Iron Ore Holdings Ltd

Bungaroo South: Subterranean Fauna Assessment

Final Report

Prepared for Iron Ore Holdings Ltd
by Bennelongia Pty Ltd

August 2013
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Bungaroo South: Subterranean Fauna Assessment

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Client – Iron Ore holdings Limited

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EXECUTIVE SUMMARY

Iron Ore Holdings Ltd (IOH) is planning to mine iron ore at Bungaroo South (the Proposal) within the Buckland Project. Bungaroo South is 45 km south of Pannawonica in the Pilbara region of Western Australia. Production of between four and eight million tonnes per annum is expected from the Proposal. The mine life is estimated to be 15 years, based on initial ore reserves of 92 million tonnes. The Proposal encompasses three mine-pit areas known as Western Pit, Eastern Pits and Dragon, which are situated on lease MLA47/1464.

Key mining components and activities of the Proposal include:

- Mining of the ore deposits by conventional open pit methods, which will involve drilling and blasting, digging and loading using hydraulic excavators and front-end loaders, and transport by haul trucks.
- Processing of ore on-site, with waste dumps located outside of the pits and supporting infrastructure including an accommodation village, mine site offices and utilities.
- De-watering of the Western Pit and Eastern Pits areas to access approximately 24% of the ore that is located below the water table. The de-watering discharge will be used on-site for dust suppression, ore processing and within the mine facilities. Any discharge in excess of these requirements may potentially be returned to the environment downstream of mining.

The proposed area of mine pits is expected to be 199.4 ha, with excavation extending to depths of 105 m below ground and 53 m below the water table (although the drawdown cone is yet to be modelled). While the likely area of mining impact is small relative to the ranges of most restricted species, the pit excavation and dewatering may potentially threaten any highly restricted species of subterranean fauna occurring within the Proposal.

Troglofauna

Troglofauna survey at the Proposal was conducted according to EPA guidelines. At Western Pit and Eastern Pits the sample effort was just below the recommend level of 60 samples, with 59 and 58 samples, respectively, while at Dragon 37 samples were taken. Additional data on troglofauna collected as by-catch during stygofauna sampling were included in the assessment.

At least 40 species of troglofauna belonging to 15 Orders were collected including Pseudoscorpionida, Palpigradi, Schizomida, Araneae, Isopoda, Geophilomorpha, Polydesmida, Spirostreptida, Pauropodina, Cephalostigmata, Diplura, Blattodea, Hemiptera, Coleoptera and Diptera.

Fifteen species of troglofauna, including 10 singletons and one doubleton species (two specimens at one bore), are currently known only from within the proposed mine pits of the Proposal. It is likely that the apparently localised ranges of these 15 species are artefacts of them occurring at low abundance.

Given that the smallest known range of a well sampled troglofauna species is 89 ha in an area with strong topography and likely barriers to troglofauna movement, it appears unlikely that 15 troglofauna species would be restricted to Western Pit, Eastern Pits and Dragon, with areas of 70, 94.7 and 34.7 ha, respectively. A review of the ranges of similar species suggests three troglofauna species may possibly be restricted to the proposed mine pits, while the remaining 12 species currently known only from these areas are unlikely to be restricted.

Habitat characterisation, and fact that 58% of the species collected at more than one drill hole in the Survey Area occurred in at least two pit areas, further suggest that the species currently only known from the proposed mine pits are unlikely to be restricted to the pits. The CID and the alluvium in the palaeodrainage channel in particular well connected and form a single continuous geological unit, which extends well beyond the proposed mine pits.

Stygofauna

Stygofauna survey at the Proposal was conducted according to EPA guidelines. Altogether, 61 stygofauna samples were collected from the area likely to be impacted by groundwater drawdown. Additional data on stygofauna collected as by-catch during troglofauna sampling were included in the assessment.

At least 28 stygofauna species of 10 higher level taxonomic groups were recorded, including Rotifera, Gastropoda, Acariformes, Ostracoda and Isopoda, Oligochaeta, Copepoda, Syncarida, Amphipoda, and Nematoda. Eight of the stygofauna species collected are known to occur widely in the Pilbara, while another six occur widely in the Robe catchment. On the basis of existing data, 12 species are known only from within the Survey Area; this includes nine identified species and three taxa identified only to family or genus (the ranges of two nematodes and rotifers were not assessed).

Based on existing information on the distributions of Pilbara stygofauna, it is unlikely that the 12 stygofauna species only known from the Survey Area are actually restricted that that area. However, a review of the ranges of taxonomically similar species suggested it is possible that five of the 12 species have ranges not much larger than the Survey Area.

Habitat characterisation showed that the CID/alluvial aquifer in palaeochannels of the Robe and Bungaroo catchments, which occurs both upstream and downstream of the Proposal potentially provides considerable habitat connectivity for stygofauna beyond the Proposal and would appear to reduce the risk likelihood of any species being restricted to the Survey Area.

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1. INTRODUCTION

Iron Ore Holdings Ltd (IOH) is planning to mine iron ore at Bungaroo South (the Proposal) within the Buckland Project. Bungaroo South is 45 km south of Pannawonica in the Pilbara region of Western Australia (WA) (Figure 1.1). Production of between four and eight million tonnes per annum is expected from the Proposal. The mine life is estimated to be 15 years based on initial ore reserves of 92 million tonnes. The Proposal encompasses three pit areas known as Western Pit, Eastern Pits and Dragon, which are situated on lease MLA47/1464.

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This report assesses the risk to subterranean fauna associated with the Project. The defining characteristic of subterranean fauna is that they spend all, or most, of their lifecycle underground and are morphologically adapted to the subterranean environment. Adaptations include pallid colouration, reduction or loss of eyes, elongate body, long slender appendages and well developed sensory setae.

A high proportion of subterranean fauna species are short-range endemics (SREs), defined by Harvey (2002) as species with ranges of <10,000 km^2. In fact most subterranean fauna species have much smaller ranges (Eberhard et al. 2009). The restricted ranges of most subterranean fauna species means they are particularly vulnerable to extinction from anthropogenic activities and, hence, are a focus for conservation (see Fontaine *et al*. 2007).

There are two types of subterranean fauna, stygofauna and troglofauna. Stygofauna occur in groundwater, whereas troglofauna are air-breathing and occur at depth in the various unsaturated soil and rock habitats above the water table (Gibert and Deharveng 2002). In general terms, stygofauna may be threatened by groundwater drawdown and troglofauna by excavation of mine pit (or other large scale) excavations.

The objectives of this assessment were:

(1) Document the subterranean fauna communities occurring at the Proposal;

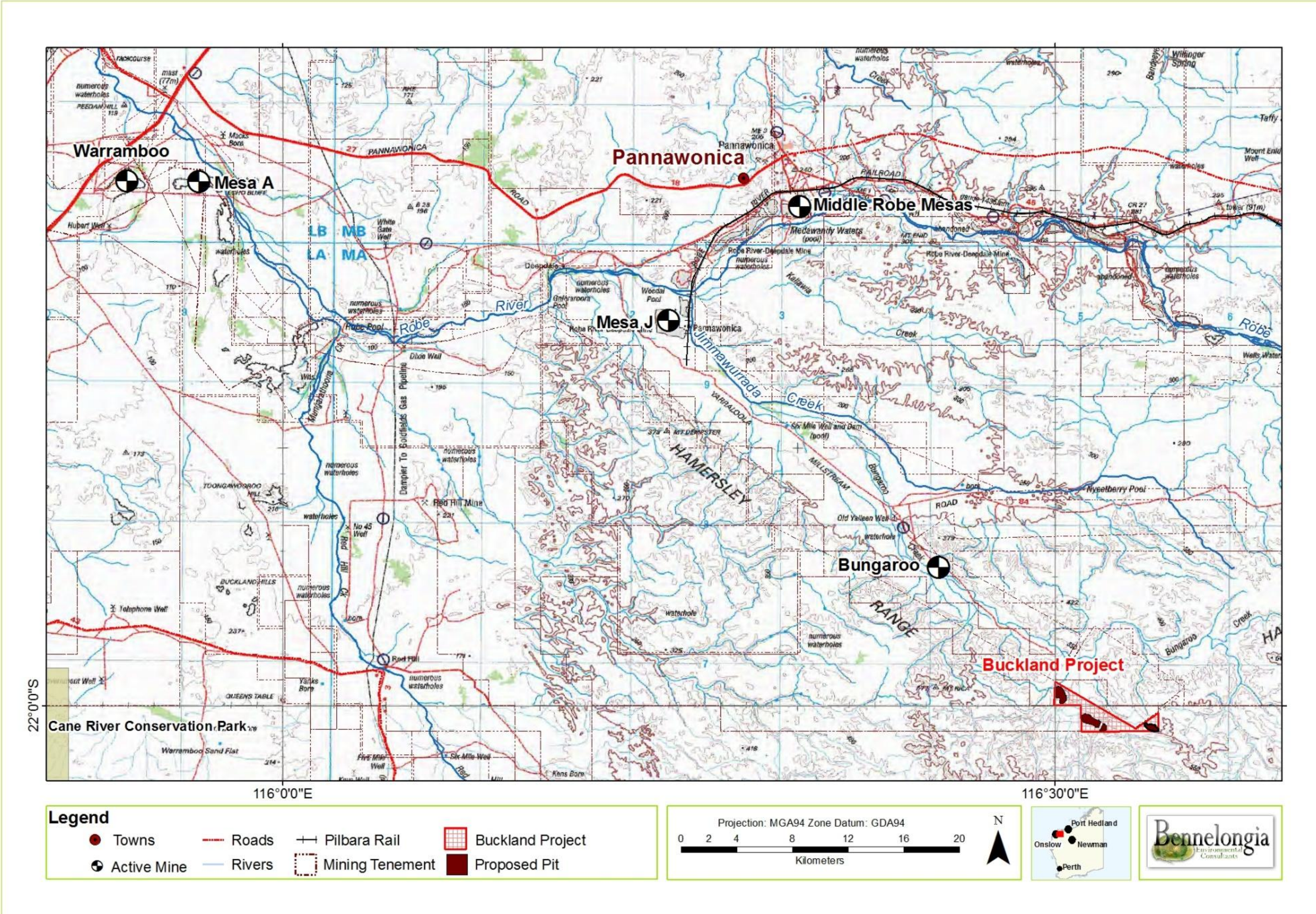

Figure 1.1. Location of the Buckland Hills Project.

(2) Characterise the subterranean fauna habitat in and around Proposal; and

(3) Identify the potential threats to the conservation of subterranean fauna species arising from the Proposal development.

2. SUBTERRANEAN FAUNA

2.1. Troglofauna

While the earliest work on troglofauna was focussed on their occurrence in caves, surveys during the past five years have shown that troglofauna are widespread in the landscape matrix of the Pilbara and are represented by many invertebrate groups, including isopods, palpigrads, spiders, schizomids, pseudoscorpions, harvestmen, millipedes, centipedes, pauropods, symphylans, diplurans, silverfish, cockroaches, bugs, beetles and fungus-gnats. Although abundance and diversity of troglofauna appear to be greatest in the Pilbara, at a regional scale troglofauna are ubiquitous in WA outside caves and have been recorded from the Kimberley (Harvey 2001), Cape Range (Harvey *et al*. 1993), Barrow Island (Biota 2005a), Mid-West (Ecologia 2008) and Yilgarn (Bennelongia 2009a), and South-West (Biota 2005b).

Troglofauna habitat is usually considered to extend from the lower layers of soil and sand at the ground surface down to the interface with groundwater (Juberthie *et al*. 1981). Troglofauna occupy interstices, vugs, cavities and fissures within this realm, so that their occurrence is closely linked to the structure of the rock or other layers present. If no fissures or voids are present, no troglofauna will occur. When subterranean spaces are present, their pattern of occurrence largely determines the abundance and distribution of troglofauna. Vertical connectivity with the surface is important for supplying carbon and nutrients to maintain populations of different species (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 occur widely in the mineralized iron formations of the Pilbara (Bennelongia 2008a,b,c; 2009a,b; Biota 2006a). There is relatively little information about the occurrence of troglofauna outside mineralized habitats because mine development has been the primary reason for most of the sampling programs. However, it has been shown that troglofauna occur in calcrete and alluvium in the Pilbara (Edward and Harvey 2008; Rio Tinto 2008), Yilgarn (Barranco and Harvey 2008; Platnick 2008; Bennelongia 2009a) and elsewhere (Biota 2005a, b).

2.2. Stygofauna

Stygofauna are predominantly crustaceans, although stygofaunal worms, snails and water mites also occur. In addition, groundwater contains nematodes, bdelloid rotifers and some other groups with taxonomy that is so poorly resolved that stygal species cannot be reliably distinguished from surface forms. In general, stygofauna are characterised by the loss of eyes and skin pigmentation and development of a vermiform body shape and more elongated appendages than surface relatives. Some species retain reduced eyes and not all species have a vermiform shape.

Studies to date suggest that the Pilbara region contains the richest stygofauna communities in Australia and that these communities are also rich by global standards (Guzik *et al*. 2011). Up to 54 species have been collected from an individual bore and a total of about 350 species are known from the region (Halse *et al*. in prep.). New species are constantly being discovered (Finston *et al*. 2008; Karanovic and

Hancock 2009) and it has been estimated that 500-550 species of stygofauna will eventually be found (Eberhard *et al*. 2009).

Calcrete and alluvium aquifers are typically considered productive habitats for stygofauna, although mafic volcanics support rich stygofauna communities, compared to a moderate abundance in banded iron formation (Halse *et al*. in prep.). Stygofauna inhabit fissures and voids within an aquifers and highly transmissive aquifers usually yield larger numbers of stygofauna. Both lateral and vertical connectivity of fissures and voids are important. Lateral connectivity enables animals to move about underground, while vertical connectivity through to the surface enables recharge of carbon and nutrients to the stygofauna community.

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). Apart from salinity, the physicochemical tolerance of stygofauna to different groundwater parameters has been poorly defined. It should also be noted that in the vast majority of stygofauna studies, physicochemical parameters have been recorded in the upper metre of the aquifer, which may not reflect the conditions experienced by stygofauna in deeper groundwater.

3. HABITAT CHARACTERISATION

The Proposal lies in the upper catchment of Bungaroo Creek, a tributary of the Robe River that is incised into the Hamersley Ranges, within the Hamersley Basin of the Pilbara Craton. The incision of the Bungaroo Creek valley into the bedrock of the Hamersley Ranges has formed a deep palaeodrainage channel, which has been in-filled over time by a sequence of sedimentary deposits, including precipitated Channel Iron Deposits (CID) (RPS Aquaterra 2012).

