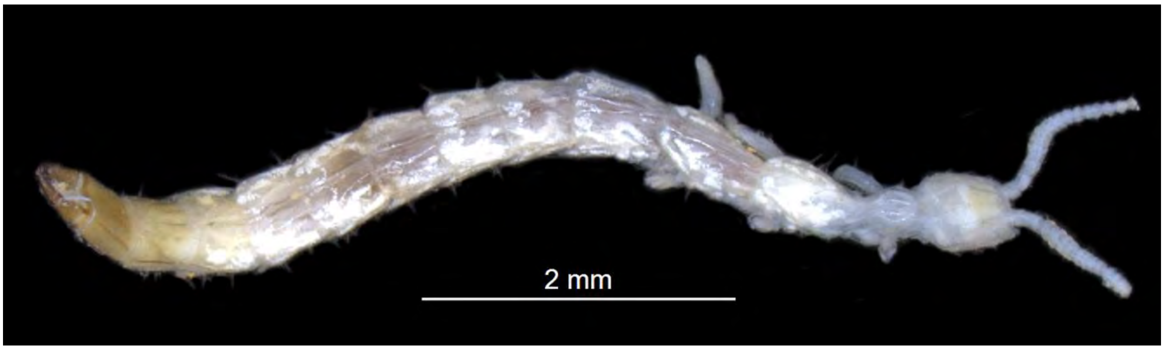

Figure 4-17 Image of Japygidae 'D1'

4.5.5.2 Parajapygidae 'D1'

Members of the dipluran family Parajapygidae can be identified by the absence of labial palps, antennae without trichobothria and the possessing heavily sclerotized forcipulate cerci (Condé & Pagés 1991). The taxonomy of the Pilbara species is unknown and like Japygidae, virtually all of the species level identifications and regional context are based on genomic comparisons (Phoenix 2011). Most Pilbara species appear to be likely SREs.

Survey records: Parajapygidae 'D1' was represented by one specimen recorded from bore R162^{DNA} (Figure 4-19).

Taxonomic resolution: morphospecies of Parajapygidae are usually based on the morphology of the cerci and their setation. Several of the japygid samples had cerci damaged, making them impossible to identify.

Genomic taxonomy: the single sample of Parajapygidae was sequenced and analysed with three reference specimens from the Pilbara. Specimens differed from each other by between 15.2% and 17.4% sequence divergence (Appendix 4). These specimens therefore represent four different species and we refer to the specimen from Rocklea as Parajapygidae 'D1'.

SRE status: Parajapygidae 'D1' is a likely SRE.

Known distribution: only known from this survey.

4.5.5.3 Projapygidae 'D1', Projapygidae 'D2'

Projapygidae possess filamentous cerci and are therefore instantly identifiable from Projapygidae and Japygidae. They also possess well-developed labial palps, and antennae with trichobothria on segments 4–22 and last abdominal segment possessing filamentous cerci (Condé & Pagés 1991). The taxonomy of the Pilbara species is unknown and, like Japygidae, virtually all of the species level identifications and regional context are based on genomic comparisons. Most Pilbara species appear to be likely SREs (Phoenix 2011; Subterranean Ecology 2010).

Survey records:

- Projapygidae 'D1' (Figure 4-18) was represented by one specimen recorded from bore R156^{DNA} (Figure 4-19)
- Projapygidae 'D2' was represented by one specimen recorded from bore R187^{DNA} (Figure 4-19)
- **Taxonomic resolution:** differences between projapygid morphospecies is challenging and is based on a combination of the following characters: morphology and station of the antennae and cerci, morphology of the tarsi and of the abdominal sternites; however, these features are often damaged during capture or sample preparations.

Genomic taxonomy: two specimens of Projapygidae were sequenced and analysed with seven reference species from the Pilbara. The Rocklea specimens differed from each other by 17% and the nine specimens differed from each other by between 11.3% and 20% sequence divergence (Appendix 4). The two Rocklea specimens are therefore likely to represent two new species, referred to here as Projapygidae 'D1' and Projapygidae 'D2'.

SRE status: Projapygidae 'D1' and Projapygidae 'D1' are likely SREs.

Known distribution: only known from this survey.

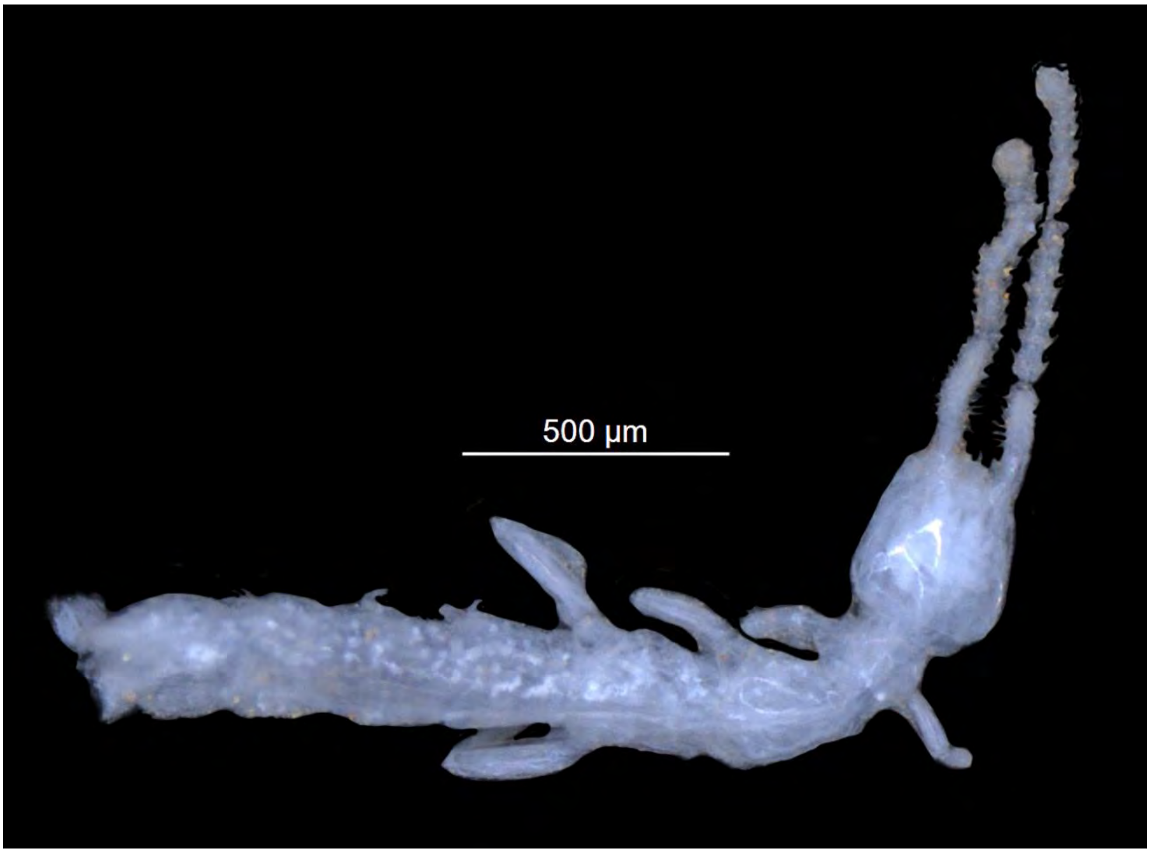

Figure 4-18 Image of Projapygidae 'D1'

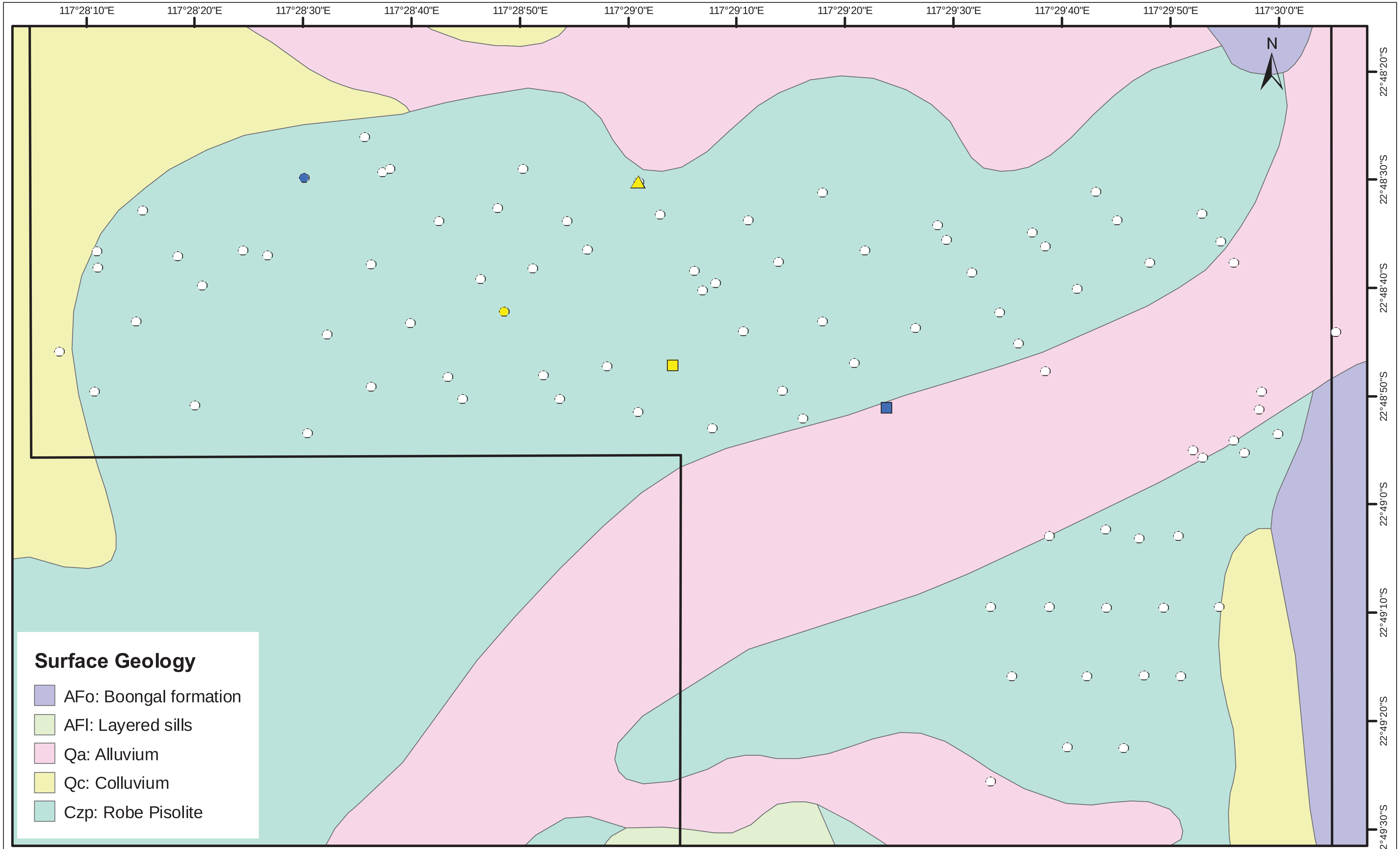

Figure 4-19 Dipluran site records

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR: E.S. Volschenk	CLIENT: Dragon Energy Ltd.
DATE: February 2013	Scale: 1:13,737

Rocklea Iron Ore Project

Coordinate System: Projection: Transverse Mercator; DATUM: GDA94

0 0.125 0.25 0.5 0.75 Kilometers

Parajapygidae 'D1'
Projapygidae 'D2'
Projapygidae 'D1'
Japygidae 'D2'
Japygidae 'D1'
Survey Sites
Study Area

4.5.6 Arthropoda: Insecta: Blattaria

Blattaria are commonly referred to as cockroaches. This order of insects is extremely widespread and its pest species *Peripalneta americana* (American cockroach), *Periplaneta australasiae* (Australian cockroach) and *Blattella germanica* (German cockroach) are infamous. While about 30 species are associates with human habitation, there are more than 4,000 species of cockroach globally (Roth 1991).

Troglobitic forms of several cockroach species are known; however the most common family of cockroaches in the Pilbara is Nocticolidae, represented by the single genus *Nocticola.* Nocticola are primitive cockroaches and are characterised by wingless females, and males that possess soft membranous wings. Epigean *Nocticola* species are known from the tropics and some species have also been recorded living with termites (Roth 1991). *Nocticola* are most often troglobitic and these species have reduced eyes or lack them, and the males often have much reduced wings.

Genetic studies on the Pilbara *Nocticola* species (Phoenix 2011; Subterranean Ecology 2010) has revealed the presence of two undescribed *Nocticola* species with widespread (not SRE) distributions, as well as some species that are likely SREs (Appendix 4).

4.5.6.1 *Nocticola* 'Pilbara 1'

Survey records: *Nocticola* 'Pilbara1' (Figure 4-20) was represented by a 23 specimens recorded from eight bores (Figure 4-21): R123 ^{DNA}, R151, R193, R228, R230, R252 ^{DNA}, R267 and R268.
Taxonomic resolution: little is known about the *Nocticola* of WA, however genetic data indicates that there is a diverse fauna in the Pilbara. The most complete data set with which to gauge species boundaries are DNA sequences. Morphospecies can also be identified from wing and genital morphology of the males.

Genomic taxonomy: two specimens were sequenced for genomic comparisons. Specimens differed from each other by 4.1% sequence divergence. These specimens were also placed in a clade containing reference specimens from 11 other localities in the Pilbara. The genetic divergence between members of this clade was between 4.7% and 7.4%, therefore indicating that they are likely to belong to the same species (Appendix 4). The species has no common reference name and we referred to it as *Nocticola* 'Pilbara 1'.

Divergence within *Nocticola* 'Pilbara 1' is greater than is usually seen within a population and suggests that the two Rocklea specimens originated from populations that have low levels of gene flow between them. Alternatively, these populations may be isolated and under incipient speciation (Appendix 4).

SRE status: *Nocticola* 'Pilbara1' is a widespread species but is comprised of several populations that may be under incipient speciation, and may therefore be of conservation significance.

Known distribution: *Nocticola* 'Pilbara1' has been recorded from numerous localities throughout the Pilbara, both north and south of the Fortescue Plain (Appendix 4).

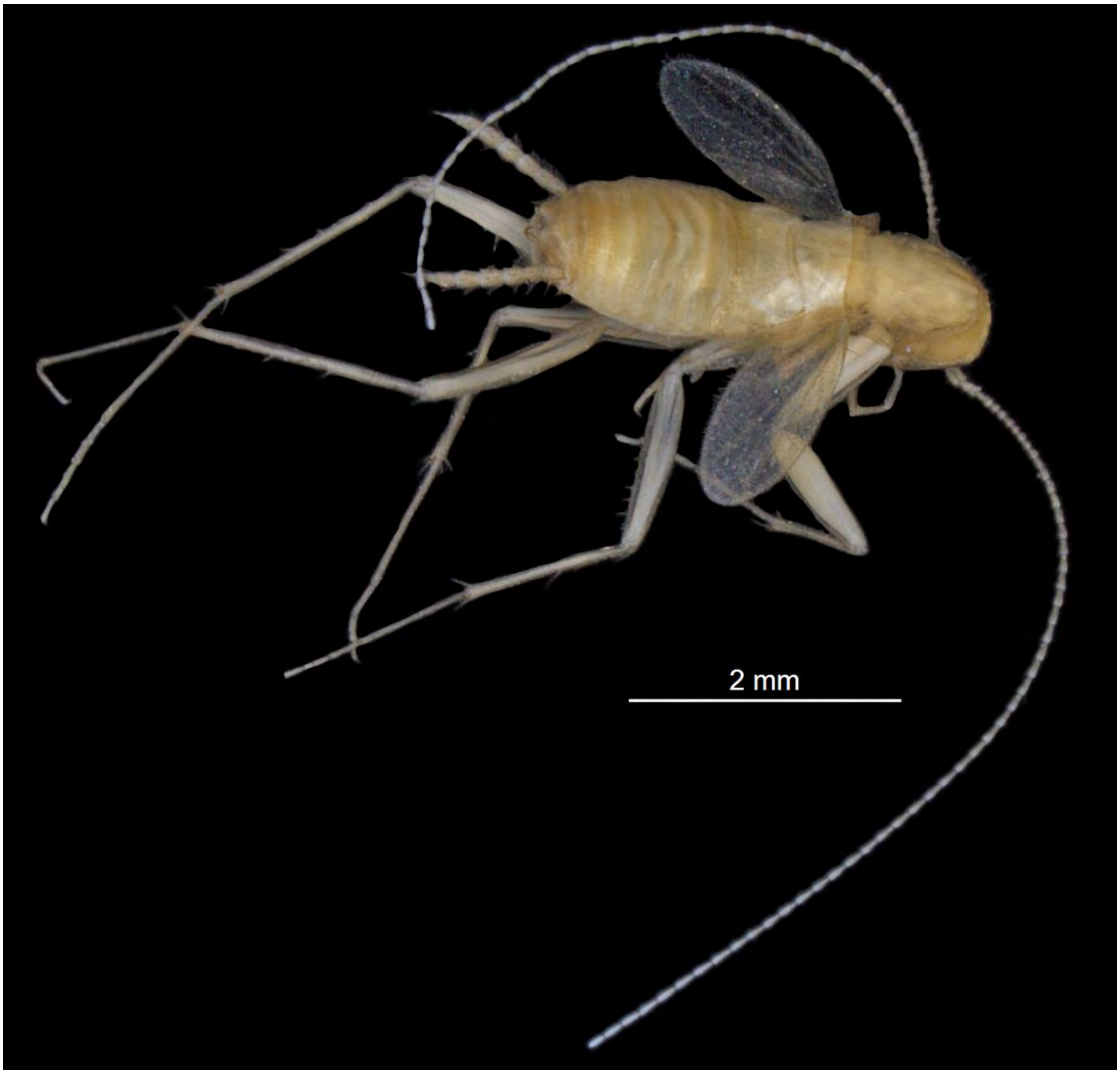

Figure 4-20 Image of *Nocticola* 'Pilbara1'

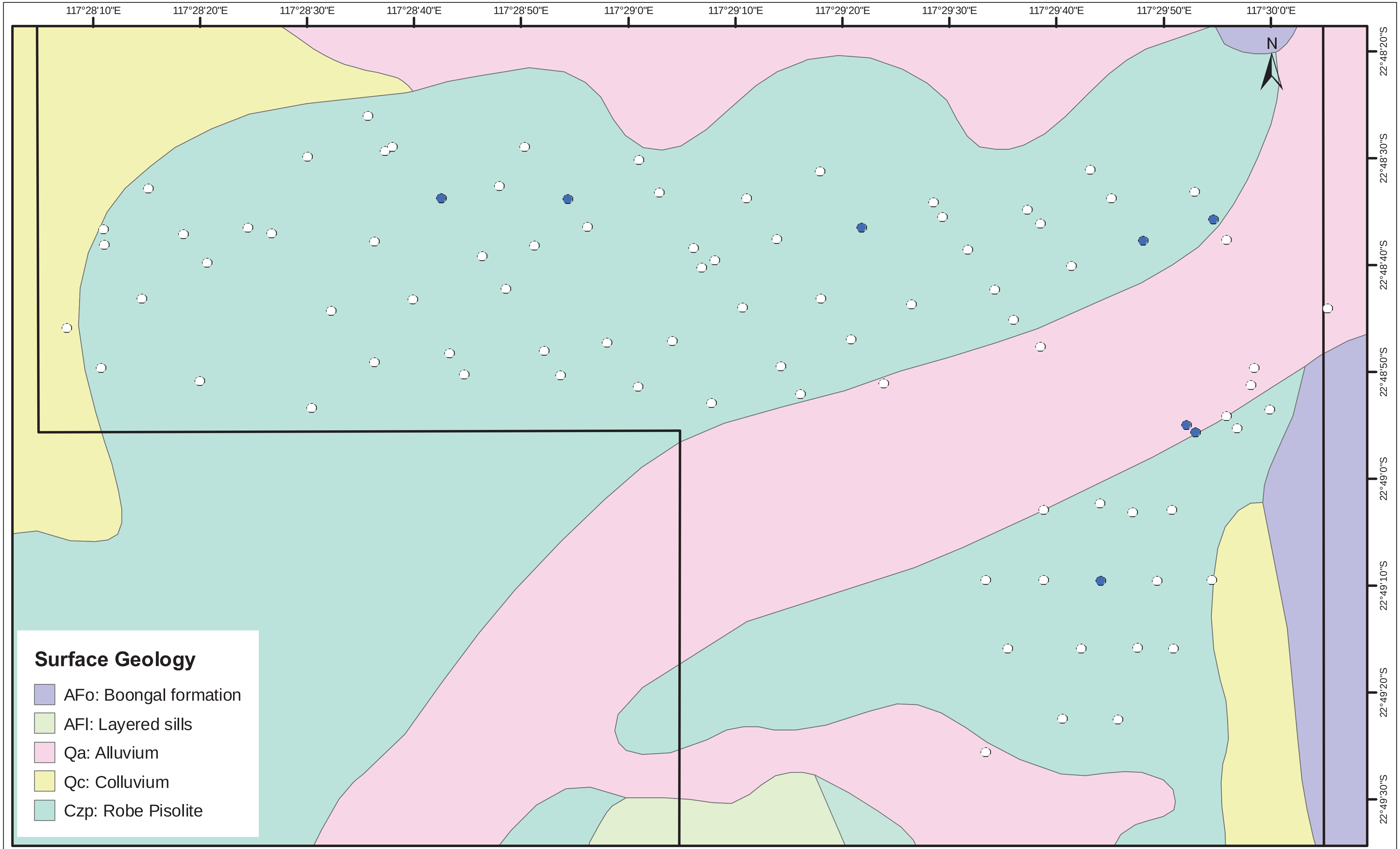

Figure 4-21 *Nocticola* 'Pilbara1' site records

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Nocticola 'Pilbara1' Survey Sites Study Area

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DATE: February 2013	**Scale:** 1:13,906

Rocklea Iron Ore Project

Coordinate System: Projection: Transverse Mercator; DATUM: GDA94

0 0.125 0.25 0.5 0.75 Kilometers

4.5.7 Arthropoda: Insecta: Hemiptera

Hemiptera are true bugs or sucking bugs. The order is characterised by the presence of mouthparts characteristically modified into a tube, through which they feed. Hemiptera is a diverse order with between 50,000 and 80,000 species. They are globally distributed and both predatory and non-predatory species are known (Carver *et al.* 1991). Hemiptera contains species of both agricultural significance (such as aphids and scale insects) as well a medical significance (such as Bed bugs) (Carver *et al.* 1991). Subterranean Hemiptera include members of the families Meenoplidae, Cixiidae and Reduviidae, and most species are likely SREs based genetic comparisons (Carver *et al.* 1991).

4.5.7.1 Meenoplidae 'widespread'

The family Meenoplidae is characterised by the presence distinctive leg spinnation and distal mouthparts that are much longer than wide.

Survey records: Meenoplidae 'widespread' (Figure 4-22) was represented by 61 specimens recorded from 11 bores (Figure 4-23): R087 ^{DNA}, R112, R123, R149, R151, R163, R178, R225, R230, R267and R272 ^{DNA}

Taxonomic resolution: Meenoplidae of WA are very poorly known and taxonomy of these species is largely based on the morphology of the adults. Morphospecies identification is dependent on leg spinnation, sculpturing of the head, and wing venation, amongst other features. Since adults are rarely collected, the only reliable method for determining regional context of Pilbara meenoplids relies on genomic assessment. Species of Meenoplidae are considered to be potential SREs.

Genomic taxonomy: two specimens of what was thought to be a single species were sequenced for genomic comparisons. These two specimens differed from each other by 3.6% sequence divergence (Appendix 4), thus indicating that they are likely to represent the same species. These two specimens were placed within a clade containing specimens from two other localities in the Pilbara. The genetic distances between representatives of this clade were between 0.7% and 3.1% and suggest that they belong to a single species here referred to as Meenoplidae 'widespread', the same name used by Helix to identify this clade.

SRE status: Meenoplidae 'widespread' does not appear to be an SRE.

Known distribution: this species appears to be widespread in the Pilbara.

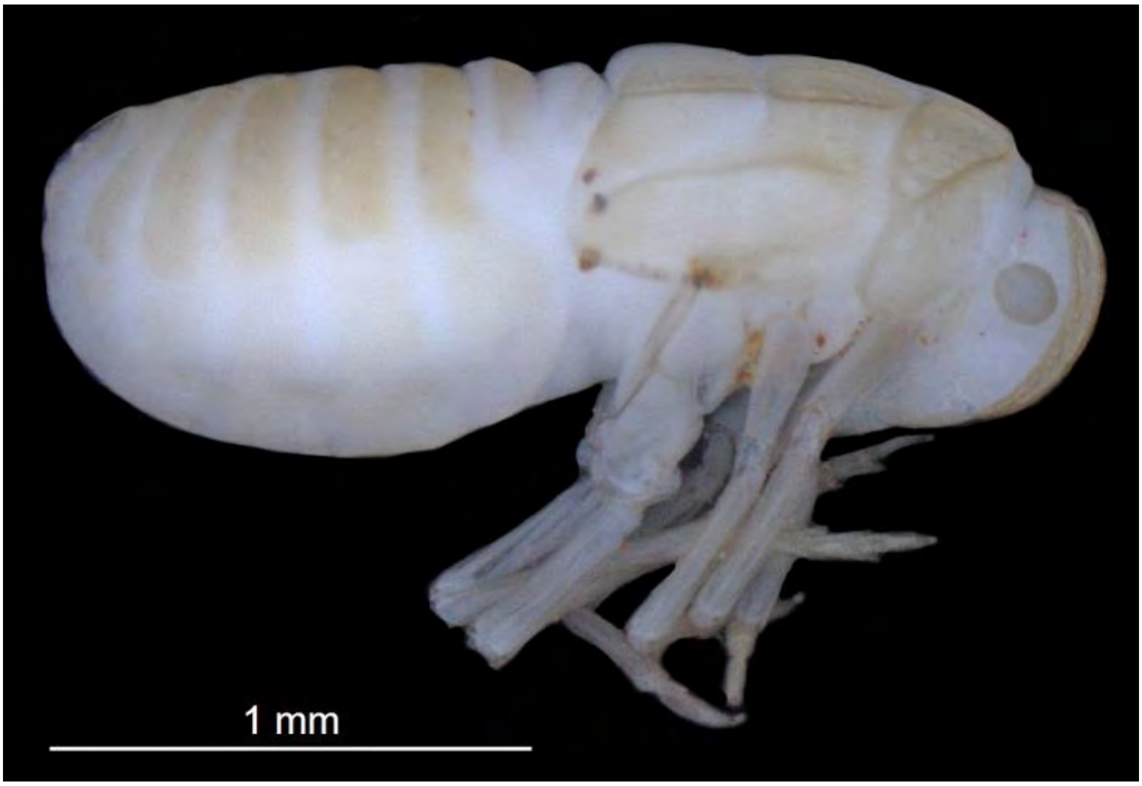

Figure 4-22 Image of Meenoplidae 'widespread'

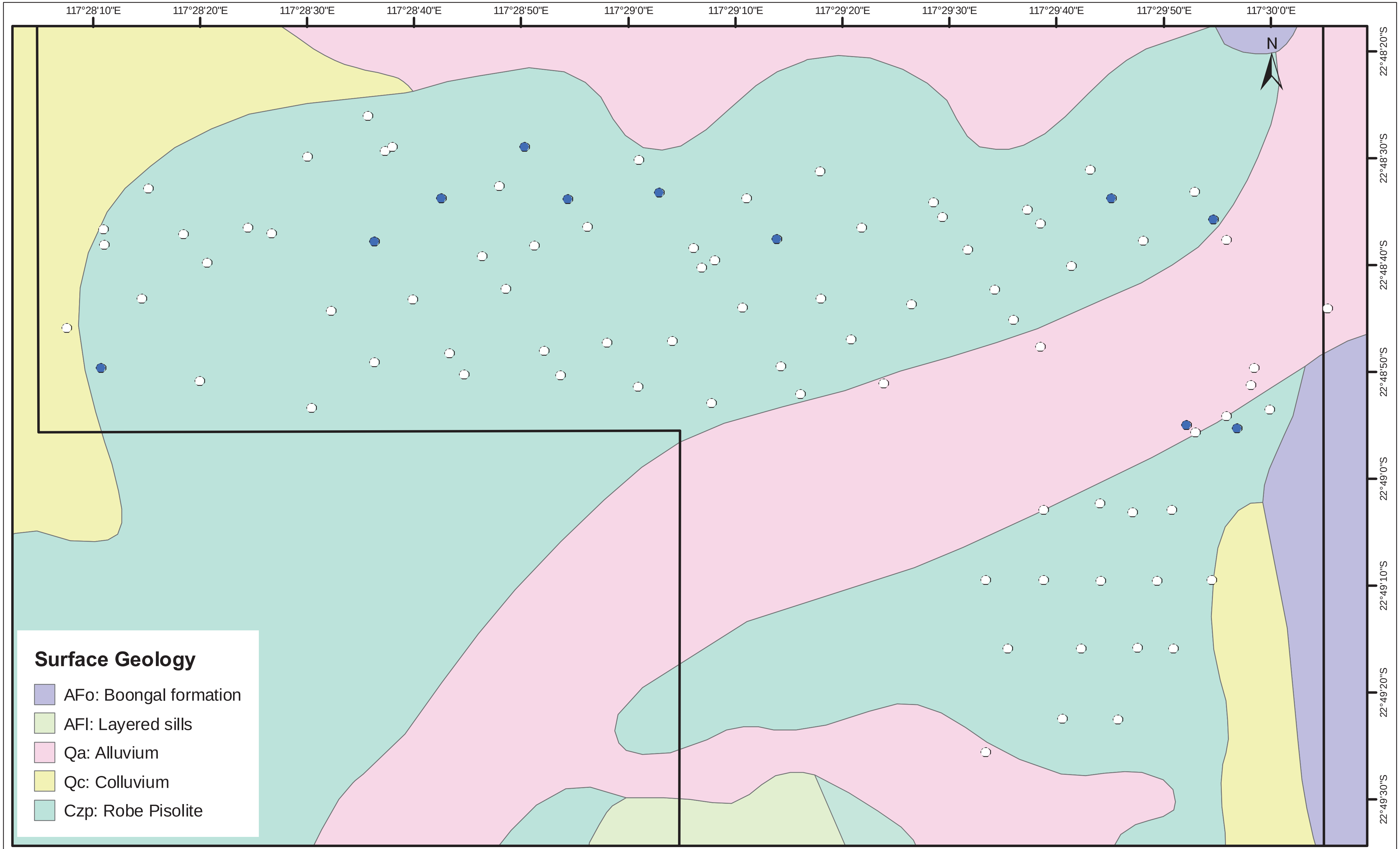

Figure 4-23 Meenoplid site records

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DATE: February 2013 | Scale: 1:13,906

Rocklea Iron Ore Project

Coordinate System: Projection: Transverse Mercator; DATUM: GDA94

0 0.125 0.25 0.5 0.75 Kilometers

Meenoplidae 'widespread' Survey Sites Study Area

4.5.8 Arthropoda: Insecta: Thysanura

Thysanurans are an order of insects, sometimes also called Zygentoma. While they possess external mouth parts, the lack wings and possess abdominal appendages (styes); however, their most noteworthy feature is the three circi that protrude from the last abdominal segment (Smith & Watson 1991). The most commonly encountered thysanuran is *Ctenolepisma longicaudata* (silverfish), a pest species in the family Lepismatidae (Smith & Watson 1991). Species in the family Nicoletiidae (comprising the subfamilies Nicoletiinae and Atelurinae) are often encountered in subterranean surveys and are likely SREs (Phoenix 2011).

4.5.8.1 Atelurinae 'D1'

Survey records: Atelurinae 'D1' (Figure 4-24) was represented by one specimen recorded from bore R123^{DNA} (Figure 4-26):

Taxonomic resolution: morphospecies of Nicoletiidae are based in part on adult size end morphology of the abdomen, but genomic assessment is required to obtain finer resolution identifications.

Genomic taxonomy: a single morphospecies of Atelurinae was detected and tissues from one specimen were submitted for genomic comparisons. The specimen failed to yield COI sequences, but sequences of the gene 12S were successfully amplified and were used in the absence of COI. The species failed to group with any of the reference species (Appendix 4), indicating that it is likely to represent a new species; here referred to as Atelurinae 'D1'. The close morphological similarity between the sequenced specimens and the remaining atelurid specimen led to both specimens being considered the same species.

SRE status: Atelurinae 'D1' is a likely SRE.

Known distribution: only known from this study.

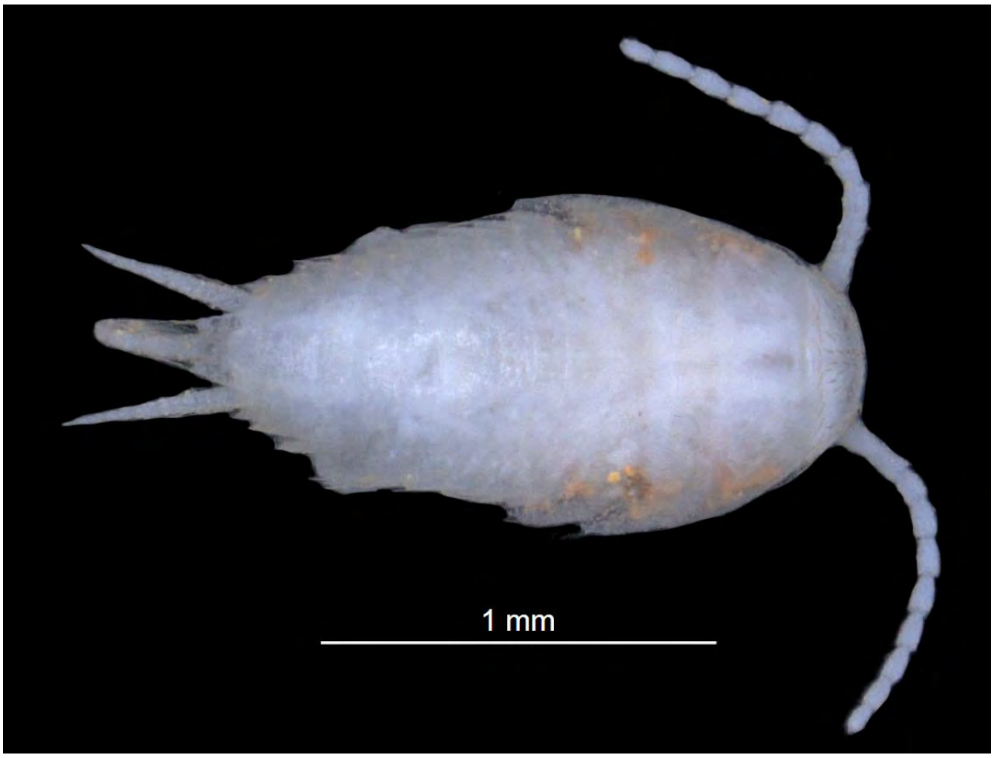

Figure 4-24 Image of Atelurinae 'D1'

4.5.8.2 *Trinemura* 'D1'

Trinemura are the only known representative of the subfamily Nicoletiinae in Western Australia (Smith & Watson 1991). Genetic data indicate that this genus is moderately diverse, and often locally endemic in the Pilbara (Phoenix 2011).

Survey records: *Trinemura* 'D1' (Figure 4-25)was represented by a seven specimens recorded from five bores (Figure 4-26): R096, R114, R123, R134 and R170.

Taxonomic resolution: little is known about the subterranean *Trinemura* of WA. Like Atelurinae, morphospecies of *Trinemura* are based in part on adult size end morphology of the abdomen, but genomic assessment is required to obtain finer resolution identifications.

Genomic taxonomy: a single morphospecies of *Trinemura* was detected; however, all efforts to amplify genes from one specimen failed. In the absence of genomic data, it is clear that at least one species is present, and we refer to this species here as *Trinemura* 'D1'.

SRE status: this species is a likely SRE.

Known distribution: the records obtained for this morphospecies represent its known distribution.

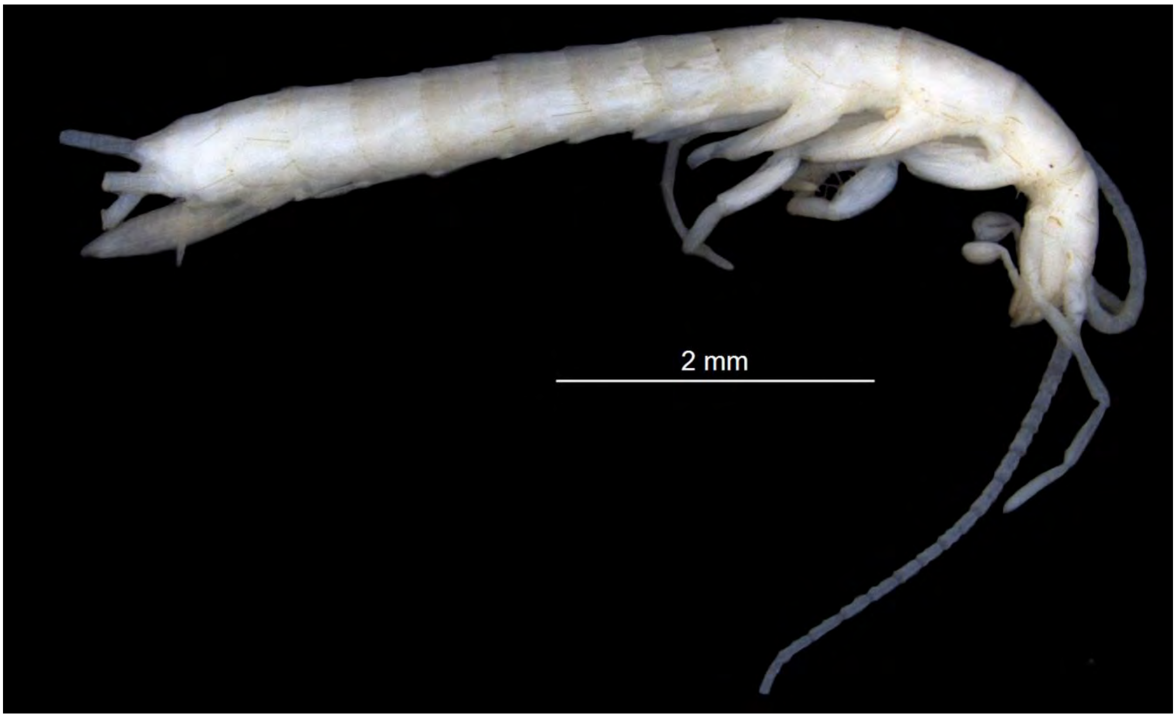

Figure 4-25 Image of *Trinemura* 'D1'

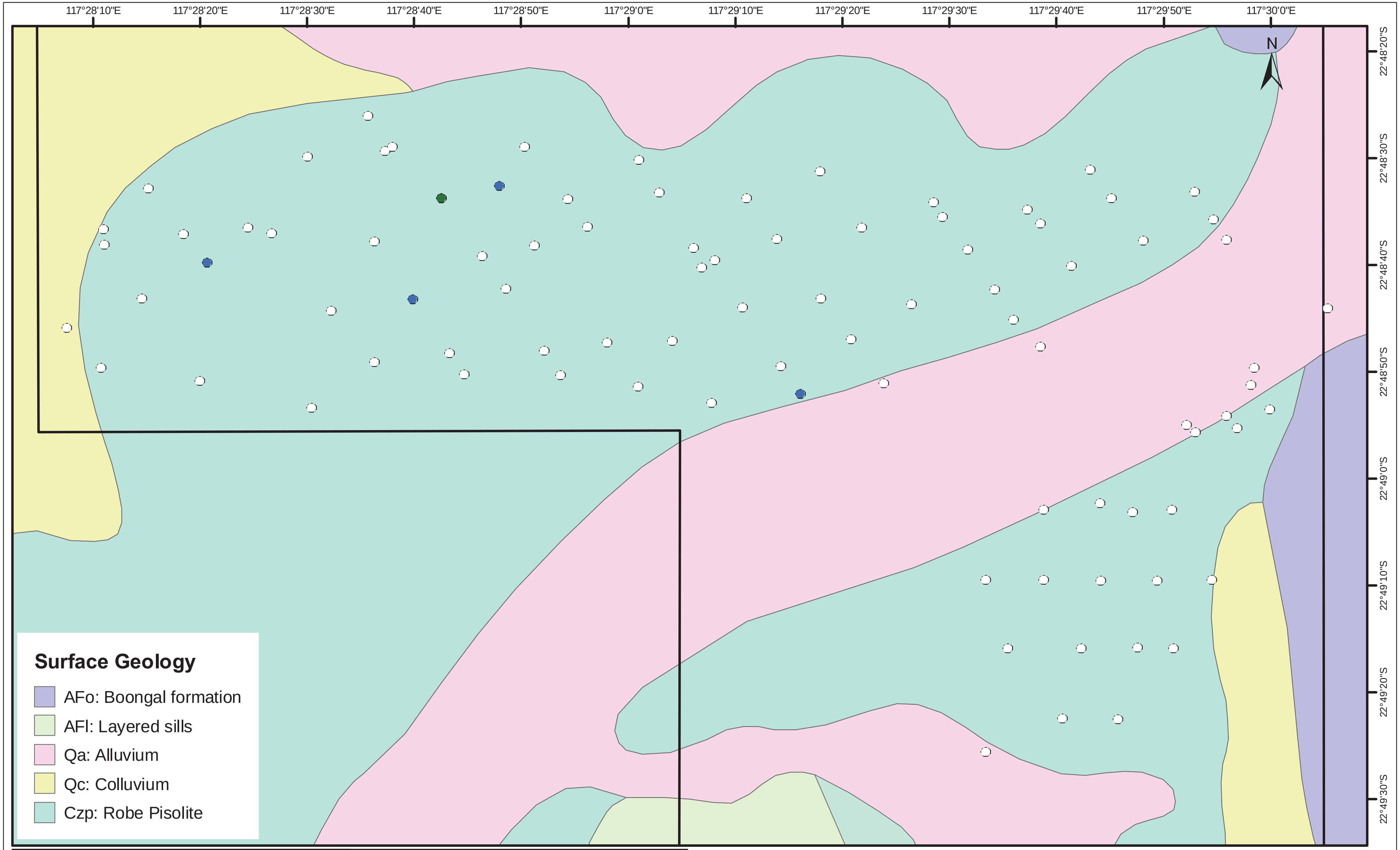

Figure 4-26 Thysanura site records

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DATE: February 2013	Scale: 1:13,906

Rocklea Iron Ore Project

Coordinate System: Projection: Transverse Mercator; DATUM: GDA94

4.5.9 Arthropoda: Myriapoda: Chilopoda: Scolopendromorpha

Chilopoda are commonly referred to as centipedes and can be identified by the possession of more than 15 pairs of legs, with each body segment possessing a single pair of legs. They can have between 15 and 191 pairs of legs. The first pair of legs is modified into a pair of poison claws that contain venom glands and are used to subdue prey (Edgecombe & Giribet 2007).

The order Scolopendromorpha represents the 'true' centipedes and adults have 21 or 23 pairs of legs and are dorsoventrally flattened (Edgecombe & Giribet 2007). Two scolopendramorph families are represented in the Pilbara subterranean fauna: Cryptopidae and Scolopendridae. Scolopendrids differ from cryptopids by the presence of 'teeth' on the margins on the maxillipede coxosternite, in cryptopids they are without teeth (Edgecombe & Giribet 2007). All cryptopids are also defined by largely troglomorphic characteristics: eyeless and generally pale body. These features make the identification of troglobitic forms extremely difficult.

Cryptopids are often encountered during subterranean fauna surveys in the Pilbara (Subterranean Ecology 2010). Very little is known about the cryptopid centipedes of WA and genetic comparisons of the Pilbara species indicates that they are usually locally endemic and can be considered likely SREs (Subterranean Ecology 2010).

4.5.9.1 *Cryptops* 'D1'

Survey records: *Cryptops* 'D1' (Figure 4-27) was represented by three specimens, recorded from the following three localities (Figure 4-28): R163, R208 and R266 [DNA].

Taxonomic resolution: the only means of obtaining regional context for Pilbara cryptopids relies on genomic assessment. Cryptopids in the Pilbara frequently appear to be locally endemic (Subterranean Ecology 2010).

Genomic taxonomy: two specimens from this survey were submitted for DNA sequencing sequenced. Only one specimen yielded DNA sequences. A distinct species was detected which differed from other by 16.1% and 22.9% divergence, indicating that it is likely to be new species.

SRE status: *Cryptops* 'D1' is a likely SRE.

Known distribution: only known from this survey.

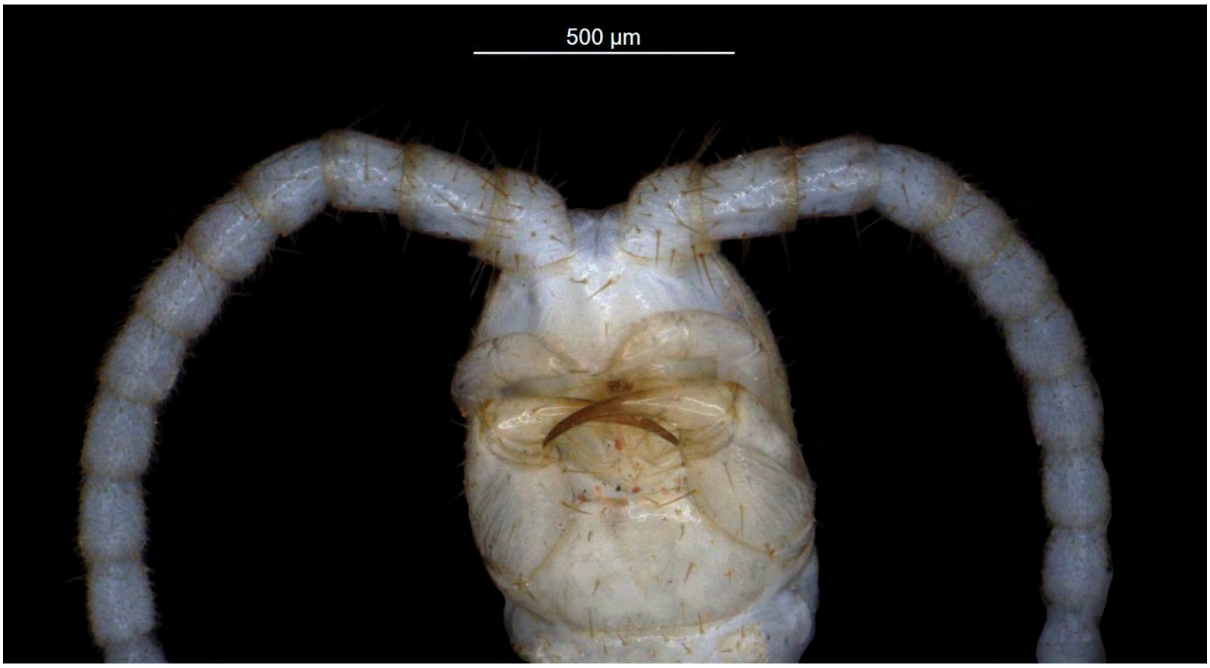

Figure 4-27 Image of *Cryptops* 'D1'

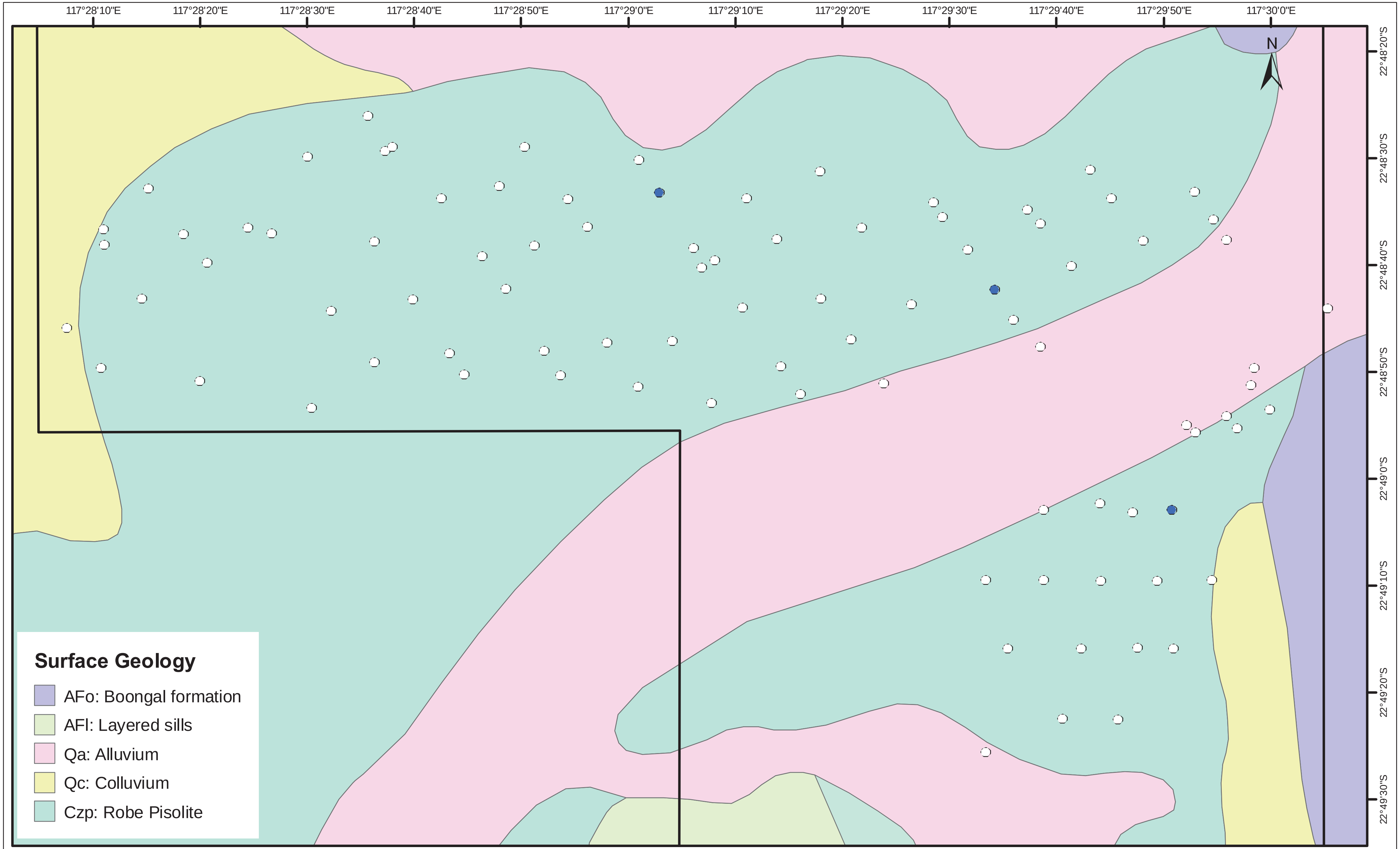

Figure 4-28 *Cryptops* 'D1' site records

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DATE: February 2013 | **Scale:** 1:13,906

Coordinate System: Projection: Transverse Mercator; DATUM: GDA94

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Rocklea Iron Ore Project

0 0.125 0.25 0.5 0.75 Kilometers

4.5.10 Arthropoda: Myriapoda: Diplopoda: Polyxenida

Members of the order Polyxenida are commonly referred to as pincushion millipedes. Like all millipedes (Diplopoda), they possess numerous body segments with two pairs of legs per segment. Polyxenids differ from all other millipede orders by their soft bodies and characteristic tufts or rows of setae (Shelley 2003).

4.5.10.1 Polyxenidae 'PXD1'

Polyxenida of the Pilbara have been relatively well studied in unpublished studies by Helix Molecular Solutions (Appendix 4). These studies indicate that one species of polyxenid is very widespread throughout the Pilbara; however, there are also several locally endemic species. For this reason we treat polyxenids as potential SREs.

Survey records: Polyxenidae 'PXD1' (Figure 4-29) was represented by seven specimens, recorded from the following seven bores (Figure 4-30): R090 [DNA], R112, R120, R125, R152, R203 and R229 [DNA].

Taxonomic resolution: there are no polyxenid experts with detailed knowledge of the Pilbara fauna and assessment of species and regional context relies on genomic assessment.

Genomic taxonomy: two specimens of Polyxenidae 'PXD1' were sequenced for the COI gene in order to make genomic level comparisons. Specimens were found to be very similar, differing by only 0.5% and therefore represent the same species. These species also grouped with a clade of polyxenids that are widespread in the Pilbara, therefore demonstrating that this species is not an SRE (Appendix 4).

SRE status: Polyxenidae 'PXD1' is not an SRE.

Known distribution: this species has been widely collected in the Pilbara (Appendix 4).

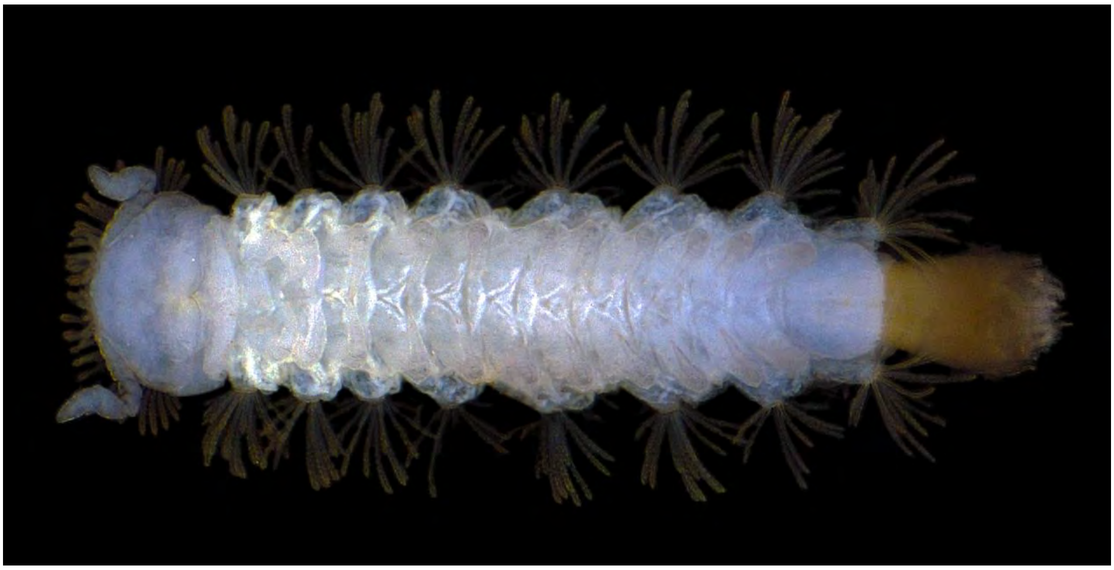

Figure 4-29 Image of Polyxenidae 'PXD1'

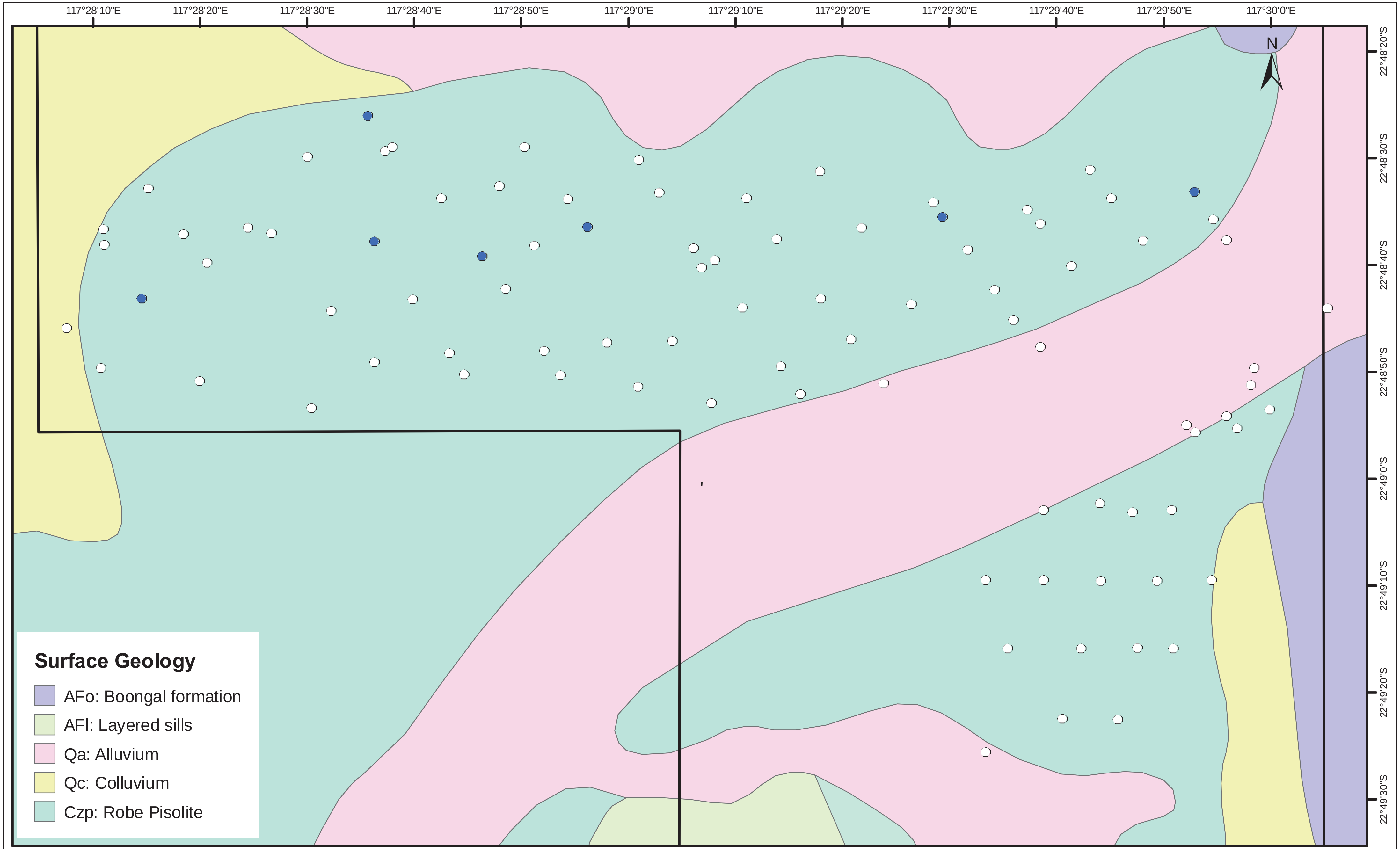

Figure 4-30 Polyxenid site records

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Rocklea Iron Ore Project

0 0.125 0.25 0.5 0.75 Kilometers

Polyxenidae 'PXD1' Survey Sites Study Area

4.5.11Arthropoda: Myriapoda: Diplopoda: Polydesmida

The Australian millipedes are poorly studied and biogeographic patterns remain largely unresolved (Black 1997; Shelley & Golovatch 2011). At least eight orders of millipedes are native to Australia; all species in the order Julida are introduced (Mesibov 2006). Millipedes belong to one of the main target groups of SRE surveys. Short-range endemism is particularly common within the orders Sphaerotheriida (rolling millipedes), Polydesmida, and Chordeumatida (not known from WA) (EPA 2009; Harvey 2002). The family Haplodesmidae belongs to the order Polydesmida, commonly called flanged or keeled millipedes. Like all polydesmids, they are blind and they are further characterised by highly sculptured body segments with prominent lateral flanges, they are generally quite cryptic owing to their small size and males have tend to have reduced gonopods relative to other polydesmids (Sergei *et al.* 2009).

4.5.11.1 Haplodesmidae 'D1', Haplodesmidae 'D2'

Taxonomic resolution: the taxonomy of haplodesmids is largely based on the morphology of the male gonopods (Sergei *et al.* 2009). Gonopods were not found on any of the specimens captured and it is therefore assumed that they are either subadults or females. Genomic comparisons represented the only available alternative to enable species.

Survey records:

- Haplodesmidae 'D1' was represented by one specimen, recorded from bore R145 [DNA] (Figure 4-32)
- Haplodesmidae 'D2' was represented by one specimen, recorded from bore R266 [DNA] (Figure 4-32)
- Haplodesmidae sp. indet. (Figure 4-31) was represented by 39 specimens, recorded from the following 10 bores (Figure 4-32): R266, R170, R212, R230, R264, R266, R267, R268, R272 and R273.

Genomic taxonomy: two specimens of this species were selected for DNA sequencing. The genetic distance between the two Rocklea species was 20.4%, indicating that they do not belong to the same species. These two species differed from the reference haplodesmids by between 18% and 31% sequence divergence, indicating that the Rocklea species are not the same as the reference species (Appendix 4). These two Rocklea haplodesmid species are likely to represent two new species and are here referred to as Haplodesmidae 'D1' and Haplodesmidae 'D2'.

SRE status: Haplodesmidae 'D1' and Haplodesmidae 'D2' are likely SREs owing to the strong endemicity seen in other Pilbara Polydesmida.

Known distribution: records of these species obtained during this survey represent their known distributions.

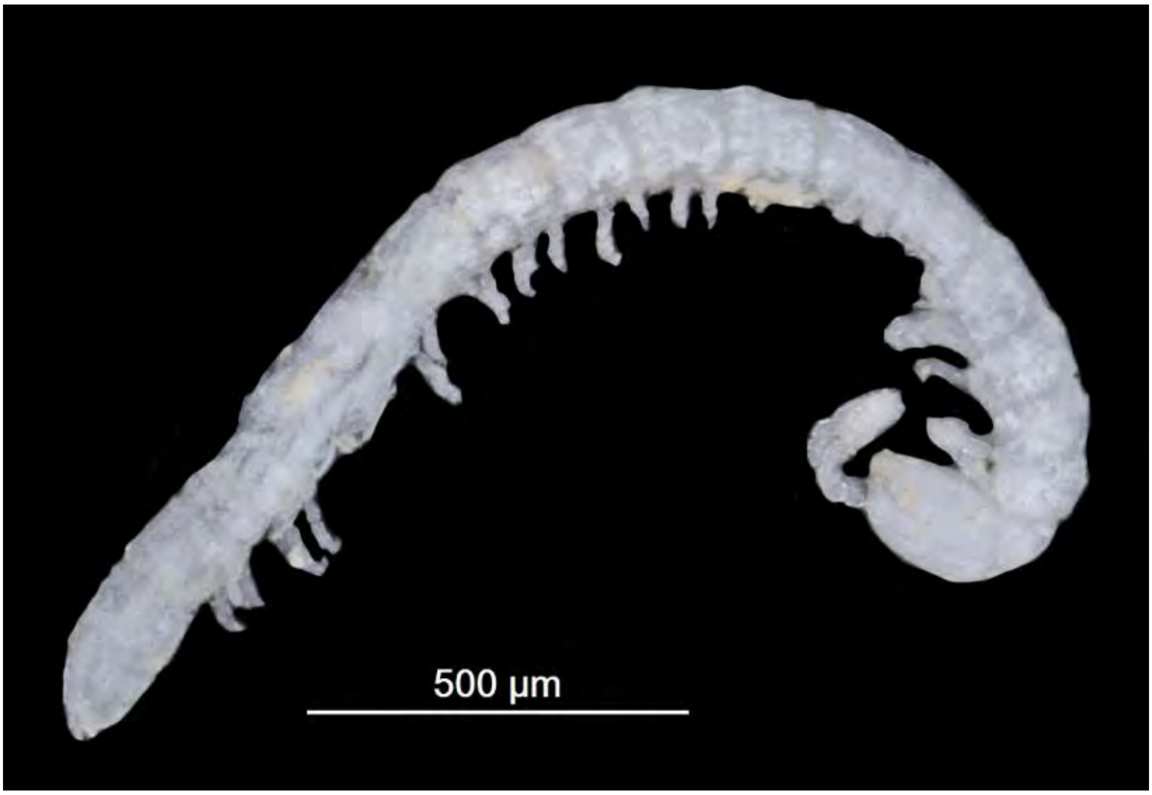

Figure 4-31 Image of Haplodesmidae sp. indet.

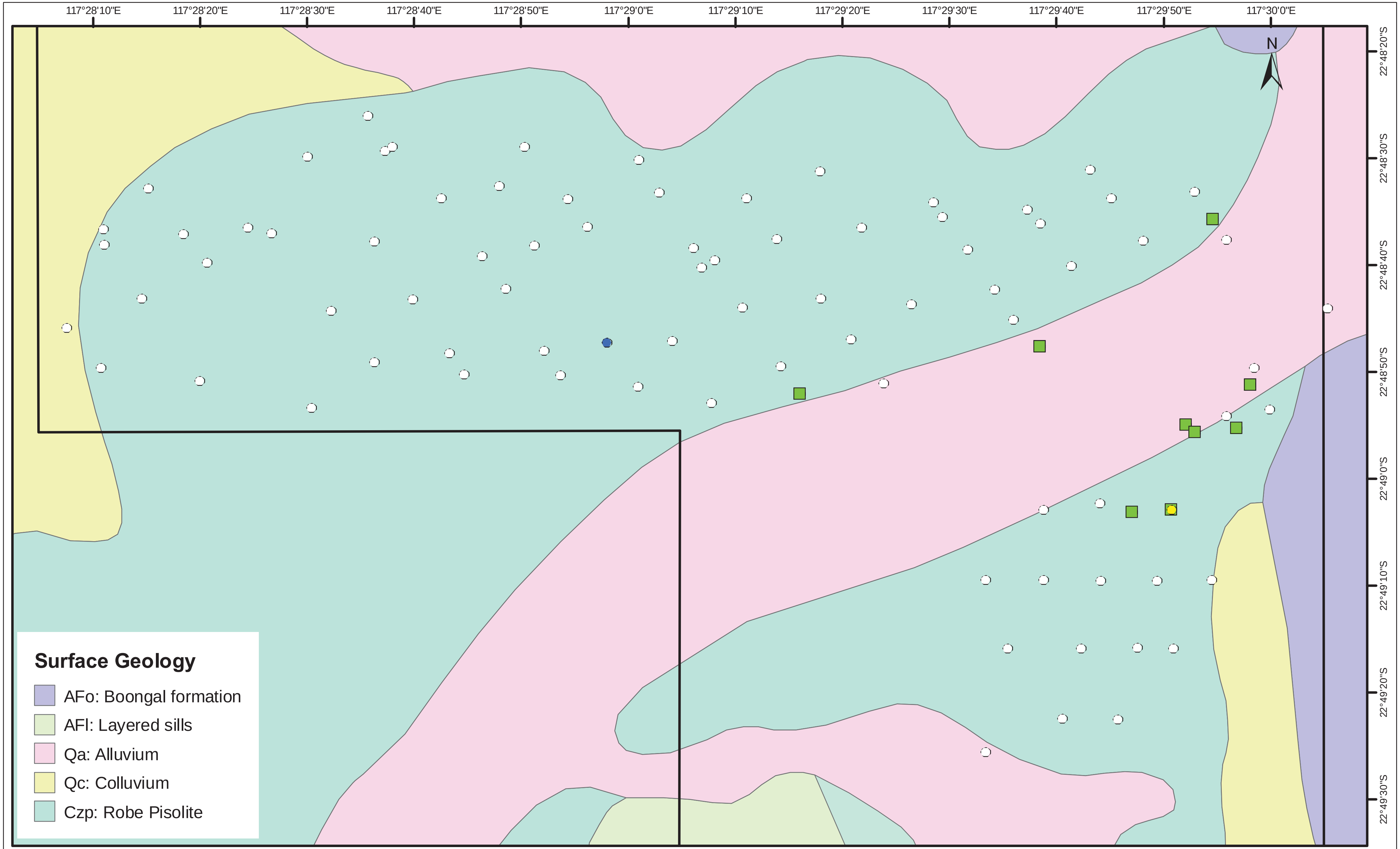

Figure 4-32 Haplodesmid site records

AUTHOR: E.S. Volschenk	CLIENT: Dragon Energy Ltd.
DATE: February 2013	Scale: 1:13,906

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Rocklea Iron Ore Project

Coordinate System: Projection: Transverse Mercator; DATUM: GDA94

4.5.12Arthropoda: Myriapoda: Pauropoda

Pauropods are tiny myriapods, distantly related to centipedes and millipedes. Like centipedes, they are characterised by multi-segmented and elongated bodies with 9-11 pairs of legs, one pair of legs per body segment. They are characterised by branching antennae and many species also possess conspicuous pairs of long setae on the sides of the body segments (Rupert & Barnes 1994). Very little is known about the Pauropoda of Western Australia, and there are no resident pauropod experts in WA. Recent studies undertaken on the genetics of pauropods indicate high levels of local endemism of species from subterranean habitats.

4.5.12.1 Pauropoda 'D1' and Pauropoda 'D1'

Survey records:

- Pauropoda 'D1' was represented by one specimen from bore R249[DNA] (Figure 4-34)
- Pauropoda 'D2' was represented by one specimen from bore R145[DNA] (Figure 4-34)
- Pauropoda sp. indet. (Figure 4-33) was represented by four specimens from four bores: R138, R148, R249 and R271 (Figure 4-34).

Taxonomic resolution: in the absence of local pauropod experts, the only reliable species level identifications depend on parataxonomy supported by genomic confirmation.

Genomic taxonomy: tissues from three specimens were submitted for sequencing; however, only two specimens yielded DNA sequences for genomic comparisons. These two specimens were found to have highly divergent sequences (32% sequence divergence Appendix 4) and therefore represent two distinct species: Pauropoda 'D1' and Pauropoda 'D2'. These species did not group with any of the six reference specimens, and the sequence divergence between all eight specimens ranged from 7.2% to 32.4%, indicating that both Rocklea species are different to the reference species

SRE status: Pauropoda 'D1', Pauropoda 'D2' are likely to be SREs owing to the high instance of local endemism observed in species of Pauropoda (Phoenix 2011). Four specimens could not be placed into species and were not sequenced. This ambiguous taxon is here referred to as Pauropoda sp. indet.

Known distribution: the records obtained for these species represent their known distribution.

