Bennelongia Environmental Consultants

Cameco Australia Pty Ltd

Subterranean Fauna Assessment of the Kintyre Uranium Deposit

Final Report

Prepared for Cameco Australia Pty Ltd by Bennelongia Pty Ltd

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EXECUTIVE SUMMARY

Cameco Australia Pty Ltd (Cameco) is planning to develop the Kintyre Uranium Deposit to mine uranium oxide. The Project is located approximately 90 km south of the Telfer Goldmine in the Shire of East Pilbara. Production of 2.7-3.6 kilotonnes per annum is expected from the Project. The mine life is estimated to be 15 years from ore reserves of 28-36 kilotonnes. Ore will be transported by road from the mine to export ports in Adelaide, South Australia via the Great Northern Highway, Goldfields Highway and the Eyre Highway.

The specific aims of the subterranean fauna survey at the Project were to:

1. Document the subterranean fauna communities of the Project area and their constituent species.
2. Determine the likely impact of the Project on the subterranean fauna community.

The collection of 23 troglofauna species of 12 Orders, and 15 stygofauna species of seven higher level groups, represents a moderately rich troglofauna and a relatively sparse stygofauna community for the Pilbara region.

The community composition and abundance of troglofauna within the Study Area is unremarkable. Pseudoscorpions, palpigrads, spiders, isopods, centipedes, millipedes, pauropods, symphylans, diplurans, silverfish, cockroaches and hemipterans are all commonly collected in the Pilbara. Notably, schizomids and coleopterans were absent from the Survey Area.

Two species of troglofauna, the pauropods Pauropodidae sp. B26 (8 specimens from one bore) and the cockroach *Nocticola* sp. (a singleton), are currently known only from within the proposed mine pit at Kintyre and mining poses potential conservation risks for these species. However, based on the small size of the proposed mine pit in relation to the likely ranges of both species (inferred from ranges of related species), it is unlikely that this potential risk will be realised.

The stygofauna community composition within the Study Area is also unremarkable, with all of the commonly collected higher order groups recorded, with the exception of ostracods. Nine undescribed species were recorded in the Survey Area, but this may be expected in an area not previously sampled.

Stygofauna habitat within the Survey Area appears to have a high degree of heterogeneity, although the hydrogeological units are repeated. It is possible that some habitat units defined by water chemistry or aquifer type are poorly connected with similar units. This may apply to calcrete, which is commonly recognised as isolated stygofauna habitat in the Yilgarn. Four of the species recorded within the area of predicted groundwater drawdown are not known to occur elsewhere and mining poses potential conservation risks for these species. The species are the copepods *Nitocrella* sp. B04 (nr obesa), *Nitocrella* sp. B05, *Parastenocaris* sp. B07 and the syncarid *Atopobathynella* sp.

Based on the ranges of related species, it is considered likely that *Nitocrella* sp. B05, *Parastenocaris* sp. B07, and *Atopobathynella* sp. (which were all collected in low abundance) have ranges extending beyond the zone of groundwater drawdown. Thus, the potential threat from mine development will not be realised for these species.

The likely range of the more abundant *Nitocrella* sp. B04 (nr *obesa*) is unclear. However, it should be recognised that, depending on the aquifer in which the species occurs, groundwater drawdown will not necessarily adversely impact stygofauna. Information about the aquifers used by different species is not currently available.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

Cameco Australia Pty Ltd (Cameco) is planning to develop the Kintyre Uranium Deposit (the Project) to mine uranium oxide. The Project is located approximately 90 km south of the Telfer Goldmine in the Shire of East Pilbara (Figure 1.1). Production of 2.7-3.6 kilotonnes per annum is expected from the Project. The mine life is estimated to be 15 years from ore reserves of 28-36 kilotonnes. The Project encompasses the following tenements: P45/2632-2643, M45/264, 266, 267, 420, MLA45/693-696, L45/66. Ore will be transported via road from the mine to export ports in Adelaide, South Australia via the Great Northern Highway, Goldfields Highway and the Eyre Highway.

Key mining components and activities of the proposed Project include:

- Mining of the ore deposit by selective open pit methods. This will involve drilling and blasting, digging and loading using hydraulic excavators and front-end loaders.
- De-watering of the ore deposit to access approximately the 95% of ore below the water table. The de-watering discharge will be used on-site for dust suppression, ore processing and within the mine facilities and accommodation village.
- Processing of ore on-site, with waste rock dumps located outside of the pit.
- Supporting infrastructure including an accommodation village, mine site offices and utilities.

It is proposed that the mine pit will occupy about 85 ha with an approximate depth of 250 m. The watertable lies at approximately 12-15 m below ground surface. Although the proposed mine pit and cone of groundwater depression are small relative to the ranges of most subterranean species, mine development may potentially threaten the conservation status of highly restricted species of subterranean fauna, if such species occur within the vicinity of the Project.

Describing species as widespread, restricted and highly restricted is somewhat arbitrary. To help standardise the process, Harvey (2002) proposed that species with ranges <10,000 km^2 should be classified as short range endemics (SREs). About 70% of stygofauna in the Pilbara meet the range criterion for SREs (Eberhard *et al*. 2009) and the proportion of troglofaunal SREs is likely to be even higher (see Lamoreux 2004). This is a much higher proportion of restricted species than occurs in any groups of surface invertebrate species and highlights the fact that subterranean fauna represent an extreme example of SREs, with very poor dispersal capacity.

Restricted ranges make subterranean fauna species particularly vulnerable to extinction as a result of anthropogenic activities and, therefore, they are a focus for conservation policy. The Environmental Protection Authority (EPA) have produced two guidance statements dealing with the principles and methodology appropriate to assessing possible impacts of development on subterranean fauna (EPA 2003, 2007).

Subterranean fauna were surveyed in and around the Project area (referred to as the Survey Area) with the specific aims of:

1. Documenting the subterranean fauna communities of the Project area and their constituent species.
2. Determining the likely impact of Project development on the conservation significance of the subterranean fauna community.

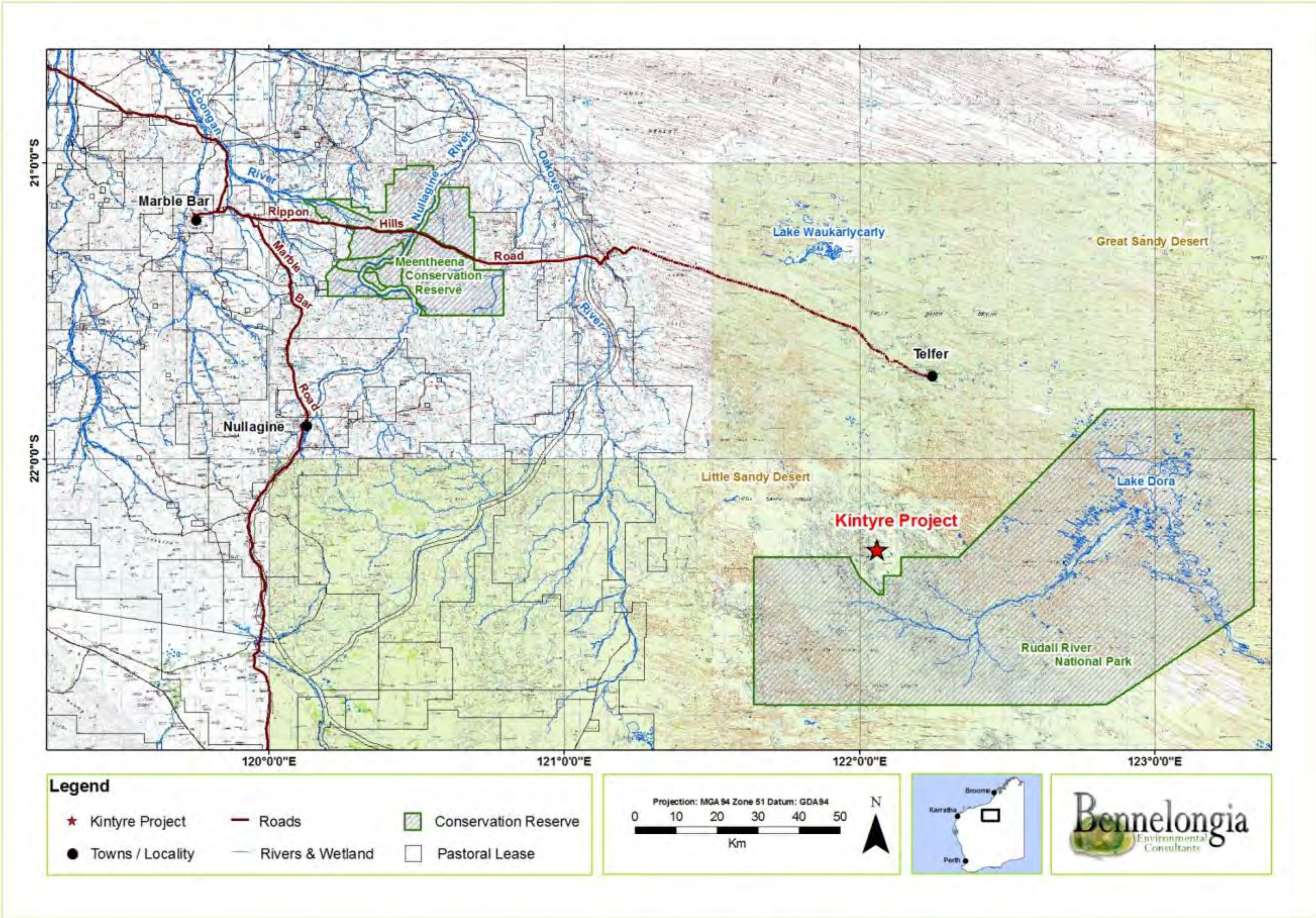

Figure 1.1. Location of the Kintyre Project.

2. EXISTING INFORMATION ON SUBTERRANEAN FAUNA

Subterranean fauna include both terrestrial (troglofauna) and aquatic (stygofauna) species. Troglofauna occur in underground cavities, fissures and interstitial spaces above the watertable. Stygofauna inhabit groundwater. Most subterranean fauna are invertebrates, although both troglofaunal reptiles and stygofaunal fish have been recorded in Western Australia (Whitely 1945; Aplin 1998).

The stygofauna of the Pilbara region are considered to be of global significance in terms of richness and diversity (Eberhard *et al*. 2009; Guzik *et al*. 2011) and emerging evidence indicates that the same is true for troglofauna (see Biota 2005a, 2006; Subterranean Ecology 2007; Bennelongia 2008a,b,c, 2009a,b).