The potential capacity of habitat within the Proposal to support subterranean faunal was assessed using geology and hydrogeology information from:

- Geological investigations carried out by RPS Aquaterra and IOH; and
- Discussions and communications with IOH geologists.

3.1. Geology

The Pilbara Craton is dominated by Archaean granite and greenstone rocks. It is overlain by Archaean-Proterozoic volcanic and sedimentary rocks deposited in the Hamersley and Bangemall Basins. The Hamersley Basin, which occupies most of the southern part of the Pilbara Craton, can be divided into three broad stratigraphic units: the Fortescue, Hamersley and Turee Creek Groups (Trendall *et al.* 2004).

The geology of the Proposal consists of Late Archaean to Early Proterozoic Hamersley Group rocks overlain by Cainozoic CID of the Robe Pisolite and Cainozoic alluvial deposits in the palaeochannel. The Hamersley Group bedrock at the Project contains rocks of (from oldest to youngest) the Wittenoom Formation (Bee Gorge Member), Mt Sylvia Formation, Mt MacRae Shale and Brockman Iron Formation (Dales Gorge Member) (IOH 2012).

1. The Bee Gorge Member is composed of argillite, chert, volcaniclastic rock and banded iron formation (BIF). The BIF probably contains vugs and other spaces. However, diamond-drill samples at Western Pit and Eastern Pit did not reach the depth of Bee Gorge member, so the porosity could not be verified;

2. Mt Sylvia Formation is composed of shale and dolomitic shale with three BIF layers. As above, the BIF is likely to contain vugs and spaces, but this could not be confirmed as diamond-drill samples did not reach this depth;
3. Mt MacRae Shale contains shale and dolomitic shale with thinly bedded chert. Diamond-drill logs showed that there were few vugs or other spaces in the chert and shale, and this is unlikely to be suitable subterranean fauna habitat; and
4. Dales Gorge Member contains the majority of BIF in the area, being composed of many alternating BIF and shale macrolayers. Few vugs were observed in the small amount of BIF visible in diamond-drill samples at Western and Eastern Pits. Enriched BIF such as that at Dragon deposit is likely to be porous and suitable for subterranean fauna (Bennelongia 2009a, b) but diamond drill logs were not available to confirm this.

The CID deposits of the Robe Pisolite were divided into four main types by IOH based on exploratory core samples: weathered pisolite, reworked CID (near the surface), main CID mineralisation and low grade CID mineralisation (underlying the main CID) (IOH 2012). Unconsolidated deposits of Tertiary and Quaternary alluvium usually overlay the CID deposits in the palaeochannel. Diamond-drill logs at the Western and Eastern Pits indicated that the CID is porous and contains many vugs and fissures that could provide habitat for subterranean fauna, especially to depths of 20 or 30 m. The overlying alluvial deposits were too loose in the diamond-drill samples to be able to determine the porosity, but alluvial deposits in the Pilbara are known to be productive habitats for subterranean fauna (Eberhard *et al.* 2005; Edward and Harvey 2008; Guzik *et al.* 2010; Rio Tinto 2008).

In addition to the above described habitats, as with most of the Pilbara, a semi-continuous ‘hardcap’ zone is present where bedrock is exposed. The hardcap zone can be extremely variable in texture and is known to contain frequent voids and cavities, making an important habitat for troglofauna.

The mineralisation to be mined at Western Pit and Eastern Pits comprises CID deposits with a portion of these deposits below the water table. The mineralisation at the Dragon deposit is martite-goethite enriched rocks of the Dales Gorge Member. Based on current data, all of the Dragon deposit to be mined is above the water table.

3.2. Hydrogeology

There are two main aquifer systems in the Proposal area and these lie within:

1. CID in-fill of the palaeochannel (alluvium and CID); and
2. Hamersley Group bedrock.

The CID and associated channel deposits act as a semi-confined aquifer and dominate the hydrogeology of the Project area. The Hamersley Group bedrock is thought to contain one aquifer within highly interconnected fractured rock. Groundwater recharge into the aquifers probably occurs through the recent saturated alluvium overlying the palaeodrainage channels (RPS Aquaterra 2012). The groundwater in the aquifers is fresh (<700 µ/cm) and pH is neutral to slightly alkaline (RPS Aquaterra 2012).

Testing of bores within the Proposal found that both aquifers are relatively transmissive (RPS Aquaterra 2012). RPS calculated the average hydraulic conductivity of the CID aquifer in the Western and Eastern deposits as 0.14 m/day and 1.7 m/day, respectively. The average hydraulic conductivity in the bedrock aquifer at the Western and Eastern deposits was calculated as 2.1 m/day and 0.6 m/day respectively.

Both aquifers in the Project area represent potential stygofauna habitat. The palaeochannel aquifer is likely to be the most prospective habitat because the enriched and weathered CID within it is highly vuggy. Alluvial deposits in palaeodrainage systems also often support rich stygofauna communities (Halse *et al*. in prep.). The Hamersley Group bedrock aquifer, however, also represents prospective habitat. Although not as enriched and weathered as the CID, the high degree of connectivity through fracture zones means the bedrock aquifer is also likely to contain stygofauna, particularly if it is interconnected with the palaeochannel aquifer system.

The MacRae Shale typically has low permeability, and has been known to disrupt regional connectivity of aquifers (RPS Aquaterra 2012). The Mt Sylvia Formation and Bee Gorge Members are typically not recognised as prospective regional aquifers, although localised fracturing can increase groundwater transmissivity (RPS Aquaterra 2012).

4. PROJECT IMPACTS

Two broad categories of impacts arising from mine development are recognized in this report: 1) *Primary Impacts* result in direct removal of subterranean fauna habitat and threaten the persistence of any species restricted to the impact area; and 2) *Secondary Impacts* reduce the quality of subterranean fauna habitat through pollution, reduced availability of energy and similar changes that usually reduce population densities rather than threatening species persistence (Scarsbrook and Fenwick 2003; Masciopinto *et al*. 2006).

Secondary impacts may include: 1) percussion from blasting; 2) overburden stockpiles and waste dumps; 3) aquifer recharge with poor quality water; 4) de-watering below troglofauna habitat; and 5) contamination of groundwater by hydrocarbons. Additional background on these impacts is provided in Appendix 1 but the impacts are not considered further in this assessment because they are not considered to threaten species persistence.

Only primary impacts were assessed in terms of the risk they pose to the persistence of subterranean fauna.

4.1. Troglofauna

4.1.1. Primary Impacts at the Project

Of all the mining activities at the Project, only *pit excavation* will cause habitat loss on a scale likely the threaten troglofauna species. All pit excavations at the Project are considered to represent primary impacts. The areas of impact at Western Pit, Eastern Pits and Dragon are 70, 94.7 and 34.7 ha, respectively.

4.2. Stygofauna

4.2.1. Primary Impacts at the Project

De-watering of aquifers to prevent flooding of mine pits is considered to represent a primary impact. The extent of groundwater drawdown resulting from Project de-watering is yet to be modelled although there is a general appreciation of the likely extent of drawdown.

Within the CID and alluvium-based aquifer in the palaeochannel and its tributaries, dewatering will probably result in the gradual development of an elongated drawdown cone extending about 3 km upstream from the mine during the currently proposed mine life. Downstream of the West Pit, dewatering drawdown is likely to be limited if excess de-watered groundwater is returned to the environment in the downstream area (RPS Aquaterra 2012).

Within the aquifer in fractured bedrock, de-watering may theoretically cause groundwater drawdown for up to 12 km from the mine. However, topographic and geological maps suggesting barriers to flow exist about 1 to 6 km away from the deposits and it is expected the area of drawdown will be constrained by these barriers (RPS Aquaterra 2012).

5. SUBTERRANEAN FAUNA SURVEYS

5.1. Troglofauna

5.1.1. Survey Rationale

Troglofauna survey at the Project was conducted according to the general principles laid out in EPA Guidance Statements Nos 54 and 54A (EPA 2003, 2007). Sampling was organised around clusters of bores inside the proposed mine pits. Reference areas, sampled to determine whether species recorded within the mine pits occur more widely, were located outside but, in the vicinity of, the proposed mine pits. Collectively the impact and reference areas are referred to as the *Survey Area*.

5.1.2. Sampling Methods

Each troglofauna sample consisted of two sub-samples collected by separate techniques. These were scraping and trapping:

1. Scraping occurred immediately prior to setting traps. A troglofauna net (weighted ring net, 150 µm mesh, aperture varied according to bore diameter) was lowered to the bottom of the bore, or to the water table, and scraped back to the surface along the bore walls. Each scrape comprised four sequences of lowering and retrieving with the aim of scraping all troglofauna present on the walls of the bore into the net. After each scrape, the contents of the net were transferred to a 125 ml vial and preserved in 100% ethanol.
2. Custom made cylindrical PVC traps (270 x 70 mm, entrance holes side and top) were used for trapping. Traps were baited with moist leaf litter (sterilised by microwaving) and lowered on nylon cord to within several metres of the water table or end of the bore. Each bore was set with two traps. Bores were sealed while traps were set to minimise the capture of surface invertebrates. Traps were retrieved 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.

5.1.3. Sample Effort and Timing

Altogether 154 troglofauna impact samples from bores within the proposed mine pits, and a further 92 reference samples, were collected (Table 5.1 and Figure 5.1). Sampling was conducted over two rounds: Round 1 from 19 July 2012 (scraping and trap setting) to 11 September 2012 (trap collection), Round 2 from 5 October 2012 to 28 November 2012. A complete list of bores sampled is provided in Appendix 2.

5.1.4. Other Sampling

Records of troglofauna collected as by-catch during the concurrent stygofauna sampling are included in survey results. These records provided additional information on species distribution and conservation significance.

Table 5.1. Sampling effort for troglofauna in the Survey Area.
As recognised by DEC, the scrape and trap (single or double) taken at a site constitute a single sample in calculations of sample effort. S Trap = single trap, D Trap = double trap.

	East Pit		West Pit		Dragon	
	Impact	*Reference*	*Impact*	*Reference*	*Impact*	*Reference*
Round 1						
Scrape	32	13	26	19	13	-
S Trap	24	8	21	14	10	-
D Trap	8	5	5	5	3	-
Samples	**32**	**13**	**26**	**19**	**13**	**-**
Round 2						
Scrape	27	15	32	23	24	21
S Trap	19	15	25	16	16	16
D Trap	8	1	7	7	8	5
Samples	***27***	***16***	***32***	***23***	***24***	***21***
Total Samples	**59**	**29**	**58**	**42**	**37**	**21**

5.1.5. Sample Sorting and Species Identification
Trap contents were air-freighted in insulated containers to the laboratory, where troglofauna and other invertebrates were picked live out of leaf litter using a dissecting microscope. Live-picking of samples was found to be more efficient than use of the Berlese funnels recommended by the EPA (Halse and Pearson in prep.)

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.

All fauna picked out of the samples were 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 are in the process of being lodged with the Western Australian Museum. Data on lodgements thus far completed are provided in Appendix 3.

5.2. Stygofauna

5.2.1. Survey Rationale
Stygofauna survey at the Project was conducted according with the general principles laid out in EPA Guidance Statements Nos 54 and 54A (EPA 2003, 2007).

Conservation of stygofauna may rely on species having wider occurrence than the extent of drawdown but currently all bores sampled are considered likely to be within the drawdown cone and, hence, all samples are classified as impacted.

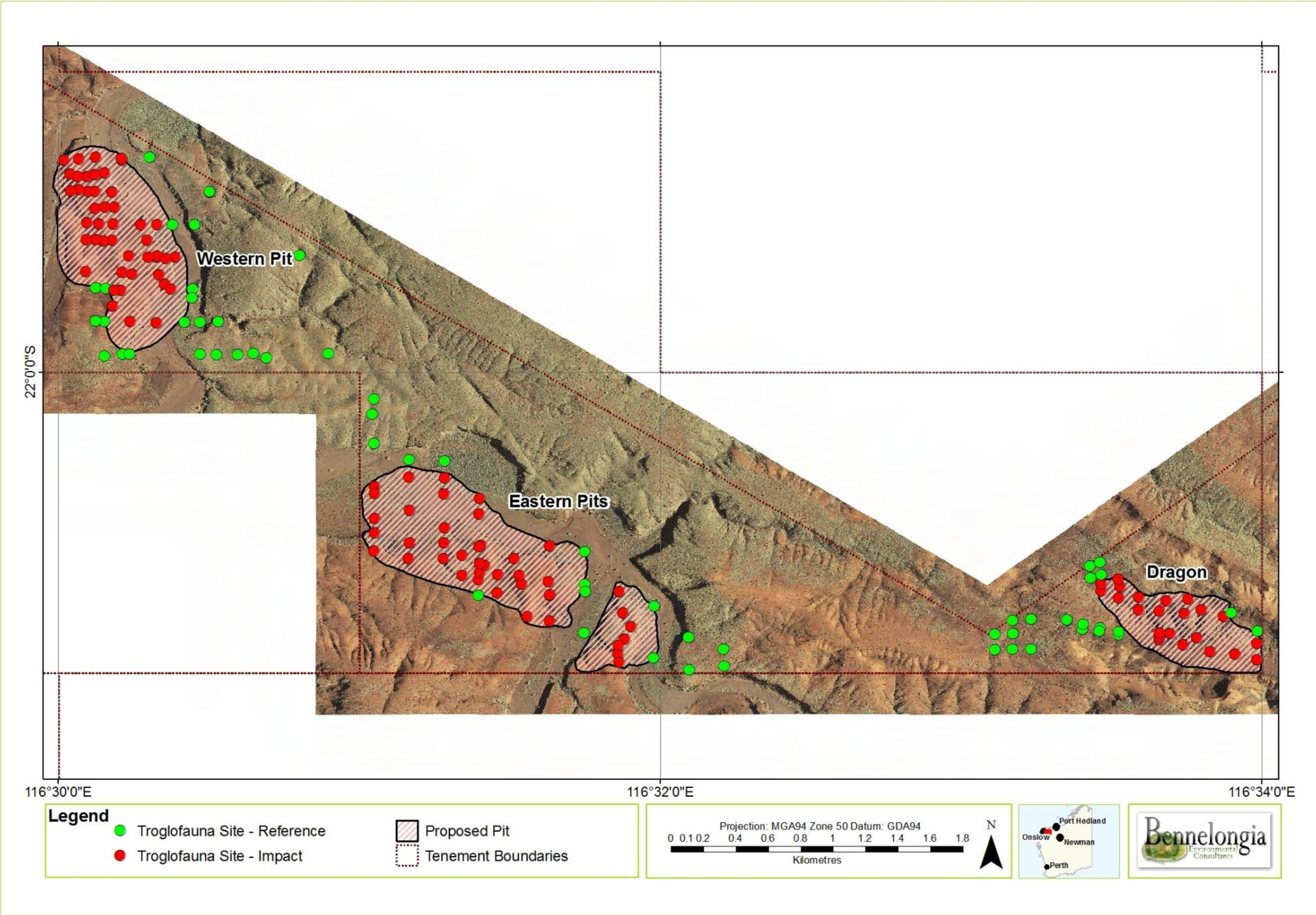

Figure 5.1. Bores sampled for troglofauna in the Survey Area.

