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BUILDING A BETTER WORLD

Atopobathynella sp. OES9

FINAL REPORT

Mount Keith Satellite Operations Subterranean Fauna Assessment

Prepared for BHP Billiton Nickel West

September 2016

QUALITY STATEMENT

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Executive Summary

BHP Billiton Nickel West (Nickel West) is proposing to develop the Mount Keith Satellite Operations (the Project), located approximately 25 km south of Mount Keith in the Northern Goldfields Region of Western Australia. MWH Australia Pty Ltd (formerly Outback Ecology) was commissioned to undertake a subterranean fauna assessment of the proposed Project.

The Project comprises the development of two open-cut pits, Goliath and Six-Mile Well, which will provide nickel disseminated sulphide ore to the Nickel West Mount Keith (NMK) operation. Waste rock will be directed to a waste rock landform adjacent to the mining operations.

The objective of this study reported herein was to investigate the subterranean fauna values of the Project Area and to assess if the removal or modification of potential habitat and groundwater drawdown will place any stygofauna or troglofauna species within the Project Area at risk. The scope of this study encompassed a literature review, database searches and stygofauna and troglofauna surveys of the Project Area.

Stygofauna

The stygofauna survey effort, summarised in **ES Table 1**, involved 64 net haul samples collected over five sample rounds, 2006 (Biota), November 2010, March 2011 June 2011 and February 2012 by MWH.

ES Table 1: Stygofauna survey effort

Area		No. Samples	No. Bores
Inside Proposed Pit Boundaries	Goliath	12	4
	Six-mile Well	4	1
Outside Pits	<500m	8	3
	>500m, <1km	22	6
	>1km	18	7
Totals		**64**	**21**

The Project Area was found to host a stygofauna assemblage of low diversity, with six of the seven species identified known from only one or two individuals. Only one species was collected from more than one bore. Findings, including work conducted by Biota, are summarised as follows:

- four stygofauna species were only recorded from within the proposed impact areas:
  - Goliath: one amphipod species recorded from within from within likely groundwater drawdown zone;
  - Six-Mile Well: two species, *Atopobathynella* sp. OES8 and *Atopobathynella* sp. OES11 from within proposed pit boundary. One species, *Gomphodella* sp. IK2 from within modelled 5m bSWL groundwater drawdown contour.

- two stygofauna species, *Atopobathynella* sp. OES9 and Bathynellidae sp. OES2, were collected from outside the proposed Project impact areas.

An assessment of survey adequacy found that further stygofauna sampling is required to more reliably characterise the stygofauna assemblage present and to provide a higher level of confidence in assessing the potential impacts posed by the proposed Project.

The current findings indicate that the development of the Project will pose a significant conservation risk to four stygofauna species through the removal of habitat by mining excavation and pit dewatering.

Troglofauna

The troglofauna survey effort, summarised in **ES Table 2**, involved sixty seven litter trap samples deployed over two trapping rounds conducted for nine weeks during March to May, 2011, and for seven weeks during May to July, 2011. In addition, 14 net haul scrape samples were also collected.

ES Table 2: Troglofauna survey effort

Area		No. Samples	No. Bores
Inside Proposed Pit Boundaries	Goliath	15	8
	Six-mile Well	8	4
Outside Pits	<500m	8	5
	>500m, <1km	35	13
	>1km	15	7
	Totals	**81**	**37**

The Project Area was found to host a troglofauna assemblage of very low diversity and abundance, with only two species collected. Survey findings are summarised as follows:

- *Troglarmadillo* sp. OES3 (known from two specimens only) and Campodeidae sp. OES2 (known from one specimen) were both recorded from outside the proposed Project impact areas;
- no troglofauna species were recorded from inside any Project impact areas; and
- regolith and weathered fractured rock habitat from troglofauna species were collected is extensive and contiguous in the Project Area and surrounding local region.

An assessment of survey adequacy found that no further troglofauna sampling is required to more reliably characterise the assemblage present. The proposed Project is considered to not pose a risk to the long-term survival of any known troglofauna species as no species were collected from the within the proposed impact areas. In addition, the distributions of potentially undetected troglomorphic species are unlikely to be restricted to small areas such as the proposed impact areas because of the continuity and extent of habitat present.