2.1. Troglofauna

Early troglofauna research focussed on caves. However, surveys in the Pilbara and Yilgarn during the past seven years have demonstrated that troglofauna occur outside caves within various rock-forms in both of these regions. The invertebrate groups containing troglofauna include: pseudoscorpions, spiders, palpigrads, schizomids, harvestmen, isopods, centipedes, millipedes, pauropods, symphylans, diplurans, silverfish, cockroaches, bugs, beetles and fungus-gnats. While diversity and abundance of troglofauna seem to be greatest in the Pilbara, troglofauna occur in most regions of Western Australia and have been recorded from the Kimberley (Harvey 2001), Cape Range (Harvey *et al.* 1993), Barrow Island (Biota 2005b), the Mid-West (Ecologia 2008) and Yilgarn (Bennelongia 2009c), South-West (Biota 2005a), and Nullarbor (Moore 1995).

Most troglofauna surveys for environmental assessment have been in areas of pisolite and Banded Iron Formation in the Pilbara, Yilgarn and Mid-West. The micro-habitats used by troglofauna within these lithologies are yet to be fully characterised but it is inferred they occupy fissures and voids associated with weathering, enrichment and faulting. Knowledge of troglofauna outside mineralised habitats is poorly developed because mining has been the primary motive for most surveys. However, it has been demonstrated that troglofauna also occur in calcrete and alluvium in the Pilbara (Edward and Harvey 2008; Rio Tinto 2008), Yilgarn (Barranco and Harvey 2008; Platnick 2008; Bennelongia 2009c) and elsewhere (Biota 2005a,b).

2.2. Stygofauna

Stygofauna surveys of the Pilbara commenced in the 1990s (Humphreys 1999), followed by a rapid increase in knowledge during the last decade as a result of the Pilbara Biodiversity Survey (see Eberhard *et al*. 2005, 2009). Calcrete and alluvium are typically considered to be the most productive habitats for stygofauna (Humphreys 1999; Humphreys 2008), although mafic volcanics may support rich populations and stygofauna occur in moderate richness in BIF (Halse *et al*. in prep.).

The Pilbara is estimated to support between 500 and 550 stygofauna species, with the density of species being relatively uniform across the region (Eberhard *et al.* 2009). Stygofauna communities in the Pilbara are dominated by crustaceans with ostracods, copepods and amphipods contributing most of the animals and species (Eberhard *et al.* 2005; Halse *et al*. in prep.).

Stygofauna sampling in the Pilbara has been skewed towards areas of proposed development for water supply borefields and mine de-watering and the species richness reported in these habitats has been roughly proportional to sampling effort (Eberhard *et al.* 2005). Survey areas with more than 20 species are generally considered to be moderately species rich.

3. HABITAT ASSESSMENT

3.1. Geology

The Kintyre deposit occurs in the Rudall region on the northern margin of the Rudall Metamorphic Complex, which consists of a basement complex of metamorphic sedimentary rocks. The uranium deposit is a vein type occurrence and the host rocks for the mineralisation are schists and metasediments (Yandagooge Formation). This formation is underlain by granitic gneiss, which is overlain by Coolbro Sandstone of the Yeena Group (Environ 2010; MWH 2010). The deposit is associated with a number of major shear and fault zones that trend towards the northwest. Proterozoic bedrock has been incised by glaciations and subsequent deposition of sediments of the Permian Paterson Formation cover much of the area, in-filling deep U-shaped valleys. Alluvial deposits are generally localised to sand plain areas and active modern day drainages. The key geological components of the sequence are described in the following sections (MWH 2010).

3.1.1. Cenozoic Sediments

Recent alluvium and colluvium form a thin sediment cover and veneer over most of the Project area. Colluvial sediments usually consist of silty, clayey sands and gravels which form low angle fans flanking ridges and hills. Alluvial sediments comprise silty, clayey sands which have been deposited over flat plain areas between the ridges and hills. Alluvial deposits generally occur in channels of the larger drainages and often contain a coarse gravel layer at the base. Aeolian sediments occur predominately as a thin surface layer with localised sand dune formations. Laterite and silcrete form ferruginous capping on hills and sheets overlain by sand plain. Calcrete generally occurs between the main bedrock areas and is well developed in Cenozoic drainage channels, particularly to the north of the Project area.

3.1.2. Permian Sediments

Permian sediments in the Rudall region, known as the Paterson Formation, comprise materials deposited as a result of widespread glaciations. These deposits appear in both palaeochannel infill or as capping to the Proterozoic rocks. Paterson Formation can be divided into two broad units:

1. An upper unit consisting of a variable sequence of glaciofluvial and glaciolacustrine sands, silts and clays;
2. A lower coarser basal unit consisting of sands, gravels and conglomerate of glaciofluvial origin.

Two major glacial palaeochannel valleys with numerous tributaries are present in the Kintyre area. The tributaries join to form a single channel about 5 km north of the Project area. These palaeochannels roughly follow the drainage lines of the modern day Yandagooge Creek. These palaeochannels are greater than 170 m deep in some areas.

3.1.3. Proterozoic Formations

Proterozoic rocks in the Rudall region consist of Rudall Metamorphic Complex, which is an older suite of highly metamorphosed, altered and complexly folded schists, carbonates and quartzite. The Rudall Metamorphic Complex occurs in the central portion of the Project area and has been divided into two suites of rocks:

1. An older suite of banded adamellite gneiss enclosing belts of mafic-ultramafic gneisses, paragneiss with mica schists, quartzite and meta-iron formations;
2. A younger suite dominated by quartzite and quartz-muscovite schists with minor iron formation, graphitic schist, meta-basalt and chlorite-carbonate schists.

A younger sedimentary group (Yeneena Group) unconformably overlies the metamorphic rocks. Tight folding in this sequence increases in intensity towards the western margin of the metamorphic rocks, with thrust faulting present. The basal unit of this group is the Coolbro Sandstone, consisting of quartz sandstone with sericite matrix and, sometimes, a coarse grained conglomerate at the base.

3.2. Hydrogeology

The Project area lies between two branches of Yandagooge Creek, referred to as the South Branch and the West Branch. The tributaries converge north of Kintyre and continue to flow on a northerly course to Coolbro Creek, which flows east towards the Great Sandy Desert where the surface drainage dissipates into dune systems. The catchment of the Yandagooge Creek System is separated from the Rudall River catchment by low hills (Environ 2010).

3.2.1. Cenozoic Sediments

The majority of the alluvial and colluvial deposits occur above the water table and are unsaturated. Where they are saturated they usually contain brackish to saline water. The recent sands and gravel associated with the larger drainage areas contain coarser sediments and can contain moderate amounts of good quality groundwater. These aquifers are generally considered to be of only minor significance from a water supply viewpoint because they are shallow and have limited storage. However, they provide an important mechanism for recharge to underlying sheared Proterozoic rocks and coarse grained Permian sediments (MWH 2010).

North and west of the Project area there are extensive areas of calcrete along a large broad drainage system that drains to towards Lake Waukarlycarly. The aquifer in this area is likely to be extensive but relatively thin; the groundwater quality is likely to vary from relative fresh to brackish (MWH 2010).

3.2.2. Permian Sediments

The upper glaciolacustrine unit of the Paterson Formation generally consist of fine grained sediments which contain thin discontinuous sand aquifers with small amounts of poor to moderate quality groundwater. This unit is not considered an important aquifer zone.

The lower unit is composed of coarser sediments (an upper sand zone and a basal sand and gravel, conglomerate zone) and is considered to be a major confined aquifer. The thickness and permeability of this aquifer appears to increase downstream in the glacial channels. Hydraulic connection appears to exist between the upper and lower sequence.

3.2.3. Proterozoic Formations

The Proterozoic rocks in the Rudall area have little or no intergranular permeability, with groundwater yields and aquifer characteristics dependent on secondary structures such as fault and shear zones. The most dominant of these structures are a series of north-west trending folds, faults and shear zones. The most permeable units in the Proterozoic formations are those associated with shear zones in the Coolbro Sandstone, which locally have high permeability and good water quality. The metamorphic rocks in the proximity of the Project area are locally fractured and sheared, and potentially contain minor amounts of poor quality groundwater. The aquifers most likely associated with the deposit are:

1. The Kintyre Shear Zone (in Coolbro Sandstone);
2. Vuggy footwall carbonate to the east of the deposit (in lower Permian sediment);
3. Localised fractures within the quartz chlorite schists (in Proterozoic formations); and

4. Fractured zones in the graphite schists (in Proterozoic formations) (MWH 2010).

3.3. Habitat Requirements for Troglofauna

Troglofauna presence is dependent on geology and, if no fissures or voids are present below ground, no troglofauna will occur. If subterranean spaces are present, the pattern of their occurrence will largely determine the abundance and distribution of troglofauna. Vertical connectivity with the surface is important for supplying carbon and nutrients to maintain subterranean fauna populations (plant roots are an important surface connection), while lateral connectivity of voids is crucial to underground dispersal. Geological features such as dykes may block off the continuity of habitat and act as barriers to dispersal, leading to species having highly restricted ranges.

Troglofauna habitat is usually considered to occur from the lower layers of sand and soil at the ground surface to the interface with groundwater (Juberthie *et al*. 1981). Troglofauna occupy interstices, vugs, cavities and fissures in this subterranean space.

3.4. Survey Area as Troglofauna Habitat

Habitat characterisation suggests prospective troglofauna habitat is present within the Survey Area at depths between 1 and 15 m (watertable is at 12-15 m depth). There are several key lithological units within this vertical span that, where present, are likely to represent prospective troglofauna habitat:

1. Colluvial and alluvial sediments;
2. Laterite and silcrete that form ferruginous capping on hilly areas;
3. Calcrete; and
4. Sheared Proterozoic rocks (Kintyre Shear Zone, Coolbro Sandstone, fractured schists) that remain unsaturated.

3.5. Habitat Requirements of Stygofauna

Stygofauna occur in an array of different groundwater habitats including porous, karstic and fractured-rock aquifers, springs and the hyporheos of streams (Eberhard *et al*. 2005). Stygofauna inhabit interstitial spaces, fissures and voids in groundwater. Lateral connectivity of these spaces is important because it enables animals to move about underground, while vertical connectivity through to the surface is important for supplying carbon and nutrients. Geological features such as dykes may act as barriers to dispersal of stygofauna below-ground and lead to species having highly restricted ranges.