5.2.2. Sampling Methods

Stygofauna sampling followed the methods outlined in Eberhard *et al*. (2005) and recommended by the EPA (2007). At each bore, six net hauls were collected using a weighted plankton net. After the net was lowered to the bottom of the bore it was jerked up and down briefly to agitate benthic and epibenthic stygofauna into the water column prior to a slow retrieve of the net. Contents of the net were transferred to a 125 ml polycarbonate vial after each haul and the contents were preserved in 100% ethanol. Nets were washed between bores to minimise contamination between sites. Three hauls were taken using a 50 µm mesh net and three with a 150 µm mesh net.

5.2.3. Sampling Effort and Timing

Sixty-one stygofauna were collected in the Survey Area. Sampling was undertaken in two sampling rounds: Round 1 from 17 to 19 July 2012 and Round 2 from 4 to 5 October 2012 (Table 5.2, Figure 6.2). A complete list of bores sampled is provided in Appendix 4.

Table 5.2. Stygofauna samples taken in the Survey Area.

	East Pit		West Pit		Dragon	Total Samples
Site	**Round 1**	**Round 2**	**Round 1**	**Round 2**	**Round 2**	
Impact	15	16	15	14	1	61

5.2.4. Other sampling

Records of stygofauna collected as by-catch during troglofauna sampling are included in survey results. These records provided additional information on species distribution and conservation significance.

5.2.5. 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 are in the process of being lodged with the Western Australian Museum. Data on lodgements thus far completed are provided in Appendix 3.

5.3. Compiling Species Lists

In several cases, animals could not be identified to species level because they were damaged, juvenile or the wrong sex for species determination. These higher level (i.e. above species level) identifications were included in calculations of the number of species present in the Survey Area only if the specimens could not belong to a species already recorded (e.g. *Nocticola* sp. was not included as an additional species because the genus *Nocticola* was already represented by *Nocticola* sp. B24).

5.4. Genetic Characterisation of Species

DNA analysis of selected animals was undertaken at the South Australian Museum and results were used to establish species boundaries or to identify juvenile or damaged animals as being conspecific with specimens of particular conservation interest.

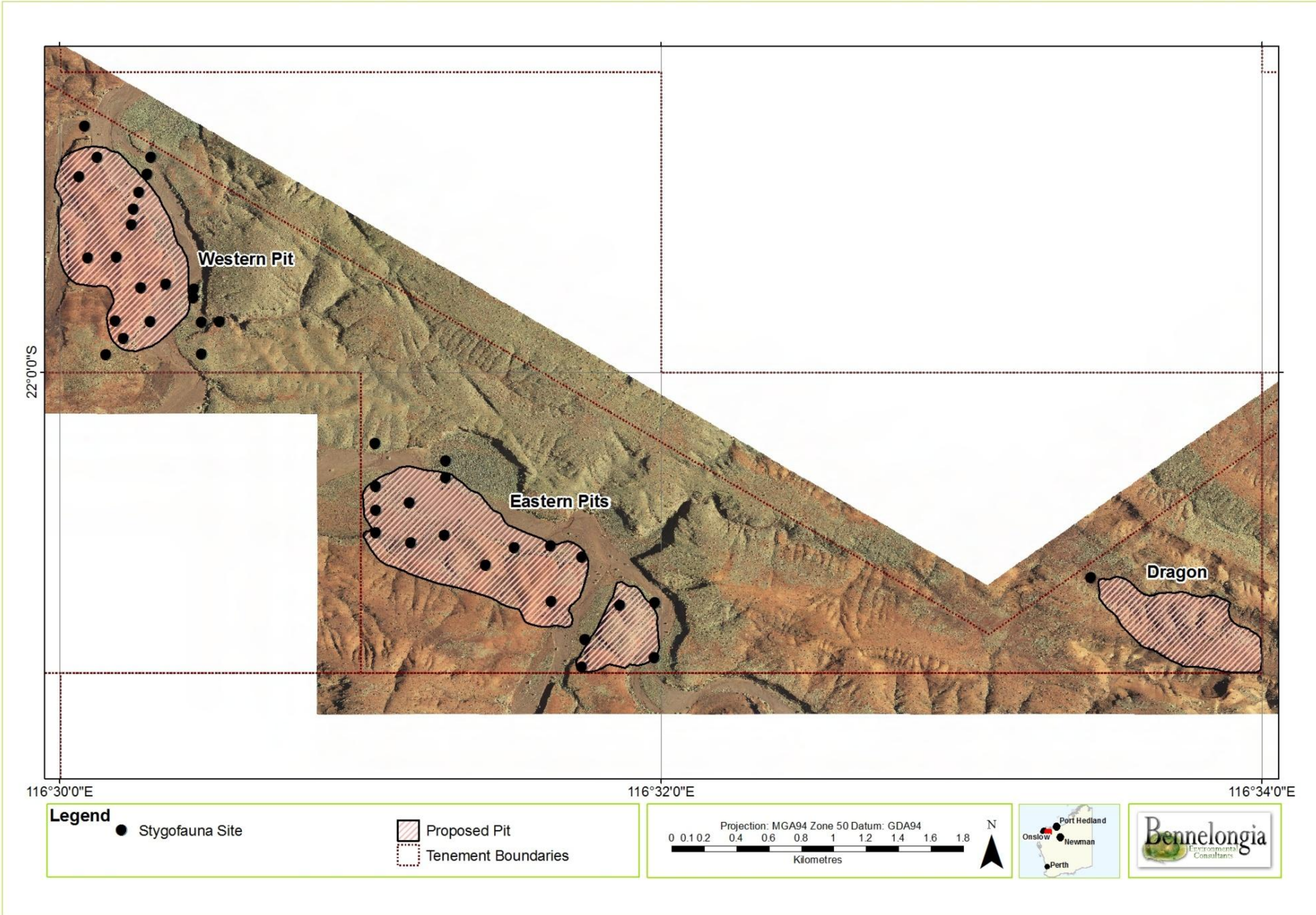

Figure 5.2. Bores sampled for stygofauna in the Survey Area.

5.5. Personnel

Fieldwork was undertaken by Grant Pearson, Jeremy Quartermaine and Sean Bennett. Samples were sorted by Michael Scanlon, Jim Cocking, Jane McRae, Grant Pearson, Heather McLetchie, Dean Main, Jeremy Quartermaine and Sean Bennett. All identifications were done by Jane McRae and Dean Main except for oligochaetes (Michael Scanlon) and ostracods (Stuart Halse).

6. RESULTS

6.1. Troglofauna

6.1.1. Occurrence and Abundance

Sampling yielded 280 troglofaunal animals, representing eight Classes, 15 Orders and 40 species (see examples of the species in Figure 6.1). Animals are documented either as species in Table 6.1 or at the lowest level of identification achievable (because the specimens were damaged, juvenile or the wrong sex for identification) in Table 6.2. These lists include both specimens that were collected by dedicated troglofauna sampling and specimens collected as by-catch during concurrent stygofauna surveys.

The four Orders of arachnids recorded were Pseudoscorpionida (6 species), Palpigradi (1 species), Schizomida (6 species) and Araneae (3 species). The only crustacean Order collected was Isopoda (3 species). One Order of centipede was recorded (Geophilomorpha, 1 species). Millipedes were represented by two Orders: Polydesmida (1 species) and Spirostreptida (1 species). Pauropods were represented by the only known Order in this group (Pauropodina, 1 species). Pseudocentipedes (symphylans) were represented by one Order (Cephalostigmata, 2 species). There were six Orders of hexapods (Entognatha/Insecta): Diplura (6 species), Blattodea (1 species), Hemiptera (2 species), Coleoptera (5 species) and Diptera (1 species) (Table 6.1).

Insects were the numerically dominant group in the Survey Area, with Hemiptera sp. B02, *Nocticola* sp. B24/*Nocticola* sp. and Meenoplidae sp. B07/Meenoplidae sp. the most commonly collected (assuming conspecificity of the latter two listings). The arachnid group Schizomida was also reasonably abundant with 58 specimens collected. These represented at least six species; most specimens were juvenile or female and could not be indentified to species without molecular analysis (Figure 6.2, Tables 6.1 and 6.2).

The vast majority of species were collected a very low abundance and were represent by one (singleton) or two (doubleton) specimens. A surprising high proportion (65%) of species in the Survey Area are represented by a single animal (Table 6.1).

6.1.2. Species Identification Issues

All specimens that could not be identified to species level (Table 6.2) are likely to belong to species listed in Table 6.1. Five taxa identified only to class, family or genus are listed in Table 6.1 instead of Table 6.2 because they appear to represent species not otherwise recorded. The taxa were Palpigradida sp., three spiders *Anapistula* sp., nr *Encoptarthria* sp., *Prethopalpus* sp. and a millipede Iulomorphidae sp. Apart from nr *Encoptarthria* sp., which was represented by single records at both Western Pit (reference) and Dragon (impact), these taxa were represented by singleton records. The two nr *Encoptarthria* sp. specimens are considered to belong to the same species.

Figure 6.1. Troglofauna photographs (A) Dalodesmidae sp. B05; (B) Anajapygidae sp. B04; (C) *Stylopauropoides* sp. B01; (D) *Draculoides* sp. B40; (E) Bembidiinae sp. B13; and (F) *Troglarmadillo* sp. B32.

Table 6.1. Troglofauna species recorded at the Proposal Survey Area with known distribution indicated.

Class **Order** Species	**Western Pit**		**Eastern Pits**		**Dragon**		**Recorded Outside of the Proposal Mine Pits**	**Comments on Range**
	Impact	**Reference**	**Impact**	**Reference**	**Impact**	**Reference**		
Arachnida								
Pseudoscorpionida								
Atemnidae sp. B04	1		1				No	Only known from Survey Area
Indohya sp. B05						1	Yes	Only known from Survey Area
Lagynochthonius sp. B16		1					Yes	Only known from Survey Area
Lagynochthonius sp. B17						1	Yes	Only known from Survey Area
Lagynochthonius sp. B18				1			Yes	Only known from Survey Area
Tyrannochthonius sp. B23			1	1			Yes	Only known from Survey Area
Palpigradida								
Palpigradida sp.				1			Yes	Range uncertain due to taxonomic resolution
Schizomida								
Draculoides sp. B37					3	2	Yes	Only known from Survey Area
Draculoides sp. B38	1						No	Only known from Survey Area
Draculoides sp. B39				4				Only known from Survey Area
Draculoides sp. B40		3	2	1				Only known from Survey Area
Draculoides sp. B41			1				No	Only known from Survey Area
Draculoides sp. B42	3						No	Only known from Survey Area
Araneae								
Anapistula sp.		1					Yes	Range uncertain due to taxonomic resolution
nr *Encoptarthria* sp.		1			1		Yes	Range uncertain due to taxonomic resolution
Prethopalpus sp.			1				No	Range uncertain due to taxonomic resolution
Crustacea								
Isopoda								
Troglarmadillo sp. B32				1			Yes	Only known from Survey Area
Philosciidae sp. B22			1				No	Only known from Survey Area
Philosciidae sp. B20		1					Yes	Only known from Survey Area
Chilopoda								
Geophilomorpha								
Geophilidae (nr *Geophilus*) sp. B02				1			Yes	Only known from Survey Area
Diplopoda								

Class **Order** Species	**Western Pit**		**Eastern Pits**		**Dragon**		**Recorded Outside of the Proposal Mine Pits**	**Comments on Range**
Polydesmida								
Dalodesmidae sp. B05			1	1			Yes	Only known from Survey Area
Spirostreptida								
Iulomorphidae sp.				1			Yes	Range uncertain due to taxonomic resolution
Pauropoda								
Pauropodina								
Stylopauropoides sp. B01			1				No	Only known from Survey Area
Symphyla								
Cephalostigmata								
Hanseniella sp. B18						1		Only known from Survey Area
Symphyella sp. B16				1				Only known from Survey Area
Entognatha								
Diplura								
Anajapygidae sp. B04			1				No	Only known from Survey Area
Campodeidae sp. B07	1			1				Only known from Survey Area
Heterojapygidae sp. B02	1						No	Only known from Survey Area
Japygidae sp. B17			1				Yes	Warramboo Creek Catchment (Lower Robe)[1]
Japygidae sp. B30	2						No	Only known from Survey Area
Japygidae sp. B31			1				No	Only known from Survey Area
Insecta								
Blattodea								
Nocticola sp. B24	5		8				No	Only known from Survey Area
Hemiptera								
Hemiptera sp. B02	28	24	7	28	4	1		Widespread in the Pilbara[2]
Meenoplidae sp. B07			3	6				Only known from Survey Area
Coleoptera								
Bembidiinae sp. B12		1			1			Only known from Survey Area
Bembidiinae sp. B13	1		1				No	Only known from Survey Area
Bembidiinae sp. B14			1				No	Only known from Survey Area
Curculionidae Genus 1 sp. B11			1				No	Only known from Survey Area
Curculionidae Genus 2 sp. B14		1	2		1			Only known from Survey Area
Diptera								
Sciaridae sp. B01					1			Widespread in the Pilbara[2]

[1]Bennelongia unpublished data; [2]Bennelongia (2009b,c).

Table 6.2. Higher order troglofauna identifications (immature/incomplete specimens collected at the Proposal Survey Area).

	Western Pit		Eastern Pits		Dragon		
Taxa	**Impact**	**Reference**	**Impact**	**Reference**	**Impact**	**Reference**	**Likely Species**
Arachnida							
Pseudoscorpionida							
Indohya sp.						1	Indohya sp. B05
Chthoniidae sp.				1			Any of the chthoniids in Table 6.1
Schizomida							
Draculoides sp.	7	11	6		6	5	Seven Draculoides species have been recorded in the Survey Area and the specimens in this table are likely to be conspecific only with species collected within the deposit these specimens come from
Schizomida sp.	1		1		1		As above
Crustacea							
Isopoda							
Philosciidae sp.	1						Philosciidae sp. B20
Entognatha							
Diplura							
Japygidae sp.				1			Japygidae sp. B31
Diplura sp.	1						Any of the diplurans in Table 6.1
Insecta							
Blattodea							
Nocticola sp.	1	2	20	3			Nocticola sp. B24
Meenoplidae sp.			6	24			Meenoplidae sp. B07
Coleoptera							
Bembidiinae sp.		1				1	Any of the three Bembidions in Table 6.1
Curculionidae Genus 1 sp.				1			Curculionidae Genus 1 sp. B11
Diptera							
Sciaridae sp.			2				Sciaridae sp. B01

The *Prethopalpus* sp. specimen was juvenile and species level identification requires mature males. *Prethopalpus* sp. was recorded only from an impact bore at Eastern Pits and is considered to be of conservation significance.