BHP Billiton Nickel West

Mount Keith Satellite Operations Subterranean Fauna Assessment

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1.1 Project Location and Description

BHP Billiton Nickel West (Nickel West) commissioned MWH Australia (MWH; formerly Outback Ecology) to undertake a subterranean fauna assessment of the proposed Mount Keith Satellite Operations (the Project). The Project is located in the Northeastern Goldfields region of Western Australia, within the Yakabindie and Mt Keith pastoral leases, approximately 25 km south of the existing Mt Keith Nickel Operation and immediately west of the Wanjarri Nature Reserve (**Figure 1-1**).

The main components of the Project comprise two proposed open-cut pits at the Goliath and Six-mile Well deposits, waste rock landform, and other associated facilities/infrastructure (e.g. stockpiles, and run-of mine (ROM) pad) (**Figure 1-2**). The proposed pits will provide nickel disseminated sulphide ore to the Mt Keith Operation for processing via a proposed transport corridor extending north from the Project. Additional infrastructure will include a causeway crossing Jones Creek, the ephemeral stream which bisects the Project Area, offices, fuel farm, dewater facility, and a primary access road servicing the Project from the south.

1.2 Assessment Scope and Objectives

The scope of this assessment encompassed a desktop study (literature review and database searches), stygofauna surveys (conducted between 2010 and 2012) and troglofauna surveys (conducted in 2011). The overarching aim was to investigate the subterranean fauna values of the Project Area and assess whether the removal of potential habitat through pit excavation and groundwater drawdown will place any stygofauna or troglofauna within the Project Area at risk. Specific objectives of the assessment were to:

- evaluate the potential of habitat within the proposed mining areas to support subterranean fauna;
- consider the conservation significance of any subterranean fauna assemblage or species occurring within the Project Area; and
- identify any potential risks to obligate subterranean fauna from the proposed mining activities.

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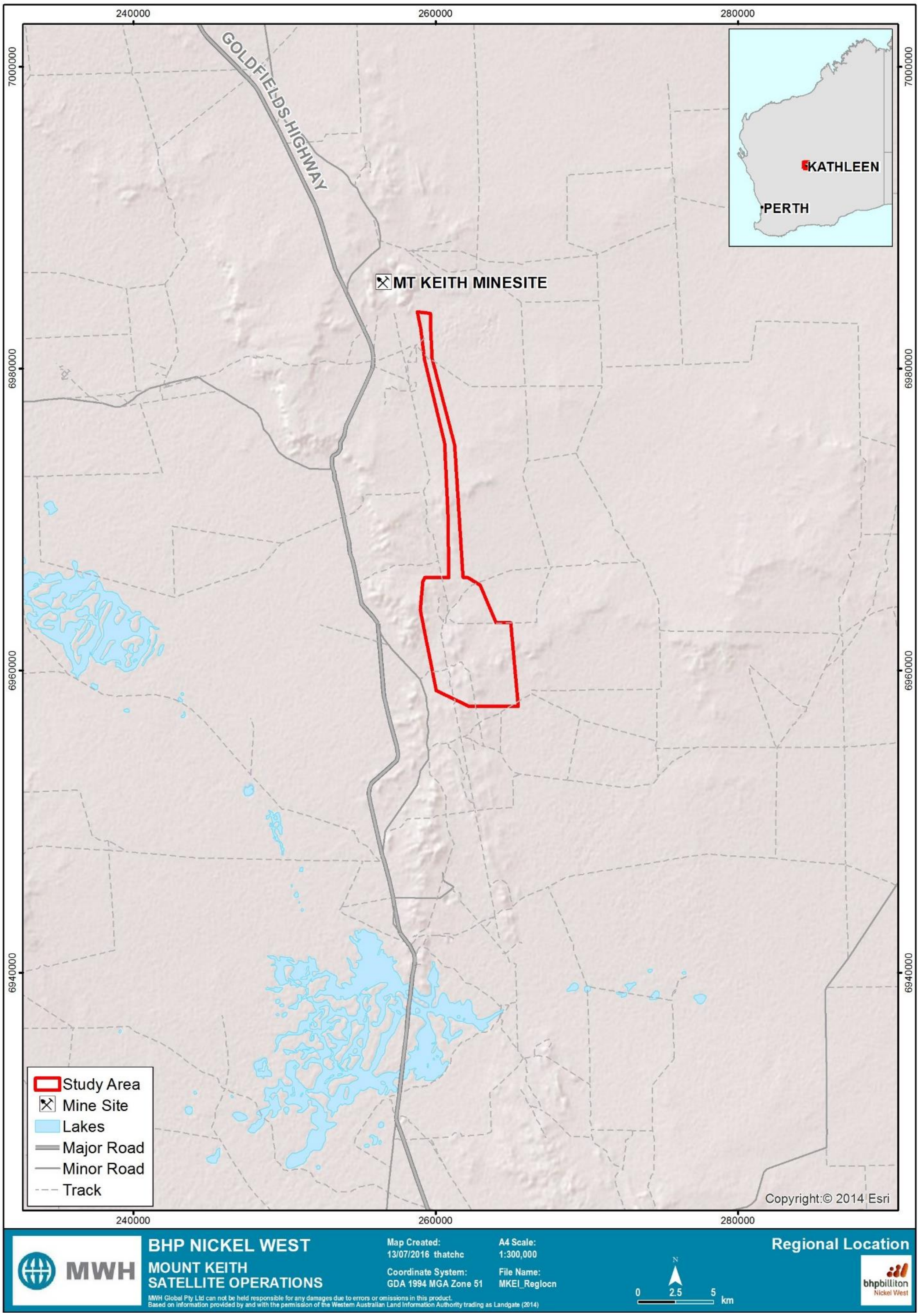