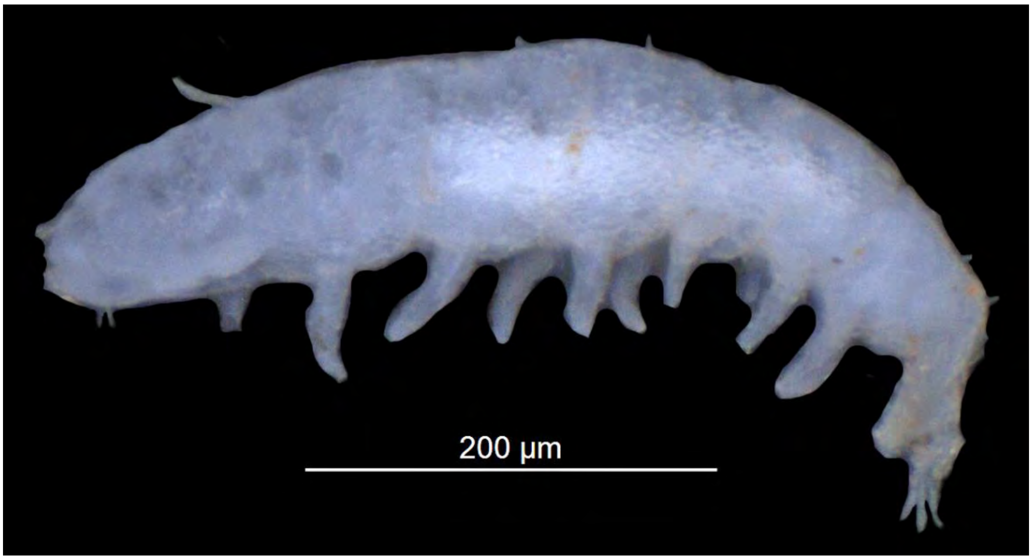

Figure 4-33 Image of Pauropoda sp. indet.

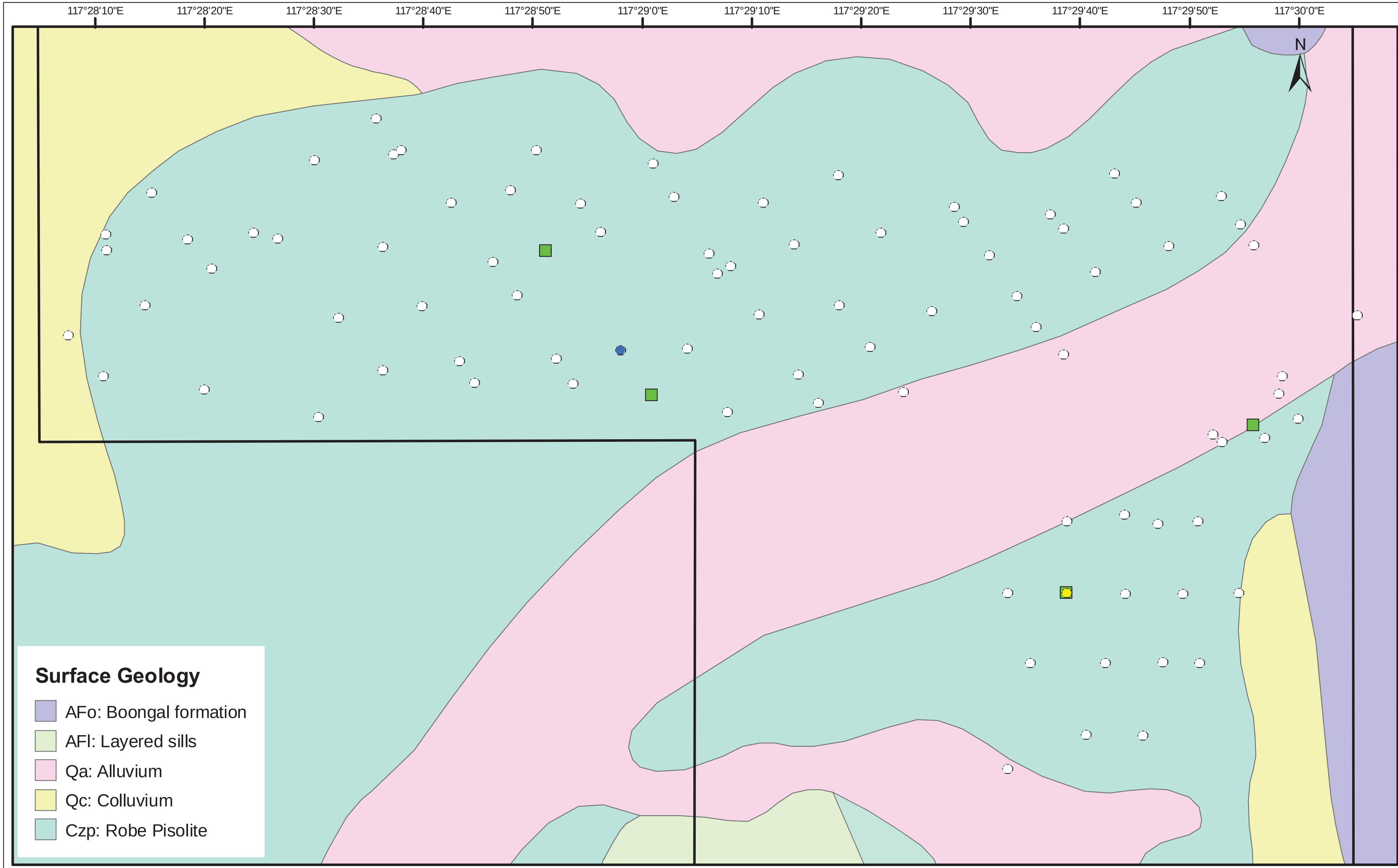

Figure 4-34 Pauropoda site records

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Coordinate System: Projection: Transverse Mercator; DATUM: GDA94	

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Rocklea Iron Ore Project

0 0.125 0.25 0.5 0.75 Kilometers

Pauropoda 'D1'
Pauropoda 'D2'
Pauropoda sp.
Survey Sites
Study Area

4.5.13Arthropoda: Myriapoda: Symphyla

Symphylans are a group of animals resembling centipedes in that they have a multi-segmented body which bears 1 pair of legs per segment. All Symphylans are blind and pale, possess 12 pairs of legs and a pair of long antennae and are usually less than 1 cm in length (Rupert & Barnes 1994). Symphylans can be found in the soil, leaf litter and under rocks. This group is poorly known and literature on the Australian species is very limited.

Species level identification of symphylans relies on genomic analysis. Genomic studies undertaken by Phoenix and Helix (unpublished) indicate that numerous undescribed species exist in the Pilbara and that most appear to be SREs. These studies have focussed on specimens collected from subterranean surveys and relationships between epigean species in the Pilbara are largely unstudied.

4.5.13.1 Symphyla 'D1a', Symphyla 'D1b' and Symphyla 'D2'.

Survey records:

- **Genetic species:**
    - Symphyla 'D1a' was represented by one specimen recorded from bore R263 (Figure 4-36)
    - Symphyla 'D1b' was represented by one specimen recorded from bore R228 (Figure 4-36)
    - Symphyla 'D2' was represented by one specimen recorded from bore R095 (Figure 4-36)
- **Species groups:**
    - Symphyla sp. indet. (Figure 4-35)was represented by seven specimens recorded from seven bores (Figure 4-36)

Taxonomic resolution: in the absence of local expertise on this group the only reliable species level identifications depend on genomic verification.

Genomic taxonomy: tissues from four specimens were submitted for sequencing; however, one specimen failed to yield COI sequences. The three specimens that were amplified from Rocklea were compared with 18 other reference species. The Rocklea specimens differed from the reference specimens by between 18.4% and 26.2% sequence divergence, indicating that they are different, and probably new species.

The Rocklea specimens differed from each other by between 4.3% and 24.4%, indicating that at least two species are present: Symphyla 'D1,-a -b' and Symphyla 'D2'. The genetic divergence between two specimens, here referred to as Symphyla 'D1a' and Symphyla 'D1b', was 4.3% which is below the average species discrimination difference of 8% (Hebert *et al.* 2003a; Hebert *et al.* 2003b); however, it is greater than what would be expected from specimens from the same population. This species may currently be undergoing speciation.

SRE status: Symphyla 'D1' and Symphyla 'D2' is likely to be an SRE. Four specimens could not be placed as they were not sequenced. This ambiguous taxon is here referred to as Symphyla sp. indet..

Known distribution: the records obtained for these species represent their known distributions.

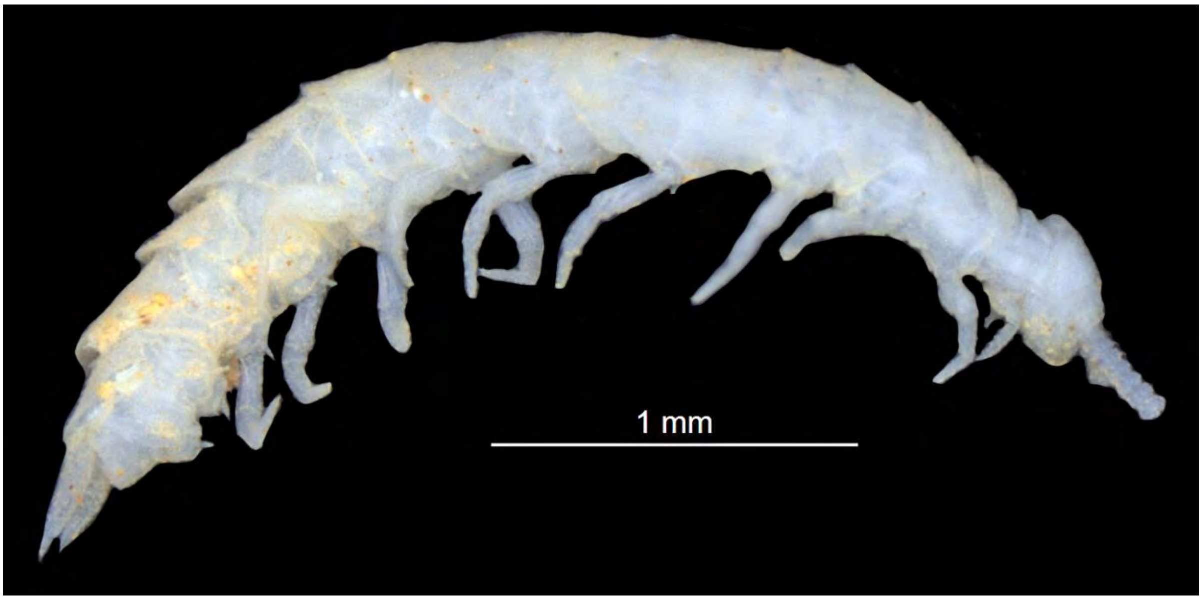

Figure 4-35 Image of Symphyla sp. indet.

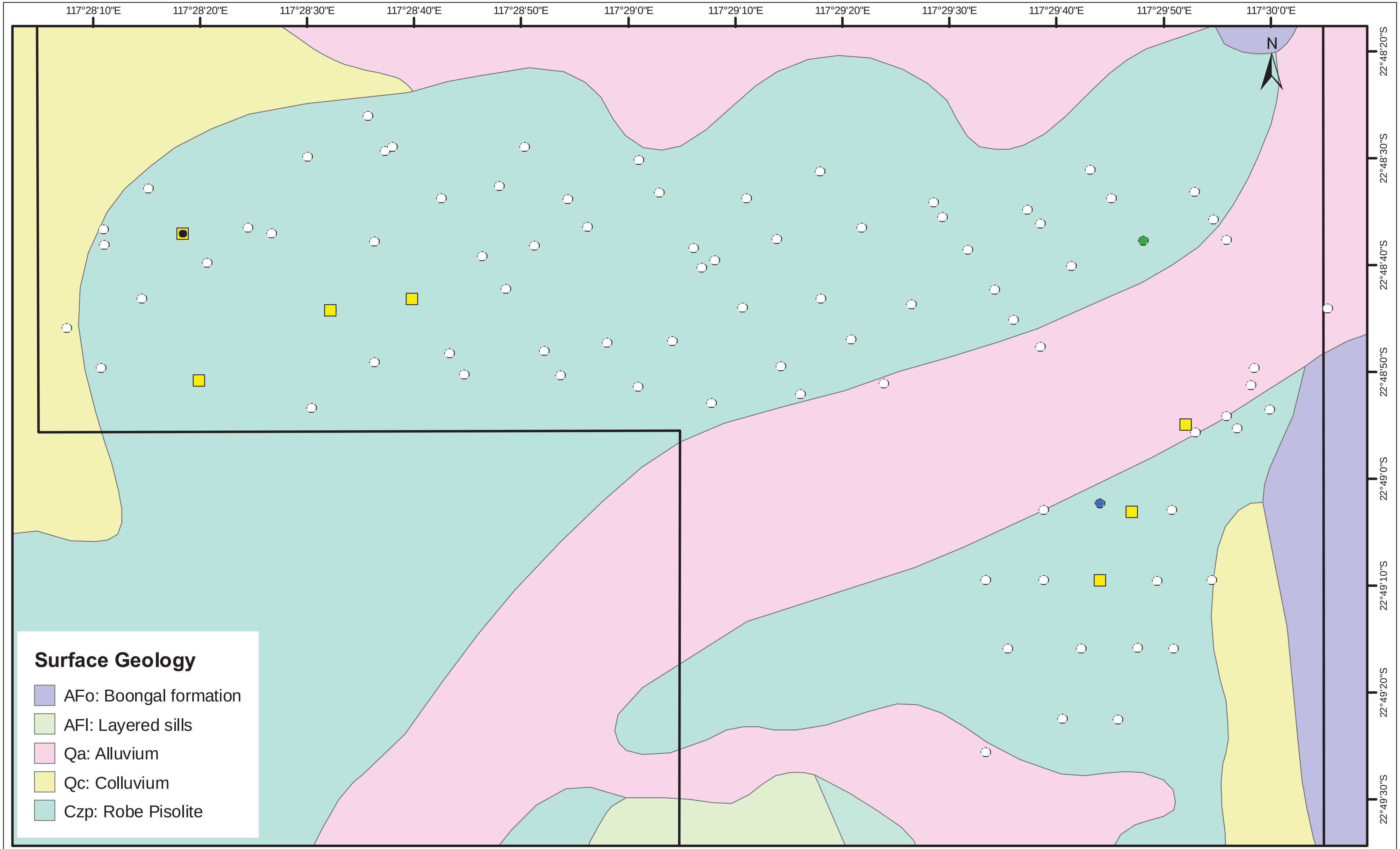

Figure 4-36 Symphylan site records

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CLIENT: Dragon Energy Ltd.

DATE: February 2013

Scale: 1:13,906

Coordinate System: Projection: Transverse Mercator; DATUM: GDA94

PHOENIX ENVIRONMENTAL SCIENCES

Rocklea Iron Ore Project

0 0.125 0.25 0.5 0.75 Kilometers

Symphyla 'D1a'

Symphyla 'D1b'

Symphyla 'D2'

Symphyla sp. indet.

Survey Sites

Study Area

4.6 TROGLOFAUNA COMMUNITY ASSESSMENT

Surface geology data obtained from DMP indicated the potential for two discrete and separate outcroppings of troglofauna habitat, each comprised of Robe River Pisolite (eastern and western). Both areas appeared to share common species, based on morphological assessment; however, troglofauna speciation often leads to a common suite of specialised morphologies, troglomorphies, which may result in different species with very similar looking morphologies.

Barcoding analyses of COI DNA sequences was used to assess the relationship between phylogenetic species, found in both eastern and western outcrops. Samples of species perceived to be the same on the basis of morphological assessment were selected from each resource outcrop (**Error! Reference source not found.**).

Table 4-4 Morphospecies samples selected for barcoding from the western and eastern outcrops

Taxon group	Sample location		Genetic difference
	Western outcrop	Eastern outcrop	
Cryptops sp.	R163	R266	Sequencing unsuccessful
Draculoides sp.	R123	R240	0.6%
Haplodesmidae	R145	R266	20.4%
Meenoplidae	R087	R272	3.6%
Nocticola 'Pilbara1'	R123	R252	4.1%
Palpigradi	R100	R271	Sequencing unsuccessful
Pauropoda	R145	R249	32%
Polyxenidae	R090	R229	0.5%
Symphyla	R095	R263, R228	22.4%

Three species pairs (Haplodesmidae, Pauropoda and Symphyla) had greater than 4% genetic difference between species pairs living in the western and eastern outcrops. Genetic divergence for *Nocticola* ‘Pilbara1’, a widespread species in the Pilbara, was only 4.1% between outcrop populations. This level of genetic difference is only slightly above the species delineation threshold used here. Three species pairs showed less than 4% genetic difference (*Draculoides*, Meenoplidae ‘widespread’ and Polyxenidae ‘PXD1’) between representatives in the western and eastern outcrop populations; however, two of these species are known to be widespread in the Pilbara.

The overall pattern of genetic similarity between the species pairs studies, suggests that most of the locally endemic species (species restricted to the Rocklea study area) are sister species pairs, with one species occurring in the eastern outcrop and another species occurring in the western outcrop. The current observations are based on sequencing of single specimens from each outcrop; additional specimens from each population in each taxonomic group would need to be sequenced to properly test this hypothesis.

4.7 STYGOFAUNA RECORDS

Nineteen putative stygofauna species were recorded from this survey. Four (21%) of these species were represented by only one or two specimens (Figure 4-37). Stygofauna specimens were recorded from 70 bores (Figure 4-38).

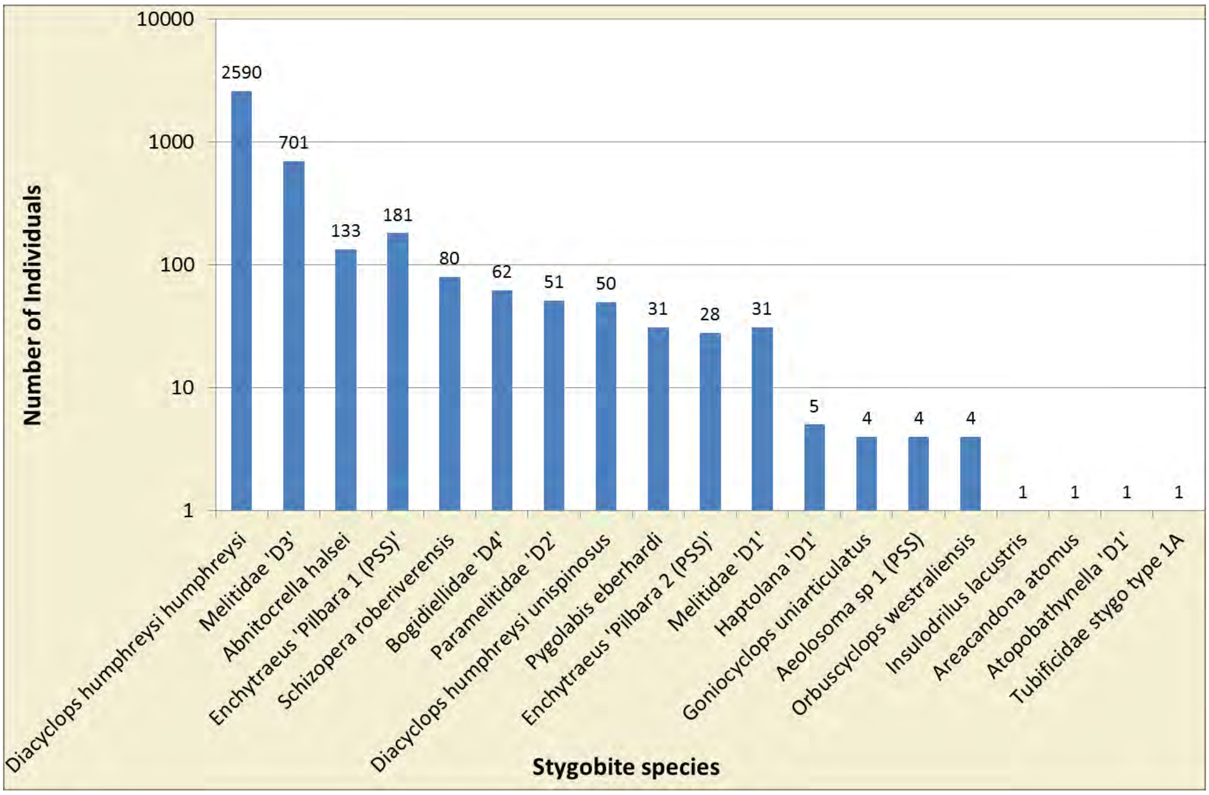

Figure 4-37 Abundance records for stygofauna species

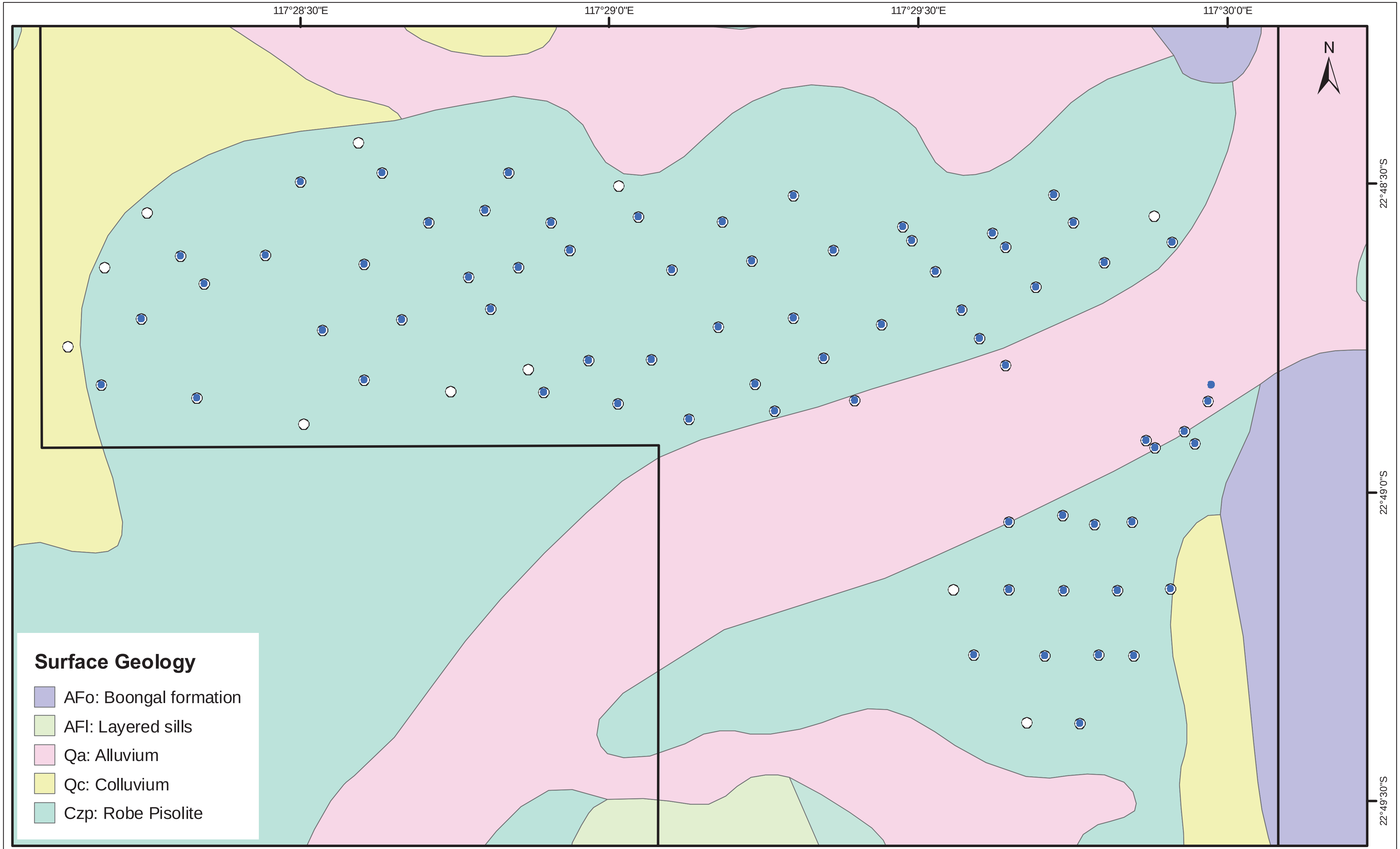

Figure 4-38 Stygofauna records from the survey

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0 0.125 0.25 0.5 0.75 Kilometers

Stygofauna records   Stygofauna sample sites   Study Area

4.7.1 Annelida: Clitellata: Haplotaxida

Clitellata are annelid worms (Annelida) that possess a clitellum, an organ that they use to produce cocoons into which their eggs are laid and in which part of their development occurs (Rupert & Barnes 1994). The order Haplotaxida is synonymous with Oligochaeta (Pinder 2010).

Fourteen specimens of Oligochaeta could not be identified to family or species owing to physical damage or immaturity of the specimens, these specimens were recorded from two sites: bore sample R103 and the Karaman-Chappuis site, Hardey River kar2, and referred to collectively as Oligochaeta sp. indet.

4.7.1.1 Enchytraeidae

Enchytraeidae is a large and complex family of annelid worms. They are characterised by the placement of the clitellum between segments XII–XIII and have all chetae single pointed (Pinder 2010). Their diversity and taxonomy are poorly known in Western Australia.

Survey records:

- **Morphospecies**
  - *Enchytraeus* 'Pilbara 1 (PSS)' was represented by 181 specimens recorded from 15 bores: R123, R125, R151, R158, R170, R184, R223, R225, R228, R230, R255, R263, R268, R271 and R273 (Figure 4-39)
  - *Enchytraeus* 'Pilbara 2 (PSS)' was represented by 28 specimen recorded from bore R125 (Figure 4-39)
- **Species groups**
  - *Enchytraeus* sp. indet. was represented by 13 specimen recorded from 10 bores R112, R145, R148, R169, R187, R223, R225, R230, R267 and R272 (Figure 4-39)

Taxonomic resolution: specimens were identified to *Enchytraeus* 'Pilbara 1 (PSS)' and *Enchytraeus* 'Pilbara 2 (PSS). Additional immature or damaged specimens were also identified to Enchytraeidae sp. indet.; however, they are likely to be either of the 'known' species listed here.

Genomic taxonomy: no genomic analyses were undertaken owing to the morphological identifications obtained.

SRE status: neither *Enchytraeus* 'Pilbara 1 (PSS)'nor *Enchytraeus* 'Pilbara 2 (PSS)' are considered to be an SRE.

Known distribution: Both of these species are widely distributed throughout the Pilbara (M. Scanlon 2011, pers. comm. to E.S. Volschenk).

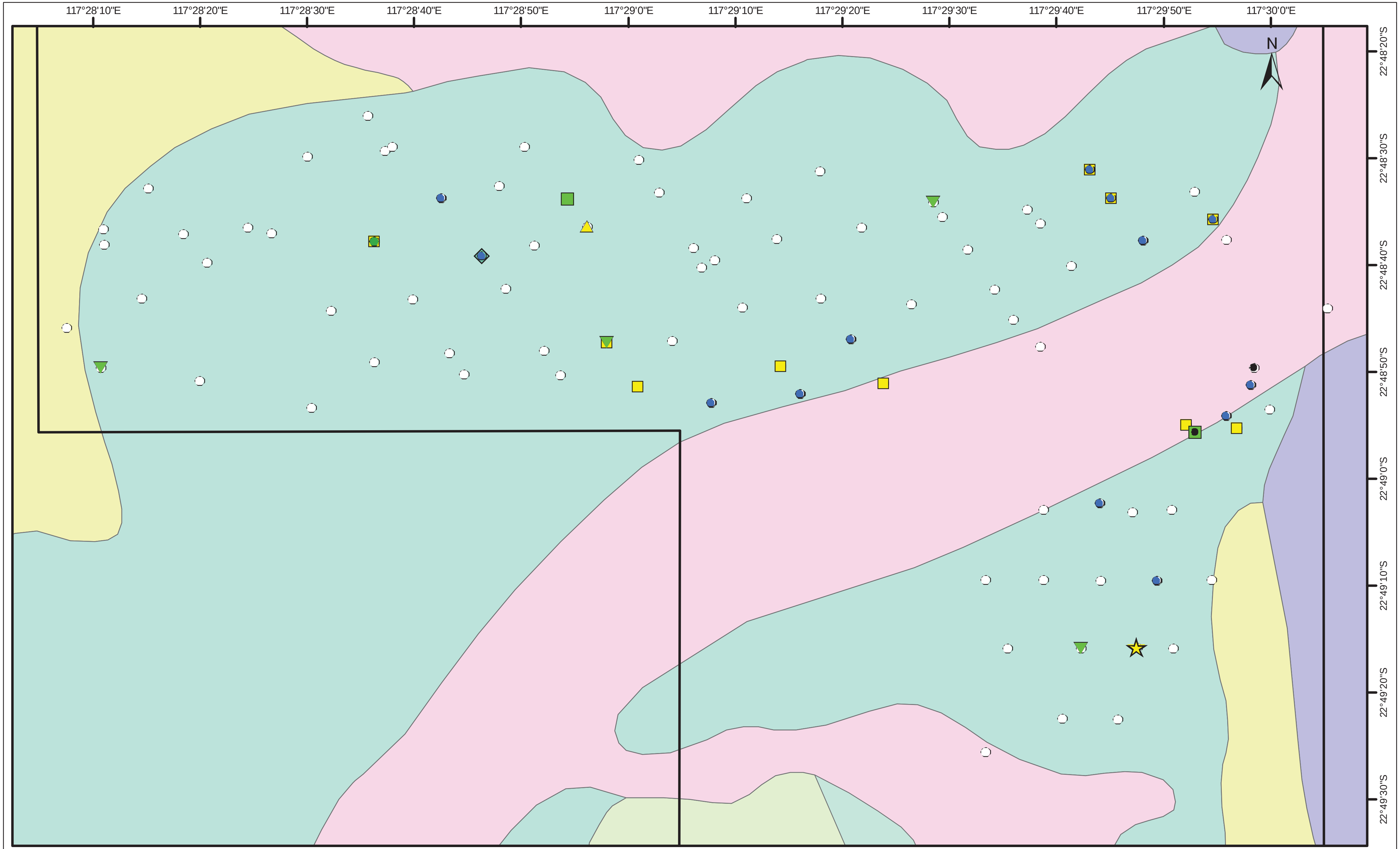

Figure 4-39 Annelid site records

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4.7.1.2 Naididae

Naididae are characterised by the position of the clitellum, between segments IV–VIII. Naidids are also referred to a sludge worms owing to their occurrence in fine sediments (Pinder 2010). They are often represented in stygofauna surveys and most species appear to be widespread (Subterranean Ecology 2010)

Survey records: Tubificidae stygo type 1 was represented by six specimens from one bore and two Karaman-Chappuis sites: R268 (Figure 4-39), Hardey River kar1 and Hardey River kar2.

Taxonomic resolution: specimens were identified to morphospecies. A single species of Naididae, Tubificidae stygo type 1, was identified from the survey.

Genomic taxonomy: no genomic analyses were undertaken owing to the morphological identifications obtained.

SRE status: Tubificidae stygo type 1 is not considered to be an SRE.

Known distribution: this species is widespread in the Pilbara.

4.7.1.3 Phreodrilidae

Phreodrillidae are characterised by the position of the clitellum, between segments XII–XIII (Pinder 2010). Phreodrillids are often represented in stygofauna surveys and most species appear to be widespread (Subterranean Ecology 2010).

Survey records:

- **Morphospecies**
  - *Insulodrilus lacustris* was represented by two specimens from one bore and one Karaman-Chappuis site: R112 (Figure 4-39), Hardey River kar1
- **Species groups**
  - Phreodrilid 'with dissimilar ventral chaetae' was represented by two specimens from bore R152 (Figure 4-39)
  - *Phreodrilus* sp. indet. was represented by three specimens from two bores: R151 and R268 (Figure 4-39)
  - Phreodrilidae sp. indet. was represented by 8 specimens from four bores: R087, R145, R202 and R240 (Figure 4-39)
  - *Insulodrilus* sp. indet. was represented by 26 specimens from two bores: R203 and R268 (Figure 4-39)

Taxonomic resolution: specimens were identified to morphospecies. One morphospecies was identified, *Insulodrilus lacustris*. Phreodrilidae 'with dissimilar ventral chaetae' does not represent a species level identification (Pinder 2010).

Genomic taxonomy: no genomic analyses were undertaken owing to the morphological identifications obtained.

SRE status: *Insulodrilus lacustris* is not an SRE species.

Known distribution: Phreodrilidae 'with dissimilar ventral chaetae' and *Insulodrilus lacustris* are widespread species.

4.7.1.4 Annelida: Polychaeta: Scolecida

Aelosomatids are extremely unusual annelids and are loosely placed in the Order Polychaeta. Aelosomatids are therefore unusual representatives of the order, living in fresh water, since almost all polychaetes are marine (Beesley *et al.* 1998). Little is known about the Aelosomatids of the Pilbara but they are thought to be widespread and are probably not SREs (Pinder 2010).

Survey records: *Aeolosoma* sp 1 (PSS) was represented by four specimens from bore R242 (Figure 4-39).

Taxonomic resolution: specimens were identified to *Aeolosoma* sp 1 (PSS).

Genomic taxonomy: no genomic analyses were undertaken owing to the morphological identifications obtained.

SRE status: *Aeolosoma* sp 1 (PSS) not an SRE.

Known distribution: *Aeolosoma* sp 1 (PSS) have been collected widely from the Pilbara; however, they never appear to be abundant and often have very patchy distributions.

4.7.2 Arthropoda: Malacostraca: Amphipoda

Amphipods of WA are relatively well studied; however, the diversity of subterranean species from the Pilbara and Yilgarn regions of WA is extremely high and continues to yield many new species, as is evidence by the 4 new species discovered by this survey. In the Pilbara, subterranean amphipods are represented by the families Bogidellidae, Melitidae and Paramelitidae, all of which are characterised by locally endemic species distributions and are likely SREs (Finston *et al.* 2005; Finston *et al.* 2004; Finston *et al.* 2007).

Stygobitic amphipods from the Pilbara are relatively well studied (Finston *et al.* 2004; Finston & Johnson 2004; Finston *et al.* 2007). These studies clearly indicate both, the high levels of endemicity that exist within pilbara amphipods, and the inconsistency between morphology and genomic information in obtaining reliable species level identifications.

Taxonomic resolution: morphological features can be misleading and species level identifications are heavily reliant on genomic assessment. Current knowledge of Pilbara amphipods indicates that they are typically endemic to aquifers and that their distributions reflect an interaction of modern geological events and paleodrainage systems (Finston & Johnson 2004).

The survey at Rocklea detected four different morphospecies of amphipods based on morphological examination. Two families were identified (Melitidae and Paramelitidae), and a possible third (Bogidellidae) were detected from morphology.

Genomic taxonomy (high level): seven specimens representing the four morphospecies were submitted for sequencing. Forty-three reference specimens representing different species from the Pilbara were included in the analyses. This analysis confirmed the family placements of the Rocklea amphipods made on the basis of morphology, as well as the parataxonomy of these specimens (Appendix 4):

- the family Paramelitidae was represented by a single haplotype, one specimen sequenced
- the family Melitidae was represented by two haplotypes: four specimens sequenced, two specimens of each morphospecies
- the family Bogidellidae was represented by one haplotype: two specimens sequenced.

Nineteen specimens from nine bores (R096, R114, R149, R165, R225, R242, R249, R255, R267) could not be identified to species owing to physical damage, these are referred to collectively as Amphipoda sp. indet.

4.7.2.1 Paramelitidae 'D1'

Genomic taxonomy: only one specimen of this species was sequenced owing to its unique morphology. The analysed included 21 reference paramelitids. The Rocklea species differed from the reference species by between 18.5% and 23.2% sequence divergence therefore it is not conspecific with any of the reference species, and is here referred to as Paramelitidae 'D1' .

Survey records: Paramelitidae 'D1' (Figure 4-40) was represented by 51 specimens recorded from 19 bores (Figure 4-42): R112, R145, R151, R156, R158, R163, R175, R181, R187, R193, R208, R212, R228, R249, R252, R260, R263, R264 and R268.

SRE status: Paramelitidae 'D1'is a likely SRE.

Known distribution: Paramelitidae 'D1' is only known from this study.

Figure 4-40 Image of Paramelitidae 'D1'

4.7.2.2 Bogidellidae 'D1'

Survey records: Bogidellidae 'D1' (Figure 4-41) was represented by a 62 specimen recorded from 22 bores (Figure 4-42): R090[DNA], R112, R123, R129, R138, R148, R156, R163, R165, R169, R175, R193, R216, R223, R228, R230, R240, R242[DNA], R252, R255, R260 and R267.

Genomic taxonomy: two specimens of this morphospecies were sequenced. The analysis included nine reference bogidellid species. The analyses found the two specimens of the Rocklea morphospecies to differ by only 2.2% sequence divergence, indicating that they belong to the same species and population, here referred to as Bogidellidae 'D1'. This species differed from the reference bogidellids by between 18.1% and 24.4% indicating that it is not one of the reference species and it therefore likely to be a new species.

SRE status: Bogidellidae 'D1' is a likely SRE.

Known distribution: only known from this survey.

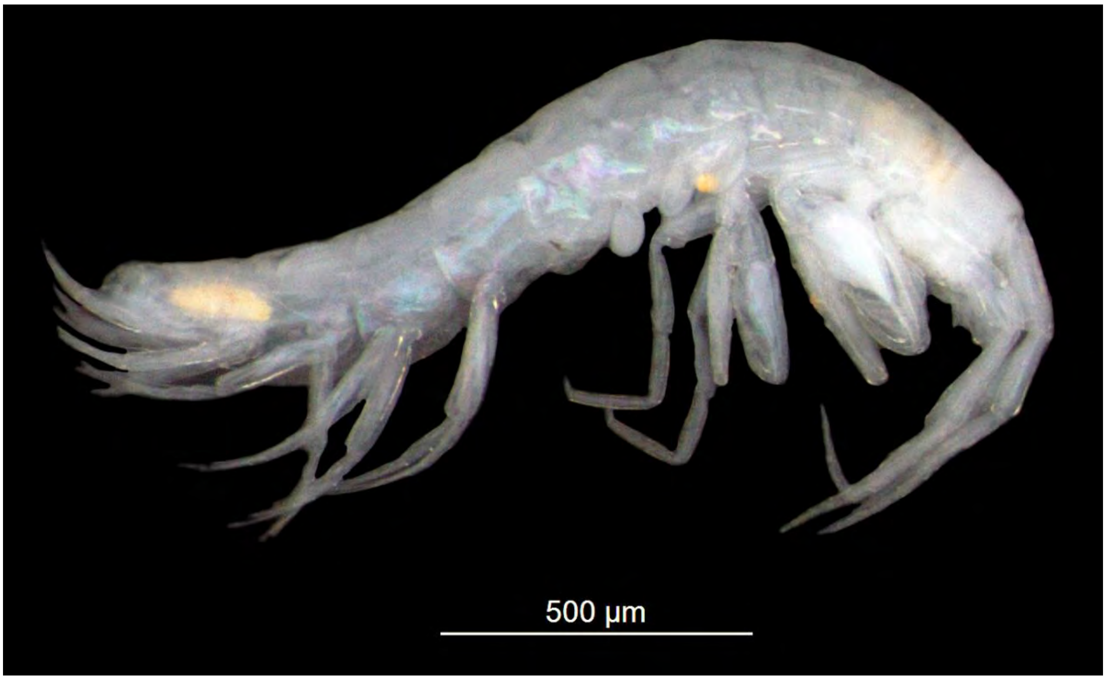

Figure 4-41 Image of Bogidellidae 'D1'

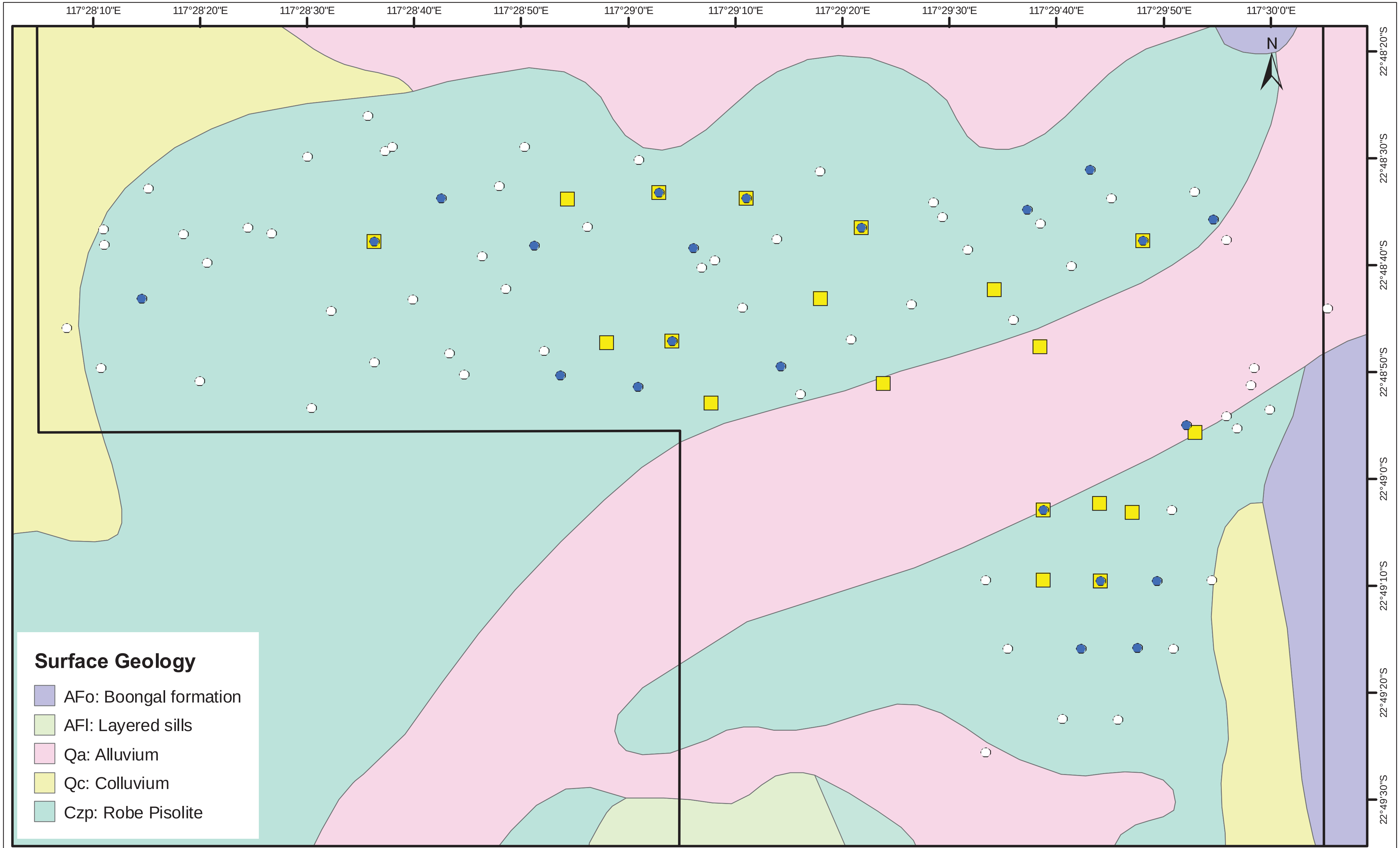

Figure 4-42 Paramelitidae 'D1' and Bogidellidae 'D1' site records

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0 0.125 0.25 0.5 0.75 Kilometers

Melitidae 'D1' and Melitidae 'D2'

Survey records:

- Melitidae 'D1' (Figure 4-44) was represented by a 31 specimen recorded from 25 bores (Figure 4-45): R112, R123^{DNA}, R148, R149, R175, R208, R210, R220, R228, R242^{DNA}, R252, R255, R260, R266, R267 and R273.
- Melitidae 'D2' (Figure 4-43) was represented by 701 specimens recorded from 49 bores (Figure 4-45): R090, R092, R105, R108, R112, R114, R123^{DNA}, R126, R129, R134, R138, R145, R148, R149, R151, R152, R156, R158, R163, R169, R175, R178, R184, R187, R197, R205, R208, R210, R212, R216, R217, R220, R223, R223, R228, R230, R240, R242^{DNA}, R244, R249, R252, R255, R260, R263, R266, R267 and R268.

Genomic taxonomy: four specimen representing two clearly different morphospecies were sequenced, two specimens of each species. The analyses included 14 reference melitid species. The two Rocklea species differed from each other by 17% sequence divergence indicating that they do not belong to the same species. They also differed from the reference melitids by between 9.5% and 18.9% sequence divergence, indicating that the Rocklea species do not belong to any of the reference species. For this reason it is likely that both of these species are new and are here referred to as Melitidae 'D1' and Melitidae 'D2', The position of these species within the phylogeny indicates that it they may belong to the genus *Nedsia.*

SRE status: Both Melitidae 'D1' and Melitidae 'D2' are likely to be SREs owing to the high incidence of local endemism seen in other species of Melitidae.

Known distribution: only known from this survey.

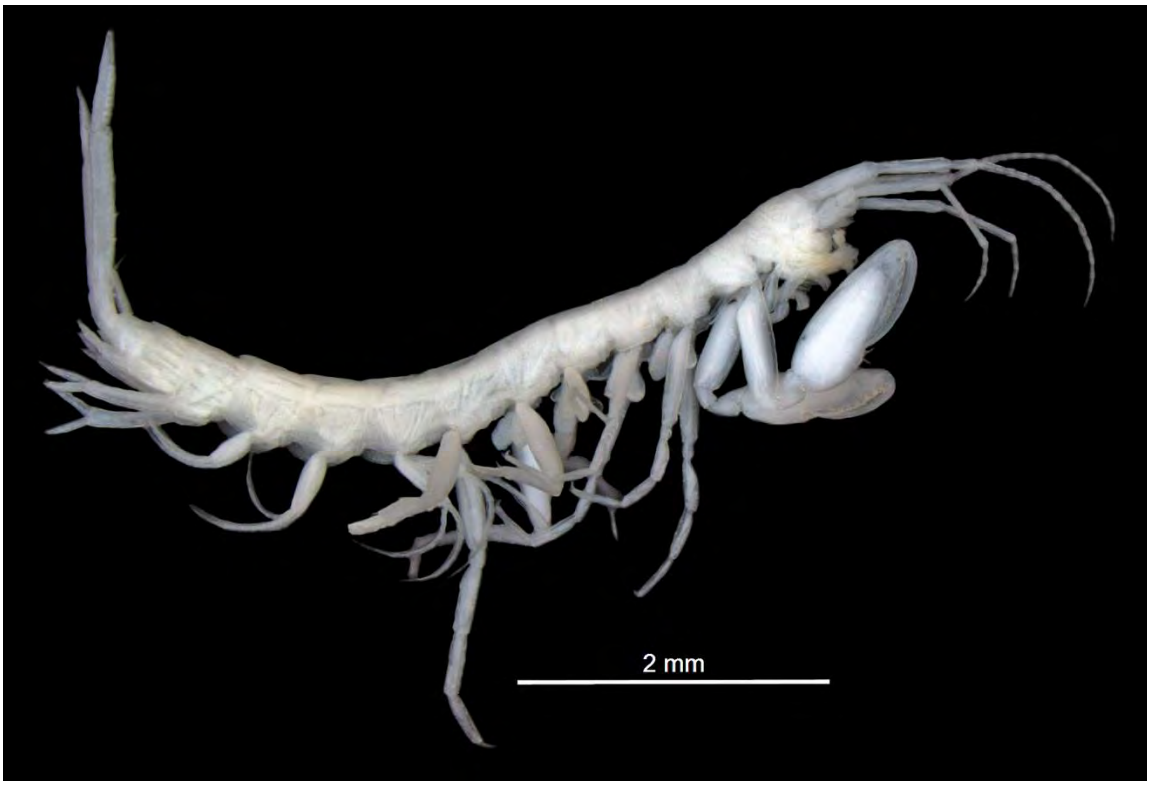

Figure 4-43 Image of Melitidae 'D1'

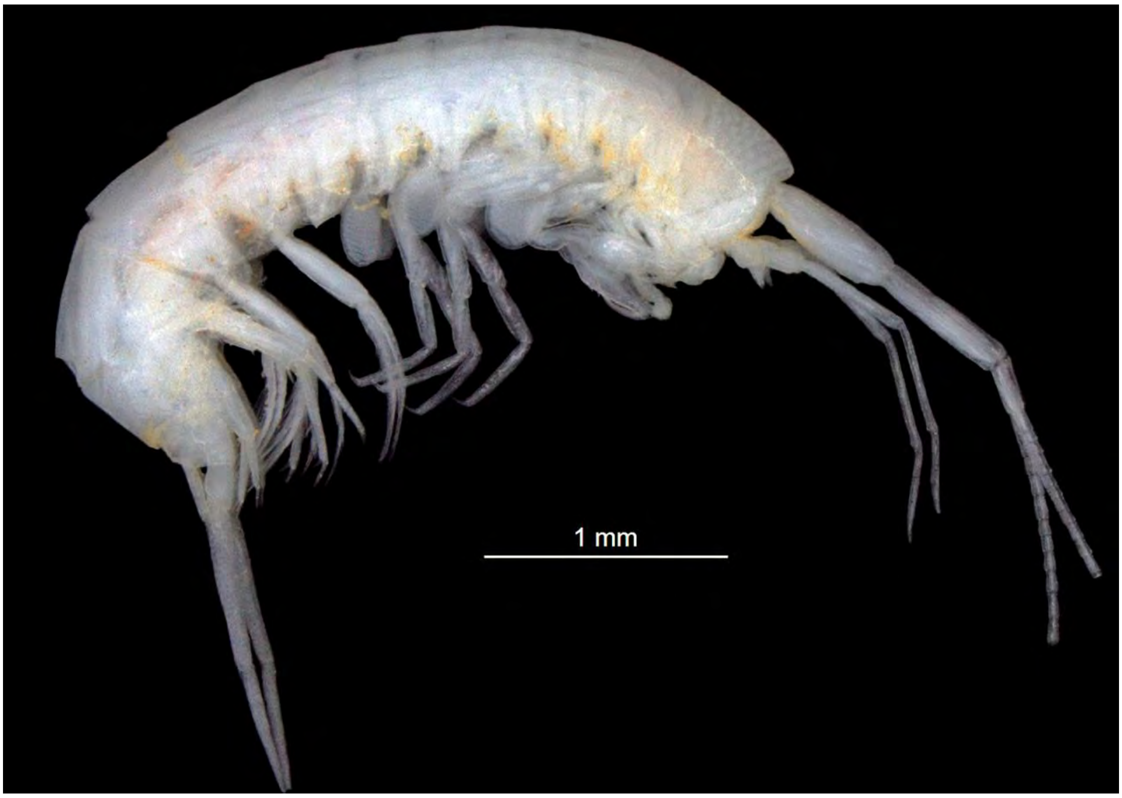

Figure 4-44 Image of Melitidae 'D2'

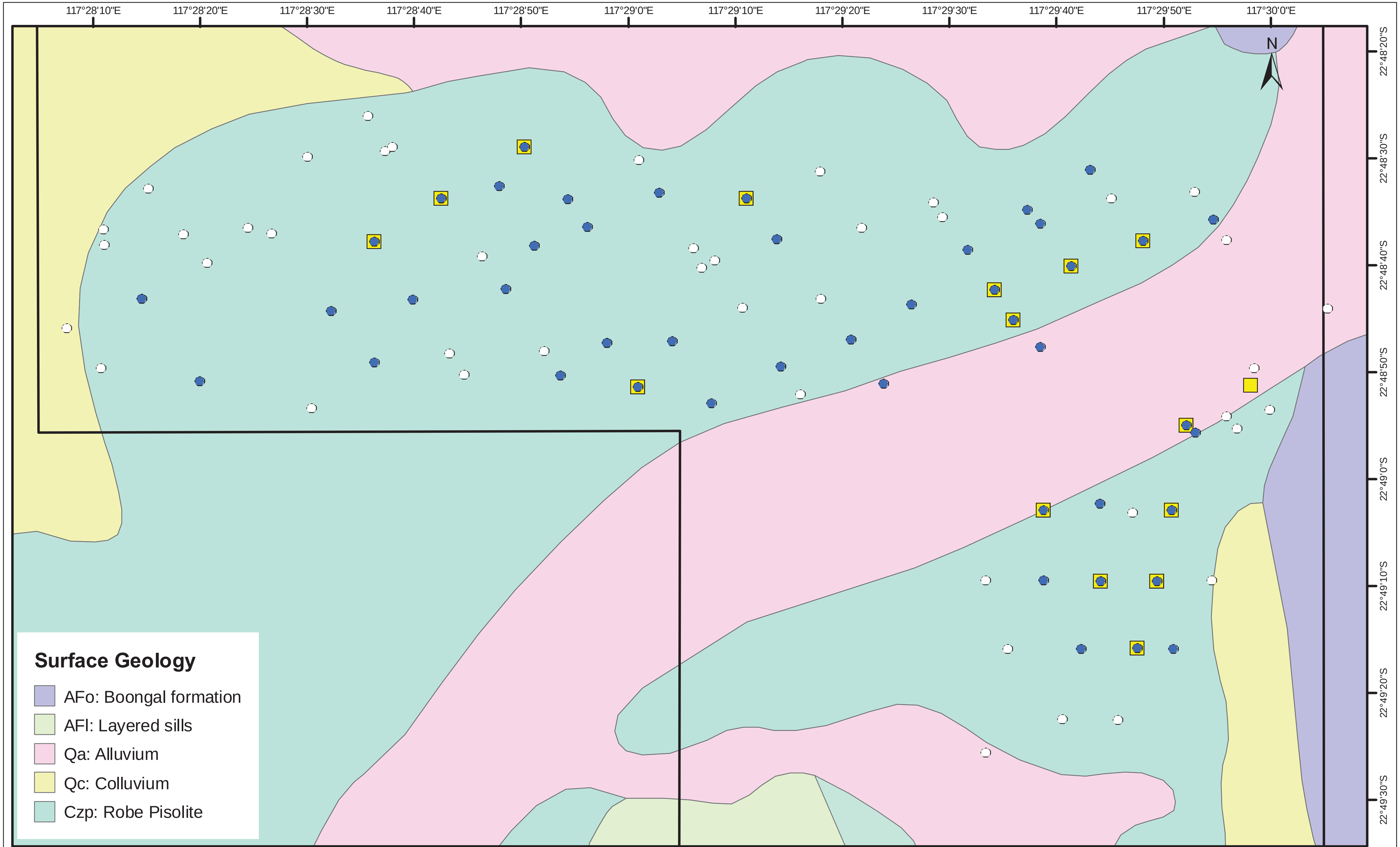

Figure 4-45 Melitid site records

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Rocklea Iron Ore Project

0 0.125 0.25 0.5 0.75 Kilometers

Melitidae 'D2' Survey Sites

Melitidae 'D1' Study Area

4.7.3 Arthropoda: Malacostraca: Isopoda

The family Tainisopidae, is endemic to Western Australia where it is represented by the genera *Tainisopus* (only known from the Kimberley region) and *Pygolabis* (mostly confined to the Pilbara region). All representatives of the family are stygobitic (Wilson 2003). The genus *Pygolabis* is currently represented by five described species and many additional species are known from the Pilbara area (Phoenix unpublished data).

4.7.3.1 *Pygolabis eberhardi*

Survey records: *Pygolabis eberhardi* (Figure 4-46) was represented by 31 specimens recorded from 16 bores (Figure 4-48): R105, R114, R129, R138, R151, R156, R163, R167, R175, R210, R223, R228, R235, R242, R252 and R263.

Taxonomic resolution: this species appears to be conspecific with *Pygolabis eberhardi* (Figure 4-46), identified using Keable & Wilson (2006). The Rocklea area is approximately 20 km from the type locality of *Pygolabus eberhardi* further supporting this identification.

Genomic taxonomy: tissues from two specimens of this species were submitted for genomic comparisons; however, none yielded sequences; therefore, genomic confirmation of morphospecies was not possible.

SRE status: *Pygolabus eberhardi* this species is a likely SRE.

Known distribution: : Keable & Wilson (2006) indicated a widespread distribution for this species (over 150 km between the Hardey River bore field and Red Well). Those species decisions were based entirely on morphological identifications; however, more recent genomic data on the distributions of *Pygolabis* species (Phoenix unpublished data) suggests that such a widespread distribution is unlikely and that multiple species are probably involved. We consider the immediate surrounds of the 'type locality' for this species more likely to represent its natural distribution.

Figure 4-46 Image of *Pygolabis eberhardi*

4.7.3.2 *Haptolana* 'D1'

Stygobitic Cirolanidae are unique amongst the stygobitic isopods of the Pilbara in possessing, uropods and telson in a fan-shaped arrangement. Most members of this family are marine, however one stygobitic species has been described from Barrow Island (Bruce 1986; Bruce & Humphreys 1993). Very little is known about the subterranean Cirolanidae of the Pilbara.

Survey records: *Haptolana* 'D1' (Figure 4-47) was represented by five specimens recorded from four bores (Figure 4-48): R145[DNA], R242[DNA], R252 and R268.

Taxonomic resolution: no stygobitic cirolanids have been described from the Pilbara; however, specimens have been recorded from several localities on Barrow Island (Bruce & Humphreys 1993).

Genomic taxonomy: tissues from two specimens of a morphospecies of cirolanid isopod were sequenced and analysed. Fifteen reference isopods were included in the analysis. Four specimens of *Haptolana pholeta* were included among the reference specimens, the only described freshwater cirolanids from WA. The two specimens from Rocklea differed from each other by 0.0% sequence divergence indicating that they belong to the same species. The Rocklea specimens differed from *Haptolana pholeta* by 17% sequence divergence, confirming that they belong to a different species that is probably new, but possibly belonging to the same genus (Appendix 4) and it is here referred to as *Haptolana* 'D1'.

SRE status: *Haptolana* 'D1' is likely to be an SRE owing to the high incidence of local endemism seen in other morphospecies of Cirolanidae in the Pilbara. The Pilbara cirolanids are currently under review and several additional species are known but are not presently available for investigation (W. Humphreys 2011, pers. comm.).

Known distribution: the records obtained for this species represent its known distribution.

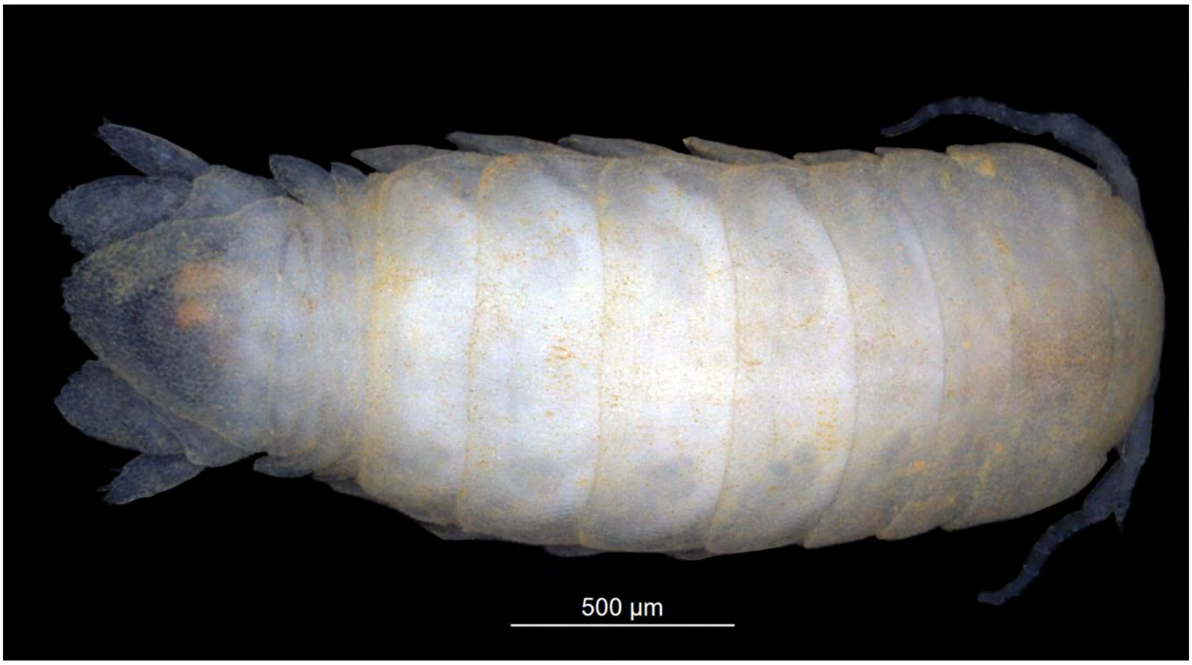

Figure 4-47 Image of *Haptolana* 'D1'

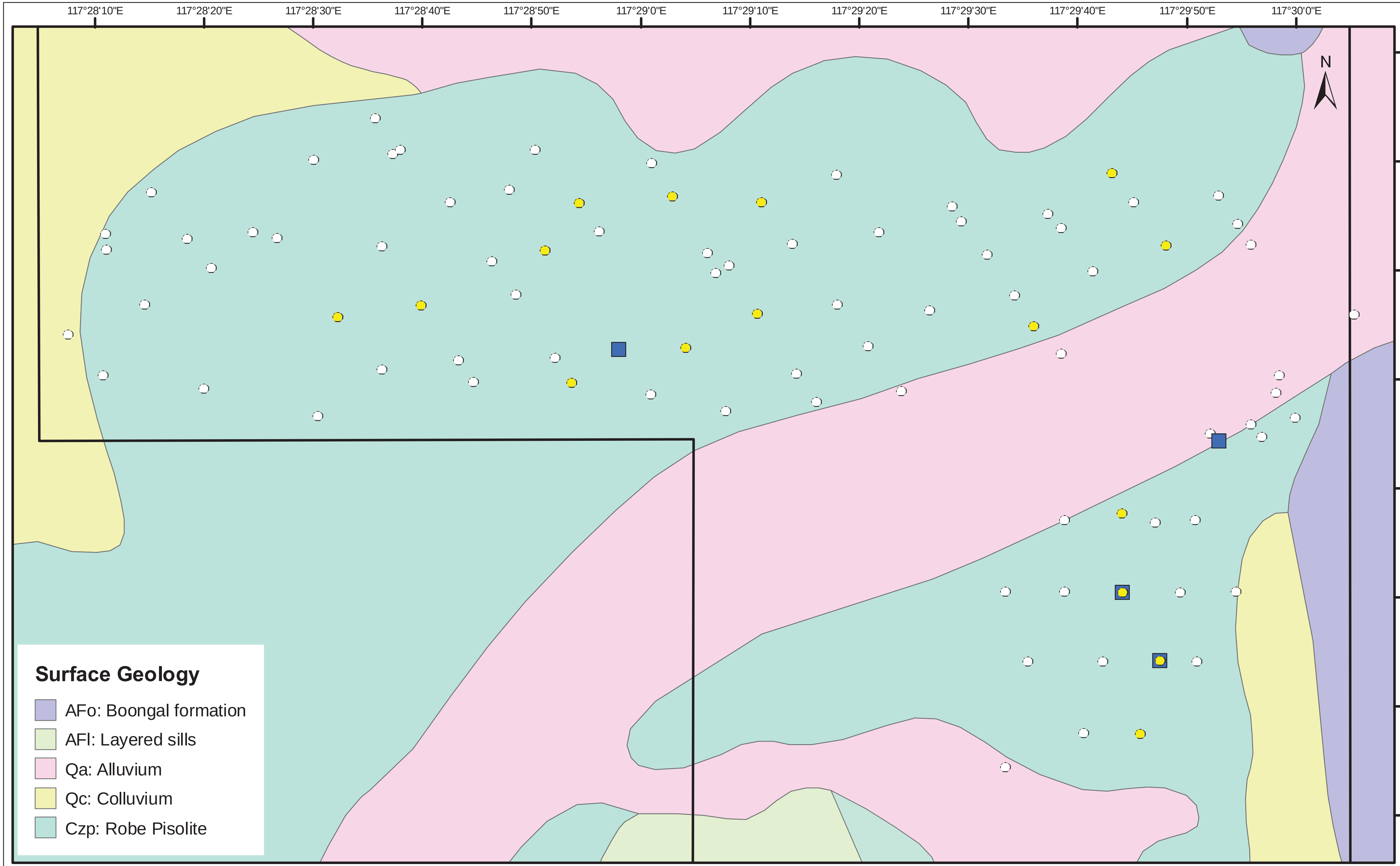

Figure 4-48 *Pygolabis eberhardi* and *Haptolana* 'D1' site records

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4.7.4 Arthropoda: Malacostraca: Syncarida

Syncarids are an ancient order of crustaceans and while very diverse, they are almost entirely subterranean (Rupert & Barnes 1994). In Western Australia, the families Bathynellidae and Parabathynellidae are known from both stygal and hyporheic habitats (Phoenix 2011; Subterranean Ecology 2010).

Bathynellidae are identified from Parabathynellidae by the roughly equal development of the first and second antennae and by the presence of one or two short appendages on the ventral side of the abdomen. Parabathynelids have second antennae significantly smaller than the first antennae, and the abdomen possesses no ventral appendages. Parabathynellids appear to be more commonly surveyed than bathynellids; however, representatives of both families often appear to be locally endemic and are therefore likely SREs (Phoenix 2011).

4.7.4.1 *Atopobathynella* 'D1'

Survey records: *Atopobathynella* 'D1' (Figure 4-49) was represented by one specimen recorded from bore R203 (Figure 4-50):

Taxonomic resolution: very little is known about the Parabathynellidae of WA and reliable species level identifications depend on parataxonomy and supported by genomic confirmation. Genomic studies by Phoenix and Helix (unpublished) have demonstrated the highly endemic nature of stygobitic parabathynellids.

Genomic taxonomy: a single species was identified and one specimen was chosen for DNA sequencing. This specimen was compared with 33 reference specimens, comprising 21 specimens of Parabathynellidae and 12 specimens of Bathynellidae. The position of the Rocklea specimen within Parabathynellidae was supported, and the placement of this species within a clade containing species of *Atopobathynella*, indicates that it is likely to belong to this genus.

The Rocklea specimen differed from other representatives of the *Atopobathynella* clade by between 16.1% and 17.8% sequence divergence, indicating that this specimen does not belong to any of the reference species and we refer to it here as *Atopobathynella* 'D1'(Figure 4-49). This is likely to be a new species.

SRE status: *Atopobathynella* 'D1' is likely to be an SRE based on the distributions of other stygobitic Parabathynellidae.

Known distribution: the records of *Atopobathynella* 'D1' obtained in this survey represent the known distribution of this species.

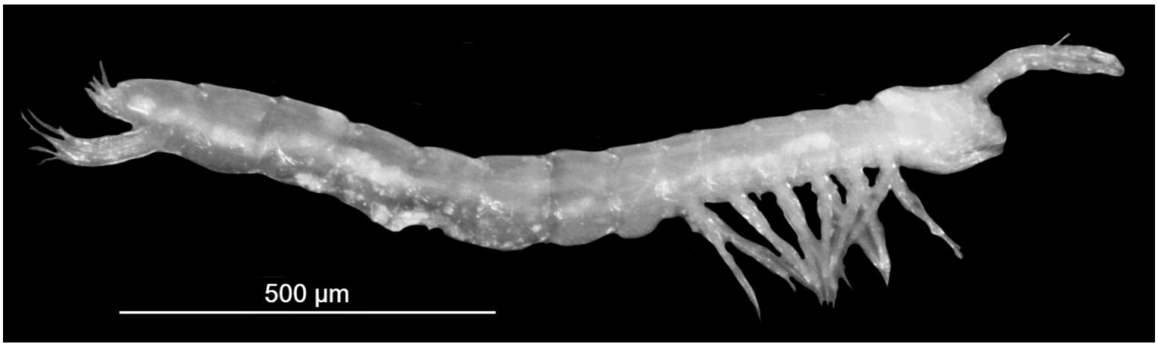

Figure 4-49 Image of *Atopobathynella* 'D1'

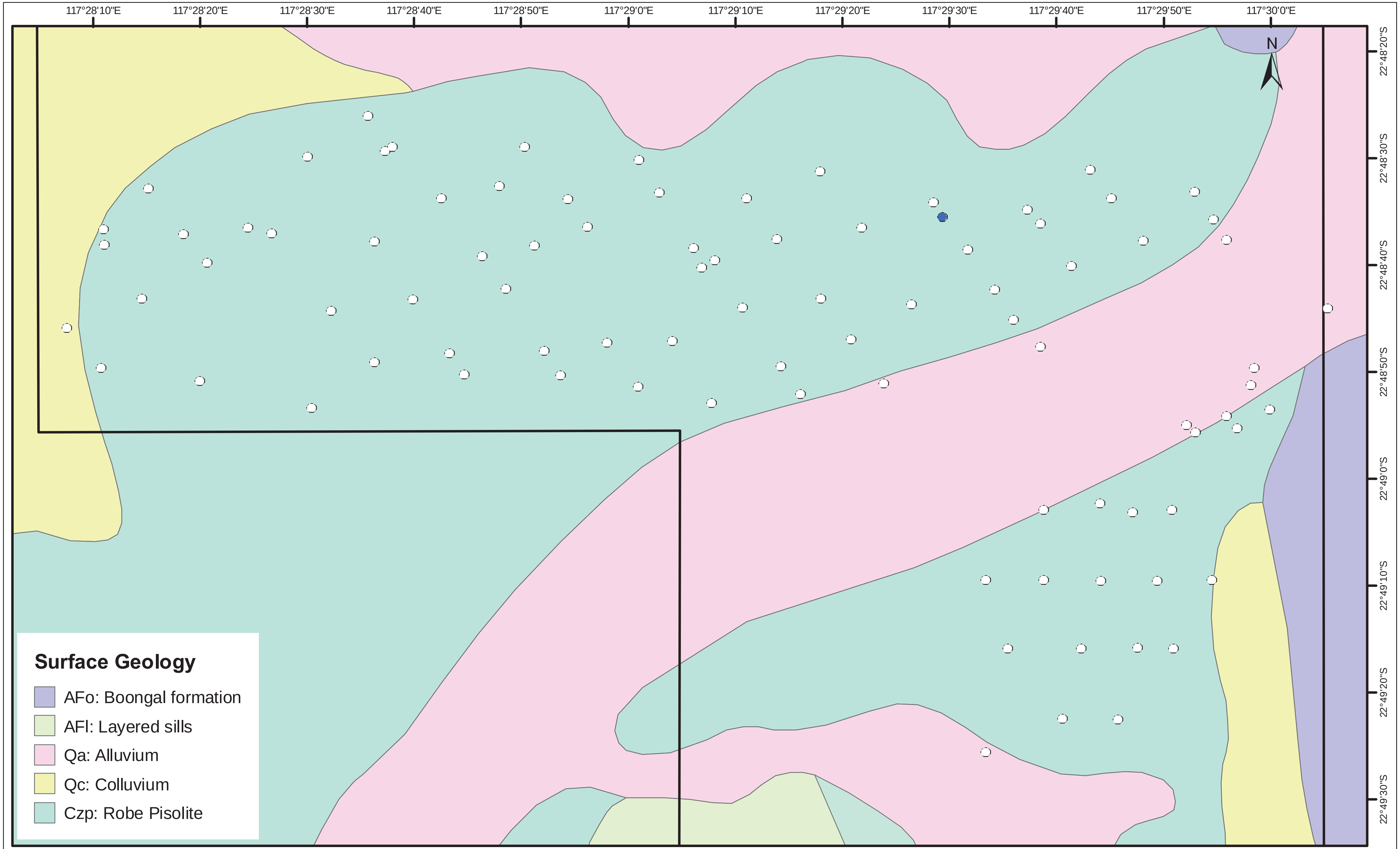

Figure 4-50 ***Atopobathynella*** **'D1' site record**

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Rocklea Iron Ore Project

0 0.125 0.25 0.5 0.75 Kilometers

Atopobathynella 'D1'   Survey Sites   Study Area

4.7.5 Arthropoda: Maxillopoda: Copepoda

4.7.5.1 *Cyclopoida*

Survey records: specimens were recorded from the following localities (Figure 4-52):

- *Diacyclops humphreysi humphreysi* (Figure 4-51) was represented by approximately 2,610 specimens from 58 bore samples and one Karaman-Chappuis sample: R090, R095, R105, R110, R112, R122, R123, R125, R126, R129, R134, R138, R145, R148, R149, R151, R152, R156, R158, R163, R167, R169, R175, R178, R181, R184, R187, R190, R193, R197, R202, R208, R210, R212, R216, R217, R220, R223, R225, R228, R230, R235, R236, R240, R242, R244, R249, R252, R255, R258, R260, R263, R264, R267, R268, R271, R273 and Hardey River kar2.
- *Diacyclops humphreysi unispinosus* was represented by approximately 50 specimens from bore R105.
- *Goniocyclops uniarticulatus* was represented by four specimens from bore R217
- *Orbuscyclops westraliensis* was represented by three specimens from three bores: R122, R249 and R255.