6.1.3. Troglofauna Distributions

Two species collected (Hemiptera sp. B02 and Sciaridae sp. B01) are known to be widespread in the Pilbara and one species (Japygidae sp. B17) is also known from the lower Robe (Table 6.1). A wide distribution is usually interpreted as meaning that a species is able to travel freely below ground or that it has a surface dispersal mechanism and is a troglophile. It can also mean that the species has moved underground recently (in an evolutionary sense) and its current subterranean range reflects a formerly wide surface range.

Twelve of the species only known from the Survey Area were represented by specimens collected at more than one bore. These species have ranges of 0.6 to 5.9 km, with seven (58%) of the species recorded from more than one deposit (Figure 6.3). These results suggest that all insect and some arachnid species are likely to occur across the whole Study Area but most arachnids will be more restricted.

6.1.4. Troglofauna Species of the Proposed Mine Pits

Twenty-seven of the 40 species collected in the Survey Area were recorded within the proposed mine pits. Ten of the 27 species were also collected in reference areas, while another two are known from locations elsewhere in the Pilbara (although not found in the references areas). At present 15 of the 40 species recorded at the Survey Area have only been recorded from bores within the proposed mine pits (Table 6.1, Figure 6.4).

Ten of 15 species that are known only from with the proposed mine pits were collected as single animals and only four of the 15 species were collected from more than bore. These four species (Atemnidae sp. B04, *Draculoides* sp. B42, *Nocticola* sp. B24 and Bembidiinae sp. B13) had ranges of between 0.9 and 3.4 km (Figure 6.4). Japygidae sp. B30 was represented by two specimens from one bore (Table 6.1).

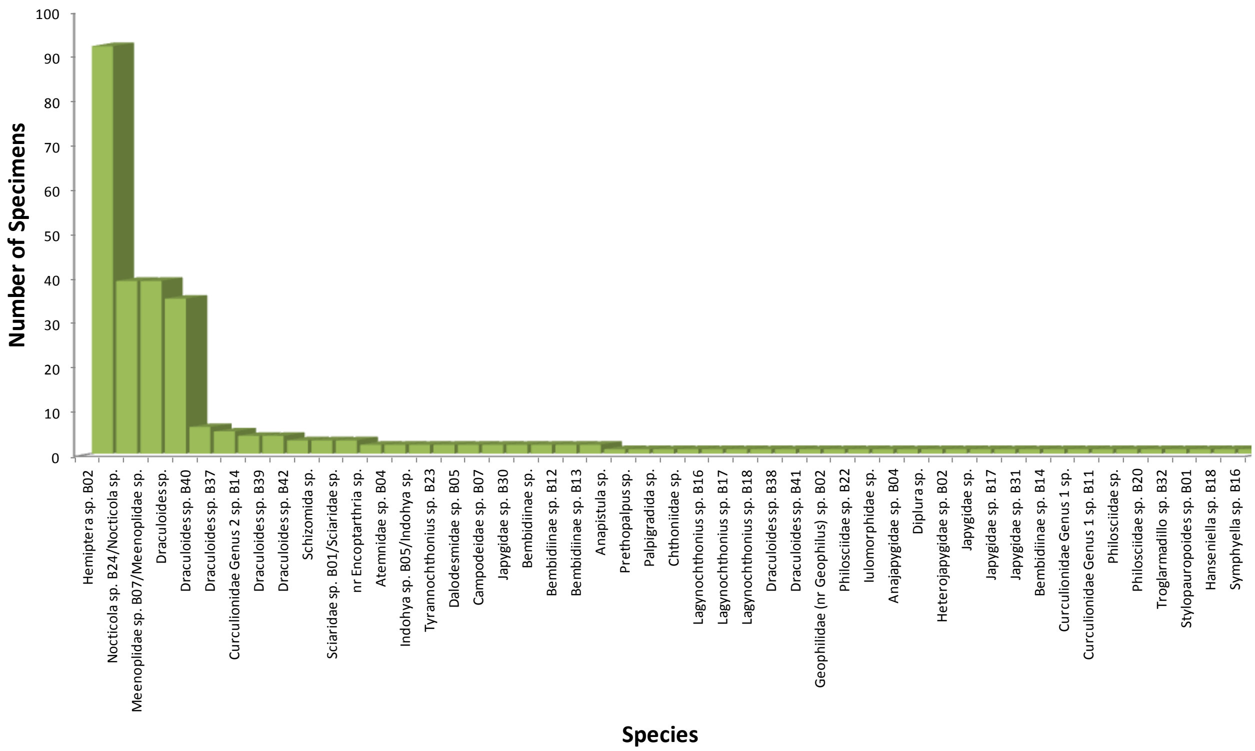

Figure 6.2. Capture abundance of troglofauna in the Survey Area.

Note: where possible, higher order identifications are presented according to the likely conspecificity given in Table 6.2.

6.2. Stygofauna

6.2.1. Occurrence and Abundance

Stygofauna sampling yielded 1832 animals belonging to at least 28 species of 10 higher level taxonomic groups (see examples of the species in Figure 6.5). The groups represented were Rotifera, Gastropoda, Acariformes, Ostracoda and Isopoda (each with 1 species), Oligochaeta (4 species), Copepoda (10 species), Syncarida (3 species), Amphipoda (5 species), and Nematoda (treated as 1 species but probably more) (Table 6.3). These specimens were documented either as species in Table 6.3 or at the lowest level of identification achievable (because the specimens were damaged, juvenile or the wrong sex for identification) in Table 6.4.

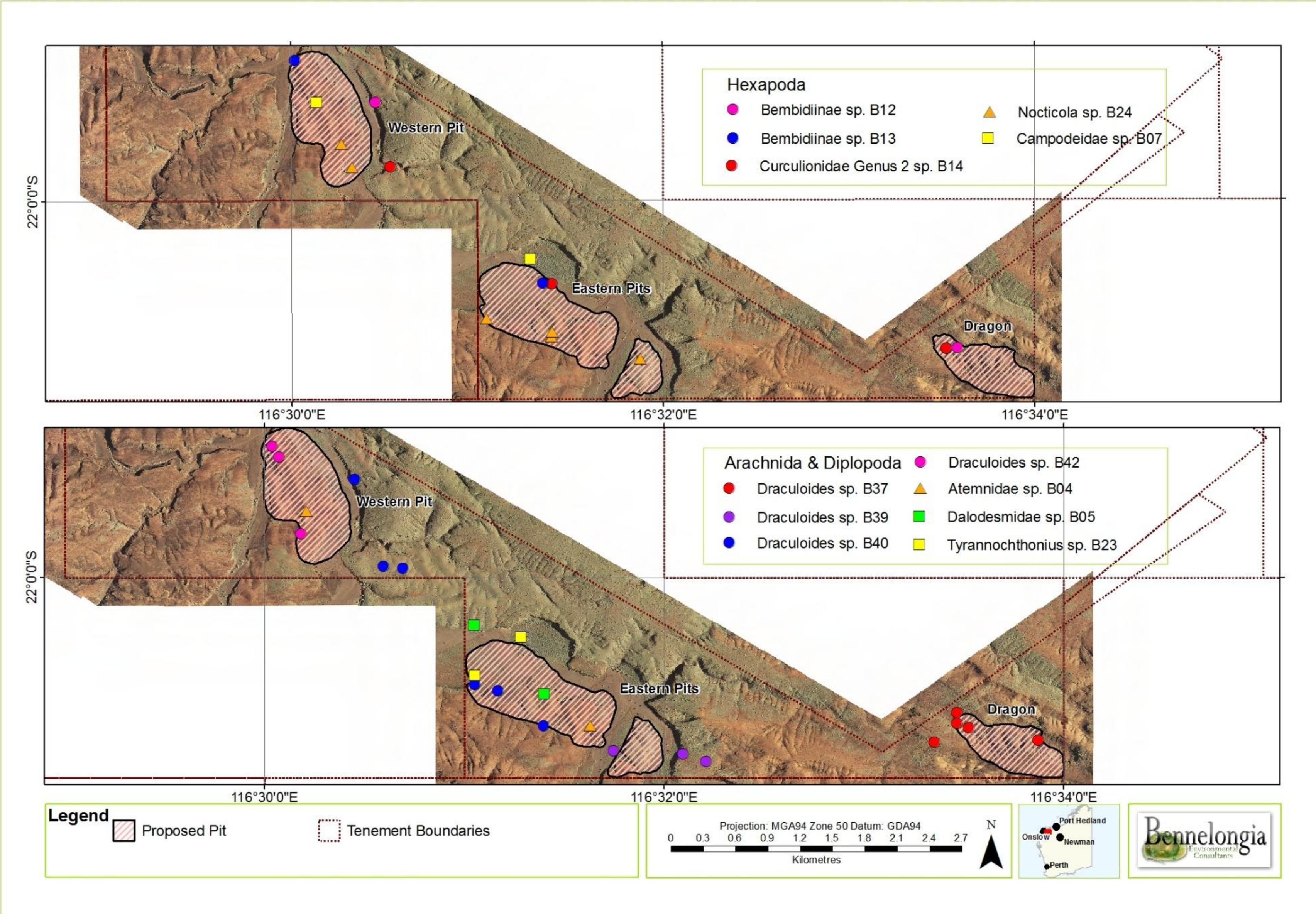

Figure 6.3. Distribution of species only recorded at Proposal Survey Area, but recorded at more than one bore.

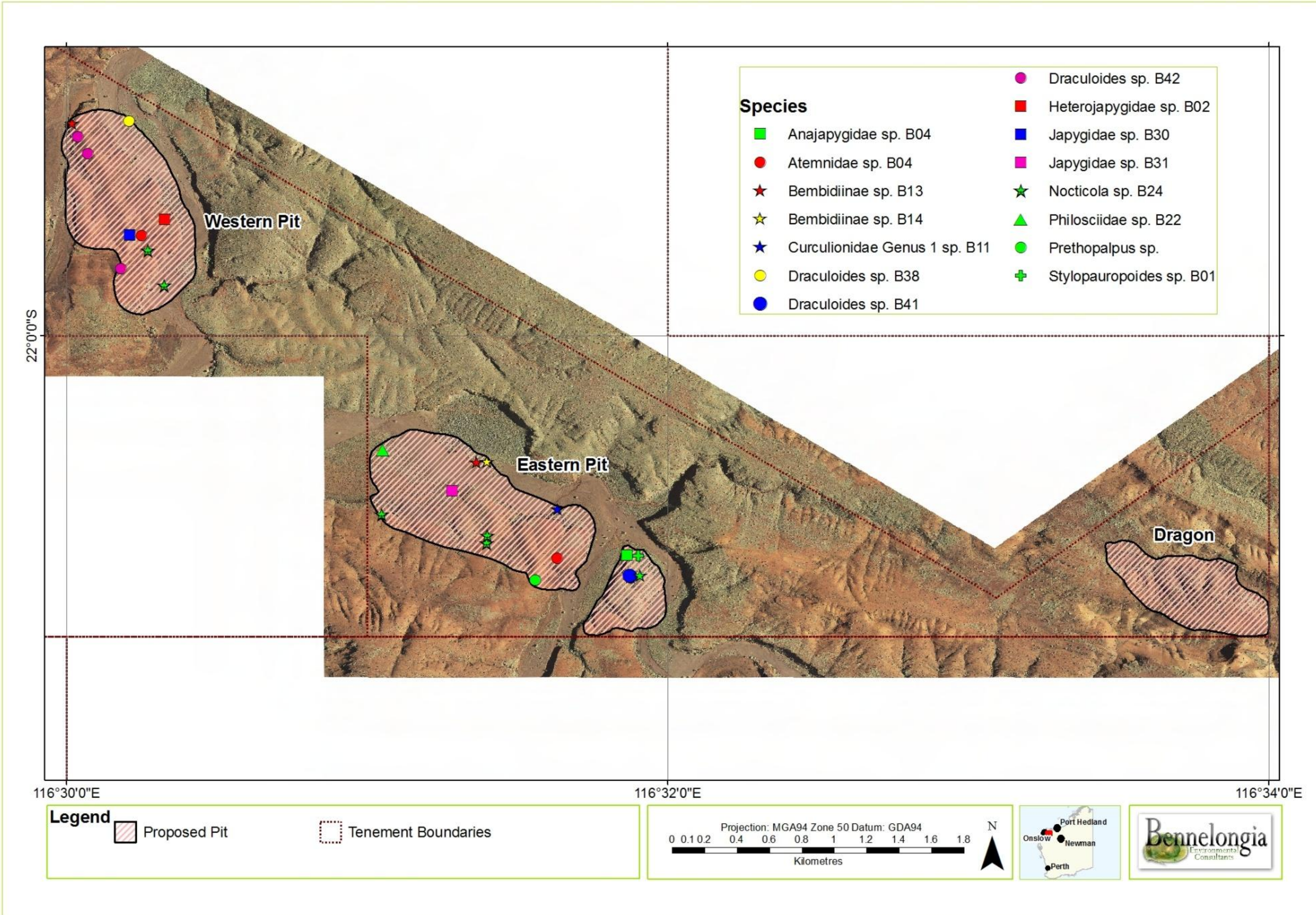

Figure 6.4. Troglofauna species only collected within the proposed mine pits.

These lists in the tables include both specimens that were collected by dedicated stygofauna sampling and specimens collected as by-catch during concurrent troglofauna surveys. No stygofauna were collected from the one bore sampled at Dragon.

Nematodes were the numerically dominant group in samples, with syncarids, copepods, oligochaetes and amphipods also relatively abundant. The six most numerous species were Nematoda sp., *Nedsia* nr *sculptilis*, *Diacyclops humphreysi humphreysi*, *Anzcyclops* sp. B03, *Enchytraeus* Pilbara sp. 2 (PSS) and *Billibathynella* sp. B06. All other species were represented by <100 specimens (Table 6.3, Figure 6.6).