Apart from salinity, the physiochemical tolerance of stygofauna has not been well defined (see Humphreys 2008). Furthermore it should be noted that for the vast majority of stygofauna studies, physiochemical parameters have been recorded in the first metre of the upper aquifer, and therefore, relationships with stygofauna that inhabit the deeper aquifers cannot be established.

Stygofauna have mostly been recorded from fresh to brackish groundwater but may occur in salinities up to 60,000 mg/L TDS (Watts and Humphreys 2006; Reeves *et al*., 2007; Ecologia 2009). Stygofauna are known to be rich in calcareous systems where the pH is typically between 7.2 and 8.2 (Humphreys 2001). Occurrence at lower pH was reported by Biota (2008), where a mean pH of 6.7 was observed from profiling 15 bores that contained stygofauna at various locations in the Pilbara. Stygofauna are known to be tolerant of low concentrations of dissolved oxygen; e.g. Biota (2008) reported a mean DO of 38.2% saturation from 15 bores profiled that contained stygofauna at various locations in the Pilbara (Biota 2008).

3.6. Survey Area as Stygofauna Habitat

There are five key lithologies within the aquifer units that are likely to represent prospective stygofauna habitat:

1. Pebble layers within the Cenozoic sediments (where saturated, brackish to saline);
2. Areas of calcrete that occur in association with the Cenozoic sediments. Note that the extensive areas of calcrete that occur along the drainage system leading to Lake Waukarlycarly (to the north of the Project) are likely to represent significant stygofauna habitat;
3. Permian sediments, including upper sand aquifers (probably lower quality), and the lower basal sand, gravel and conglomerate (suitability is dependent on pore spaces);
4. Sheared Proterozoic rocks (Kintyre Shear Zone, Coolbro Sandstone, fractured schists); and
5. Vuggy footwall carbonate (Proterozoic) to the east of the deposit.

3.7. Habitat Continuity

In broad terms, geology is similar both inside the proposed impact footprints (pit excavation and groundwater drawdown) and in the landscape surrounding the Survey Area. However, geology is variable, both laterally and vertically, on a scale of tens to hundreds of metres throughout.

3.7.1. Stygofauna

The aquifers in the Survey Area form part of the extensive regional aquifer system of the Yandagooge Creek and extensive survey has indicated that most stygofauna species in the adjacent Pilbara have catchment scale ranges (see Finston *et al*. 2007; Biota 2010; Finston *et al*. 2011).

Nevertheless, geology is spatially variable in the vicinity of the Survey Area and it is possible that restricted hydrogeological units are where restricted stygofauna occur. In particular calcrete, which is commonly recognised as isolated stygofauna habitat in the Yilgarn (Humphreys 2001; Cooper *et al*. 2002, 2007, 2008; Guzik *et al*. 2008, 2011; Watts and Humphreys 2006), occurs in the Project area. Its extent and connectivity with other calcrete, such as that of the drainage system entering Lake Waukarlcarly, is unknown.

3.7.2. Troglofauna

Quantifying habitat connectivity for troglofauna is inherently difficult and in most cases connectivity is inferred via the lack of obvious barriers to troglofauna dispersal. Prospective geologies for troglofauna occur in the Survey Area and surrounding landscape but most geologies have a patchy occurrence, so that there will be large areas of continuous troglofauna habitat only if several prospective geologies are interlinked. It is considered likely that this interlinking occurs but there is no conclusive evidence to support the assumption.

4. METHODS

4.1. Troglofauna Sampling

Troglofauna survey of the Project area was conducted according to the general principles laid out in EPA Guidance Statements Nos 54 and 54A (EPA 2003, 2007). The impact area for the purpose of assessment was defined at the proposed mine pit. Areas outside the proposed mine pit but in the vicinity of the Project were treated as reference areas and used to examine whether species recorded occurred more widely than the mine pit (Figure 4.1). Collectively the impact and reference areas are referred to as the Survey Area.

4.1.1. Sampling Methods
In nearly all cases, each troglofauna sample was collected using two separate techniques that provided two separate subsamples. The two techniques used were trapping and scraping.

1. *Trapping*. Custom made 270 mm long and 70 mm diameter cylindrical PVC traps, with entrance holes on the side and top, were used for trapping. Traps were baited with moist leaf litter, previously sterilised by microwaving, and lowered on nylon cord to within a few metres of the watertable or end of the drill hole. In every fourth hole, a second trap was set mid-way down the hole. Drill holes were sealed while traps were set to minimise the ingress of surface invertebrates. Traps were retrieved seven or eight weeks later and their contents (bait and captured fauna) were emptied into a zip-lock bag and road freighted to the laboratory in Perth.

2. *Scraping*. Prior to setting traps, holes were scraped. This was done using a weighted 150 µm mesh troglofauna net with variable aperture to best fit the diameter of the hole. The net was lowered to the bottom of the hole, or to the watertable, and pulled back to the surface so that it scaped along the walls of the drill hole. Each scrape comprised four drop and retrieve sequences with the aim of scraping any troglofauna off the walls and into the net. After each scrape, the contents of the net were transferred to a 125 ml vial and preserved in 100% ethanol.

In accordance with best practice, the scrape and trap (single or double) subsamples taken from a single drill hole during each phase of the survey were combined as a single sample for the purposes of calculating sampling effort.

4.1.2. Timing and Sample Effort
Eighty-two impact and 108 reference samples were collected during three sampling rounds: Round 1 - 24 February 2010 to 29 April; Round 2 - 27 July to 23 September 2010; Round 3 - 19 October to 15 December 2010 (Table 4.1). A list of drill-holes sampled for troglofauna is provided in Appendix A.

4.1.3. Other Sampling
Records of troglofauna collected as by-catch during the concurrent stygofauna sampling program (see Section 4.2) were included with the troglofauna survey results. These records provided additional information on the distributions and conservation significance of troglofauna species.

4.1.4. Sample Sorting and Species Identification
Troglofauna caught in traps were extracted from the leaf litter using Berlese funnels under halogen lamps. Light drives troglofauna and soil invertebrates out of the litter into the base of the funnel containing 100% ethanol (EPA 2007). After about 72 hours, the ethanol and its contents were removed and sorted under a dissecting microscope. Litter from each funnel was also examined under a microscope for any remaining live or dead animals.

Preserved scrapes were elutriated to separate animals from heavier sediment and sieved into size fractions (250, 90 and 53 µm) to remove debris and improve searching efficiency. Samples were then sorted under a dissecting microscope.

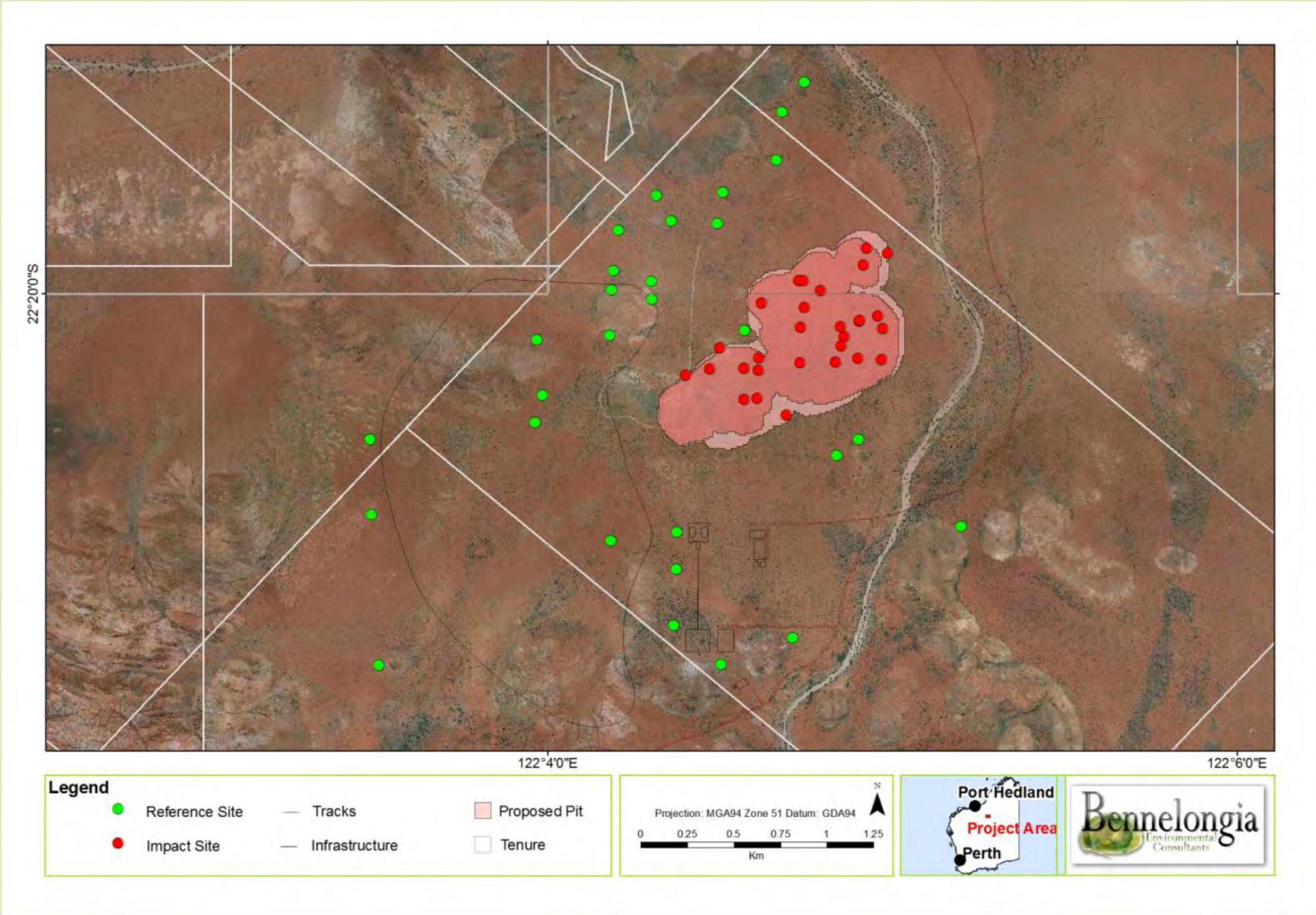

Figure 4.1. Drill-holes sampled for troglofauna in the Survey Area.