Taxonomic resolution: Cyclopoid copepods are very diverse and often abundant freshwater crustaceans. Stygomorphic species were identified by the absence, or major reduction, of eyes or eyes pots. Specimens were identified to species level by Ms Jane McRae (Bennelongia Environmental services). Specimens were identified to morphospecies level.

Four morphospecies were identified from this survey: *Diacyclops humphreysi humphreysi, Diacyclops humphreysi unispinosus, Goniocyclops uniarticulatus, Orbuscyclops westraliensis*.

Genomic taxonomy: all of the cyclopoids were identified to morphospecies level from morphology; therefore, genomic investigation was not deemed necessary.

SRE status: none of the cyclopoid copepods identified from this survey are recognised as SREs.

Known distribution: all of these species are widespread in the Pilbara (EPA 2007).

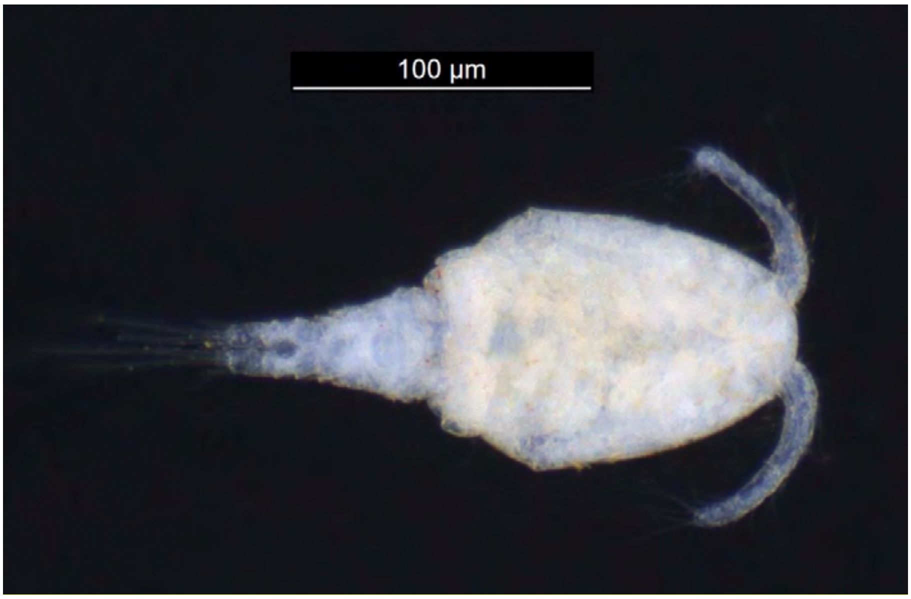

Figure 4-51 Image of *Diacyclops humphreysi humphreysi*

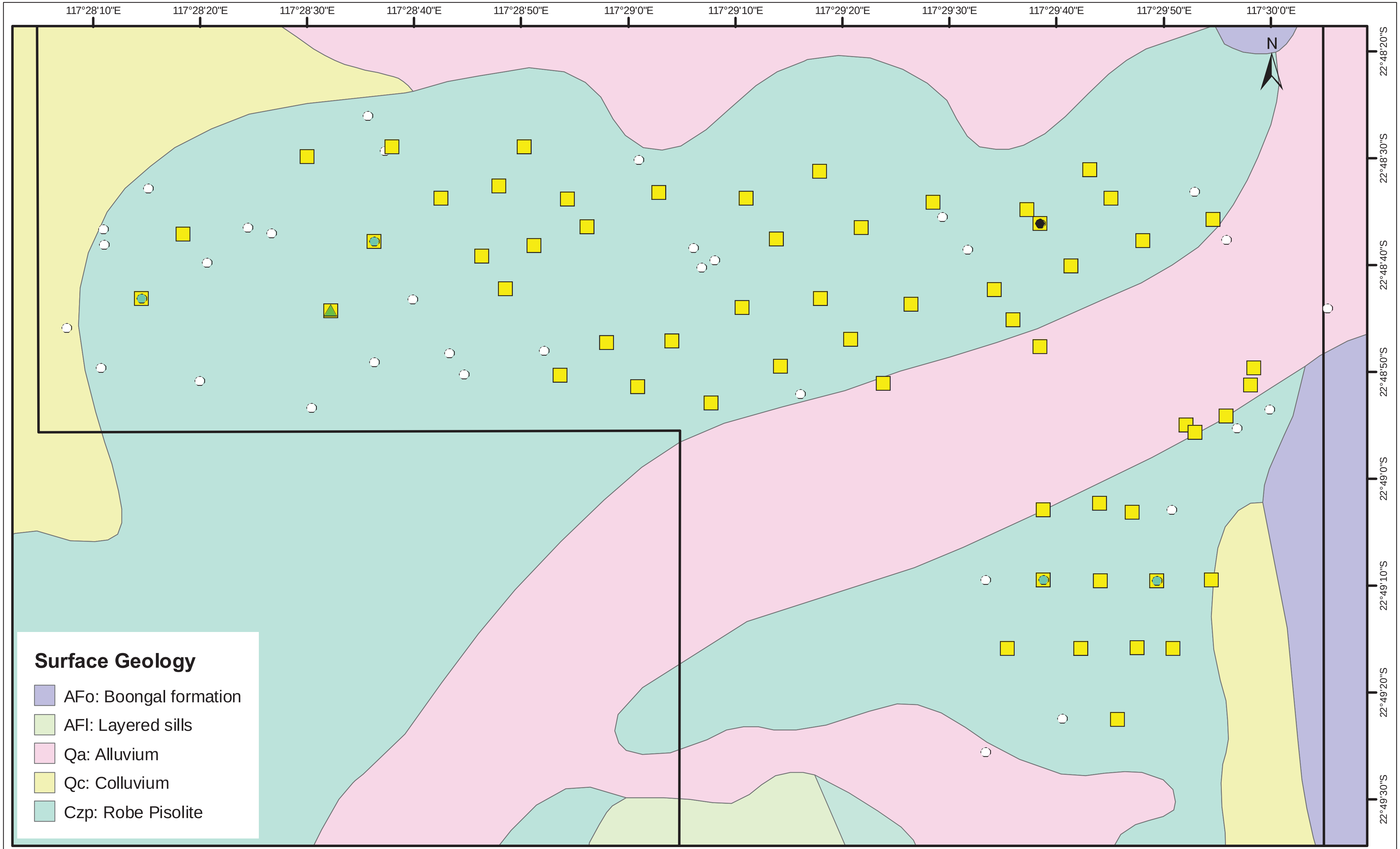

Figure 4-52 Cyclopoid copepod site record

AUTHOR: E.S. Volschenk	**CLIENT:** Dragon Energy Ltd.
DATE: February 2013	**Scale:** 1:13,906

Coordinate System: Projection: Transverse Mercator; DATUM: GDA94

PHOENIX ENVIRONMENTAL SCIENCES

Rocklea Iron Ore Project

0 0.125 0.25 0.5 0.75 Kilometers

Orbocyclops westraliensis
Goniocyclops nr uniarticulatus
Diacyclops humphreysi unispinosus
Diacyclops humphreysi humphreysi
Survey Sites
Study Area

4.7.5.2 Harpacticoida

Survey records: specimens were recorded from the following localities:

- *Abnitocrella halsei* was represented by 133 specimens from 17 bores (Figure 4-52): R105, R129, R138, R145, R148, R156, R163, R175, R184, R208, R210, R228, R249, R252, R255, R260 and R267.
- *Schizopera roberiverensis* was represented by 80 specimens, from14 bores (Figure 4-52): R105, R138, R149, R151, R156, R163, R181, R223, R242, R249, R252, R255, R267 and R268.

Taxonomic resolution: harpacticoid copepods are very diverse and abundant freshwater crustaceans that are frequently represented in subterranean systems. Stygomorphic species were identified by the absence, or major reduction, of eyes or eye spots. Specimens were identified to species level by Ms Jane McRae (Bennelongia Environmental services). Specimens were identified to morphospecies level.

Two species of harpacticoid copepod were identified: *Abnitocrella halsei* and *Schizopera roberiverensis.*

Genomic taxonomy: all of the harpacticoids were identified to morphospecies level from morphology; therefore, genomic investigation was not deemed necessary.

SRE status: neither of the these species are considered to be SREs

Known distribution: *Schizopera roberiverensis* and *Abnitocrella halsei* are widespread in the Pilbara

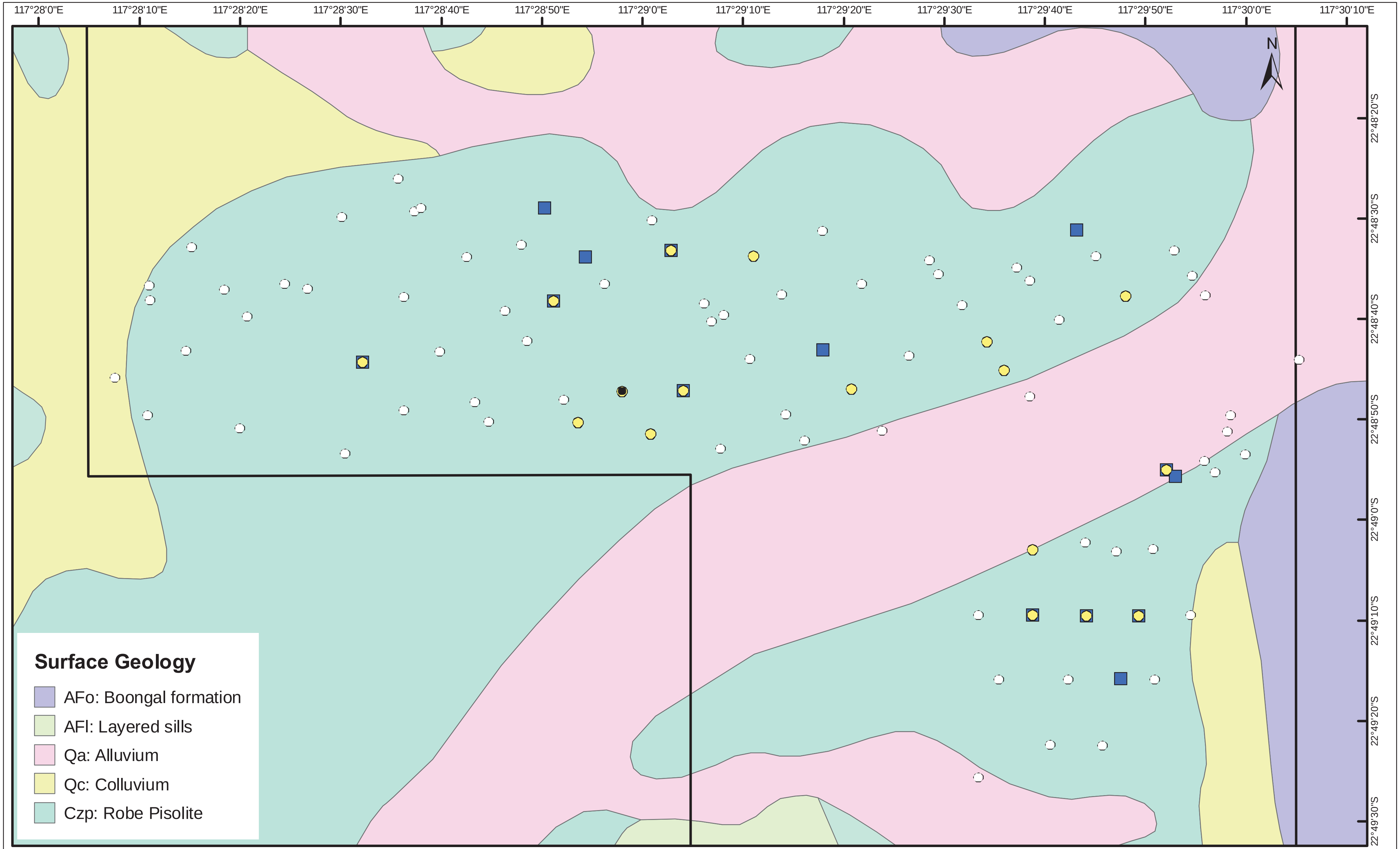

Figure 4-53 Harpacticoid copepod and ostracod site records

AUTHOR: E.S. Volschenk	CLIENT: Dragon Energy Ltd.	PHOENIX ENVIRONMENTAL SCIENCES
DATE: February 2013	Scale: 1:14,796	Rocklea Iron Ore Project
Coordinate System: Projection: Transverse Mercator; DATUM: GDA94		0 0.03 0.06 0.12 0.18 Kilometers

4.7.6 Arthropoda: Ostracoda

4.7.6.1 *Podocopida*

Survey records: *Areacandona atomus* (Figure 4-54) was represented by a single specimen from bore R145 (Figure 4-52):

Ostracods are small bivalve crustaceans that are commonly referred to as seed shrimps (Williams 1981). The ostracod fauna of the Pilbara is very diverse, with numerous epigean and subterranean species known (Eberhard *et al.* 2005; Karanovic 2006).

Taxonomic resolution: a single morphospecies of ostracod was identified from the family Candonidae: *Areacandona atomus.*

Genomic taxonomy: no genomic analyses were undertaken owing to the morphological identifications obtained.

SRE status: *Areacandona atomus* is considered to be a likely SRE on the basis that 70% of Pilbara stygobitic ostracods are SREs (Eberhard *et al.* 2009).

Distribution: *Areacandona atomus* was described from the Turee Creek Borefield (23°22'06"S 117°57'35"E) (Karanovic 2007) approximately 78 km from the area surveyed. At that time it was only known from a single specimen. This specimen represents a significant extension to the known distribution of this species.

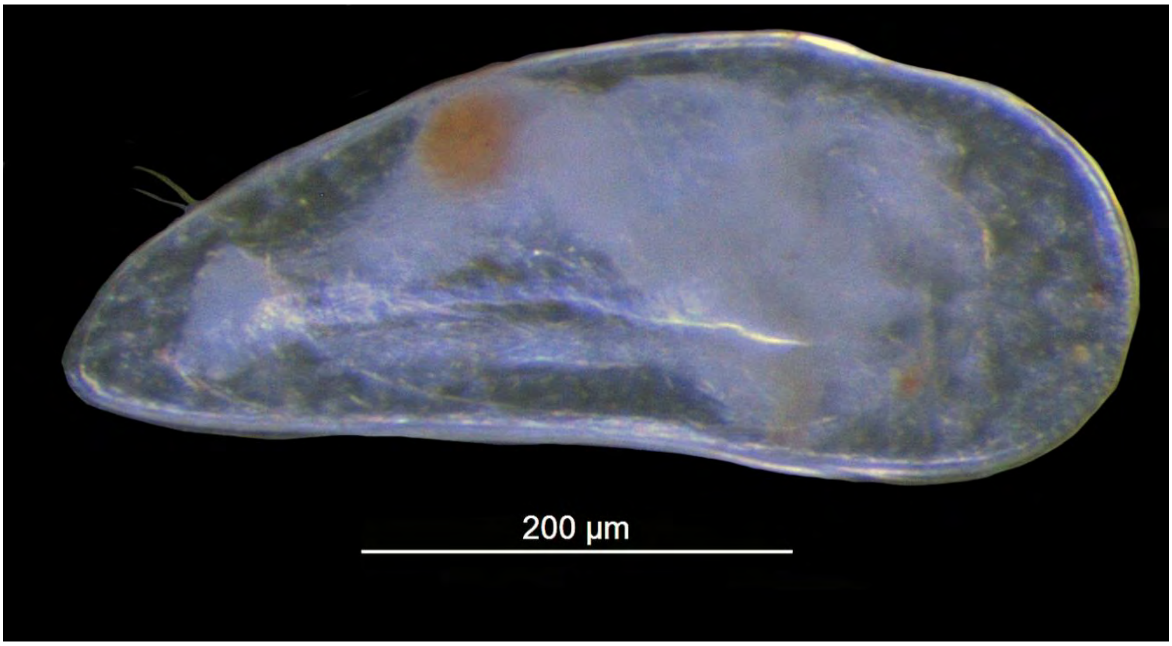

Figure 4-54 Image of *Areacandona atomus*

5 DISCUSSION

This survey of the subterranean fauna within the Rocklea study area revealed a diverse sample of 24 troglobitic species and 22 stygobitic species. Of these records 21 troglofauna and eight stygofauna species represent potential or likely SREs. None of the troblobitic SREs are previously described species and only two of the stygobitic SRE are previously described: *Pygolabus eberhardi* and *Areacandona atomus*.

Both troglofauna and stygofauna species richness estimators suggest more fauna are present within in the study area; however, the diversity estimations for the troglofauna are hampered by numerous singletons and disproportionate survey effort of two likely troglofauna communities (see section 5.1).

5.1 CHARACTERISATION OF SUBTERRANEAN HABITAT AND SPECIES DISTRIBUTIONS

5.1.1 Troglofauna

Deriving patterns for the troglofauna of the study area is hampered by the presence of numerous singleton records, as distribution patterns can only be derived from three or more records. The distribution of troglofauna in the survey area is not uniform. Based on the sequencing of species pairs, the eastern and western Robe Pisolite outcrops appear to have locally endemic fauna. The western outcrop supported 10 endemic species while the eastern outcrop supported five endemic species (Table 5-1). Two species had distributions that span both habitats; however, one of these *Cryptops* 'D1' may represent more than one species since only one specimen yielded sequences.

The diameter of the largest widespread troglofauna morphospecies within the study area, Nocticola ‘Pilbara1’ was approximately 2.5 mm. Troglofauna movements are likely to be restricted by the size of the microcaverns they inhabit, therefore the habitat extent of Nocticola ‘Pilbara1’ represents a potential means of extrapolating the extent of suitable microcaverns in which smaller species of troglofauna could move and disperse. Based on this hypothesis, the distribution of this species in both eastern and western outcrops is likely to reflect the distribution of the troglofauna communities within the respective outcrops.

Both the eastern and western outcrops extend outside the study area and it is likely that the extent of these outcrops reflects the distribution of their respective troglofauna (Figure 5-1).

Table 5-1 Distribution of troglobitic SRE species in the two outcrops of the central deposit

Species	Western outcrop only	Eastern outcrop only	Both areas
Tyrannochthonius 'D1'	**X**		
Indohya 'D1'		**X**	
Draculoides 'D1'			**X**
Japygidae 'D1'	**X**		
Japygidae 'D1'	**X**		
Parajapygidae 'D1'	**X**		
Projapygidae 'D2'	**X**		
Atelurinae 'D1'	**X**		
Trinemura 'D1'	**X**		
Cryptops 'D1'			**X?**
Haplodesmidae 'D1'	**X**		
Haplodesmidae 'D2'		**X**	
Pauropoda 'D1'	**X**		
Pauropoda 'D2'		**X**	
Symphyla 'D1a'	**X**		
Symphyla 'D1a'		**X**	
Symphyla 'D2'		**X**	
Total species counts	**10**	**5**	**2**

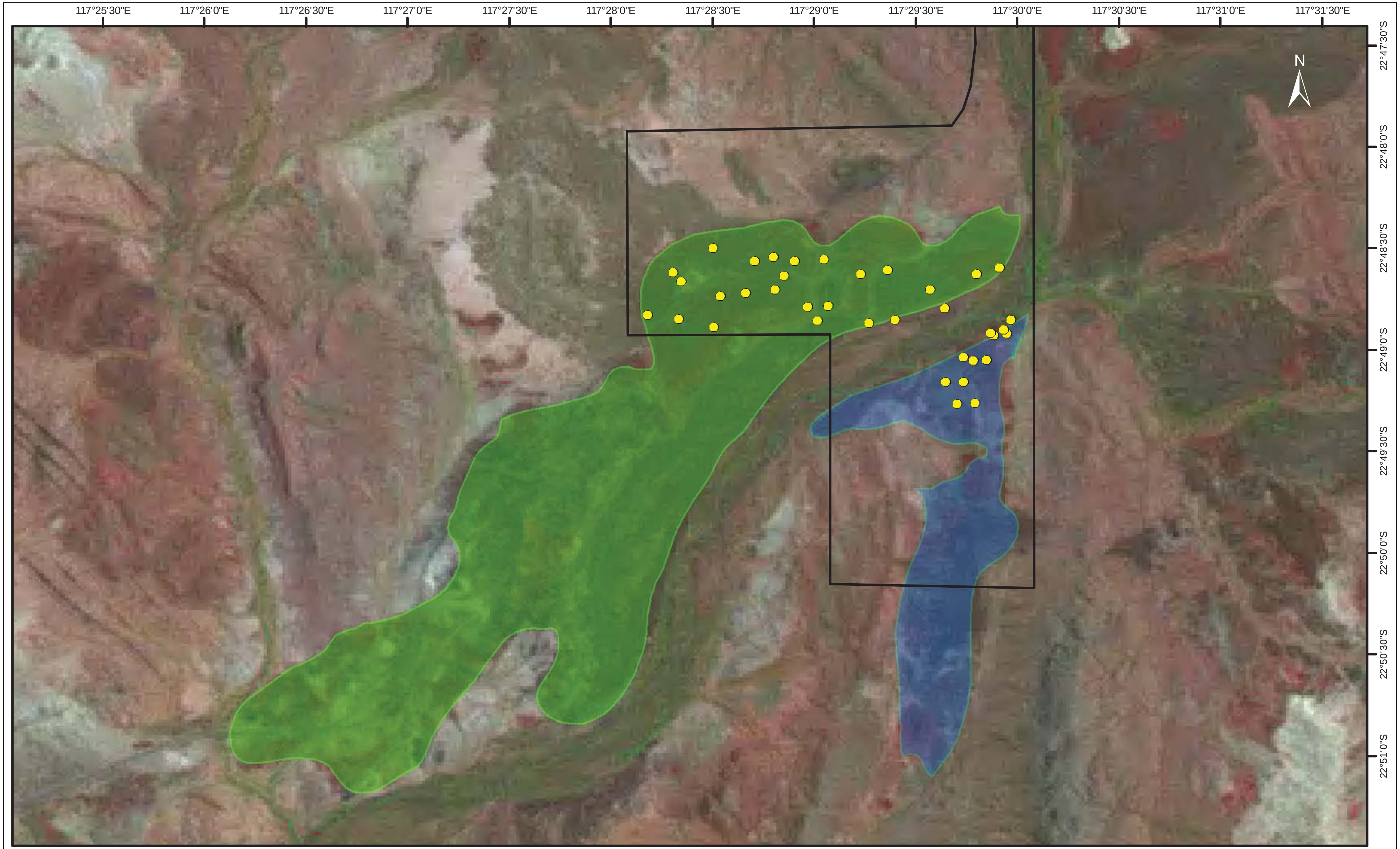

Figure 5-1 Potential extent of Rocklea troglofauna habitats

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR: E.S. Volschenk	**CLIENT:** Dragon Energy Ltd.
DATE: March 2013	**Scale:** 1:43,950

Rocklea Iron Ore Project

Coordinate System: Projection: Transverse Mercator; DATUM: GDA94

0 0.4 0.8 1.6 2.4 Kilometers

Eastern outcrop
Western outcrop
Troglofauna records
Study Area

5.1.2 Stygofauna

All of the stygobitic species with multiple records are known from both deposits indicating one community is present (Figure 5-2). It is likely that habitat extends into the calcrete in the east of the study area, since that calcrete extends southwards (approximately 20 km) to the type locality for *Pygolabis eberhardi*.

Since *Pygolabis eberhardi* was detected in our survey, there is likely to be connectivity of the aquifers through the calcrete and pisolitic geologies. Other stygofauna might also have this distribution, but this needs to be confirmed.

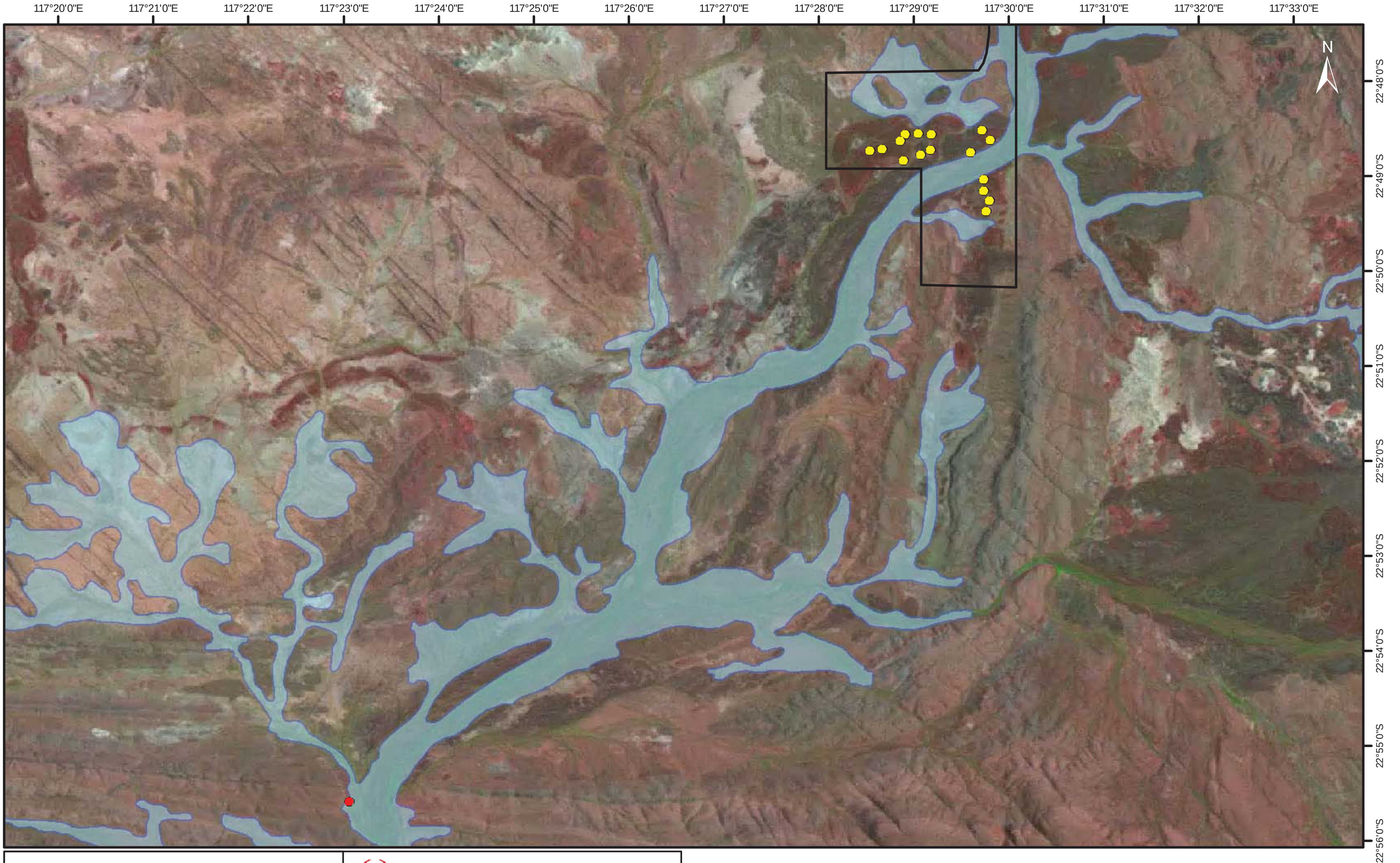

Figure 5-2 Potential extent of distribution corridors for Rocklea Stygofauna

AUTHOR: E.S. Volschenk	**CLIENT:** Dragon Energy Ltd.
DATE: February 2013	**Scale:** 1:94,272

Coordinate System: Projection: Transverse Mercator; DATUM: GDA94

PHOENIX ENVIRONMENTAL SCIENCES

Rocklea Iron Ore Project

0 S 0.5 1 2 3 4 5 Kilometers

Pygolabis eberhardi Type locality

Pygolabis eberhardi survey records

Study Area

Potential Stygofauna Habitat

5.2 SURVEY LIMITATIONS

5.2.1 Survey intensity

The survey intensity met the minimum intensity requirements for an environmental impact assessment, outlined in GS54a for troglofauna and stygofauna in terms of number of bores sampled and number of seasons.

The effectiveness of subterranean fauna surveys can be gauged by the percentage of recovery of the extrapolated species richness observed from the survey. The survey sampled between 15% and 80% of the extrapolated diversity. The data matrix on which these extrapolations were based is not ideal since many of the species are represented as singletons and this may explain the extremely wide ranging diversity extrapolations. This may be resolved by obtaining identifications for more of the indeterminate species (“sp. indet.” in Table 4-1).

Additional factors that may have contributed to this wide range of species richness extrapolations include:

- the apparent likelihood that the data were collected from two separate habitats with different survey intensity in each
- the lower than average wet season observed in early 2012 (Figure 2-2)
- the unintentional amalgamation of the two populations into one.

The species richness estimators for stygofauna were more stable, ranging between 40% and 87% of the predicted richness (Figure 4-4). Despite meeting the minimum requirements of the EPA (2007) the survey intensity was insufficient to sample 95% of the extrapolated species richness. Surveying 95% or more of the extrapolated species richness is a recommendation of the EPA (2007) for environmental impact assessment.

5.2.2 Bore hole condition

Guidance Statement 54a (EPA 2007) includes a requirement for all bores sampled for stygofauna to be at least six months old to allow for colonisation. All of the stygofauna bore samples in this survey were greater than six months in age. All bores found to contain anaerobic water or oil were excluded from sampling.

Many of the boreholes in the study area had their caps removed by cattle. This led to the loss of several troglofauna traps which resulted in the traps either becoming loose or dropping to the bottom of the bore, or had been pulled out of the bore completely. Six troglofauna traps were lost this way.

5.2.3 Taxonomic resolution and regional context

Guidance Statement 54a (EPA 2007) includes a requirement for specimens to be identified to species or morphospecies level. In the absence of specialists to undertake morphological identifications, species boundaries need to be assessed on genetic data. Attempts were made to access gene sequences for all of the target species for which taxonomic knowledge is lacking, thus meeting the requirements of the EPA (EPA 2007).

Genomic investigations identified several cryptic species: Haplodesmidae 'D1', Haplodesmidae 'D2'; Pauropoda 'D1', Pauropoda 'D2'; and Symphyla 'D1a', Symphyla 'D1b' and Symphyla 'D2'. Additional representatives of these groups were not identified to species level since they were not sequenced:

Haplodesmidae sp. indet., Pauropoda sp. indet. and Symphyla sp. indet. Sequencing these remaining groups would verify the distribution of these cryptic species.

5.2.4 Seasonality

Guidance Statement 54a (EPA 2007) advises a seasonal survey approach; however, if a single season of surveying is implemented, it must occur over the 'wet' season. This survey was undertaken over two seasons, thereby meeting this requirement of Guidance Statement 54a. Rainfall for 2012 was generally below average (Figure 2-2) and this may have had an effect on the distribution and abundance on troglofauna records.

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Appendix 1 Site localities and coordinates (datum, GDA94)

Site code	Latitude (decimal degrees)	Longitude (decimal degrees)	UTM easting	UTM northing	UTM zone
R085	7477132	548099	117.4686954	-22.8127521	50K
R087	7477009	548195	117.4696347	-22.8138605	50K
R088	7477359	548196	117.4696336	-22.8106988	50K
R090	7477217	548307	117.470718	-22.811979	50K
R092	7476962	548463	117.4722476	-22.8142773	50K
R093	7477534	548322	117.4708559	-22.8091143	50K
R095	7477402	548416	117.471779	-22.810303	50K
R096	7477314	548478	117.4723828	-22.8110971	50K
R100	7476891	548761	117.4751536	-22.8149101	50K
R103	7477411	548651	117.4740655	-22.8102159	50K
R105	7477178	548817	117.4756903	-22.8123159	50K
R108	7477026	548927	117.4767669	-22.8136857	50K
R110	7477613	548751	117.4750336	-22.8083883	50K
R112	7477372	548927	117.4767560	-22.8105602	50K
R114	7477201	549027	117.4777358	-22.8121020	50K
R118	7476960	549195	117.4793804	-22.8142741	50K
R120	7477739	548910	117.476578	-22.807243	50K
R122	7477650	548975	117.477211	-22.808052	50K
R123	7477492	549094	117.4783795	-22.8094713	50K
R125	7477328	549213	117.4795442	-22.8109493	50K
R126	7477234	549277	117.4801708	-22.8117966	50K
R128	7477056	549376	117.4811411	-22.8134016	50K
R129	7476993	549418	117.4815524	-22.8139694	50K
R134	7477532	549258	117.4799762	-22.8091052	50K
R138	7477365	549351	117.480888	-22.810612	50K
R145	7477087	549544	117.48278	-22.813118	50K
R148	7476958	549625	117.483574	-22.814281	50K
R149	7477641	549327	117.4806451	-22.8081185	50K
R151	7477497	549433	117.4816825	-22.8094162	50K
R152	7477412	549492	117.4822601	-22.8101823	50K
R156	7477090	549718	117.484474	-22.813089	50K
R158	7476911	549821	117.485481	-22.814701	50K
R162	7477610	549623	117.4835303	-22.8083898	50K
R163	7477517	549684	117.484131	-22.809229	50K
R165	7477355	549780	117.4850682	-22.8106887	50K
R167	7477181	549899	117.4862333	-22.8122570	50K
R169	7477015	550008	117.4873007	-22.8137532	50K
R170	7476936	550058	117.487793	-22.814465	50K
R175	7477500	549917	117.486397	-22.80938	50K
R178	7477381	549992	117.4871331	-22.8104475	50K
R181	7477207	550114	117.4883274	-22.8120157	50K

Site code	Latitude (decimal degrees)	Longitude (decimal degrees)	UTM easting	UTM northing	UTM zone
R184	7477094	550188	117.4890521	-22.8130342	50K
R187	7476965	550279	117.489944	-22.814194	50K
R190	7477558	550099	117.4881700	-22.8088454	50K
R193	7477413	550221	117.4893634	-22.8101516	50K
R197	7477193	550355	117.490677	-22.812134	50K
R202	7477485	550414	117.491241	-22.809494	50K
R203	7477437	550440	117.4914965	-22.8099283	50K
R205	7477351	550502	117.4921035	-22.8107033	50K
R208	7477239	550581	117.4928769	-22.8117126	50K
R210	7477149	550627	117.493324	-22.812525	50K
R212	7477068	550695	117.4939933	-22.8132539	50K
R216	7477464	550663	117.493668	-22.809681	50K
R217	7477415	550696	117.4939917	-22.8101193	50K
R220	7477299	550787	117.4948822	-22.8111644	50K
R223	7477578	550832	117.495316	-22.808647	50K
R225	7477493	550884	117.4958210	-22.8094090	50K
R228	7477367	550975	117.4967118	-22.8105444	50K
R229	7477513	551103	117.4979543	-22.8092217	50K
R230	7477432	551166	117.4985708	-22.8099515	50K
R232	7476001	550749	117.4945542	-22.8228908	50K
R235	7475997	550899	117.4960161	-22.8229224	50K
R236	7476204	550607	117.493164	-22.821062	50K
R240	7476197	550797	117.4950156	-22.8211188	50K
R242	7476203	550947	117.4964771	-22.8210601	50K
R244	7476198	551045	117.4974322	-22.8211022	50K
R246	7476402	550553	117.4926312	-22.8192743	50K
R249	7476399	550707	117.4941320	-22.8192968	50K
R252	7476401	550855	117.4955741	-22.8192743	50K
R255	7476397	551004	117.4970262	-22.8193059	50K
R258	7476403	551154	117.4984877	-22.8192471	50K
R260	7476600	550703	117.4940865	-22.8174812	50K
R263	7476620	550849	117.4955085	-22.8172961	50K
R264	7476589	550951	117.4965034	-22.8175731	50K
R266	7476597	551040	117.4973704	-22.8174981	50K
R267	7476841	551084	117.4977912	-22.8152926	50K
R268	7476822	551110	117.498047	-22.815466	50K
R271	7476866	551191	117.4988330	-22.8150635	50K
R272	7476835	551221	117.499123	-22.815344	50K
R273	7476959	551258	117.499481	-22.81422	50K
Hardey River kar1	7436170	539985	117.389992	-22.939091	50K
Hardey River kar2	7477009	551266	117.499557	-22.813774	50K

Appendix 2 Table of sample types relative to field trip and locations

Site code	Visit numbers	Bore scrape	Stygofauna haul	Troglobite trap	Karaman-Chappuis
R085	T1,T2	Yes	No	Yes	No
R087	T1,T2	Yes	No	Yes	No
R088	T1,T2	Yes	No	Yes	No
R090	T1,T2	Yes	Yes	Yes	No
R092	T1,T2	Yes	Yes	Yes	No
R093	T1,T2	Yes	Yes	No*	No
R095	T1,T2	Yes	Yes	Yes	No
R096	T1,T2	Yes	Yes	Yes	No
R100	T1,T2	Yes	Yes	Yes	No
R103	T1,T2	Yes	Yes	Yes	No
R105	T1,T2	Yes	Yes	No*	No
R108	T1,T2	Yes	No	Yes	No
R110	T1,T2	Yes	Yes	Yes	No
R112	T1,T2	Yes	Yes	Yes	No
R114	T1,T2	Yes	Yes	Yes	No
R118	T1,T2	Yes	Yes	Yes	No
R120	T1,T2	Yes	No	Yes	No
R122	T1,T2	Yes	Yes	Yes	No
R123	T1,T2	Yes	Yes	Yes	No
R125	T1,T2	Yes	No	Yes	No
R126	T1,T2	Yes	Yes	Yes	No
R128	T1,T2	Yes	Yes	Yes	No
R129	T1,T2	Yes	Yes	Yes	No
R134	T1,T2	Yes	No	Yes	No
R138	T1,T2	Yes	Yes	Yes	No
R145	T1,T2	Yes	Yes	No*	No
R148	T1,T2	Yes	Yes	No*	No
R149	T1,T2	Yes	Yes	Yes	No
R151	T1,T2	Yes	Yes	Yes	No
R152	T1,T2	Yes	Yes	Yes	No
R156	T1,T2	Yes	Yes	Yes	No
R158	T1,T2	Yes	No	Yes	No
R162	T1,T2	Yes	No	Yes	No
R163	T1,T2	Yes	Yes	No*	No
R165	T1,T2	Yes	Yes	Yes	No
R167	T1,T2	Yes	No	Yes	No
R169	T1,T2	Yes	Yes	Yes	No
R170	T1,T2	Yes	Yes	Yes	No
R175	T1,T2	Yes	Yes	Yes	No
R178	T1,T2	Yes	Yes	Yes	No
R181	T1,T2	Yes	No	Yes	No
R184	T1,T2	Yes	Yes	Yes	No
R187	T1,T2	Yes	Yes	No*	No
R190	T1,T2	Yes	No	Yes	No

Site code	Visit numbers	Bore scrape	Stygofauna haul	Troglobite trap	Karaman-Chappuis
R193	T1,T2	Yes	No	Yes	No
R197	T1,T2	Yes	Yes	Yes	No
R202	T1,T2	Yes	Yes	Yes	No
R203	T1,T2	Yes	Yes	Yes	No
R205	T1,T2	Yes	Yes	Yes	No
R208	T1,T2	Yes	Yes	Yes	No
R210	T1,T2	Yes	Yes	Yes	No
R212	T1,T2	Yes	No	No*	No
R216	T1,T2	Yes	No	No*	No
R217	T1,T2	Yes	Yes	Yes	No
R220	T1,T2	Yes	Yes	Yes	No
R223	T1,T2	Yes	Yes	No*	No
R225	T1,T2	Yes	Yes	Yes	No
R228	T1,T2	Yes	Yes	Yes	No
R229	T1,T2	Yes	Yes	Yes	No
R230	T1,T2	Yes	Yes	No*	No
R232	T1,T2	Yes	No	Yes	No
R235	T1,T2	Yes	Yes	No*	No
R236	T1,T2	Yes	No	Yes	No
R240	T1,T2	Yes	Yes	Yes	No
R242	T1,T2	Yes	Yes	No*	No
R244	T1,T2	Yes	Yes	Yes	No
R246	T1,T2	Yes	Yes	Yes	No
R249	T1,T2	Yes	Yes	Yes	No
R252	T1,T2	Yes	Yes	No*	No
R255	T1,T2	Yes	Yes	Yes	No
R258	T1,T2	Yes	Yes	Yes	No
R260	T1,T2	Yes	Yes	Yes	No
R263	T1,T2	Yes	Yes	Yes	No
R264	T1,T2	Yes	No	Yes	No
R266	T1,T2	Yes	Yes	Yes	No
R267	T1,T2	Yes	Yes	Yes	No
R268	T1,T2	Yes	Yes	Yes	No
271	T1,T2	Yes	Yes	Yes	No
272	T1,T2	Yes	No	Yes	No
273	T1,T2	Yes	No	Yes	No
Hardey River 1	T1	No	No	No	Yes
Hardey River 2	T1	No	No	No	Yes

Appendix 3 Water chemistry readings from stygofauna survey bores

Site code	Trip number	PH	Temp (°c)	O^2 (ppm)	O^2 (%)	ORP (mv/mm)	TDS (ppm)	Salinity (ppm)	Conductivity (mS)
R087	T1	7.17	28	9.92	131.6	-57.2	1339	1.04	2167
R090	T1	7.31	29	2.77	37.1	136.5	1170	0.9	1934
R090	T2	7.32	28.8	4.72	64.3	106.6	0.77	852.5	1650
R092	T1	7.15	28.6	2.83	35.3	149.4	1534	1.2	2515
R092	T2	9.1	37.1	2.55	37		1.01	1105.5	2257
R093	T1	7.09	26.7	0	0	240.9	1508	1.19	2319
R093	T2	7.06	28.7	1.41	19.4	54.8	0.96	1045	2025
R095	T1	7.38	28.2	0	0	42.2	1352	1.06	2207
R095	T2	7.37	28.9	1.46	20.1	34.9	0.85	935	1818
R096	T1	7.34	25.4	0.68	10.7	135.2	1300	1.01	2007
R096	T2	7.23	28.9	3.85	60.1	83.7	83	913	1772
R100	T1	7.3	28.3	0	0	204.6	1514.9	1.19	2450
R100	T2	7.48	32	2.95	36	43.1	1.71	1820.5	3792
R103	T1	7.25	30.1	0.32	4.5	192.4	1365	1.06	2313
R103	T2	7.23	29.7	2.94	41.2	65.6	0.87	957	1890
R105	T1	7.14	28.6	0.4	5	206.3	1475.5	1.15	2424
R105	T2	7.4	28.7	3.68	49.6	104.6	0.99	1078	2083
R110	T1	7.36	29.7	0.75	10	179.8	1248	0.97	2085
R110	T2	7.47	29.7	2.64	36.4	41.3	0.8	874.5	1732
R112	T1	1.19	28.1	1.24	16.7	205.3	988	0.76	1610
R112	T2	7.13	28.7	2.5	34.7	114.3	1.13	1221	2375
R114	T1	7.12	28.1	1	12.3	189.2	825.5	0.63	1338
R114	T2	7.03	29.6	3.67	51.9	118.7	0.91	995.5	1966
R118	T1	7.59	26.2	1.75	21.6	286.6	1885	1.5	2958
R117	T2	7.58	28.9	6.06	82.1	103.4	1.26	1358.5	2625
R122	T1	7.3	28.2	0	0	188	1592.5	1.25	2500
R122	T2	7.3	30.7	0.83	11.9	-1.5	1.02	1111	2232
R123	T1	7.17	28	0.43	0.43	197.9	1534	1.21	2470
R123	T2	7.07	29.1	3.78	52.2	101.8	1.01	1100	2163
R126	T1	7.17	26.2	0.96	12	242.6	1332.5	1.04	2097
R126	T2	7.21	30.9	2.3	33.6	-46.2	0.89	979	1980
R128	T1	7.29	27	1.17	14.1	252.5	1443	1.13	2266
R128	T2	7.24	30.5	2.9	42.1	0	0.97	1056	2125
R129	T1	7.47	25.2	1.78	22	213.4	793	0.62	2016
R129	T2	-46.6	31.4	3.19	46		0.99	1079	2194

Site code	Trip number	PH	Temp (°c)	O^2 (ppm)	O^2 (%)	ORP (mv/mm)	TDS (ppm)	Salinity (ppm)	Conductivity (mS)
R138	T1	7.28	25.1	0.47	5.4	221.9	1410.5	1.11	2113
R138	T2	7.15	29.7	2.63	36.3	79	0.94	1034	2046
R145	T1	7.04	27.5	0.35	5.3	196.2	1274	0.99	2047
R145	T2	7.14	30.3	3.3	46.7	60.7	0.86	940.5	1883
R148	T1	7.45	27.8	1.56	20.7	211.9	1306.6	1.02	2105
R148	T2	7.53	32.4	5.83	85.1	8.9	0.87	862.2	2000
R149	T1	7.36	28	0.27	2.9	209.5	1527.5	1.2	2474
R149	T2	7.41	31.2	2.55	36.6	19	1.02	1116.5	2275
R151	T1	7.28	29.2	0.85	11.2	234.2	1248	0.97	2080
R151	T2	7.19	31.6	4.29	59.7	3.1	0.85	935	1921
R152	T1	7.31	28.6	1.02	13.5	215	1293.5	1	2124
R152	T2	7.13	31.2	2.42	35.1	7	0.88	362.5	1957
R156	T1	7.23	28.8	0.64	8.4	176.4	1443	1.13	2383
R156	T2	7.16	31.1	2.68	38.7	15.4	0.97	1067	2163
R163	T1	7.29	24.3	1.02	11.9	214	1306.5	1.02	1980
R163	T2	7.28	31.1	2.67	38.5	6	0.84	929.5	1884
R165	T1	7.39	24.8	1.86	22.3	151.4	1378	1.08	2094
R165	T2	7.15	28.9	4.99	67.3	111.9	0.93	1012	1939
R169	T2	7.26	28.1	5.18	69.4	101.4	1.01	1089	2072
R170	T1	7.73	27.2	0.68	8.2	198.1	760.5	0.58	1217
R170	T2	7.72	26.6	1.23	16	65.8	0.83	907.5	1702
R175	T1	7.42	28.4	0.67	8.6	175.3	1248	0.97	2045
R175	T2	7.42	29	4.8	66	82.9	0.88	968	1897
R178	T1	7.35	28.1	9.6	12.3	196.5	1274	0.99	2076
R178	T2	7.38	42	29.2	3.05	84.6	0.85	935	1839
R184	T1	7.35	30.2	0.11	1.5	197.3	1592.5	1.25	2712
R184	T2	7.3	29.2	5.12	71.1	103.9	1.05	1138.5	2239
R187	T1	7.51	29.8	0.97	12.8	176.3	1313	1.02	2201
R187	T2	7.36	28.2	1.97	26.4	101.7	0.86	946	1821
R193	T1	7.83	25.7	1.2	14.8	167.9	1222	0.95	1892
R197	T1	7.41	27.3	0.86	10.6	177.5	1339	1.04	2139
R197	T2	7.33	30.5	3.33	45.5	51.9	0.9	990	1989
R202	T1	7.5	28.9	1.56	19.8	183.5	1033.5	0.79	1705
R202	T2	7.49	32.3	5.97	87.7	-31	0.7	781	1617
R203	T1	7.33	28.3	0.78	9.8	183	1079	0.83	1763
R203	T2	7.24	31.4	2.96	43.3	12.4	0.55	572	1202

Site code	Trip number	PH	Temp (°c)	O^2 (ppm)	O^2 (%)	ORP (mv/mm)	TDS (ppm)	Salinity (ppm)	Conductivity (mS)
R205	T1	7.31	27.6	0.11	1.3	190.5	1033.5	0.8	1652
R205	T2	7.22	30.9	3.27	47.1	34.4	69	770	1561
R208	T1	7.32	26.8	0.9	1.1	192.7	2015	1.61	3204
R208	T2	7.33	31.3	2.57	38.9	-5	1.31	1419	2891
R210	T1	7.35	27.6	1.04	13.3	200.7	1573	1.24	2457
R210	T2	7.38	26.5	4.95	65	88.6	1.01	1100	2033
R217	T1	7.35	29.8	0.25	3.1	192.7	1098	0.85	1845
R217	T2	7.22	31.2	4.47	64.1	67.7	0.68	759	1539
R220	T1	7.29	30	0.9	12.1	181.2	1209	0.93	2029
R220	T2	7.39	33	5	73.9	10.2	0.87	962.5	2022
R223	T1	7.35	24.9	0.56	6.5	163.5	981.5	0.76	1507
R223	T2	7.32	27.5	3.28	44	92.5	0.39	445.5	860
R225	T1	7.42	29.9	0.51	6.9	188.7	981.5	0.75	1651
R225	T2	7.36	29.6	3.28	46.2	94.3	0.62	693	1373
R228	T1	7.25	28.7	0.01	0.1	212.1	1235	0.96	2031
R228	T2	7.32	27.2	4.25	57.4	90.7	0.82	902	1729
R229	T1	7.34	26.9	0.05	0.8	189.7	1215.5	0.95	1936
R229	T2	7.29	30.1	2.07	29	47	0.76	841.5	1682
R230	T1	7.31	27	0	-3.2	182	676	0.51	1074
R230	T2	7.49	28.7	1.94	27.1	50.8	0.78	858	1672
R235	T1	7.58	25.3	1.85	23.7	159.6	4914	4.17	7601
R235	T2	7.33	33	3.14	47.1	40.5	1.95	2057	4440
R240	T1	7.54	27.5	2.12	27	201.6	1573	1.24	2534
R240	T2	7.47	30.7	3.26	46.5	44.1	2.21	2222	4480
R242	T1	7.55	28.4	1.66	21.3	200.8	2684.5	2.18	4390
R242	T2	7.51	30.6	3.14	45.1	37.7	1.79	1897.5	3820
R244	T1	7.36	28.8	0	0	198	2236	1.79	3636
R244	T2	7.41	30.1	3	53	44.7	7.62	1727	3504
R246	T1	7.74	26.8	0.05	0.6	212.7	1937	1.54	3086
R246	T2	7.81	28.3	3.77	51.8	72.8	1.32	1413.5	2734
R249	T1	7.47	27.4	0.82	10.3	205.9	2275	1.83	3660
R249	T2	7.43	28.3	2.99	41.4	76.3	1.7	1798	3472
R252	T1	7.28	27.5		-4.3	196.3	2307.5	1.85	3713
R252	T2	7.25	28.3	1.8	25.6	68.1	1.68	1776.5	3435
R255	T1	7.34	28.3	0.64	8.4	199.3	2392	1.93	3911
R255	T2	7.49	29.1	3.25	45.5	50.1	0.97	1061.5	2087

Site code	Trip number	PH	Temp (°c)	O^2 (ppm)	O^2 (%)	ORP (mv/mm)	TDS (ppm)	Salinity (ppm)	Conductivity (mS)
R258	T1	7.33	28.8	0.68	9.3	191.4	994.5	0.76	1644
R258	T2	7.32	30	2.36	33.6	47.8	0.66	737	1482
R260	T1	7.23	27.5	0.25	3.1	244.7	1651	1.3	2647
R260	T2	7.08	28.4	1.89	25.7	90.3	1.15	1237.5	2398
R263	T1	7.1	29	0	0	221.8	2145	1.71	3549
R263	T2	7.01	28	2.26	30	90.4	1.5	1595	3050
R266	T1	7.31	27.2	0.08	1	231.3	1547	1.22	2497
R266	T2	7.18	28	2.27	33.8	79	1.03	1116.5	2135
R267	T1	7.24	28.9	0	0	196.4	1475.5	1.15	2433
R267	T2	7.2	29.8	1.48	20.6	51.1	1	1089	2160
R268	T1	7.33	28.7	0	0	186	1124.5	0.87	1860
R268	T2	7.25	30	2.4	34	57.9	0.75	830.5	1651
R271	T1	7.31	28.7	0.48	6.3	185.1	1293.5	1	2122
R271	T2	7.38	30.7	3.01	44.4	43.8	0.85	940.5	1944
Hardey River 1	T1	7.53	12.8	0.03	0.3	109.5	1553.5	1.24	1831
Hardey River 2	T1	8	13.9	0.48	4.7	227.4	1599	1.28	1933

Appendix 4 Report on the molecular systematics of Troglofauna and Stygofauna from the Hardey River

Appendix 5 Species records from desktop review

Taxa	Significance	SRE status	Source (PSS=Pilbara Stygofauna Survey)
Arachnida			
Gnaphosoidea	Troglofauna	Likely SRE	WAM Arachnid search
Prethopalpus oneillae	Troglofauna	Likely SRE	WAM Arachnid search
Prethopalpus 'Solomon Mine'	Troglofauna	Likely SRE	WAM Arachnid search
Prethopalpus sp. 'B23'	Troglofauna	Likely SRE	Bennelongia, 2012
Draculoides 'DELTA'	Troglofauna	Likely SRE	WAM Arachnid search
Draculoides 'SCH003'	Troglofauna	Likely SRE	WAM Arachnid search
Draculoides 'SCH004'	Troglofauna	Likely SRE	WAM Arachnid search
Draculoides 'SOLOMON1'	Troglofauna	Likely SRE	WAM Arachnid search
Draculoides 'SOLOMON2'	Troglofauna	Likely SRE	WAM Arachnid search
Draculoides sp.	Troglofauna	Likely SRE	WAM Arachnid search
Paradraculoides sp.	Troglofauna	Likely SRE	WAM Arachnid search
Hubbardiinae	Troglofauna	Potential SRE	WAM Arachnid search
Palpigradi	Troglofauna	Potential SRE	Biota, 2006; WAM Arachnid search
Indohya 'PSE004'	Troglofauna	Likely SRE	WAM Arachnid search
Lagynochthonius sp. 'B13'	Troglofauna	Likely SRE	Bennelongia, 2012
Linnaeolpium 'sp. 2'	Troglofauna	Likely SRE	WAM Arachnid search
Oratemnus 'Tom Price'	Troglofauna	Likely SRE	WAM Arachnid search
Myriapoda			
Cryptops sp. 'B26'	Troglofauna	Likely SRE	Bennelongia, 2012
Antichiropus sp.	Troglofauna	Potential SRE	WAM Arachnid search
Polyxendidae sp.	Troglofauna	Potential SRE	WAM Arachnid search; WAM trog/stygo search
Pauropoda	Troglofauna	Potential SRE	WAM Arach search
Cryptops sp. 'B26'	Troglofauna	Likely SRE	Bennelongia, 2012
Crustacea: Amphipoda			
Amphipoda sp.	Stygofauna	Likely SRE	WAM trog/stygo search; PSS
Bogidellidae 'sp. 2'	Stygofauna	Likely SRE	PSS
Bogidiellidae sp.	Stygofauna	Likely SRE	WAM trog/stygo search; PSS
Chydaekata sp.	Stygofauna	Likely SRE	PSS
Chydeakata breviclava	Stygofauna	Likely SRE	WAM Crustacea search
Chydeakata nudula	Stygofauna	Likely SRE	WAM Crustacea search
Crangonyctoid sp.	Stygofauna	Likely SRE	WAM trog/stygo search
Melitidae 'sp. 1' (PSS)	Stygofauna	Likely SRE	PSS
Melitidae sp.	Stygofauna	Likely SRE	PSS
Molina cf. pleobranchos	Stygofauna	Likely SRE	PSS
Nedsia 'sp 2' (PSS)	Stygofauna	Likely SRE	PSS
Nedsia 'sp 3' (PSS)	Stygofauna	Likely SRE	PSS
Nedsia 'sp 4' (PSS)	Stygofauna	Likely SRE	PSS

Taxa	Significance	SRE status	Source (PSS=Pilbara Stygofauna Survey)
Nedsia 'sp 5' (PSS)	Stygofauna	Likely SRE	PSS
Nedsia nr '24' (PSS)	Stygofauna	Likely SRE	PSS
Nedsia nr 'sp. 176' (PSS)	Stygofauna	Likely SRE	PSS
Nedsia nr hurlberti	Stygofauna	Likely SRE	PSS
Nedsia sp.	Stygofauna	Likely SRE	PSS
Paramelitidae 'sp. 2' (PSS)	Stygofauna	Likely SRE	PSS
Paramelitidae 'sp. 4' (PSS)	Stygofauna	Likely SRE	PSS
Paramelitidae sp.	Stygofauna	Likely SRE	PSS
Parameltidiae cf. 'sp. 2' (PSS)	Stygofauna	Likely SRE	PSS
Pilbarus millsi	Stygofauna	Likely SRE	PSS
Crustacea: Isopoda			
Armadillidae 'sp. B04'	Troglofauna	Potential SRE	WAM Crustacea search
Armadillidae 'sp. B05'	Troglofauna	Potential SRE	WAM Crustacea search
Hanoniscus sp.	Troglofauna	Likely SRE	WAM Crustacea search
Haptolana 'sp. 1'	Stygofauna	Likely SRE	PSS
Kagalana tonde	Stygofauna	Likely SRE	WAM Crustacea search
Philoscidae 'sp. B13'	Troglofauna	Likely SRE	WAM Crustacea search
Philoscidae sp. 'B07'	Troglofauna	Likely SRE	WAM Crustacea search
Pygolabis 'Weeli Wolli'	Stygofauna	Likely SRE	PSS
Pygolabis eberhardi	Stygofauna	Likely SRE	WAM Crustacea search; PSS
Pygolabis Paraburdoo	Stygofauna	Likely SRE	WAM Crustacea search; PSS
Pygolabis sp.	Stygofauna	Likely SRE	WAM Crustacea search; PSS
Speocirolana? 'sp. 1' (PSS)	Stygofauna	Likely SRE	PSS
Crustacea: Copepoda (Cyclopoida)			
Diacyclops cockingi	Stygofauna	Not SRE	WAM Crustacea Search; PSS
Diacyclops humphreysi humphreysi	Stygofauna	Not SRE	PSS; WAM Crustacea search
Diacyclops humphreysi X *unispinosus*	Stygofauna	Not SRE	PSS
Diacyclops scanloni	Stygofauna	Not SRE	WAM Trog/Stygo Search; WAM Crustacea Search
Diacyclops sobeprolatus	Stygofauna	Not SRE	WAM Crustacea Search; PSS
Gomphodella 'hirsuta'	Stygofauna	Not SRE	PSS
Gomphodella cf. sp. 5	Stygofauna	Not SRE	PSS
Gomphodella sp. 1	Stygofauna	Not SRE	PSS
Gomphodella sp. 3	Stygofauna	Not SRE	PSS
Gomphodella sp. 4	Stygofauna	Not SRE	PSS
Gomphodella sp. 5	Stygofauna	Not SRE	PSS
Gomphodella sp. 6	Stygofauna	Not SRE	PSS
Limnocythere sp. 1	Stygofauna	Not SRE	PSS
Mesocyclops brooksi	Stygofauna	Not SRE	PSS

Taxa	**Significance**	**SRE status**	**Source (PSS=Pilbara Stygofauna Survey)**
Mesocyclops holynskae	Stygofauna	Not SRE	WAM Trog/Stygo Search; WAM Crustacea Search
Microcyclops varicans	Stygofauna	Not SRE	WAM Trog/Stygo Search; WAM Crustacea Search; PSS
Orbuscyclops westraliensis	Stygofauna	Not SRE	WAM Crustacea Search; PSS
Crustacea: Copepoda (Harpacticoida)			
Abnitocrella halsei	Stygofauna	Not SRE	WAM Crustacea search; PSS
Abnitocrella sp.	Stygofauna	Not SRE	PSS
Archinitocrella newmanensis	Stygofauna	Not SRE	WAM Crustacea search; WAM Trog/Stygo Search
Harpacticoida sp. 1	Stygofauna	Potential SRE	PSS
Nitocrellopsis 'sp. 1' (PSS)	Stygofauna	Not SRE	PSS
'Rockleanitocrella' 'sp. 1' (PSS)	Stygofauna	Potential SRE	PSS
Parapseudoleptomesochra tureei	Stygofauna	Likely SRE	WAM Crustacea search; PSS
Parastenocaris jane	Stygofauna	Not SRE	WAM Crustacea Search; PSS
Parastenocaris sp. 3	Stygofauna	Potential SRE	PSS
Schizopera 'sp. 3' (PSS)	Stygofauna	Not SRE	PSS
Schizopera 'sp. 4' (PSS)	Stygofauna	Not SRE	PSS
Schizopera 'sp. 5' (PSS)	Stygofauna	Not SRE	PSS
Schizopera roberiverensis	Stygofauna	Not SRE	WAM Crustacea search; PSS
Schizopera weelumurra	Stygofauna	Not SRE	WAM Crustacea search; WAM Trog/Stygo Search
Crustacea: Ostracoda			
Areacandona 'sp. 5' (PSS)	Stygofauna	Potential SRE	PSS
Areacandona 'sp. 8' (PSS)	Stygofauna	Potential SRE	PSS
Areacandona ake	Stygofauna	Not SRE	PSS
Areacandona astrepte	Stygofauna	Not SRE	PSS
Areacandona atomus	Stygofauna	Likely SRE	PSS
Areacandona brookanthana	Stygofauna	Likely SRE	WAM Crustacea search
Areacandona cellulosa	Stygofauna	Likely SRE	PSS
Areacandona scanlonii	Stygofauna	Likely SRE	PSS
Areacandona weelumurrae	Stygofauna	Likely SRE	WAM Crustacea search; PSS
Areacandona nammuldi	Stygofauna	Likely SRE	WAM Crustacea search; PSS
Candonidae ?Genus2 sp. 1	Stygofauna	Likely SRE	PSS
Candonidae ?Genus5 sp. 1	Stygofauna	Likely SRE	PSS
Candonidae ?*Meridiescandona* sp. 1	Stygofauna	Likely SRE	PSS
Candonopsis pilbarae	Stygofauna	Likely SRE	WAM Crustacea Search; PSS
Deminutiocandona aporia	Stygofauna	Likely SRE	WAM Crustacea search; PSS
Deminutiocandona atope	Stygofauna	Likely SRE	PSS
Deminutiocandona mica	Stygofauna	Likely SRE	PSS
Deminutiocandona quasimica	Stygofauna	Likely SRE	PSS
Deminutiocandona stomachosa	Stygofauna	Likely SRE	WAM Crustacea search; PSS

Taxa	**Significance**	**SRE status**	**Source (PSS=Pilbara Stygofauna Survey)**
Humphreyscandona 'sp. 2' (PSS)	Stygofauna	Likely SRE	PSS
Humphreyscandona adorea	Stygofauna	Likely SRE	PSS
Humphreyscandona cf. imperfecta	Stygofauna	Likely SRE	PSS
Humphreyscandona janeae	Stygofauna	Likely SRE	WAM Crustacea search; PSS
Humphreyscandona woutersi	Stygofauna	Likely SRE	PSS
Leicacandona carinata	Stygofauna	Likely SRE	PSS
Neocandona novitas	Stygofauna	Likely SRE	WAM Crustacea search
Origocandona cf. inanitas	Stygofauna	Likely SRE	PSS
Origocandona inanitas	Stygofauna	Likely SRE	PSS
Pilbaracandona colonia	Stygofauna	Likely SRE	PSS
Pilbaracandona 'sp. 3' (PSS)	Stygofauna	Likely SRE	PSS
Pilbaracandona 'sp. 4' (PSS)	Stygofauna	Likely SRE	PSS
Pilbaracandona temporaria	Stygofauna	Likely SRE	PSS
Crustacea: Syncarida			
Atopobathynella 'sp. A'	Stygofauna	Likely SRE	PSS
Bathynellaceae sp.	Stygofauna	Likely SRE	WAM Trog/Stygo Search
Bathynellidae sp.	Stygofauna	Likely SRE	WAM Trog/Stygo Search
Notobathynella sp.	Stygofauna	Likely SRE	PSS
Parabethynellidae sp.	Stygofauna	Likely SRE	PSS
Polychaeta			
Aeolosoma 'sp. 1'	Stygofauna	Not SRE	PSS
Aeolosoma 'sp. 2'	Stygofauna	Not SRE	PSS
Aeolosoma 'sp. 4'	Stygofauna	Not SRE	PSS
Oligochaeta			
Dero (*Allodero*) 'WA2'	Stygofauna	Not SRE	WAM Trog/Stygo Search
Dero 'WA1'	Stygofauna	Not SRE	WAM Trog/Stygo Search
Enchytraeus Pilbara sp. 1 (PSS)	Stygofauna	Not SRE	PSS
Phreodrilus peniculus	Stygofauna	Not SRE	PSS
Tubificidae stygo morphotype 2	Stygofauna	Not SRE	PSS
Tubificidae stygo type 1 (imm Ainudrilus WA25/26?)	Stygofauna	Not SRE	PSS
Tubificidae stygo type 2A	Stygofauna	Not SRE	PSS
Insecta: Blatteria			
Nocticola sp. 'B1'	Troglofauna	Likely SRE	Bennelongia, 2012
Insecta: Diplura			
Japygidae sp. 'B28'	Troglofauna	Likely SRE	Bennelongia, 2012
Parajapygidae sp. 'B23'	Troglofauna	Likely SRE	Bennelongia, 2012
Insecta: Hemiptera			
Meenoplidae sp.	Troglofauna	Likely SRE	Bennelongia, 2012

Taxa	Significance	SRE status	Source (PSS=Pilbara Stygofauna Survey)
Hemiptera sp. 'B2'	Troglofauna	Likely SRE	Bennelongia, 2012
Insecta: Thysanura			
Atelurinae sp. 'B2'	Troglofauna	Likely SRE	Bennelongia, 2012
Lophoproctidae sp. 'B1'	Troglofauna	Likely SRE	Bennelongia, 2012
Hemitrinemura sp. 'B7'	Troglofauna	Likely SRE	Bennelongia, 2012

Bennelongia, 2012 - Bennelongia. 2012. Turee Syncline Iron Ore Project troglofauna survey. Bennelongia Environmental Consultants Pty Ltd, Jolimont, WA. Unpublished report prepared for Rio Tinto Iron Ore.

Vertebrate fauna survey of the Rocklea Iron Ore Project

Prepared for Dragon Energy Ltd

December 2011

Final Report

Vertebrate fauna survey of the Rocklea Iron Ore Project

Prepared for Dragon Energy Ltd

Final Report

Author: Guillaume Bouteloup

Reviewer: Jarrad Clark and Karen Crews

Date: 1 December 2011

Submitted to: Gang Xu, Mark Hafer

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Karen Crews	Editorial review	1.2	15/11/11
Guillaume Bouteloup	Final for technical review	2.0	28/11/11
Jarrad Clark	Final for editorial review	2.1	30/11/2011
Karen Crews	Final for editorial review	2.2	30/11/2011
Guillaume Bouteloup	Final submitted to client	2.3	01/12/2011

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EXECUTIVE SUMMARY

Dragon Energy Ltd is developing the Rocklea Iron Ore Project (the Project), located 34 km southwest of Tom Price in the Pilbara region of WA. The Project comprises a channel iron deposit and mining is proposed to commence in mid-2013 in a staged format, with up to 2 million tonnes per annum of ore transported to a Pilbara port via road. The anticipated level of assessment is a mining proposal.

In September 2011, Phoenix Environmental Sciences Pty Ltd (Phoenix) was commissioned to undertake a single season, Level 2 vertebrate fauna survey of the Project. This report presents the results of that survey.

A desktop review and remote habitat characterisation were undertaken prior to the field survey. Habitats with the potential to support conservation significant fauna were identified through these data sources, based on known habitats of such species within the Pilbara region and previous survey reports.