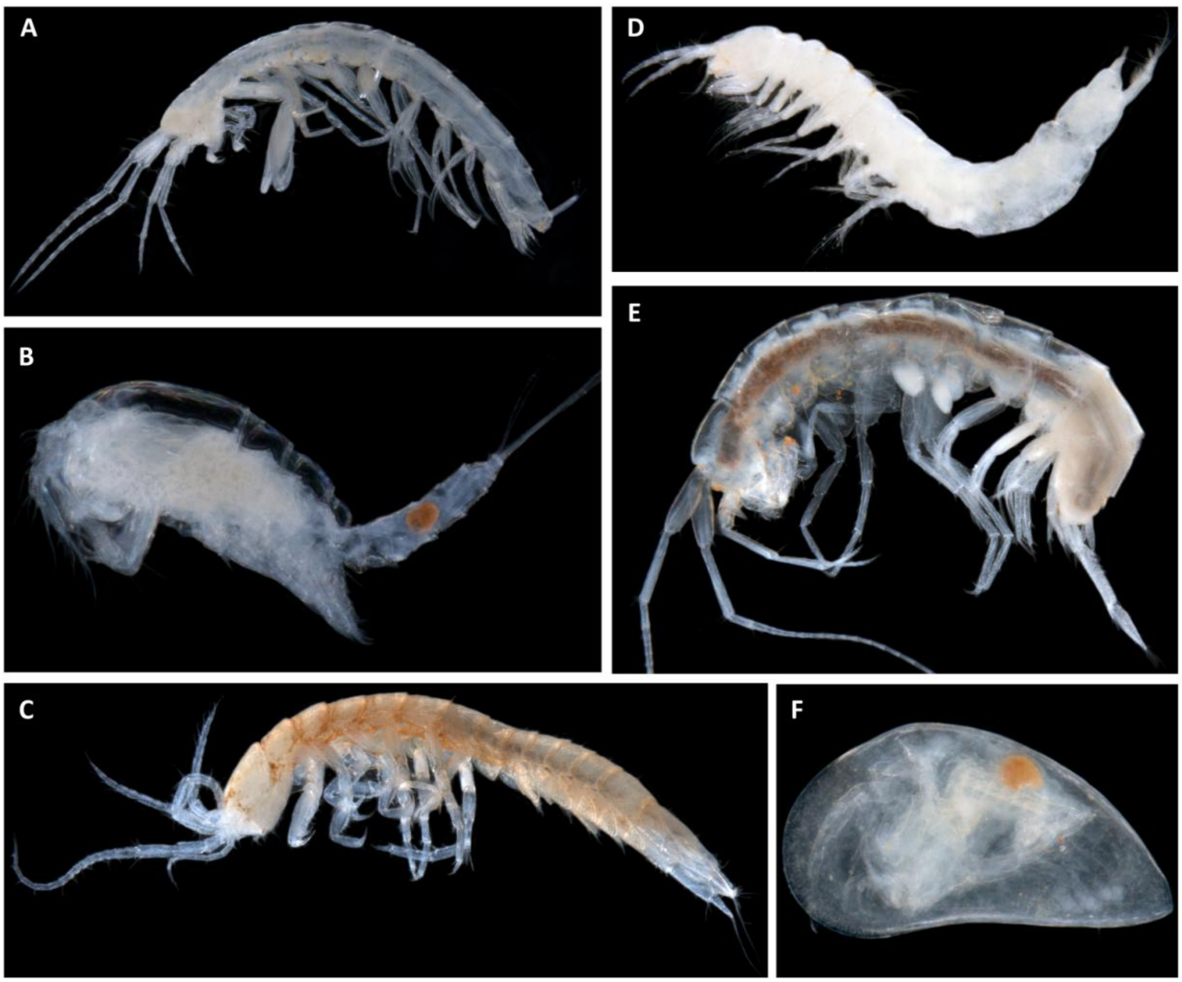

Figure 6.5. Stygofauna photographs (A) Melitidae sp. B02 (sp. 1 group); (B) *Halicyclops* (*Rochacyclops*) *roachi*; (C) *Pygolabis* sp.; (D) *Billibathynella* sp. B06; (E) *Nedsia sculptilis* group (PSS); and (F) *Areacandona* nr *brookanthana*.

Table 6.3. Stygofauna species collected at the Survey Area.

Higher Group* Species	**Western Pit**	**Eastern Pits**	**Known from outside likely Impact Footprint**	**Range/ Location**
Nematoda				
Nematoda sp.	240	280	Not assessed in EIAs[1]	Range not considered in this report, but probably widespread[2]
Rotifera				
Dissotrocha sp. B01 (nr *aculeata*)	20		Not assessed in EIAs[1]	Range not considered in this report
Gastropoda				
Hydrobiidae sp. B05	1		Yes	Robe Catchment[3]
Oligochaeta				
Enchytraeus Pilbara sp. 1 (PSS)		1	Yes	Pilbara-wide[2]
Enchytraeus Pilbara sp. 2 (PSS)	116	82	Yes	Pilbara-wide[2]
Pristina longiseta	11	4	Yes	Pilbara-wide[2,4]
Tubificidae sp.		1	No	Range uncertain due to taxonomic resolution
Acariformes				
Limnesia sp. B04	1		No	Only known from Survey Area
Ostracoda				
Areacandona nr *brookanthana*	16		Yes	Robe Catchment[3]
Copepoda				
Elaphoidella humphreysi		1	Yes	Western and eastern Pilbara[2,3,5]
Anzcyclops sp. B03		202	No	Only known from Survey Area
Diacyclops humphreysi humphreysi	98	103	Yes	Pilbara-wide and beyond[2,6]
Halicyclops (*Rochacyclops*) *roachi*	62	3	Yes	Pilbara-wide[5]
Metacyclops sp. B01 (nr *pilbaricus*)	23	3	Yes	Robe Catchment, Fortescue Valley, Weelumurra Catchment[3]
Microcyclops varicans	32	5	Yes	Cosmopolitan[7]
Thermocyclops sp. B05 (nr *aberrans*)	3		No	Only known from Survey Area
nr *Dussartstenocaris* sp. B05		1	No	Only known from Survey Area
nr *Kinnecaris* sp. B03		7	No	Only known from Survey Area
Parastenocaris sp.		1	No	Range uncertain due to taxonomic resolution
Syncarida				

Higher Group* Species	**Western Pit**	**Eastern Pits**	**Known from outside likely Impact Footprint**	**Range/ Location**
Bathynella sp. B09		3	No	Only known from Survey Area
Bathynella sp. B10		7	No	Only known from Survey Area
Billibathynella sp. B06	176	8	No	Only known from Survey Area
Amphipoda				
Neoniphargidae sp. B02 (nr *Wesniphargus*)	1		Yes	Robe Catchment[2]
Melitidae sp. B02 (sp. 1 group)	7	1	Yes	Robe Catchment[3]
Nedsia nr *hurlberti*		2	Yes	Robe Catchment[3]
Nedsia nr *sculptilis*	102	125	Yes	Robe Catchment[3]
Paramelitidae Genus 2 sp. B12	1		No	Only known from Survey Area
Isopoda				
Pygolabis sp.	1	1	No	Range uncertain due to taxonomic resolution

*Commonly used nomenclature for major aquatic invertebrate groups following Williams (1980).
[1]EPA (2007); [2]Halse *et al.* (in prep); [3]Bennelongia unpublished data; [4]Pinder and Brinkhurst (1994); [2,3,5]Karanovic (2006); [6]Pesce and De Laurentiis (1996); [7]Sars (1863);

Table 6.4. Higher order troglofauna identifications (immature/incomplete specimens collected at the Proposal Survey Area).

Higher Group* Lowest Identification	**Western Pit**	**Eastern Pits**	**Likely Species**
Gastropoda			
Hydrobiidae sp.		3	Hydrobiidae sp. B05
Oligochaeta			
Oligochaeta sp.	3	5	Any of the oligochaetes in Table 6.3
Enchytraeidae sp.		5	Either of the two Enchytraeids in Table 6.3.
Copepoda			
Diacyclops sp.	2		*Diacyclops humphreysi*
Metacyclops sp.		1	*Metacyclops* sp. B01 (nr *pilbaricus*)
Parastenocarididae sp.	2	5	*Parastenocaris* sp.
Syncarida			
Parabathynellidae sp.	51		*Billibathynella* sp. B06
Amphipoda			
Nedsia sp.	2		Either of the two *Nedsia* in Table 6.3.
Paramelitidae sp.		1	Paramelitidae Genus 2 sp. B12

*Commonly used nomenclature for major aquatic invertebrate groups following Williams (1980).

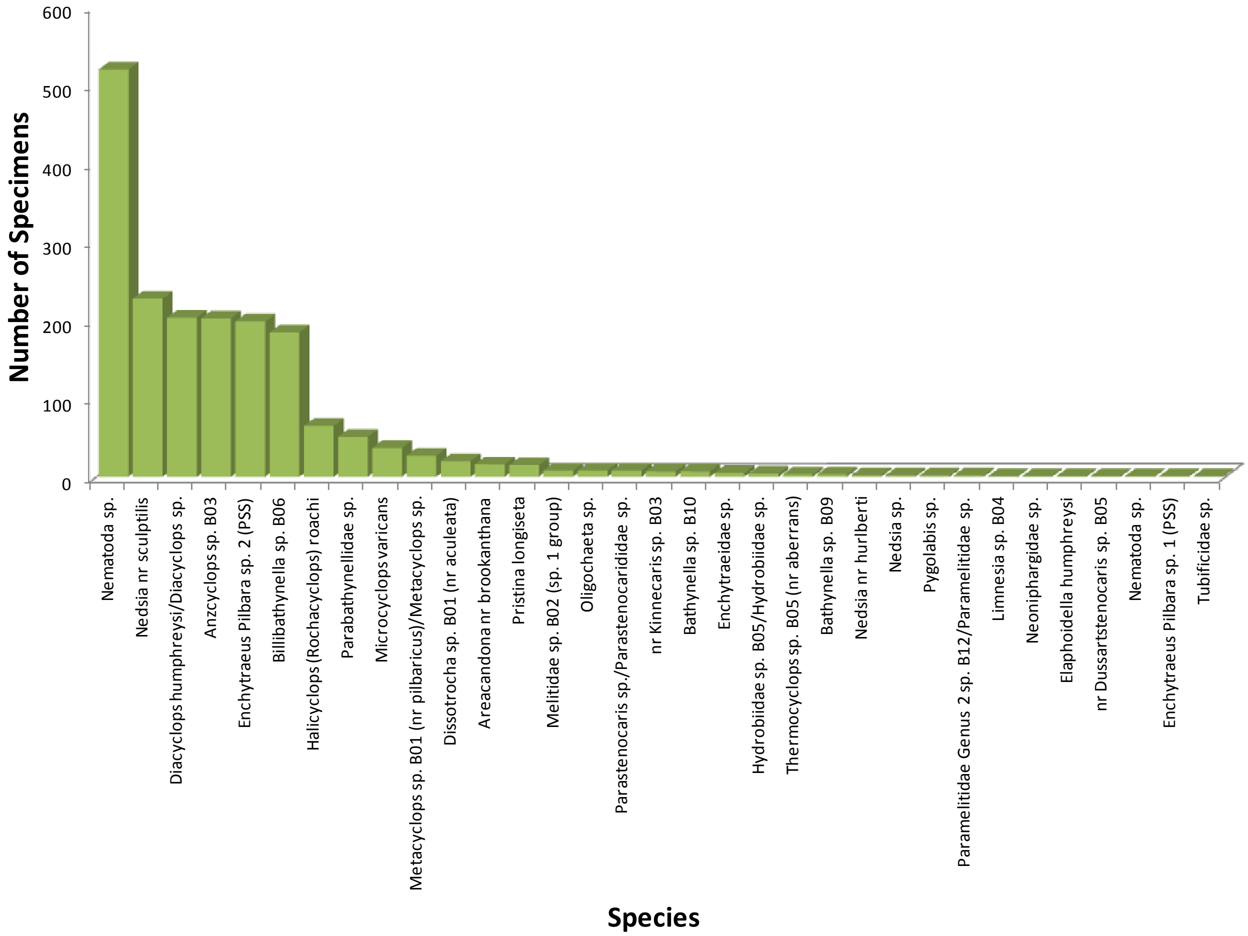

Figure 6.6. Capture abundance of stygofauna at the Survey Area.
Note: where possible, higher order identifications are presented according to the likely conspecificity given in Table 6.4.

6.2.2. Species Identification Issues

Some stygofauna could not be identified to species level and these specimens are listed in Table 6.4 at the level of identification achievable. All specimens are likely to belong to species listed in Table 6.3. Three taxa identified only to either family or genus levels are presented in Table 6.3 because they appeared to represent species not otherwise recorded. The taxa were Tubificidae sp., *Parastenocaris* sp. and *Pygolabis* sp.

No attempt was made to determine the number of nematode species present it is technically very difficult (best done with live animals) and not a requirement of environmental impact assessments (EPA 2007).

6.2.3. Stygofauna Distributions

Eight of the species collected are known to be widespread in the western Pilbara or beyond (Table 6.3). Six species are also known from elsewhere in the Robe catchment (Table 6.1). At present, 12 of the 26 species (assessed in terms of distribution) at the Survey Area have only been recorded from bores likely to be impacted by groundwater drawdown (including the three taxa recorded above species level) (Figure 6.7).