Table 4-1. Troglofauna sample effort at the Survey Area.

Sample Round	*Impact*	*Reference*
Round 1		
Scrape	25	29
S Trap	21	19
D Trap	4	10
Samples	25	29
Round 2		
Scrape	28	29
S Trap	22	18
D Trap	6	10
Samples	28	29
Round 3		
Scrape	29	50
S Trap	14	7
D Trap	2	4
Samples	29	50
Total Samples	**82**	**108**

S Trap = single trap in the drill hole; D Trap = two traps in the drill hole

All fauna were picked from samples and examined for troglomorphic characteristics (lack of eyes and pigmentation, well developed sensory organs, long slender appendages, vermiform body shape). Surface and soil-dwelling animals were identified only to Order level. Troglofauna were, as far as possible, identified to species or morphospecies level, unless damaged, juvenile or the wrong sex for identification (as stipulated by EPA 2007). Identifications were made under dissecting and/or compound microscope and specimens were dissected as necessary. Unpublished and informal taxonomic keys were used to assist identification of taxa for which no published keys exist.

Representative animals will be lodged with the Western Australian Museum after assessment is completed.

4.2. Stygofauna Sampling

Stygofauna survey of the Project area was conducted according with the general principles laid out in EPA Guidance Statements Nos 54 and 54A (EPA 2003, 2007). The impact area was defined as the extent of >2 m of groundwater drawdown. Reference areas were defined as areas where there was <2 m of drawdown (Figure 4.2). Collectively the impact and reference areas are referred to as the Survey Area.

4.2.1. Sampling Methods

At each bore, six net hauls were collected using weighted plankton nets; three hauls with a 50 µm mesh net and three with a 150 µm mesh net. After the net was lowered to the bottom of the bore it was oscillated up and down briefly to agitate benthic stygofauna into the water column prior to slowly retrieving the net. Contents of the net were transferred to a 125 ml polycarbonate vial after each haul and preserved in 100% ethanol. Nets were washed between bores to minimise contamination between sites.

4.2.2. Timing and Sample Effort

One hundred and forty-six samples were collected across the Project area during four sampling rounds: Round 1 - April 2010; Round 2 - September 2010; Round 3 - December 2011 and Round 4 - April 2012 (Table 4.2). A list of drill-holes sampled for stygofauna is provided in Appendix B.

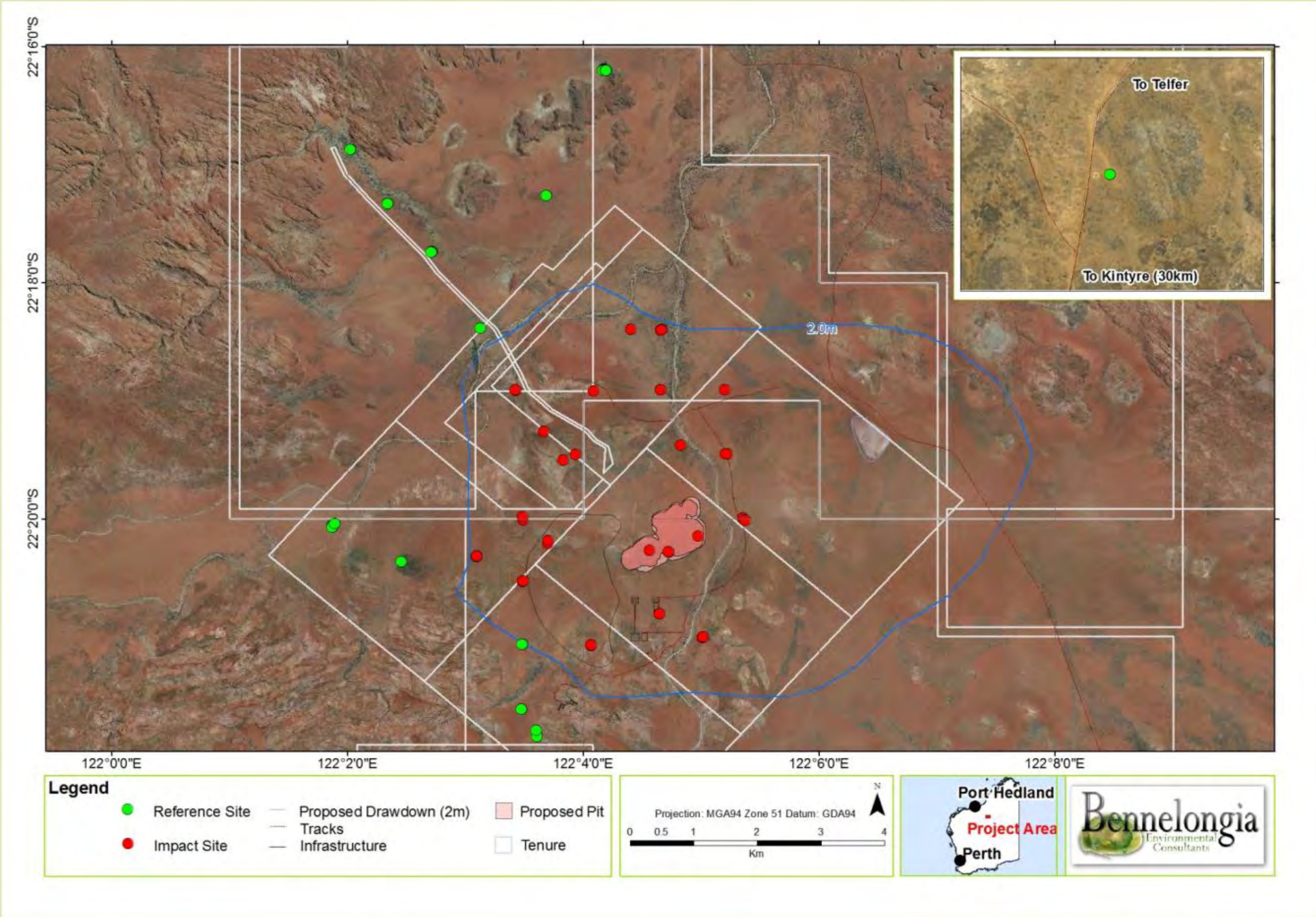

Figure 4.2. Drill-holes sampled for stygofauna in the Survey Area.

4.2.3. Other Sampling
Records of stygofauna collected as by-catch during concurrent troglofauna sampling were included in stygofauna survey results. These records provided additional information on the distributions and conservation status of stygofauna species.

4.2.4. Species Sorting and Identification
In the laboratory, samples were elutriated to separate out heavy sediment particles and sieved into size fractions using 250, 90 and 53 µm screens. All samples were sorted under a dissecting microscope. Sorted animals were identified to species or morphospecies using available keys and species descriptions. When necessary, animals were dissected and examined under a compound microscope. Morphospecies determinations were based on characters used in species keys.

Representative animals will be lodged with the Western Australian Museum after assessment is completed.

4.3. Compiling Species Lists
Troglofauna and stygofauna specimens that could not be identified to species or morphospecies level were included in estimates of species richness only if they could not belong to species already recorded. For example, damaged silverfish specimens of the family Nicoletiinae sp. and mature specimens identified as the morphospecies *Trinemura* sp. B07 were treated as a single species because it was likely that the animals identified to family level as Nicoletiinae were, in fact, those already recorded as *Trinemura* sp. B07. The purpose of this criterion was to prevent higher level identifications falsely inflating species richness.

4.4. Personnel
Fieldwork was undertaken by Grant Pearson, Jim Cocking, Dean Main, Michael Curran, Jeremy Quartermaine and Peter Cocking. Sample sorting was done by Jane McRae, Mike Scanlon, Jim Cocking, Grant Pearson, Andrew Trotter, Heather McLetchie, Dean Main, Michael Curran Jeremy Quartermaine, and Yoav Bar-Ness. Identifications were made by Jane McRae, Dean Main and Mike Scanlon.

Table 4-2. Sample effort for stygofauna sampling at the Survey Area.

Site Type	Round 1	Round 2	Round 3	Round 4	Total
Impact	33	33		7	66
Reference	8	8	38	19	54
Total Samples	**41**	**41**	**38**	**26**	**146**

5. RESULTS

5.1. Troglofauna

5.1.1. Troglofauna Occurrence and Abundance
Sampling yielded 93 troglofaunal animals, representing six Classes, 12 Orders and 23 species. Three Orders of arachnids were recorded: Pseudoscorpionida (1 species), Palpigradi (1 species), and Araneae (1 species). The only crustacean Order collected was Isopoda (3 species). One Order of centipede was recorded: Scolopendromorpha (3 species). Millipedes were represented by one Order, Polyxenida (1 species). Pauropods were represented by the only known Order in this group (Pauropodina) (3 species).

Pseudocentipedes were represented by one Order: Cephalostigmata (3 species). There were four Orders of hexapods (Entognatha/Insecta): Diplura (4 species), Thysanura (2 species), Blattodea (1 species), Hemiptera (1 species) (Table 5.1).

The numerically dominant species were Lophoproctidae sp. B01 and *Trinemura* sp. B07 (Table 5.1, Figure 5.1). All other species were collected in low abundance (≤10 specimens) and seven species were recorded as singletons, i.e. only one animal of that species was collected.

Documenting the composition of troglofauna communities, and the distribution of the constituent species, is difficult because a high proportion of troglofauna species occur in low abundance. Only two species were represented by more than ten animals in sampling results and the less abundant two-thirds of all species were represented by only 32% of animals (Figure 5.1).

Despite the low abundance of most individual species, the average number of troglofaunal animals caught at the Survey Area was 0.49 per sample, which is double the historical capture rate of 0.25 for the Pilbara (Subterranean Ecology 2007). Capture rates were higher in the reference than impact area (0.59 specimens per sample versus 0.39).

5.1.2. Troglofauna Distributions

Fourteen of the 23 species were recorded within the proposed mine pit (Table 5.1). Of these 14 species, 12 species are known to occur in reference areas outside the mine pit. The pauropod Pauropodidae sp. B26 and probably the cockroach *Nocticola* sp. are only known from the proposed mine pit (Figure 5.2). Two species, Lophoproctidae sp. B01 and Palpigradida sp. B01, have been recorded in previous surveys. Both are widespread across the Pilbara (Bennelongia 2009a,b, unpublished data).