The following eight broad fauna habitat types were identified within the study area:

- grass plain
- grassland on rocky slope
- minor drainage line
- non-riparian mulga woodland
- riparian woodland
- river bed
- woodland on rocky slope
- cleared habitats.

The field survey took place from 23 September to 2 October 2011. Survey techniques included systematic trapping in eight sites representing all major fauna habitats, avifauna surveys, active searches, targeted searches, spotlighting and recording of bat activity using Song Meters.

A total of 280 vertebrate fauna species were identified in the desktop review as potentially occurring in the study area. The potential assemblage comprised 39 mammals (31 native and eight introduced), 146 birds, 88 reptiles and seven amphibians.

The survey recorded 114 native and three introduced vertebrate species representing three classes of vertebrate taxa. The recorded assemblage was strongly dominated by birds.

Two species listed as Priority 4 on the DEC Priority List (Bush Stone-curlew and Western Pebble-mound Mouse) and one species listed as Migratory under the *Environment Protection and Biodiversity Conservation Act 199*9 (EPBC Act; Rainbow Bee-eater) were recorded in the surveys. A further 18 conservation significant species may occur.

The study area contains important habitat for:

- Western Pebble-mound Mouse mainly on grasslands on rocky slopes and occasionally in non-riparian mulga woodlands
- Bush Stone-curlew in all type of riparian habitats (Hardey River bed and associated riparian woodlands) and also in non-riparian mulga woodlands in general
- Rainbow Bee-eater in all type of riparian habitats (Hardey River bed and associated riparian woodlands) and also along minor drainage lines

- Australian Bustard (Priority 4; not recorded but highly likely to occur) in grass plains, especially on the flats, in the western part of the study area
- the riparian habitats along the Hardey River are important for fauna generally.

Although not recorded, there is suitable habitat for Northern Quoll (Endangered under the EPBC Act; Schedule 1 under the *Wildlife Conservation Act 1950*) along the Hardey River within the study area which connects to a rocky ridge extending south of the study area. The Project occurs within the distribution range of the Northern Quoll.

It is considered likely that Pilbara Olive Python (Vulnerable under the EPBC Act; Schedule 1 under the *Wildlife Conservation Act 1950*) may occur in the study area. Suitable habitat exists in the low lying, eastern portion of the study area, which contains semi-permanent water and a rock range forming a corridor to the Hardey River. The Pilbara Olive Python has been recorded from a number of locations close to the study area.

A preliminary assessment has identified several potential impacts to vertebrate fauna from the Project:

- habitat loss
- loss of individual fauna
- displacement of individuals
- hydrological impacts
- spread of introduced fauna and flora
- pollution events
- visual and acoustic disturbance
- fire
- dust.

Several conservation significant species may be impacted by the Project; however, the assessment should be treated as tentative as a detailed project footprint was not available at the time of writing this report. Preliminary recommendations have been made to address potential impacts of the Project on fauna.

A more detailed impact assessment should be undertaken once the project footprint has been more clearly defined.

A second seasonal survey is not considered likely to be required. Targeted surveys for the Northern Quoll and Pilbara Olive Python may need to be undertaken in 2012 depending on whether the project footprint intersects suitable habitat for these species in the study area.

1 INTRODUCTION

In September 2011 Phoenix Environmental Sciences Pty Ltd (Phoenix) was commissioned by Dragon Energy Ltd to undertake a single season, Level 2 vertebrate fauna survey for the Rocklea Iron Ore Project (the Project). This report presents the results of that survey. The requirement for a second seasonal survey was to be assessed on the basis of the initial survey results.

1.1 BACKGROUND

The project is located 34 km southwest of Tom Price in the Pilbara region of WA (Figure 1-1). The Project comprises a channel iron deposit (CID) with a JORC inferred resource of 63.1Mt@ 53.4% Fe (60.4% caFe).

Mining is proposed to commence in mid-2013 in a staged format, with (under current plans) up to 2 million tonnes per annum of ore transported to a Pilbara port via road. The anticipated level of assessment is a mining proposal via the Department of Mines and Petroleum. No detailed mapping of the project layout (location of the main pit, waste dump, accommodation village, etc.) was provided prior to the survey and therefore the survey design was based on representative habitats present and habitat condition therein.

1.2 SCOPE OF WORK AND SURVEY OBJECTIVES

The scope of work was as follows:

- conduct a desktop review of technical reports and relevant databases to determine the potential vertebrate fauna species and respective habitats within the study area
- conduct field surveys for vertebrate fauna within the study area
- undertake an analysis of field-derived data
- prepare maps showing significant species records and fauna habitats in the study area
- prepare technical reports outlining survey methods, results, assessment of significant species and habitats, assessment of potential impacts on fauna from the Project and recommendations for management and mitigation of impacts.

Where practicable, survey design, methodology and report-writing adhered to relevant principles and guidelines, including:

- Environmental Protection Authority (EPA) Position Statement No. 3: *Terrestrial biological surveys as an element of biodiversity protection* (EPA 2002)
- EPA Guidance Statement No. 56: *Terrestrial fauna surveys for environmental impact assessment in Western Australia* (EPA 2004)
- EPA & DEC Technical Guide: *Terrestrial vertebrate fauna surveys for environmental impact assessment* (EPA & DEC 2010).

The study area was defined as a sub-area of tenement (E47/1024) (Figure 1-2). No information was provided at the time of field mobilisation with respect to the location of the proposed pit and associated supporting infrastructure (e.g. accommodations, waste dump, tracks, haul road).

Figure 1-1 **Location of the Rocklea Iron Ore Project**		PHOENIX ENVIRONMENTAL SCIENCES
AUTHOR: G. Bouteloup	CLIENT: Dragon Energy Ltd.	
DATE: November 2011	Scale: 1:1746870	PROJECT: Rocklea Iron Ore Project
Coordinate System: Projection: Transverse Mercator; Datum: WGS84		

Town
Previous survey
Study area
Railway
Road

N

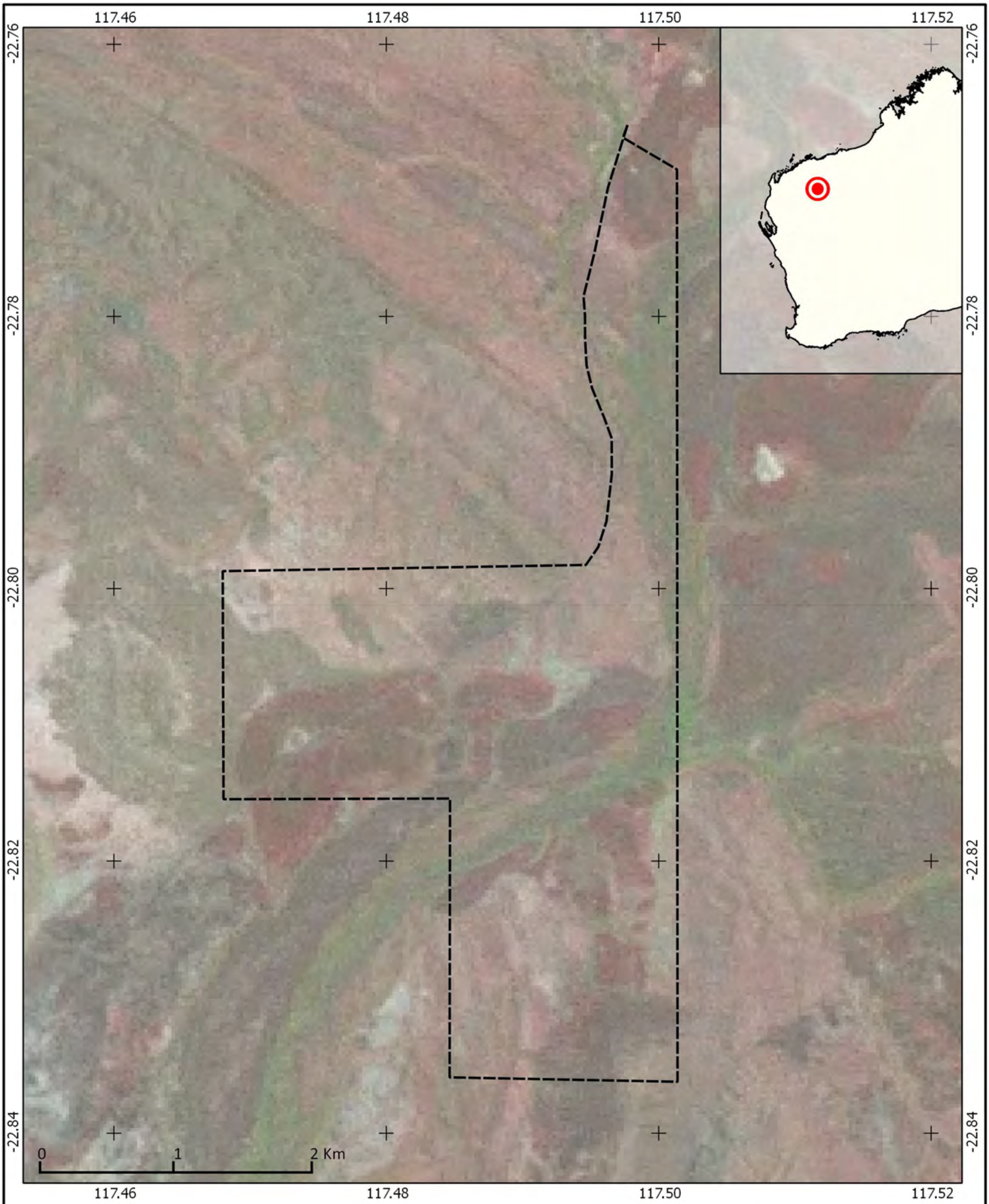

Figure 1-2
Study area for vertebrate fauna survey of the Rocklea Iron Ore Project

Study area

N

PHOENIX
ENVIRONMENTAL SCIENCES

AUTHOR: G. Bouteloup	CLIENT: Dragon Energy Ltd.
DATE: November 2011	Scale: 1:30000
Coordinate System: Projection: Transverse Mercator; Datum: WGS84	

PROJECT: Rocklea Iron Ore Project

2 EXISTING ENVIRONMENT

2.1 INTERIM BIOGEOGRAPHIC REGIONALISATION OF AUSTRALIA (IBRA) REGION

Bioregions are defined as large land areas characterised by broad, landscape-scale natural features, and environmental processes that influence the functions of entire ecosystems. Their purpose is to capture the large-scale geophysical patterns that occur across the Australian continent. The identified patterns in the landscape are linked to fauna and flora assemblages and processes at the broad ecosystem scale. They are a useful means for simplifying and reporting on more complex patterns of biodiversity (Thackway & Cresswell 1995).

Western Australia contains 26 IBRA bioregions and 53 subregions. The nature and scale of threatening processes varies across the bioregions, as does the extent of intact vegetation and the extent protection under the State reserve system.

The study area falls within the Pilbara bioregion, which covers an area of 178 500km^2. The Pilbara bioregion contains four main geological components (subregions) (DEWHA 2009; Kendrick 2001):

- Chichester (PIL1): undulating granite and basalt plains supporting shrub steppe of *Acacia pyrifolia* over *Triodia pungens* hummock grasslands.
- Fortescue (PIL2): alluvial plains and river frontages, northern limit of Mulga, permanent springs fed by an extensive calcrete aquifer, supports large permanent wetlands.
- Hamersley (PIL3): mountainous area of ranges and plateaux dissected by gorges, vegetation is mostly comprised of Mulga woodland over grasses on fine texture soils.
- Roebourne (PIL4): alluvial and older colluvial coastal and sub-coastal plains with a grass savannah.

The study area is situated within the Hamersley subregion (Figure 2-1). The Hamersley subregion is characterised by a semi-desert tropical climate (average of 300 mm annual rainfall) and represents 34% of the Pilbara bioregion. Several features are distinctive of the Hamersley subregion (Kendrick 2001):

- rare features: gorges of the Hamersley range, Palm spring, Duck Creek, *Themeda* grasslands, Red Hill Station mulga stands
- centres of endemism (calcrete deposits for troglofauna)
- refugia (gorges of the Hamersley Range, calcrete deposits, mountain tops of the Hamersley Range, permanent spring systems)
- high species and ecosystem diversity (*Acacia*, *Triodia*, *Ptilotus*, *Corymbia* and *Sida* sp., crustacean stygofauna within the calcrete environment).

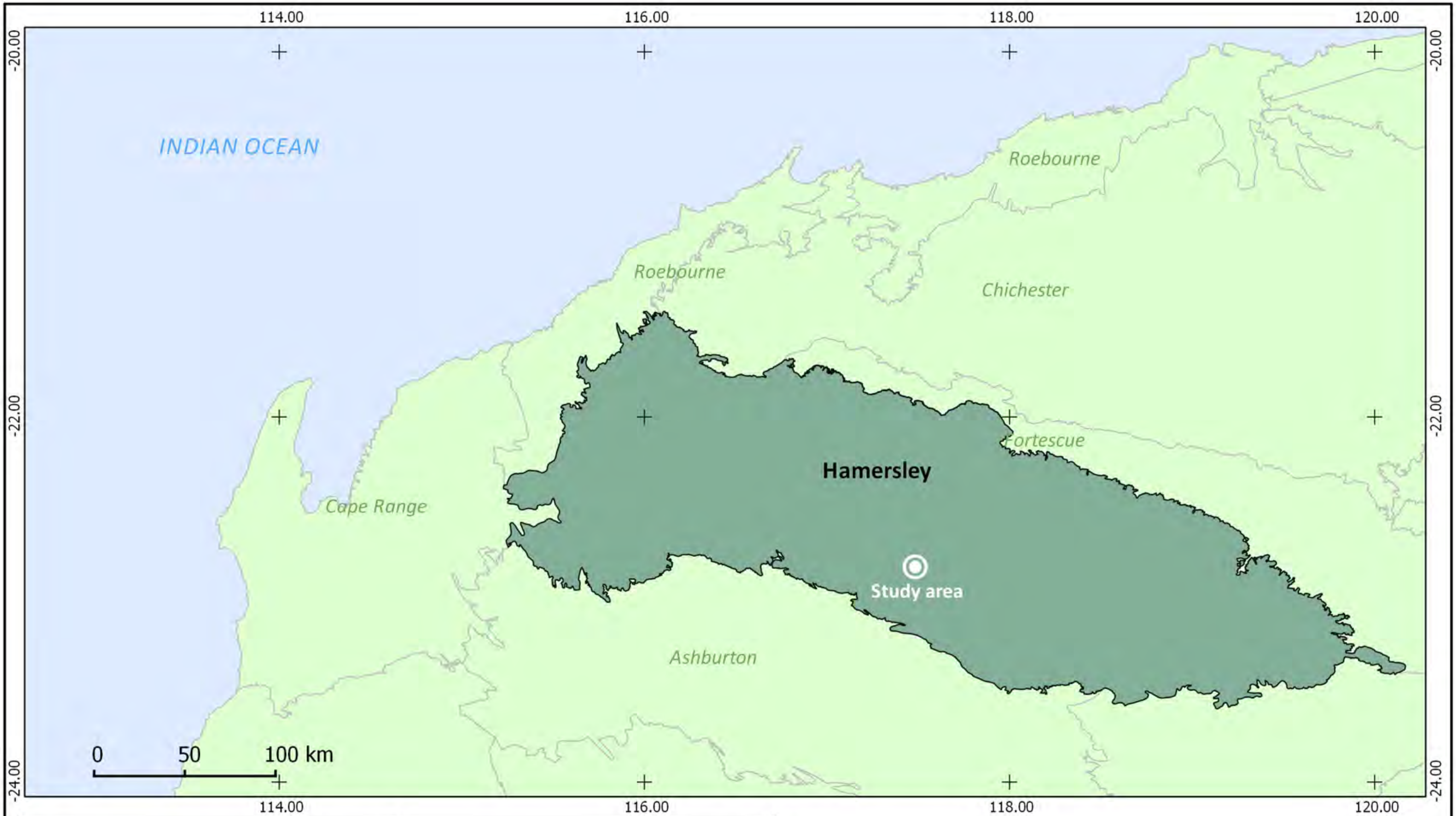

Figure 2-1
Biogeographic subregion of the study area

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AUTHOR: G. Bouteloup	**CLIENT:** Dragon Energy Ltd.	
DATE: November 2011	**Scale:** 1:2310495	**PROJECT:** Rocklea Iron Ore Project
Coordinate System: Projection: Transverse Mercator; Datum: WGS84		

2.2 LAND SYSTEMS

The Department of Agriculture and Food Western Australia (Van Vreeswyk *et al.* 2004) has mapped the land systems of the region from aerial photography, providing the largest-scale interpretation of vegetation units for the study area. The study area traverses six land systems (Figure 2-2):

- Robe: low limonite mesas and buttes supporting soft spinifex (and occasionally hard spinifex) grasslands
- Boolgeeda: stony lower slopes and plains below hill systems supporting hard and soft spinifex grasslands and mulga shrublands
- Rocklea: basalt hills, plateaux, lower slopes and minor stony plains supporting hard spinifex (and occasionally soft spinifex) grasslands
- Paraburdoo: basalt derived stony gilgai plains and stony plains supporting snakewood and mulga shrublands with spinifex and tussock grasses
- River: active flood plains and major rivers supporting grassy eucalypt woodlands, tussock grasslands and soft spinifex grasslands
- Table: low calcrete plateaux, mesas and lower plains supporting mulga and cassia shrublands and minor spinifex grasslands.

The dominant land systems present in the study area are the Robe, Boolgeeda, Rocklea and Paraburdoo land systems. The rocky habitats present in (particularly) the Rocklea, Boolgeeda and Robe land systems, and the riparian habitats of the River land system, can potentially support conservation significant fauna species. The Table and Paraburdoo land systems are less likely to support species of conservation significances given their physical and geomorphological features.

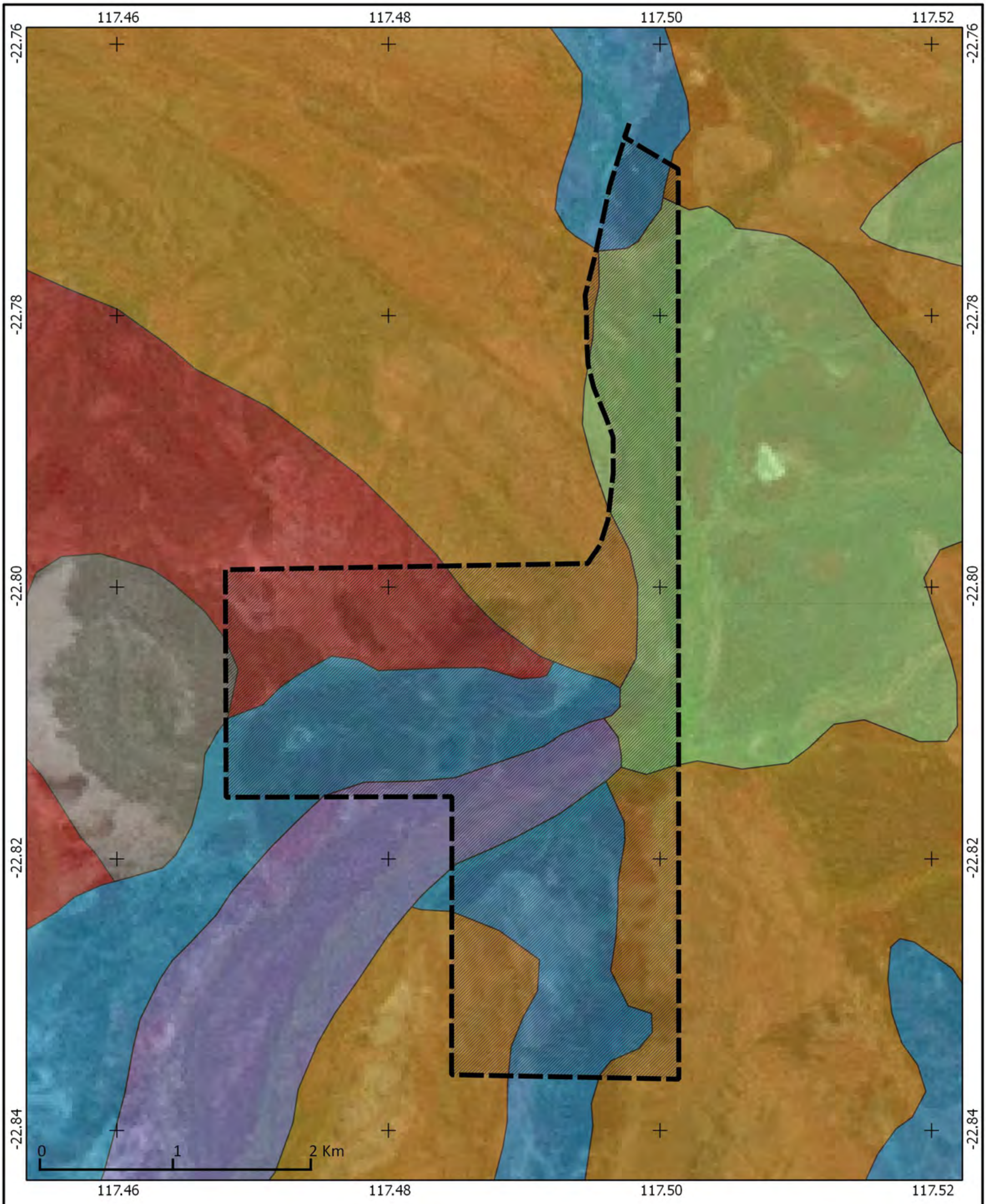

Figure 2-2
Land systems of the study area

AUTHOR: G. Bouteloup	**CLIENT:** Dragon Energy Ltd.
DATE: November 2011	**Scale:** 1:30000
Coordinate System: Projection: Transverse Mercator; Datum: WGS84	

PROJECT: Rocklea Iron Ore Project

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2.3 CLIMATE AND WEATHER

The Pilbara bioregion has an arid climate with average maximum temperatures over 40°C from November to February and an average of 25°C during the winter months. The average rainfall ranges from about 200 mm to 350 mm. The average yearly evaporation (2500 mm) exceeds the annual rainfall.

The nearest and currently active Bureau of Meteorology (BOM) weather station is located at Paraburdoo airport (Latitude: 23.17°S, Longitude: 117.75°E) approximately 50 km south-east of the Project. Paraburdoo records the highest maximum mean monthly temperature (41°C) in January, the lowest maximum mean annual temperature (9.8°C) in July and an average annual rainfall of 404.8 mm (BOM 2011b); Figure 2-3).

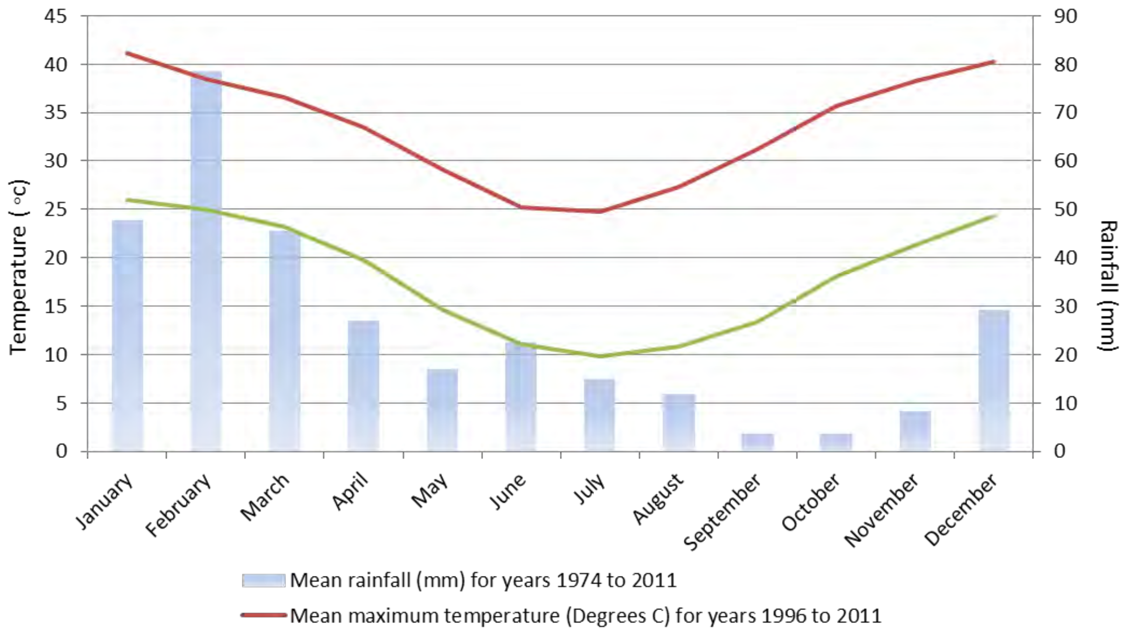


Figure 2-3 **Average monthly temperatures (maximum and minimum) and rainfall records from Paraburdoo Aero (BOM 2011a)**

2.4 LAND USE

The study area lies within the broader region of the Pilbara, an area distinct from (but including) the Pilbara IBRA bioregion. The Pilbara region was historically dominated by native grazing and pastoral activities. Current land use in this region is more diverse, comprising pastoral grazing; mineral exploration and mining activities; and dedication of land to Crown Reserves (e.g. Jigalong Aboriginal Reserve, Karijini National Park and Millstream National Park(Van Vreeswyk *et al.* 2004). In 2009, land tenure in the broader Pilbara region was approximately 60% pastoral lease, 10% conservation reserve, 5% Aboriginal Reserve and 25% unallocated Crown land (McKenzie *et al.* 2009). Within the Hamersley subregion, dominant land uses are grazing, UCL and crown reserves, native pastures, conservation, mining and urban (Kendrick 2001).

Grazing is prevalent across the study area. Stocking rates appear high on Rocklea station, especially in the low-lying, shadier portions of the study area.

2.5 BIOLOGICAL CONTEXT

2.5.1 Vertebrate fauna

The Pilbara has very diverse flora and fauna; however, its biota remains poorly documented despite a considerable amount of localised surveys by government and tertiary institutions, as well as mining companies and their environmental consultants (McKenzie *et al.* 2009). A comprehensive biological survey of the Pilbara (the Pilbara Biological Survey) was conducted by the Department of Environment and Conservation (DEC) from 2002–2007. This survey provided a benchmark for environmental assessment studies in the Pilbara, as it comprehensively surveyed the biota and summarised faunistic and floristic data for the region for many groups of plants and animals. Survey data has provided substantial background information on the small mammal, bat and bird fauna of the region (Burbidge *et al.* 2010; Gibson & McKenzie 2009; McKenzie & Bullen 2009).

Species may be of conservation significance from a local or regional perspective, for example, due to their distributions and migrating patterns. Native species are often considered valuable to local people, particularly to traditional owners. These values are rarely formally recognised through conservation legislation. Species that are restricted to a particular biogeographic region, while generally not given additional protection under legislation, may be considered to be of significance because of their restricted distribution. The Chichester subregion of the Pilbara bioregion has a number of bioregional endemic vertebrate species (Table 2-1)(Thackway & Cresswell 1995).

Table 2-1 Bioregional endemic vertebrate fauna species of the Pilbara region

Mammals	Reptiles
Ningaui timealeyi,	*Diplodactylus savagei*
An undescribed Planigale	*Diplodactylus wombeyi*
Dasykaluta rosamondae	*Delma elegans*
Pseudomys chapmani	*Delma pax*
Pseudantechinus roryi	*Ctenotus rubicundus*
	Egernia pilbarensis
	Lerista zietzi
	Lerista flammicauda
	Lerista neander
	Notoscincus butleri
	Varanus pilbarensis
	Acanthophis wellsi
	Demansia rufescens
	Ramphotyphlops pilbarensis
	Ramphotyphlops ganei

2.5.2 Threatening processes

There are several threatening processes to the flora and fauna of the Pilbara bioregion, in particular:

- **Wildfire and alteration of fire regimes**: over 72% of the Pilbara region was burnt between 1993 and 2006 (van Leeuwen *et al.* 1995 in McKenzie et al. 2009). The extent of Mulga woodland in the central Hamersley Range is decreasing as a consequence of too-frequent fires. These woodlands support assemblages of species that do not persist in the spinifex scrublands that are replacing the mulga.
- **Habitat alteration through grazing**: livestock grazing started depleting the native grass cover along the main river channels in the early 1900s, resulting in increasingly occluded drainage systems with substantial bed loads. Simultaneously, the introduced Buffel grass (*Cenchrus ciliaris*) rapidly colonised alluvial surfaces via these river systems. Subsequently, it has displaced indigenous shrubs and grasses from a variety of Pilbara environments (McKenzie *et al.* 2009).
- **Spread of introduced fauna including unmanaged livestock and feral bees:** twelve introduced mammals compete with and/or prey on indigenous species in the Pilbara, including house mice, black rats, feral dogs and cats, European Red Fox, European rabbit, brumbies, feral pigs and camels (see also McKenzie & Burbidge 2002).
- **Spread of weeds**: a total of 103 weed species are currently established in the Pilbara comprising 6.3% of the region's flora. Fourteen of these species alter the region at a landscape scale by altering fire patterns, modifying soil characteristics or competing directly with native species. Another 15 species significantly modify particular habitats such as wetlands, six are major threats to islands, and a further 16 have potential threat to Pilbara environments (Keighery 2010).
- **Climate change**: current predictions suggest that the Pilbara region will become warmer with more hot days and fewer cold nights, and may experience less annual rainfall, droughts will be more severe, and storm events will become more common (McKenzie *et al.* 2009). These effects may enhance the effects of other threatening processes, in particular the likelihood of fire and the introduction of more species from the tropics.
- **Habitat destruction through mining and associated infrastructure:** several large-scale mining developments are present in the area (e.g. Paraburdoo, Tom Price). The cumulative effects of these projects are not well understood. Large scale projects such as these and associated infrastructure developments such as railways also potentially impact surface and sub-surface hydrology which in turn may affect surface vegetation and therefore dependent fauna species and assemblages.

2.6 RELEVANT LEGISLATION AND AGREEMENTS

2.6.1 International

Migratory species are protected under a number of international agreements:

- Japan-Australia Migratory Bird Agreement (JAMBA)
- China-Australia Migratory Bird Agreement (CAMBA)
- Convention on the Conservation of Migratory Species of Wild Animals (Bonn)
- Agreement between the Government of Australia and the Government of the Republic of Korea on the Protection of Migratory Birds (ROKAMBA).

2.6.2 Commonwealth

Under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), actions that have, or are likely to have, a significant impact on a matter of national environmental significance (NES) require approval from the Australian Government Minister for the Environment, Water, Heritage and the Arts. The EPBC Act provides for the listing of nationally threatened native species. Fauna species of national conservation significance may be classified as 'critically endangered', 'endangered', 'vulnerable' or 'conservation dependent'.

The EPBC Act is also the enabling legislation for protection of migratory species under the international agreements listed above.

2.6.3 State

Native species in Western Australia which are under identifiable threat of extinction are protected under the Western Australian *Wildlife Conservation Act 1950* (WC Act). Under the WC Act, the *Wildlife Conservation (Specially Protected Fauna) Notice 2008 (2)* recognises four classifications of rare and endangered fauna:

- **Schedule 1:** fauna that is rare or is likely to become extinct
- **Schedule 2:** fauna presumed to be extinct
- **Schedule 3:** birds subject to an agreement between the government of Australia and the governments of Japan, China and the Republic of Korea relating to the protection of migratory birds
- **Schedule 4:** fauna in need of special protection.

In addition, the DEC produces a list of Priority species (last update: August 2010) that have not been assigned statutory protection under the *WC Act*. Species on this list are considered to be of conservation priority because there is insufficient information to make an assessment of their conservation status or they are considered to be rare but not threatened and are in need of monitoring. The DEC Priority Fauna List categories are:

- **Priority 1:** taxa with few, poorly known populations on threatened lands
- **Priority 2:** taxa with few, poorly known populations on conservation lands
- **Priority 3:** taxa with several, poorly known populations, some on conservation lands
- **Priority 4:** taxa in need of monitoring – considered not currently threatened but could be if present circumstances change
- **Priority 5:** taxa in need of monitoring – considered not currently threatened but subject to a conservation program, the cessation of which could result in the species becoming threatened.

3 METHODS

3.1 DESKTOP REVIEW

The desktop review was completed using available local and regional published and unpublished reports, databases and spatial data. Four databases were reviewed to identify significant species that may occur within the study area:

- EPBC Act protected matters database search centred on coordinates 22°49'29.61"S and 117°29'26.52"E with a 10 km buffer (maximum radius allowed).
- DEC Threatened Fauna database search centred on coordinates 22°49'29.61"S and 117°29'26.52"E with a 40 km buffer.
- DEC NatureMap database search centred on coordinates 22°49'29.61"S and 117°29'26.52"E with a 40 km buffer.
- Birds Australia Birdata database search centred on coordinates 22°49'29.61"S and 117°29'26.52"E with a 40 km buffer.

Further, a literature search was completed in order to identify available reports on vertebrate fauna surveys conducted within the vicinity of the study area to build on the species list developed from the database searches:

- (Biota 2005). Fauna habitats and fauna assemblage of the Brockman Syncline 4 Project, near Tom Price. Biota Pty. Ltd. (35km NW)
- (Biota 2008). Marandoo Mine Phase 2, Seasonal Fauna Survey. Prepared for Rio Tinto. Biota Pty. Ltd. (70km NE, in Karijini NP)
- (Biota 2009). West Turner Syncline Section 10 Development, Two-phase fauna survey. Prepared for Pilbara Iron Company. Biota Pty. Ltd. (22km NE).

Additional data only documenting conservation significant species were also available from RioTinto (2011) for the Channar mine, south of Paraburdoo, 60km SE of the study area. This report is based on data collected by Ninox in 1985/86.

3.2 HABITAT ASSESSMENT AND SITE SELECTION

Initial habitat characterisation was undertaken using various remote geographical tools, including aerial photography, land system maps and topographic maps. Habitats with the potential to support conservation significant fauna were then identified through these data sources, based on known habitats of such species within the Pilbara region and previous survey reports.

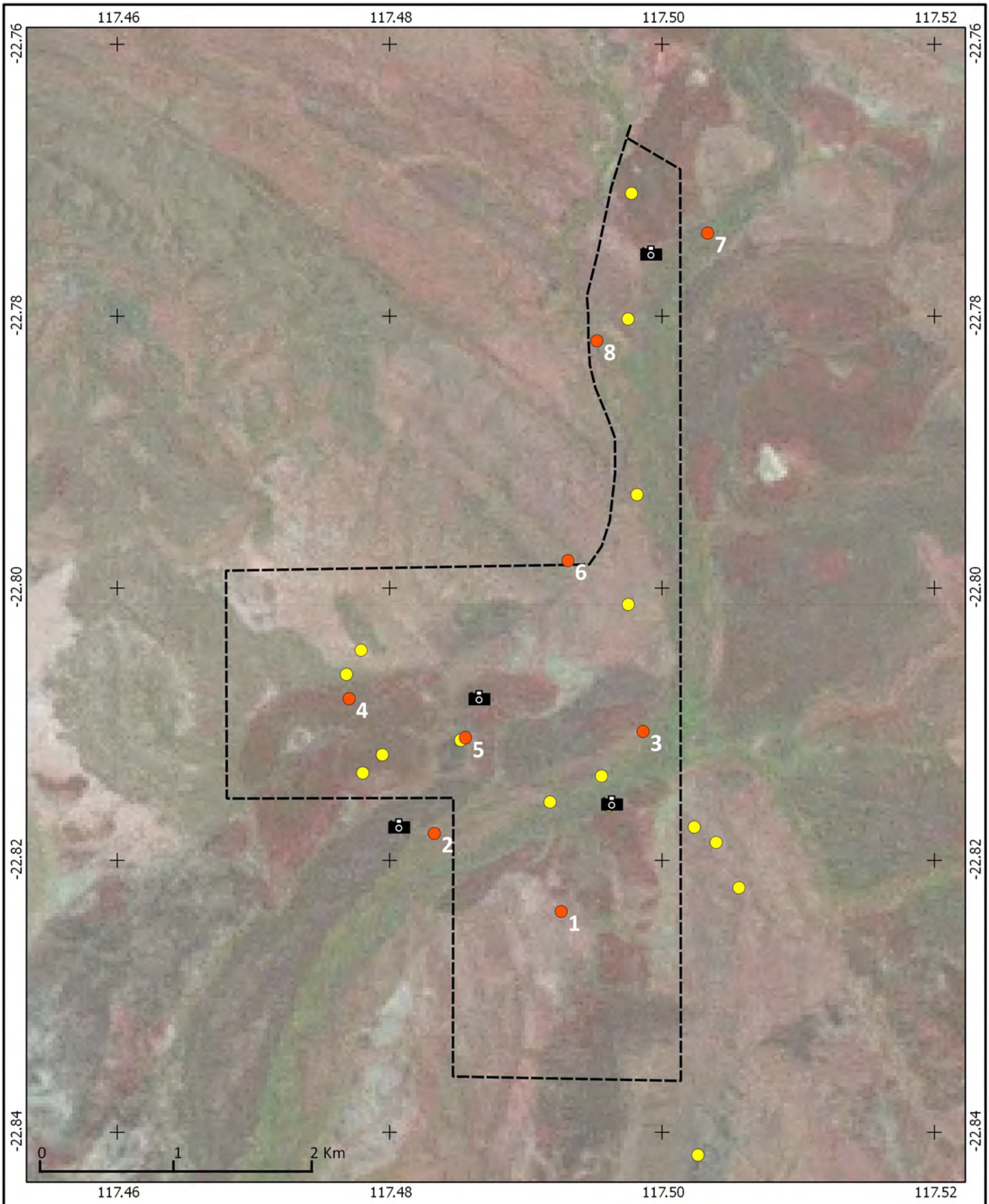
The following eight broad fauna habitat types were identified within the study area:

- grass plain
- grassland on rocky slope
- minor drainage line
- non-riparian mulga woodland
- riparian woodland
- river bed
- woodland on rocky slope
- disturbed area.

At the broadest scale, site selection considered aspect, topography and land systems. At the finer scale, consideration was given to proximity to water bodies (drainage lines and creeks), vegetation condition and soil type (where known). Sites were primarily chosen:

- to represent the best example of a distinct habitat within the broader habitat associations of the study area
- when considered the best choice to inform the assessment process.

Eight systematic survey sites were selected, representing the full range of fauna habitats and landscape variations within the study area with the exception of disturbed area (Figure 3-1). All systematic and opportunistic survey sites were formally described and photographed. Two sites installed for the Pilbara Biological Survey were opened, therefore providing further contextual information from which to draw conclusions.



Camera trap

Systematic trapping site

Opportunistic survey site

Figure 3-1
Survey site locations

AUTHOR: G. Bouteloup	CLIENT: Dragon Energy Ltd.
DATE: November 2011	Scale: 1:30000
Coordinate System: Projection: Transverse Mercator; Datum: WGS84	

PROJECT: Rocklea Iron Ore Project

PHOENIX ENVIRONMENTAL SCIENCES

3.3 LEVEL 2 FIELD SURVEY

The field survey took place from 23 September to 2 October 2011. Eight sites identified in the habitat assessment were surveyed (Figure 3-1; Appendix 2). Survey work was undertaken over 10 consecutive days and comprised:

- systematic trapping for ground-dwelling mammals, reptiles and amphibians
- systematic avifauna surveys
- recording of bat echolocation calls using Song Meter 2 devices
- spotlighting for nocturnal species
- active searches
- recording of opportunistic sightings
- infrared motion camera traps
- targeted searching for species of conservation significance.

The survey components are described in more detail in sections 3.3.1 to 3.3.8.

3.3.1 Trapping grids for ground dwelling mammals, reptiles and amphibians

Trapping grids aimed to catch terrestrial mammals, reptiles and amphibians. The grids comprised ten pit traps consisting of five PVC pipes (15 cm diameter x 50 cm depth) and five buckets (20 L) installed at approximately 20 m intervals along a transect. The pits were installed flush with the substrate, with a 5 m long and 30 cm high aluminium drift fence bisecting each pit. One drift fence with associated traps is referred to as a 'trap line'. Traps were left open overnight and checked within three hours of sunrise.

Twenty funnel traps measuring 75 cm x 18 cm x 18 cm were placed at each end of the ten aluminium drift fences. Twenty Elliott traps (9 cm x 10 cm x 33 cm) were placed in pairs, parallel to each of the ten pit traps at each site (Figure 3-2).

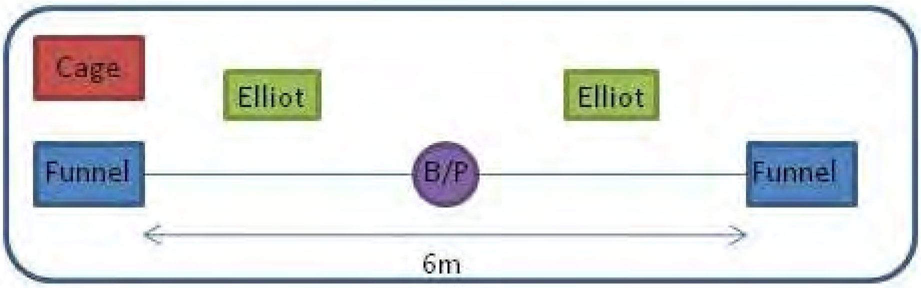


Figure 3-2 Systematic trapping site conceptual layout

The Elliott traps contained a mixture of oats, peanut butter and sardines ('universal bait') to attract small mammals. Two Sheffield cage traps (60 cm x 20 cm x 20 cm) were baited and positioned at each site.

Elliott and funnel traps were shrouded with reflective closed cell insulation (R2.5 rated) to provide shade and protection for any captured animals. All traps, including the cages, were given as much shade as possible, including leaf litter or vegetation cover where necessary. Styrofoam cups and leaf litter were used to provide shade in the bottom of pit traps.

The total vertebrate trapping effort for the eight trapping grid sites during the surveys was 2790 trap-nights (Table 3-1); where a trap-night is defined as one trap remaining open for one night. The camera traps were not set-up at the systematic trapping sites and are therefore not included in Table 3-1.

Table 3-1 Summary of trapping effort

Site number	Nights open	# pit traps	# funnel traps	# Elliott traps	# cage traps	Pit trap effort (nights)	Funnel trap effort (nights)	Elliott trap effort (nights)	Cage trap effort (nights)	Total trap nights
1	7	10	20	20	2	70	140	140	14	**364**
2	7	10	20	20	2	70	140	140	14	**364**
3	6	10	20	20	2	60	120	120	12	**312**
4	7	5	20	20	2	35	140	140	14	**329**
5	7	10	20	20	2	70	140	140	14	**364**
6	7	5	20	20	2	35	140	140	14	**329**
7	7	10	20	20	2	70	140	140	14	**364**
8	7	10	20	20	2	70	140	140	14	**364**
TOTAL										**2790**

3.3.2 Avifauna surveys

Two independent, 60 minute bird surveys were undertaken at each systematic survey site. The surveys were conducted from sunrise to 10:30 am, which is a period of high activity for birds. Sampling was conducted across the coherent habitat units of the trapping site. Additional 20 minute surveys were also undertaken at opportunistic sites selected on the basis of habitat features, location, physical characteristics and relevance to the potential impacts of the project.

Opportunistic sightings were also recorded while other field work was being completed, including observations made during spotlighting, active searches and images captured by camera trapping (sections 3.3.4 to 3.3.7).

3.3.3 Bat echolocation call recordings

Song Meter 2 recording devices were used to record bat echolocation calls at each systematic trapping site. In total, nine nights of surveying were conducted, recording between 10 and 12 continuous hours per night.

Detectors were aimed at a 45° angle to the ground, and were set to record overnight. Areas of habitat likely to have increased insect activity and to attract bats (i.e. permanent water, creeklines and stands of trees) were targeted.

The recorded data was analysed by Dr. Bob Bullen (Bat Call WA), an expert in the field (Appendix 1).

3.3.4 Spotlighting

Spotlighting was undertaken to detect the presence of any nocturnal vertebrate species. The total time spent spotlighting at each systematic trapping site was a minimum of one person hour over the survey period.

Nocturnal searches were undertaken between sunset and 9:30 pm when activity levels were highest for most nocturnal species. Each nocturnal survey consisted of searches using head torches to detect animal movement, eye shine, or other evidence of species presence and occasionally tape luring to detect nocturnal bird species. These searches also targeted reptiles and amphibians. Opportunistic sightings of species on roads using car-mounted spotlights were also recorded.

3.3.5 Active searches

Active surveys primarily targeted diurnal herpetofauna and mammals from direct sightings and secondary evidence of species occurrence. Active searching was undertaken at each systematic survey site as well as opportunistic sites.

Active surveys comprised searches of any observable microhabitats likely to support mammals, reptiles and amphibians. Techniques included: raking leaf and bark litter, overturning logs and stones, searching beneath the bark of trees, investigating dead trees and logs, investigating overhangs and crevices, investigating burrows, and recording tracks, diggings, scats and other secondary evidence. A minimum of one hour was spent active searching at each systematic trapping site over the survey period.

3.3.6 Opportunistic records

All opportunistic observations of vertebrate species were recorded during the surveys. Opportunistic or non-systematic sampling involved recording all sightings of vertebrate fauna species while working and travelling within the study area, day and night. Opportunistic records included species sighted:

- before or just after the fixed-time of active searches or bird censuses
- during reconnaissance visits to the survey sites
- during trap line establishment
- while travelling to and from the survey sites.

Opportunistic survey site locations were recorded (Appendix 2).

3.3.7 Motion camera trapping

Camera traps increase the chance of collecting evidence of animals that are not likely to be captured or sighted using the regular surveying techniques. They are particularly useful for detecting species that are difficult to trap or detect due to their shy or cryptic nature. Such animals include Northern Quoll, rock wallabies and introduced foxes, cats and dogs.

Three infrared motion-sensor camera traps (Reconyx Hyperfire™ HC600) were deployed at four selected sites in areas that showed signs of animal movement or disturbance, or provided potential habitat for conservation significant species (Figure 3-1; Appendix 2). These included areas with permanent or semi-permanent water such as wells and natural pools (see examples in Figure 3-3).

Cameras were deployed for up to five nights at each site. Each camera was set to take between ten consecutive pictures every time a movement was detected, 24 hours a day. The cameras contained no-glow infrared sensors and flashes to minimise disturbance to nocturnal species. Cameras were set up to record the greatest coverage of each site.

Figure 3-3 Sample images of a camera trap setup at a well (Common Bronzewings at dusk and Emu during the day).

3.3.8 Targeted searching

Targeted searches were undertaken in suitable habitat throughout the study area for evidence of conservation significant species, particularly Northern Quoll, Pilbara Olive Python and Pebble-mound Mouse. For these species, rocky slopes and ridges in the proximity of water bodies were searched.

3.4 TAXONOMY AND NOMENCLATURE

The taxonomy and nomenclature used in this report followed several sources, depending on the fauna group:

- mammals (Menkhorst & Knight 2011)
- birds (Christidis & Boles 2008)
- reptiles (Wilson & Swan 2010)
- amphibians (Tyler & Doughty 2009).

Some taxonomy and nomenclature for species records from previous surveys near the study area has been updated based on the above publications for consistency.

3.5 STATISTICAL ANALYSES

Species accumulation curves were generated from all systematically recorded data from the survey (species captured at the vertebrate trapping sites, and the ornithological and bat records collected at the each trapping site) using PRIMER v5.0 software.

Species accumulation curves provide a tool with which to gauge the adequacy of a sampling program. A curve that reaches an asymptote indicates that the sample design and sample size, but also seasonality, were sufficient to inventory a majority of the expected target faunal assemblage.

The data set was not transformed prior to calculations and was based on abundance data. The data was permutated 999 times as part of the calculation process. The total assemblage recorded at each site over six to seven trapping nights formed the basis of the analysis. The Jacknife1, Jacknife 2 and Bootstrap methods were performed. The analysis was performed for the entire assemblage simultaneously and for each taxonomic group (birds, reptiles and frogs, and mammals). In addition to the species accumulation curve, a hierarchical cluster analysis was conducted on the same dataset.

3.6 Survey personnel and acknowledgements

The Level 2 vertebrate fauna survey was conducted by experienced zoologists (Table 3-2).

Table 3-2 Project team

Name	Qualifications	Position and role/s
Jarrad Clark	B.Sc. (Env. Mgt.)	Project Manager, Senior Zoologist Field survey, report review
Guillaume Bouteloup	B.Sc. (Land Cons. Man.)	Senior Ornithologist and Zoologist Field survey, reporting and GIS
Ryan Ellis	Dip. (CALM)	Zoologist Field survey
Tom Parkin	B.Sc. (Env. Mgt.) (on-going)	Zoologist Field survey
Travis Murray	PhD Agri. (ongoing)	Field assistant Field survey

4 RESULTS

4.1 DESKTOP REVIEW

A total of 280 vertebrate fauna species were identified in the desktop review as potentially occurring in the study area (Appendix 3). This comprised 39 mammals (31 native and eight introduced), 146 birds, 88 reptiles and seven amphibians. As some of the database records are historical, the search results are likely to overestimate the number of vertebrate species that may currently inhabit the study area.

A total of six species listed under the EPBC Act and/or the WC Act (except Schedule 3) were identified as potentially occurring in the study area (Table 4-1). A further eight species listed as Priority (DEC list) and seven species of birds listed as 'Migratory' under the EPBC Act were identified as potentially occurring in the study area (Table 4-1).

A number of these species are considered unlikely to be present within the study area due to a lack of suitable habitat. These include the Lesser Stick-nest Rat (*Leporillus apicalis*; Extinct, EPBC; Schedule 2, WC Act; Extinct) and the Greater Bilby (*Macrotis lagotis*; Vulnerable, EPBC; Schedule 1, WC Act; Vulnerable).

Table 4-1 Conservation significant species identified through database searches as occurring or potentially occurring in the study area

Scientific Name	Common name	EPBC	WC Act	DEC
Apus pacificus	Fork-tailed Swift	M	S3	
Ardea modesta	Eastern Great Egret	M	S3	
Ardea ibis	Cattle Egret	M	S3	
Falco peregrinus	Peregrine Falcon		S4	
Ardeotis australis	Australian Bustard			P4
Burhinus grallarius	Bush Stone-curlew			P4
Charadrius veredus	Oriental Plover	M	S3	
Gallinago megala	Swinhoe's Snipe	M	S3	
Actitis hypoleucos	Common Sandpiper	M	S3	
Merops ornatus	Rainbow Bee-eater	M	S3	
Neochmia ruficauda subclarescens	Star Finch			P4
Notoscincus butleri	No Common Name			P4
Liasis olivaceus barroni	Pilbara Olive Python	VU	S1	VU
Dasyurus hallucatus	Northern Quoll	EN	S1	EN
Sminthopsis longicaudata	Long-tailed Dunnart			P4
Macrotis lagotis	Bilby, Dalgyte	VU	S1	VU
Macroderma gigas	Ghost Bat			P4
Rhinonicteris aurantius	Orange Leafnosed-bat	VU	S1	VU
Leggadina lakedownensis	Short-tailed Mouse			P4
Leporillus apicalis	Lesser Stick-nest Rat	EX	S2	EX
Pseudomys chapmani	Western Pebble-mound Mouse			P4

M – Migratory under the EPBC Act; VU – Vulnerable; EN – Endangered; EX – Extinct; S1, 2, 3, 4 – Schedule of the WC Act; P4 – Priority 4 of the DEC Priority fauna list

4.2 Environmental Parameters

Weather recording from Paraburdoo Aero during the survey period were typical for this time of the year with no rainfall received and high temperatures during the day (Figure 4-1).

The rainfall and temperature data suggest that conditions for vertebrate fauna activity were good but not optimal; however, it should be noted that these conditions are an approximate indication of weather in the region and are not indicative of exact conditions on site. Based on observations from previous surveys in the region, small mammals and reptiles usually require temperatures of nearly 20°C at night to be active, as the soil remains warm for the few hours following the sunset and doesn't cool down too quickly throughout the night.

The area experiences an average annual rainfall amount of 316 mm and a monthly average in October of 272.4 mm. In October 2011 the amount of rainfall for the year 2011 had already reached 380 mm. The condition of the vegetation and the presence of water pools in one particular section of the Hardey River were consistent with these measurements. The year 2011 can therefore be considered as a year receiving above-the-average rainfall.

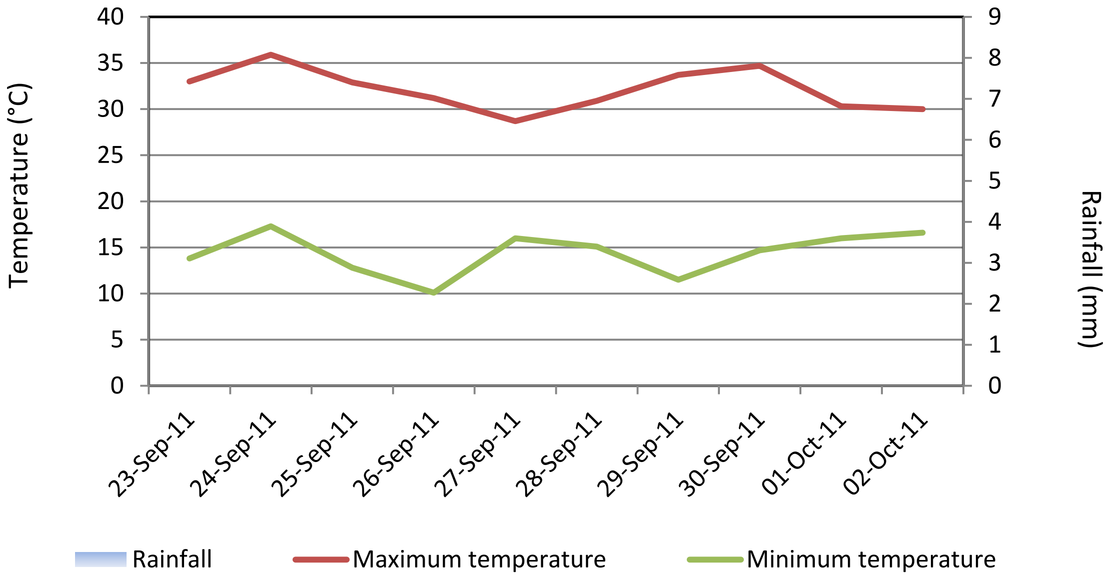


Figure 4-1 Temperature and rainfall variables collected during the field surveys

4.3 Habitat Descriptions

The study area contains the following fauna habitats (ranked by coverage percentage, high to low, indicated in brackets; Figure 4-2):

- Non riparian mulga woodland (40.3%) – mostly found across the southern half of the study area on different types of soils, mostly small gravels and pebbles on hard clay.
- Grass plain (26.3%) – found everywhere except at the northern tip of the study area. The substrate is usually loamy clay, occasionally coarse gravels.
- Riparian woodland (11.7%) – exclusively found along the Hardey River, with some portions up to 500 m wide. Mostly dominated by tall *Eucalyptus* sp. with occasionally dense understorey of acacia shrubs.

- Grassland on rocky slope (10.4%) – found across a transversal section of the southern half and at the northern tip of the study area. None of the slopes are steep and all are of moderate height.
- Minor drainage line (6.8%) – six upstream arms are found along the Hardey River, the largest one is heavily impacted by cattle tramping and grazing.
- River bed (3%) – this habitat only includes open gravel soil with almost no vegetation cover, which is the core bed of the river. At its widest section (within the study area) the river bed is 140 m wide. An assemblage of two small semi-permanent pools (15 m diameter each) was located in the river bed.
- Open woodland on rocky slope (1.5%) – only two patches of this habitat are found in the study area, one at the northern tip and one along the Hardey River. The latest is a massive steep block of rocks overhang dominating a semi-permanent pool.
- Cleared land (0.1%) – a small portion of the study area has been completely cleared recently and no vegetation is apparent. Cattle activity limits vegetation recovery.

Site specific habitat descriptions are given in the Table 4-2 for the systematic trapping sites and in Appendix 4 for the opportunistic survey sites.

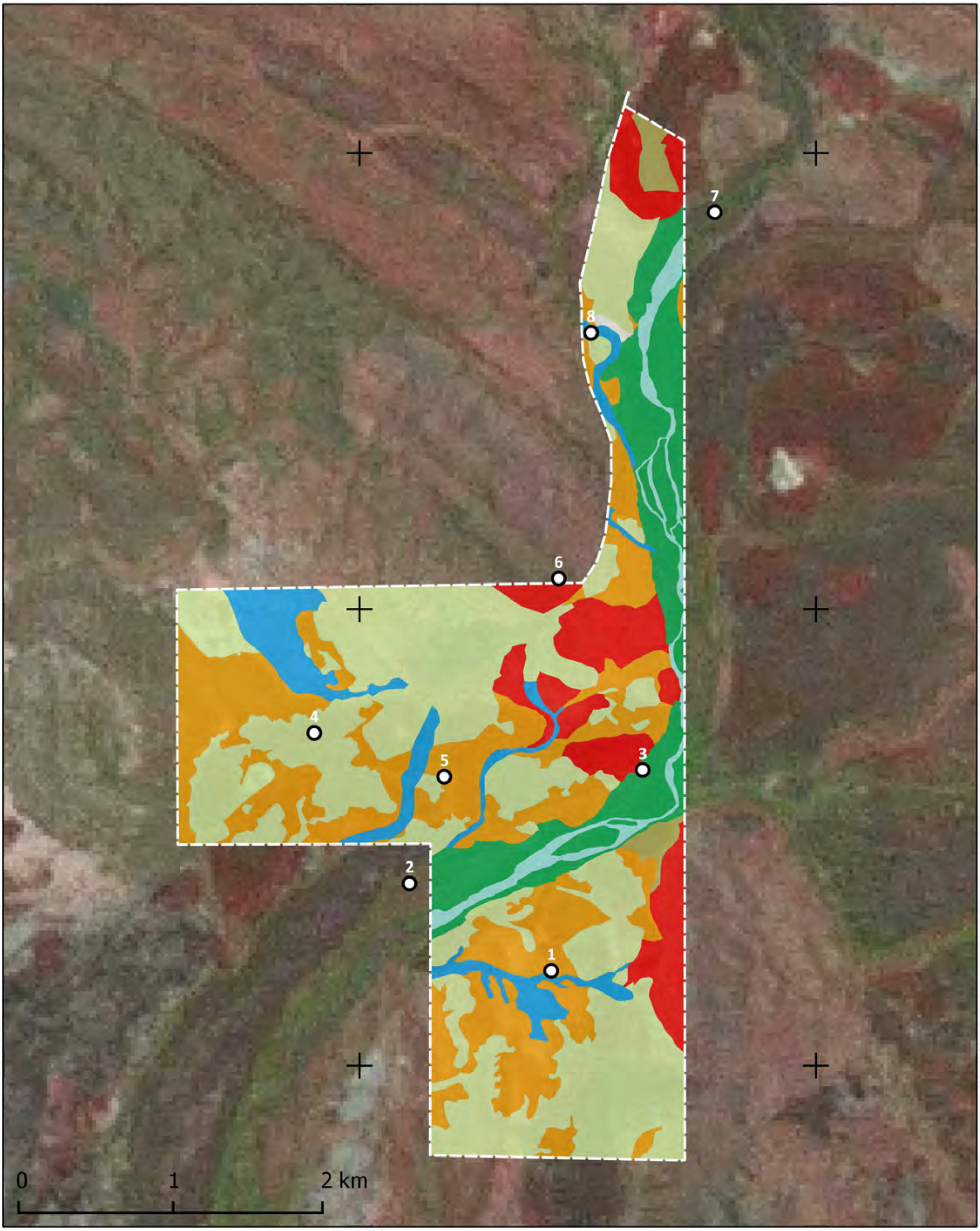


Figure 4-2
Location of the eight systematic trapping sites and the eight broad fauna habitat types in the study area

Cleared habitat
Grass plain
Grassland on rocky slope
Minor drainage line
Non riparian mulga woodland
Riparian woodland
River bed
Woodland on rocky slope
Systematic trapping sites

N

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR: Guillaume	CLIENT: Dragon Energy Ltd.
DATE: November 2011	Scale: 1:28000

PROJECT: Rocklea Iron Ore Project

Coordinate System: Projection: Transverse Mercator; Datum: WGS84

Table 4-2 Habitat descriptions of the systematic trapping sites

Site number	**1**
Site type	Trap Site
Latitude	-22.823765
Longitude	117.4926
Habitat	Plain
Habitat type	Shrubland
Dominant tree	Mulga
Tree cover	0-25
Dominant shrub	Acacia
Shrub cover	0-25
Dominant grass	Spinifex
Grass cover	26-50
Slope	Negligible
Soil texture	Clay Loam
Soil colour	Red/Brown
Surface	Slight cracking; Fine gravel
Rock cover	<5% cover
Leaf litter distribution	0-25%
Litter distribution	Concentrated under vegetation
Dead wood	Sparse
Disturbance details	Grazing - Med
Fire history	None evident
Fire intensity	Low

Description:
Shrub land dominating a spinifex plain with stands of mulga trees over moderately dense patches of acacias shrubs over moderately dense spinifex on red/brown loamy clay with fine gravel.

Site number	2
Site type	Trap Site
Latitude	-22.818016
Longitude	117.483283
Habitat	Flood Plain
Habitat type	Open woodland
Dominant tree	Mulga
Tree cover	26-50
Dominant shrub	Acacia
Shrub cover	26-50
Dominant grass	Buffel grass
Grass cover	26-50
Slope	Negligible
Soil texture	Sand
Soil colour	Brown
Surface	Fine gravel; Coarse Gravel; Stones; Loose soil
Rock cover	5-30% cover
Leaf litter distribution	25-50%
Litter distribution	Concentrated under vegetation
Dead wood	Moderate
Disturbance details	Grazing
Fire history	None evident
Fire intensity	-

Description:
Riparian woodland with scattered *Eucalyptus* sp. over moderately dense mulga trees over heavily grazed Buffel grass on sandy soil.

Site number	3
Site type	Trap Site
Latitude	-22.810546
Longitude	117.498604
Habitat	Flood Plain
Habitat type	Woodland
Dominant tree	Acacia (not Mulga)
Tree cover	51-75
Dominant shrub	Acacia
Shrub cover	0-25
Dominant grass	Buffel grass
Grass cover	51-75
Slope	Negligible
Soil texture	Sand
Soil colour	Brown
Surface	Coarse Gravel; Stones
Rock cover	5-30% cover
Leaf litter distribution	50-75%
Litter distribution	Evenly distributed
Dead wood	-
Disturbance details	Grazing - High
Fire history	None evident
Fire intensity	-

Description:
Woodland floodplain. *Eucalyptus* sp. to 9 m over dense acacias to 5 m over acacia shrubs 0.5-1.5 m over Buffel grass.

Site number	4
Site type	Trap Site
Latitude	-22.808145
Longitude	117.477024
Habitat	Plain
Habitat type	Woodland
Dominant tree	Mulga
Tree cover	26-50
Dominant shrub	Acacia
Shrub cover	26-50
Dominant grass	Spinifex
Grass cover	75-100%
Slope	Negligible
Soil texture	Clay Loam
Soil colour	Red
Surface	Coarse Gravel; Stones
Rock cover	>90% cover
Leaf litter distribution	25-50%
Litter distribution	Concentrated under vegetation
Dead wood	Dense
Disturbance details	None evident
Fire history	None evident
Fire intensity	-

Description:
Open mulga woodland with scattered trees over dense spinifex on brown clay with coarse gravels and stones.

Site number	5
Site type	Trap Site
Latitude	-22.810992
Longitude	117.485565
Habitat	Plain
Habitat type	Spinifex grassland
Dominant tree	*Eucalyptus/Corymbia*
Tree cover	-
Dominant shrub	Acacia
Shrub cover	51-75
Dominant grass	Spinifex
Grass cover	26-50
Slope	Gentle
Soil texture	Sand
Soil colour	Red/Brown
Surface	Fine gravel; Coarse Gravel
Rock cover	50-90% cover
Leaf litter distribution	0-25%
Litter distribution	Concentrated under vegetation
Dead wood	Sparse
Disturbance details	Grazing - Low
Fire history	None evident
Fire intensity	-

Description:
Low rolling hills with spinifex grassland. Very sparse eucalypts to 4 m over low sparse acacia shrubs to 1.5 m over low shrubs and mature spinifex hummocks to 0.6 m.

Site number	**6**
Site type	Trap Site
Latitude	-22.797981
Longitude	117.493095
Habitat	Hilltop
Habitat type	Spinifex grassland
Dominant tree	-
Tree cover	-
Dominant shrub	Acacia
Shrub cover	0-25
Dominant grass	Spinifex
Grass cover	75-100%
Slope	Moderate
Soil texture	Clay Loam
Soil colour	Red
Surface	Fine gravel; Coarse Gravel
Rock cover	>90% cover
Leaf litter distribution	0-25%
Litter distribution	Concentrated under vegetation
Dead wood	Sparse
Disturbance details	None evident
Fire history	None evident
Fire intensity	-

Description:
Rocky hilltop with low sparse shrub land of acacia, low shrubs/tall shrubs to 2.5 m over low mixed sparse shrubs over mulla mulla and mixed herbs to 0.5 m over spinifex hummocks to 0.4 m.

Site number	7
Site type	Trap Site
Latitude	-22.773889
Longitude	117.50335
Habitat	Major Creek
Habitat type	Woodland
Dominant tree	*Eucalyptus/Corymbia*
Tree cover	26-50
Dominant shrub	Acacia
Shrub cover	26-50
Dominant grass	Buffel grass
Grass cover	0-25
Slope	Negligible
Soil texture	Sand
Soil colour	Brown
Surface	Coarse Gravel; Stones
Rock cover	50-90% cover
Leaf litter distribution	25-50%
Litter distribution	Evenly distributed
Dead wood	Dense
Disturbance details	Grazing - Med
Fire history	None evident
Fire intensity	

Description:
Hardey river just above the main channel. Large eucalypts to 7 m over tall acacia to 5 m over mixed medium and low shrubs. Reduced ground cover with plenty of debris and leaf litter, transported stones and coarse gravel, some large tree hollows evident.

Site number	8
Site type	Trap Site
Latitude	-22.781815
Longitude	117.495216
Habitat	Minor Creek/Drainage Line
Habitat type	Woodland
Dominant tree	Acacia (not Mulga)
Tree cover	26-50
Dominant shrub	Acacia
Shrub cover	26-50
Dominant grass	Buffel grass
Grass cover	-
Slope	Negligible
Soil texture	Sand
Soil colour	Brown
Surface	Coarse Gravel; Stones
Rock cover	30-50% cover
Leaf litter distribution	25-50%
Litter distribution	Evenly distributed
Dead wood	Moderate
Disturbance details	Grazing - Med
Fire history	None evident
Fire intensity	-

Description:
Woodland above minor creek line. Acacia and eucalypts to 5 m over, moderately tall acacia shrubs to 3 m, over mixed shrubs to 1.5 m over herbs, grasses and spinifex hummocks.

4.4 Fauna Records

The surveys recorded 117 vertebrate species representing three classes of vertebrate taxa (Table 4-3). The recorded assemblage was strongly dominated by birds.

Two Priority species were recorded (section 5). One species of bird listed as 'Migratory' under the EPBC Act was recorded.

Table 4-3 Vertebrate taxa recorded during the survey and the total number of species potentially occurring in the study area

Taxa	No. of species recorded during this survey	Total no. of species potentially occurring in study area[1]
Mammals	18	39
Birds	68	146
Reptiles	31	88
Amphibians	0	7
Total fauna species	**117**	**280**

1 - data derived from relevant literature, published and unpublished reports, and various databases.

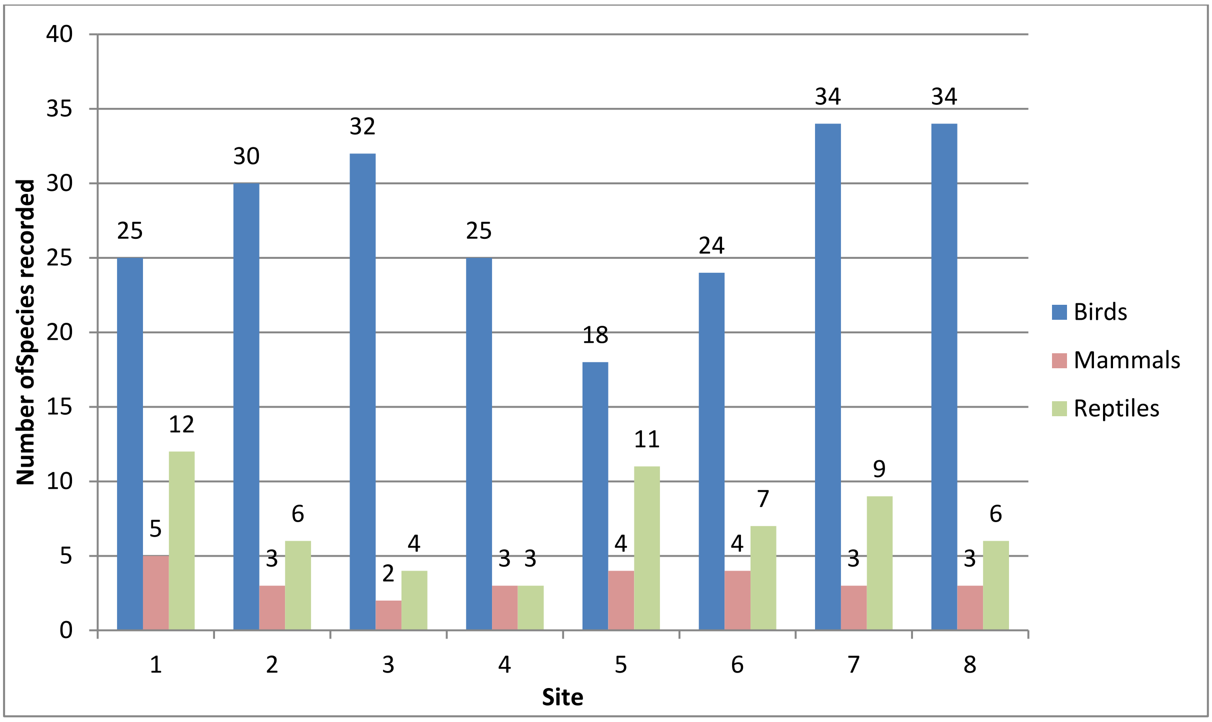


Figure 4-3 The number of species recorded in each class, at each site

4.4.1 Statistical analysis

The species accumulation curves generated from the systematically recorded dataset (bat data and opportunistic species record data excluded) indicated that a proportion of the vertebrate faunal assemblage were not recorded, that is, the curves did not reach an asymptote (Figure 4-4).