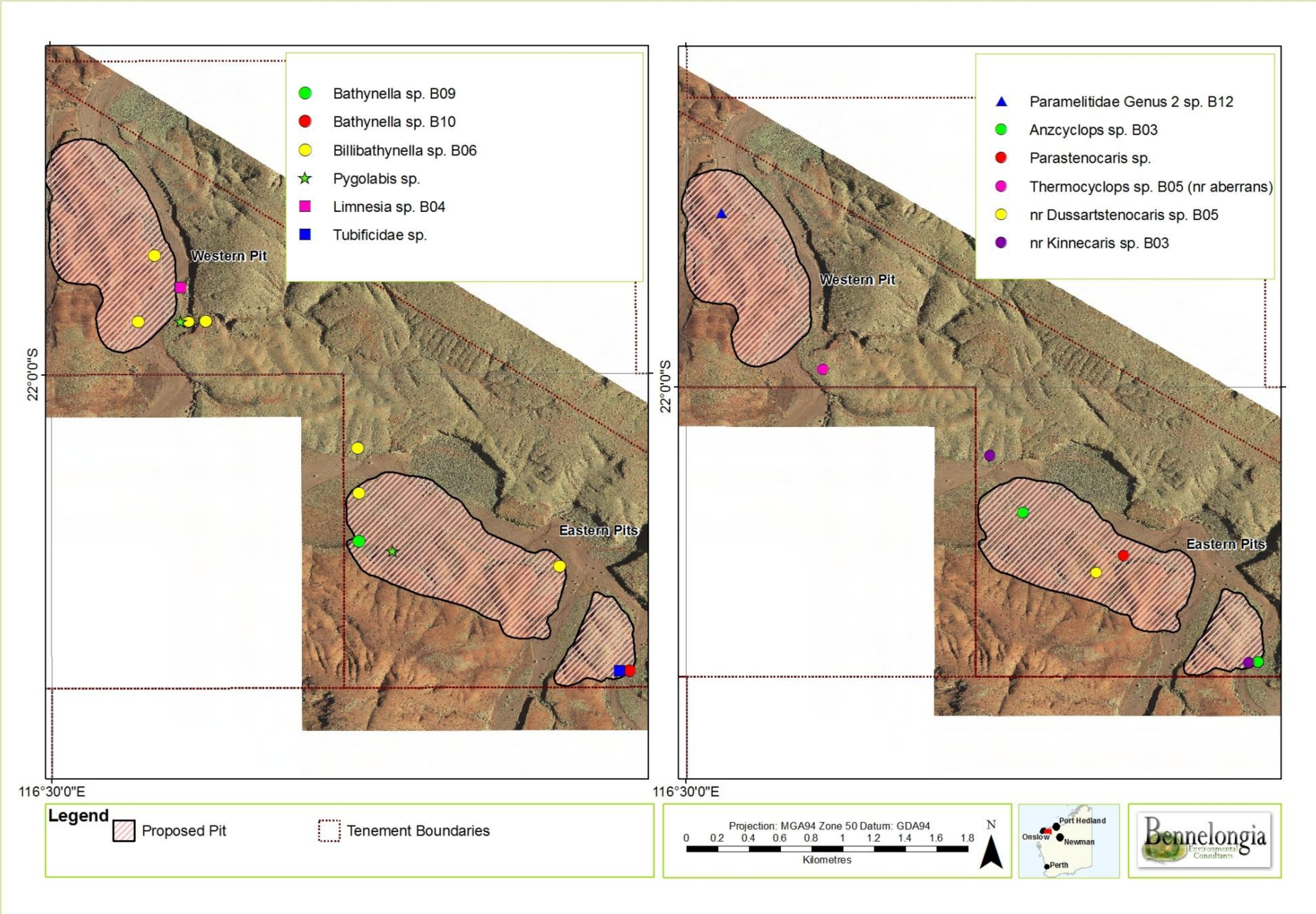

Figure 6.7. Stygofauna species only collected within likely impact footprint.

7. DISCUSSION

7.1. Troglofauna

7.1.1. Troglofauna Distributions and Conservation Threats at the Proposal

The troglofauna community at the Proposal Survey Area contains both widespread species (probably troglophiles) and species known more locally from only from the Survey Area (probably troglobites).

Fifteen species of troglofauna, including 10 singletons and one doubleton species (both specimens at the same drill hole), are currently known only from within the proposed mine pits at the Proposal (Figure 6.4, Table 7.1). It is likely that the known occurrences of these 15 species only in mine pits is an artefact of them occurring at low abundance but mining poses a potential conservation risk to any species that is, in fact, restricted to the proposed impact footprint.

Table 7.1. Troglofauna species localised to the proposed mine pits at the Proposal.
Highlight indicates species recorded at only one bore.

Class **Order** Species	**Number of Specimens**	**Number of Sites**	**Number of Deposits**	**Linear Range (km)**	**Restricted**
Arachnida					
Pseudoscorpionida					
Atemnidae sp. B04	2	2	2	3.1	not likely
Schizomida					
Draculoides sp. B38	1	1	1		not likely
Draculoides sp. B41	1	1	1		possible
Draculoides sp. B42	3	3	1	0.9	not likely
Araneae					
Prethopalpus sp.	1	1	1		possible
Crustacea					
Isopoda					
Philosciidae sp. B22	1	1	1		possible
Pauropoda					
Pauropodina					
Stylopauropoides sp. B01	1	1	1		not likely
Entognatha					
Diplura					
Anajapygidae sp. B04	1	1	1		not likely
Heterojapygidae sp. B02	1	1	1		not likely
Japygidae sp. B30	2	1	1		not likely
Japygidae sp. B31	1	1	1		not likely
Insecta					
Blattodea					
Nocticola sp. B24	13	6	2	3.4	not likely
Coleoptera					
Bembidiinae sp. B13	2	2	2	3.1	not likely
Bembidiinae sp. B14	1	1	1		not likely

When considering the likelihood of a species having a range confined to the proposed mine pits, it must be emphasized that there is a preponderance of low-abundance species in the troglofauna community of the Survey Area. Defining the ranges of species represented by singletons or low numbers of animals with any certainty represents a perennial biological problem that requires extensive sampling (Miller *et* *al*. 1989, Guisan *et al*. 2006). It is usually more practicable to accept some uncertainty and infer the ranges of such species based on information on the ranges of related species and the surrounding habitat.

It should also be noted that species ranges are likely to be under-estimated in this report (and most others) because of the logistical limitations of troglofauna sampling, such as an absence of drill holes in areas not seen as prospective for mining and lack of access to sampling results from leases held by other companies.

Inferences about the distributions of the 15 species based on the ranges of related species are discussed below, together with some remarks about geology.

7.1.1.1. Arachnids

<u>Atemnidae sp. B04</u>
Pseudoscorpions are rarely collected in large numbers and are very commonly collected as singletons. When represented by multiple specimens, members of the family Chthoniidae (genera *Tyrannochthonius* and *Lagynochthonius*) are most commonly observed to have ranges in the tens of kilometres, up to about 50 km (Bennelongia unpublished data). There is far less information about the family Atemnidae and Bennelongia has collected only three other troglofaunal species of this family in the Pilbara in more than 10,500 samples. In the one case where multiple specimens were recorded a range of almost 8 km was observed (Bennelongia unpublished data).

As Atemnidae sp. B04 was collected at both Western Pit and Eastern Pits (with a range of 3.1 km) it is most likely to occur in the intervening landscape and is considered unlikely to be at risk from the proposed mining.

<u>*Draculoides* sp. B38, *Draculoides* sp. B41 and *Draculoides* sp. B42</u>
Schizomids are probably the most studied troglofauna, in terms of distributions, in Western Australia. Their ranges are variable. Harvey *et al*. (2008) reported that six species of schizomid in the Robe Valley were each tightly restricted to single mesas (the largest only 989 ha), although *D. vinei* in the Cape Range had a linear range of about 50 km.

Of the six schizomid species collected at the Survey Area, three are currently only known from proposed mine pits. Two are represented by singletons (*Draculoides* sp. B38 and *Draculoides* sp. B41), while *Draculoides* sp. B42 is known from three specimens from three sites at Western Pit with a range of 0.9 km (Figure 6.4, Table 7.1). The three other schizomids collected at the Survey Area all occurred outside the proposed mine pits (Table 6.1) and have ranges of between 0.8-2.9 km (all confirmed by molecular analysis; Reijs unpublished data).

Schizomids are speciose in the Survey Area and their distributions do not appear to be closely related to geology. Both species (*Draculoides* sp. B39 and *Draculoides* sp. B40) found in Western Pit and Eastern Pits, where the focus is mining of CID, occur outside the palaeochannel as well as within the CID of the channel (Figure 7.1). It is assumed that animals collected beyond the CID and palaeochannel are residing in BIF of the Dales Gorge Member, probably in the hardcap zone.

Draculoides sp. B37 at Dragon was collected in both commercial and non-commercial grade BIF, emphasizing that the occurrence of voids (which is typical of hardcap) limits distributions rather than suitability of the rock for mining *per se*.

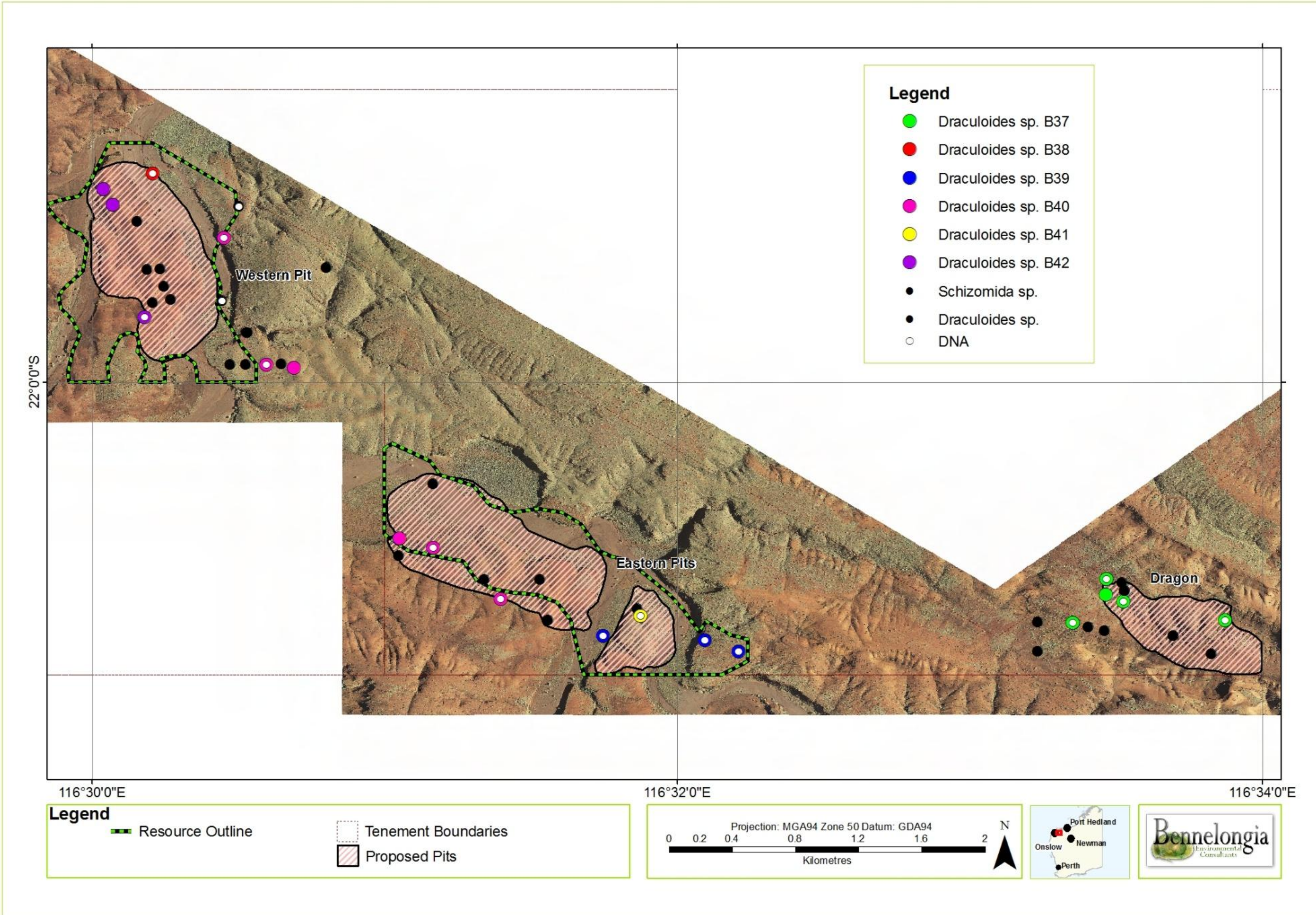

Figure 7.1. Schizomids collected at the Proposal Survey Area.

Prethopalpus sp.

Spiders, like pseudoscorpions, are typically collected at low abundance and determining ranges can be difficult. *Prethopalpis* are commonly collected as troglofauna. Where multiple records exist from past studies, the ranges of *Prethopalpis* species tend to be relatively small (Bennelongia unpublished data). However, the range observed for the recently described *Prethopalpus maini* is 18 km (Baehr 2012).

It is likely that *Prethopalpis* sp. will have a linear range <10 km. Given that it occurred very close to the southern boundary of the Eastern Pits, it is unlikely that the species is restricted to the proposed mine pit although the species may have a smaller linear range than required to be restricted to the pit (1.6 km).

7.1.1.2. Isopoda

Philosciidae sp. B22

Troglofaunal philosciids are relatively rare in the Pilbara but some of the recorded species appear to have restricted ranges (e.g. linear range 0.7 km, Bennelongia 2008f). Given that it occurred very close to the western boundary of the Eastern Pits, it is unlikely that Philosciidae sp. B22 is restricted to the proposed mine pit although the species may have a smaller linear range than required to be restricted to the pit (1.6 km).

7.1.1.3. Paurapoda

Stylopauropoides sp. B01

The taxonomy of pauropods in Australia is not well established (Scheller 2011) but some species in the Pilbara have extensive ranges, such as the circumtropical *Decapauropus tenuis* and Pauropodidae sp. B01 (known linear range of 143 km), while other species typically have smaller ranges in the order of 10 km or less (Bennelongia 2009b,c, unpublished data). Even if *Stylopauropoides* sp. B01 has a relatively small range it is unlikely to be restricted to the Eastern Pits given that the drill holes in which it was collected are at the north-eastern end of the Eastern Pits. The species would need to have a linear range of <0.6 km to be restricted to the pit in which it was recorded.

7.1.1.4. Diplura

Anajapygidae sp. B04, Heterojapygidae sp. B02, Japygidae sp. B30 and Japygidae sp. B31

The limited information about the ranges of troglofaunal Anajapygidae and Heterojapygidae suggests that species of these families may sometimes have tightly restricted ranges but tend to occur in valley sediments rather than across ranges (Bennelongia unpublished data). Therefore, it is considered likely that Anajapygidae sp. B04 and Heterojapygidae sp. B02 occur more widely along the Bungaroo Creek drainage lines than the layout of the drill holes sampled allowed to be demonstrated.

Troglofaunal japygids are considered to relatively widespread in the Pilbara (Halse 2010), as was illustrated by the Pilbara-wide range of Japygidae sp. B04 (Bennelongia 2009b, c) and linear range of at least 84 km for Japygidae sp. B17 (Table 6.1). It is expected that the ranges of Japygidae sp. B30 and Japygidae sp. B31 extend beyond the Proposed mine pits.

7.1.1.5. Blattodea

Nocticola sp. B24

This species was recorded at six locations in the Proposal Survey Area at both Western Pit and Eastern Pits, with a linear range of 3.4 km (Figure 6.4, Table 7.1). It is most likely this species occurred in the intervening landscape between the proposed mine pits and the occurrence of *Nocticola* sp. specimens in this landscape seemed to provide the evidence of wider distribution. However, attempts to confirm this through molecular analysis were unsuccessful because no usable sequence could be amplified (Reijs unpublished data).