5.2. Stygofauna

5.2.1. Stygofauna Occurrence and Abundance

Stygofauna sampling yielded 532 specimens consisting of at least 15 species of seven higher order groups, including Rotifera (1 species), Oligochaeta (1 species), Copepoda (7 species), Syncarida (2 species), Amphipoda (2 species), Isopoda (1 species) and nematodes of unknown order/s (Table 5.2).

Oligochaetes were the numerically dominant group, with amphipods and copepods also relatively abundant (Table 5.2). The most numerous species were the oligochaete Tubificidae stygo type 5, the amphipod Paramelitidae sp. B07, and the copepod *Nitocrella* sp. B04 (nr *obesa*). The majority of taxa were collected at low abundance with the most abundant third of the species accounting for 98% of all the animals collected (Table 5.3).

5.2.2. Stygofauna Distributions

Four of the 15 species collected are known from beyond the Survey Area, with three of the species widespread in the Pilbara or beyond (Table 5.2). A further two of the 'species' collected (Nematoda sp. and *Filinia* sp.) were based on higher level identifications; neither nematodes nor rotifers are included in formal environmental impact assessment and it is expected that the species represented by Nematoda sp. and *Filinia* sp. are widespread.

Of the nine species probably known only from the Survey Area, four are 'localised' within the proposed drawdown cone. These are three copepods *Nitocrella* sp. B04 (nr obesa), *Nitocrella* sp. B05 and *Parastenocaris* sp. B07 and one syncarid *Atopobathynella* sp. (Figure 5.4).

Table 5-1. Troglofauna collected in the Survey Area.

Taxonomy	Impact	Reference	Comment on Range
Arachnida			
Pseudoscorpionida			
Lechytia sp. B03		1	Reference only
Palpigradida			
Palpigradida sp. B01		4	Reference only, but wide-spread in the Pilbara
Araneae			
'*Prethopalpus*' sp. B20	3	1	Also known from reference area
Crustacea			
Isopoda			
Hanoniscus sp. B05	3	1	Also known from reference area
Philosciidae sp.		1	Reference only
Troglarmadillo sp. B19	2	1	Also known from reference area
Chilopoda			
Scolopendromorpha			
Cryptopidae (nr *Cryptops*) sp. B12	2	3	Also known from reference area
Cryptopidae (nr *Cryptops*) sp. B13	2	1	Also known from reference area
Cryptops sp. B19		2	Reference only
Diplopoda			
Polyxenida			
Lophoproctidae sp. B01	3	11	Wide-spread in the Pilbara
Pauropoda			
Pauropodina			
Pauropodidae sp. B24		2	Reference only
Pauropodidae sp. B25		1	Reference only
Pauropodidae sp. B26	8		Impact only
Symphyla			
Cephalostigmata			
Scutigerella sp. B02	1	8	Also known from reference area
Symphyella sp. B06	3	3	Also known from reference area
Symphyella sp. B08		2	Reference only
Entognatha			
Diplura			
Japygidae sp.	1	1	Likely to be one species in both impact and reference area
Parajapygidae sp. B13		1	Reference only
Projapygidae sp. B03	1	1	Also known from reference area
Projapygidae sp. B07		1	Reference only
Insecta			
Thysanura			
Nicoletiinae*	1	2	Probably *Trinemura* sp. B07
Trinemura sp. B07	1	12	Also known from reference area
Blattodea			
Nocticola sp.	1		Uncertain, but likely to represent a local species
Hemiptera			
Systelloderes sp.		1	Reference only

*Nicoletiinae is not considered an additional species.

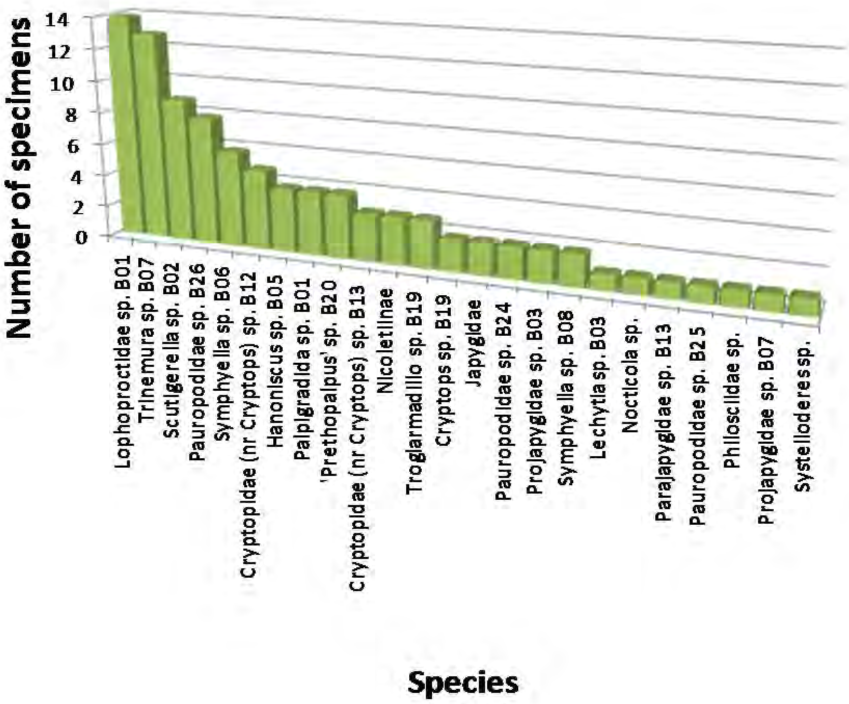

Figure 5.1. Capture abundance of each troglofauna species recorded in the Survey Area.

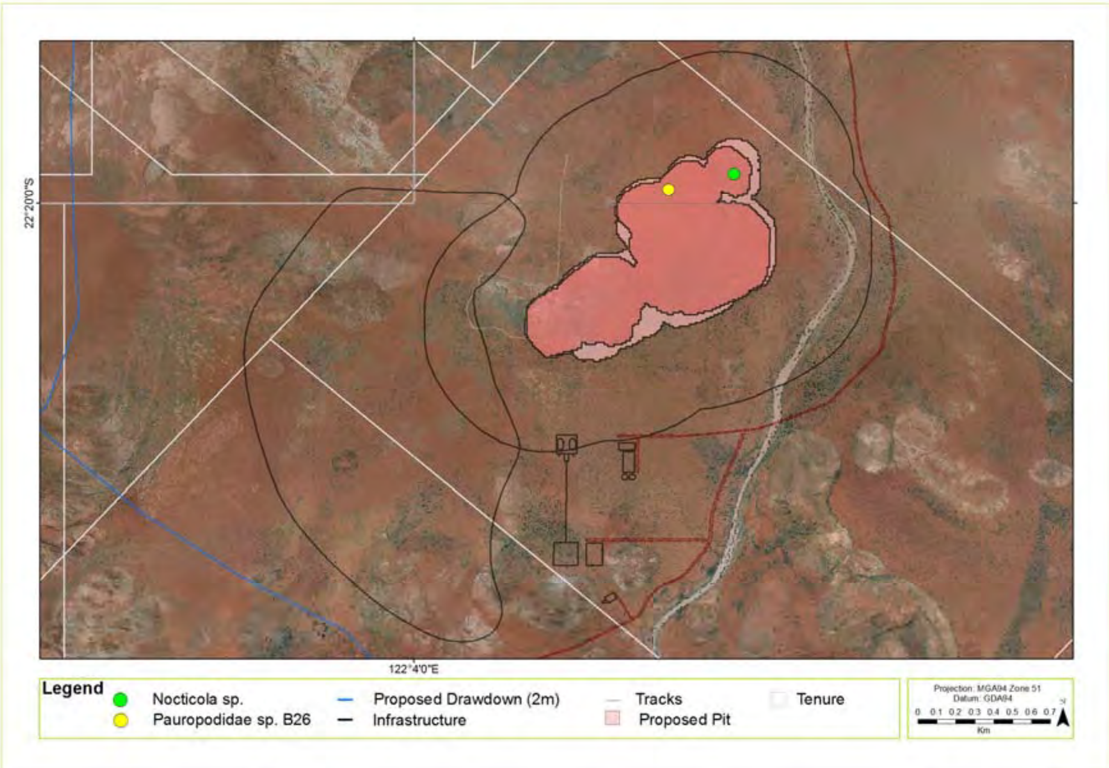

Figure 5.2. Troglofauna species known only from the proposed mine pit.

Table 5-2. Stygofauna collected in the Survey Area.

Taxonomy	Impact	Reference	Comment on Range
Nematoda			
Nematoda sp.		1	Not assessed in EIAs
Rotifera			
Flosculariacea			
Filinia sp.	3		Not assessed in EIAs
Oligochaeta			
Tubificida			
Tubificidae stygo type 5		249	Reference and widespread in the Pilbara
Crustacea			
Copepoda			
Cyclopoida*	1		Likely to belong to one of the species listed below
Orbuscyclops westaustraliensis	10		Known from Hamersley and Yarraloola stations
Nitocrella sp. B04 (nr obesa)	84		Impact only
Nitocrella sp. B05	1		Impact only
Parastenocaris sp. B07	2		Impact only
Parastenocaris sp. B20		1	Reference only
Harpacticoida sp. B01		3	Reference only
Eudiaptomus lumholtzi	2		Widespread in northern Australia
Syncarida			
Atopobathynella sp.	1		Uncertain, but likely to represent a local species
Notobathynella sp. B06		1	Reference only
Amphipoda			
Bogidiellidae sp. B02	1		Known from ~100 km north
Paramelitidae sp. B07	63	114	Impact and reference sites
Isopoda			
Microcerberidae sp. B04		1	Reference only

* Cyclopoida is not considered an additional species.