Figure 1-1: Regional location of the Mount Keith Satellite Operations Area.

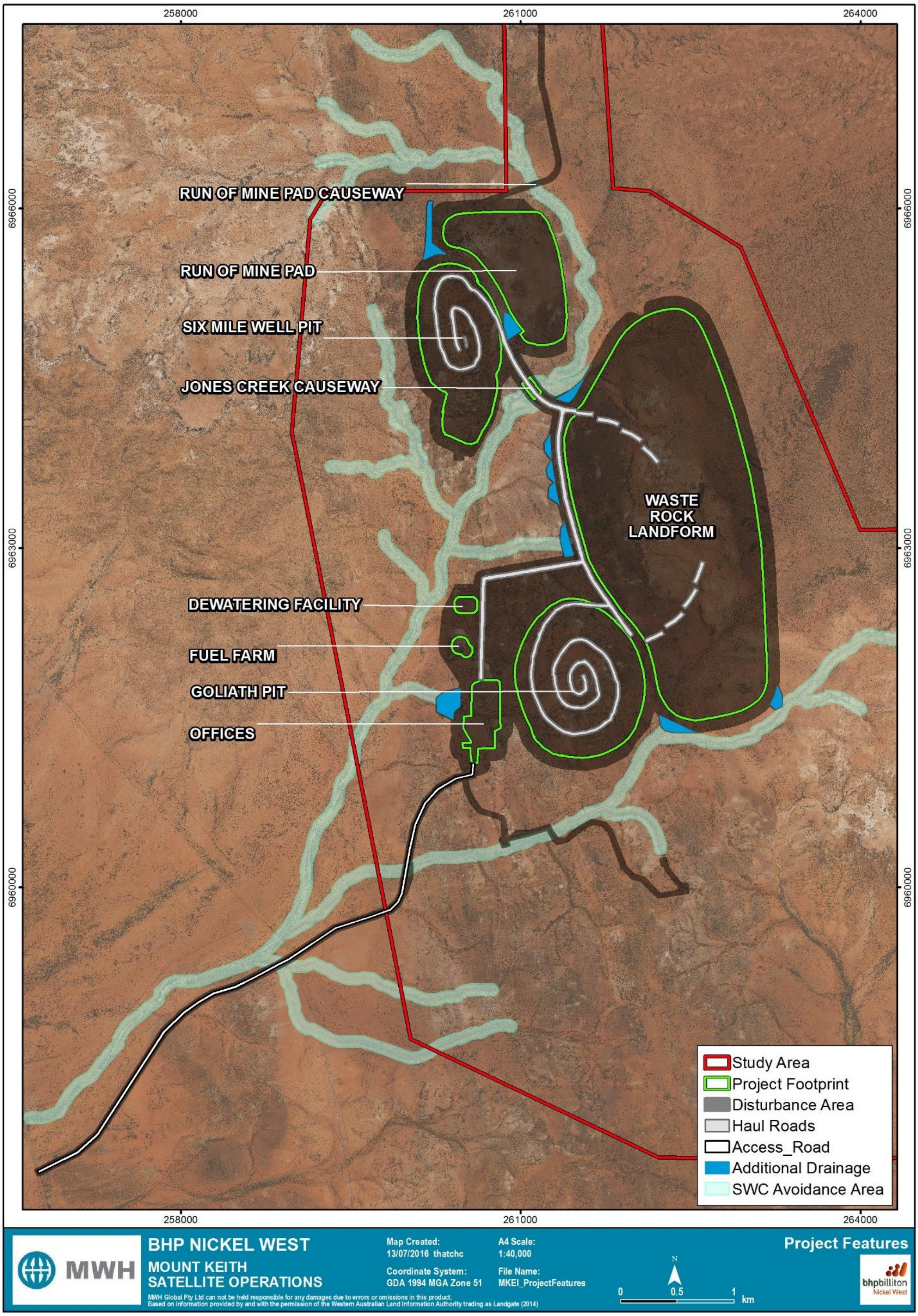

Figure 1-2: The Mount Keith Satellite Operations Area proposed impact footprint.

2 Existing Environment

2.1 Biogeographic Region

As defined by the Interim Biogeographic Regionalisation for Australia (IBRA), the Project Area is located in the East Murchison (MUR1) subregion of the Murchison bioregion in Western Australia (Department of Sustainability Environment Water Population and Communities 2012a, b). This subregion consists of extensive areas of elevated red/red-brown desert sandplains with minimal dune development, breakaway complexes and internal drainage and saline lake systems associated with occluded Palaeodrainage systems which have been found to host diverse subterranean fauna assemblages (Cooper *et al.* 2002, Humphreys 2008, Outback Ecology 2008, 2011a, 2012b, c, d, Subterranean Ecology 2011b).

2.2 Land Use

The dominant land use (85%) within the Eastern Murchison subregion is grazing of sheep and cattle on native pastures (Australian Natural Resources Atlas 2010, Cowan 2001). Other land uses include Unallocated Crown Land (UCL), Crown reserves, and mining (predominantly gold and nickel). Most mining lease areas in the subregion, including the Project Area are still required to be stocked, as they come under the Pastoral Lands Act (Cowan 2001).