7.1.1.6. Coleoptera

<u>Bembidiinae sp. B13 and Bembidiinae sp. B14</u>

Bembidiinae are a speciose group and many species have been collected in subterranean habitats of the Pilbara (Bennelongia unpublished data). To date none of the species has appeared to have a small range if represented by a moderate number of specimens (Bennelongia 2010; Bennelongia unpublished data).

Bembidiinae sp. B12 was recorded outside the Western Pit and at Dragon, with a linear range of 8 km. Bembidiinae sp. B13 was represented by one specimen in each of the Western and Eastern Pits, with linear ranges of 3.1 km (Figure 6.4, Table 7.1). This species is likely to occur in the intervening landscape that will not be mined. Bembidiinae sp. B14 was recorded as a singleton at Eastern Pits but given the distributions of its sister species and other well collected Bembidiinae in the Pilbara, it is unlikely that the species is restricted to the proposed mine pits.

7.1.2. Habitat Connectivity between Mine Pits and Surrounds

The most suitable geology for troglofauna at the Proposal is probably represented by the CID, alluvium and the hardcap zone of Dales Gorge Member (BIF) and these habitats are likely to have good connectivity. The CID and the alluvium in the palaeodrainage channel in particular are expected to be well connected as they are stratigraphically closely related. Furthermore, troglofauna habitat within the proposed mine pits (mostly CID with some alluvium overlying it in places) is certain to be well connected with troglofauna habitat both downstream and upstream in the palaeodrainage channel as they are all part of the one continuous geological unit (RPS Aquaterra 2012). In fact, the Western and Eastern Pits could potentially be a single mine pit if the mine lease extended between them.

This assertion of habitat connectivity within the Survey Area is well supported by sampling results. Twelve of the species only known from the Survey Area that were represented by specimens collected at more than one bore clearly demonstrate habitat connectivity. Seven of the 12 species in the Survey Area that were collected from more than one bore occur in at least two of the proposed mine pit (Figure 6.1). Two of these species (Bembidiinae sp. B12 and Curculionidae Genus 2 sp. B14) occurred in both BIF at Dragon and in CID at Western Pit or Eastern Pits or both.

Draculoides sp. B40 occurred in CID in two pit areas and also occurred beyond the CID, presumably in BIF (Figure 7.1).

7.2. Stygofauna

7.2.1. Stygofauna Distributions and Conservation Risk for Species

Most of the stygofauna species collected were known to, or probably, occurred beyond the Survey Area and likely drawdown cone (Table 6.3). However, nine species are currently known only from within the Survey Area (Table 6.3), while the status of further three species identified only to family or genus (Tubificidae sp., *Parastenocaris* sp. and *Pygolabis* sp.) is unclear and they must also be regarded as restricted to the Survey Area (Figure 6.7, Table 7.2).

Existing information about the likely ranges of these species is discussed below.

Table 7.2. Stygofauna species from bores likely to be impacted by groundwater drawdown at the Proposal. Highlight indicates species recorded at only one bore.

Higher Group* Species	**Number of Specimens**	**Number of Sites**	**Number of Deposits**	**Linear Range (km)**	**Restricted**
Oligochaeta					
Tubificidae sp.	1	1	1		not likely
Acariformes					
Limnesia sp. B04	1	1	1		not likely
Copepoda					
Anzcyclops sp. B03	202	2	1	1.7	possible
Thermocyclops sp. B05 (nr *aberrans*)	3	1	1		not likely
nr *Dussartstenocaris* sp. B05	1	1	1		possible
nr *Kinnecaris* sp. B03	7	2	1	2	possible
Parastenocaris sp.	1	1	1		not likely
Syncarida					
Bathynella sp. B09	3	1	1		possible
Bathynella sp. B10	7	1	1		possible
Billibathynella sp. B06	184	7	2	3	not likely
Amphipoda					
Paramelitidae Genus 2 sp. B12	1	1	1		not likely
Isopoda					
Pygolabis sp.	2	2	2	1.8	not likely

*Commonly used nomenclature for major aquatic invertebrate groups following Williams (1980).

7.2.1.1. Tubificidae sp.

This family level identification of a single damaged specimen is most unlikely to represent a species restricted to the likely drawdown cone because few oligochaetes in the Pilbara have tightly restricted ranges (Pinder 2000, 2006) (Table 7.2).

7.2.1.2. *Limnesia* sp. B04

Most species of the genus are collected in surface waters and the few stygal species in the Pilbara are considered to be moderately wide-ranging (Halse *et al*. in prep.), although taxonomy is yet to be undertaken. Accordingly, it is considered unlikely that the species is restricted to the Survey Area (Table 7.2).

7.2.1.3. Copepoda

Six species of Copepoda are known only from the Survey Area:

- *Anzcyclops* sp. B03 is known from 202 specimens collected at Eastern Pits;
- *Thermocyclops* sp. B05 (nr *aberrans*) is known from three specimens collected at Western Pit;
- nr *Dussartstenocaris* sp. B05 is known from one specimen at Eastern Pits;
- nr *Kinnecaris* sp. B03 is known from seven specimens at Eastern Pits; and
- *Parastenocaris* sp. is listed based on one immature specimen from Eastern Pits.

Most stygal copepods in the Pilbara are widespread (Karanovic 2006); however some do have ranges limited to single catchments or tributaries (Bennelongia unpublished data). Species of *Anzcyclops* are infrequently collected and species have not been observed to have ranges beyond the scale of a single tributary. *Anzcyclops* sp. B03 is likely to be restricted to the Robe Catchment or possibly the Bungaroo Creek catchment (Table 7.2).

Species of *Thermocyclops* are typically wide-ranging and are considered to be stygophiles with surface, as well as groundwater populations. *Thermocyclops* sp. B05 (nr *aberrans*) was likely to have a relatively wide range (Table 7.2).

Nr *Dussartstenocaris* and *nr Kinnecaris* are rarely collected in the Pilbara and possibly both nr *Dussartstenocaris* sp. B05 and nr *Kinnecaris* sp. B03 had restricted ranges (Table 7.2). There is currently too little taxonomic information for further comment.

Some *Parastenocaris* species are wide-ranging (e.g. *Parastenocaris jane*: Karanovic 2006), while others have catchment-scale ranges. Despite the poor taxonomic resolution of *Parastenocaris* sp., it is considered unlikely the species is restricted to the Study Area (Table 7.2).

7.2.1.4. Syncarida

Bathynella sp. B09, *Bathynella* sp. B10 and *Billibathynella* sp. B06

Stygofaunal syncarid species are usually considered to have small ranges (Guzik *et al*. 2008), although there is evidence that ranges increase with sampling effort (Camecho and Valdecasas 2008). Given the high numbers in which they were collected and their widespread occurrence within the Survey Area (seven bores across Western Pit and Eastern Pits), it is most likely that *Billibathynella* sp. B06 occurred both upstream and downstream of the Proposal (Table 7.2).

Bathynella species are less commonly collected than parabathynellids and, in general, appear to be more restricted in range (Bennelongia unpublished data). It is possible that both *Bathynella* sp. B09 and *Bathynella* sp. B10 were restricted to the Survey Area (Table 7.2).

7.2.1.5. Amphipoda

Paramelitidae Genus 2 sp. B12

Paramelitidae Genus 2 sp. B12 was represented by a single specimen from Western Pit. Most paramelitid species have tributary-scale ranges and none yet are known to have a range as small as that of the likely drawdown cone of the Proposal (Finston *et al*. 2007, 2011). Therefore, it is considered unlikely that Paramelitidae Genus 2 sp. B12 was restricted to the Survey Area (Table 7.2).

7.2.1.6. Isopoda

Pygolabis sp.

Two specimen of *Pygolabis* sp. were recorded in the Survey Area; both were immature and lacked characters needed for species level identifications. Given that other known *Pygolabis* species have substantially larger ranges than the Survey Area (Keable and Wilson 2006), it is considered unlikely that *Pygolabis* sp. is restricted to the Survey Area (Table 7.2); although Finston (2009) provided some evidence of additional species and smaller ranges.

7.2.2. Habitat Connectivity between Mine Pits and Surrounds

The most suitable habitat for stygofauna at the Proposal is the CID in-fill aquifer of the palaeochannel (alluvium and CID). Downstream of the Proposal, the geology and hydrogeology are essentially the same in terms of the rock strata and aquifers present. MWH (2006, in RPS Aquaterra 2012) defined the conceptual groundwater system in the Bungaroo valley as a sequence of modern day river alluvium overlying Tertiary pisolite (occupying a deeply incised palaeochannel), which had been incised into dolomites and shale units of the Proterozoic Bee Gorge and Paraburdoo Members. The remainder of the Bungaroo Creek catchment and the Robe River catchment are known to have very significant CID aquifers. Thus, other aquifers of the Robe and Bungaroo catchments, both upstream and downstream of the Proposal, probably provide considerable habitat connectivity for stygofauna beyond the Proposal.

The stygofauna survey data illustrated this, with six of the species recorded at the Proposal already known to occur elsewhere in the Robe catchment (Bennelongia unpublished data, see Table 6.3).

8. CONCLUSION

8.1. Troglofauna

Troglofauna survey at the Proposal was conducted according to EPA guidelines. At Western Pit and Eastern Pits the sample effort was just below the recommend level of 60 samples, with 59 and 58 samples, respectively, while at Dragon 37 samples were taken. Additional data on troglofauna collected as by-catch during stygofauna sampling were included in the assessment.

At least 40 species of troglofauna belonging to 15 Orders were collected including Pseudoscorpionida, Palpigradi, Schizomida, Araneae, Isopoda, Geophilomorpha, Polydesmida, Spirostreptida, Pauropodina, Cephalostigmata, Diplura, Blattodea, Hemiptera, Coleoptera and Diptera (Table 6.1).

Fifteen species of troglofauna, including 10 singletons and one doubleton species (two specimens at one bore), are currently known only from within the proposed mine pits of the Proposal (Figure 6.4, Table 7.1). It is likely that the apparently localised ranges of these 15 species are artefacts of them occurring at low abundance.

Given that the smallest known range of a well sampled troglofauna species is 89 ha in an area with strong topography and likely barriers to troglofauna movement (Biota 2006), it appears unlikely that 15 troglofauna species would be restricted to Western Pit, Eastern Pits and Dragon, with areas of 70, 94.7 and 34.7 ha, respectively. A review of the ranges of similar species suggests three troglofauna species may possibly be restricted to the proposed mine pits, while the remaining 12 species currently known only from these areas are unlikely to be restricted.

Habitat characterisation, and fact that 58% of the species collected at more than one drill hole in the Survey Area occurred in at least two pit areas, further suggest that the species currently only known from the proposed mine pits are unlikely to be restricted to the pits. The CID and the alluvium in the palaeodrainage channel in particular well connected and form a single continuous geological unit, which extends well beyond the proposed mine pits (RPS Aquaterra 2012).

8.2. Stygofauna

Stygofauna survey at the Proposal was conducted according to EPA guidelines. Altogether, 61 stygofauna samples were collected from the area likely to be impacted by groundwater drawdown. Additional data on stygofauna collected as by-catch during troglofauna sampling were included in the assessment.

At least 28 stygofauna species of 10 higher level taxonomic groups were recorded, including Rotifera, Gastropoda, Acariformes, Ostracoda and Isopoda, Oligochaeta, Copepoda, Syncarida, Amphipoda, and Nematoda (Table 6.3). Eight of the stygofauna species collected are known to occur widely in the Pilbara, while another six occur widely in the Robe catchment. On the basis of existing data, 12 species are known only from within the Survey Area; this includes nine identified species and three taxa identified only to family or genus (the ranges of two nematodes and rotifers were not assessed).

Based on existing information on the distributions of Pilbara stygofauna, it is unlikely that the 12 stygofauna species only known from the Survey Area are actually restricted that that area. However, a review of the ranges of taxonomically similar species suggested it is possible that five of the 12 species have ranges not much larger than the Survey Area.

Habitat characterisation showed that the CID/alluvial aquifer in palaeochannels of the Robe and Bungaroo catchments, which occurs both upstream and downstream of the Proposal potentially provides considerable habitat connectivity for stygofauna beyond the Proposal and would appear to reduce the risk likelihood of any species being restricted to the Survey Area.

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10. APPENDICES

Appendix 1: Secondary Impacts of Mining on Subterranean Fauna

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 threats to either stygofauna or troglofauna outside the proposed mine pits.

Overburden Stockpiles and Waste Dumps

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 are likely to be greater for troglofauna than stygofauna (because lateral movement of groundwater should bring in carbon and nutrients). 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.

Aquifer Recharge with Poor Quality Water

Quality of recharge water declines during, and after, mining operations as a result of rock break up and soil disturbance (i.e. Gajowiec 1993; McAuley and Kozar 2006). Impacts can be minimised through management of surface water and installing drainage channels, sumps and pump in pits to prevent of recharge though the pit floor.

Contamination of Groundwater with Hydrocarbons

Any contamination is likely to be localised and may be minimised by engineering and management practices to ensure containment.