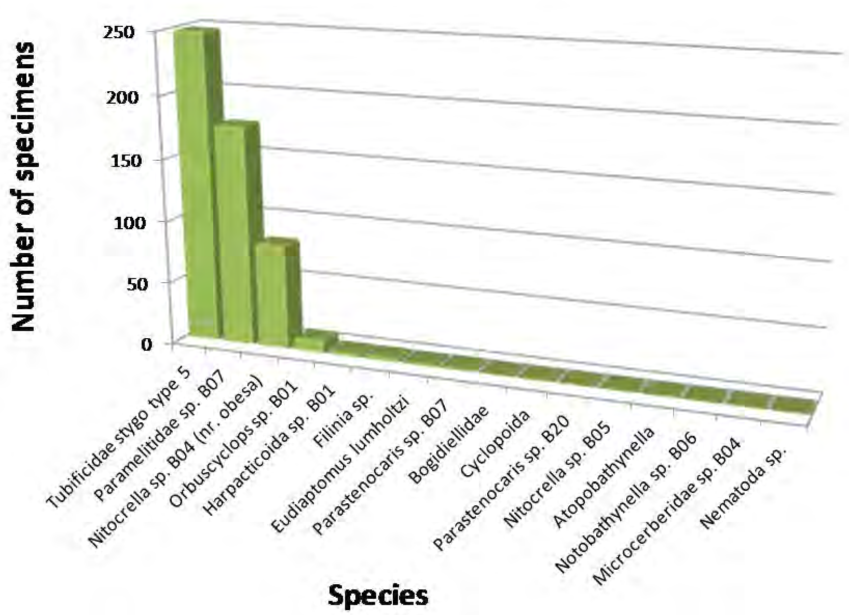

Figure 5.3. Capture abundance of each stygofauna species recorded in the Survey Area.

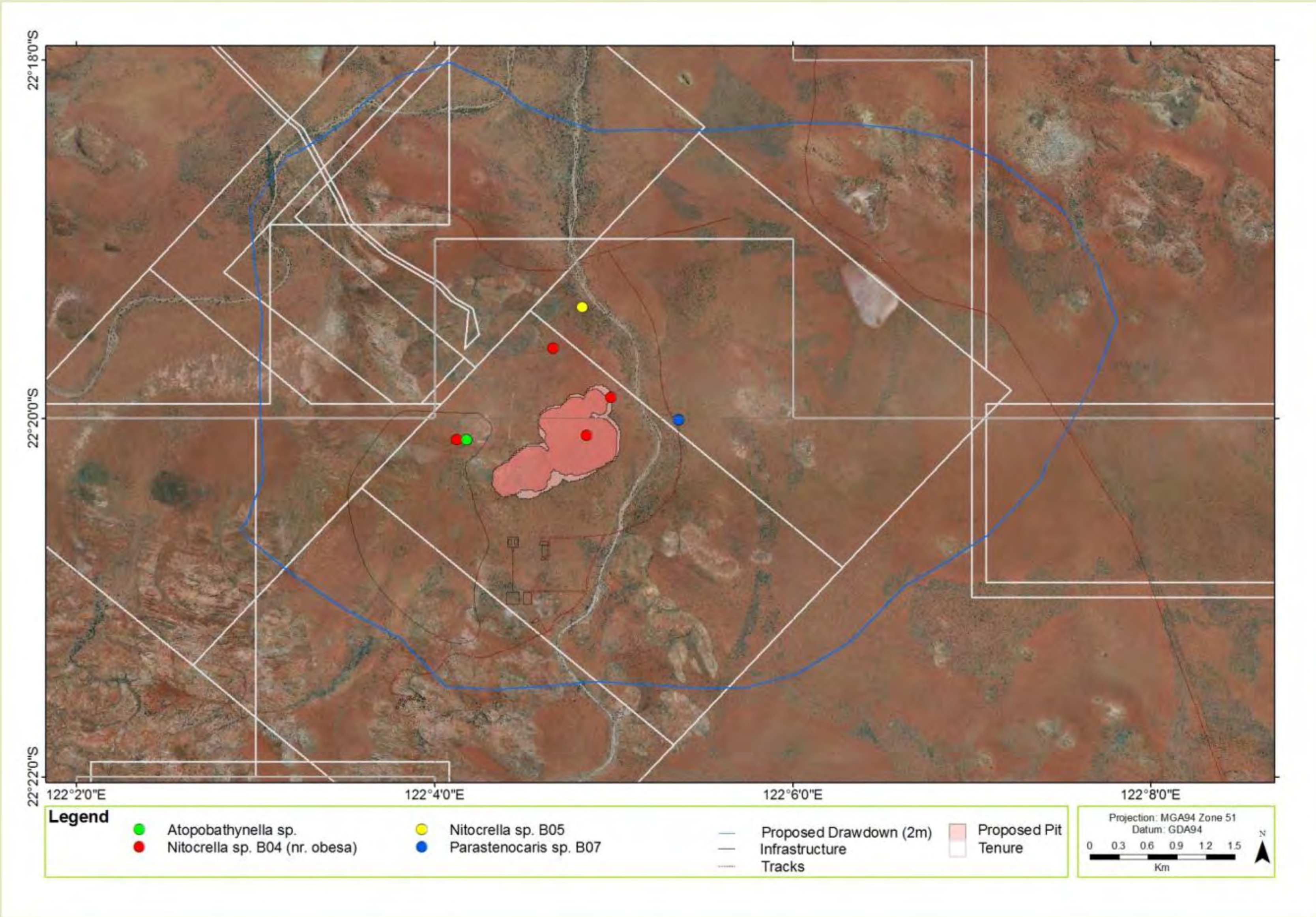

Figure 5.4. Stygofauna species known only from the proposed drawdown cone.

6. IMPACT ASSESSMENT

6.1. Principal Impact of Mining the Kintyre Deposit

Activities that cause direct *habitat loss* are considered to be *primary* impacts that have the potential to lead to extinction of tightly restricted subterranean species. For proposed mining at the Project these primary impacts are:

1. *Pit excavation*. Removal of overburden and ore in the mining process has the potential to pose a significant risk to restricted troglofauna species.
2. *De-watering.* Drawdown of aquifers to prevent flooding of mine pits has the potential to pose a significant risk to stygofauna species unless the underlying aquifers also provide habitat. All areas where drawdown is predicted to be >2 m below natural levels were considered likely to result in significant reduction in stygofauna habitat. Watertable levels fluctuate about 2 m annually (Johnson and Wright 2001).

6.2. Secondary Impacts of Mining the Kintyre Deposit

The ecological impacts of activities that *reduce the quality* of subterranean fauna habitat have been little studied in Australia (or elsewhere) but it is considered that these impacts are more likely to reduce population size than cause species extinction (Scarsbrook and Fenwick 2003; Masciopinto *et al*. 2006). These impacts are therefore considered to be of *secondary* importance.

Mining activities at the Project that may result in secondary impacts to subterranean fauna include:

1. *De-watering below troglofauna habitat*. The impact of a lowered water table on subterranean humidity and therefore the quality of troglofauna habitat is poorly studied, but it may pose a risk to troglofauna species in some cases. The extent to which humidity of the vadose zone is affected by depth to the watertable is unclear. Given that pockets of residual water probably remain trapped throughout de-watered areas and keep the overlying substrate saturated with water vapour, de-watering may have minimal impact on the humidity in the unsaturated zone. In addition, troglofauna may be able to avoid undesirable effects of a habitat drying out by moving deeper into the substrate if suitable habitat exists at depth. Overall, de-watering outside the proposed mine pits is not considered to be a significant risk to troglofauna in the Blacksmith tenement.
2. *Overburden stockpiles*. These artificial landforms may cause localised reduction in rainfall recharge and associated entry of dissolved organic matter and nutrients because water runs off stockpiles rather than infiltrating through them and into the underlying ground. The effects of reduced carbon and nutrient input are likely to be expressed over many years and may be greater for troglofauna than stygofauna because lateral movement of groundwater is likely to transport carbon and nutrients from beyond areas covered by stockpiles. The extent of impacts on troglofauna will largely depend on the importance of chemoautotrophy in driving the subterranean system compared with infiltration-transported surface energy and nutrients. Stockpiles are unlikely to cause species extinctions, although population densities of species may decrease.
3. *Percussion from blasting*. Impacts on both stygofauna and troglofauna may occur through the physical effect of explosions. Blasting may also have indirect detrimental effects through altering underground structure (usually rock fragmentation and collapse of voids) and transient

increases in groundwater turbidity. The effects of blasting are often referred to in grey literature but are poorly quantified and have not been related to ecological impacts. Any effects of blasting are likely to dissipate rapidly with distance from the pit and are not considered to be a significant risk to either stygofauna or troglofauna outside the proposed mine pits.

4. *Aquifer recharge with poor quality water*. Quality of recharge water usually declines during, and after, mining operations as a result of rock break up and soil disturbance (e.g. Gajowiec 1993; McAuley and Kozar 2006). Impacts can be minimised by management of surface water through the installation of drainage channels, and sumps and pumps in the mine pit to prevent recharge though the pit floor.
5. *Contamination of groundwater*. Any change or contamination of groundwater either during or after mining could impact subterranean communities. However, the risk of contamination from many sources; e.g. petroleum spills, can be minimised by engineering and management practices to ensure their containment.

6.3. Troglofauna Species in the Proposed Mine Pit

Of the 23 species collected from the Study Area, 14 were recorded from drill holes in the impact area. However, all but two of these species were also recorded from reference holes. The two species being treated as only from impact holes were Pauropodidae sp. B26 (8 specimens from one bore) and *Nocticola* sp. (a single animal) (Figure 5.2). *Nocticola* sp. is a higher level identification but the species is likely to be local (though not necessarily restricted to the Survey Area).

The most obvious aspect of troglofauna distributions at Kintyre is that only a very small proportion (9%) of the troglofauna species found in the proposed mine pit are apparently restricted to the pit. The proportion of apparently restricted troglofauna species at approved mining developments typically ranges up to 25% (e.g. Bennelongia 2008b,c, 2009a,b,c).

Two of the most common factors leading to apparently restricted occurrence of troglofauna species are: 1) low abundance, and 2) patchy distributions. Both factors lead to infrequent or irregular collection of specimens (see Venette *et al*. 2002; Guisan *et al*. 2006). All but two species recorded in the Study Area were collected in low or moderate abundance (≤10 specimens) and seven species were recorded as single animals. In the case of Pauropodidae sp. B26, it was collected at moderate abundance but, as frequently observed for paurapods, from only one bore.

Records from single locations provide no information about the likely range of a species (as distinct from information about the region in which it occurs) and the best predictors of likely ranges of species collected at single locations are: 1) the extent of habitat continuity around the collecting site (inferred from geological characterisation), 2) life history characteristics and known distributions of related species, and 3) the distribution of other species in the troglofauna community.

- *Habitat continuity*. As outlined in Section 3.7.2, there is little geological evidence on which to base prediction of troglofauna ranges. Although there is heterogeneity in the composition and structure of the strata across the Survey Area, it is considered likely that prospective troglofauna habitats are sufficiently interlinked to provide continuous habitat (see below). There is no landform or obvious geological barrier (such as dykes) to troglofauna dispersal.