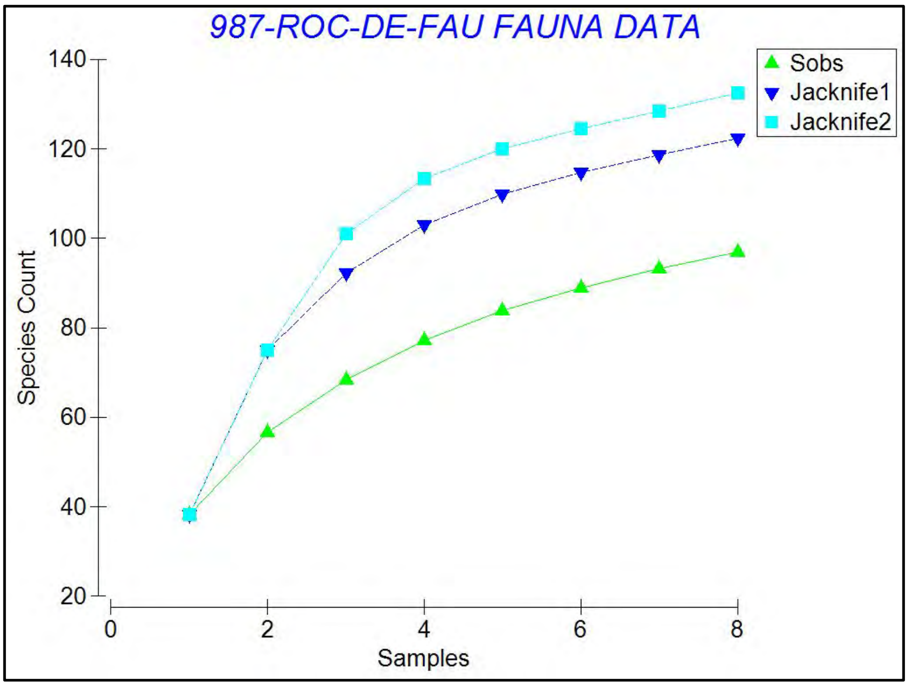


Figure 4-4 Species accumulation curve for species records from the Level 2 fauna survey

This result was further supported when the raw output data from the curves (expected species richness) was compared to the observed species richness (Figure 4-5); however results varied somewhat between methods. The result of the Jacknife 2 method suggested only 73% of the expected assemblage was recorded, while the Bootstrap method indicated that 89% was recorded. There are a number of reasons for this result; these are discussed further in section 4.5.

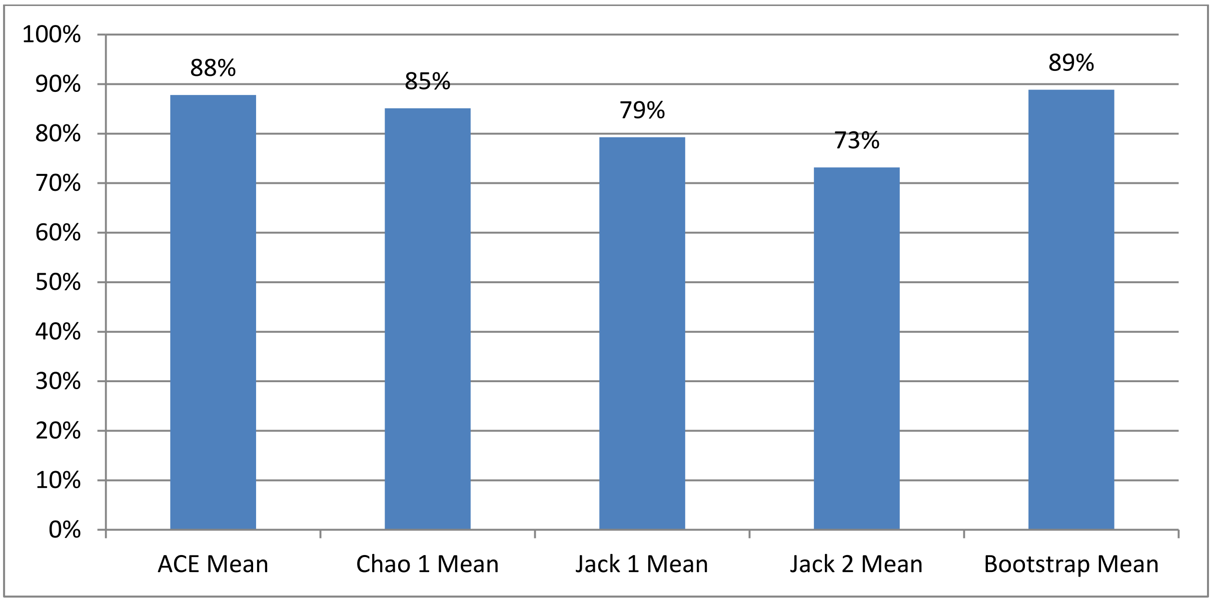


Figure 4-5 The percentage of the observed faunal assemblage compared with that expected based on the species accumulation analyses (Estimate-S)

The hierarchical cluster analysis (Figure 4-6) strongly indicated that the faunal assemblage was largely driven by vegetation structure and substrate. Sites 2, 3, 7 and 8 are all creekline associated habitats (riparian woodland, major and minor drainage lines). The understory of these habitats are typically heavily degraded by cattle in the study area, whereas sites 1, 4, 5 and 6 are much less impacted by cattle and represent habitats dominated by low *Acacia* shrubs or open Mulga woodlands over spinifex grasslands; all are on stony, hard substrates.

These trends were also evident in the class assemblages at each site (Figure 4-3), where sites 2, 3, 7 and 8 recorded the highest number of bird species (respectively), while sites 1, 4, 5 and 6 generally recorded higher numbers of ground dwelling mammal and reptile species and a lower number of bird species.

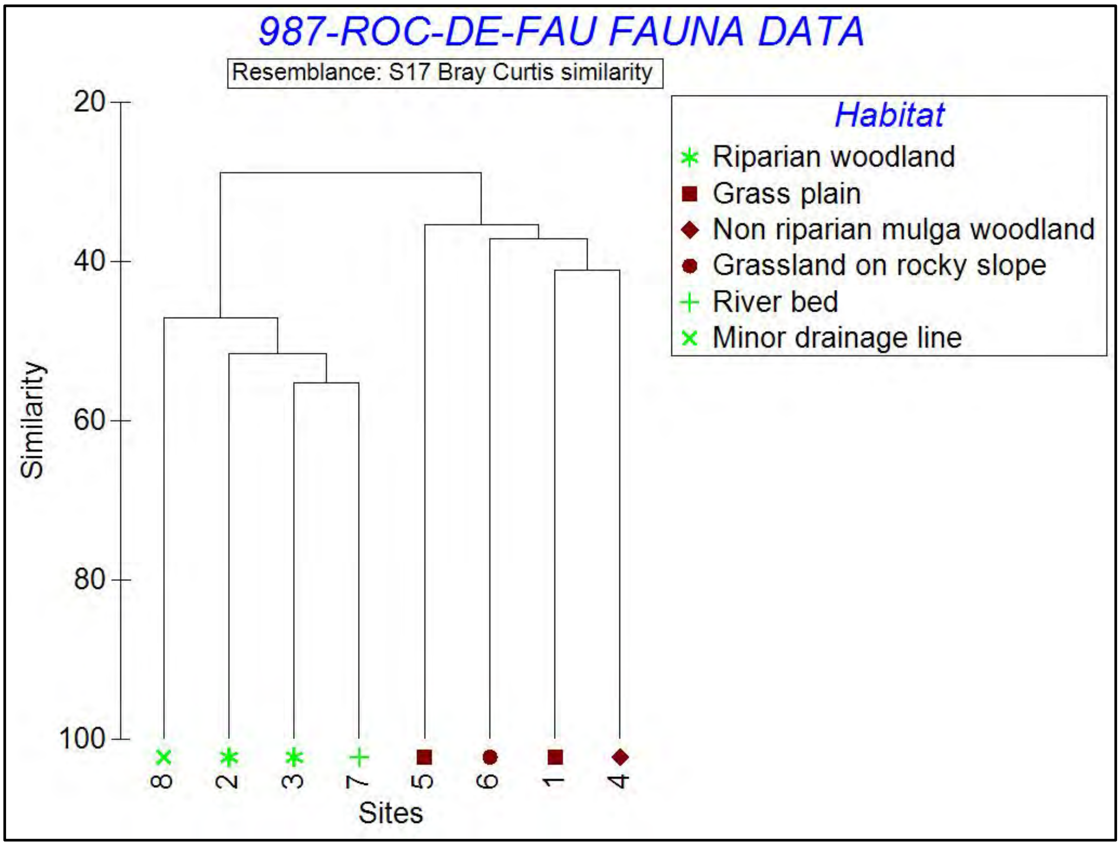


Figure 4-6 Hierarchical Cluster Analysis of the faunal assemblage based on the Habitat Type grouping

4.4.2 Mammals

A total of 18 mammal species were recorded in the study area, including six species of bats and three introduced species (Table 4-4). This represents nearly half of the species that are likely to occur in the study area according to the results of the desktop review.

Dasyurids (carnivorous native marsupials), bats and small rodents dominate the mammal assemblage. The total number of mammal species recorded is consistent with numbers found during previous surveys conducted in the vicinity of the study area (19 to 20 species, n=3) despite the fact that the current survey comprised a single phase, as opposed to two phases in the three other nearby historic surveys (Biota 2009) (Biota 2005) (Biota 2008).

The taxonomy of the planigales from the Pilbara bioregion is currently under revision with at least one species likely to be split (common planigale), thus all the individuals captured were only identified at the genus level.

Three of the recorded species are new to the study area (i.e. not previously recorded within a 40 km radius of the study area, nor returned in the database searches):

- Echidna (*Tachyglossus aculeatus*)
- Lesser Long-eared Bat (*Nyctophilus geoffroyi)*
- Northern Freetail Bat (*Chaerephon jobensis*).

Two of the species recorded are endemic to Pilbara bioregion: the Little Red Kaluta (*Dasykaluta rosamondae*) and the Western Pebble-mound Mouse (*Pseudomys chapmani*; DEC Priority 4). The latest is the only mammal species of conservation significance recorded. No individuals were captured but 15 inactive mounds were located. This species is discussed further in section 5.

There are suitable habitats for the Northern Quoll (*Dasyurus hallucatus*; EPBC Endangered, WC Act Schedule 1) along the Hardey River (within the study area) and south of the study area in a rocky ridge, containing a number of boulder piles on steep slopes. The study area is located within the distribution range of the Northern Quoll. Several records exist to the east and northeast of the study area, the closest of which is approximately 71 km from the study area (Appendix 5).

Due to time constraints limited targeted searching for the species was undertaken. No evidence was found of the species within the riparian zones of the Hardey River in the study area. The rocky hills extend all the way down to a bend in the Hardey River and at this point dense thickets of *Melaleuca* paperbarks are present surrounding a sizeable rocky outcrop, with semi-permanent water present at the time of sampling. A camera trap was set at this location and no photographs of quolls were captured. The camera was only operational for two nights as this site was only discovered on day six of the survey. It is considered likely that Northern Quoll, if present within the rocky range, would use this range as a corridor to access the water pool and forage within the riparian zone of the Hardey River.

Only three introduced mammal species were recorded but all are likely to be having a heavy impact on the native flora and subsequently the ground dwelling fauna. Large scale habitat deterioration was observed across the vast majority of the lower lying portions of the study area due to overgrazing and trampling by cattle. A long period of drought prior to the 2010-2011 wet season has probably also contributed to the poor quality of the vegetation in these areas by encouraging cattle to more heavily utilise these areas.

Overall, the mammal species assemblage is typical of the Pilbara bioregion (particularly the small ground-dwelling mammals). Results are consistent, in terms of overall diversity, with the findings of Gibson and McKenzie (2009) with a core assemblage comprised of common species found across the three main Pilbara substrates (rock, clay, sand); but no truly specialised species were recorded.

The results differ in terms of site specific diversity. The same authors (Gibson & McKenzie 2009) found an average number of 3.4 species of small ground-dwelling mammals per site during the Pilbara Biological Survey. The current survey only recorded an average of 1.3 species of small ground-dwelling mammals per site. Of the eight systematic trapping sites those with no evidence of cattle grazing (four) recorded more small ground dwelling mammal species (mean=2) than the sites with evidence of cattle grazing (mean=0.75). The impact of cattle grazing on the small ground-dwelling mammal community may therefore be significant (see Figure 4-3).

In terms of habitat significance, the upland mulga woodlands and the grasslands on rocky slopes are the only habitats supporting a conservation significant species of mammal. Details on bat species assemblages are provided in Appendix 1.

Table 4-4 Mammal species recorded during the survey

Family; species	Common name	Desktop review	Current survey
Tachyglossidae			
Tachyglossus aculeatus	Echidna		●
Dasyuridae			
Dasykaluta rosamondae	Little Red Kaluta	●	●
Dasyurus hallucatus	Northern Quoll	●	
Ningaui timealeyi	Pilbara Ningaui	●	●
Planigale sp.	Planigale sp.		●
Planigale ingrami	Long-tailed Planigale	●	
Pseudantechinus roryi	Rory's Pseudantechinus	●	
Pseudantechinus woolleyae	Woolley's Pseudantechinus	●	
Sminthopsis longicaudata	Long-tailed Dunnart	●	
Sminthopsis macroura	Stripe-faced Dunnart	●	●
Thylacomyidae			
Macrotis lagotis	Bilby, Dalgyte	●	
Macropodidae			
Macropus robustus erubescens	Euro, Biggada	●	●
Macropus rufus	Red Kangaroo, Marlu	●	●
Petrogale rothschildi	Rothschild's Rock-wallaby	●	
Megadermatidae			
Macroderma gigas	Ghost Bat	●	
Hipposideridae			
Rhinonicteris aurantius	Orange Leafnosed-bat	●	
Emballonuridae			
Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat	●	
Taphozous georgianus	Common Sheathtail-bat	●	●
Vespertilionidae			
Chalinolobus gouldii	Gould's Wattled Bat	●	●
Chalinolobus morio	Chocolate Wattled Bat	●	
Nyctophilus arnhemensis	Arnhem Land Long-eared Bat	●	
Nyctophilus geoffroyi	Lesser Long-eared Bat		●
Scotorepens balstoni	Inland Broad-nosed Bat	●	
Scotorepens greyii	Little Broad-nosed Bat	●	●
Vespadelus finlaysoni	Finlayson's Cave Bat	●	●
Molossidae			
Chaerephon jobensis	Northern Freetail-bat		●
Mormopterus loriae	Little Northern Freetail-bat	●	
Tadarida australis	White-striped Freetail-bat	●	
Muridae			
Leggadina lakedownensis	Short-tailed Mouse	●	
Leporillus apicalis	Lesser Stick-nest Rat	●	
Mus musculus	House Mouse	●	

Family; species	Common name	Desktop review	Current survey
Notomys alexis	Spinifex Hopping-mouse	●	
Pseudomys chapmani	Western Pebble-mound Mouse	●	●
Pseudomys desertor	Desert Mouse	●	
Pseudomys hermannsburgensis	Sandy Inland Mouse	●	●
Zyzomys argurus	Common Rock-rat	●	
Leporidae			
Oryctolagus cuniculus	Rabbit	●	
Canidae			
Canis lupus dingo	Dingo	●	●
Vulpes vulpes	Red Fox	●	
Felidae			
Felis catus	Cat	●	●
Mustelidae			
Equus asinus	Donkey	●	
Equus caballus	Horse	●	
Bovidae			
Bos taurus	European Cattle	●	●

4.4.3 Avifauna

A total of 68 bird species were recorded in the study area (Table 4-5). This represents nearly half of the 146 species that could potentially occur in the study area according to the results of the desktop review. In addition, this equals the average number of bird species recorded across three different surveys conducted near the study area despite the fact that these surveys were comprised of two phases each, as opposed to a single phase undertaken in this survey. None of the species recorded during the current survey are new to the region. The large majority of the species (60) have been recorded during the systematic bird surveys and only eight were exclusively recorded during opportunistic surveys.

The major difference between the data derived from the desktop reviews and the current survey is the absence of waterbirds in this survey. The database search considered a 40 km radius centred on the study area. This encompassed several permanent, artificial water bodies of reasonable size (ponds, pools, dam) that support a variety of migratory and resident waterbirds (ducks, shorebirds, ardeidae, cormorants). The study area does not encompass any permanent water with the exception of three degraded stock wells. Two small semi-permanent pools were found in the bed of the Hardey River on the eastern side of the study area.

Some of the species recorded during the current survey were only sighted on some rare occasions during the Pilbara Biological Survey. The Black-tailed Treecreeper (*Climacteris melanura)* was only recorded at six of the 297 Pilbara Biological Survey sites but was recorded at several locations in the riparian woodlands of the Hardey River during the current survey. This is also the case for the Brown Goshawk (*Accipiter fasciatus*, 7/297) and the Collared Sparrowhawk (*Accipiter cirrocephalus*, 5/297) in the same riparian woodlands.

The Bush Stone-curlew (*Burhinus grallarius*; DEC Priority 4) and the Rainbow Bee-eater (*Merops ornatus*; EPBC migratory) are the only species of conservation significance recorded during the current survey. The Bush Stone-curlew was seen on two occasions in the bed of the Hardey River and in mulga woodland. The Rainbow Bee-eater was sighted on nine occasions in riparian woodland and in a minor drainage line.

Despite targeted searches no Australian Bustard (*Ardeotis australis*; DEC Priority 4) was sighted in the study area and no secondary evidence (tracks) could be found. This species is commonly recorded throughout the Pilbara bioregion. The species has a large territory and its presence in the study area is very likely given the habitats present.

Most migratory species (shorebirds and ardeidae) are unlikely to occur in the study area due to the absence of permanent water. There is potential for the Peregrine Falcon (*Falco peregrinus*; WC Act Schedule 4) to occur, with good foraging (Hardey River) and nesting habitats (large rocky ranges within 20km of the study area) present. The species is rare in general but the Hamersley range is presumably its stronghold in the Pilbara (Storr 1984).

Given the habitats and the presence of semi-permanent water in the Hardey River, the Star Finch (*Neochmia ruficauda subclarescens*, DEC Priority 4) could potentially occur, but the impact of cattle grazing on the understorey vegetation is considered far too significant. This species feeds on the seeds and grasses found in the proximity of water and overgrazing is listed as one of the main cause of its historic decline in Western Australia (Garnett & Crowley 2000) where the population is now thought to be stable (Garnett *et al.* 2011).

Overall the bird assemblage of the study area is typical of the Pilbara bioregion with results consistent with that of the Pilbara Biological Survey (Burbidge *et al.* 2010) and identical habitat-characteristic species representing the major habitats. The average number of species per site for the current survey (27.75) was much higher than that of the Pilbara Biological Survey (19.01). Of the 10 most common species recorded during the Pilbara Biological Survey four were also the commonest recorded species of the current survey (Zebra Finch, *Taeniopygia guttata*; Willie Wagtail, *Rhipidura leucophrys*; Diamond Dove, *Geopelia cuneata*; and Black-faced Cuckoo-shrike, *Coracina novaehollandiae*).

The indirect impact of heavy grazing on bird habitat did not seem to significantly affect bird richness overall. Birds seemed to be more sensitive to the presence / absence of trees rather than to the presence / absence of grazing. Habitats with trees recorded far more bird species on average than open habitats with no trees (mean = 30 vs. 22.75) (see Figure 4-3).

Overall, the riparian habitats of the Hardey River and the mulga woodlands in general, support the highest bird diversity of the study area, as well as the two conservation significant bird species recorded.

Table 4-5 Bird species recorded during the survey

Family; species	Common name	Desktop review	Current survey
Casuariidae			
Dromaius novaehollandiae	Emu	●	●
Phasianidae			
Coturnix pectoralis	Stubble Quail	●	
Coturnix ypsilophora	Brown Quail	●	
Anatidae			
Dendrocygna eytoni	Plumed Whistling-Duck	●	
Cygnus atratus	Black Swan	●	
Chenonetta jubata	Australian Wood Duck	●	
Malacorhynchus membranaceus	Pink-eared Duck	●	

Family; species	Common name	Desktop review	Current survey
Anas gracilis	Grey Teal	●	
Anas superciliosa	Pacific Black Duck	●	
Aythya australis	Hardhead	●	
Podicipedidae			
Tachybaptus novaehollandiae	Australasian Grebe	●	
Poliocephalus poliocephalus	Hoary-headed Grebe	●	
Columbidae			
Columba livia	Rock Dove	●	
Phaps chalcoptera	Common Bronzewing	●	●
Ocyphaps lophotes	Crested Pigeon	●	●
Geophaps plumifera	Spinifex Pigeon	●	●
Geopelia cuneata	Diamond Dove	●	●
Geopelia striata	Peaceful Dove	●	●
Podargidae			
Podargus strigoides	Tawny Frogmouth	●	
Eurostopodidae			
Eurostopodus argus	Spotted Nightjar	●	●
Aegothelidae			
Aegotheles cristatus	Australian Owlet-nightjar	●	
Apodidae			
Apus pacificus	Fork-tailed Swift	●	
Anhingidae			
Anhinga novaehollandiae	Australasian Darter	●	
Phalacrocoracidae			
Microcarbo melanoleucos	Little Pied Cormorant	●	
Phalacrocorax sulcirostris	Little Black Cormorant	●	
Pelecanidae			
Pelecanus conspicillatus	Australian Pelican	●	
Ardeidae			
Ardea pacifica	White-necked Heron	●	●
Ardea modesta	Eastern Great Egret	●	
Ardea intermedia	Intermediate Egret	●	
Ardea ibis	Cattle Egret	●	
Egretta novaehollandiae	White-faced Heron	●	
Egretta garzetta	Little Egret	●	
Nycticorax caledonicus	Nankeen Night-Heron	●	
Threskiornithidae			
Threskiornis spinicollis	Straw-necked Ibis	●	
Accipitridae			
Elanus axillaris	Black-shouldered Kite	●	
Lophoictinia isura	Square-tailed Kite	●	
Haliastur sphenurus	Whistling Kite	●	●
Milvus migrans	Black Kite	●	

Family; species	Common name	Desktop review	Current survey
Accipiter fasciatus	Brown Goshawk	●	●
Accipiter cirrocephalus	Collared Sparrowhawk	●	●
Circus assimilis	Spotted Harrier	●	
Aquila audax	Wedge-tailed Eagle	●	●
Hieraaetus morphnoides	Little Eagle	●	
Falconidae			
Falco cenchroides	Nankeen Kestrel	●	
Falco berigora	Brown Falcon	●	●
Falco longipennis	Australian Hobby	●	●
Falco peregrinus	Peregrine Falcon	●	
Rallidae			
Gallirallus philippensis	Buff-banded Rail	●	
Porzana pusilla	Baillon's Crake	●	
Porzana fluminea	Australian Spotted Crake	●	
Porzana tabuensis	Spotless Crake	●	
Tribonyx ventralis	Black-tailed Native-hen	●	
Fulica atra	Eurasian Coot	●	
Otididae			
Ardeotis australis	Australian Bustard	●	
Burhinidae			
Burhinus grallarius	Bush Stone-curlew	●	●
Recurvirostridae			
Himantopus himantopus	Black-winged Stilt	●	
Charadriidae			
Charadrius ruficapillus	Red-capped Plover	●	
Charadrius veredus	Oriental Plover	●	
Elseyornis melanops	Black-fronted Dotterel	●	●
Erythrogonys cinctus	Red-kneed Dotterel	●	
Scolopacidae			
Gallinago megala	Swinhoe's Snipe	●	
Actitis hypoleucos	Common Sandpiper	●	
Turnicidae			
Turnix velox	Little Button-quail	●	●
Laridae			
Chlidonias hybrida	Whiskered Tern	●	
Cacatuidae			
Eolophus roseicapillus	Galah	●	●
Cacatua sanguinea	Little Corella	●	●
Nymphicus hollandicus	Cockatiel	●	●
Psittacidae			
Barnardius zonarius	Australian Ringneck	●	●
Melopsittacus undulatus	Budgerigar	●	●
Neopsephotus bourkii	Bourke's Parrot	●	

Family; species	Common name	Desktop review	Current survey
Cuculidae			
Chalcites basalis	Horsfield's Bronze-Cuckoo	●	●
Chalcites osculans	Black-eared Cuckoo	●	
Cacomantis pallidus	Pallid Cuckoo	●	
Strigidae			
Ninox novaeseelandiae	Southern Boobook	●	●
Tytonidae			
Tyto javanica	Eastern Barn Owl	●	
Halcyonidae			
Dacelo leachii	Blue-winged Kookaburra	●	●
Todiramphus pyrrhopygius	Red-backed Kingfisher	●	●
Todiramphus sanctus	Sacred Kingfisher	●	●
Meropidae			
Merops ornatus	Rainbow Bee-eater	●	●
Climacteridae			
Climacteris melanura	Black-tailed Treecreeper	●	●
Ptilonorhynchidae			
Ptilonorhynchus guttatus	Western Bowerbird	●	●
Maluridae			
Malurus leucopterus	White-winged Fairy-wren	●	●
Malurus lamberti	Variegated Fairy-wren	●	●
Stipiturus ruficeps	Rufous-crowned Emu-wren	●	●
Amytornis striatus whitei	Striated Grasswren (Pilbara)	●	●
Acanthizidae			
Pyrrholaemus brunneus	Redthroat	●	●
Smicrornis brevirostris	Weebill	●	●
Gerygone fusca	Western Gerygone	●	●
Acanthiza robustirostris	Slaty-backed Thornbill	●	
Acanthiza chrysorrhoa	Yellow-rumped Thornbill	●	
Acanthiza uropygialis	Chestnut-rumped Thornbill	●	●
Acanthiza apicalis	Inland Thornbill	●	
Aphelocephala leucopsis	Southern Whiteface	●	
Pardalotidae			
Pardalotus rubricatus	Red-browed Pardalote	●	●
Pardalotus striatus	Striated Pardalote	●	●
Meliphagidae			
Certhionyx variegatus	Pied Honeyeater	●	
Lichenostomus virescens	Singing Honeyeater	●	●
Lichenostomus keartlandi	Grey-headed Honeyeater	●	●
Lichenostomus plumulus	Grey-fronted Honeyeater	●	
Lichenostomus penicillatus	White-plumed Honeyeater	●	●
Purnella albifrons	White-fronted Honeyeater	●	
Manorina flavigula	Yellow-throated Miner	●	●

Family; species	Common name	Desktop review	Current survey
Acanthagenys rufogularis	Spiny-cheeked Honeyeater	●	●
Conopophila whitei	Grey Honeyeater	●	
Epthianura tricolor	Crimson Chat	●	
Sugomel niger	Black Honeyeater	●	
Lichmera indistincta	Brown Honeyeater	●	●
Melithreptus gularis	Black-chinned Honeyeater	●	
Pomatostomatidae			
Pomatostomus temporalis	Grey-crowned Babbler	●	●
Pomatostomus superciliosus	White-browed Babbler	●	
Eupetidae			
Cinclosoma castaneothorax	Chestnut-breasted Quail-thrush	●	
Psophodes occidentalis	Chiming Wedgebill	●	
Neosittidae			
Daphoenositta chrysoptera	Varied Sittella	●	
Campephagidae			
Coracina maxima	Ground Cuckoo-shrike	●	
Coracina novaehollandiae	Black-faced Cuckoo-shrike	●	●
Lalage sueurii	White-winged Triller	●	●
Pachycephalidae			
Pachycephala pectoralis	Golden Whistler	●	
Pachycephala rufiventris	Rufous Whistler	●	●
Colluricincla harmonica	Grey Shrike-thrush	●	●
Oreoica gutturalis pallescens	Crested Bellbird	●	●
Artamidae			
Artamus personatus	Masked Woodswallow	●	
Artamus cinereus	Black-faced Woodswallow	●	●
Artamus minor	Little Woodswallow	●	●
Cracticus torquatus	Grey Butcherbird	●	
Cracticus nigrogularis	Pied Butcherbird	●	●
Cracticus tibicen	Australian Magpie	●	●
Rhipiduridae			
Rhipidura albiscapa	Grey Fantail	●	
Rhipidura leucophrys	Willie Wagtail	●	●
Corvidae			
Corvus bennetti	Little Crow	●	
Corvus orru	Torresian Crow	●	●
Monarchidae			
Grallina cyanoleuca	Magpie-lark	●	●
Petroicidae			
Petroica goodenovii	Red-capped Robin	●	●
Melanodryas cucullata	Hooded Robin	●	●
Alaudidae			
Mirafra javanica	Horsfield's Bushlark	●	

Family; species	Common name	Desktop review	Current survey
Acrocephalidae			
Acrocephalus australis	Australian Reed-Warbler	●	
Megaluridae			
Cincloramphus mathewsi	Rufous Songlark	●	●
Cincloramphus cruralis	Brown Songlark	●	
Eremiornis carteri	Spinifexbird	●	●
Hirundinidae			
Hirundo neoxena	Welcome Swallow	●	
Petrochelidon ariel	Fairy Martin	●	
Petrochelidon nigricans	Tree Martin	●	●
Nectariniidae			
Dicaeum hirundinaceum	Mistletoebird	●	●
Estrildidae			
Taeniopygia guttata	Zebra Finch	●	●
Neochmia ruficauda subclarescens	Star Finch	●	
Emblema pictum	Painted Finch	●	●
Motacillidae			
Anthus novaeseelandiae	Australasian Pipit	●	●

4.4.4 Reptiles

A total of 31 reptile species were recorded in the study area (Table 4-6) which represents a third of the species that could potentially occur according to the findings of the desktop review (88 species).

Previous surveys conducted near the study area recorded an average of 51 species per survey, all across bi-seasonal trapping as opposed to the current results obtained through a single season survey. The temperatures at night (all below 20°C) recorded during the current survey were sub-optimal for reptiles.

The impact of cattle grazing may be partially responsible for the small numbers of reptiles recorded. In the absence of a consistent vegetation understorey it may be more difficult for reptiles (most species are ground dwellers) to shelter during the day and find abundant resources at night. The four systematic trapping sites with no evidence of cattle grazing recorded an average of 8.25 species of reptiles, whereas the systematic trapping sites with evidence of cattle grazing recorded an average 6.25 species.

In addition, if the reptile group is excluded from the results, the current survey recorded a total 86 species of vertebrate. This compares with other surveys that recorded an average total of 90 species of vertebrates if reptiles are excluded, across bi-seasonal surveys as opposed to a single season for the current survey. With the reptile group included the current survey recorded a total of 117 vertebrates as opposed to an average number of 141 species for the three other surveys.

The Broad-banded Sand Swimmer (*Eremiascincus richardsonii*) is the only reptile that was not recorded previously in the vicinity of the study area according to the results of the desktop review.

No conservation significant species were recorded. A targeted search for Pilbara Olive Python (*Liasis olivaceus barroni*; EPBC Vulnerable, WC Act Schedule 1) was conducted in a small area adjacent to the Hardey River in a rocky outcrop, above a semi-permanent water pool. No evidence of the species was found. However; the presence of semi-permanent water and a rock range forming a corridor to the Hardey River, it is considered likely that this species may occur in the low lying, eastern portion of the study area. The Pilbara Olive Python has been recorded from a number of location close to the study area (see Appendix 5).

No *Notoscincus butleri* (DEC Priority 4) was captured. This was expected and would have been a range extension southward for this species.

The open grasslands dominated by *Triodia sp.* on rocky substrate supported the highest species richness for reptiles. This is probably due to the near absence of cattle grazing observed in this type of habitat.

Table 4-6 Reptile species recorded during the survey

Family; species	Common name	Desktop review	Current survey
Cheloniidae			
Chelodina steindachneri	Flat-shelled Turtle	●	
Agamidae			
Amphibolurus longirostris	No Common Name	●	●
Caimanops amphiboluroides	No Common Name	●	
Ctenophorus caudicinctus	Ring-tailed Dragon	●	●
Ctenophorus isolepis	Crested Dragon	●	
Ctenophorus nuchalis	Central Netted Dragon	●	
Ctenophorus reticulatus	Western Netted Dragon	●	
Diporiphora valens	No Common Name	●	●
Pogona minor	No Common Name	●	●
Tympanocryptis cephalus	Pebble Dragon	●	
Crenadactylus ocellatus horni	No Common Name	●	
Diplodactylus conspicillatus	Fat-tailed Gecko	●	●
Diplodactylus savagei	No Common Name	●	
Lucasium stenodactylum	No Common Name	●	●
Lucasium wombeyi	No Common Name	●	
Oedura marmorata	Marbled Velvet Gecko	●	●
Rhynchoedura ornata	Beaked Gecko	●	●
Strophurus elderi	No Common Name	●	
Strophurus wellingtonae	No Common Name	●	
Carphodactylidae			
Nephrurus wheeleri cinctus	No Common Name	●	●
Gekkonidae			
Gehyra punctata	No Common Name	●	●
Gehyra variegata	No Common Name	●	●
Heteronotia binoei	Bynoe's Gecko	●	●
Heteronotia spelea	Desert Cave Gecko	●	
Pygopodidae			
Delma elegans	No Common Name	●	
Delma haroldi	No Common Name	●	

Family; species	Common name	Desktop review	Current survey
Delma nasuta	No Common Name	●	
Delma pax	No Common Name	●	
Delma tincta	No Common Name	●	
Lialis burtonis	No Common Name	●	●
Pygopus nigriceps	No Common Name	●	●
Scincidae			
Carlia munda	No Common Name	●	●
Cryptoblepharus buchananii	No Common Name	●	●
Cryptoblepharus carnabyi	No Common Name	●	
Cryptoblepharus plagiocephalus	No Common Name	●	
Cryptoblepharus ustulatus	No Common Name	●	
Ctenotus duricola	No Common Name	●	
Ctenotus grandis	No Common Name	●	
Ctenotus hanloni	No Common Name	●	
Ctenotus helenae	No Common Name	●	●
Ctenotus pantherinus	Leopard Ctenotus	●	●
Ctenotus rubicundus	No Common Name	●	●
Ctenotus rutilans	No Common Name	●	●
Ctenotus saxatilis	Rock Ctenotus	●	●
Ctenotus schomburgkii	No Common Name	●	●
Ctenotus uber	No Common Name	●	
Cyclodomorphus melanops	Slender Blue-tongue	●	
Egernia formosa	No Common Name	●	
Eremiascincus richardsonii	Broad-banded Sand Swimmer		●
Lerista flammicauda	No Common Name	●	
Lerista jacksoni	No Common Name	●	
Lerista muelleri	No Common Name	●	
Lerista verhmens	No Common Name	●	●
Lerista zietzi	No Common Name	●	
Menetia greyii	No Common Name	●	
Menetia surda	No Common Name	●	
Morethia ruficauda exquisita	No Common Name	●	
Notoscincus butleri	No Common Name	●	
Notoscincus ornatus ornatus	No Common Name	●	
Proablepharus reginae	No Common Name	●	
Tiliqua multifasciata	Central Blue-tongue	●	
Varanidae			
Varanus acanthurus	Spiny-tailed Monitor	●	
Varanus brevicauda	Short-tailed Pygmy Monitor	●	●
Varanus bushi	Pilbara Mulga Monitor	●	
Varanus caudolineatus	No Common Name	●	
Varanus eremius	Pygmy Desert Monitor	●	

Family; species	Common name	Desktop review	Current survey
Varanus giganteus	Perentie	●	
Varanus panoptes	Yellow-spotted Monitor	●	●
Varanus pilbarensis	Pilbara Rock Monitor	●	
Varanus tristis tristis	Racehorse Monitor	●	●
Typhlopidae			
Ramphotyphlops ammodytes	No Common Name	●	●
Ramphotyphlops grypus	No Common Name	●	
Ramphotyphlops hamatus	No Common Name	●	
Ramphotyphlops pilbarensis	No Common Name	●	
Boidae			
Antaresia perthensis	Pygmy Python	●	
Aspidites melanocephalus	Black-headed Python	●	
Liasis olivaceus barroni	Pilbara Olive Python	●	
Elapidae			
Acanthophis pyrrhus	Desert Death Adder	●	
Acanthophis wellsi	Pilbara Death Adder	●	
Brachyurophis approximans	No Common Name	●	
Demansia psammophis	Yellow-faced Whipsnake	●	
Demansia rufescens	Rufous Whipsnake	●	●
Furina ornata	Moon Snake	●	
Parasuta monachus	No Common Name	●	
Pseudechis australis	Mulga Snake	●	●
Pseudonaja modesta	Ringed Brown Snake	●	●
Pseudonaja nuchalis	Gwardar; Northern Brown Snake	●	
Suta fasciata	Rosen's Snake	●	
Vermicella snelli	No Common Name	●	

4.4.5 Amphibians

No amphibians were recorded in the study area during the survey (Table 4-7). The desktop review indicated that seven species could potentially occur in the study area, none of which are conservation significant. The three previous surveys conducted in the proximity of the study area recorded on average two species per survey.

Despite the presence of two small ponds in the Hardey River, no amphibians could be found. The seasonality (the end of the dry season) and the absence of a second phase limited the likelihood of recording amphibians.

Table 4-7 Amphibian species recorded in previous surveys in the vicinity of the study area

Family; species	Common name	Other surveys in vicinity of study area	Current survey
Hylidae			No species recorded
Cyclorana australis	Giant Frog	●	
Cyclorana maini	Sheep Frog	●	
Cyclorana platycephala	Water-holding Frog	●	
Litoria rubella	Little Red Tree Frog	●	
Limnodynastidae			
Notaden nichollsi	Desert Spadefoot	●	
Platyplectrum spenceri	Centralian Burrowing Frog	●	
Myobatrachidae			
Pseudophryne douglasi	Gorge Toadlet	●	

4.5 LIMITATIONS

Guidance Statement 56 (EPA 2004) identified potential limitations that may be encountered in terrestrial fauna surveys. With respect to this guidance, the following limitations were encountered in this survey:

- all the vertebrates recorded were identified to species level with the exception of the *Planigales* sp. as their taxonomy is currently under revision
- temperatures at night were sub-optimal for reptile activity
- site 3 was sampled for 6 nights instead of 7, as for all the other sites, due to freight delays
- the impact of cattle grazing has significantly affected the overall habitat quality of the low lying portions of the study area, with the data suggesting that reptiles were more affected than the other groups of vertebrates (see section 4.4.4 for more details)
- two Pilbara Biological Survey systematic trapping sites were sampled of which only five pitfall traps each were located (instead of 10 traps as is Phoenix's standard sample size). The layout of the trapping grid was also slightly different with all the pits linked together with a single fence and funnel traps placed every 5 m along the fence on either side of it.

5 CONSERVATION SIGNIFICANT SPECIES RECORDED

This section provides an overview of the conservation significant species that were recorded in the surveys.

Two species listed as Priority 4 (DEC) and one species listed as Migratory (EPBC Act) were recorded in the surveys. The locations of all the conservation significant species records are given in Figure 5-1. A further 18 conservation significant species may occur, details on these species are provided in the section 6.2

5.1 BUSH STONE-CURLEW (*BURHINUS GRALLARIUS*)

Status: Priority 4 (DEC Priority Fauna List)

Distribution and ecology: The Bush Stone-curlew is a relatively large bird that prefers lightly wooded country near daytime shelter such as thickets or long grass. It can be found across much of Australia except the arid interior and southern coast. In Western Australia, the species is considered to be uncommon to common in the northern subhumid and semi-arid zones, and rare to uncommon and locally extinct further south (Johnstone & Storr 1998).The species is considered sedentary (stable home range and non-migratory) (Garnett & Crowley 2000).

The Bush Stone-curlew is a ground-dwelling species and therefore susceptible to predation and local disturbance by humans. Garnett *et al.* (2011) indicate that the populations found across northern Australia are now stable.

Records and likely distribution in the study area: One individual was sighted at site 7, in the Hardey River bed. The bird was foraging and moved in the adjacent riparian woodlands after being flushed. A pair was flushed near site 8, in acacia woodland located near the Hardey River and a minor drainage line. The presence of the Hardey River and its associated riparian woodlands is a key component of the study area for the Bush Stone-curlew.

5.2 WESTERN PEBBLE-MOUND MOUSE (*PSEUDOMYS CHAPMANI*)

Status: Priority 4 (DEC Priority Fauna List)

Distribution and ecology: The Western Pebble-mound Mouse is widespread in the ranges of the central and southern Pilbara and extends into the Little Sandy Desert Ranges (Van Dyck & Strahan 2008). Originally classified as a Priority 1 species, recent survey records have found the species is widespread and its conservation status has since been downgraded to Priority 4.

These mice construct large mounds from small pebbles. Colonies of up to 25 mice may live inside a mound. Pebble size averages 3.5 grams and the mounds may cover 0.5–9.0 m^2. The mounds are located on the gentle slopes of rocky ranges covered in rocky mulch, hard spinifex and sparse trees and shrubs (*Eucalyptus*, *Senna*, *Acacia* and *Ptilotus*). They are also often found near Acacia-dominated drainage lines (Van Dyck & Strahan 2008).

Threats to the Western Pebble-mound Mouse are not well known but predation by Feral Cat (*Felis catus*) and Red Fox (*Vulpes vulpes*) may be responsible for the species' range contraction and mining activities may locally be responsible of small-scale population reduction (Morris & Burbidge 2008).

Records and likely distribution in the study area: The nearest records are located nearly 25 km east of the study area (GBIF 2011). Overall, 15 inactive mounds were located during the current survey; no active mound was found. Mounds were found in non-riparian mulga woodlands (n=2) and in grasslands on rocky slopes (n=13) within the study area. Two mounds were located outside the study area. At most recorded mound sites revegetation was fairly advanced, suggesting the mounds were old. The stretch of medium-sized rocky slopes that runs across the central part of the study area may have supported a reasonable population of Western Pebble-mound Mice given the number of mounds present. This set of hills is at the south-eastern tip of a larger range that extends westward (beyond the study area) and that range may support an active population.

5.3 RAINBOW BEE-EATER (*MEROPS ORNATUS*)

Status: Migratory (EPBC)

Distribution and ecology: The Rainbow Bee-eater is a migratory bird that moves between Australia and Asia. It can be found across Australia, with complex seasonal movements depending on location and rainfall, preferring the more watered areas of the country. In Western Australia, the Rainbow Bee-eater can be found in lightly wooded, preferably sandy country near water, occurring as a resident, breeding visitor, postnuptial nomad, passage migrant or winter visitor, and being highly mobile, they can be scarce to common locally (Johnstone & Storr 1998).

Records and likely distribution in the study area: Rainbow Bee-eaters were recorded on nine occasions. Two records are located outside the study area. All records are within riparian habitats (riparian woodlands and minor drainage line). All the sightings were of birds foraging and no sign of breeding was recorded. The Rainbow Bee-eater breeds in burrows dug in sandy substrate. Some portions of the Hardey River present potential nesting sites for the species.

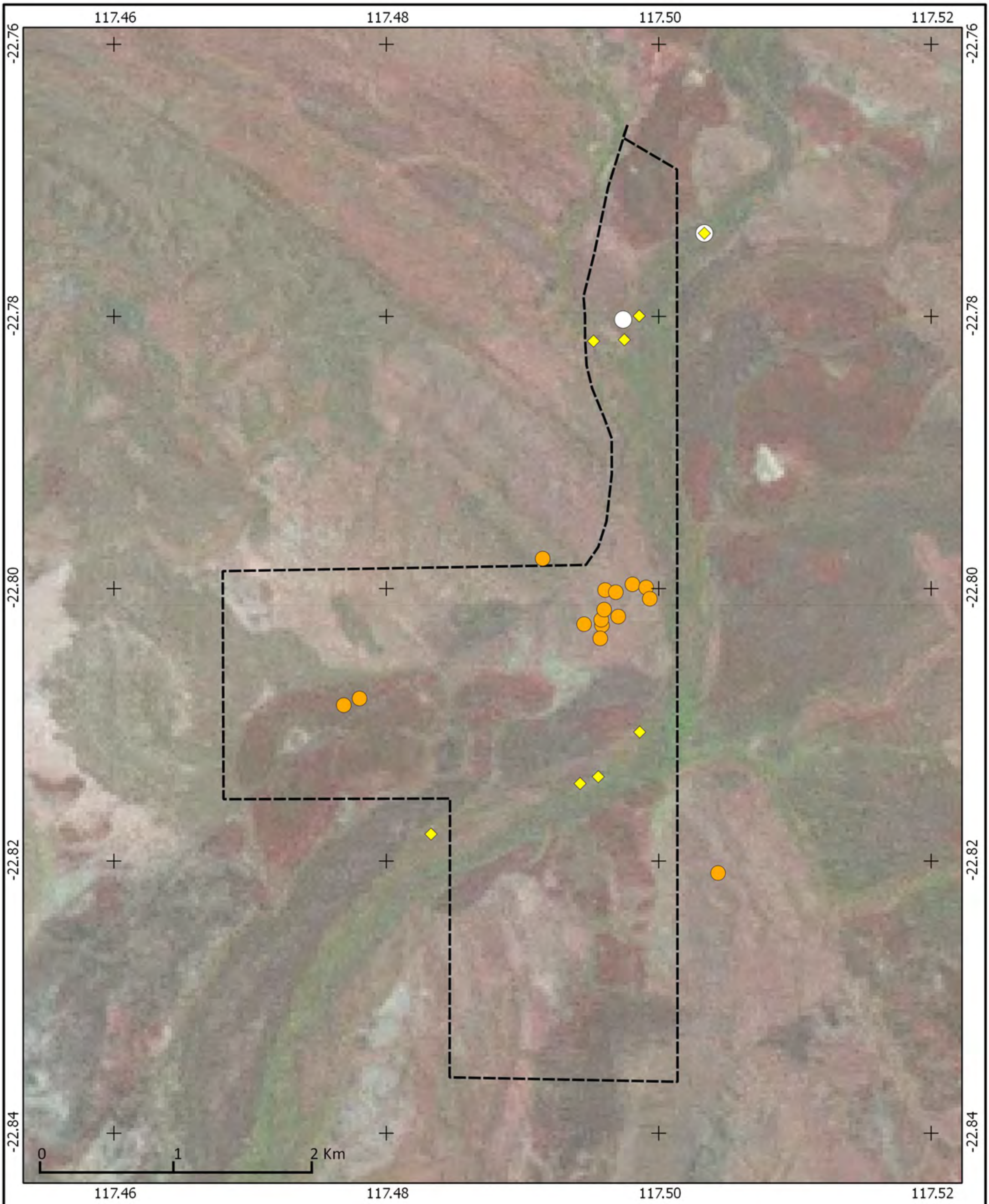


Figure 5-1
Conservation significant species recorded during the survey

Rainbow Bee-eater
Bush Stone-curlew
Western Pebble-mound Mouse (inactive mounds)
Study area

AUTHOR: G. Bouteloup	CLIENT: Dragon Energy Ltd.
DATE: November 2011	Scale: 1:30000
Coordinate System: Projection: Transverse Mercator; Datum: WGS84	

PROJECT: Rocklea Iron Ore Project

PHOENIX ENVIRONMENTAL SCIENCES

6 DISCUSSION

This section presents an assessment of potential impacts to vertebrate fauna from the proposed Project. In assessing development proposals, the EPA's broad objective for vertebrate fauna is to maintain the abundance, diversity, geographic distribution, and productivity of fauna at the species and ecosystem level, through the avoidance or management of adverse impacts and improvement in knowledge.

Accordingly, the main aim of this assessment was to determine whether the Project will result in the decline of faunal abundance, diversity, distribution or productivity, with particular emphasis on conservation significant species. As the project footprint was not defined at the time of writing, this assessment is considered preliminary and indicative of the potential impacts based on

6.1 POTENTIAL IMPACTS

6.1.1 Habitat loss

Habitat loss can be direct (e.g. clearing for digging/building) and/or indirect (e.g. caused by fragmentation or degradation). Some loss of fauna habitat is inevitable from the proposed Project; however, the extent of loss cannot be quantified until a project footprint has been defined. As a minimum, clearing for minesite infrastructure and resource extraction will result in the direct loss of habitat.

The scale and nature of impacts on vertebrate species from habitat loss can vary depending on:

- the extent and pattern of habitat loss
- the type of habitat loss –some species have critical habitat requirements, for example for breeding or foraging
- when the loss occurs – for example, clearing during the breeding season for many species may significantly disrupt or reduce breeding success rates.

The potential impacts on vertebrate fauna from habitat loss may include:

- loss of shelter, food resources, nesting resources
- displacement of individuals/populations
- reduction in breeding activity and
- decline in a population and in extreme cases, local extinction of a population.

Within the study area the mulga woodlands and riparian habitats (Hardey River bed and associated riparian woodlands) support the highest species richness and the highest number of conservation significant species. These are therefore considered the fauna habitats of highest conservation significance in the study area and clearing of these habitats may have greater impacts than clearing of other habitat types.

6.1.2 Loss of individual fauna

Mining operations can result in the direct and indirect loss of fauna. Individuals are likely to be killed mostly by vehicle strike, ground disturbance and associated vegetation clearance. Some species can die afterward of stress, exposure, lack of accessible resources, increased predation, introduction of diseases and any other possible effects associated with human activities and settlements. Young at den or at nest can be abandoned by their parents if they are scared, injured, killed or unable to find enough resources due to habitat destruction and inaccessibility.

The vertebrate groups most vulnerable to direct mortality from ground disturbing activities are small ground-dwelling animals, such as skinks and rodents. Ground-dwelling birds, such as the Emu and Bush Stone-curlew, are more vulnerable to vehicle strike.

Collisions with aerial infrastructure (e.g. towers, cables) can also cause the death of large bird species, such as raptors, bustards and species with a large wingspan and limited range of flight manoeuvrability.

6.1.3 Displacement of individuals

Mining operations may lead to the displacement of vertebrate fauna due to:

- noise emissions
- light emissions
- habitat loss (fragmentation, partial or complete clearance)
- reduction in available resources
- changes in surface water regimes (on site, downstream and upstream) leading to habitat becoming unsuitable.

6.1.4 Hydrological impacts

Many species rely on freshwater resources to breed, forage and survive, especially in arid inland environments. Thus, most vertebrate species in the Pilbara depend on the vegetation associations defined by the climate and the hydrological flow regimes.

Mining activities often require the modification of water tables, water course re-alignments and/or the clearing of minor drainage lines. These operations can significantly and permanently disrupt/degrade fauna habitats and lead to decline in species assemblages both at a small (local) scale and at a larger (downstream watershed) scale.

Burbidge *et al.* (2010) underlined the importance of riparian habitats for the avifauna of the Pilbara bioregion. The results of the current survey demonstrate how important this habitat is both in terms of species richness and species of conservation significance. Most of the species records of the current survey are concentrated around the Hardey River which supports large units of riparian woodlands adjacent to a river bed up to 140 m wide in sections. The presence of semi-permanent water is also likely to attract migratory species not recorded during the current survey.

It is not known if groundwater drawdown is proposed for the Project; however, if it is then the extent of drawdown will need to be modelled to assess potential effects on the riparian habitats.

It is not known if any modification to surface water systems will be required for the Project. If such modifications are required, the potential effects on fauna habitats will need to be assessed.

6.1.5 Spread of introduced fauna and flora

Introduced flora and fauna represent some of the greatest threats to native fauna in Australia and are attributed to biodiversity decline on a large scale. Seven invasive fauna species are known to occur in the Pilbara bioregion and some have been recorded in the study area (Feral Cat, Dog). Cattle have also had a heavy impact on native vegetation in parts of the study area.

Mining operations can facilitate the introduction of new species or increase the number of individuals of introduced species that already occur in an area. For example, vehicles and machinery coming from other parts of the country may be vectors for dispersal of plants and animals; the construction of new access tracks and roads can make it easier for predatory feral mammals to move into new areas.

6.1.6 Pollution events

Chemical/pollution spills during mining operations may occur from the use of heavy machinery (e.g. fuel, coolants, oil) or daily maintenance, such as treatment of human waste and general hygiene procedures.

Chemical spills can be absorbed into the soil and locally affect the flora (soil bio-chemistry) and fauna, directly or indirectly (direct contact, trophic bio-accumulation, reduction in vegetation cover and associated effects on resource availability). Discharge of pollution or chemicals into water systems can cause downstream habitat degradation.

6.1.7 Visual and acoustic disturbance

Increased light and noise levels are likely to result from the Project in immediately adjacent fauna habitats. Vertebrate fauna species (especially nocturnal ones) can be sensitive to such disturbances. For example, the foraging activity of bats can be disrupted by nocturnal lighting. Nocturnal bird species may also be affected by lighting, particularly while breeding and foraging. Permanent lighting at night can also affect the nycthemeral behaviour of diurnal birds for example, causing some species to sing continuously at night.

The close proximity of the proposed pit to the Hardey River may result in nocturnal bird species and bats being driven downstream and upstream of the project area due to light spill.

Some vertebrate groups are vulnerable to noise disturbance, particularly birds and bats when foraging or breeding. There is evidence however, that many species can become habituated to increased noise levels. Noise disturbance must also be considered when using explosives or activities involving heavy machinery

6.1.8 Fire

In an arid environment, fire is a key component that influences vegetation succession, species assemblages (flora and fauna) and biodiversity in general.

Since the arrival of Europeans in Australia the fire regime has changed dramatically. These changes usually result in less diverse vegetation communities, inadequate cover for native fauna, and reduction of resources in general.

Mining operations can increase the risk of accidental fire, for example through the use of heavy machinery, especially in the proximity of highly flammable vegetation (spinifex, Buffel grass).

6.1.9 Dust

Vehicle and machinery activities can increase the amount of dust movement due to soil disturbance. Dust deposition can affect the vegetation, limiting its capacity for photosynthesis, particularly along tracks that are regularly used. A reduced vegetation cover implies less cover and fewer resources available, especially for small ground-dwelling species.

6.2 CONSERVATION SIGNIFICANT SPECIES

Up to 21 species of conservation significance or migratory fauna may potentially occur in the study area (Table 6-1). The study area contains important habitat for:

- Western Pebble-mound Mouse mainly on grasslands on rocky slopes and occasionally in non-riparian mulga woodlands

- Bush Stone-curlew in all types of riparian habitats (Hardey River bed and associated riparian woodlands) and also in non-riparian mulga woodlands in general
- Rainbow Bee-eater in all types of riparian habitats (Hardey River bed and associated riparian woodlands) and also along minor drainage lines
- Australian Bustard (not recorded but highly likely to occur) in spinifex grass plains, especially on the flats, in western part of the study area
- migratory and other species dependent on the riparian habitats for foraging, roosting and/or nesting.

There is potential for the Pilbara Olive Python and the Northern Quoll to occur in the study area along the Hardey River and in the rocky hills located in the south-western part of the study area. Details on these species are given in the sections 4.4.2 and 4.4.4.

Several conservation significant species may be impacted by the Project, depending of the level of disturbance in the different habitats (Table 6-1). Likelihood of occurrence and potential impacts have been assessed for each of these species (Table 6-1).

In order to facilitate the project design, the fauna habitats of the study area have been given a priority rating based on an assessment of the fauna values of each habitat type, particularly the value of the habitats to conservation significant fauna. Habitats were classified into one of three categories (Figure 6-1):

- Low priority habitats: no conservation significant species have been recorded in these habitats and they have a low potential to support conservation significant species.
- Medium priority habitats: no more than two conservation significant species have been recorded in these habitats and they have a fair potential for additional conservation significant species with the exclusion of species listed under the EPBC Act
- High priority habitats: several conservation significant species have been recorded in these habitats and they have a good potential to support additional conservation significant species; these areas include the typical habitats where the Northern Quoll or the Pilbara Olive Python are likely to occur.

Disturbance to those areas classified as high priority fauna habitats should be avoided as far as practicable.

Table 6-1 Summary of conservation significant species likelihood of occurrence and potential impacts

Scientific Name	Common name	EPBC	WC Act	DEC	Records	Likelihood of occurrence	Potential impacts
BIRDS							
Apus pacificus	Fork-tailed Swift	M	S3		-	Likely	None expected
Ardea modesta	Eastern Great Egret	M	S3		-	Likely	None if water regimes remain unaltered and riparian habitats are preserved.
Ardea ibis	Cattle Egret	M	S3		-	Likely	None if water regimes remain unaltered and riparian habitats are preserved.
Falco peregrinus	Peregrine Falcon		S4		-	Likely	Small effect on prey abundance due to vegetation clearing
Ardeotis australis	Australian Bustard			P4	-	Very likely	Direct habitat destruction, displacement of individuals, local scale fragmentation
Burhinus grallarius	Bush Stone-curlew			P4	two direct sightings	Recorded	Direct habitat destruction, displacement of individuals, local scale fragmentation, disturbance due to noise and lighting, direct mortality (road kill)
Charadrius veredus	Oriental Plover	M	S3		-	Likely	Direct habitat destruction
Gallinago megala	Swinhoe's Snipe	M	S3		-	Unlikely	None if water regimes remain unaltered and riparian habitats are preserved.
Actitis hypoleucos	Common Sandpiper	M	S3		-	Likely	None if water regimes remain unaltered and riparian habitats are preserved.
Merops ornatus	Rainbow Bee-eater	M	S3		nine direct sightings	Recorded	None if water regimes remain unaltered and riparian habitats are preserved.
Neochmia ruficauda subclarescens	Star Finch			P4	-	Likely	None if water regimes remain unaltered, potential positive effect if riparian woodlands are not affected and cattle removed.
REPTILES							
Notoscincus butleri	No Common Name			P4	-	Unlikely	Direct habitat destruction
Liasis olivaceus barroni	Pilbara Olive Python	VU	S1	VU	-	Likely	None if water regimes remain unaltered and riparian habitats are preserved.
MAMMALS							
Dasyurus hallucatus	Northern Quoll	EN	S1	EN	-	Likely	None if riparian habitats are not altered.

Scientific Name	Common name	EPBC	WC Act	DEC	Records	Likelihood of occurrence	Potential impacts
Sminthopsis longicaudata	Long-tailed Dunnart			P4	-	Likely	Direct habitat destruction, direct mortality.
Macrotis lagotis	Bilby, Dalgyte	VU	S1	VU	-	Unlikely	Direct habitat destruction.
Macroderma gigas	Ghost Bat			P4	-	Unlikely	Possible reduction of prey abundance.
Rhinonicteris aurantius	Orange Leaf nosed-bat	VU	S1	VU	-	Unlikely	Possible reduction of prey abundance.
Leggadina lakedownensis	Short-tailed Mouse			P4	-	Unlikely	Direct habitat destruction, direct mortality.
Leporillus apicalis	Lesser Stick-nest Rat	EX	S2	EX	-	None	-
Pseudomys chapmani	Western Pebble-mound Mouse			P4	15 inactive mounds	Recorded	Direct habitat destruction, risk of direct mortality.

EN – Endangered (EPBC Act); VU – Vulnerable (EPBC Act); S1 – Schedule 1 (WC Act); S4 – Schedule 4 (WC Act) P1 – Priority 1 (DEC); P2 – Priority 2 (DEC); P3 – Priority 3 (DEC); P4 – Priority 4 (DEC); M – Migratory species (EPBC Act). Likelihood of occurrence is based on the following six grades rating (highest to lowest): recorded/very likely/likely/possible/unlikely/none

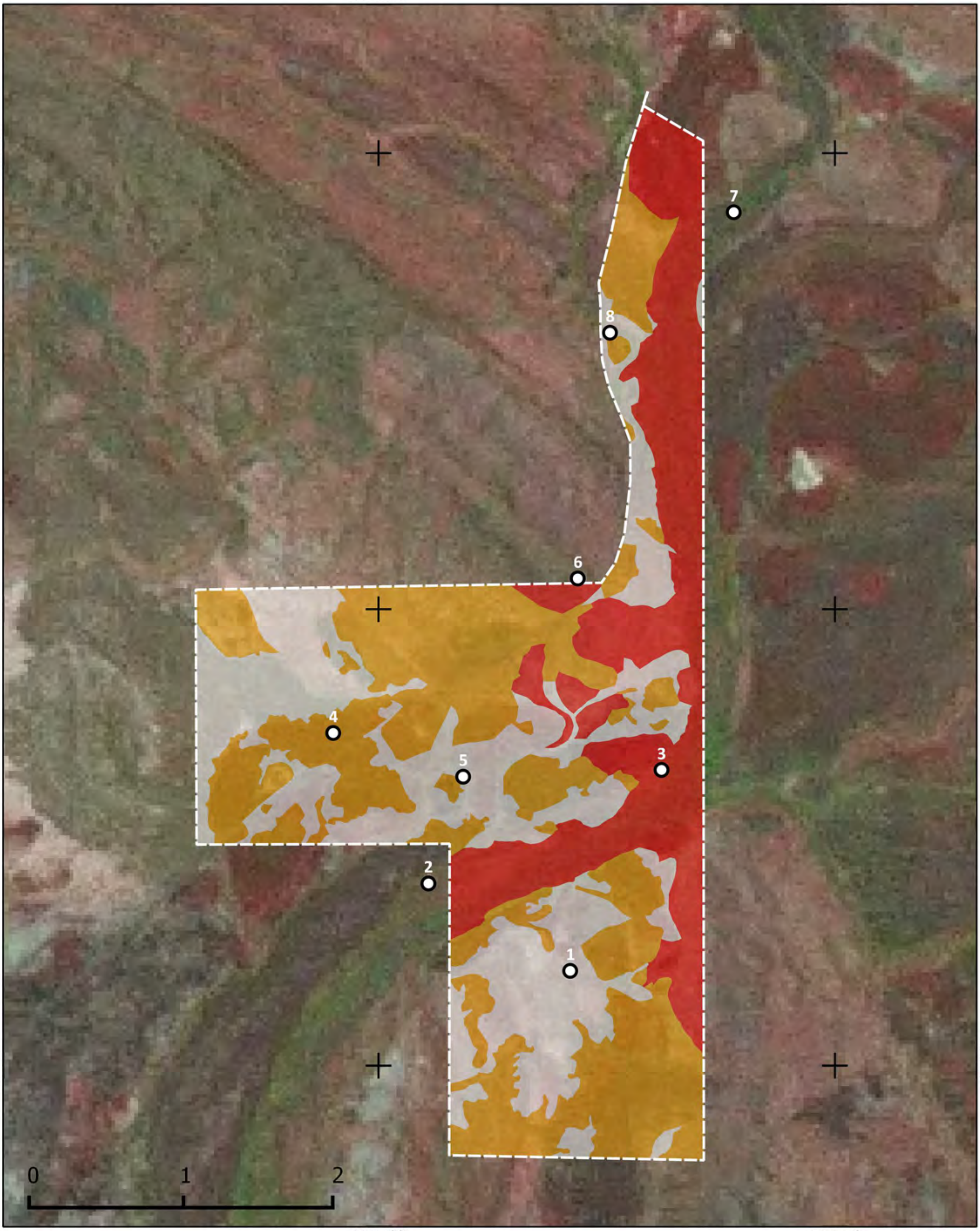


Figure 6-1
Priority fauna habitats of the study area

Systematic trapping site

Habitat priority
Low priority
Medium priority
High priority

AUTHOR: Guillaume	CLIENT: Dragon Energy Ltd.
DATE: November 2011	Scale: 1:28000
Coordinate System: Projection: Transverse Mercator; Datum: WGS84	

PROJECT: Rocklea Iron Ore Project

PHOENIX ENVIRONMENTAL SCIENCES

6.3 RECOMMENDATIONS

Central to conservation strategies for threatened species is the protection of habitat. Protection of habitat for conservation significant species has the added benefit of protecting broader species assemblages and helping to maintain whole of ecosystem functions. This concept is equally relevant at the Project level and focus should be on avoiding or minimising impacts to important habitat as much as individual animals.

Not all the potential impacts of the Project on fauna will be avoidable and therefore recommendations are made to minimise and/or rectify impacts where possible (Table 6-2). The recommendations are based on limited information about project impacts, in the absence of a project footprint. A more detailed assessment of impacts to vertebrate fauna and appropriate mitigation and management responses is warranted once the Project is more well-defined.

There is potential to generate some improvement in the biological values of the study area by removing of fencing off cattle from the Hardey River and associated riparian woodland habitats. This would greatly relieve the grazing pressure on these important fauna habitats and allow improvement in vegetation and fauna habitat condition.

As mentioned previously, the Northern Quoll and the Pilbara Olive Python are likely to occur in the study area, particularly in the south-western part and beyond (Hardey River, rocky hills extending south). Appendix 5 displays the locations of previous records of these two species close to the study area.

In the absence of detailed data on the mining proposal (location of the main pit, waste dump, accommodation village, modification of water regimes) it is not possible to assess if the Project is likely to have an impact on these species.

In the event that any aspect of the proposed Project is found to impact upon the habitats of these two species, targeted surveys will be required, the results of which will need to be included within the mining proposal. It is worth noting that Northern Quoll surveys must be conducted from May to August only; beyond these months trapping programs are considered potentially detrimental to breeding success. The Pilbara Olive Python can be targeted at any time of the year.

Table 6-2 Recommendations to address potential impacts

Potential impact	Recommendations
Direct loss of habitat	• where species records are poor, conduct additional surveys to better define species distributions relative to impact areas, in particular Northern Quoll and Pilbara Olive Python • avoid disturbance to important habitats (riparian woodlands, Hardey River bed, non-riparian mulga woodlands • where disturbance can’t be avoided, minimise the extent of habitat loss by putting strict clearing controls on place • consider fauna habitat rehabilitation in mine closure planning • consider providing artificial shelters for ground-dwelling species and for cavity-nesting birds as a medium-term measure

Potential impact	Recommendations
Direct mortality	• limit vehicle speeds throughout project area to limit the risk of collision • prevent any strike in areas at-risk (e.g. potential breeding habitat for Bush Stone-curlew) using appropriate signage and developing mandatory environmental awareness inductions • conduct pre-clearing surveys for conservation significant species • install visual objects on aerial infrastructures to prevent bird strikes
Water table and water regime	• avoid or minimise disturbance to surface and sub-surface hydrological regimes
Introduced species	• develop and implement topsoil management and weed control procedures • control and manage all types of waste appropriately; prevent fauna from accessing and/or feeding on rubbish at all times • limit the numbers of tracks and roads created to limit the potential dispersion of introduced species
Contamination	• provide chemical and/or hydrocarbon spill kits in all vehicles • develop and implement a chemical spill management plan, including: ➢ training staff in the prevention and management of possible chemical spills ➢ storing and controlling the use of all the chemicals on-site appropriately ➢ controlling the storage and evacuation of chemical wastes on a regular basis
Light and noise	• consider fauna habitats and sensitive species in lighting design consider noise dispersion in project design • avoid blasting during peak times for crepuscular species (no less than 3 hours after sunrise and no more than 3 hours before sunset)
Fire	• implement an appropriate fire risk management plan
Dust	• implement appropriate dust suppression measures to minimise dust mobilisation during construction and operation

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Appendix 1 Bat echolocation call analysis

Rocklea Iron Ore Project
Fauna Survey

Echolocation Survey of Bat Activity.

Prepared for Phoenix Environmental Sciences

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Prepared by:
R. D. Bullen – Bat Call WA
10 October 2011

Background

Chiroptera species presence, with an estimate of activity level, is presented for the Rocklea Iron Ore Project in the central Pilbara's Hamersley Range. Phoenix Environmental Sciences carried out a systematic echolocation based survey during September of 2011. The survey includes nine recording nights. Bat Call WA has reviewed the recordings made and provided species lists for the bats present.

Habitats

Sites for the Chiroptera survey were chosen by Phoenix. They include the habitats typical of the Hardey River valley in the central Pilbara being dominated by rivers riparian line. Site-specific details are presented in Table 1.

Bat Fauna

A microbat assemblage of six insectivorous species was confirmed as present in the study area in September. Species recorded and the characteristics of their calls are presented in Table 2. There were no conservation significant species detected.

Bat activity level was confirmed as generally low (see criteria below) although higher activity levels were noted for *Chalinolobus gouldii* and *Chaerephon jobensis* at one site, see Table 3 below. Numbers of calls recorded were typical of the plains of the central Pilbara bioregion.

Survey Timing, Moon Phase and Weather

The systematic echolocation survey was conducted between 24th September and 1st of October 2011. The survey was conducted in a warm and dry period. All sampling evenings were fine with minimum temperatures around 15 degC overnight. The moon in this period was new.

Survey Team

Staff of Phoenix conducted the bat sampling work. No activities were conducted that directly impacted upon the bat fauna present.

R.D. Bullen of Bat Call WA completed analysis of echolocation recordings.

Systematic Sampling

The systematic survey consisted of completing nine overnight bat sound recordings, beginning at twilight, at a location within the survey area. The recordings were "continuous" (Hyder *et al.* 2010) made using SM2BAT SongMeter (Wildlife Acoustics Inc, USA) detectors. The jumper and audio settings used for the SM2BAT followed the manufacturers recommendations for bat detection contained in the user manual (Wildlife Acoustics 2010). Selectable filters and triggers were also set using the manufacturers recommendations, see Table 4.

For the SM2BAT recordings, once reformatted as .wav files, COOL EDIT 2000 (Now available as AUDITION from Adobe Systems Inc.) was used to display each sequence for identification. Calls were identified manually. Only good quality call sequences were used. Details of calls analysed are provided in Table 2 as recommended by Australasian Bat Society (ABS 2006). Reference data for the species identified are available in Bullen and McKenzie 2002, McKenzie and Bullen 2003 and McKenzie and Bullen 2009.

Bat activity was then characterised as “Low”, “Medium” or “High” based on the rate of call sequences recorded.