The National Land and Water Resources Audit (Australian Natural Resources Atlas 2010) states that just 1.4% of the Murchison bioregion is classified as conservation estate. In 2001, Cowan reported that 1.8% of the Eastern Murchison subregion was classified as conservation estate. Since then, a comprehensive land acquisition program has contributed additional land for conservation, and in 2009 land vested in reserves increased to 8 % (Department of Environment and Conservation 2010).

2.3 Climate

The region has an arid climate, with hot summers and cool winters (Gentilli 1979). Limited annual rainfall, averaging approximately 220 mm, coincides with high evaporation rates (2,400 mm/yr) and is generally characterised by a bimodal distribution (Beard 1976). Winter rainfall is typically associated with low-pressure frontal systems from the south and tends to be widespread and of variable intensity. Summer rainfall is mainly linked to local thunderstorms or the influence of tropical cyclones to the north (Beard 1990, Pringle *et al.* 1994).

Rainfall data from Yakabindie Station (Station no. 012088), the closest weather station to the Project Area, highlights the variability in rainfall patterns within and across years (**Figure 2-1**). While the mean rainfall for the area is approximately 220 mm per annum, rainfall at Yakabindie in 2011 at was greater than 450 mm. Rainfall in September 2010, prior to the first round of stygofauna sampling (November 2010), was more than sixfold that of the long term monthly average (Bureau of Meteorology 2016). Rainfall between December 2010 and February 2011 also well exceeded the monthly averages, in response to large, extropical, low pressure systems. In particular, February 2011 recorded a monthly rainfall total of 185.7 mm, resulting in the flooding of Jones Creek and the terminal drainage claypans.