- *Inference of range.* Relevant information about the life history characteristics and known distributions of species related to the two localised species is summarised below:

Pauropodidae sp. B26 was represented by eight specimens from one bore. Three species of pauropod were collected in the Survey Area, none of which has been recorded elsewhere (Table 5.1). However, the taxonomy of pauropods in Australia is poorly developed, so that there are few records of pauropods discriminated even at morphospecies level. Consequently, little range information would be expected to be available even for widespread species.

It is known that two widespread species of pauropods, Pauropodidae sp. B01 and Pauropodidae sp. B04 (Bennelongia 2009a, unpublished data), occur in the Pilbara. While it is possible that other species have small ranges, based on the limited available information; it is suggested that Pauropodidae sp. B26 is also likely to have a large range.

Cockroaches of the genus *Nocticola* are frequently collected as troglofauna in the Pilbara; to date Bennelongia (unpublished data) has collected 15 species. None of the species with multiple records has had a mine pit-scale range. In fact, one species is known to have a range of about 350 km (Bennelongia unpublished data). Thus, it is very unlikely that *Nocticola* sp. has a tightly restricted range.

- *Other species in the troglofauna community*. Twelve (75%) of the 16 species collected from multiple drill holes in the Survey Area were found in both the impact and reference areas. This finding strongly suggests that there is interlinking of prospective troglofauna habitats to provide habitat continuity between the proposed mine pit and surrounding areas.

6.3.1. Conservation of Troglofauna Species

The conservation status of only two troglofauna species, Pauropodidae sp. B26 and *Nocticola* sp., is possibly threatened by mine development. Irrespective of whether the ranges of these are centred on the proposed mine pit, the threat to both will be small because the mine pit will occupy only 85 ha. The likelihood of either species having a range this small is very low.

As concluded above, it is unlikely that either Pauropodidae sp. B26 or *Nocticola* sp. has a small range. In fact, there is only one troglofauna species in north-western Australia with a known range as small as the proposed mine pit, a schizomid in a Robe Valley mesa, with its range delimited by the extent of the mesa (Biota 2006; Harvey *et al*. 2008). Other schizomids in the same landscape have ranges up to 1970 ha. There are no equivalent physical barriers to species ranges in the Survey Area, where all species would be expected to have much larger ranges than the Robe Valley species.

6.4. Stygofauna Species in the Proposed Drawdown

Of the 15 species collected at the Study Area, probably four species have been recorded only from bores within the drawdown cone. These are *Nitocrella* sp. B04 (nr obesa), *Nitocrella* sp. B05, *Parastenocaris* sp. B07 and *Atopobathynella* sp. (Figure 5.4). The threat to these species is directly proportional to the range of each species in relation to the extent of groundwater drawdown. The likely ranges of these species are discussed below.

Apart from *Nitocrella* sp. B04 (nr *obesa*), the four species recorded only in the drawdown cone were collected at low abundance. As with troglofauna, two of the most common most factors leading to a species being considered 'restricted' in occurrence are: 1) low abundance; and 2) patchy distributions. These factors lead to infrequent or irregular collection of a species, so that there needs to be a large amount of collecting before species ranges can be reliably estimated. *Nitocrella* sp. B05 and

Atopobathynella sp. were recorded as singletons, while two *Parastenocaris* sp. B07 specimens were collected from one bore. The proposition that *Nitocrella* sp. B05, *Atopobathynella* sp. and *Parastenocaris* sp. B07 are restricted to the proposed drawdown cone is likely to be wrong although determining the actual ranges of species is probably impracticable within the context of sampling effort applied to environmental impact assessments.

The standard predictors used to infer ranges of low abundance subterranean fauna are not easily applied in the Survey Area:

- *Habitat continuity.* Individual stygofauna species may have strong preferences for specific water chemistry (i.e. salinity and other parameters) for which no spatial information is available. This may be one of the factors that drives the patchy capture pattern of individual species. Another is that multiple aquifers occur within the Study Area. There are differing amounts of vertical connectivity between aquifers and bores usually access only some of the aquifers. Species restricted to a particular aquifer may be rarely collected because few bores access that aquifer.

  It is not obvious, from sampling results and existing aquifer information, which are the more prospective aquifers in the Survey Area. The geology of the Survey Area and surrounding landscape is heterogeneous but the geological units and associated aquifers are repeated many times. Whether the hydrogeological units comprising stygofauna are well connected is unclear.

- *Inference of range.* Relevant information about the life history characteristics and known distributions of species related to the two localised species is summarised below:

  Nitocrella sp. B05 has many similarities to *Nitocrella trajani* from the Yilgarn, which is currently known from a single calcrete (Karanovic 2004). A similar species *Nitocrella* sp. B03 (nr *trajani*) is known from calcrete near Telfer (Bennelongia unpublished data). Existing information suggests that *Nitocrella* sp. B05 is likely to be associated with calcrete in the Survey Area and have a small range.

  Species of *Parastenocaris* in north-western Australia do not appear to have restricted distributions, with *Parastenocaris jane* occurring throughout the Pilbara and the undescribed *Parastenocaris* sp. B02 being moderately widespread in the central Pilbara (Bennelongia unpublished data; T. Karanovic personal communication). Thus, *Parastenocaris* sp. B07 is expected to extend beyond the Survey Area.

  Described species of *Atopobathynella* in Western Australia have linear ranges up to about 40 km (Cho *et al*. 2006). In some cases species are known from a single location in river channels and will certainly have larger ranges than records suggest. A further eight undescribed species have known ranges varying from a few kilometres to about 50 km (Bennelongia unpublished data). The evidence suggests that *Atopobathynell*a sp. probably extends beyond the Survey Area but is likely to be restricted to the broader Kintyre area.

- *Other species in the stygofauna community.* Ignoring the *Filina* rotifer, only one (12%) of the eight species collected from the drawdown cone was collected in nearby reference sampling. This was the amphipod Paramelitidae sp. B07, which was collected from 11 bores in the drawdown area and two reference bores (Figure 6.1). Three other species from the drawdown zone have much wider ranges than the Study Area (amphipod Bogidiellidae sp. B02, copepods *Eudiaptomus lumholtzi, Orbuscyclops westaustraliensis*).

Given that only one species was found in both impact and reference areas, despite 66 impact and 54 reference samples being collected, it appears likely that some impact zone species have, at best, limited occurrence in the surrounding Survey Area. However, the collection of Bogidiellidae sp. B02, *Eudiaptomus lumholtzi* and *Orbuscyclops westaustraliensis* only from the impact area demonstrates that impact species may be widely distributed without obvious pathways of connectivity between the impact area and the surrounding landscape.

The fourth apparently restricted species *Nitocrella* sp. B04 (nr *obesa*) was collected in abundance from four bores within the impact area. *Nitocrella* sp. B04 (nr *obesa*) is closely related to *Nitocrella* nr *obesa*, which is known from two areas of calcrete about 25 km apart in the Yilgarn (Karanovic 2004). It is likely that *Nitocrella* sp. B04 (nr *obesa*) is associated with calcrete and has a small range. More information than currently available about spatial patterns of water chemistry and the extent of aquifers in the Survey Area is required to assess the likelihood of *Nitocrella* sp. B04 (nr *obesa*) extending beyond the impact area.

6.4.1. Conservation of Stygofauna Species

The conservation status of four stygofauna species, *Nitocrella* sp. B04 (nr obesa), *Nitocrella* sp. B05, *Parastenocaris* sp. B07, and *Atopobathynella* sp., is possibly threatened by mine development.

Based on the ranges of related species, it is considered likely that the three species collected in low abundance, *Nitocrella* sp. B05, *Parastenocaris* sp. B07, and *Atopobathynella* sp., have ranges extending beyond the zone of groundwater drawdown. Thus, the species are unlikely to be threatened by proposed mine development.

The likely range of *Nitocrella* sp. B04 (nr *obesa*) is unclear. However, it should be recognised that, depending on the aquifer in which the species occurs, groundwater drawdown will not necessarily adversely impact stygofauna. Species in deeper aquifers will remain unaffected by small drawdowns (>2 m drawdown is the boundary of what is defined as impact). For example, the Permian aquifer is in excess of 150 m thick and will not be de-saturated during dewatering. Species in shallower Cenozoic aquifers may have the potential to migrate into the hydraulically connected Permian aquifer below and avoid the effects of any de-saturation of overlying Cenozoic strata.

6.5. Stygofauna Community

The stygofauna community composition within the Study Area is unremarkable by Pilbara standards, with all of the commonly collected higher order groups recorded, with the exception of ostracods. Nine new species were recorded in the Survey Area, but this is not unusual for surveys in the Pilbara, particularly when considering that the nearest stygofauna surveys have been conducted at Telfer approximately 70 km north.

In terms of richness the Study Area Community is depauperate by Pilbara standards, e.g. 15 species from 146 samples (54 bores) were collected from the Study Area whereas 34 species (17 samples from 7 bores) were recorded in the upper Fortescue area near Newman (Ethel Gorge community, Halse *et al*. in prep).