- Low species activity is referred when a species is recorded with call spacing less often than ten minutes,
- Medium species activity refers to call recordings more often than 10 minutes but less often than two minutes apart for a significant time period followed by sporadic records for the remainder of the session.
- High species activity refers to call recording more often than two minutes apart for significant periods followed by reasonably regular records for the remainder of the session.

Further details of the calls analysed including graphical presentations are available from Bat Call WA on request.

Survey Limitations

All sites surveyed were accessible on foot and the recorders were set at ground level with the microphone pointing horizontally. Bat sound recording was carried out overnight beginning at twilight. The survey method using SM2 detectors gives optimum recorder effectiveness.

Bat species density is impossible to estimate from echolocation records. Bat activity is therefore substituted as an approximate guide to the relative numbers of each species using the study area.

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Table 1: Site specific details

Date	Site	Habitat	Recording Time	Latitude	Longitude
SM2 Unit 1					
25 Sept	Site 6	Grassland on rocky slope	Overnight recording using SM2BAT (SN TBA	-22.797981	117.493095
29 Sept	Site 7	Hardey River bed	Overnight recording using SM2BAT (SN TBA	-22.773889	117.50335
SM2 Unit 2					
24 Sept	Site 1	Grass plain	Overnight recording using SM2BAT (SN TBA	-22.823765	117.4926
25 Sept	Site 2	Riparian woodland	Overnight recording using SM2BAT (SN TBA	-22.818016	117.483283
26 Sept	Site 5	Grass plain	Overnight recording using SM2BAT (SN TBA	-22.810992	117.485565
28 Sept	Site 8	Minor drainage line	Overnight recording using SM2BAT (SN TBA	-22.781815	117.495216
29 Sept	Site 4	Non-riparian mulga woodland	Overnight recording using SM2BAT (SN TBA	-22.808145	117.477024
30 Sept	NQ (night1)	Hardey River bed with semi-permanent pond	Overnight recording using SM2BAT (SN TBA	-22.815708	117.491779
1 Oct	NQ (night2)	-	Overnight recording using SM2BAT (SN TBA	-	-

Table 2: Summary of echolocation call characteristics for microbat species present

Genus species Authority	Common name	Typical F_{peakC} kHz	Ave. Q	Typical Duration msec	Typical Call Shape
Chaerephon jobensis (Miller 1902)	Northern free-tailed bat	20	5	8 - 15	Shallow FM
Chalinolobus gouldii (Grey 1841)	Gould's wattled bat	32	10	7 - 11	FM
Nyctophilus geoffroyi Leach 1821	Lesser long-eared bat	47	2.5	5	Steep FM
Scotorepens greyii (Gray 1843)	Little broad-nosed bat	38	10	7 - 13	FM
Taphozous georgianus Thomas 1915	Common sheath-tailed bat	24.5	14	9 - 18	CF– shallow FM
Vespadelus finlaysoni (Kitchener, Jones and Caputi 1987)	Inland cave bat	55	14	4 - 8	FM

Note: FpeakC and Q are defined in McKenzie and Bullen 2003, 2009.

Table 3. Phase 1 Microbat lists obtained presented by site

Date	Site	*Chaerephon jobensis*	*Chalinolobus gouldii*	*Nyctophilus geoffroyi*	*Scotorepens greyii*	*Taphozous georgianus*	*Vespadelus finlaysoni*
SM2 Unit 1							
25 Sept	Site 6	Low	Low				Low
29 Sept	Site 7	Med	Med			Low	Low
SM2 Unit 2							
24 Sept	Site 1	Low	Low		Low	Low	Low
25 Sept	Site 2	Low	Low	Low	Low		Low
26 Sept	Site 5		Low			Low	Low
28 Sept Note 1	Site 8						
29 Sept Note 1	Site 4						
30 Sept-1Oct Note 1	NQ						

Note 1: No bats were recorded on the four nights between 28 Sept and 1 October

Table 4 SM2 Audio settings used during survey

Parameter	Setting
Sample rate	384,000 kHz
Channel used	Left
Compression protocol	WAC4 (12 bit audio samples)
Gain - left channel	0.00
Digital high pass filter Left channel	fs/48 (giving 8 kHz minimum frequency)
Digital high pass filter Left channel	Off
Triggering level Left channel	6SNR (adaptive +6 dB triggering)
Triggering window Left channel	0.5 sec.

Note: These settings are as recommended in Wildlife Acoustics (2010) except the high pass filter. This is set lower to 8kHz to record any *Tadarida australis* that my be present

Appendix 2 Survey site coordinates (Datum, WGS84)

Site number	Coordinates in Decimal Degrees		Coordinates in UTM.		
	Latitude	Longitude	Northing	Easting	Zone
Reference sites, outside the area of impact from the proposed development					
Opp1-JC-30092011	-22.817551	117.502368	7476589	551553	50K
Opp2-JC-30092011	-22.818681	117.503977	7476464	551718	50K
Opp3-JC-30092011	-22.822012	117.505651	7476094	551888	50K
Opp4-JC-30092011	-22.841678	117.502636	7473918	551571	50K
2	-22.818016	117.483283	7476544	549594	50K
6	-22.797981	117.493095	7478759	550608	50K
7	-22.773889	117.50335	7481422	551670	50K
Camera1	-22.817470	117.480677	7476605	549326	50K
Sites within the area of impact from the proposed development					
1	-22.823765	117.4926	7475904	550548	50K
3	-22.810546	117.4986	7477366	551169	50K
4	-22.808145	117.477	7477639	548955	50K
5	-22.810992	117.4856	7477321	549831	50K
8	-22.781815	117.4952	7480548	550832	50K
Camera2	-22.775361	117.499176	7481261	551241	50K
Camera3	-22.808065	117.486566	7477644	549934	50K
Camera4	-22.815781	117.496305	7476787	550931	50K
opp2-jc027092011	-22.770964	117.4978	7481748	551097	50K
Well north	-22.775363	117.4992	7481261	551241	50K
Opp27sep11gb02	-22.801208	117.4975	7478400	551061	50K
Opp1-JC-28092011	-22.8138	117.4956	7477007	550856	50K
Opp2-JC-28092011	-22.815708	117.4918	7476797	550467	50K
Opp3-JC-28092011	-22.815969	117.4961	7476767	550908	50K
Opp4-JC-28092011	-23.204009	117.6727	7433737	568836	50K
Opp1-JC-29092011	-22.811176	117.4852	7477301	549795	50K
Opp2-JC-29092011	-22.813571	117.478	7477038	549056	50K
Opp3-JC-29092011	-22.812233	117.4795	7477186	549204	50K
Op01gb29sep11	-22.79313	117.4982	7479294	551130	50K
Opp1-JC-30092011	-22.817551	117.5024	7476589	551553	50K
Opp2-JC-30092011	-22.818681	117.504	7476464	551718	50K
Opp3-JC-30092011	-22.822012	117.5057	7476094	551888	50K
Opp4-JC-30092011	-22.841678	117.5026	7473918	551571	50K
Opp01gb2oct11	-22.78023	117.497389	7480725	551068	50K

Site number	Coordinates in Decimal Degrees		Coordinates in UTM.		
	Latitude	Longitude	Northing	Easting	Zone
Opp1-JC-02102011	-22.806351	117.4768	7477838	548936	50K
Opp2-JC-02102011	-22.804572	117.4779	7478035	549047	50K

Appendix 3 Species records from desktop review and surveys

BIRDS

Scientific Name	Common name	EPBC Protected Matters	Threatened Fauna Database	Birdata	NatureMap	Biota (2009)	Biota (2008)	Biota (2005)	Current Survey
Casuariidae									
Dromaius novaehollandiae	Emu			●	●			●	●
Phasianidae									
Coturnix pectoralis	Stubble Quail						●		
Coturnix ypsilophora	Brown Quail				●				
Anatidae									
Dendrocygna eytoni	Plumed Whistling-Duck				●				
Cygnus atratus	Black Swan				●				
Chenonetta jubata	Australian Wood Duck				●		●		
Malacorhynchus membranaceus	Pink-eared Duck				●				
Anas gracilis	Grey Teal			●	●			●	
Anas superciliosa	Pacific Black Duck			●	●			●	
Aythya australis	Hardhead				●				
Podicipedidae									
Tachybaptus novaehollandiae	Australasian Grebe			●	●				
Poliocephalus poliocephalus	Hoary-headed Grebe				●				
Columbidae									
Columba livia	Rock Dove				●				
Phaps chalcoptera	Common Bronzewing			●	●	●	●	●	●
Ocyphaps lophotes	Crested Pigeon			●	●	●	●	●	●
Geophaps plumifera	Spinifex Pigeon			●	●	●	●	●	●
Geopelia cuneata	Diamond Dove			●	●	●	●	●	●
Geopelia striata	Peaceful Dove			●	●	●			●
Podargidae									
Podargus strigoides	Tawny Frogmouth			●	●				
Eurostopodidae									
Eurostopodus argus	Spotted Nightjar			●	●			●	●
Aegothelidae									
Aegotheles cristatus	Australian Owlet-nightjar			●	●				
Apodidae									
Apus pacificus	Fork-tailed Swift	●			●				
Anhingidae									
Anhinga novaehollandiae	Australasian Darter			●	●				
Phalacrocoracidae									
Microcarbo melanoleucos	Little Pied Cormorant			●	●				
Phalacrocorax sulcirostris	Little Black Cormorant			●	●				
Pelecanidae									

Scientific Name	Common name	EPBC Protected Matters	Threatened Fauna Database	Birdata	NatureMap	Biota (2009)	Biota (2008)	Biota (2005)	Current Survey
Pelecanus conspicillatus	Australian Pelican			•	•				
Ardeidae									
Ardea pacifica	White-necked Heron			•	•			•	•
Ardea modesta	Eastern Great Egret	•		•	•				
Ardea intermedia	Intermediate Egret				•				
Ardea ibis	Cattle Egret	•							
Egretta novaehollandiae	White-faced Heron			•	•			•	
Egretta garzetta	Little Egret			•					
Nycticorax caledonicus	Nankeen Night-Heron			•	•				
Threskiornithidae									
Threskiornis spinicollis	Straw-necked Ibis			•	•		•		
Accipitridae									
Elanus axillaris	Black-shouldered Kite			•	•	•	•		
Lophoictinia isura	Square-tailed Kite				•				
Haliastur sphenurus	Whistling Kite			•	•	•	•	•	•
Milvus migrans	Black Kite			•	•				
Accipiter fasciatus	Brown Goshawk			•	•			•	•
Accipiter cirrocephalus	Collared Sparrowhawk				•		•		•
Circus assimilis	Spotted Harrier				•	•		•	
Aquila audax	Wedge-tailed Eagle			•	•	•	•	•	•
Hieraaetus morphnoides	Little Eagle				•	•	•	•	
Falconidae									
Falco cenchroides	Nankeen Kestrel			•	•	•	•	•	
Falco berigora	Brown Falcon			•	•	•	•	•	•
Falco longipennis	Australian Hobby			•	•	•		•	•
Falco peregrinus	Peregrine Falcon		•		•				
Rallidae									
Gallirallus philippensis	Buff-banded Rail				•				
Porzana pusilla	Baillon's Crake				•				
Porzana fluminea	Australian Spotted Crake				•				
Porzana tabuensis	Spotless Crake				•				
Tribonyx ventralis	Black-tailed Native-hen				•				
Fulica atra	Eurasian Coot			•	•				
Otididae									
Ardeotis australis	Australian Bustard		•		•	•		•	
Burhinidae									
Burhinus grallarius	Bush Stone-curlew		•		•			•	•
Recurvirostridae									
Himantopus himantopus	Black-winged Stilt				•				

Scientific Name	Common name	EPBC Protected Matters	Threatened Fauna Database	Birdata	NatureMap	Biota (2009)	Biota (2008)	Biota (2005)	Current Survey
Charadriidae									
Charadrius ruficapillus	Red-capped Plover				•				
Charadrius veredus	Oriental Plover	•							
Elseyornis melanops	Black-fronted Dotterel			•	•		•	•	•
Erythrogonys cinctus	Red-kneed Dotterel				•				
Scolopacidae									
Gallinago megala	Swinhoe's Snipe				•				
Actitis hypoleucos	Common Sandpiper				•				
Turnicidae									
Turnix velox	Little Button-quail			•	•		•	•	•
Laridae									
Chlidonias hybrida	Whiskered Tern				•				
Cacatuidae									
Eolophus roseicapillus	Galah			•	•	•		•	•
Cacatua sanguinea	Little Corella			•	•	•	•	•	•
Nymphicus hollandicus	Cockatiel			•	•	•	•	•	•
Psittacidae									
Barnardius zonarius	Australian Ringneck			•	•	•	•	•	•
Melopsittacus undulatus	Budgerigar			•	•	•	•	•	•
Neopsephotus bourkii	Bourke's Parrot				•				
Cuculidae									
Chalcites basalis	Horsfield's Bronze-Cuckoo				•	•	•	•	•
Chalcites osculans	Black-eared Cuckoo				•	•			
Cacomantis pallidus	Pallid Cuckoo			•	•	•	•	•	
Strigidae									
Ninox novaeseelandiae	Southern Boobook			•	•				•
Tytonidae									
Tyto javanica	Eastern Barn Owl			•	•			•	
Halcyonidae									
Dacelo leachii	Blue-winged Kookaburra			•	•			•	•
Todiramphus pyrrhopygius	Red-backed Kingfisher			•	•	•	•	•	•
Todiramphus sanctus	Sacred Kingfisher			•	•				•
Meropidae									
Merops ornatus	Rainbow Bee-eater	•		•	•	•	•	•	•
Climacteridae									
Climacteris melanura	Black-tailed Treecreeper			•	•			•	•
Ptilonorhynchidae									
Ptilonorhynchus guttatus	Western Bowerbird			•	•	•	•	•	•
Maluridae									

Scientific Name	Common name	EPBC Protected Matters	Threatened Fauna Database	Birdata	NatureMap	Biota (2009)	Biota (2008)	Biota (2005)	Current Survey
Malurus leucopterus	White-winged Fairy-wren			•	•	•	•	•	•
Malurus lamberti	Variegated Fairy-wren			•	•	•	•	•	•
Stipiturus ruficeps	Rufous-crowned Emu-wren				•	•		•	•
Amytornis striatus whitei	Striated Grasswren (Pilbara)					•	•	•	•
Acanthizidae									
Pyrrholaemus brunneus	Redthroat			•	•				•
Smicrornis brevirostris	Weebill			•	•	•	•	•	•
Gerygone fusca	Western Gerygone			•	•	•	•	•	•
Acanthiza robustirostris	Slaty-backed Thornbill				•				
Acanthiza chrysorrhoa	Yellow-rumped Thornbill				•				
Acanthiza uropygialis	Chestnut-rumped Thornbill			•	•	•		•	•
Acanthiza apicalis	Inland Thornbill				•	•		•	
Aphelocephala leucopsis	Southern Whiteface				•				
Pardalotidae									
Pardalotus rubricatus	Red-browed Pardalote			•	•	•	•	•	•
Pardalotus striatus	Striated Pardalote			•	•	•		•	•
Meliphagidae									
Certhionyx variegatus	Pied Honeyeater					•			
Lichenostomus virescens	Singing Honeyeater			•	•	•	•	•	•
Lichenostomus keartlandi	Grey-headed Honeyeater			•	•	•	•	•	•
Lichenostomus plumulus	Grey-fronted Honeyeater				•				
Lichenostomus penicillatus	White-plumed Honeyeater			•	•	•		•	•
Purnella albifrons	White-fronted Honeyeater				•			•	
Manorina flavigula	Yellow-throated Miner			•	•	•	•	•	•
Acanthagenys rufogularis	Spiny-cheeked Honeyeater			•	•	•	•	•	•
Conopophila whitei	Grey Honeyeater				•	•			
Epthianura tricolor	Crimson Chat				•			•	
Sugomel niger	Black Honeyeater				•				
Lichmera indistincta	Brown Honeyeater			•	•	•	•	•	•
Melithreptus gularis	Black-chinned Honeyeater				•			•	
Pomatostomatidae									
Pomatostomus temporalis	Grey-crowned Babbler			•	•	•	•	•	•
Pomatostomus superciliosus	White-browed Babbler				•			•	
Eupetidae									
Cinclosoma castaneothorax	Chestnut-breasted Quail-thrush			•	•			•	
Psophodes occidentalis	Chiming Wedgebill				•				
Neosittidae									
Daphoenositta chrysoptera	Varied Sittella				•				
Campephagidae									

Scientific Name	Common name	EPBC Protected Matters	Threatened Fauna Database	Birdata	NatureMap	Biota (2009)	Biota (2008)	Biota (2005)	Current Survey
Coracina maxima	Ground Cuckoo-shrike				●	●		●	
Coracina novaehollandiae	Black-faced Cuckoo-shrike			●	●	●	●	●	●
Lalage sueurii	White-winged Triller			●	●	●		●	●
Pachycephalidae									
Pachycephala pectoralis	Golden Whistler				●				
Pachycephala rufiventris	Rufous Whistler			●	●	●	●	●	●
Colluricincla harmonica	Grey Shrike-thrush			●	●	●	●	●	●
Oreoica gutturalis pallescens	Crested Bellbird			●	●	●	●	●	●
Artamidae									
Artamus personatus	Masked Woodswallow			●	●	●			
Artamus cinereus	Black-faced Woodswallow			●	●	●	●	●	●
Artamus minor	Little Woodswallow				●	●	●	●	●
Cracticus torquatus	Grey Butcherbird			●	●	●	●	●	
Cracticus nigrogularis	Pied Butcherbird			●	●	●	●	●	●
Cracticus tibicen	Australian Magpie			●	●	●		●	●
Rhipiduridae									
Rhipidura albiscapa	Grey Fantail				●	●			
Rhipidura leucophrys	Willie Wagtail			●	●	●	●	●	●
Corvidae									
Corvus bennetti	Little Crow			●	●	●	●		
Corvus orru	Torresian Crow			●	●	●	●	●	●
Monarchidae									
Grallina cyanoleuca	Magpie-lark			●	●	●	●	●	●
Petroicidae									
Petroica goodenovii	Red-capped Robin				●	●		●	●
Melanodryas cucullata	Hooded Robin				●	●	●	●	●
Alaudidae									
Mirafra javanica	Horsfield's Bushlark			●	●				
Acrocephalidae									
Acrocephalus australis	Australian Reed-Warbler			●	●				
Megaluridae									
Cincloramphus mathewsi	Rufous Songlark			●	●		●	●	●
Cincloramphus cruralis	Brown Songlark				●	●		●	
Eremiornis carteri	Spinifexbird			●	●	●	●	●	●
Hirundinidae									
Hirundo neoxena	Welcome Swallow				●				
Petrochelidon ariel	Fairy Martin			●	●			●	
Petrochelidon nigricans	Tree Martin			●	●			●	●
Nectariniidae									

Scientific Name	Common name	EPBC Protected Matters	Threatened Fauna Database	Birdata	NatureMap	Biota (2009)	Biota (2008)	Biota (2005)	Current Survey
Dicaeum hirundinaceum	Mistletoebird			●	●	●		●	●
Estrildidae									
Taeniopygia guttata	Zebra Finch			●	●	●	●	●	●
Neochmia ruficauda subclarescens	Star Finch				●				
Emblema pictum	Painted Finch			●	●	●	●	●	●
Motacillidae									
Anthus novaeseelandiae	Australasian Pipit			●	●			●	●

MAMMALS

Scientific name	Common name	EPBC Protected Matters	Threatened Fauna Database	NatureMap	Biota (2009)	Biota (2008)	Biota (2005)	RioTinto (2011)	Current Survey
Tachyglossidae									
Tachyglossus aculeatus	Echidna								•
Dasyuridae									
Dasykaluta rosamondae	Little Red Kaluta			•	•		•		•
Dasyurus hallucatus	Northern Quoll	•				•			
Ningaui timealeyi	Pilbara Ningaui			•	•	•	•		•
Planigale sp.	Planigale sp.								•
Planigale ingrami	Long-tailed Planigale			•	•				
Pseudantechinus roryi	Rory's Pseudantechinus			•					
Pseudantechinus woolleyae	Woolley's Pseudantechinus			•	•				
Sminthopsis longicaudata	Long-tailed Dunnart		•	•				•	
Sminthopsis macroura	Stripe-faced Dunnart			•	•	•			•
Thylacomyidae									
Macrotis lagotis	Bilby, Dalgyte							•	
Macropodidae									
Macropus robustus erubescens	Euro, Biggada			•	•	•	•		•
Macropus rufus	Red Kangaroo, Marlu			•	•		•		•
Petrogale rothschildi	Rothschild's Rock-wallaby							•	
Megadermatidae									
Macroderma gigas	Ghost Bat		•	•		•			
Hipposideridae									
Rhinonicteris aurantius	Orange Leafnosed-bat	•	•						
Emballonuridae									
Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat				•	•			
Taphozous georgianus	Common Sheathtail-bat			•	•	•	•		•
Vespertilionidae									
Chalinolobus gouldii	Gould's Wattled Bat			•	•	•	•		•
Chalinolobus morio	Chocolate Wattled Bat				•				
Nyctophilus arnhemensis	Arnhem Land Long-eared Bat						•		
Nyctophilus geoffroyi	Lesser Long-eared Bat								•
Scotorepens balstoni	Inland Broad-nosed Bat					•			
Scotorepens greyii	Little Broad-nosed Bat			•	•	•	•		•
Vespadelus finlaysoni	Finlayson's Cave Bat			•	•	•	•		•
Molossidae									
Chaerephon jobensis	Northern Freetail-bat								•
Mormopterus loriae	Little Northern Freetail-bat						•		
Tadarida australis	White-striped Freetail-bat						•		

Scientific name	Common name	EPBC Protected Matters	Threatened Fauna Database	NatureMap	Biota (2009)	Biota (2008)	Biota (2005)	RioTinto (2011)	Current Survey
Muridae									
Leggadina lakedownensis	Short-tailed Mouse		●	●					
Leporillus apicalis	Lesser Stick-nest Rat							●	
Mus musculus	House Mouse			●	●	●	●		
Notomys alexis	Spinifex Hopping-mouse			●					
Pseudomys chapmani	Western Pebble-mound Mouse		●	●	●	●	●	●	●
Pseudomys desertor	Desert Mouse			●	●	●	●		
Pseudomys hermannsburgensis	Sandy Inland Mouse			●	●	●	●		●
Zyzomys argurus	Common Rock-rat			●	●	●	●		
Leporidae									
Oryctolagus cuniculus	Rabbit	inv.							
Canidae									
Canis lupus dingo	Dingo				●	●	●		●
Vulpes vulpes	Red Fox	inv.							
Felidae									
Felis catus	Cat	inv.			●	●	●		●
Mustelidae									
Equus asinus	Donkey					●	●		
Equus caballus	Horse						●		
Bovidae									
Bos taurus	European Cattle			●					●

(inv. = invasive)

REPTILES

Scientific name	Common name	EPBC Protected Matters	Threatened Fauna Database	NautreMap	Biota (2009)	Biota (2008)	Biota (2005)	Desktop review	Current Survey
Cheloniidae									
Chelodina steindachneri	Flat-shelled Turtle			•				•	
Agamidae									
Amphibolurus longirostris	No Common Name			•	•	•	•	•	•
Caimanops amphiboluroides	No Common Name			•		•		•	
Ctenophorus caudicinctus	Ring-tailed Dragon			•	•	•	•	•	•
Ctenophorus isolepis	Crested Dragon			•	•	•	•	•	
Ctenophorus nuchalis	Central Netted Dragon			•				•	
Ctenophorus reticulatus	Western Netted Dragon			•				•	
Diporiphora valens	No Common Name			•	•	•	•	•	•
Pogona minor	No Common Name			•	•	•	•	•	•
Tympanocryptis cephalus	Pebble Dragon			•				•	
Crenadactylus ocellatus horni	No Common Name			•				•	
Diplodactylus conspicillatus	Fat-tailed Gecko			•	•	•	•	•	•
Diplodactylus savagei	No Common Name			•	•		•	•	
Lucasium stenodactylum	No Common Name			•		•	•	•	•
Lucasium wombeyi	No Common Name			•			•	•	
Oedura marmorata	Marbled Velvet Gecko			•	•	•		•	•
Rhynchoedura ornata	Beaked Gecko			•	•		•	•	•
Strophurus elderi	No Common Name			•	•	•	•	•	
Strophurus wellingtonae	No Common Name			•	•	•	•	•	
Carphodactylidae									
Nephrurus wheeleri cinctus	No Common Name			•			•	•	•
Gekkonidae									
Gehyra punctata	No Common Name			•	•		•	•	•
Gehyra variegata	No Common Name			•	•	•	•	•	•
Heteronotia binoei	Bynoe's Gecko			•	•	•	•	•	•
Heteronotia spelea	Desert Cave Gecko			•				•	
Pygopodidae									
Delma elegans	No Common Name			•		•		•	
Delma haroldi	No Common Name					•		•	
Delma nasuta	No Common Name			•	•	•	•	•	
Delma pax	No Common Name			•	•	•	•	•	
Delma tincta	No Common Name			•	•	•	•	•	
Lialis burtonis	No Common Name			•	•	•	•	•	•
Pygopus nigriceps	No Common Name			•			•	•	•
Scincidae									
Carlia munda	No Common Name			•	•	•	•	•	•

Scientific name	Common name	EPBC Protected Matters	Threatened Fauna Database	NautreMap	Biota (2009)	Biota (2008)	Biota (2005)	Desktop review	Current Survey
Cryptoblepharus buchananii	No Common Name			•				•	•
Cryptoblepharus carnabyi	No Common Name					•	•	•	
Cryptoblepharus plagiocephalus	No Common Name				•		•	•	
Cryptoblepharus ustulatus	No Common Name			•				•	
Ctenotus duricola	No Common Name			•	•	•	•	•	
Ctenotus grandis	No Common Name			•	•		•	•	
Ctenotus hanloni	No Common Name				•			•	
Ctenotus helenae	No Common Name			•	•	•	•	•	•
Ctenotus pantherinus	Leopard Ctenotus			•	•	•	•	•	•
Ctenotus rubicundus	No Common Name			•	•			•	•
Ctenotus rutilans	No Common Name			•			•	•	•
Ctenotus saxatilis	Rock Ctenotus			•	•	•	•	•	•
Ctenotus schomburgkii	No Common Name			•	•	•	•	•	•
Ctenotus uber	No Common Name			•				•	
Cyclodomorphus melanops	Slender Blue-tongue			•	•	•	•	•	
Egernia formosa	No Common Name			•		•	•	•	
Eremiascincus richardsonii	Broad-banded Sand Swimmer								•
Lerista flammicauda	No Common Name			•	•			•	
Lerista jacksoni	No Common Name				•			•	
Lerista muelleri	No Common Name			•			•	•	
Lerista verhmens	No Common Name			•				•	•
Lerista zietzi	No Common Name			•				•	
Menetia greyii	No Common Name			•	•	•	•	•	
Menetia surda	No Common Name			•	•	•	•	•	
Morethia ruficauda exquisita	No Common Name			•	•		•	•	
Notoscincus butleri	No Common Name				•		•	•	
Notoscincus ornatus ornatus	No Common Name			•				•	
Proablepharus reginae	No Common Name			•				•	
Tiliqua multifasciata	Central Blue-tongue			•	•	•	•	•	
Varanidae									
Varanus acanthurus	Spiny-tailed Monitor			•	•	•	•	•	
Varanus brevicauda	Short-tailed Pygmy Monitor			•	•	•	•	•	•
Varanus bushi	Pilbara Mulga Monitor			•	•	•		•	
Varanus caudolineatus	No Common Name			•				•	
Varanus eremius	Pygmy Desert Monitor						•	•	
Varanus giganteus	Perentie						•	•	
Varanus panoptes	Yellow-spotted Monitor					•	•	•	•
Varanus pilbarensis	Pilbara Rock Monitor			•		•	•	•	

Scientific name	Common name	EPBC Protected Matters	Threatened Fauna Database	NautreMap	Biota (2009)	Biota (2008)	Biota (2005)	Desktop review	Current Survey
Varanus tristis tristis	Racehorse Monitor			●	●	●	●	●	●
Typhlopidae									
Ramphotyphlops ammodytes	No Common Name			●	●			●	●
Ramphotyphlops grypus	No Common Name			●	●	●	●	●	
Ramphotyphlops hamatus	No Common Name			●		●		●	
Ramphotyphlops pilbarensis	No Common Name						●	●	
Boidae									
Antaresia perthensis	Pygmy Python			●				●	
Aspidites melanocephalus	Black-headed Python			●				●	
Liasis olivaceus barroni	Pilbara Olive Python	●	●	●	●			●	
Elapidae									
Acanthophis pyrrhus	Desert Death Adder				●			●	
Acanthophis wellsi	Pilbara Death Adder			●		●		●	
Brachyurophis approximans	No Common Name			●	●	●	●	●	
Demansia psammophis	Yellow-faced Whipsnake			●		●	●	●	
Demansia rufescens	Rufous Whipsnake			●	●			●	●
Furina ornata	Moon Snake			●	●	●	●	●	
Parasuta monachus	No Common Name			●	●	●	●	●	
Pseudechis australis	Mulga Snake			●			●	●	●
Pseudonaja modesta	Ringed Brown Snake			●	●	●		●	●
Pseudonaja nuchalis	Gwardar; Northern Brown Snake				●		●	●	
Suta fasciata	Rosen's Snake				●	●		●	
Vermicella snelli	No Common Name			●	●	●		●	

AMPHIBIANS

Scientific name	Common name	EPBC Protected Matters	Threatened Fauna Database	NatureMap	Biota (2009)	Biota (2008)	Biota (2005)
Hylidae							
Cyclorana australis	Giant Frog			•			
Cyclorana maini	Sheep Frog			•	•	•	•
Cyclorana platycephala	Water-holding Frog			•			
Litoria rubella	Little Red Tree Frog			•		•	•
Limnodynastidae							
Notaden nichollsi	Desert Spadefoot			•			
Platyplectrum spenceri	Centralian Burrowing Frog					•	
Myobatrachidae							
Pseudophryne douglasi	Gorge Toadlet			•			

Appendix 4 Site descriptions of opportunistic survey sites

Site number	**opp2-jc027092011**
Site type	Active Search Site
Latitude	-22.770964
Longitude	117.497757
Habitat	NONE
Habitat type	0-25
Dominant tree	Acacia
Tree cover	0-25
Dominant shrub	Spinifex
Shrub cover	-
Dominant grass	Hilltop
Grass cover	Spinifex Grassland
Slope	Moderate
Soil texture	Clay Loam
Soil colour	Red/Brown
Surface	Coarse Gravel; Boulders; Stones;
Rock cover	>90% cover
Leaf litter distribution	0-25%
Litter distribution	Concentrated under vegetation;
Dead wood	Sparse
Disturbance details	Grazing - Low;
Fire history	>5 years
Fire intensity	Medium

Description:
Minor rolling hills, spinifex grassland with pockets of shrub land. A few mulga burnt in intense fire. A number of defunct Western Pebble-mound Mouse mounds.

NO PHOTO AVAILABLE

Site number	Well north
Site type	Camera trap
Latitude	-22.775363
Longitude	117.499175
Habitat	Eucalyptus/Corymbia
Habitat type	0-25
Dominant tree	Acacia
Tree cover	26-50
Dominant shrub	Buffel grass
Shrub cover	
Dominant grass	Flood Plain
Grass cover	Open Woodland
Slope	NONE
Soil texture	Sandy Loam
Soil colour	Orange
Surface	Loose soil;
Rock cover	-
Leaf litter distribution	-
Litter distribution	-
Dead wood	Sparse
Disturbance details	Grazing - High; Livestock Tracks;
Fire history	None evident
Fire intensity	

Description:
Open woodland of eucalyptus over sparse acacias over grazed Buffel grass on red sandy loam.

NO PHOTO AVAILABLE

Site number	Opp27sep11gb02
Site type	Active Search Site
Latitude	-22.801208
Longitude	117.49752
Habitat	Acacia (not Mulga)
Habitat type	0-25
Dominant tree	Acacia
Tree cover	26-50
Dominant shrub	Spinifex
Shrub cover	76-100
Dominant grass	Hill Slope
Grass cover	Spinifex Grassland
Slope	Negligible
Soil texture	Clay Loam
Soil colour	Orange
Surface	Coarse Gravel;
Rock cover	5-30% cover
Leaf litter distribution	-
Litter distribution	-
Dead wood	-
Disturbance details	None evident;
Fire history	>5 years
Fire intensity	-

Description:
Rocky slope with very open acacia woodland over dense spinifex on hard rocky clay.

Site number	Opp1-JC-28092011
Site type	Active Search Site
Latitude	-22.8138
Longitude	117.49556
Habitat	Eucalyptus/Corymbia
Habitat type	51-75
Dominant tree	Acacia
Tree cover	26-50
Dominant shrub	Buffel grass
Shrub cover	76-100
Dominant grass	Flood Plain
Grass cover	Woodland
Slope	Negligible
Soil texture	Sand
Soil colour	Brown
Surface	Coarse Gravel;
Rock cover	<5% cover
Leaf litter distribution	25-50%
Litter distribution	Concentrated under vegetation;
Dead wood	Dense
Disturbance details	Grazing - High;
Fire history	None evident
Fire intensity	

Description:
Hardey River riparian zone/floodplain. Large eucalypts up to 9 m over acacia trees to 5 m over sparse acacia shrubs to 2 m over sparse low shrubs and Buffel grass. Many large hollows and nesting birds. Plenty of debris and leaf litter.

Site number	Opp2-JC-28092011
Site type	Active Search Site
Latitude	-22.815708
Longitude	117.491779
Habitat	Acacia (not Mulga)
Habitat type	26-50
Dominant tree	Acacia
Tree cover	0-25
Dominant shrub	Buffel grass
Shrub cover	26-50
Dominant grass	Flood Plain
Grass cover	Woodland
Slope	Negligible
Soil texture	Sandy Clay
Soil colour	Red/Brown
Surface	Fine gravel; Coarse Gravel;
Rock cover	5-30% cover
Leaf litter distribution	50-75%
Litter distribution	Evenly distributed;
Dead wood	Dense
Disturbance details	Grazing - High;
Fire history	None evident
Fire intensity	

Description:
Acacia woodland associated with Hardey River. Relatively dense cover of acacia to 6 m over sparse understorey of acacia shrubs and Buffel grass; heavily grazed. Some spinifex mature hummocks. Plentiful log debris.

NO PHOTO AVAILABLE

Site number	Opp3-JC-28092011
Site type	Active Search Site
Latitude	-22.815969
Longitude	117.496077
Habitat	Eucalyptus/Corymbia
Habitat type	26-50
Dominant tree	Acacia
Tree cover	0-25
Dominant shrub	Spinifex
Shrub cover	51-75
Dominant grass	Major Creek
Grass cover	Riparian Zone
Slope	Moderate
Soil texture	Sandy Clay
Soil colour	Red/Brown
Surface	Coarse Gravel;
Rock cover	50-90% cover
Leaf litter distribution	25-50%
Litter distribution	Concentrated under vegetation;
Dead wood	Moderate
Disturbance details	Grazing - High;
Fire history	None evident
Fire intensity	

Description:
Hardey River riparian zone.

NO PHOTO AVAILABLE

Site number	Opp4-JC-28092011
Site type	Active Search Site
Latitude	-23.204009
Longitude	117.6727
Habitat	Eucalyptus/Corymbia
Habitat type	26-50
Dominant tree	Paperbark
Tree cover	26-50
Dominant shrub	Spinifex
Shrub cover	51-75
Dominant grass	Breakaway
Grass cover	Riparian Zone
Slope	Steep
Soil texture	Sandy Clay
Soil colour	Red
Surface	Coarse Gravel; Boulders; Stones;
Rock cover	>90% cover
Leaf litter distribution	25-50%
Litter distribution	Evenly distributed;
Dead wood	Dense
Disturbance details	Grazing - Med;
Fire history	None evident
Fire intensity	

Description:
Rocky breakaway above water. Eucalyptus to 9 m over paperbarks and mixed low shrubs over spinifex hummocks. Lots of debris and hollows at ground level. Paperbark providing dense cover. Potential Northern Quoll site.

NO PHOTO AVAILABLE

Site number	Opp1-JC-29092011
Site type	Active Search Site
Latitude	-22.811176
Longitude	117.485221
Habitat	Acacia (not Mulga)
Habitat type	26-50
Dominant tree	Acacia
Tree cover	0-25
Dominant shrub	Spinifex
Shrub cover	26-50
Dominant grass	Plain
Grass cover	Open Woodland
Slope	Gentle
Soil texture	Sandy Clay
Soil colour	Red/Brown
Surface	Fine gravel; Coarse Gravel; Stones;
Rock cover	30-50% cover
Leaf litter distribution	75-100%
Litter distribution	Concentrated under vegetation;
Dead wood	Moderate
Disturbance details	Grazing - Low;
Fire history	None evident
Fire intensity	

Description:
Open mulga woodland on spinifex grass plain. Mulga to 3.5 m over mixed low shrubs over mature spinifex hummocks. Deep litter under mulga.

NO PHOTO AVAILABLE

Site number	Opp2-JC-29092011
Site type	Active Search Site
Latitude	-22.813571
Longitude	117.478025
Habitat	Mulga
Habitat type	26-50
Dominant tree	Acacia
Tree cover	0-25
Dominant shrub	Spinifex
Shrub cover	51-75
Dominant grass	Breakaway
Grass cover	Open Woodland
Slope	Moderate
Soil texture	Sandy Clay
Soil colour	Red/Brown
Surface	Coarse Gravel; Boulders; Stones;
Rock cover	>90% cover
Leaf litter distribution	0-25%
Litter distribution	Concentrated under vegetation;
Dead wood	Sparse
Disturbance details	Grazing - Low;
Fire history	None evident
Fire intensity	

Description:
Small area of woodland on breakaway, southern edge of minor hill. Mulga to 3.5 m over mixed low shrubs.

NO PHOTO AVAILABLE

Site number	Opp3-JC-29092011
Site type	Active Search Site
Latitude	-22.812233
Longitude	117.479465
Habitat	Mulga
Habitat type	26-50
Dominant tree	Acacia
Tree cover	0-25
Dominant shrub	Spinifex
Shrub cover	26-50
Dominant grass	Hilltop
Grass cover	Open Woodland
Slope	Gentle
Soil texture	Sandy Clay
Soil colour	Red/Brown
Surface	Coarse Gravel; Boulders; Stones;
Rock cover	>90% cover
Leaf litter distribution	0-25%
Litter distribution	Concentrated under vegetation;
Dead wood	Moderate
Disturbance details	Drill Pads and Tracks;
Fire history	>5 years
Fire intensity	High

Description:
Open Mulga woodland on hilltop. Old drill pads and tracks visible, but successful rehabilitation. Mixed acacia species to 3.5 m over mixed acacia shrubs to 2 m over mixed low shrubs over herbs and mature spinifex hummocks.

Site number	**Op01gb29sep11**
Site type	Active Search Site
Latitude	-22.79313
Longitude	117.498164
Habitat	Acacia (not Mulga)
Habitat type	0-25
Dominant tree	Acacia
Tree cover	51-75
Dominant shrub	Spinifex
Shrub cover	51-75
Dominant grass	Hilltop
Grass cover	Spinifex Grassland
Slope	Moderate
Soil texture	Loam
Soil colour	Red
Surface	Boulders;
Rock cover	>90% cover
Leaf litter distribution	0-25%
Litter distribution	
Dead wood	Sparse
Disturbance details	Grazing - Low;
Fire history	None evident
Fire intensity	Op01gb29sep11

Description:
Rocky slope cover with acacia shrubs over dense spinifex on dense red boulders.

Site number	Opp1-JC-30092011
Site type	Active Search Site
Latitude	-22.817551
Longitude	117.502368
Habitat	Mulga
Habitat type	0-25
Dominant tree	Acacia
Tree cover	0-25
Dominant shrub	Spinifex
Shrub cover	26-50
Dominant grass	Hill Slope
Grass cover	Open Woodland
Slope	Gentle
Soil texture	Sandy Clay
Soil colour	Brown
Surface	Coarse Gravel; Boulders; Stones;
Rock cover	50-90% cover
Leaf litter distribution	0-25%
Litter distribution	Concentrated under vegetation;
Dead wood	Moderate
Disturbance details	Grazing - Low;
Fire history	None evident
Fire intensity	

Description:
Open mulga woodland on lower slopes of minor hills. Mulga to 4 m over mixed acacia shrubs to 2 m over low shrubs to 1 m over spinifex hummocks and Buffel grass.

Site number	**Opp2-JC-30092011**
Site type	Active Search Site
Latitude	-22.818681
Longitude	117.503977
Habitat	-
Habitat type	0-25
Dominant tree	Acacia
Tree cover	0-25
Dominant shrub	Spinifex
Shrub cover	
Dominant grass	Hilltop
Grass cover	Spinifex Grassland
Slope	Moderate
Soil texture	Sandy Clay
Soil colour	Red/Brown
Surface	Coarse Gravel; Boulders; Stones;
Rock cover	>90% cover
Leaf litter distribution	0-25%
Litter distribution	Concentrated under vegetation;
Dead wood	Sparse
Disturbance details	Grazing - Low; Livestock Tracks;
Fire history	1-5 Years
Fire intensity	Medium

Description:
Spinifex grassland on minor hilltop at the end of a long medium range.

Site number	Opp3-JC-30092011
Site type	Active Search Site
Latitude	-22.822012
Longitude	117.505651
Habitat	NONE
Habitat type	
Dominant tree	Acacia
Tree cover	0-25
Dominant shrub	Spinifex
Shrub cover	26-50
Dominant grass	Hilltop
Grass cover	Spinifex Grassland
Slope	Moderate
Soil texture	Sandy Clay
Soil colour	Red
Surface	Coarse Gravel; Boulders; Stones;
Rock cover	>90% cover
Leaf litter distribution	0-25%
Litter distribution	Concentrated under vegetation;
Dead wood	Sparse
Disturbance details	None evident;
Fire history	1-5 Years
Fire intensity	Medium

Description:
Hilltop Spinifex grassland. Fire has killed all mulga. Areas of boulder fields.

Site number	Opp4-JC-30092011
Site type	Active Search Site
Latitude	-22.841678
Longitude	117.502636
Habitat	Acacia (not Mulga)
Habitat type	0-25
Dominant tree	Acacia
Tree cover	0-25
Dominant shrub	Spinifex
Shrub cover	26-50
Dominant grass	Hill Slope
Grass cover	Spinifex Grassland
Slope	Steep
Soil texture	Sandy Clay
Soil colour	Red
Surface	Coarse Gravel; Boulders; Stones;
Rock cover	>90% cover
Leaf litter distribution	0-25%
Litter distribution	Concentrated under vegetation;
Dead wood	Sparse
Disturbance details	None evident;
Fire history	>5 years
Fire intensity	Medium

Description:
Steep rocky hill slope with large boulder fields. Ridge runs all the way north to Hardey River.

Site number	Opp01gb2oct11
Site type	Opportunistic Species Record
Latitude	-22.78023
Longitude	117.497389
Habitat	Acacia (not Mulga)
Habitat type	26-50
Dominant tree	Acacia
Tree cover	26-50
Dominant shrub	Other grasses
Shrub cover	0-25
Dominant grass	Plain
Grass cover	Woodland
Slope	NONE
Soil texture	Loam
Soil colour	Orange
Surface	Coarse Gravel; Stones;
Rock cover	>90% cover
Leaf litter distribution	25-50%
Litter distribution	Concentrated under vegetation;
Dead wood	Moderate
Disturbance details	Grazing - High; Livestock Tracks; Erosion Channels;
Fire history	None evident
Fire intensity	

Description:
Semi open acacia woodland of moderately dense acacia trees over moderately dense acacia shrubs over scattered grass sp. on rocky soil.

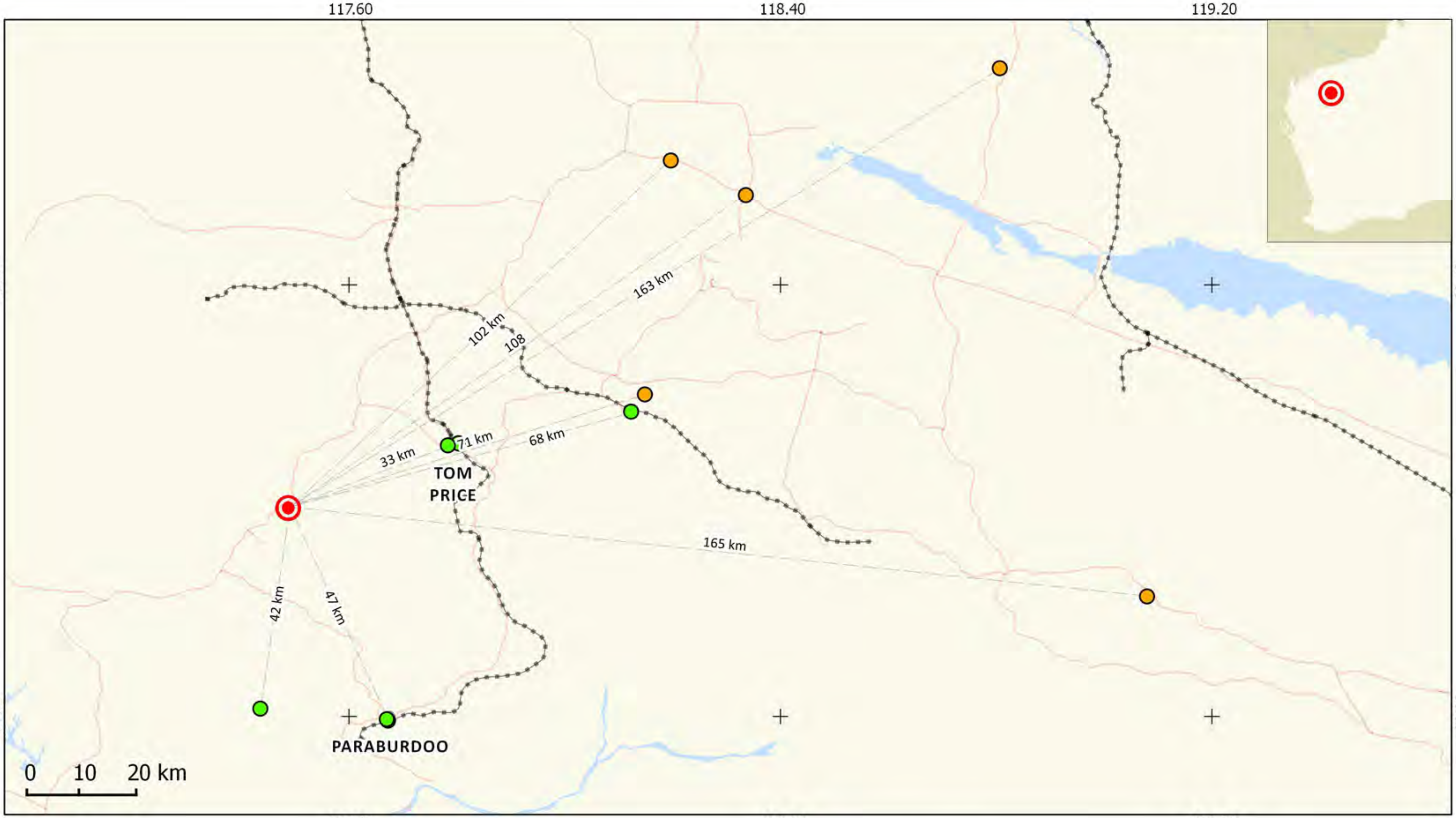
NO PHOTO AVAILABLE

Site number	Opp1-JC-02102011
Site type	Active Search Site
Latitude	-22.806351
Longitude	117.476832
Habitat	NONE
Habitat type	0-25
Dominant tree	Acacia
Tree cover	0-25
Dominant shrub	Spinifex
Shrub cover	51-75
Dominant grass	Plain
Grass cover	Spinifex Grassland
Slope	Negligible
Soil texture	Sandy Clay
Soil colour	Brown
Surface	Fine gravel; Coarse Gravel;
Rock cover	<5% cover
Leaf litter distribution	0-25%
Litter distribution	Concentrated under vegetation;
Dead wood	Sparse
Disturbance details	None evident;
Fire history	None evident
Fire intensity	

Description:

Site number	Opp2-JC-02102011
Site type	Active Search Site
Latitude	-22.804572
Longitude	117.477906
Habitat	NONE
Habitat type	0-25
Dominant tree	Acacia
Tree cover	
Dominant shrub	Buffel grass
Shrub cover	
Dominant grass	Plain
Grass cover	Cracking Clay
Slope	NONE
Soil texture	Sandy Clay
Soil colour	Brown
Surface	Slight cracking; Surface crust; Fine gravel; Coarse Gravel;
Rock cover	<5% cover
Leaf litter distribution	0-25%
Litter distribution	Concentrated under vegetation;
Dead wood	Sparse
Disturbance details	Grazing - High; Livestock Tracks; Erosion Channels;
Fire history	None evident
Fire intensity	

Description:



Olive Python record
Northern Quoll records
Study area
Town
Distance line
Railway
Road

Appendix 5

Location of the closest records from previous surveys for the Northern Quoll and the Pilbara Olive Python

PHOENIX ENVIRONMENTAL SCIENCES

AUTHOR: G. Bouteloup	**CLIENT:** Dragon Energy Ltd.	
DATE: November 2011	**Scale:** 1:800000	**PROJECT:** Rocklea Iron Ore Project
Coordinate System: Projection: Transverse Mercator; Datum: WGS84		

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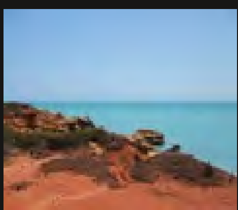
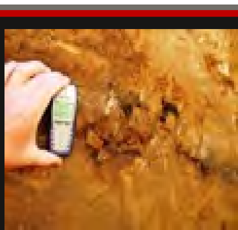
LEVEL 2 FLORA & VEGETATION SURVEY ROCKLEA PROJECT AREA

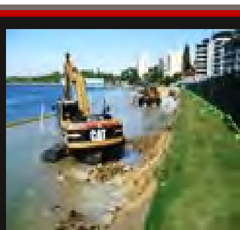
This document has been prepared for:

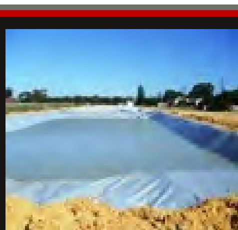
DRAGON ENERGY LTD

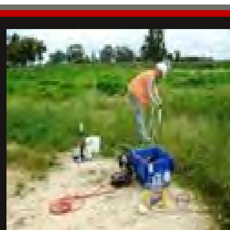
April 2012











REVISION CHART					
Version	**Description**	**Author**	**Reviewed**	**Client Copy**	**Date**
Level 2 Flora and Vegetation Survey	*Final Report for Issue*	Caroline Gill	J.Bird	Electronic	*13/04/12*

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Version/Date: Final Report, April 2012

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EXECUTIVE SUMMARY

The findings of the Level 2 Flora and Vegetation Survey conducted in September 2011 of the Rocklea Project area can be summarised as follows:

- Botanists recorded 203 taxa across the Rocklea Project survey area representing 41 families and 101 genera.

- No Declared Rare Flora species as listed under subsection (2) of Section 23F of the Western Australian *Wildlife Conservation Act 1950* or under the *Environment Protection and Biodiversity Conservation Act 1999* were recorded within the survey area.

- One Priority Flora species as listed by the DEC (Smith, 2010) was recorded within the survey area: *Ptilotus trichocephalus* (P4). Thirty four individuals of this priority species were recorded in one population on the colluvial flat approximately 120 m northwest of the Wittenoom-Nanutarra Road within vegetation unit Ax.Av.Aap.Tw.Ta.

- Nine exotic (weed) species were recorded for the survey area, which represents 4.4% of the total flora recorded. Four High and Moderate category weeds (as rated by The Environmental Weeds Strategy for WA (CALM, 1999)) were recorded for the survey area:

  **Cenchrus ciliaris* (Buffel Grass) was widespread and abundant throughout the creekline vegetation units, and present but less abundant throughout the vegetation of the colluvial plains and drainage zones.

  **Cenchrus setiger* (Birdwood Grass) was widespread throughout the same units but was significantly less abundant.

  **Malvastrum americanum* was recorded in low densities throughout the stony plains and drainage zones vegetation types.

  **Sonchus oleraceus* was recorded in one sampling quadrat (RQ14) within the creekline vegetation unit.

- No Declared Plants (as listed under the *Agriculture and Related Resources Protection Act 1976*) were recorded for the survey area.

- Nine vegetation units were mapped and described for the survey area. Broadly these represent four major topographic groups: Hilltops and slopes; stony rises and swales; stony plains and drainage zones; and creeklines. Descriptions are as follows:

Aa.Apr.Epo.Te - *Acacia aptaneura* and *A. pruinocarpa* Open Low Woodland over *Acacia* spp. and *Eremophila phyllopoda* subsp. *obliqua* Shrubland to Open Shrubland over *Triodia epactia* Hummock Grassland.

El.Aan.Te - Scattered *Eucalyptus leucophloia* over *Acacia ancistrocarpa* Open Shrubland over *Triodia epactia* Hummock grassland on stony hilltops, and *Acacia aptaneura* and other *Acacia* spp. over *Triodia* spp. Hummock Grassland on slopes.

El.Ap.Ta - Scattered *Eucalyptus leucophloia* over patches of *Acacia pruinocarpa* over *Triodia angusta* greater than *T. wiseana* Closed Hummock Grassland.

Aap.Ax.Epo.Sgch.Tb - *Acacia aptaneura* Low Open Woodland on upper gentle stony slopes and *Acacia xiphophylla* on lower stony slopes over *Eremophila phyllopoda* subsp. *obliqua* and *Senna glutinosa* subsp. *chatelainiana* Low Open Shrubland over *Triodia brizoides* Hummock Grassland with patches of *Sporobolus australasicus* Tussock Grassland.

Ch.Ta - Scattered to Low Open Woodland of *Corymbia hamersleyana* over *Acacia* spp., *Eremophila* spp. and *Senna* spp. Open Shrubland over *Triodia angusta* Hummock Grassland.

Aap.Aan.Ec.Ef.Ta - *Acacia aptaneura* and *A. ancistrocarpa* Low Woodland over *Eremophila cuneifolia* and *E. fraseri* subsp. *fraseri* Open Shrubland over *Triodia angusta* Hummock Grassland (and **Cenchrus ciliaris* where condition is poor) in drainage lines; and *Acacia xiphophylla* Open Low Woodland over *Acacia victoriae, Senna glutinosa* subsp. *pruinosa* and *Eremophila cuneifolia* Open Shrubland over *Triodia angusta* Hummock grassland on stony lower slopes.

Ax.Sgch.Ec.Ss.Sa.Tw - *Acacia xiphophylla* Tall Shrubland to Tall Open Shrubland over patches of *Senna glutinosa* subsp. *chatelainiana* and *Eremophila cuneifolia* and *Scaevola spinescens* over *Sporobolus australasicus* Open Tussock Grassland and patches of *Triodia wiseana* on stony plains.

Ax.Av.Aap.Tw.Ta - *Acacia xiphophylla* and *A. victoria* Tall Shrubland to Tall Open Shrubland, with *A. aptaneura* in drainage lines, over *Eremophila* spp. and *Senna* spp. over mixed low shrubs over annual grasses and *Triodia wiseana* and/or *T. angusta* Hummock Grassland.

Eco.Ac.Ass.Ml.*Cc - *Eucalyptus camaldulensis* subsp. obtusa Open Woodland over patches of *Acacia citrinoviridis*, *A. sclerosperma* subsp. *sclerosperma* and *Melaleuca lasiandra* over **Cenchrus ciliaris* Open Tussock Grassland.

- Vegetation condition throughout the Rocklea Project survey area was recorded as Excellent to Very Good on hilltops and slopes, and rises and swales away from tracks. Vegetation condition was however, considerably poorer on the flats, broad stony colluvial plains and drainage lines within the survey area, and particularly along the minor and major creeklines where weed infestation by Buffel Grass was widespread and abundant. Disturbance by livestock was widespread and most pronounced throughout the creeklines and adjacent floodplains. Another major disturbance within the survey area comprised the Nanutarra-Wittenoom Road and road-side parking area where weed infestation, clearing and rubbish-dumping were evident in the adjacent vegetation, as well as along smaller tracks throughout the survey area.

- The population of Priority 4 species *Ptilotus trichocephalus* recorded for the survey area, is of significance because it represents the northern-most extent of its recorded range. The nearest record occurs 48 km to the south-south-east. It is important to note however, that the initial mining operations and infrastructure which are to be located south of the Nanutarra-Wittenoom Road, will not impact this population which lies approximately 120 m north of the road.

- No Threatened Ecological Communities or Priority Ecological Communities as defined by the Department of Environment and Conservation, or listed under the *Environment Protection and Biodiversity Conservation Act 1999* were recorded for the survey area.

- The vegetation of the survey area represented by the vegetation units: Aap.Aan.Ec.Ef.Ta, Aa.Apr.Epo.Te, El.Aan.Te., and Aap.Ax.Epo.Sgch.Tb is considered to be of elevated conservation significance because these vegetation types correspond with the "ecosystem at risk" *Lower-slope mulga* (May and McKenzie, 2002). These *Acacia aptaneura* (Mulga) shrublands over *Triodia* spp. hummock grassland vegetation units are significant due to their sensitivity to fire.

- The vegetation of the survey area represented by the vegetation unit: Eco.Ac.Ass.Ml.*Cc is considered to be of elevated conservation significance because it corresponds with the "ecosystem at risk" *All major ephemeral water courses* (May and McKenzie, 2002). This vegetation type is likely to support habitat-specific flora and fauna species. In addition to this the dominant tree species, *Eucalyptus camaldulensis* subsp. *obtusa,* is phraetophytic (ground-water dependent), and as such is susceptible to groundwater drawdown resulting from mine dewatering.

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APPENDICES

1.0 INTRODUCTION

In August 2011, Dragon Energy Ltd commissioned Dinglebird Environmental Pty Ltd (Dinglebird) to undertake a single visit Level 2 Flora and Vegetation Survey (EPA, 2004) of the Rocklea Project area (hereafter referred to as “the survey area”). The survey area comprises approximately 1,200 ha within tenement E47/1024. Located on the Nanutarra-Wittenoom Road 32 km west-south-west of the township of Tom Price in the Pilbara region of Western Australia (Figure 1), the project area intersects with a channel iron deposit (CID). The initial mining operations and associated infrastructure will be located south of the Nanutarra-Wittenoom Road, and the mining will be restricted to the removal of ore from above the water table which will range from about 5 m to 15 m below ground surface.

1.1 Survey and Report Objectives

After discussions with the Native Vegetation Assessment Branch at the Department of Mines and Petroleum (DMP), and the Native Vegetation Branch at the Department of Environment and Conservation (DEC), it was concluded that a single visit Detailed (Level 2) Flora Survey would, at this stage, be adequate to assess the flora and vegetation for Environmental Impact Assessment of the proposal. However, should a supplementary survey be deemed necessary by the regulators, to gather additional data to support a Purpose Clearing Permit application at a later date, a revisit could be undertaken. Design and implementation of the field survey was carried out without the provision of a mine plan determining the location of the proposed pit and associated infrastructure, and so the main objective was to sample the range of landforms and vegetation types represented across the project area.

The Level 2 Flora and Vegetation Survey was undertaken, as far as practicable, in accordance with the following Environmental Protection Authority (EPA) Guidance Statements:

- Position Statement 3 – *Terrestrial Biological Surveys as an Element of Biodiversity Protection* (EPA, 2002)

- Guidance Statement 51 – *Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia* (EPA, 2004)

The Level 2 Flora and Vegetation assessment aimed to provide baseline information regarding vegetation and flora values of the survey area, and involved the following components:

- desktop review of available information including literature and significant flora species identified in the Department of Environment and Conservation (DEC) database search
- a site visit to detail the vegetation and flora present on site
- a targeted search for any Threatened (T) or Priority (P) species known from the area (as identified in the DEC database search)
- mapping of delineated vegetation units within the survey area
- assessment of the condition and conservation significance of the flora and vegetation
- preparation of a report and relevant maps

2.0 EXISTING INFORMATION

2.1 Environment

2.1.1 Climate and Rainfall

The climate of the Pilbara bioregion is semi-desert tropical, with the summers characterised by prolonged periods of hot, dry conditions, interrupted by tropical thunderstorm and cyclone events (Kendrick, 2001). Rainfall averages between about 250 and 400 mm a year, mostly falling during the summer period December to March (Van Vreeswyk, et al.,2004).

Rainfall for the area for the six months leading up to the survey (April to September 2011) was 86.4 mm compared to a long-term average for the same period of 97 mm. This represents a rainfall anomaly of 10.9%. April 2011 received higher than average rainfall for the month (49.8 mm compared to the long-term average of 27.1 mm) however, the following five months received a much lower than average rainfall. Historical rainfall data (years 1974-2012) for the Paraburdoo Aero weather station (50 km southeast of the survey area) compared to 2011 data is presented in Figure A (Bureau of Meteorology, 2012).

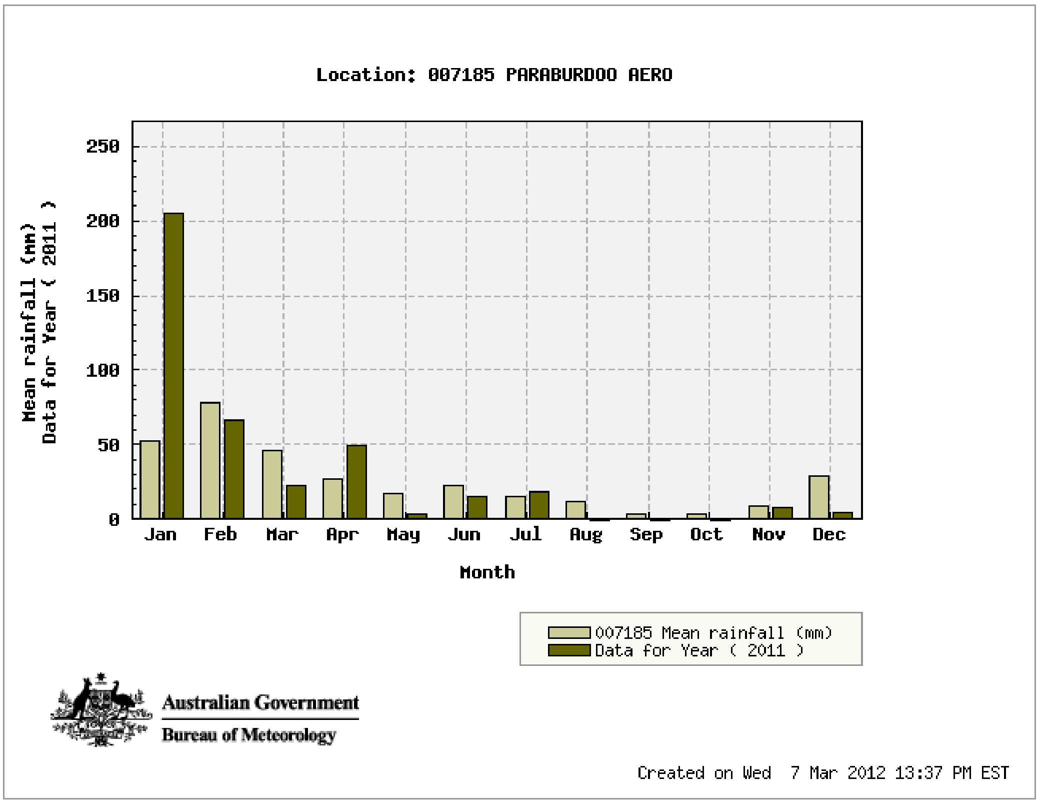

Figure A: Mean Monthly Rainfall (mm) for Paraburdoo Aero Weather Station for Years 1974 to 2012, and Rainfall Data for 2011 (BoM, 2012)

2.1.2 Biogeographic Region

Thackway and Cresswell (1995) describe a system of 85 “biogeographic regions” across Australia, known as the Interim Biogeographic Regionalisation for Australia (IBRA). The bioregions are delineated on the basis of climate, geomorphology, landform and characteristic flora and fauna. Within Western Australia there are 23 bioregions and 53 subregions.

The Rocklea Project area falls within the Pilbara bioregion, and within the Pilbara 3 (PIL3) Hamersley subregion which is defined by Kendrick (2001) as:

The Southern section of the Pilbara Craton. Mountainous area of Proterozoic sedimentary ranges and plateaux, 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 on skeletal soils of the ranges.

2.1.3 Geomorphology and Soils

The survey area falls within the Hamersley Plateau Geomorphic Province, as defined by Payne et al. (1988), which occupies the watershed between the Ashburton River and the Fortescue River, and is based on a series of Proterozoic rocks including jaspilite and basalt, and to a lesser extent dolomite, shale, siltstone and acid volcanics. The area is characterised by a rugged terrain of high plateaus, mountain ranges, and hills with steep stony slopes.

The soils of the survey area belong to two soil regions as mapped and described by Payne et al. (1988); the Fortescue and the Alluvial soil regions. The Fortescue soil region occurs on hills, plateaus, valley plains and narrow drainage floors formed on basalts. The soils are predominantly nutrient-poor skeletal loams on hills and hillsides, and shallow stony alkaline loams and clays on lower footslopes. The Alluvial soil region is restricted to flood plains and watercourses and within the survey area is represented across the Hardey River and the adjacent alluvial plains. The soils are relatively fertile deep silty loams and clays, with minor areas of nutrient-poor sands.

2.1.4 Conservation Reserves within the Hamersley (PIL3) Subregion

The Hamersley (PIL3) Subregion has 14.1% of its area reserved within the following reserves designated to the conservation of fauna and flora, and recreation:

- A-class Karijini National Park, which lies approximately 70 km north of the survey area.
- C-class Cane River Conservation Park, which lies approximately 190 km northwest of the survey area.

2.1.5 Major Threats to Flora and Vegetation within the PIL3 Subregion

The major threats to biodiversity within the subregion are associated with the main land uses of the area; pastoralism and mining.

Pastoralism has resulted in a highly modified environment: erosion and compaction due to trampling by livestock; reduced flora species diversity and densities as a result of grazing, and their subsequent replacement by both less palatable native species and introduced pasture species such as **Cenchrus ciliaris* (Buffel Grass); and destruction of native fauna habitat. These modifications are most evident in areas where water is present, both natural watercourses (creeks and rivers) and developed water points (dams and bores) where livestock gather. Plains adjacent to drainage zones and watercourses are also impacted as their soils are susceptible to erosion and the native tussock grasslands and chenopod shrublands are preferentially grazed (Payne et al., 1998; Van Vreeswyck et al., 2004).

The major threats associated with mining activity in the subregion are land clearing, and changes to hydrological regimes resulting from mine dewatering and extraction of water for domestic and production purposes. These effects can have a profound impact on natural habitats albeit very localised (Van Vreeswyck et al., 2004).

2.1.6 Land Systems

In their regional survey of the Ashburton River Catchment (of which the Rocklea Project area was part) undertaken on behalf of the Western Australian Department of Agriculture, Payne et al. (1988) defined 63 land systems based on landform, soils and vegetation. Within the Rocklea Project survey area five land systems are represented: Robe; Rocklea; Paraburdoo; Boolgeeda; and River (Figure 2). Descriptions for these Land Systems are as follows:

Boolgeeda Drainage floors supporting moderately dense mulga low woodlands over *Triodia pungens*; and lower stony plains supporting *Acacia aneura* and other *Acacia* shrubs over *Triodia wiseana* grasslands. Within the survey area it is represented along the drainage floor of the Hardey River and the lower colluvial plains, hills and rises adjacent to it.

Paraburdoo Basalt derived stony gilgai plains. Within the survey area this system occurs across the upper interfluves supporting *Acacia xiphophylla* shrublands, numerous low shrubs and annual grasses as well as *Triodia wiseana*; and the wide drainage zones supporting *Acacia xiphophylla* and *A. victoriae* shrublands, over degraded chenopod low shrublands/herblands in the western corner of the survey area.

River Active flood plains flanking major rivers and creeks with moderately dense tall shrublands and Eucalypt woodlands. The River system occurs across a section the Hardey River and associated sandy flood banks, and nearby stony plains. This system supports a large proportion of the stock within the survey area due to the high pastoral value of the (introduced) Buffel Grass tussock grasslands. Vegetation condition is generally poor.

Robe Low plateaus, mesas and buttes of limonite with soft and hard spinifex grasslands. This system occurs across the low plateaus, lower slopes and minor drainage lines within the survey area.

Rocklea Basalt hills, plateaux, lower slopes and minor stony plains supporting hard spinifex (and occasionally soft spinifex) grasslands; vegetation mostly in very good condition.

2.2 Vegetation

2.2.1 Beard Vegetation Mapping

Beard (1975) mapped the vegetation of the Pilbara at a scale of 1:1,000,000. The Rocklea Project area lies within the Fortescue Botanical District of the Eremaean Botanical Province (Beard, 1990). The vegetation of this province is typically open, and frequently dominated by *Triodia* spp. (spinifex), *Acacia* spp. (wattles) and occasional Eucalypts. Of the four major physiographic units within the Fortescue District identified by Beard the survey area belongs to the Hamersley Plateau sub-region (generally equivalent to the Hamersley (PIL3) IBRA subregion) which is described by Van Vreeswyk, et al. (2004) as:

"rounded hills and ranges, mainly of jaspilite and dolomite with some shale, siltstone and volcanics…..and dominated by tree steppe with Eucalyptus leucophloia (snappy gum), Acacia aneura (Mulga) low woodland in valleys, …and sparse shrub steppe with Acacia xiphophylla (snakewood) on drainage lines".

Beard further delineated these broad units into vegetation associations. The vegetation associations represented within the survey area are presented in Figure 3 and defined as follows:

- Shrublands; snakewood scrub (Association 162)
- Hummock grasslands, shrub steppe; mulga & kanji over soft spinifex and *Triodia basedowii* (Association 567)

As part of the Biodiversity Audit of WA (May & McKenzie, 2002), vegetation associations (Shepherd et al., 2000) were assessed according to their reservation status in IUCN Class I-IV Reserves, non-IUCN Reserves, and CALM managed pastoral leases, and their priority for acquisition and reservation ranked as low (L), medium (M) or high (H). The rankings for the vegetation associations represented within the survey area are presented in Table 1.