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Appendix 2. Bores Sampled for Troglofauna

Orebody	Bore Code	Latitude	Longitude	Site Type
Dragon	RI014	-22.0148	116.561	Impact
Dragon	RI005	-22.0155	116.5638	Impact
Dragon	RI004	-22.0147	116.5631	Impact
Dragon	RI003	-22.0156	116.5652	Impact
Dragon	RI002	-22.015	116.5664	Impact
Dragon	RI006	-22.0145	116.5616	Impact
Dragon	RI007	-22.0132	116.561	Impact
Dragon	RI008	-22.0127	116.5614	Impact
Dragon	RI009	-22.0132	116.5633	Impact
Dragon	RI013	-22.0125	116.5599	Impact
Dragon	RI011	-22.0125	116.5588	Impact
Dragon	RI010	-22.0121	116.5578	Impact
Eastern Pits	BH188	-22.0147	116.5349	Control
Eastern Pits	BH186	-22.0165	116.5349	Control
Eastern Pits	BH190	-22.0163	116.5369	Control
Eastern Pits	BH168	-22.0117	116.5291	Control
Eastern Pits	BH165	-22.0144	116.5291	Control
Eastern Pits	BH191	-22.0153	116.5368	Control
Eastern Pits	BH134	-22.0059	116.5214	Impact
Eastern Pits	BH135	-22.0049	116.5214	Control
Eastern Pits	BH124	-22.0058	116.5194	Impact
Eastern Pits	BH125	-22.0049	116.5194	Control
Eastern Pits	BH112	-22.0015	116.5175	Control
Eastern Pits	BH113	-22.0023	116.5174	Control
Eastern Pits	BH118	-22.0063	116.5175	Impact
Eastern Pits	BH126	-22.0099	116.5175	Impact
Western Pit	BH105	-21.999	116.5088	Control
Western Pit	BH107	-21.999	116.5099	Control
Western Pit	BH108	-21.999	116.5108	Control
Western Pit	BH109	-21.9992	116.5115	Control
Western Pit	BH100	-21.9972	116.5078	Control
Western Pit	BH091	-21.9918	116.5063	Control
Western Pit	BH082	-21.9883	116.5035	Impact
Western Pit	BH070	-21.9881	116.5035	Impact
Western Pit	BH044	-21.99	116.5084	Control
Western Pit	BH043	-21.99	116.5084	Control
Western Pit	BH045	-21.9918	116.5075	Control
Western Pit	BH099	-21.9972	116.507	Control
Western Pit	BH055	-21.9991	116.5025	Control
Western Pit	BH054	-21.999	116.5036	Control
Western Pit	BH036	-21.9972	116.5025	Control
Western Pit	BH051	-21.9972	116.504	Impact
Western Pit	BS019	-21.9972	116.5021	Control
Western Pit	BS016	-21.9953	116.5021	Control
Western Pit	BH088	-21.9954	116.5026	Control
Western Pit	BH087	-21.9955	116.5034	Impact
Western Pit	BH085	-21.9951	116.5059	Impact
Western Pit	BH034	-21.9936	116.5054	Impact
Western Pit	BH144	-21.9936	116.5054	Impact
Western Pit	BS013	-21.9936	116.5039	Impact
Western Pit	BH078	-21.9918	116.5022	Impact
Western Pit	BH079	-21.9917	116.5016	Impact
Western Pit	BH027	-21.99	116.5016	Impact
Western Pit	BS021	-21.99	116.502	Impact
Western Pit	BH146	-21.99	116.5029	Impact
Western Pit	BS022	-21.9899	116.5011	Impact
Western Pit	BH028	-21.9899	116.5007	Impact
Western Pit	BS024	-21.9891	116.5016	Impact
Western Pit	BS001	-21.9891	116.502	Impact

Orebody	Bore Code	Latitude	Longitude	Site Type
Western Pit	BS023	-21.9889	116.5026	Impact
Western Pit	BH076	-21.9918	116.5046	Impact
Western Pit	BH092	-21.9918	116.5054	Impact
Western Pit	BH093	-21.9936	116.5064	Impact
Western Pit	GT02	-21.9954	116.5062	Impact
Western Pit	BS020	-21.9909	116.502	Impact
Western Pit	BS010	-21.9883	116.5003	Impact
Western Pit	BS005	-21.9944	116.5035	Impact
Western Pit	BS029	-21.9954	116.5031	Impact
Eastern Pits	BH178	-22.0122	116.5311	Impact
Eastern Pits	BH214	-22.0133	116.5313	Impact
Eastern Pits	BH175	-22.0148	116.5314	Impact
Eastern Pits	BH174	-22.0156	116.531	Impact
Eastern Pits	BH176	-22.0141	116.5317	Impact
Eastern Pits	BH152	-22.0124	116.5233	Control
Eastern Pits	BH151	-22.0115	116.5233	Impact
Eastern Pits	BH149	-22.0096	116.5234	Impact
Eastern Pits	BH155	-22.0136	116.526	Impact
Eastern Pits	BH217	-22.0117	116.5257	Impact
Eastern Pits	BH154	-22.0113	116.5255	Impact
Eastern Pits	BH153	-22.0103	116.5252	Impact
Eastern Pits	BH039	-22.0124	116.5272	Impact
Eastern Pits	BH157	-22.0116	116.5271	Impact
Eastern Pits	BH159	-22.0138	116.5272	Impact
Eastern Pits	BH137	-22.0079	116.5233	Impact
Eastern Pits	BH138	-22.007	116.5233	Impact
Eastern Pits	BH170	-22.0099	116.5291	Control
Eastern Pits	BH133	-22.0068	116.5214	Impact
Eastern Pits	BH131	-22.0086	116.5214	Impact
Eastern Pits	BH130	-22.0094	116.5214	Impact
Eastern Pits	BH129	-22.0103	116.5213	Impact
Eastern Pits	BH127	-22.0103	116.5194	Impact
Eastern Pits	BH116	-22.0081	116.5175	Impact
Eastern Pits	BH041	-22.0111	116.5233	Impact
Eastern Pits	BH040	-22.0097	116.5233	Impact
Eastern Pits	BH216	-22.0123	116.5272	Impact
Eastern Pits	BH150	-22.0107	116.5236	Impact
Eastern Pits	BH115	-22.0089	116.5175	Impact
Eastern Pits	BH120	-22.0094	116.5194	Impact
Western Pit	BH106	-21.9972	116.5088	Control
Western Pit	BH104	-21.999	116.5079	Control
Western Pit	BH096	-21.9954	116.5074	Control
Eastern Pits	BH114	-22.0039	116.5175	Control
Dragon	PROP006	-22.0153	116.5539	Control
Dragon	PROP008	-22.0137	116.5539	Control
Dragon	PROP003	-22.0153	116.5529	Control
Dragon	PROP005	-22.0138	116.5529	Control
Dragon	PROP002	-22.0145	116.5519	Control
Dragon	PROP001	-22.0154	116.5519	Control
Dragon	RI012	-22.0132	116.5598	Impact
Dragon	RI022	-22.0107	116.5571	Control
Dragon	PROP018	-22.0117	116.5578	Impact
Dragon	PROP020	-22.0105	116.5577	Control
Dragon	PROP021	-22.0119	116.5588	Impact
Dragon	PROP024	-22.0114	116.5587	Impact
Dragon	PROP032	-22.0126	116.5626	Impact
Dragon	PROP033	-22.0143	116.5664	Control
Dragon	PROP029	-22.0136	116.5646	Impact
Dragon	PROP027	-22.0151	116.5623	Impact
Dragon	PROP025	-22.0134	116.5624	Impact
Dragon	PROP034	-22.0159	116.5664	Impact
Dragon	PROP019	-22.0112	116.5578	Control

Orebody	Bore Code	Latitude	Longitude	Site Type
Dragon	PROP023	-22.0114	116.5572	Control
Dragon	PROP017	-22.0147	116.561	Impact
Dragon	PROP016	-22.0144	116.561	Impact
Dragon	PROP015	-22.0146	116.5587	Control
Dragon	PROP014	-22.0144	116.5588	Control
Eastern Pits	BH209	-22.0158	116.5329	Control
Eastern Pits	BS062	-22.0151	116.531	Impact
Dragon	PROP004	-22.0145	116.5529	Control
Dragon	PROP007	-22.0137	116.5559	Control
Dragon	PROP009	-22.0137	116.5559	Control
Dragon	PROP011	-22.0143	116.5567	Control
Dragon	PROP010	-22.014	116.5568	Control
Dragon	PROP012	-22.0142	116.5577	Control
Dragon	PROP013	-22.0143	116.5577	Control
Dragon	PROP030	-22.0133	116.565	Control
Eastern Pits	BS074	-22.0129	116.533	Control
Eastern Pits	BH207	-22.0121	116.5292	Control
Eastern Pits	BH160	-22.0096	116.5272	Impact
Eastern Pits	BS091	-22.0101	116.5224	Impact
Eastern Pits	BS089	-22.0113	116.5224	Impact
Eastern Pits	BS084	-22.0106	116.5233	Impact
Eastern Pits	BS036	-22.0112	116.5243	Impact
Eastern Pits	BS037	-22.0122	116.5243	Impact
Eastern Pits	BH123	-22.0077	116.5194	Impact
Eastern Pits	BH213	-22.0067	116.5175	Impact
Eastern Pits	BS063	-22.0161	116.5311	Impact
Western Pit	BH202	-21.9881	116.5021	Impact
Western Pit	BS038	-21.9927	116.5049	Impact
Western Pit	BS118	-21.9927	116.503	Impact
Western Pit	BS122	-21.9909	116.5026	Impact
Western Pit	BS121	-21.9909	116.5031	Impact
Western Pit	BH110	-21.9935	116.5134	Control
Western Pit	BH111	-21.999	116.5149	Control
Western Pit	BS125	-21.9973	116.5054	Impact
Western Pit	BS128	-21.9959	116.5074	Control
Western Pit	BH200	-21.9881	116.505	Control
Western Pit	BS096	-21.999	116.5039	Control
Western Pit	BS006	-21.9963	116.503	Impact
Western Pit	BS111	-21.9946	116.5041	Impact
Western Pit	BS114	-21.9946	116.5056	Impact
Western Pit	BS015	-21.9937	116.5059	Impact
Western Pit	BS014	-21.9936	116.505	Impact
Western Pit	BS117	-21.9927	116.5025	Impact
Western Pit	BS123	-21.989	116.5006	Impact
Western Pit	BS009	-21.9882	116.5011	Impact
Western Pit	BS002	-21.9891	116.5011	Impact
Western Pit	BS026	-21.9918	116.503	Impact
Western Pit	BS116	-21.9927	116.5021	Impact
Western Pit	BS115	-21.9927	116.5015	Impact
Western Pit	BS107	-21.9944	116.5015	Impact

Appendix 3. Records of Subterranean Fauna Specimens Lodged at the Museum

Troglofauna

Taxa	WAM Number
Anapistula sp.	129670
Lagynochthonius sp. B16	129683
Lagynochthonius sp. B17	129684
Lagynochthonius sp. B18	129685
Tyrannochthonius sp. B23	129690
Indohya sp. B05	129681
Atemnidae sp. B04	129671
Palpigradi sp.	129687
Draculoides sp. B37	129673
Draculoides sp. B38	129674
Draculoides sp. B39	129675
Draculoides sp. B40	129676
Draculoides sp. B41	129677
Draculoides sp. B42	129678
Prethopalpus sp.	129688
nr *Encoptarthria* sp.	129686
Philosciidae sp. B20	52194
Philosciidae sp. B22	52195
Troglarmadillo sp. B32	52196
Geophilidae (nr *Geophilus*) sp. B02	129679
Iulomorphidae sp.	129682
Dalodesmidae sp. B05	129672
Stylopauropoides sp. B01	129641
Hanseniella sp. B18	129680
Symphyella sp. B16	129689
Japygidae `DPL014`	lodged 8/4/13
Heterojapygidae sp. B02	lodged 8/4/13
Japygidae sp. B30	lodged 8/4/13
Japygidae sp. B31	lodged 8/4/13
Campodeidae sp. B07	lodged 8/4/13
Anajapygidae sp. B04	lodged 8/4/13
Nocticola sp. B24	lodged 8/4/13
Meenoplidae sp. B07	lodged 8/4/13
Hemiptera sp. B02	lodged 8/4/13
Bembidiinae sp. B12	lodged 8/4/13
Bembidiinae sp. B13	lodged 8/4/13
Bembidiinae sp. B14	lodged 8/4/13
Curculionidae Genus 1 sp. B11	lodged 8/4/13
Curculionidae Genus 2 sp. B14	lodged 8/4/13
Sciaridae sp. B01	lodged 8/4/13

Stygofauna

Taxa	WAM Number
Dissotrocha sp. B01 (nr *aculeata*)	52178
Hydrobiidae sp.	S83980
Pristina longiseta	52191
Enchytraeus Pilbara sp. 1 (PSS)	52179
Enchytraeus Pilbara sp. 2 (PSS)	52180
Limnesia sp. B04	129691
Areacandona nr *brookanthana*	52173

Taxa	**WAM Number**
Microcyclops varicans	52184
Metacyclops sp. B01 (nr *pilbaricus*)	52183
Halicyclops (*Rochacyclops*) *roachi*	52181
Diacyclops humphreysi humphreysi	52177
Thermocyclops sp. B05 (nr *aberrans*)	52193
Anzcyclops sp. B03	52172
nr *Kinnecaris* sp. B03	52188
Parastenocarididae sp.	52190
Bathynella sp. B09	52174
Bathynella sp. B10	52175
Billibathynella sp. B06	52176
Paramelitidae Genus 2 sp. B12	52189
Neoniphargidae sp.	52187
Nedsia nr *hurlberti*	52185
Nedsia sculptilis group (PSS)	52186
Melitidae sp. B02 (sp. 1 group)	52182
Pygolabis sp.	52192

Appendix 4. Bores Sampled for Stygofauna

Orebody	Bore Code	Latitude	Longitude
Western Pit	BH200	-21.9880833	116.505028
Western Pit	BH068	-21.9863333	116.501361
Western Pit	BH096	-21.9953889	116.507417
Western Pit	BH104	-21.999	116.507861
Western Pit	BH106	-21.9971944	116.508833
Western Pit	BH097	-21.9971944	116.505
Western Pit	BH201	-21.99	116.504389
Western Pit	BH202	-21.9880833	116.502056
Western Pit	BH142	-21.9918056	116.503972
Western Pit	BH011	-21.9936111	116.503139
Western Pit	BH086	-21.9953056	116.5045
Western Pit	MB2	-21.9990278	116.502528
Western Pit	BS007	-21.9981111	116.5035
Western Pit	BH049	-21.9936389	116.501528
Western Pit	BS002	-21.9891389	116.501056
Eastern Pits	BH115	-22.0088889	116.517528
Eastern Pits	BH211	-22.0072222	116.519389
Eastern Pits	BH120	-22.0094444	116.519444
Eastern Pits	BH148	-22.0090278	116.521306
Eastern Pits	BH150	-22.0106944	116.523611
Eastern Pits	BH205	-22.0097222	116.525194
Eastern Pits	BH160	-22.0096389	116.527222
Eastern Pits	BH206	-22.01025	116.528944
Eastern Pits	BH177	-22.0129167	116.531056
Eastern Pits	BH172	-22.0163333	116.528944
Eastern Pits	BH209	-22.0158333	116.532944
Eastern Pits	BH208	-22.0148333	116.529111
Eastern Pits	BH114	-22.0039444	116.517472
Eastern Pits	BH212	-22.0076667	116.5175
Eastern Pits	BH134	-22.0058611	116.521389
Eastern Pits	BS030	-21.9909444	116.504056
Western Pit	BH085	-21.9951111	116.505861
Eastern Pits	BS018	-21.9971389	116.503056
Eastern Pits	BS128	-21.9958611	116.507389
Western Pit	BH100	-21.9972222	116.507833
Eastern Pits	BH118	-22.0063333	116.517528
Eastern Pits	BS041	-22.0127222	116.52725
Eastern Pits	BS074	-22.0127778	116.533
Eastern Pits	BH135	-22.0049167	116.521389
Dragon	PROP023	-22.0113889	116.557194
Western Pit	BS137	-21.9890278	116.504833