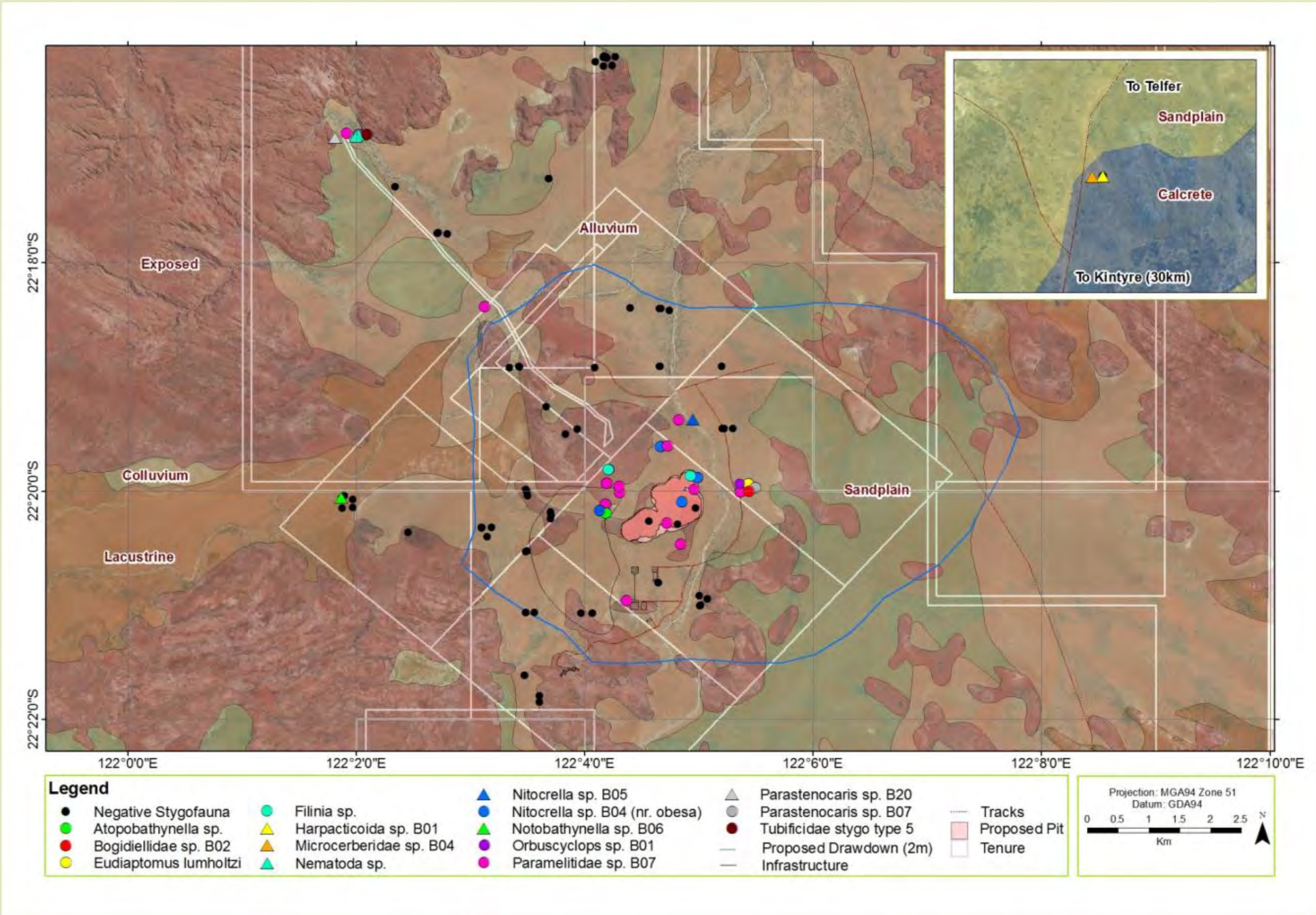

Figure 6.1. Distribution of stygofauna in the Survey Area in relation to geology.

7. CONCLUSION

The collection of 23 troglofauna species of 12 Orders, and 15 stygofauna species of seven higher level groups, represents a moderately rich troglofauna and a relatively sparse stygofauna community for the Pilbara region.

The community composition and abundance of troglofauna within the Study Area is unremarkable. Pseudoscorpions, palpigrads, spiders, isopods, centipedes, millipedes, pauropods, symphylans, diplurans, silverfish, cockroaches and hemipterans are all commonly collected in the Pilbara (Biota 2006; Bennelongia 2009a,b). Notably, schizomids and coleopterans were absent from the Survey Area.

Two species of troglofauna, the pauropods Pauropodidae sp. B26 (8 specimens from one bore) and the cockroach *Nocticola* sp. (a singleton), are currently known only from within the proposed mine pit at Kintyre and mining poses potential conservation risks for these species. However, based on the small size of the proposed mine pit in relation to the likely ranges of both species (inferred from ranges of related species), it is unlikely that this potential risk will be realised.

The stygofauna community composition within the Study Area is also unremarkable, with all of the commonly collected higher order groups recorded, with the exception of ostracods. Nine undescribed species were recorded in the Survey Area, but this may be expected in an area not previously sampled.

Stygofauna habitat within the Survey Area appears to have a high degree of heterogeneity, although the hydrogeological units are repeated. It is possible that some habitats units defined by water chemistry or aquifer type are poorly connected with similar units. This may apply to calcrete, which is commonly recognised as isolated stygofauna habitat in the Yilgarn. Four of the species recorded within the area of predicted groundwater drawdown are not known to occur elsewhere and mining poses potential conservation risks for these species. The species are the copepods *Nitocrella* sp. B04 (nr obesa), *Nitocrella* sp. B05, *Parastenocaris* sp. B07 and the syncarid *Atopobathynella* sp.

Based on the ranges of related species, it is considered likely that *Nitocrella* sp. B05, *Parastenocaris* sp. B07, and *Atopobathynella* sp. (which were all collected in low abundance) have ranges extending beyond the zone of groundwater drawdown. Thus, the potential threat from mine development will not be realised for these species.

The likely range of the more abundant *Nitocrella* sp. B04 (nr *obesa*) is unclear. However, it should be recognised that, depending on the aquifer in which the species occurs, groundwater drawdown will not necessarily adversely impact stygofauna. Information about the aquifers used by different species is not currently available.

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9. APPENDICES

Appendix A. Bores Sampled for Troglofauna in the Survey Area

Bore Code	Latitude	Longitude	Site Type
TR22	-22.3373	122.0733	Impact
TR58	-22.3354	122.0696	Control
TR45	-22.3356	122.0661	Control
TR46	-22.3382	122.0664	Control
TR59	-22.3396	122.066	Control
TR48	-22.344	122.0581	Control
TR49	-22.3513	122.0585	Control
TR56	-22.3453	122.0697	Control
TR52	-22.3449	122.0729	Control
TR50	-22.3467	122.0729	Control
TR51	-22.3494	122.0728	Control
TR55	-22.3513	122.075	Control
TR19	-22.35	122.0785	Control
TR47	-22.3404	122.0581	Control
TR40	-22.3246	122.078	Control
TR39	-22.3231	122.0791	Control
TR23	-22.337	122.0745	Impact
TR28	-22.3369	122.0761	Impact
TR29	-22.3384	122.0761	Impact
TR24	-22.3384	122.0768	Impact
TR36	-22.3404	122.0817	Control
TR37	-22.3412	122.0806	Control
TR04	-22.3367	122.0789	Impact
TR03	-22.3349	122.0789	Impact
TR05	-22.334	122.0791	Impact
TR32	-22.3332	122.0798	Impact
TR10	-22.3319	122.0819	Impact
TR17	-22.3314	122.0831	Impact
TR09	-22.3311	122.0821	Impact
TR01	-22.3349	122.0808	Impact
TR11	-22.3347	122.0817	Impact
TR14	-22.335	122.0829	Impact
TR08	-22.3354	122.081	Impact
TR33	-22.3365	122.0828	Impact
TR12	-22.3365	122.0816	Impact
TR07	-22.3366	122.0806	Impact
TR02	-22.3327	122.0788	Impact
TR27	-22.3338	122.077	Impact
TR26	-22.3364	122.0769	Impact
TR25	-22.337	122.0768	Impact
TR18	-22.3446	122.0866	Control
TR15	-22.3344	122.0826	Impact
TR41	-22.3269	122.0777	Control
TR20	-22.3284	122.0751	Control
TR54	-22.3298	122.0726	Control
TR60	-22.3286	122.0719	Control
TR43	-22.3303	122.0701	Control
TR38	-22.3299	122.0749	Control
TR35	-22.3336	122.0717	Control
TR34	-22.3327	122.0717	Control
TR42	-22.3322	122.0698	Control
TR57	-22.3331	122.0698	Control
TR31	-22.3359	122.075	Impact
TR30	-22.3351	122.0762	Control

Bore Code	Latitude	Longitude	Site Type
AD244	-22.3327	122.079	Impact
KINUNK01	-22.3392	122.0782	Impact
KDH076	-22.3346	122.0818	Impact
KINUNK02	-22.3359	122.0808	Impact

Appendix B. Bores Sampled for Stygofauna in the Survey Area

Bore Code	Latitude	Longitude	Site Type
CWB-5S	-22.3422	122.058	Impact
CWB-5D	-22.3422	122.0582	Impact
CWB-2S	-22.3511	122.0581	Control
CWB-2D	-22.3511	122.058	Control
CWB-1D	-22.3603	122.0578	Control
CWB-3D	-22.3513	122.0677	Impact
CWB-3S	-22.3512	122.0677	Impact
6PI	-22.3369	122.0617	Impact
6PD	-22.3364	122.0617	Impact
CWB-6D	-22.3335	122.0582	Impact
CWB-6S	-22.3331	122.058	Impact
10PI	-22.3381	122.0788	Impact
10PS	-22.338	122.0786	Impact
KWX7A	-22.3378	122.076	Impact
CWB-4S	-22.3468	122.0774	Impact
CWB-4D	-22.3468	122.0774	Impact
CWB-11D	-22.3153	122.0571	Impact
CWB-11S	-22.3152	122.057	Impact
WEX-4	-22.2878	122.0614	Control
WEX-2	-22.2956	122.0453	Control
WEX-1	-22.2889	122.0389	Control
OBS-16	-22.2813	122.0337	Control
2PD	-22.3501	122.0834	Impact
2PS	-22.3501	122.0835	Impact
2PI	-22.3501	122.0836	Impact
9PI	-22.3333	122.0892	Impact
9PS	-22.3335	122.0894	Impact
9PD	-22.3336	122.0896	Impact
CWB-7D	-22.3242	122.0869	Impact
CWB-7S	-22.3242	122.0867	Impact
CWB-8S	-22.3152	122.0867	Impact
CWB-9S	-22.3152	122.0776	Impact
CWB-9D	-22.3152	122.0776	Impact
WEX-5D	-22.3066	122.0733	Impact
WEX-5S	-22.3067	122.0777	Impact
CWB-10D	-22.3154	122.0681	Impact
4PS	-22.3387	122.0515	Impact
4PI	-22.3387	122.0516	Impact
4PD	-22.3388	122.0515	Impact
1PS	-22.3343	122.0311	Control
14PS	-22.3359	122.0828	Impact
OLD BORE	-21.9892	122.0354	Control
OB1	-22.3341	122.0315	Control
1PI	-22.3344	122.0312	Control
1PD	-22.3346	122.0312	Control
KSH011	-22.3642	122.06	Control
KSH013	-22.3633	122.06	Control
TPB3	-22.2701	122.0698	Control
OB3	-22.27	122.0698	Control
3PDD	-22.2699	122.0695	Control
3PI	-22.2699	122.0695	Control
3PD	-22.2699	122.0694	Control
3PS	-22.27	122.0694	Control
CWB15	-22.2957	112.0451	Control