Table 1: Reservation Priorities of Beard Vegetation Associations Represented within the Survey Area (Kendrick, 2001)

Beard Veg. Assoc.	Description	IUCN I-IV	Non-IUCN	DEC-Purchased Lease	Priority for Acquisition and Reservation
162	Shrublands ; snakewood scrub	0.0	0.0	0.0	H
567	Hummock grasslands, shrub steppe; mulga & kanji over soft spinifex and Triodia basedowii	189,578	1,716	0.0	L

2.2.2 Threatened Ecological Communities

Within Western Australia, Threatened Ecological Communities (TECs) are defined by DEC as those which are found to fit into one of the categories in Table 2. The categories ‘Data Deficient’ and ‘Lower Risk’ can be used to provide a list of communities not classified as threatened, but that require more information. Within Western Australia, TECs have limited protection under the *Wildlife Conservation Act 1950* and the *Environmental Protection Act 1986* (as amended). TECs are identified under the *EPBC Act* as a *matter of national environmental significance*. Any proposed impacts to federally listed TECs are required to be referred to the Department of Environment Water heritage and the Arts as a “controlled action and require assessment and approval by the Minister for Environment, Heritage and the Arts.

Table 2: Threatened Ecological Communities Category of Threat (English and Blyth, 1997).

Category	Definition
Presumed Totally Destroyed (PD)	An ecological community will be listed as presumed totally destroyed if there are no recent records of the community being extant and either of the following applies: A) Records within the last 50 years have not been confirmed despite thorough searches or known or likely habitats or B) All occurrences recorded within the last 50 years have since been destroyed.
Critically Endangered (CR)	An ecological community will be listed as **Critically Endangered** when it has been adequately surveyed and is found to be facing an extremely high risk of total destruction in the immediate future. This will be determined on the basis of the best available information, by it meeting **any one or more** of the following criteria: A) The estimated geographic range, and/or total area occupied, and/or number of discrete occurrences since European settlement have been reduced by at least 90% and **either or both** of the following apply: ▪ geographic range, and/or total area occupied and/or number of discrete occurrences are continuing to decline such that total destruction of the community is imminent (within approximately 5 years) ▪ modification throughout its range is continuing such that in the immediate future (within approximately 5 years) the community is unlikely to be capable of being substantially rehabilitated. B) Current distribution is limited, and **one or more** of the following apply (i, ii or iii): ▪ geographic range and/or number of discrete occurrences, and/or area occupied is highly restricted and the community is currently subject to known threatening processes which are likely to result in total destruction throughout its range in the immediate future (within approximately 5 years) ▪ there are very few occurrences, each of which is small and/or isolated and extremely vulnerable to known threatening processes ▪ there may be many occurrences but total area is very small and each occurrence is small and/or isolated and extremely vulnerable to known threatening processes C) The ecological community exists only as highly modified occurrences which may be capable of being rehabilitated if such work begins in the immediate future (within approximately 5 years).

Category	Definition
Endangered (EN)	An ecological community will be listed as Endangered when it has been adequately surveyed and is not Critically Endangered but is facing a very high risk of total destruction in the near future. This will be determined on the basis of the best available information, by it meeting any one or more of the following criteria (A, B or C): A) The estimated geographic range, and/or total area occupied, and/or number of discrete occurrences since European settlement have been reduced by at least 70% and either or both of the following apply (i or ii) ▪ geographic range, and/or total area occupied and/or number of discrete occurrences are continuing to decline such that total destruction of the community is likely in the short term (within approximately 10 years) ▪ modification throughout its range is continuing such that in the short term future (within approximately 10 years) the community is unlikely to be capable of being substantially restored or rehabilitated. B) Current distribution is limited, and one or more of the following apply (i, ii or iii): ▪ geographic range and/or number of discrete occurrences, and/or area occupied is highly restricted and the community is currently subject to known threatening processes which are likely to result in total destruction throughout its range in the short term future (within approximately 10 years) ▪ there are very few occurrences, each of which is small and/or isolated and extremely vulnerable to known threatening processes ▪ there may be many occurrences but total area is very small and each occurrence is small and/or isolated and extremely vulnerable to known threatening processes C) The ecological community exists only as highly modified occurrences which may be capable of being rehabilitated if such work begins in the short term future (within approximately 10 years).
Vulnerable (VU)	An ecological community will be listed as Vulnerable when it has been adequately surveyed and is not Critically Endangered or Endangered but is facing a high risk of total destruction in the medium to long-term future. This will be determined on the basis of the best available information, by it meeting any one or more of the following criteria (A, B or C): A) The ecological community exists largely as modified occurrences which are likely to be capable of being substantially restored or rehabilitated. B) The ecological community can be modified or destroyed and would be vulnerable to threatening processes, is restricted in area and/or range and/or is only found at a few locations. C) The ecological community may still be widespread but is believed likely to move into a category of higher threat in the medium to long-term future because of existing or impending threatening processes.
Data Deficient (DD)	An ecological community which has not been adequately evaluated with respect to status or where there is currently insufficient information to assign it to a particular category. (An ecological community with poorly known distribution or biology that is suspected to belong to any of the above categories. These ecological communities have a high priority for survey and/or research.)
Lower Risk (LR)	An ecological community that has been adequately surveyed and does not qualify for any of the above categories of threat and appears unlikely to be under threat of significant modification or destruction in the short to medium term future.

The *EPBC Act* provides protection for a subset of the state listed TECs under federal legislation. TECs under the *EPBC Act* are defined as those communities which are:

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

2.2.3 Priority Ecological Communities

Possible TECs that do not meet survey criteria or that are not adequately defined are added to DEC's Priority Ecological Community List under Priorities 1, 2 and 3. These three categories are ranked in order of priority for survey and/or definition of the community, and evaluation of conservation status, so that consideration can be given to their declaration as TECs. Ecological communities that are adequately known, and are rare but not threatened or meet criteria for Near Threatened (P1, 2 or 3), or that have been recently removed from the threatened list, are placed in Priority 4. These ecological communities require regular monitoring. Conservation dependent ecological communities are placed in Priority 5.

2.2.4 TEC and PEC Database Search

DEC identify and list TECs, and enter known populations and their locations into the Department's database. A search of DEC's database for known records of TECs and PECs was undertaken using the search coordinates 548000mE ; 7480000mN, 552000mE ; 7480000mN, 552000mE ; 7471000mN, 548000mE ; 7471000mN plus a 30 km radial buffer. Four occurrences of the TEC *Themeda grasslands of the Pilbara region* were recorded within the search area, the nearest being approximately 25 km north on Hamersley Station. This "Vulnerable" ecological community is restricted to areas of heavy clays, and is considered to be at risk from grazing and trampling by stock, weed invasion, changed fire regimes and alteration of hydrology.

In addition to TECs and PECs there are a set of ecological communities not yet formally approved by the Minister for the Environment, but considered by ecologists to be "ecosystems at risk" (May and McKenzie, 2002). Ecological communities that fall into this category, that are recorded for this IBRA subregion, and that may be of relevance to the survey area are:

- *Lower-slope mulga* - listed as being under threat from frequent fires preventing regeneration (Kendrick, 2001).
- *All major ephemeral water courses* - listed as being under threat from grazing and trampling by stock, large fires and invasion by Buffel Grass (**Cenchrus ciliaris*) and Ruby Dock (**Acetosa vesicaria*) Kendrick (2001).

2.3 Threatened and Priority Flora

2.3.1 State Legislation

Threatened Flora (T) are flora that have been adequately surveyed and are considered to be in danger of extinction, rare, or otherwise in need of special protection within Western Australia. Threatened Flora are protected under the *Wildlife Conservation Act 1950* (as amended).

Additionally in Western Australia there are four categories of Priority Flora, which are not specifically covered under current legislation, but their conservation status warrants some protection. Three categories of Priority Flora are allocated to species that are poorly known (Priority 1 to 3). These require more information to be assessed for inclusion as Threatened Flora. The categories are arranged to give an indication of the priority for undertaking further surveys based on the number of known sites, and the degree of threat to those populations. A fourth category of priority (Priority 4) is included for those species that have been adequately surveyed and are considered to be rare but not currently threatened.

2.3.2 Threatened and Priority Flora Database Search Results

A search of the DEC's Threatened (Declared Rare) and Priority Flora Database (DEFL) and the Western Australian Herbarium (WAH) Specimen Database was undertaken for known records within a 30 km radius of the survey area using the search coordinates 548000mE ; 7480000mN, 552000mE ; 7480000mN, 552000mE ; 7471000mN, 548000mE ; 7471000mN. The search revealed that seventeen conservation significant flora species were recorded within the survey area plus 30 km radial buffer, comprising one Threatened Flora species and sixteen Priority Flora species. The list of these Threatened and Priority Flora is provided in Table 3.

Table 3: Significant Flora Species Records Known from within a 30 km Radius of the Survey Area.

Species name	Cons. Code (State)	Cons. Code (EPBC)
Lepidium catapycnon	T	Vulnerable
Bothriochloa decipiens var. *cloncurrensis*	1	Not listed

Species name	Cons. Code (State)	Cons. Code (EPBC)
Eucalyptus lucens	1	Not listed
Lepidium amelum	1	Not listed
Sida sp. Hamersley Range (K. Newbey 10692)	1	Not listed
Indigofera ixocarpa	2	Not listed
Scaevola sp. Hamersley Range basalts (S. van Leeuwen 3675)	2	Not listed
Spartothamnella puberula	2	Not listed
Dampiera anonyma	3	Not listed
Geijera salicifolia	3	Not listed
Goodenia sp. East Pilbara (A.A. Mitchell PRP 727)	3	Not listed
Olearia mucronata	3	Not listed
Ptilotus subspinescens	3	Not listed
Rostellularia adscendens var. *latifolia*	3	Not listed
Acacia bromilowiana	4	Not listed
Eremophila magnifica subsp. *magnifica*	4	Not listed
Ptilotus trichocephalus	4	Not listed

2.3.3 Federal Legislation

Some flora species have additional protection under the *Environment Protection and Biodiversity Conservation Act (EPBC) 1999*. In Western Australia, this predominantly consists of Threatened Flora. Penalties apply for any damage to individuals, populations or habitats of species protected. A search of the *EPBC Act* Database identified one flora species of conservation significance known for the search area; *Lepidium catapycnon* is listed as Vulnerable under the *EPBC Act* (DSEWPC, 2011).

3.0 METHODS

3.1 Desktop Review

A desktop review was undertaken which incorporated a literature review of available regional historical geological, soil and landform, and vegetation technical bulletins, reports, maps and datasets; and of flora reports relating to survey areas within the vicinity of the Rocklea Project area (Biota, [2007] *A Vegetation and Flora Survey of the West Turner Section 10 Area*, and Pilbara Iron, [2008] *Infrastructure Corridor Botanical Survey Work for Western Turner Section 10 and Infrastructure Corridor*).

Using the search coordinates 548000mE;7480000mN, 552000mE;7480000mN, 552000mE;7471000mN, 548000mE;7471000mN plus 30 km radial buffer, a search of the following databases was undertaken to determine the conservation significant species and communities that may occur in the area:

- Department of Environment and Conservation's (DEC) databases for Threatened (Declared Rare and Priority) Flora, the Western Australian Herbarium (WAH) Specimen and Declared Rare Flora.
- DEC databases for Threatened Ecological Communities (TECs).
- DEC *NatureMap* search tool.
- Department of Sustainability, Environment, Water, Population and Communities (DSEWPAC) Protected Matters Search Tool.

3.2 Field Survey

Between 26 September and 5 October 2011, Dinglebird botanists Caroline Gill and Paul Macintyre, undertook a single visit plot-based flora and vegetation survey of the Rocklea Project area. Survey methodology was based on a Level 2 Flora and Vegetation Survey as outlined in Guidance Statement 51 (EPA, 2004), and consistent with methodology used for botanical surveys in the Pilbara region, to enable comparative referencing of data.

Nineteen 50m by 50m floristic quadrats were established and sampled in the main flowering season for the area (spring). Quadrat locations (Table 4 and Figure 4) were selected to represent the range of vegetation types and landforms occurring throughout the survey area, and were 50m by 50m as this ensures a good sample size for flora in the Pilbara bioregion. Quadrats were permanently marked using steel fence droppers at all four corners.

Table 4: Floristic Quadrat and Releve Locations within the Survey Area.

Site No.	Site Type	Coordinates (WGS84 datum) Northwest Corner
RQ01	Quadrat	551267mE 7476941mN
RQ02	Quadrat	551284mE 7481500mN
RQ03	Quadrat	550535mE 7478763mN
RQ04	Quadrat	548830mE 7477137mN
RQ05	Quadrat	548552mE 7477379mN
RQ06	Quadrat	549189mE 7477283mN
RQ07	Quadrat	548883mE 7477650mN
RQ08	Quadrat	550645mE 7475941mN
RQ09	Quadrat	549847mE 7477269mN
RQ10	Quadrat	551141mE 7475279mN
RQ11	Quadrat	549880mE 7475246mN
RQ12	Quadrat	549662mE 7478686mN
RQ13	Quadrat	549142mE 7478065mN
RQ14	Quadrat	551012mE 7479873mN
RQ15	Quadrat	550620mE 7478397mN
RQ16	Quadrat	550093mE 7476549mN
RQ17	Quadrat	551055mE 7479362mN
RQ18	Quadrat	550449mE 7477198mN
RQ19	Quadrat	550893mE 7474957mN
RR01	Releve	551380mE 7481376mN
RR02	Releve	549979mE 7475160mN

The information recorded at each 50m by 50m quadrat included:

- A GPS location at the NW corner (WGS84, accuracy <5m).
- Photograph at the NW corner.
- Vegetation structure (WAPC, 2000)(Table 4).
- Species present (including height and density).
- Soil description.
- Landform description.
- Land system allocation.
- Aspect.
- Condition (WAPC, 2000)(Table 5).

Additionally, two releves (unbounded flora survey sites) were sampled (constituting a similar sample size to a 50 m x 50 m plot) to capture additional floristic data in areas where a 50m by 50m quadrat would not have adequately captured the floristics.

An area of the site with known records of *Ptilotus trichocephalus,* a Priority 4 Flora species, was traversed in a systematic fashion to account for any records of this conservation significant species present at the time of the survey. Locations of individuals encountered were recorded using a GPS (WGS84 Datum).

3.3 Data Analysis

3.3.1 Flora and Taxonomy

The flora inventory was produced from all collections made within the survey area. Flora specimens were either identified in the field, or collected and identified using the resources (keys, publications and databases) of the WA Herbarium. Nomenclature is based on the DEC's WA Herbarium flora database, (Florabase, 2012).

3.3.2 Multivariate Analysis of Floristic Data

A multivariate analysis of the floristic plot data from the nineteen plots and two releves sampled was undertaken using PRIMER v6 software. Presence/absence data for all sampling sites was analysed using the Jaccard resemblance measure (a similarity index well suited to presence/absence ecological data). A hierarchical cluster analysis and Non-metric Multi-Dimensional Scaling (MDS) were then performed on the resemblance matrix to assess similarity between the sites in terms of species composition, and in relation to two environmental factors; Land Systems and landscape position, in an effort to determine potential environmental correlates. These analyses assist in delineating vegetation types for mapping, but in the absence of larger regional datasets[1] for comparison, are less useful in assessing vegetation conservation significance in a regional context. Similarity Percentages (SIMPER) analysis was also performed to determine which species contributed most to the dissimilarity between groups of sites from different Land Systems, and between groups of sites from different positions in the landscape.

3.3.3 Vegetation Mapping

Vegetation description and mapping was completed using a combination of aerial photo-interpretation, Land System mapping, on-ground confirmation,

1 The DEC Pilbara Biological Survey will provide a valuable regional dataset for comparison of vegetation and floristic communities for the bioregion, however data from this study is not yet available.

vegetation structure data and analysis of floristic data (using PRIMER v6). Each vegetation unit was defined by the dominant plant species (>2% cover) throughout its extent, using the vegetation structure classes of the Western Australian Planning Commission (2000) (Table 5).

Vegetation condition was assessed using the Vegetation Condition Scale (Keighery, 1994), presented in Table 6.

Table 5: Vegetation Structure Classes (Western Australian Planning Commission, 2000).

Life Form/ Height Class	Canopy Cover (percentage)			
	100% – 70%	**70% – 30%**	**30% – 10%**	**10% – 2%**
Trees 10–30m	Closed Forest	Open Forest	Woodland	Open Woodland
Trees <10m	Low Closed Forest	Low Open Forest	Low Woodland	Low Open Woodland
Shrub Mallee	Closed Shrub Mallee	Shrub Mallee	Open Shrub Mallee	Very Open Scrub Mallee
Shrubs >2m	Closed Tall Scrub	Tall Open Scrub	Tall Shrubland	Tall Open Shrubland
Shrubs 1–2m	Closed Heath	Open Heath	Shrubland	Open Shrubland
Shrubs <1m	Closed Low Heath	Open Low Heath	Low Shrubland	Low Open Shrubland
Grasses	Closed Grassland	Grassland	Open Grassland	Very Open Grassland
Herbs	Closed Herbland	Herbland	Open Herbland	Very Open Herbland
Sedges	Closed Sedgeland	Sedgeland	Open Sedgeland	Very Open Sedgeland

Table 6: Vegetation Condition Scale (Keighery, 1994).

Condition	Definition
Pristine	No obvious signs of disturbance.
Excellent	Vegetation structure intact, disturbance affecting individual species; weeds are non-aggressive species.
Very Good	Vegetation structure altered; obvious signs of disturbance.
Good	Vegetation structure significantly altered by very obvious signs of multiple disturbance; basic vegetation structure or ability to regenerate is retained.
Degraded	Basic vegetation structure severely impacted by disturbance; scope for regeneration but not to a state approaching good (sic) condition without intensive management.
Completely Degraded	Vegetation structure not intact; the area completely or almost completely without native species ('parkland cleared').

4.0 RESULTS

4.1 Flora Field Survey

4.1.1 Statistics

Botanists recorded 203 taxa across the Rocklea Project survey area, nine of which were exotic (weed) species. The flora species inventory recorded for the survey area is presented in Appendix 1.

The 203 species represented 41 families and 101 genera. The families represented by the largest number of species are shown in Table 7. The genera represented by the largest number of species are shown in Table 8.

Table 7: Most Abundant Vascular Plant Families present in the Survey Area.

Family	Common Name	No. of Species
FABACEAE	Peas	33
POACEAE	Grasses	28
MALVACEAE	Mallows	23
ASTERACEAE	Daisies	14
AMARANTHACEAE	-	14

Table 8: Most Abundant Vascular Plant Genera present in the Survey Area.

Genus	Common Name	No. of Species
Acacia	Wattles	21
Ptilotus	Mulla-mullas	11
Eremophila	Emu bush	9

There were a number of taxa that could not be positively identified due to inadequate fruiting or flowering material available at the time of the survey. These taxa are labelled with a '?' or 'sp.' in Appendix 1.

4.1.2 Flora of Conservation Significance

No Declared Rare Flora species as listed under subsection (2) of Section 23F of the Western Australian *Wildlife Conservation Act 1950* or under the *Environment Protection and Biodiversity Conservation Act 1999* were recorded within the survey area.

One Priority Flora species as listed by the DEC (Smith, 2010) was recorded within the survey area: *Ptilotus trichocephalus* (P4).

4.1.2.1 *Ptilotus trichocephalus* – Priority 4

A prostrate spreading perennial herb with white flowers in September. Grows in sandy soils on colluvial plains (Florabase, 2012) (Plates 1 and 2).

Plate 1: *Ptilotus trichocephalus* (P4). Photograph: R. Davies (Source: Florabase, 2012).

Plate 2: *Ptilotus trichocephalus* (left), and habitat (right) within the Rocklea Project area. Photograph: C.Gill October, 2011.

Thirty four individuals of this priority species were recorded (with locations marked with a hand-held GPS) in one population on the colluvial flat approximately 120 m northwest of the Nanutarra-Wittenoom Road within vegetation unit Ax.Av.Aap.Tw.Ta - *Acacia xiphophylla and A. victoria Tall Shrubland to Tall Open Shrubland, with A. aptaneura in the drainage lines, over Eremophila spp. and Senna spp. over mixed low shrubs over annual grasses and Triodia wiseana and/or T. angusta Hummock Grassland.* The boundaries of this population were mapped and are presented in Figure 4. There are twelve specimen records of this priority species at the WAH, and this population represents the northern-most extent of its recorded range which extends south approximately 200 km. The nearest record occurs 48 km to the south-south-east.

4.1.3 Introduced Flora (Weeds)

Nine exotic (weed) species were recorded for the survey area, which represents 4.4% of the total flora recorded.

The Environmental Weeds Strategy for WA (EWSWA) (CALM, 1999), rated all the weeds known for Western Australia at the time of publication, according to invasiveness, distribution and environmental impact (Table 9). Weeds were classified into four categories; High, Moderate, Mild and Low. High rated species are those that all three criteria apply to (Table 9) and Moderate to which two criteria apply. The four High and Moderate category weeds recorded for the survey area are listed in Table 10.

Table 9: Criteria for Environmental Weeds Strategy Rating.

Criteria	Description
Invasiveness	Ability to invade bushland in good to excellent condition or ability to invade waterways.
Distribution	Wide current or potential distribution including consideration of known history of wide spread distribution elsewhere in the world.
Environmental Impacts	Ability to change the structure, composition and function of ecosystems. In particular an ability to form a monoculture in a vegetation community.

Table 10: The EWSWA (CALM, 1999) **Rating of Weeds for the Rocklea Project survey area.**

Weed		Rating
*	*Cenchrus ciliaris*	High
*	*Cenchrus setiger*	High
*	*Malvastrum americanum*	Moderate
*	*Sonchus oleraceus*	Moderate

**Cenchrus ciliaris* (Buffel Grass) was widespread and abundant throughout the creekline vegetation units, and present but less abundant throughout the vegetation of the colluvial plains and drainage zones (See section 4.2.1). **Cenchrus setiger* (Birdwood Grass) was widespread throughout the same units but was significantly less abundant. **Malvastrum americanum* was recorded in low densities throughout the stony plains and drainage zones vegetation types and **Sonchus oleraceus* was recorded in one sampling quadrat (RQ14) within the creekline vegetation unit. It is worth noting that these records are from a single-visit survey that involved limited sampling of the survey area and that the number of weed species within the survey area is likely to be higher, and the occurrence of the species recorded from the current survey is likely to be more widespread.

4.1.4 Declared Weeds

The Agriculture Protection Board under the *Agriculture and Related Resources Protection Act 1976* can 'Declare' a plant that must be then controlled or eradicated by landholders when it grows on their land. The control requirements of each plant species depends on the declaration status of the plant. The list of declared plants is published by the Department of Agriculture and Food (2012). There were no exotic weed species recorded within the Rocklea Project survey area that are listed as Declared Plants.

4.1.5 Multivariate Analysis of Floristic Data

The Non-metric Multi-Dimensional Scaling (MDS) performed in PRIMER v6 on the floristic site data shows similarity of the sites in terms of species composition, in relation to landscape position (Figure B), and to both landscape position and Land System (Figure C). The analysis indicates that there is a correlation between floristic composition and position in the landscape as well as Land System, with the greatest dissimilarity in floristics occurring between the 'Hilltop' and 'Drainage line' sites (77.5% dissimilarity), and between sites on the Boolgeeda and Robe Land Systems (75% dissimilarity). Similarity Percentages (SIMPER) analysis determined that the species which contributed most to the dissimilarity between the 'Hilltop' and 'Drainage line' sites were **Cenchrus ciliaris* which occurred only in drainage lines and colluvial plains, and *Eremophila phyllopoda* subsp. *obliqua* which was recorded everywhere except the 'Drainage line' sites. Species contributing most to the dissimilarity between sites on the Boolgeeda and Robe Land Systems were *Ptilotus clementii* and *Pterocaulon sphaeranthoides* which were recorded consistently in Robe Land System sites but not at all in the Boolgeeda sites. Figures B and C show a clear separation between three 'Drainage line' sites, and all other site types in terms of floristic composition. These sites (RQ14, RQ16 and RR01) represented the major drainage system riverine vegetation of the Hardey River and adjacent flood plains.

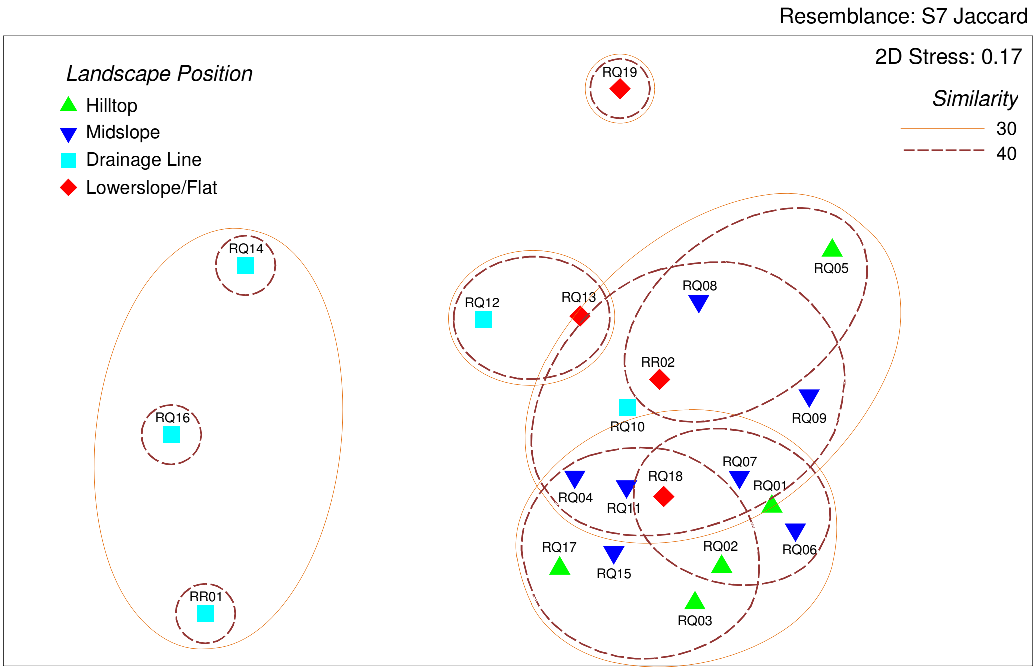

Figure B: Non-metric Multi-Dimensional Scaling (MDS) of the floristic site data in relation to Landscape Position

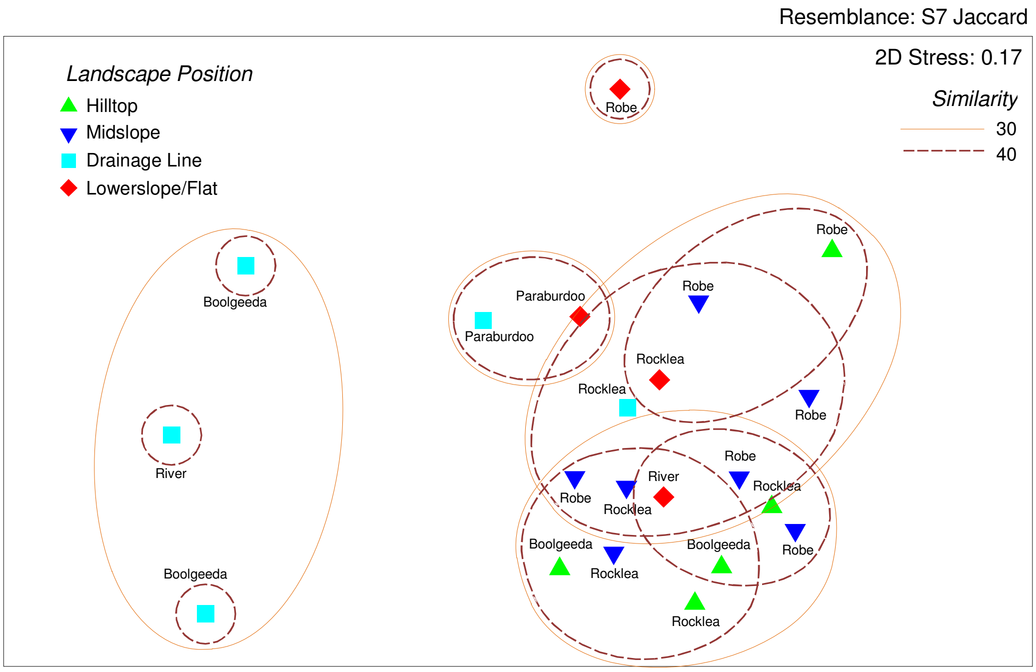

Figure C: Non-metric Multi-Dimensional Scaling (MDS) of the floristic site data in relation to Landscape Position and Land System

4.2 Vegetation

4.2.1 Vegetation Units

Nine vegetation units were mapped and described for the Rocklea Project survey area, as shown in Figure 4. Broadly these represent four major topographic groups: Hilltops and slopes; stony rises and swales; stony plains and drainage zones; and creeklines. It is important to bear in mind that although finer than the Beard (1975) mapping and Land System mapping (Payne et al., 1988), the vegetation units defined for this survey are still relatively broad and each unit incorporates a number of vegetation communities that differ in structure and floristic variants. The broad nature of the units needs to be taken into account when assessing vegetation conservation significance.

4.2.1.1 Vegetation of Hilltops, and Slopes

Four vegetation units were representative of this topographic group within the survey area, all of which were generally in Very Good to Excellent condition. Descriptions are as follows:

Aa.Apr.Epo.Te - *Acacia aptaneura* and *A. pruinocarpa* Open Low Woodland over *Acacia* spp. and *Eremophila phyllopoda* subsp. *obliqua* Shrubland to Open Shrubland over *Triodia epactia* Hummock Grassland.

El.Aan.Te - Scattered *Eucalyptus leucophloia* over *Acacia ancistrocarpa* Open Shrubland over *Triodia epactia* Hummock grassland on stony hilltops, and *Acacia aptaneura* and other *Acacia* spp. over *Triodia* spp. Hummock Grassland on slopes.

El.Ap.Ta - Scattered *Eucalyptus leucophloia* over patches of *Acacia pruinocarpa* over *Triodia angusta* greater than *T. wiseana* Closed Hummock Grassland.

Aap.Ax.Epo.Sgch.Tb - *Acacia aptaneura* Low Open Woodland on upper gentle stony slopes and *Acacia xiphophylla* on lower stony slopes over *Eremophila phyllopoda* subsp. *obliqua* and *Senna glutinosa* subsp. *chatelainiana* Low Open Shrubland over *Triodia brizoides* Hummock Grassland with patches of *Sporobolus australasicus* Tussock Grassland.

4.2.1.2 Vegetation of Rises and Swales

One vegetation unit was described for the rises and swales within the survey area. This vegetation was generally in Very Good to Excellent condition. A description is as follows:

Ch.Ta - Scattered to Low Open Woodland of *Corymbia hamersleyana* over *Acacia* spp., *Eremophila* spp. and *Senna* spp. Open Shrubland over *Triodia angusta* Hummock Grassland.

4.2.1.3 Vegetation of Stony Colluvial Plains and Drainage Lines

Three vegetation units were described for the stony colluvial plains and drainage lines within the survey area. These were generally in Good to Very Good condition. Descriptions are as follows:

Aap.Aan.Ec.Ef.Ta - *Acacia aptaneura* and *A. ancistrocarpa* Low Woodland over *Eremophila cuneifolia* and *E. fraseri* subsp. *fraseri* Open Shrubland over *Triodia angusta* Hummock Grassland (and **Cenchrus ciliaris* where condition is poor) in drainage lines; and *Acacia xiphophylla* Open Low Woodland over *Acacia victoriae, Senna glutinosa* subsp. *pruinosa* and *Eremophila cuneifolia* Open Shrubland over *Triodia angusta* Hummock grassland on stony lower slopes.

Ax.Sgch.Ec.Ss.Sa.Tw - *Acacia xiphophylla* Tall Shrubland to Tall Open Shrubland over patches of *Senna glutinosa* subsp. *chatelainiana* and *Eremophila cuneifolia* and *Scaevola spinescens* over *Sporobolus australasicus* Open Tussock Grassland and patches of *Triodia wiseana* on stony plains.

Ax.Av.Aap.Tw.Ta - *Acacia xiphophylla* and *A. victoria* Tall Shrubland to Tall Open Shrubland, with *A. aptaneura* in drainage lines, over *Eremophila* spp. and *Senna* spp. over mixed low shrubs over annual grasses and *Triodia wiseana* and/or *T. angusta* Hummock Grassland.

4.2.1.4 Vegetation of Major Creeklines

One vegetation unit was described for the major creeklines within the survey area. This unit, which comprises the riparian vegetation adjacent to the Hardey River, is generally in Good to Degraded condition. A description is as follows:

Eco.Ac.Ass.Ml.*Cc - *Eucalyptus camaldulensis* subsp. obtusa Open Woodland over patches of *Acacia citrinoviridis*, *A. sclerosperma* subsp. *sclerosperma* and *Melaleuca lasiandra* over **Cenchrus ciliaris* Open Tussock Grassland.

4.2.2 Vegetation Unit Distribution

The correspondence between the topography of the survey area, the vegetation units defined and mapped during this survey, the Land Systems, and the floristic sampling sites is presented in Table 11.

Table 11: Vegetation Units, and Floristic Sampling Sites by Land System within the Rocklea Survey Area

		Floristic Sampling Sites by Land System				
Topography	**Vegetation Unit**	**Rocklea**	**Robe**	**Boolgeeda**	**Paraburdoo**	**River**
Hilltops and Slopes	Aa.Apr.Epo.Te	RQ01	RQ06 RQ07			
	El.Ap.Ta		RQ05			
	El.Aan.Te	RQ03 RQ15		RQ02 RQ17		
	Aap.Ax.Epo.Sgch.Tb					RQ18
Rises and Swales	Ch.Ta		RQ04 RQ09			
Stony Colluvial Plains and Drainage Lines	Aap.Aan.Ec.Ef.Ta	RQ10 RQ11 RR02	RQ08			
	Ax.Sgch.Ec.Ss.Sa.Tw		RQ19			
	Ax.Av.Aap.Tw.Ta				RQ12 RQ13	
Major Creeklines	Eco.Ac.Ass.Ml.*Cc			RQ14 RR01		RQ16

4.2.3 Vegetation Condition

Vegetation condition throughout the Rocklea Project survey area was recorded as Excellent to Very Good on hilltops and slopes, and rises and swales away from tracks. Disturbance from grazing cattle was evident but minimal in these landscapes due to the hard and soft spinifex (*Triodia* spp.) hummock grassland understorey being unattractive to livestock, and the fact that the pasture grasses **Cenchrus ciliaris* (Buffel Grass) and **C. setiger* (Birdwood Grass), introduced and spread by pastoralists to enhance pastoral production, have not become widely established in these habitats. Vegetation condition was however, considerably poorer on the flats, broad stony colluvial plains and drainage lines within the survey area, and particularly along the minor and major creeklines where weed infestation by Buffel Grass was widespread and abundant due to having out-competed the native understorey species. Disturbance by livestock was widespread and most pronounced throughout the creeklines and adjacent floodplains. Another major disturbance within the survey area comprised the Nanutarra-Wittenoom Road and road-side parking area where weed infestation, clearing and rubbish-dumping were evident, as well as along smaller tracks throughout the survey area. See Appendix 3: Detailed Site Descriptions for condition of individual floristic sampling sites.

5.0 DISCUSSION

5.1.1 The Conservation Significance of the Flora within the Survey Area

Of the Threatened and Priority Flora species known from the vicinity of the survey area, as revealed in the database searches (Section 2.3.2 and Table 3) only one species, *Ptilotus trichocephalus* (P4), was recorded for the current survey and its population mapped (Figure 4). This population is of significance because it represents the northern-most extent of its recorded range. The nearest record occurs 48 km to the south-south-east. In order to investigate the presence or absence of other populations of this species, and other conservation significant species thoroughly within the survey area, a systematic search would need to be conducted, in the appropriate season, over the entire survey area following Targeted Threatened Flora Search methodology. This was beyond the scope of the current assessment. It is important to note however, that the initial mining operations and infrastructure which are to be located south of the Nanutarra-Wittenoom Road, will not impact this population which lies approximately 120 m north of the road.

5.1.2 The Conservation Significance of the Vegetation within the Survey Area

None of the vegetation units recorded from the survey area represent Threatened Ecological Communities or Priority Ecological Communities as defined by the Department of Environment and Conservation, or listed under the *Environment Protection and Biodiversity Conservation Act 1999*. However, although not yet formally recognised by the Minister for the Environment as being 'threatened' or of 'priority for conservation', there are two broad ecological communities considered to be "ecosystems at risk" (May and McKenzie, 2002) that appear to be of relevance to the survey area: *Lower-slope mulga* - listed as being under threat from frequent fires preventing regeneration (Kendrick, 2001); and *All major ephemeral water courses* - listed as being under threat from grazing and trampling by livestock, large fires and invasion by Buffel Grass (**Cenchrus ciliaris*) and Ruby Dock (**Acetosa vesicaria*) (Kendrick, 2001)

Of the vegetation units delineated and mapped for the current survey, the following are considered to be of elevated conservation significance on the basis of the information presented in Kendrick (2001):

Vegetation units Aap.Aan.Ec.Ef.Ta, Aa.Apr.Epo.Te, El.Aan.Te., and Aap.Ax.Epo.Sgch.Tb (Figure 4) correspond with the "ecosystem at risk" *Lower-slope mulga*. These *Acacia aptaneura* (Mulga) shrublands over *Triodia* spp. hummock grassland vegetation units are significant due to their sensitivity to fire.

The vegetation unit Eco.Ac.Ass.Ml.*Cc (Figure 4) represents the riverine vegetation within the survey area and corresponds with the "ecosystem at risk" *All major ephemeral water courses.* This vegetation type is likely to support habitat-specific flora and fauna species. In addition to this the dominant tree species, *Eucalyptus camaldulensis* subsp. *obtusa,* is phraetophytic (ground-water dependent), and as such is susceptible to groundwater drawdown resulting from mine dewatering. However, at this stage the mining proposal does not involve any dewatering of the permanent groundwater.

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6.0 LIMITATIONS

As with any biological survey, additional flora species including potential Threatened, Priority or other conservation significant species could be detected in subsequent surveys. For example, ephemeral species are not always present in each year/season or at the particular time a single botanical survey is conducted. This is a limitation to all botanical surveys.

Approximately 10% of Western Australian flora species are undescribed, with new species found regularly. The flora identifications for this project were completed in line with the taxonomic resources and expertise available at the time.

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FIGURES

Legend

Site Boundary

N W E S

dinglebird environmental
Level 3 Church House
26 Queen St
Fremantle WA 6160
Phone: 08 9433 6822
www.dingbird.com.au

Client:	Dragon Energy		
Project:	11-516		
Location:	Rocklea		
Date:	23/03/2012	Figure:	REV.
Drawn: AS	Checked: CG	Rocklea Project Survey Area Location	A
Fig No:	1		

Legend
- Site Boundary
- Survey Area
- Existent Road

Land Systems:
- Bg - Boolgeeda Land System
- Rir - River Land System
- Rk - Rocklea Land System
- Bob - Robe Land System
- Pa - Paraburdoo Land System
- Tab - Table Land System

0 250m 500m 1000m

dinglebird environmental
Level 3 Church House
26 Queen Street
Fremantle WA 6160
Phone: 08 9433 6822
www.dingbird.com.au

Client:	Dragon Energy
Project:	11-516
Location:	Rocklea

Date: 12/03/2012	Figure : Rocklea Project Survey Area **Land Systems**	Rev. A
Drawn: AS / Checked: CG		
Fig No : 02		

Legend
- Site Boundary
- Survey Area
- Existent Road

Pre-European Vegetation (Beard, 1975):
- Hammersley 162
- Hammersley 567

0 250m 500m 1000m

Disclaimer: The Location of all Waypoints, Shapefiles and Tracks are indicative only as the GPS used to collect the data has an accuracy of +/- 10m.
Map Boundaries should be checked before Operations proceed if this map is older than 1 year. This map should not me used if its older than 3 years.

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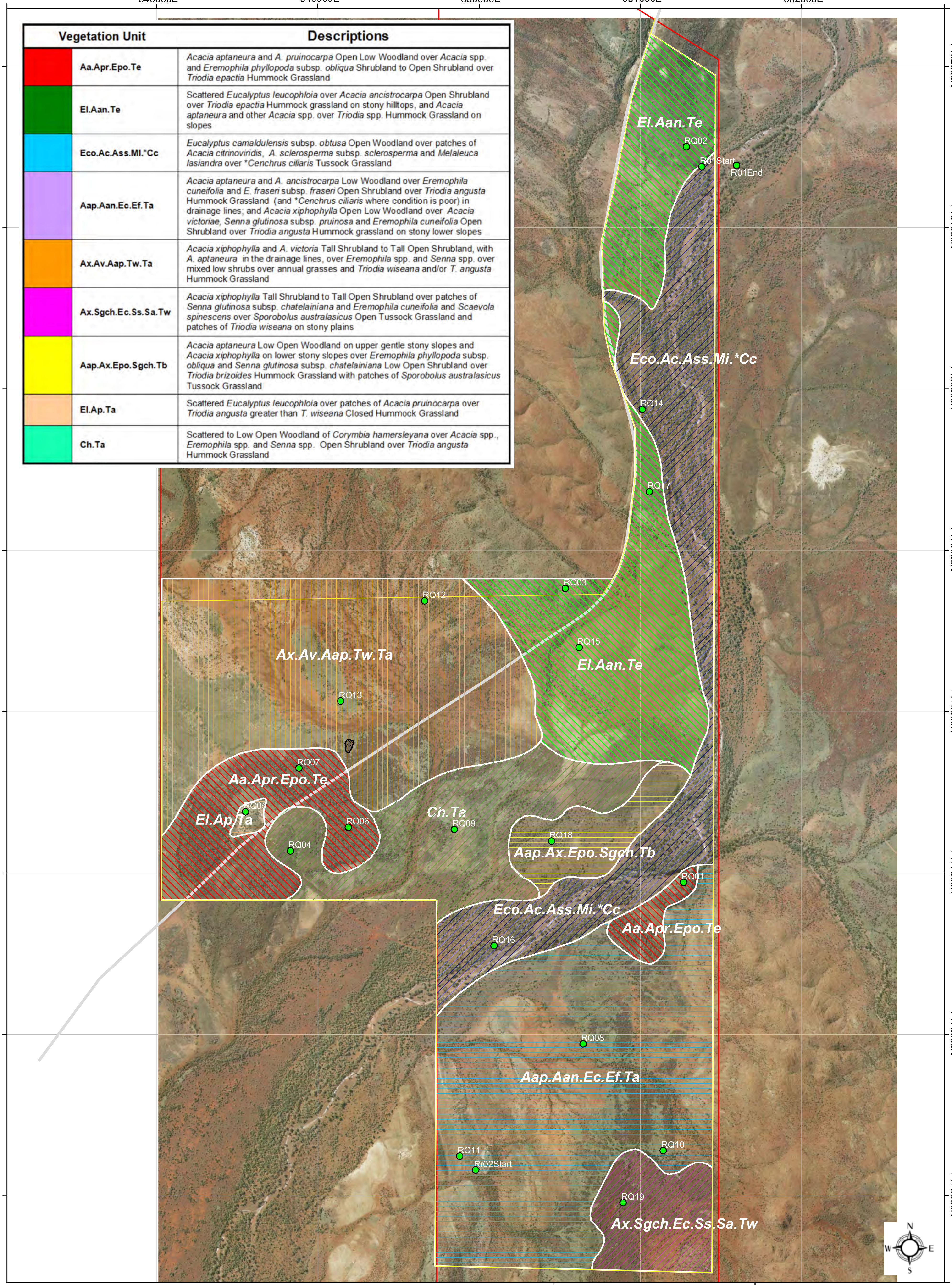
www.dingbird.com.au

Client:	Dragon Energy
Project:	11-516
Location:	Rocklea

Date: 12/03/2012	Figure : Rocklea Project Survey Area **Pre-European Vegetation by Type**	Rev. A
Drawn: AS Checked: CG		
Fig No : 03		

Vegetation Unit		Descriptions
	Aa.Apr.Epo.Te	*Acacia aptaneura* and *A. pruinocarpa* Open Low Woodland over *Acacia* spp. and *Eremophila phyllopoda* subsp. *obliqua* Shrubland to Open Shrubland over *Triodia epactia* Hummock Grassland
	El.Aan.Te	Scattered *Eucalyptus leucophloia* over *Acacia ancistrocarpa* Open Shrubland over *Triodia epactia* Hummock grassland on stony hilltops, and *Acacia aptaneura* and other *Acacia* spp. over *Triodia* spp. Hummock Grassland on slopes
	Eco.Ac.Ass.Ml.*Cc	*Eucalyptus camaldulensis* subsp. *obtusa* Open Woodland over patches of *Acacia citrinoviridis*, *A. sclerosperma* subsp. *sclerosperma* and *Melaleuca lasiandra* over *Cenchrus ciliaris* Tussock Grassland
	Aap.Aan.Ec.Ef.Ta	*Acacia aptaneura* and *A. ancistrocarpa* Low Woodland over *Eremophila cuneifolia* and *E. fraseri* subsp. *fraseri* Open Shrubland over *Triodia angusta* Hummock Grassland (and *Cenchrus ciliaris* where condition is poor) in drainage lines; and *Acacia xiphophylla* Open Low Woodland over *Acacia victoriae*, *Senna glutinosa* subsp. *pruinosa* and *Eremophila cuneifolia* Open Shrubland over *Triodia angusta* Hummock grassland on stony lower slopes
	Ax.Av.Aap.Tw.Ta	*Acacia xiphophylla* and *A. victoria* Tall Shrubland to Tall Open Shrubland, with *A. aptaneura* in the drainage lines, over *Eremophila* spp. and *Senna* spp. over mixed low shrubs over annual grasses and *Triodia wiseana* and/or *T. angusta* Hummock Grassland
	Ax.Sgch.Ec.Ss.Sa.Tw	*Acacia xiphophylla* Tall Shrubland to Tall Open Shrubland over patches of *Senna glutinosa* subsp. *chatelainiana* and *Eremophila cuneifolia* and *Scaevola spinescens* over *Sporobolus australasicus* Open Tussock Grassland and patches of *Triodia wiseana* on stony plains
	Aap.Ax.Epo.Sgch.Tb	*Acacia aptaneura* Low Open Woodland on upper gentle stony slopes and *Acacia xiphophylla* on lower stony slopes over *Eremophila phyllopoda* subsp. *obliqua* and *Senna glutinosa* subsp. *chatelainiana* Low Open Shrubland over *Triodia brizoides* Hummock Grassland with patches of *Sporobolus australasicus* Tussock Grassland
	El.Ap.Ta	Scattered *Eucalyptus leucophloia* over patches of *Acacia pruinocarpa* over *Triodia angusta* greater than *T. wiseana* Closed Hummock Grassland
	Ch.Ta	Scattered to Low Open Woodland of *Corymbia hamersleyana* over *Acacia* spp., *Eremophila* spp. and *Senna* spp. Open Shrubland over *Triodia angusta* Hummock Grassland



Legend
- Site Boundary
- Survey Area
- Existent Road

Species:
- Ptilotus trichocephalus population boundary
- Floristic quadrants

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26 Queen Street
Fremantle WA 6160
Phone: 08 9433 6822
www.dingbird.com.au

Client:	Dragon Energy
Project:	11-516
Location:	Rocklea
Date:	12/03/2012
Drawn: AS	Checked: CG
Fig No :	04

Figure :
Rocklea Project Survey Area
Vegetation Units and Priority Species Records

Rev.
A

APPENDICES

APPENDIX 1: Species List

* Denotes a weed species

Family		Species name
		Asteraceae sp.
		Convolvulaceae sp.
		Fabaceae sp.
		Malvaceae sp.
		Poaceae sp.
PTERIDACEAE		
		Cheilanthes sieberi subsp. sieberi
CYPERACEAE		
		Bulbostylis barbata
		Cyperus vaginatus
POACEAE		
		Aristida contorta
		Brachyachne prostrata
	*	*Cenchrus ciliaris*
	*	*Cenchrus setiger*
		Chrysopogon fallax
		Cymbopogon ambiguus
		Dichanthium sericeum subsp. humilius
		Dichanthium sericeum subsp. sericeum
		Enneapogon ?lindleyanus
		Enneapogon caerulescens
		Enneapogon polyphyllus
		Enneapogon robustissimus
		Enteropogon ramosus
		Eragrostis falcata
		Eriachne mucronata
		Eriachne pulchella subsp. dominii
		Eriachne pulchella subsp. pulchella
		Eulalia aurea
		Iseilema dolichotrichum
		Paraneurachne muelleri
		Paspalidium clementii
		Schizachyrium fragile
		Sporobolus australasicus
		Themeda triandra
		Triodia angusta
		Triodia brizoides

		Triodia epactia
		Triodia wiseana
PAPAVERACEAE		
	*	*Argemone ochroleuca subsp. ochroleuca*
PROTEACEAE		
		Grevillea berryana
		Grevillea stenobotrya
		Hakea lorea subsp. lorea
ZYGOPHYLLACEAE		
		Tribulus suberosus
FABACEAE		
		Acacia ?trachycarpa x tumida var. pilbarensis
		Acacia ancistrocarpa
		Acacia aneura complex
		Acacia aneura var ?aneura
		Acacia aptaneura
		Acacia bivenosa
		Acacia citrinoviridis
		Acacia cuthbertsonii subsp. cuthbertsonii
		Acacia dictyophleba
		Acacia inaequilatera
		Acacia incurvaneura
		Acacia kempeana
		Acacia monticola
		Acacia pruinocarpa
		Acacia pyrifolia
		Acacia rhodophloia
		Acacia sclerosperma subsp. sclerosperma
		Acacia synchronicia
		Acacia tetragonophylla
		Acacia victoriae
		Acacia xiphophylla
		Crotalaria medicaginea
		Indigofera monophylla
		Petalostylis labicheoides
		Rhynchosia minima
		Senna artemisioides subsp. helmsii
		Senna artemisioides subsp. oligophylla
		Senna glutinosa subsp. chatelainiana
		Senna glutinosa subsp. glutinosa
		Senna glutinosa subsp. pruinosa
		Senna notabilis
		Swainsona ?maccullochiana
		Tephrosia rosea

SURIANACEAE	
	Stylobasium spathulatum
POLYGALACEAE	
	Polygala isingii
CUCURBITACEAE	
	Cucumis maderaspatanus
CELASTRACEAE	
	Stackhousia sp.
EUPHORBIACEAE	
	Adriana tomentosa var. tomentosa
	Euphorbia alsiniflora
	Euphorbia australis
	Euphorbia biconvexa
	Euphorbia boophthona
	Euphorbia schultzii
PHYLLANTHACEAE	
	Notoleptopus decaisnei
	Phyllanthus maderaspatensis
VIOLACEAE	
	Hybanthus aurantiacus
MYRTACEAE	
	Corymbia ? dichromophloia
	Corymbia hamersleyana
	Eucalyptus camaldulensis subsp. obtusa
	Eucalyptus leucophloia
	Melaleuca lasiandra
SAPINDACEAE	
	Dodonaea petiolaris
MALVACEAE	
	Abutilon aff. lepidum
	Abutilon dioicum
	Abutilon fraseri
	Abutilon lepidum
	Abutilon sp.
	Corchorus crozophorifolius
	Corchorus lasiocarpus subsp. lasiocarpus
	Corchorus lasiocarpus subsp. parvus
	Corchorus tridens
	Gossypium australe
	Gossypium robinsonii
	Hibiscus burtonii
	Hibiscus coatesii
	Hibiscus gardneri

		Hibiscus sturtii
	*	*Malvastrum americanum*
		Melhania oblongifolia
		Sida echinocarpa
		Sida sp.
		Sida sp. spiciform panicles (E. Leyland s.n. 14/8/90)
		Sida sp. verrucose glands (F.H. Mollemans 2423)
		Triumfetta clementii
		Waltheria indica
CAPPARACEAE		
		Capparis lasiantha
		Capparis spinosa
BRASSICACEAE		
		Lepidium pholidogynum
SANTALACEAE		
		Santalum lanceolatum
LORANTHACEAE		
		Amyema fitzgeraldii
		Amyema hilliana
		Amyema sanguinea var. sanguinea
		Lysiana casuarinae
POLYGONACEAE		
	*	*Acetosa vesicaria*
CARYOPHYLLACEAE		
		Polycarpaea corymbosa
		Polycarpaea holtzei
		Polycarpaea longiflora
AMARANTHACEAE		
		Alternanthera denticulata
		Gomphrena cunninghamii
		Gomphrena kanisii
		Ptilotus aervoides
		Ptilotus aff. astrolasius
		Ptilotus auriculifolius
		Ptilotus calostachyus
		Ptilotus clementii
		Ptilotus exaltatus var. exaltatus
		Ptilotus helipteroides
		Ptilotus obovatus
		Ptilotus rotundifolius
		Ptilotus schwartzii
		Ptilotus trichocephalus (P4)
CHENOPODIACEAE		
		Dysphania rhadinostachya subsp. rhadinostachya

		Enchylaena tomentosa var. tomentosa
		Maireana georgei
		Maireana melanocoma
		Maireana planifolia
		Maireana thesioides
		Rhagodia eremaea
		Salsola australis
		Sclerolaena cornishiana
		Sclerolaena densiflora
AIZOACEAE		
		Trianthema aff. kimberleyi (MET 15 060)
		Trianthema glossostigma
NYCTAGINACEAE		
		Boerhavia coccinea
MOLLUGINACEAE		
		Mollugo molluginae
PORTULACACEAE		
		? Portulaca oleracea
RUBIACEAE		
		Oldenlandia crouchiana
BORAGINACEAE		
	*	*Heliotropium europaeum*
		Heliotropium inexplicitum
		Trichodesma zeylanicum var. zeylanicum
CONVOLVULACEAE		
		Convolvulus angustissimus
		Duperreya commixta
		Evolvulus alsinoides var. ?decumbens
		Evolvulus alsinoides var. villosicalyx
		Polymeria ambigua
SOLANACEAE		
		Nicotiana occidentalis subsp. obliqua
		Solanum lasiophyllum
		Solanum phlomoides
OLEACEAE		
		Jasminum didymum subsp. lineare
PLANTAGINACEAE		
		Stemodia grossa
SCROPHULARIACEAE		
		Eremophila abietina
		Eremophila cuneifolia
		Eremophila exilifolia
		Eremophila forrestii (Hybrid A. Brown)

		Eremophila forrestii subsp. forrestii
		Eremophila forrestii subsp. hastieana
		Eremophila fraseri subsp. fraseri
		Eremophila longifolia
		Eremophila phyllopoda subsp. obliqua
ACANTHACEAE		
		Dipteracanthus australasicus subsp. australasicus
CAMPANULACEAE		
		Wahlenbergia tumidifructa
GOODENIACEAE		
		Goodenia forrestii
		Goodenia microptera
		Goodenia muelleriana
		Goodenia stobbsiana
		Goodenia tenuiloba
		Scaevola spinescens
ASTERACEAE		
	*	*Bidens bipinnata*
		Centipeda minima
	*	*Flaveria trinervia*
		Peripleura arida
		Pluchea dunlopii
		Pluchea ferdinandi-muelleri
		Pluchea rubelliflora
		Podotheca sp.
		Pterocaulon sphaeranthoides
		Senecio pinnatifolius
	*	*Sonchus oleraceus*
		Streptoglossa bubakii
		Streptoglossa liatroides
		Streptoglossa tenuiflora
ARALIACEAE		
		Trachymene oleracea subsp. oleracea

APPENDIX 2: Species by Site

Species Name	RQ01	RQ02	RQ03	RQ04	RQ05	RQ06	RQ07	RQ08	RQ09	RQ10	RQ11	RQ12	RQ13	RQ14	RQ15	RQ16	RQ17	RQ18	RQ19	RR01	RR02
? Eriachne mucronata																	X				
Abutilon ?lepidum			X																		
Abutilon aff. *lepidum*								X	X												
Abutilon dioicum																X					
Abutilon fraseri				X																	
Abutilon lepidum							X								X		X				
Abutilon sp.								X						X							
Acacia ?dictyophleba										X											
Acacia ?trachycarpa x tumida var. *pilbarensis*																	X				
Acacia ancistrocarpa		X					X				X	X			X						X
Acacia aneura var. *?aneura*							X														
Acacia aptaneura		X	X			X	X			X	X	X			X		X	X	X		X
Acacia citrinoviridis														X		X				X	X
Acacia cuthbertsonii subsp. *cuthbertsonii*	X																				
Acacia dictyophleba															X						
Acacia inaequilatera		X							X												
Acacia kempeana		X	X	X													X				
Acacia monticola			X																		
Acacia pruinocarpa			X	X	X	X	X					X			X		X	X			
Acacia pyrifolia																X				X	
Acacia rhodophloia						X															

Species Name	**RQ01**	**RQ02**	**RQ03**	**RQ04**	**RQ05**	**RQ06**	**RQ07**	**RQ08**	**RQ09**	**RQ10**	**RQ11**	**RQ12**	**RQ13**	**RQ14**	**RQ15**	**RQ16**	**RQ17**	**RQ18**	**RQ19**	**RR01**	**RR02**
Acacia sclerosperma subsp. *sclerosperma*				X										X						X	
Acacia synchronicia			X												X		X				
Acacia tetragonophylla	X	X		X	X	X	X				X	X	X	X	X		X	X	X		X
Acacia victoriae	X	X		X	X			X	X	X	X	X	X					X			X
Acacia xiphophylla								X		X			X					X	X		X
Acetosa vesicaria																				X	
Adriana tomentosa var. *tomentosa*																				X	
Alternanthera denticulata														X							
Amyema fitzgeraldii																	X				
Amyema hilliana																X				X	
Amyema sanguinea var. *sanguinea*								X													
Argemone ochroleuca subsp. *ochroleuca*														X		X				X	
Aristida contorta	X	X	X			X	X		X		X				X			X		X	X
Asteraceae sp.	X																				
Bidens bipinnata															X		X				
Boerhavia coccinea																X					
Brachyachne prostrata																			X		
Bulbostylis barbata	X		X								X				X			X			
Capparis lasiantha																X					
Capparis spinosa																X	X				
Cenchrus ciliaris				X				X		X		X	X	X		X	X			X	X
Cenchrus setiger											X									X	
Cenchrus sp.																		X			
Centipeda minima														X							

Species Name	RQ01	RQ02	RQ03	RQ04	RQ05	RQ06	RQ07	RQ08	RQ09	RQ10	RQ11	RQ12	RQ13	RQ14	RQ15	RQ16	RQ17	RQ18	RQ19	RR01	RR02
Cheilanthes sieberi subsp. *sieberi*										X											
Chrysopogon fallax																					X
Convolvulus angustissimus										X		X	X								
Corchorus crozophorifolius	X										X			X		X			X	X	X
Corchorus lasiocarpus subsp. *lasiocarpus*				X													X				
Corchorus lasiocarpus subsp. *parvus*		X											X	X	X						
Corchorus sp.		X	X																		
Corchorus tridens												X	X	X							
Corymbia ?dichromophloia				X																	
Corymbia hamersleyana				X																	
Crotalaria medicaginea																				X	
Cucumis maderaspatanus	X		X					X		X		X		X	X	X	X	X			X
Cymbopogon ambiguus	X														X		X				
Cymbopogon sp.				X								X	X			X				X	
Cyperus vaginatus														X						X	
Dichanthium sericeum subsp. *humilius*																	X				
Dichanthium sericeum subsp. *sericeum*										X											
Dipteracanthus australasicus subsp. *australasicus*								X		X	X	X	X	X	X	X	X	X	X		X
Dodonaea petiolaris																		X	X		
Duperreya commixta				X		X				X		X		X	X	X	X	X	X		X
Dysphania rhadinostachya subsp. *rhadinostachya*	X	X	X	X		X	X			X	X				X		X	X			
Enchylaena tomentosa var. *tomentosa*								X		X									X		

Species Name	RQ01	RQ02	RQ03	RQ04	RQ05	RQ06	RQ07	RQ08	RQ09	RQ10	RQ11	RQ12	RQ13	RQ14	RQ15	RQ16	RQ17	RQ18	RQ19	RR01	RR02
Enneapogon ?lindleyanus															X			X			
Enneapogon caerulescens		X									X										
Enneapogon polyphyllus	X	X		X		X	X	X	X	X	X	X	X		X		X	X			
Enneapogon robustissimus				X																	
Enteropogon ramosus																			X		
Eremophila abietina													X								
Eremophila cuneifolia	X	X	X	X		X	X	X	X	X	X	X			X		X	X	X		X
Eremophila exilifolia																					X
Eremophila forrestii subsp. *forrestii*									X												
Eremophila forrestii subsp. *hastieana*					X		X					X	X		X						X
Eremophila fraseri subsp. *fraseri*	X	X	X						X	X	X	X	X	X			X				X
Eremophila longifolia				X																	
Eremophila phyllopoda subsp. *obliqua*	X	X	X	X	X	X	X	X	X	X	X		X		X		X	X	X		X
Eremophila sp.												X									
Eriachne mucronata				X							X	X			X		X			X	X
Eriachne pulchella subsp. *dominii*		X		X											X			X			
Eriachne pulchella subsp. *pulchella*		X		X		X	X		X										X		
Eucalyptus camaldulensis subsp. *obtusa*														X						X	
Eucalyptus leucophloia					X																
Eulalia aurea																				X	
Euphorbia ?alsiniflora												X									
Euphorbia ?boophthona				X											X						
Euphorbia australis		X		X					X		X		X				X				
Euphorbia biconvexa				X																	

Species Name	RQ01	RQ02	RQ03	RQ04	RQ05	RQ06	RQ07	RQ08	RQ09	RQ10	RQ11	RQ12	RQ13	RQ14	RQ15	RQ16	RQ17	RQ18	RQ19	RR01	RR02
Euphorbia boophthona									X				X								
Euphorbia schultzii														X		X					
Euphorbia sp.										X										X	
Evolvulus alsinoides var. *villosicalyx*		X		X						X			X		X		X				
Fabaceae sp.											X										
Flaveria trinervia																	X				
Gomphrena ?kanisii			X																		
Gomphrena cunninghamii	X		X				X		X		X				X	X		X			
Gomphrena kanisii								X			X				X						X
Goodenia forrestii	X	X		X	X	X	X	X					X								X
Goodenia microptera			X	X			X	X	X	X			X		X		X				
Goodenia muelleriana							X	X		X	X		X		X			X			X
Goodenia stobbsiana		X																			
Goodenia tenuiloba	X	X	X												X						
Gossypium australe												X									
Gossypium robinsonii																X				X	
Grevillea berryana	X					X										X		X			X
Grevillea stenobotrya						X	X								X						
Hakea lorea subsp. *lorea*		X																		X	
Heliotropium inexplicitum		X													X						X
Hibiscus burtonii						X															
Hibiscus coatesii																	X				
Hibiscus gardneri																		X			
Hibiscus sturtii								X													

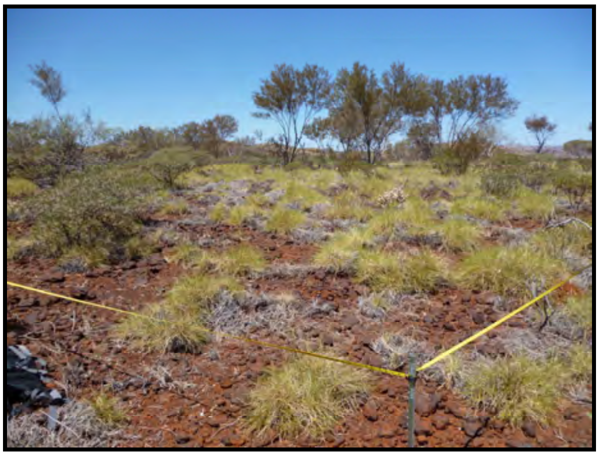
Species Name	RQ01	RQ02	RQ03	RQ04	RQ05	RQ06	RQ07	RQ08	RQ09	RQ10	RQ11	RQ12	RQ13	RQ14	RQ15	RQ16	RQ17	RQ18	RQ19	RR01	RR02
Hybanthus aurantiacus																X					
Indigofera monophylla				X											X	X				X	
Iseilema dolichotrichum			X										X		X						
Jasminum didymum subsp. *lineare*				X																	
Lysiana casuarinae																X					
Maireana melanocoma																			X		
Maireana planifolia					X																X
Malvaceae sp.													X								
Malvastrum americanum										X		X		X							
Melaleuca lasiandra														X		X				X	
Melhania oblongifolia				X						X							X	X			
Mollugo molluginae	X		X			X	X			X	X				X		X	X			X
Nicotiana occidentalis subsp. *obliqua*													X								
Notoleptopus decaisnei				X						X	X	X	X	X	X	X	X				
Oldenlandia crouchiana		X	X				X			X	X		X		X		X	X			
Paraneurachne muelleri				X																	
Paspalidium clementii		X	X												X						
Peripleura arida													X	X							
Phyllanthus maderaspatensis																X				X	
Pluchea dunlopii								X													
Pluchea ferdinandi-muelleri													X								
Pluchea rubelliflora													X								
Poaceae sp.										X											
Podotheca sp.																				X	

Species Name	RQ01	RQ02	RQ03	RQ04	RQ05	RQ06	RQ07	RQ08	RQ09	RQ10	RQ11	RQ12	RQ13	RQ14	RQ15	RQ16	RQ17	RQ18	RQ19	RR01	RR02
Polycarpaea corymbosa	X					X	X								X			X			X
Polycarpaea holtzei		X													X		X				
Polycarpaea longiflora	X	X	X	X		X					X				X		X	X			
Polygala isingii																	X				
Polymeria ambigua																X					
Pterocaulon sphaeranthoides	X	X	X	X	X	X	X	X	X	X											X
Ptilotus aervoides		X									X								X		
Ptilotus aff. astrolasius		X	X	X																	
Ptilotus auriculifolius	X	X																			
Ptilotus calostachyus		X				X															
Ptilotus clementii		X	X	X	X	X	X	X	X	X	X		X		X			X			X
Ptilotus exaltatus											X				X		X	X			
Ptilotus exaltatus var. *exaltatus*	X	X	X	X	X	X	X	X	X	X	X		X							X	X
Ptilotus helipteroides	X					X	X		X	X								X			X
Ptilotus obovatus				X				X		X	X				X	X	X				
Ptilotus rotundifolius			X								X				X		X				
Ptilotus schwartzii	X					X												X			
Ptilotus sp.						X															
Rhagodia eremaea										X									X		
Rhynchosia minima										X	X					X	X				
Salsola australis				X								X							X		
Santalum lanceolatum																X					X
Scaevola spinescens				X				X	X	X									X		
Schizachyrium fragile													X								

Species Name	RQ01	RQ02	RQ03	RQ04	RQ05	RQ06	RQ07	RQ08	RQ09	RQ10	RQ11	RQ12	RQ13	RQ14	RQ15	RQ16	RQ17	RQ18	RQ19	RR01	RR02
Sclerolaena cornishiana												X		X				X			
Sclerolaena densiflora								X													
Senecio pinnatifolius														X							
Senna artemisioides subsp. *helmsii*			X	X				X			X		X		X			X	X		X
Senna artemisioides subsp. *oligophylla*	X		X	X	X			X	X	X		X	X		X		X	X			
Senna glutinosa subsp. *?chatelainiana*	X						X	X		X											
Senna glutinosa subsp. *chatelainiana*												X						X	X		
Senna glutinosa subsp. *glutinosa*		X	X	X											X		X	X		X	X
Senna glutinosa subsp. *pruinosa*	X	X		X	X		X	X	X	X		X			X		X	X			X
Senna notabilis		X	X	X		X	X	X	X	X	X			X	X		X	X		X	
Sida ?echinocarpa															X						
*Sida ?*sp. *spiciform panicles (E. Leylands s.n 14/8/90)*								X						X							
Sida echinocarpa		X	X	X					X		X		X				X	X			X
Sida sp.											X										
Sida sp. *spiciform panicles (E. Leyland s.n. 14/8/90)*						X						X	X		X						
Sida sp. *verrucose glands (F.H. Mollemans 2423)*				X																	
Solanum lasiophyllum						X	X			X		X								X	
Solanum phlomoides	X												X	X	X			X			
Sonchus oleraceus														X							
Sporobolus australasicus	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Stackhousia sp.					X																

Species Name	RQ01	RQ02	RQ03	RQ04	RQ05	RQ06	RQ07	RQ08	RQ09	RQ10	RQ11	RQ12	RQ13	RQ14	RQ15	RQ16	RQ17	RQ18	RQ19	RR01	RR02
Stemodia grossa														X						X	
Streptoglossa bubakii											X						X	X			
Streptoglossa liatroides																				X	
Streptoglossa sp.										X											
Streptoglossa tenuiflora		X	X	X	X		X	X		X	X	X	X		X	X	X				
Stylobasium spathulatum																				X	
Tephrosia rosea																X				X	
Themeda triandra				X																X	
Trachymene oleracea subsp. *oleracea*		X	X				X				X		X		X		X	X			
Trianthema aff. kimberleyi (MET 15 060)																X					
Trianthema glossostigma								X										X	X		
Tribulus suberosus	X	X		X		X												X	X	X	
Trichodesma zeylanicum var. *zeylanicum*		X	X	X		X	X			X					X		X	X		X	
Triodia ?angusta				X	X				X	X				X							X
Triodia ?epactia	X	X		X		X	X					X									
Triodia angusta								X			X		X							X	
Triodia brizoides	X		X												X	X		X			
Triodia epactia																	X	X			
Triodia wiseana					X	X						X							X		
Triumfetta clementii	X														X		X	X			
Wahlenbergia tumidifructa														X							
Waltheria indica																				X	

APPENDIX 3: Detailed Site Descriptions



Site RQ01

Described by: Caroline Gill
Date: 26/09/2011
Type: Quadrat 50m x 50m
WGS84 Zone 50 551267mE 7476941mN

Topography: Ridge
Soil: Red skeletal stony loam
Veg Condition: Excellent to Very Good
Land System: Rocklea

Vegetation: *Acacia aneura* Complex Scattered to Low Open Woodland over *Senna glutinosa* subsp. *pruinosa* and *Acacia tetragonophylla* Open Shrubland over *Eremophila phyllopoda* subsp. *obliqua* Low Open Shrubland over *Triodia epactia* and *T. brizoides* Hummock Grassland on ironstone crest.

Species List: *Acacia aneura complex, Acacia cuthbertsonii* subsp. *cuthbertsonii* , *Acacia tetragonophylla* , *Acacia victoriae, Acacia xiphophylla, Aristida contorta, Asteraceae* sp., *Bulbostylis barbata, Corchorus crozophorifolius, Cucumis maderaspatanus, Cymbopogon ambiguus, Dysphania rhadinostachya* subsp. *rhadinostachya, Enneapogon polyphyllus, Eremophila cuneifolia, Eremophila phyllopoda* subsp. *obliqua, Gomphrena cunninghamii, Goodenia forrestii, Goodenia tenuiloba, Grevillea berryana, Mollugo molluginea, Polycarpaea corymbosa, Polycarpaea longiflora, Pterocaulon sphaeranthoides, Ptilotus auriculifolius, Ptilotus exaltatus var. exaltatus, Ptilotus helipteroides, Ptilotus schwartzii, Senna artemisioides subsp. oligophylla, Senna glutinosa* subsp. ?*chatelainiana, Senna glutinosa* subsp. *pruinosa, Solanum phlomoides, Sporobolus australasicus, Tribulus suberosus, Triodia* ?*epactia, Triodia brizoides* and *Triumfetta clementii.*

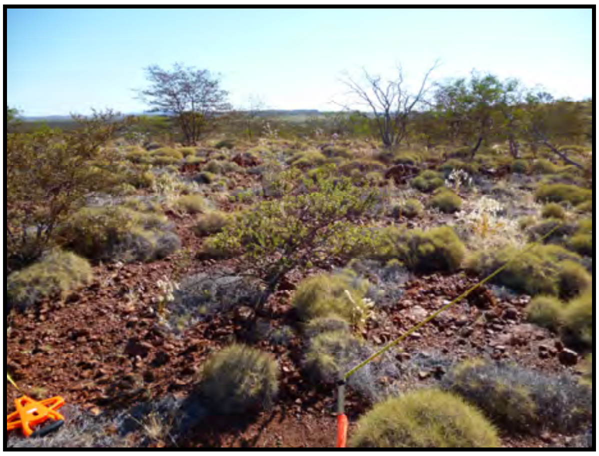
Site RQ02

Described by: Caroline Gill
Date: 27/09/2011
Type: Quadrat 50m x 50m
WGS84 Zone 50 551284mE 7481500mN

Topography: Ridge
Soil: Red skeletal stony loam
Veg Condition: Excellent to Very Good
Land System: Boolgeeda

Vegetation: Scattered *Eucalyptus leucophloia* over *Acacia ancistrocarpa* Open Shrubland with scattered patches of *A. aptaneura* over mixed scattered *Senna* spp. and *Eremophila* spp. over *Triodia epactia* Hummock Grassland on stony crest of hill.

Species List: *Acacia ancistrocarpa, Acacia aptaneura, Acacia inaequilatera, Acacia kempeana, Acacia tetragonophylla, Acacia victoriae, Aristida contorta, Corchorus lasiocarpus* subsp. *parvus, Corchorus* sp.*, Dysphania rhadinostachya* subsp. *rhadinostachya, Enneapogon caerulescens, Enneapogon polyphyllus, Eremophila cuneifolia, Eremophila fraseri* subsp. *fraseri, Eremophila phyllopoda* subsp. *obliqua, Eriachne pulchella* subsp. *dominii, Eriachne pulchella* subsp. *pulchella, Euphorbia australis, Evolvulus alsinoides* var. *villosicalyx, Goodenia forrestii, Goodenia stobbsiana, Goodenia tenuiloba, Hakea lorea* subsp. *lorea, Heliotropium inexplicitum, Oldenlandia crouchiana, Paspalidium clementii, Polycarpaea holtzei, Polycarpaea longiflora, Pterocaulon sphaeranthoides, Ptilotus aervoides, Ptilotus* aff. *astrolasius, Ptilotus auriculifolius, Ptilotus calostachyus, Ptilotus clementii, Ptilotus exaltatus* var. *exaltatus, Senna glutinosa* subsp. *glutinosa, Senna glutinosa* subsp. *pruinosa, Senna notabilis, Sida echinocarpa, Sporobolus australasicus, Streptoglossa tenuiflora, Trachymene oleracea* subsp. *oleracea, Tribulus suberosus, Trichodesma zeylanicum* var*. zeylanicum* and *Triodia ?epactia.*



Site RQ03

Described by: Caroline Gill
Date: 27/09/2011
Type: Quadrat 50m x 50m
WGS84 Zone 50 550535mE 7478763mN

Topography: Ridge
Soil: Red skeletal stony earth
Veg Condition: Very Good
Land System: Rocklea

Vegetation: Scattered *Eucalyptus leucophloia* over *Acacia ancistrocarpa* Open Shrubland with scattered patches of *A. aptaneura* over mixed scattered *Senna* spp. and *Eremophila* spp. over *Triodia brizoides* Hummock Grassland on stony crest of hill.

Species List: *Abutilon ?lepidum, Acacia aptaneura, Acacia kempeana, Acacia monticola, Acacia pruinocarpa, Acacia synchronicia, Aristida contorta, Bulbostylis barbata, Corchorus* sp., *Cucumis maderaspatanus, Dysphania rhadinostachya* subsp. *rhadinostachya, Eremophila cuneifolia, Eremophila fraseri* subsp. *fraseri, Eremophila phyllopoda* subsp. *obliqua, Gomphrena ?kanisii, Gomphrena cunninghamii, Goodenia microptera, Goodenia tenuiloba, Iseilema dolichotrichum, Mollugo molluginea, Oldenlandia crouchiana, Paspalidium clementii, Polycarpaea longiflora, Pterocaulon sphaeranthoides, Ptilotus* aff. *astrolasius, Ptilotus clementii, Ptilotus exaltatus* var. *exaltatus, Ptilotus rotundifolius, Senna artemisioides* subsp. *helmsii, Senna artemisioides* subsp. *oligophylla, Senna glutinosa* subsp. *glutinosa, Senna notabilis, Sida echinocarpa, Sporobolus australasicus, Streptoglossa tenuiflora, Trachymene oleracea* subsp. *oleracea, Trichodesma zeylanicum* var. *zeylanicum* and *Triodia brizoides.*

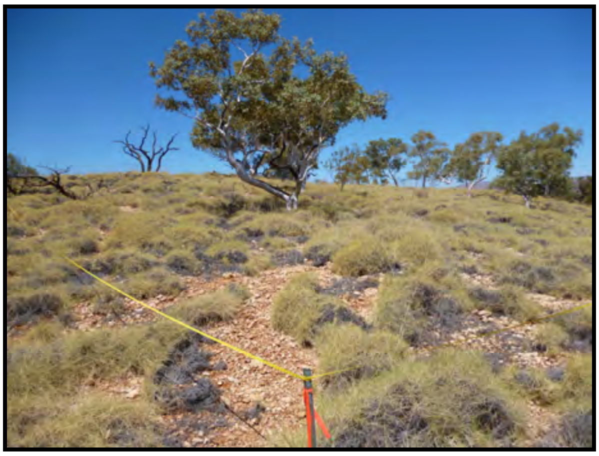
Site RQ04

Described by: Caroline Gill
Date: 28/09/2011
Type: Quadrat 50m x 50m
WGS84 Zone 50 548830mE 7477137mN

Topography: Midslope/lower slope
Soil: Black stones over red loam
Veg Condition: Excellent to Very Good
Land System: Robe

Vegetation: Scattered to Low Open Woodland of *Corymbia hamersleyana* over mixed *Acacia* spp., *Senna* spp., *Eremophila* spp. and *Petalostylis labicheoides* open Shrubland over *Triodia ?angusta* and *Triodia ?epactia* Hummock Grassland.

Species List: *Abutilon fraseri, Acacia kempeana, Acacia pruinocarpa, Acacia sclerosperma* subsp. *sclerosperma, Acacia tetragonophylla, Acacia victoriae, *Cenchrus ciliaris, Corchorus lasiocarpus* subsp*. lasiocarpus, Corymbia ?dichromophloia, Corymbia hamersleyana, Cymbopogon* sp.*, Duperreya commixta, Dysphania rhadinostachya* subsp. *rhadinostachya, Enneapogon polyphyllus, Enneapogon robustissimus, Eremophila cuneifolia, Eremophila longifolia, Eremophila phyllopoda* subsp*. obliqua, Eriachne mucronata, Eriachne pulchella* subsp*. dominii, Eriachne pulchella* subsp*. pulchella, Euphorbia ?boophthona, Euphorbia australis, Euphorbia biconvexa, Evolvulus alsinoides* var*. villosicalyx, Goodenia forrestii, Goodenia microptera, Indigofera monophylla, Jasminum didymum* subsp*. lineare, Melhania oblongifolia, Notoleptopus decaisnei, Paraneurachne muelleri, Polycarpaea longiflora, Pterocaulon sphaeranthoides, Ptilotus* aff*. astrolasius, Ptilotus clementii, Ptilotus exaltatus* var*. exaltatus, Ptilotus obovatus, Salsola australis, Scaevola spinescens, Senna artemisioides* subsp*. helmsii, Senna artemisioides* subsp*. oligophylla, Senna glutinosa* subsp*. glutinosa, Senna glutinosa* subsp*. pruinosa, Senna notabilis, Sida echinocarpa, Sida* sp*. verrucose glands (F.H. Mollemans 2423), Sporobolus australasicus, Streptoglossa tenuiflora, Themeda triandra, Tribulus suberosus, Trichodesma zeylanicum* var*. zeylanicum, Triodia ?angusta* and *Triodia ?epactia.*



Site RQ05

Described by: Caroline Gill
Date: 28/09/2011
Type: Quadrat 50m x 50m
WGS84 Zone 50 548552mE 7477379mN

Topography: Hilltop
Soil: Limonite over brown loam
Veg Condition: Excellent
Land System: Robe

Vegetation: Scattered to Open Low Woodland of *Eucalyptus leucophloia* over scattered *Acacia pruinocarpa* over *Triodia angusta* and *T. wiseana* Closed Hummock Grassland.

Species List: *Acacia aptaneura, Acacia bivenosa, Acacia tetragonophylla, Acacia victoriae, Acacia pruinocarpa, Eremophila forrestii* (Hybrid A. Brown), *Eremophila forrestii* subsp. *hastieana, Eremophila phyllopoda* subsp. *obliqua, Eucalyptus leucophloia, Goodenia forrestii, Maireana planifolia, Maireana thesioides, Pterocaulon sphaeranthoides, Ptilotus clementii, Ptilotus exaltatus* var. *exaltatus, Senna artemisioides* subsp. *oligophylla, Senna glutinosa* subsp. *pruinosa, Sporobolus australasicus, Stackhousia* sp., *Streptoglossa tenuiflora, Triodia angusta* and *Triodia wiseana.*

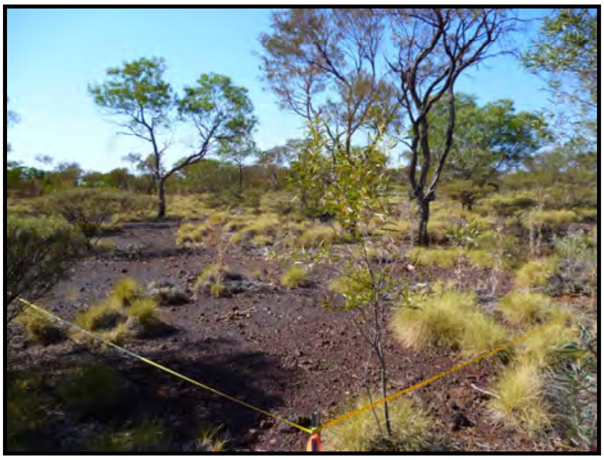
Site RQ06

Described by: Caroline Gill
Date: 29/09/2011
Type: Quadrat 50m x 50m
WGS84 Zone 50 549189mE 7477283mN

Topography: Midslope
Soil: Stony red loam
Veg Condition: Very Good to Excellent
Land System: Robe

Vegetation: *Acacia aptaneura* and *Acacia pruinocarpa* Open Low Woodland over *Acacia ancistrocarpa* and *Eremophila phyllopoda* subsp. *obliqua* Shrubland to Open Shrubland over *Trioda ?epactia*.

Species List: *?Portulaca oleracea, Acacia aptaneura, Acacia pruinocarpa, Acacia rhodophloia, Acacia tetragonophylla, Aristida contorta, Corchorus lasiocarpus* subsp. *?, Duperreya commixta, Dysphania rhadinostachya* subsp. *rhadinostachya, Enneapogon polyphyllus, Eremophila cuneifolia, Eremophila forrestii* (Hybrid A. Brown)*, Eremophila phyllopoda* subsp. *obliqua, Eriachne pulchella* subsp. *pulchella, Goodenia forrestii, Grevillea berryana, Grevillea stenobotrya, Hibiscus burtonii, Mollugo molluginea, Polycarpaea corymbosa, Polycarpaea longiflora, Pterocaulon sphaeranthoides, Ptilotus calostachyus, Ptilotus clementii, Ptilotus exaltatus* var. *exaltatus, Ptilotus helipteroides, Ptilotus schwartzii, Ptilotus* sp.*, Senna notabilis, Sida* sp. spiciform panicles (E. Leyland s.n. 14/8/90), *Solanum lasiophyllum, Sporobolus australasicus, Tribulus suberosus, Trichodesma zeylanicum* var. *zeylanicum, Triodia ?epactia* and *Triodia wiseana.*



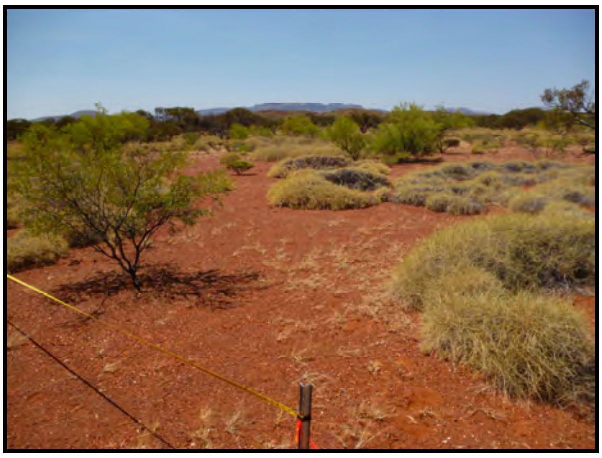
Site RQ07

Described by: Caroline Gill
Date: 29/09/2011
Type: Quadrat 50m x 50m
WGS84 Zone 50 548883mE 7477650mN

Topography: Midslope/Lower slope
Soil: Stony red loam
Veg Condition: Excellent
Land System: Robe

Vegetation: *Acacia aptaneura* and *Acacia pruinocarpa* Open Low Woodland over *Acacia ancistrocarpa* and *Eremophila phyllopoda* subsp. *obliqua* Shrubland to Open Shrubland over *Trioda ?epactia*.

Species List: *Abutilon lepidum, Acacia ancistrocarpa, Acacia aneura* var. *?aneura, Acacia aptaneura, Acacia pruinocarpa, Acacia tetragonophylla, Aristida contorta, Corchorus lasiocarpus* subsp. *? , Dysphania rhadinostachya* subsp. *rhadinostachya, Enneapogon polyphyllus, Eremophila cuneifolia, Eremophila forrestii* subsp. *hastieana, Eremophila phyllopoda* subsp. *obliqua, Eriachne pulchella* subsp. *pulchella, Gomphrena cunninghamii, Goodenia forrestii, Goodenia microptera, Goodenia muelleriana, Grevillea stenobotrya, Mollugo molluginea, Oldenlandia crouchiana, Polycarpaea corymbosa, Pterocaulon sphaeranthoides, Ptilotus clementii, Ptilotus exaltatus* var. *exaltatus, Ptilotus helipteroides, Senna glutinosa* subsp. *?chatelainiana, Senna glutinosa* subsp. *pruinosa, Senna notabilis, Solanum lasiophyllum, Sporobolus australasicus, Streptoglossa tenuiflora, Trachymene oleracea* subsp. *oleracea, Trichodesma zeylanicum* var. *zeylanicum* and *Triodia ?epactia*.



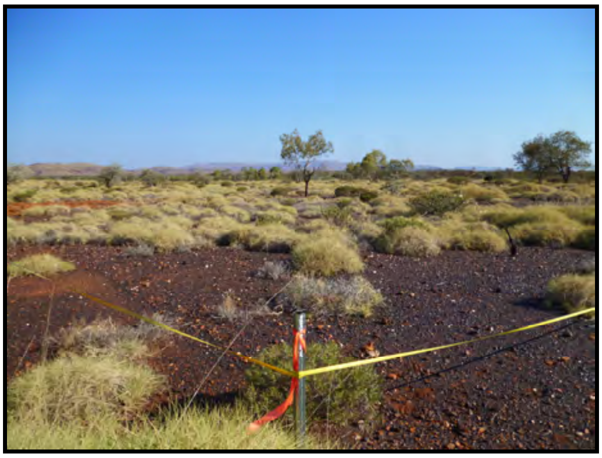
Site RQ08

Described by: Caroline Gill
Date: 29/09/2011
Type: Quadrat 50m x 50m
WGS84 Zone 50 550645mE 7475941mN

Topography: Flat
Soil: Orange-brown gravel over silt loam
Veg Condition: Very Good to Good
Land System: Robe

Vegetation: *Acacia xiphophylla* Low Open Woodland Open *Acacia victoriae* Tall Open Shrubland to Open Shrubland over *Triodia angusta* Open Hummock Grassland.

Species List: *Abutilon* aff. *lepidum, Abutilon* sp., *Acacia victoriae, Acacia xiphophylla, Amyema sanguinea* var. *sanguinea, *Cenchrus ciliaris, Cucumis maderaspatanus, Dipteracanthus australasicus* subsp. *australasicus, Enchylaena tomentosa* var. *tomentosa, Enneapogon polyphyllus, Eremophila cuneifolia, Eremophila phyllopoda* subsp. *obliqua, Gomphrena kanisii, Goodenia forrestii, Goodenia microptera, Goodenia muelleriana, Hibiscus sturtii, Lepidium pholidogynum, Pluchea dunlopii, Pterocaulon sphaeranthoides, Ptilotus clementii, Ptilotus exaltatus* var. *exaltatus, Ptilotus obovatus, Scaevola spinescens, Sclerolaena densiflora, Senna artemisioides* subsp. *helmsii, Senna artemisioides* subsp. *oligophylla, Senna glutinosa* subsp. *?chatelainiana, Senna glutinosa* subsp. *pruinosa, Senna notabilis, Sida ?*sp. spiciform panicles (E. Leylands s.n 14/8/90), *Sporobolus australasicus, Streptoglossa tenuiflora, Trianthema glossostigma* and *Triodia angusta.*



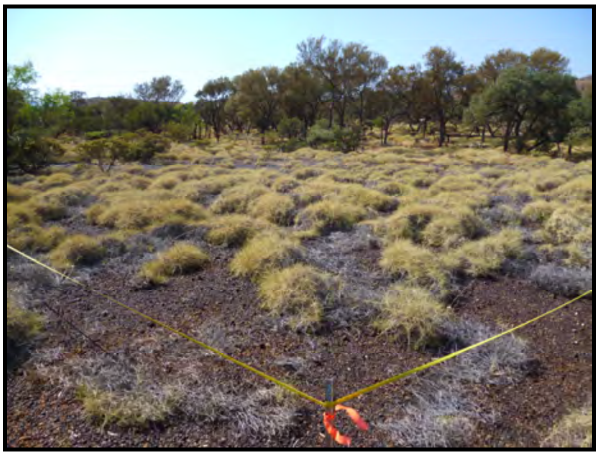
Site RQ09

Described by: Caroline Gill
Date: 29/09/2011
Type: Quadrat 50m x 50m
WGS84 Zone 50 549847mE 7477269mN

Topography: Gentle upper slope
Soil: Orange-brown gravel over clay
Veg Condition: Excellent
Land System: Robe

Vegetation: Scattered *Corymbia hamersleyana* over scattered *Acacia inaequilatera* over *Eremophila* spp. Open Low Shrubland over *Triodia ?angusta* Hummock Grassland..

Species List: *Abutilon* aff. *lepidum, Acacia inaequilatera, Acacia victoriae, Aristida contorta, Corchorus lasiocarpus* subsp. *?, Enneapogon polyphyllus, Eremophila cuneifolia, Eremophila forrestii* subsp. *forrestii, Eremophila fraseri* subsp. *fraseri, Eremophila phyllopoda* subsp. *obliqua, Eriachne pulchella* subsp. *pulchella, Euphorbia australis, Euphorbia boophthona, Gomphrena cunninghamii, Goodenia microptera, Pterocaulon sphaeranthoides, Ptilotus clementii, Ptilotus exaltatus* var. *exaltatus, Ptilotus helipteroides, Scaevola spinescens, Senna artemisioides* subsp. *oligophylla, Senna glutinosa* subsp. *pruinosa, Senna notabilis, Sida echinocarpa, Sporobolus australasicus* and *Triodia ?angusta.*



Site RQ10

Described by: Caroline Gill

Date: 30/09/2011

Type: Quadrat 50m x 50m

WGS84 Zone 50 551141mE 7475279mN

Topography: Lower slope/Minor creek

Soil: Red-brown stony earth on slopes, and clay in drainage lines

Veg Condition: Very Good (slopes) Good-Degraded (Drainage line)

Land System: Rocklea

Vegetation: *Acacia aptaneura* Low Open Forest to Low Woodland over *Eremophila cuneifolia* open Shrubland over *Triodia ?angusta* Hummock Grassland in drainage lines, and *Acacia xiphophylla* Open Low woodland over scattered *Acacia victoriae* over *Senna glutinosa* subsp. *pruinosa* and *Eremophila cuneifolia* Open Shrubland over *Triodia ?angusta* Hummock Grassland.

Species List: *Acacia ?dictyophleba, Acacia aptaneura, Acacia victoriae, Acacia xiphophylla, *Cenchrus ciliaris, Cheilanthes sieberi* subsp. *sieberi, Convolvulus angustissimus, Cucumis maderaspatanus, Dichanthium sericeum* subsp. *sericeum, Dipteracanthus australasicus* subsp. *australasicus, Duperreya commixta, Dysphania rhadinostachya* subsp. *rhadinostachya, Enchylaena tomentosa* var. *tomentosa, Enneapogon polyphyllus, Eremophila cuneifolia, Eremophila fraseri* subsp. *fraseri, Eremophila phyllopoda* subsp. *obliqua, Euphorbia* sp., *Evolvulus alsinoides* var. *villosicalyx, Goodenia microptera, Goodenia muelleriana, *Malvastrum americanum, Melhania oblongifolia, Mollugo molluginea, Notoleptopus decaisnei, Oldenlandia crouchiana, Poaceae* sp., *Pterocaulon sphaeranthoides, Ptilotus clementii, Ptilotus exaltatus* var. *exaltatus, Ptilotus helipteroides, Ptilotus obovatus, Rhagodia eremaea, Rhynchosia minima, Scaevola spinescens, Senna artemisioides* subsp. *oligophylla, Senna glutinosa* subsp. *?chatelainiana, Senna glutinosa* subsp. *pruinosa, Senna notabilis, Solanum lasiophyllum, Sporobolus australasicus, Streptoglossa* sp., *Streptoglossa tenuiflora, Trichodesma zeylanicum* var. *zeylanicum* and *Triodia ?angusta.*

Site RQ11

Described by: Caroline Gill
Date: 30/09/2011
Type: Quadrat 50m x 50m
WGS84 Zone 50 549880mE 7475246mN

Topography: Midslope
Soil: Red-brown sandy loam
Veg Condition: Very Good to Good
Land System: Rocklea

Vegetation: *Acacia aptaneura* Low Open Woodland over *Eremophila cuneifolia*, *E. fraseri* subsp. *fraseri* and *Acacia ancistrocarpa* Shrubland over *Triodia angusta* Closed Hummock Grassland

Species List: *Acacia ancistrocarpa, Acacia aptaneura, Acacia tetragonophylla, Acacia victoriae, Aristida contorta, Bulbostylis barbata, *Cenchrus setiger, Corchorus crozophorifolius, Corchorus lasiocarpus* subsp*. ?, Dipteracanthus australasicus* subsp*. australasicus, Dysphania rhadinostachya* subsp*. rhadinostachya, Enneapogon caerulescens, Enneapogon polyphyllus, Eremophila cuneifolia, Eremophila fraseri* subsp*. fraseri , Eremophila phyllopoda* subsp*. obliqua, Eriachne mucronata, Euphorbia australis,* Fabaceae sp*., Gomphrena cunninghamii, Gomphrena kanisii, Goodenia muelleriana, Mollugo molluginea, Notoleptopus decaisnei, Oldenlandia crouchiana, Polycarpaea longiflora, Ptilotus aervoides, Ptilotus clementii, Ptilotus exaltatus* var*. exaltatus, Ptilotus obovatus, Ptilotus rotundifolius, Rhynchosia minima, Senna artemisioides* subsp*. helmsii, Senna notabilis, Sida echinocarpa, Sida* sp*., Sporobolus australasicus, Streptoglossa bubakii, Streptoglossa tenuiflora , Trachymene oleracea* subsp*. Oleracea* and *Triodia angusta.*

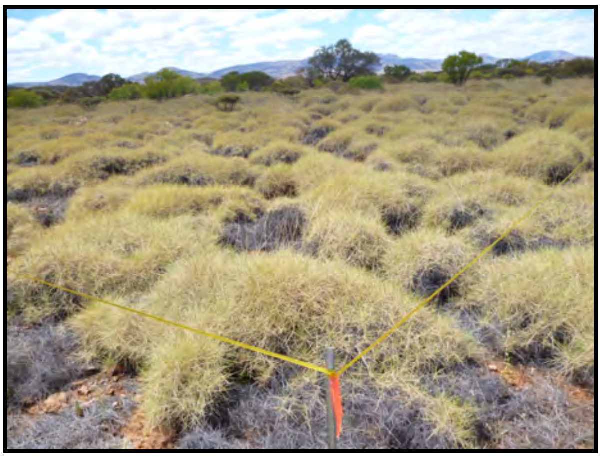
Site RQ12

Described by: Caroline Gill
Date: 2/10/2011
Type: Quadrat 50m x 50m
WGS84 Zone 50 549662mE 7478686mN

Topography: Flat, Minor creek
Soil: Red-brown clay loam
Veg Condition: Very Good to Good
Land System: Paraburdoo

Vegetation: *Acacia aptaneura* Low Woodland in drainage lines over *Acacia victoriae*, *Acacia xiphophylla*, *Acacia tetragonophylla*, *Eremophila fraseri* subsp. *fraseri* Tall Shrubland over *Eremophila cuneifolia* and *Senna glutinosa* subsp. *chatelainiana* Open Low Shrubland over *Sporobolus australasicus* Grassland with scattered patches of *Triodia* spp.

Species List: *Acacia ancistrocarpa, Acacia aptaneura, Acacia pruinocarpa, Acacia tetragonophylla, Acacia victoriae, *Cenchrus ciliaris, Convolvulus angustissimus, Corchorus tridens, Cucumis maderaspatanus, Cymbopogon* sp.*, Dipteracanthus australasicus* subsp. *australasicus, Duperreya commixta, Enneapogon polyphyllus, Eremophila cuneifolia, Eremophila forrestii* subsp. *hastieana, Eremophila fraseri* subsp. *fraseri, Eremophila phyllopoda* subsp. *obliqua, Eremophila* sp.*, Eriachne mucronata, Euphorbia ?alsiniflora, Gossypium australe, *Malvastrum americanum, Notoleptopus decaisnei, Salsola australis, Sclerolaena cornishiana, Senna artemisioides* subsp. *oligophylla, Senna glutinosa* subsp. *chatelainiana, Senna glutinosa* subsp. *pruinosa, Sida* sp. spiciform panicles (E. Leyland s.n. 14/8/90*), Solanum lasiophyllum, Sporobolus australasicus, Streptoglossa tenuiflora, Triodia ?epactia* and *Triodia wiseana.*



Site RQ13

Described by: Caroline Gill
Date: 2/10/2011
Type: Quadrat 50m x 50m
WGS84 Zone 50 549142mE 7478065mN

Topography: Flat
Soil: Red-brown clay loam
Veg Condition: Excellent to Very Good
Land System: Paraburdoo

Vegetation: Scattered *Acacia victoriae* and *Eremophila* spp. over *Triodia angusta* Closed Hummock Grassland.

Species List: *Acacia tetragonophylla, Acacia victoriae, Acacia xiphophylla, *Cenchrus ciliaris, Convolvulaceae* sp., *Convolvulus angustissimus, Corchorus lasiocarpus* subsp. *parvus, Corchorus tridens, Cymbopogon* sp., *Dichanthium sericeum* subsp. *?, Dipteracanthus australasicus* subsp. *australasicus, Enneapogon polyphyllus, Eremophila abietina, Eremophila forrestii* subsp. *hastieana, Eremophila fraseri* subsp. *fraseri, Eremophila phyllopoda* subsp. *obliqua, Euphorbia australis, Euphorbia boophthona, Evolvulus alsinoides* var. *villosicalyx, Goodenia forrestii, Goodenia microptera, Goodenia muelleriana, Iseilema dolichotrichum,* Malvaceae sp., *Nicotiana occidentalis* subsp. *obliqua, Notoleptopus decaisnei, Oldenlandia crouchiana, Peripleura arida, Pluchea ferdinandi-muelleri, Pluchea rubelliflora, Ptilotus clementii, Ptilotus exaltatus* var. *exaltatus, Schizachyrium fragile, Senna artemisioides* subsp. *helmsii, Senna artemisioides* subsp. *oligophylla, Sida echinocarpa, Sida* sp. spiciform panicles (E. Leyland s.n. 14/8/90), *Solanum phlomoides, Sporobolus australasicus, Streptoglossa tenuiflora, Swainsona ?maccullochiana, Trachymene oleracea* subsp. *oleracea* and *Triodia angusta.*

Site RQ14

Described by: Caroline Gill
Date: 2/10/2011
Type: Quadrat 50m x 50m
WGS84 Zone 50 551012mE 7479873mN

Topography: Major creek
Soil: Red-brown sandy clay loam
Veg Condition: Good to Degraded
Land System: Boolgeeda

Vegetation: *Eucalyptus camaldulensis* subsp. *obtusa* Open Woodland to Woodland over *Acacia sclerosperma* subsp. *Sclerosperma*, *Acacia citrinoviridis* and *Melaleuca lasiandra* Low Open Woodland over **Cenchrus ciliaris* Closed Tussock Grassland.

Species List: *Abutilon* sp., *Acacia citrinoviridis, Acacia sclerosperma* subsp. *sclerosperma, Acacia tetragonophylla, Alternanthera denticulata, **Argemone ochroleuca* subsp. *ochroleuca, *Cenchrus ciliaris, Centipeda minima, Corchorus crozophorifolius, Corchorus lasiocarpus* subsp. *parvus, Corchorus tridens, Cucumis maderaspatanus, Cyperus vaginatus, Dipteracanthus australasicus subsp. australasicus, Duperreya commixta, Eremophila fraseri* subsp. *fraseri, Eucalyptus camaldulensis* subsp. *obtusa, Euphorbia schultzii, *Heliotropium europaeum , *Malvastrum americanum, Melaleuca lasiandra, Notoleptopus decaisnei, Peripleura arida, Sclerolaena cornishiana, Senecio pinnatifolius, Senna notabilis, Sida ?* sp. spiciform panicles (E. Leylands s.n 14/8/90), *Solanum phlomoides, *Sonchus oleraceus , Sporobolus australasicus, Stemodia grossa, Triodia ?angusta* and *Wahlenbergia tumidifructa.*

Site RQ15

Described by: Caroline Gill
Date: 3/10/2011
Type: Quadrat 50m x 50m
WGS84 Zone 50 550620mE 7478397mN

Topography: Upper slope to midslope
Soil: Red skeletal stony loam
Veg Condition: Excellent
Land System: Rocklea

Vegetation: Scattered *Acacia aptaneura* over *Senna* spp. Open Low Shrubland on slopes and crests and *Acacia ancistrocarpa* Shrubland in gully over *Triodia brizoides* Closed Hummock Grassland.

Species List: *Abutilon lepidum, Acacia ancistrocarpa, Acacia aptaneura, Acacia dictyophleba, Acacia pruinocarpa, Acacia synchronicia, Acacia tetragonophylla, Aristida contorta, *Bidens bipinnata , Bulbostylis barbata, Corchorus lasiocarpus* subsp. *parvus, Cucumis maderaspatanus, Cymbopogon ambiguus, Dipteracanthus australasicus subsp. australasicus, Duperreya commixta, Dysphania rhadinostachya* subsp. *rhadinostachya, Enneapogon ?lindleyanus, Enneapogon polyphyllus, Eremophila cuneifolia, Eremophila forrestii* subsp. *hastieana, Eremophila phyllopoda subsp. obliqua, Eriachne mucronata, Eriachne pulchella* subsp. *dominii, Euphorbia ?boophthona, Evolvulus alsinoides* var. *villosicalyx, Gomphrena cunninghamii, Gomphrena kanisii, Goodenia microptera, Goodenia muelleriana, Goodenia tenuiloba, Grevillea stenobotrya, Heliotropium inexplicitum, Indigofera monophylla, Iseilema dolichotrichum, Mollugo molluginae, Notoleptopus decaisnei, Oldenlandia crouchiana, Paspalidium clementii, Polycarpaea corymbosa, Polycarpaea holtzei, Polycarpaea longiflora, Ptilotus clementii, Ptilotus exaltatus, Ptilotus obovatus, Ptilotus rotundifolius, Senna artemisioides* subsp. *helmsii, Senna artemisioides* subsp. *oligophylla* , *Senna glutinosa* subsp. *glutinosa, Senna glutinosa* subsp. *pruinosa, Senna notabilis, Sida ?echinocarpa, Sida* sp. spiciform panicles (E. Leyland s.n. 14/8/90), *Solanum phlomoides, Sporobolus australasicus, Streptoglossa tenuiflora, Trachymene oleracea* subsp. *oleracea, Trichodesma zeylanicum* var. *zeylanicum, Triodia brizoides* and *Triumfetta clementii.*

Site RQ16

Described by: Caroline Gill
Date: 3/10/2011
Type: Quadrat 50m x 50m
WGS84 Zone 50 550093mE 7476549mN

Topography: Major creek
Soil: Red-brown clay loam and sand in river bed
Veg Condition: Good to Degraded
Land System: River

Vegetation: *Eucalyptus camaldulensis* subsp. *obtusa* Open Woodland to Woodland over *Acacia sclerosperma* subsp. *Sclerosperma*, *Acacia citrinoviridis* and *Melaleuca lasiandra* Low Open Woodland over **Cenchrus ciliaris* Closed Tussock Grassland.

Species List: *Abutilon dioicum, Acacia citrinoviridis, Acacia pyrifolia, Amyema hilliana, **Argemone ochroleuca* subsp. *ochroleuca, Boerhavia coccinea, Capparis lasiantha, Capparis spinosa, *Cenchrus ciliaris, Corchorus crozophorifolius, Cucumis maderaspatanus, Cymbopogon* sp., *Dipteracanthus australasicus* subsp. *australasicus, Duperreya commixta, Euphorbia schultzii, Gomphrena cunninghamii, Gossypium robinsonii, Grevillea berryana, Hybanthus aurantiacus, Indigofera monophylla, Lysiana casuarinae, Melaleuca lasiandra, Notoleptopus decaisnei, Phyllanthus maderaspatensis, Polymeria ambigua, Ptilotus obovatus, Rhynchosia minima, Santalum lanceolatum, Sporobolus australasicus, Streptoglossa tenuiflora, Tephrosia rosea, Trianthema* aff. kimberleyi (MET 15 060) and *Triodia brizoides.*

Site RQ17

Described by: Caroline Gill
Date: 4/10/2011
Type: Quadrat 50m x 50m
WGS84 Zone 50 551055mE 7479362mN

Topography: Hilltop – upper slope
Soil: Red skeletal stony loam
Veg Condition: Excellent
Land System: Boolgeeda

Vegetation: *Acacia pruinocarpa*, *Acacia ?trachycarpa x tumida* var. *pilbarensis* and *Acacia inaequilatera* Tall Open Shrubland over *Senna* spp. and *Eremophila* spp. Scattered Low Shrubs over *Ptilotus* spp. and Malvaceae spp. over *Triodia epactia* Hummock Grassland.

Species List: *Eriachne mucronata, Abutilon lepidum, Acacia ?trachycarpa x tumida* var. *pilbarensis, Acacia aptaneura, Acacia kempeana, Acacia pruinocarpa, Acacia synchronicia, Acacia tetragonophylla, Amyema fitzgeraldii, *Bidens bipinnata , Capparis spinosa, *Cenchrus ciliaris, Corchorus lasiocarpus* subsp. *?,Corchorus lasiocarpus* subsp. *lasiocarpus, Cucumis maderaspatanus, Cymbopogon ambiguus, Dichanthium sericeum* subsp. *humilius, Dipteracanthus australasicus* subsp. *australasicus, Duperreya commixta, Dysphania rhadinostachya* subsp. *rhadinostachya, Enneapogon polyphyllus, Eremophila cuneifolia, Eremophila fraseri* subsp. *fraseri, Eremophila phyllopoda* subsp. *obliqua, Eriachne mucronata, Euphorbia australis, Evolvulus alsinoides* var. *villosicalyx, *Flaveria trinervia , Goodenia microptera, Goodenia muelleriana, Hibiscus coatesii, Melhania oblongifolia, Mollugo molluginea, Notoleptopus decaisnei, Oldenlandia crouchiana, Polycarpaea holtzei, Polycarpaea longiflora, Polygala isingii, Ptilotus clementii, Ptilotus exaltatus, Ptilotus obovatus, Ptilotus rotundifolius, Rhynchosia minima, Senna artemisioides* subsp. *oligophylla, Senna glutinosa* subsp. *glutinosa, Senna glutinosa* subsp. *pruinosa, Senna notabilis, Sida echinocarpa, Sporobolus australasicus, Streptoglossa bubakii, Streptoglossa tenuiflora, Trachymene oleracea* subsp. *oleracea, Trichodesma zeylanicum* var. *zeylanicum, Triodia epactia* and *Triumfetta clementii.*

Site RQ18

Described by: Caroline Gill
Date: 4/10/2011
Type: Quadrat 50m x 50m
WGS84 Zone 50 550449mE 7477198mN

Topography: Hilltop – upper slope
Soil: Red silty loam
Veg Condition: Very Good
Land System: River

Vegetation: *Acacia aptaneura* Low Open Woodland on upper gentle stony slopes and *Acacia xiphophylla* on lower stony slopes over *Eremophila phyllopoda* subsp. *obliqua* and *Senna glutinosa* subsp. *chatelainiana* Low Open Shrubland over *Triodia brizoides* Hummock Grassland with patches of *Sporobolus australasicus* Tussock Grassland on stony slopes.

Species List: *Acacia aptaneura, Acacia pruinocarpa, Acacia tetragonophylla, Acacia victoriae, Acacia xiphophylla, Aristida contorta, Bulbostylis barbata, *Cenchrus* sp., *Corchorus lasiocarpus subsp. ?, Cucumis maderaspatanus, Dipteracanthus australasicus* subsp. *australasicus, Dodonaea petiolaris, Duperreya commixta, Dysphania rhadinostachya* subsp. *rhadinostachya, Enneapogon ? lindleyanus, Enneapogon polyphyllus, Eremophila cuneifolia, Eremophila phyllopoda* subsp. *obliqua, Eriachne pulchella* subsp. *dominii, Evolvulus alsinoides* var. *?decumbens, Gomphrena cunninghamii, Goodenia muelleriana, Grevillea berryana, Hibiscus gardneri, Melhania oblongifolia, Mollugo molluginea, Oldenlandia crouchiana, Polycarpaea corymbosa, Polycarpaea longiflora, Ptilotus clementii, Ptilotus exaltatus, Ptilotus helipteroides, Ptilotus schwartzii, Sclerolaena cornishiana, Senna artemisioides* subsp. *helmsii, Senna artemisioides* subsp. *oligophylla, Senna glutinosa* subsp. *chatelainiana, Senna glutinosa* subsp. *glutinosa, Senna glutinosa* subsp. *pruinosa, Senna notabilis, Sida echinocarpa, Solanum phlomoides, Sporobolus australasicus, Streptoglossa bubakii, Trachymene oleracea* subsp. *oleracea, Trianthema glossostigma, Tribulus suberosus, Trichodesma zeylanicum* var. *zeylanicum, Triodia brizoides, Triodia epactia* and *Triumfetta clementii.*

Site RQ19

Described by: Caroline Gill
Date: 4/10/2011
Type: Quadrat 50m x 50m
WGS84 Zone 50 550893mE 7474957mN

Topography: Flat, Lower slope, minor creek
Soil: Red brown loam
Veg Condition: Good to Very Good
Land System: Robe

Vegetation: *Acacia xiphophylla* Tall Shrubland to Tall Open Shrubland over patches of *Senna glutinosa* subsp. *chatelainiana* and *Eremophila cuneifolia* and *Scaevola spinescens* over *Sporobolus australasicus* Open Tussock Grassland and occasional patches of *Triodia wiseana.*

Species List: *Acacia aptaneura, Acacia tetragonophylla, Acacia xiphophylla, Brachyachne prostrata, Corchorus crozophorifolius, Dipteracanthus australasicus* subsp*. australasicus, Dodonaea petiolaris, Duperreya commixta, Enchylaena tomentosa* var*. tomentosa, Enteropogon ramosus, Eremophila cuneifolia, Eremophila phyllopoda* subsp*. obliqua, Eriachne pulchella* subsp. *pulchella, Maireana melanocoma, Ptilotus aervoides, Rhagodia eremaea, Salsola australis, Scaevola spinescens, Senna artemisioides* subsp*. helmsii, Senna artemisioides* subsp*. helmsii, Senna glutinosa* subsp*. chatelainiana, Senna glutinosa* subsp*. chatelainiana, Sporobolus australasicus, Trianthema glossostigma, Tribulus suberosus* and *Triodia wiseana.*

Site RR01

Described by: Caroline Gill
Date: 27/9/2011
Type: Releve
WGS84 Zone 50 551380mE 7481376mN

Topography: Major creek
Soil: Red sandy loam
Veg Condition: Degraded
Land System: Boolgeeda

Vegetation: *Eucalyptus camaldulensis* subsp. *obtusa* over scattered *Acacia citrinoviridis* and patches of *Melaleuca lasiandra* over *Acacia* spp. and Malvaceae spp. over **Cenchrus ciliaris* Grassland.

Species List: *Acacia citrinoviridis, Acacia pyrifolia, Acacia sclerosperma* subsp*. sclerosperma, *Acetosa vesicaria, Adriana tomentosa* var*. tomentosa, Amyema hilliana, **Argemone ochroleuca* subsp*. ochroleuca, Aristida contorta, *Cenchrus ciliaris, *Cenchrus setiger, Corchorus crozophorifolius, Crotalaria medicaginea, Cymbopogon* sp., *Cyperus vaginatus, Eriachne mucronata, Eucalyptus camaldulensis* subsp. *obtusa, Eulalia aurea, Euphorbia* sp., *Gossypium robinsonii, Hakea lorea* subsp*. lorea, Indigofera monophylla, Melaleuca lasiandra , Phyllanthus maderaspatensis, Podotheca* sp*., Ptilotus exaltatus* var*. exaltatus, Senna glutinosa* subsp. *glutinosa, Senna notabilis, Solanum lasiophyllum, Sporobolus australasicus, Stemodia grossa, Streptoglossa liatroides, Stylobasium spathulatum, Tephrosia rosea, Themeda triandra, Tribulus suberosus, Trichodesma zeylanicum* var*. zeylanicum, Triodia angusta* and *Waltheria indica.*

Site RR02

Described by: Caroline Gill
Date: 30/9/2011
Type: Releve
WGS84 Zone 50 549979mE 7475160mN

Topography: Flat, Lower slope, Minor Creek
Soil: Red-brown sandy loam
Veg Condition: Good to Degraded
Land System: Rocklea

Vegetation: *Acacia aptaneura* and *Acacia xiphophylla* Low Open Woodland over *Acacia victoriae* and *Eremophila cuneifolia* Open Shrubland with *Acacia aptaneura* and *Acacia ancistrocarpa* Low Woodland to Open Low Woodland over scattered *Santalum lanceolatum* and *Eremophila fraseri* subsp. *fraseri* Open Shrubland over ***Cenchrus ciliaris* Closed Grassland in the drainage line.

Species List: *Acacia ancistrocarpa, Acacia aptaneura, Acacia citrinoviridis, Acacia tetragonophylla, Acacia victoriae, Acacia xiphophylla, Aristida contorta, *Cenchrus ciliaris, Chrysopogon fallax, Corchorus crozophorifolius, Cucumis maderaspatanus, Dipteracanthus australasicus subsp. australasicus, Duperreya commixta, Eremophila cuneifolia, Eremophila exilifolia, Eremophila forrestii* subsp. *hastieana, Eremophila fraseri* subsp. *fraseri, Eremophila phyllopoda* subsp. *obliqua, Eriachne mucronata, Gomphrena kanisii, Goodenia forrestii, Goodenia muelleriana, Grevillea berryana, Heliotropium inexplicitum, Maireana planifolia ,Mollugo molluginea, Polycarpaea corymbosa, Pterocaulon sphaeranthoides, Ptilotus clementii, Ptilotus exaltatus* var. *exaltatus, Ptilotus helipteroides, Santalum lanceolatum, Senna artemisioides* subsp. *helmsii, Senna glutinosa* subsp. *glutinosa, Senna glutinosa* subsp. *pruinosa, Sida echinocarpa, Sporobolus australasicus* and *Triodia ?angusta.*

Memo

To: John Dell and Claire Stevenson, Terrestrial Ecosystems Branch, OEPA

From: Karen Crews

CC: Peter Walkington, Neil Dixon, Gang Xu

Date: 4 February 2014

Subject: Rocklea Early Tonnes Iron Ore Project, advice on troglofauna

Dear John and Claire,

In preparation for our meeting regarding the Rocklea Early Tonnes Iron Ore Project, please see below a brief overview of the project and our preliminary troglofauna assessment. The meeting request is in follow up to a meeting on 23 January between OEPA officers (Peter Walkington and Sally Bowman) and Dragon Energy representatives.

As discussed we are seeking feedback on the assessment and its findings, specifically in relation to the significance of potential impacts of the Rocklea Early Tonnes Project on troglofauna and whether you consider that troglofauna may represent a key environmental factor for assessment under the EP Act in accordance with the EPA's significance framework.

Background

Dragon Energy is an ASX-listed mineral exploration company that controls a portfolio of tenements in Western Australia. The Rocklea Project, as a whole, is a 183 million tonne Channel Iron Deposit iron ore resource located approximately 34 km southwest of Tom Price and located close to the Hardey River. Further information on the initial project is provided as an Attachment. RTIO's Western Turner Syncline Project (32 mtpa) is located 8 km to the north and API's Hardey Proposal (12 mtpa) is situated 20 km southwest. Both projects were approved by the EPA in 2013.

Dragon proposes a 1.8 mtpa operation to recover about 6 Mt of iron ore resource restricted to above the water table and with a mine life of 3–4 years (Figure 1). This initial proposed mine would provide capital for the investigation and potential development of a full-scale, below-water table mining project that would commence in or around 2017, pending finalisation of further studies and receipt of all necessary approvals. The Early Tonnes project is anticipated to be submitted as a mining proposal to DMP; however, the project will initially be referred to the EPA specifically in relation to troglofauna with the aim of minimising uncertainty in the project approvals timeline. It is intended to submit the draft mining proposal with the EPA referral.

In 2011, Dragon commissioned baseline field surveys to support the environmental impact assessment for the project; this included surveys for subterranean fauna. A two-phase subterranean fauna survey was conducted between July and October 2012 by Phoenix Environmental Sciences (Phoenix; technical report provided as an Attachment). Survey intensity met the minimum intensity requirements for a full-scale (Level 2) survey in accordance with GS54a, with a total of 60 and 80 bore holes sampled for stygofauna and troglofauna respectively (Figure 2). Surveys took place from six months after establishment of the bore holes to allow for re-colonisation of fauna. Survey methods comprised bore scraping, troglofauna trapping, stygofauna netting and Karaman-Chappius sampling. A combination of morphological and genetic identification methods were used to identify species.

Twenty four species of troglofauna were collected from the study area, of which 21 were considered potential or likely SRE species, being known only from the study area. An additional three taxa were unable to be identified to species level.

Based on species distributions, there appear to be two discrete troglofauna assemblages in two Robe River Pisolite (Czp) formation outcrops (eastern and western) within the study area (Figure 2).

The two Robe River Pisolite outcrops are above water table and are surface expressions of a larger deposit that merges below the water table (Mark Hafer pers. comm., Exploration Manager, Dragon Energy). Both outcrops extend outside the study area and it is likely that the extent of these reflects the distribution of their respective troglofauna (Figure 2 and Table 1).

Table 1 Troglofauna habitat extent

Outcrop (assemblage)	Extent within pit boundary – direct impact area (ha)	Extent within study area (ha)	Inferred total extent (ha)
Western Robe River Pisolite outcrop (western assemblage)	40.5	256.2	1,013.4
Eastern Robe River Pisolite outcrop (eastern assemblage)	0	161.8	255.3

The Early Tonnes Project has been designed to avoid or minimise potential impacts to significant environmental values, including subterranean fauna, specifically:

- the project will be above-water table and therefore stygofauna will not be impacted
- the troglofauna assemblage in the eastern Robe River Pisolite outcrop will not be impacted by the Early Tonnes Project; all pit areas are within the western outcrop
- some loss of habitat associated with excavation of the CID iron ore resource will occur for the western assemblage; however, mine planning has restricted the total pit area to ~40 ha, or about one fifth of the 200 ha CID study area.

We have conducted a preliminary assessment for potential impacts to the western troglofauna assemblage in accordance with EAG 9 (EPA 2013a) and EAG 12 (EPA 2013b). This assessment is provided below. Based on the assessment, we consider it unlikely that the Early Tonnes Project will result in significant impacts to troglofauna.

Impact assessment

Habitat-based assessment for western assemblage

As shown in Figure 2, the total extent of proposed pits is 40.5 ha; this represents the total extent of direct loss of troglofauna habitat (direct impact area).

As shown in Table 1 and Figure 2, the extent of troglofauna habitat in the western Robe River Pisolite outcrop (the western assemblage) within the study area is 256.2 ha. The direct impact area represents 15.8% of this habitat extent.

As shown in Table 1 and Figure 2, the total extent of the western Robe River Pisolite outcrop, and therefore the inferred total habitat extent for the western assemblage, is 1013.4 ha. The direct impact area represents 4.0% of this habitat extent.

Preliminary assessment criteria

To examine the potential significance of the proposed loss of ~50 ha of troglofauna habitat, a high-level review of WA government policies/position statement/guidelines was conducted. To further strengthen the assessment, we looked at similar examples where these policies etc., had been put into practice:

- Viewing the troglofauna assemblage as an ecological community (i.e. a collection of co-occurring populations living together in a particular environment, consistent with Position Statement No. 2 (EPA 2000).
- For vegetation communities the clearing threshold level is 70% (EPA 2000).
- For FMG's Solomon Iron Ore Project PER, the DEC submitted that at least 30% of the troglofauna habitat be conserved if the troglofauna community is found to be restricted (FMG 2011, p.41).
- For API's West Pilbara Iron Ore Project, the EPA (bullletin 1409, p.iv) recommended that at least 50% of the CID troglofauna habitat be retained by area and volume (EPA 2011); the 50% number was based on a recommendation by API's sub fauna scientists.
- Perhaps the most famous case, RTIO's Mesa A (EPA Bulletins 1251 and 1264), 26% of the mesa by area was to be retained and 52% of the orebody (i.e. the sub-grade ore).

Based on the above guidance, our preliminary assessment is that the removal of less than 20% of troglofauna habitat within the study area is highly unlikely to have a significant impact on the ecological community/western assemblage, and that this likelihood is reduced further when considering the proportion would be significantly smaller when compared against the inferred extent of the CID habitat for the western assemblage.

Species-level assessment

It unlikely that any individual species will be significantly impacted by the Early Tonnes Project, based on the following assessment for the western assemblage:

- 17 identified species were recorded from the western assemblage (Table 2), of which
  - 3 were recorded only from the direct impact area (18%)
  - 4 were recorded from both impact and non-impact areas (23%)
  - 10 were recorded from non-impact areas only (59%).
- All three species from the impact area and nine species from outside of the impact area were only recorded from a single bore (Table 2).
- Four species were recorded from three or more bores of which two represent species known from elsewhere in the Pilbara, Meenoplidae 'widespread' and *Nocticola* 'Pilbara1'. The distribution of these four species within the study area suggests that they are evenly spread, with few bores presenting records of three or more species (Figure 3).
- Three of the four species (Meenoplidae 'widespread', *Nocticola* 'Pilbara1' and *Draculoides* 'D1') are medium to large sized species with adults having body measurements up to 2.5 mm wide or deep; all of the species recorded only from inside of the impact area are smaller.
- It is therefore unlikely that the availability of void spaces would represent a limiting factor to the distribution of these smaller species since large void spaces are clearly evident as indicated by the distribution of the larger species. Smaller troglobite species are therefore likely to be distributed throughout the western Robe River Pisolite outcrop and their presence in single bore samples represents a sampling artefact.

Further, the surface geology does not indicate any geological discontinuity that would result in fragmentation of habitat leading to isolated populations within the western Robe River Pisolite outcrop.

Summary: based on the data available, the western Robe Pisolite outcrop can be considered a discrete troglofauna community. Distribution of any particular species is unlikely to be geographically constrained within the unit, including the impact area for the Early Tonnes Project.

Table 2 Species records from direct impact and non-impact areas in the western Robe Pisolite outcrop

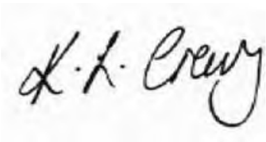
Species	Number of bores from which species were recorded		Total number of individuals sampled	
	Impact	Non-impact	Impact	Non-impact
Atelurinae 'D1'	1		3	
Japygidae 'D1'	1		2	
Symphyla 'D2'	1		3	
Draculoides 'D1'	1	4	2	5
Meenoplidae 'widespread'	5	9	15	39
Nocticola 'Pilbara1'	4	5	6	7
Polyxenida 'D1'	3	4	4	5
Symphyla 'D1b'		1		2
Haplodesmidae 'D1'		1		2
Cryptops 'D1'		2		2
Japygidae 'D2'		1		2
Parajapygidae 'D1'		1		2
Pauropoda 'D2'		1		2
Projapygidae 'D1'		1		2
Projapygidae 'D2'		1		2
Trochanteriidae 'D1'		1		2
Tyrannochthonius 'D1'		1		2
Symphyla sp. indet.[1]	3	1	3	1
Trinemura sp. indet. [1]	6	1	7	1
Pauropoda sp. indet. [1]		2		2
Palpigradi sp. indet. [1]		1		4
Haplodesmidae sp. indet.		5		19

[1] sp. indet data can't be used directly for comparisons.

Memo

In order to reduce uncertainty in the approvals pathway for the Rocklea Early Tonnes Project, we seek your advice on whether our assessment approach for troglofauna and its findings seem reasonable and sufficiently in line with relevant guidance.

Yours Sincerely,



Karen Crews

General Manager

08 9345 1608

Karen.crews@phoenixenv.com.au

1/511 Wanneroo Rd Balcatta WA 6021

References

EPA. 2000. *Environmental protection of native vegetation in Western Australia. Clearing of native vegetation, with particular reference to the agricultural area. Position statement no. 2.* Environmental Protection Authority.

EPA. 2011. *API Management Pty Ltd West Pilbara Iron Ore Project Stage 1 Mine and Rail Proposal. Report and recommendations of the Environmental Protection Authority. Report 1409*. Environmental Protection Authority.

EPA. 2013a. *Environmental assessment guideline for application of a significance framework in the environmental impact assessment process focusing on the key environmental factors*. Environmental Protection Authority.

EPA. 2013b. *Environmental assessment guideline for consideration of subterranean fauna in environmental impact assessment in Western Australia*. Environmental Protection Authority.

FMG. 2011. *Solomon Project — Response to public submissions, EPA assessment no. 1841*. Fortescue Metal Group Ltd.

Figures

Figure 1	Rocklea Early Tonnes Project layout
Figure 2	Surface geology, inferred extent, survey bores, pits, records in and out of impact
Figure 3	Troglofauna species recorded from 3 or more bores

Attachments

Rocklea Early Tonnes Project overview

Subterranean fauna technical report

Figure 1
Rocklea Early Tonnes Project layout

Study area

Rocklea Tenement M47/1024

Main road

Track

River

Pits (23 Jan 2014)

Mine site Layout (23 Jan 2014)

Western Robe River Pisolite outcrop

Eastern Robe River Pisolite outcrop

0 250 500 1,000 Metres

1:35,000

Client: Ennovate Consulting
Project: Rocklea Iron Ore Project

Author: G. Bouteloup
Date: 3/02/2014

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

PHOENIX ENVIRONMENTAL SCIENCES

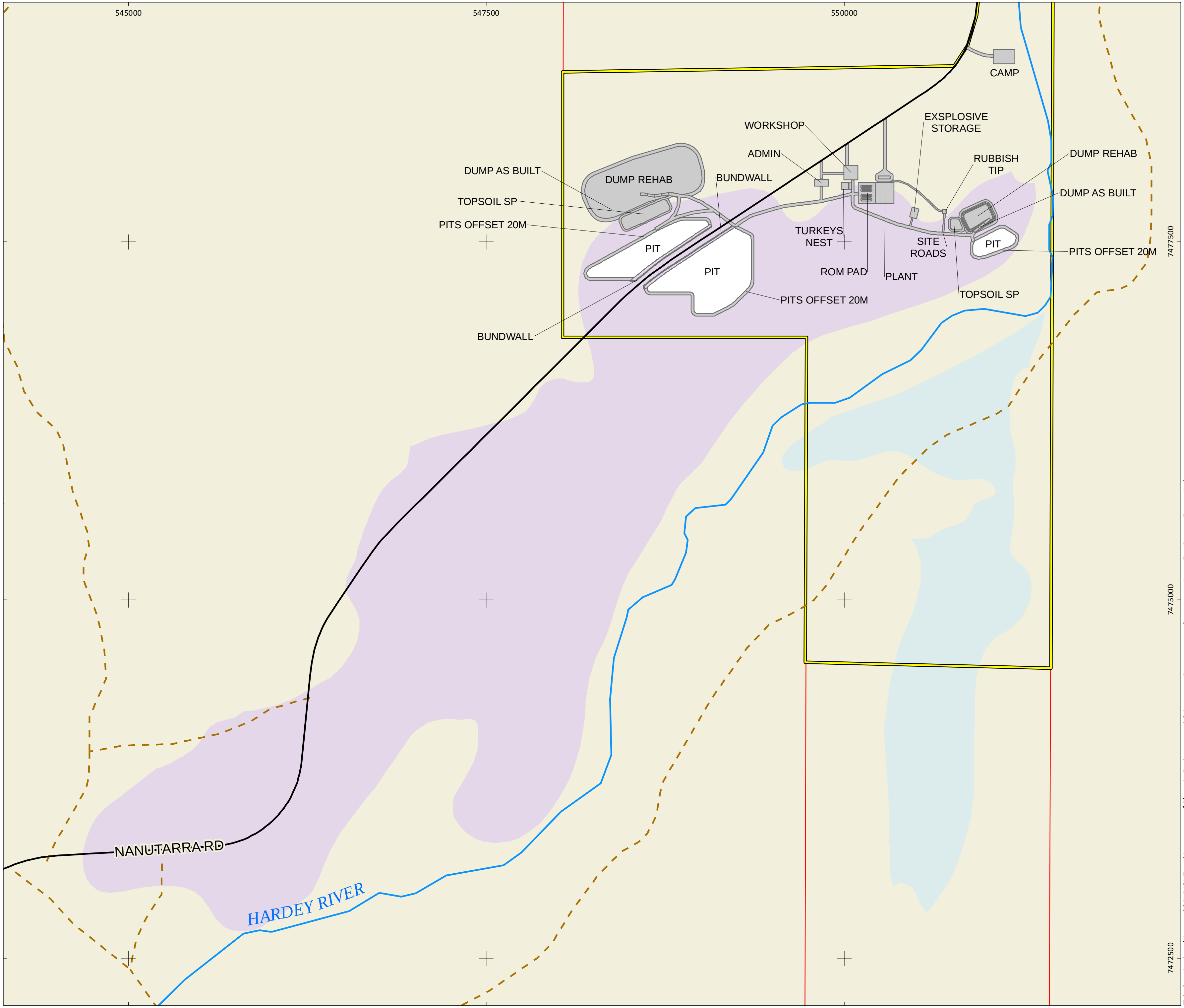


Figure 2
Troglofauna sample sites of the Rocklea Iron Ore Project

- Bores yielding species in the pits
- Bores yielding species outside the pits
- Bores not yielding any species
- Study area
- Rocklea Tenement M47/1024
- Rivers
- Main road
- Track
- Pits (23 Jan 2014)
- Western Robe River pisolite outcrop
- Eastern Robe River pisolite outcrop

Surface geology

- Czk: Calcrete
- Czp: Robe River Pisolite
- Qa: Alluvium
- Qc: Colluvium

0 0.25 0.5 1 Kilometres
1:35,000

Client: Dragon Energy Ltd / Ennovate Consulting
Project: Rocklea — Native Vegetation Clearing Permit (NVCP)

Author: G. Bouteloup
Date: 4/02/2014

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

PHOENIX ENVIRONMENTAL SCIENCES

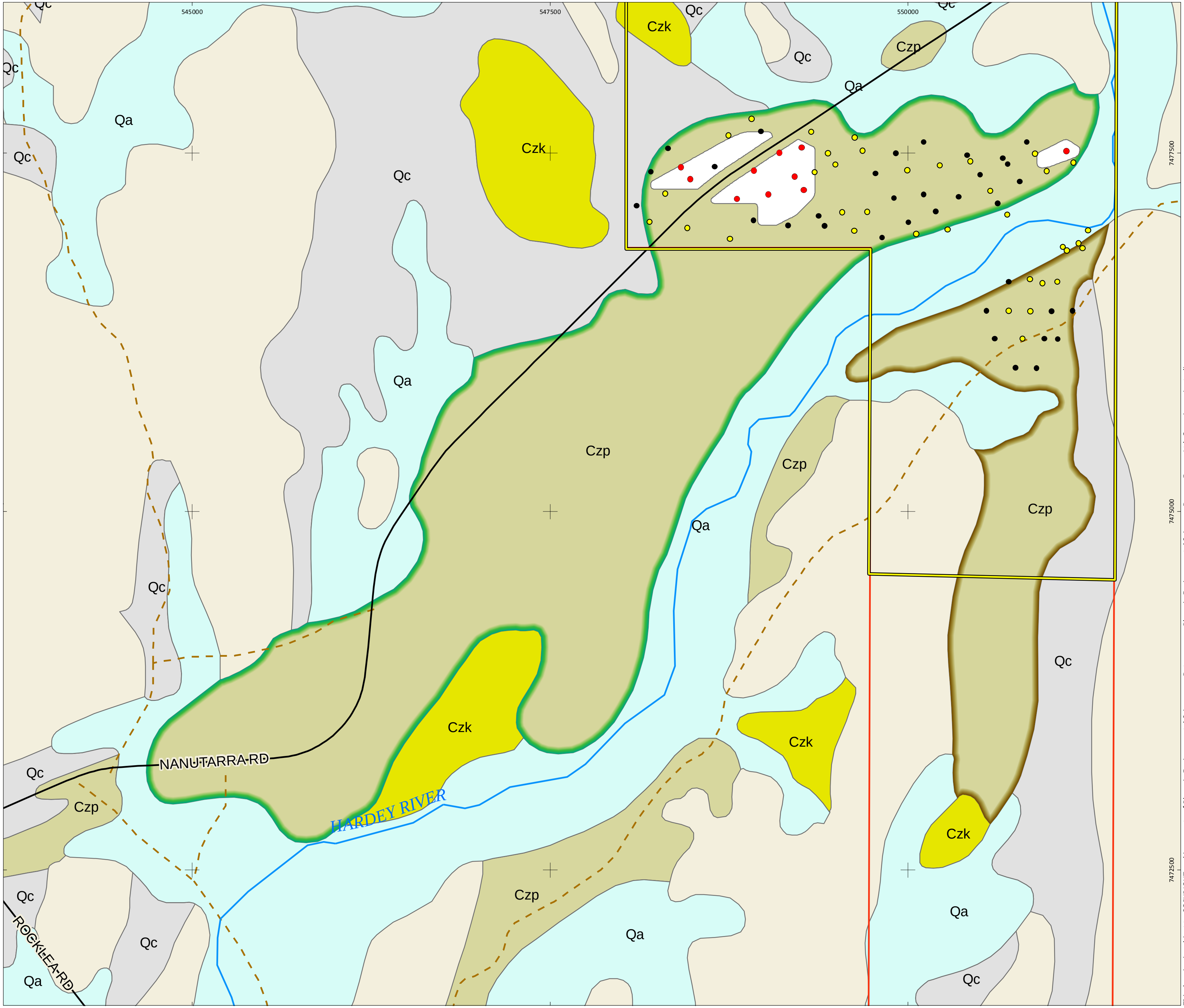
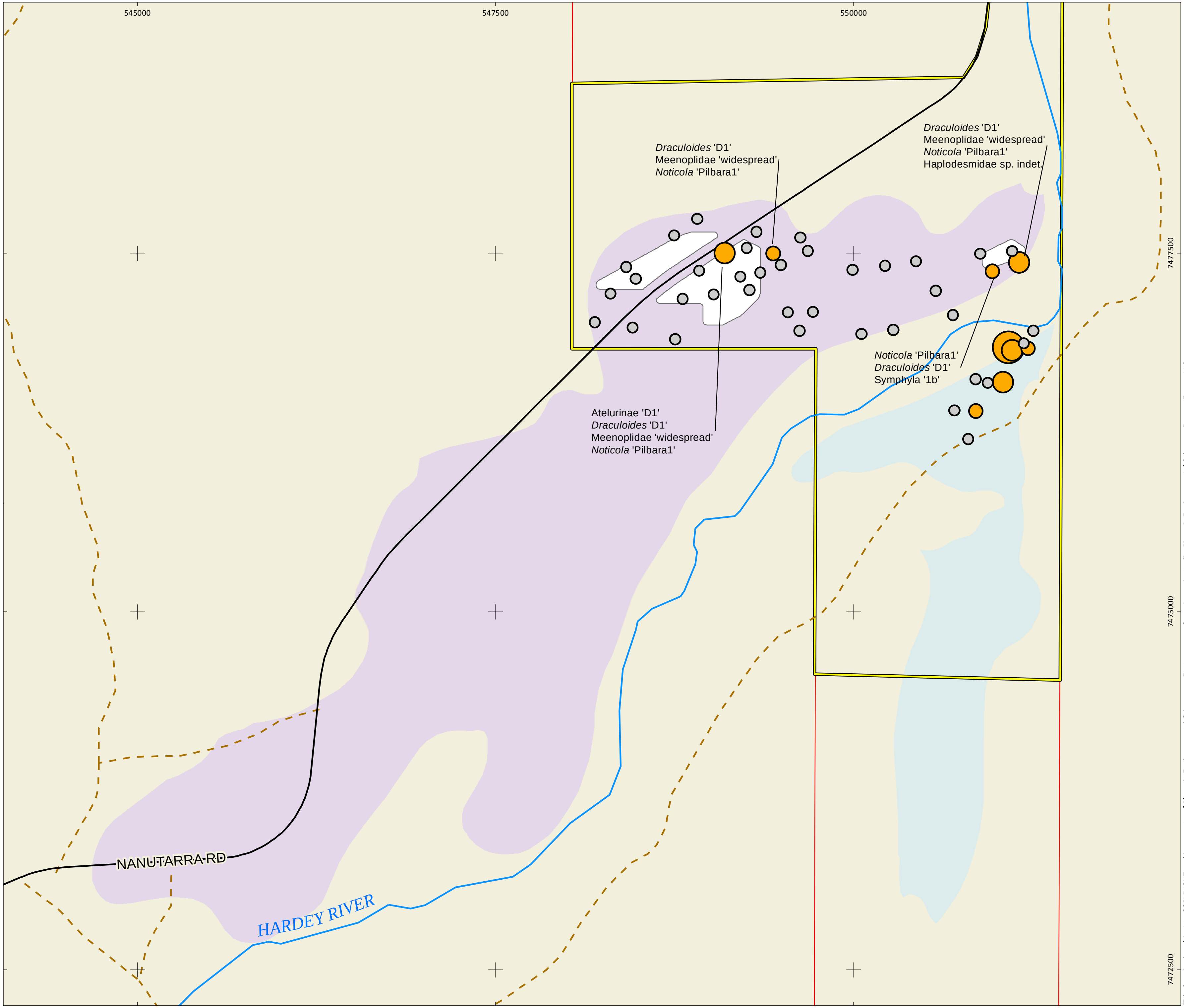


Figure 3
Troglofauna species counts per bore



species count

- 1 - 2
- 3
- 4 - 5
- 6 - 7

Study area

Rocklea Tenement

Main

Track

River

Pits (23 Jan

Western Robe River Pisolite

Eastern Robe River Pisolite

0 250 500 1,000 Metres

1:35,000

Client: Ennovate Consulting
Project: Rocklea Iron Ore Project

Author: G. Bouteloup
Date: 4/02/2014

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

PHOENIX
ENVIRONMENTAL SCIENCES