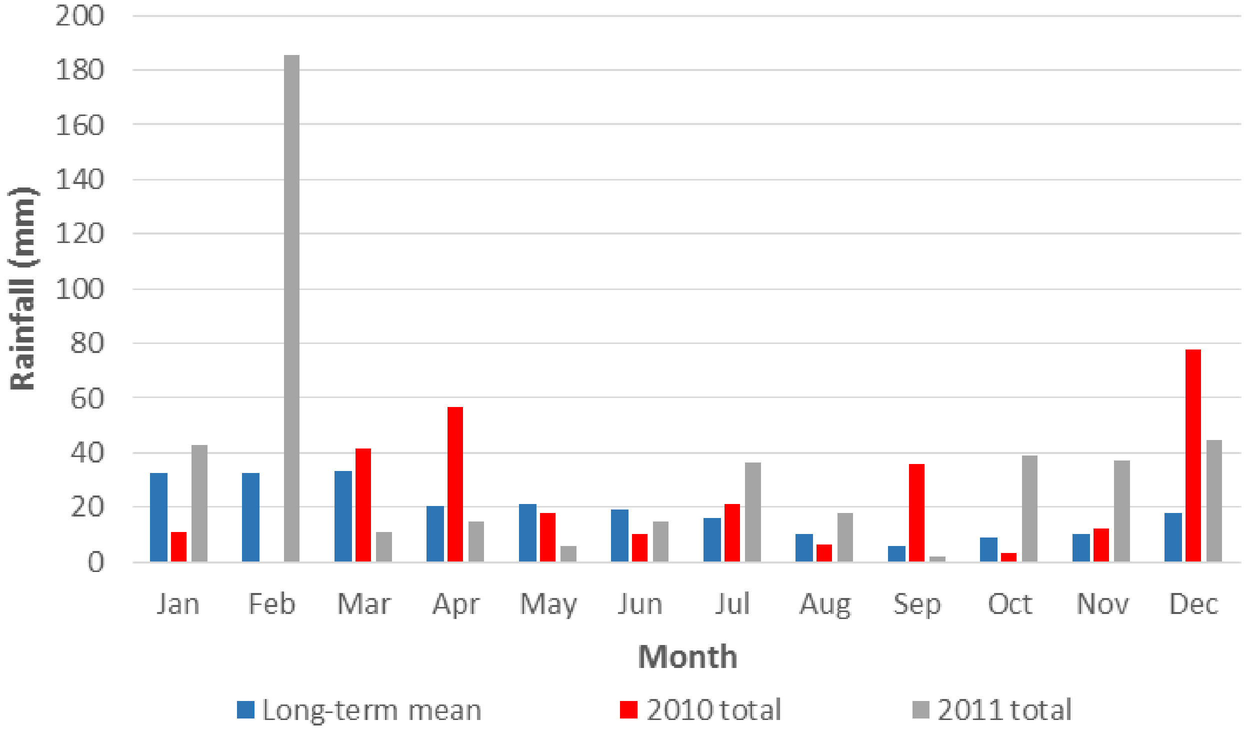

Figure 2-1 Rainfall data collected from Yakabindie Station (Station no. 012088) showing annual rainfall received during years (2010 and 2011) subterranean fauna sampling was undertaken against the long term average. Long-term data have been calculated from records collected since 1931 to 2016 (Bureau of Meteorology 2016).

2.4 Hydrology

The main tributary in the Project Area is Jones Creek which is a lateral tributary system, incised into the Barr-Smith Range. The majority of runoff for this ephemeral water course is received from the upper catchment, which covers an area of 64.1 km^2. In large flood events, water is rapidly shed from this part of the catchment into the creek, aided by the rocky nature of the terrain. The terminus for the creek is a large floodplain area to the south west, containing a number of claypans (BHP Billiton Nickel West 2011b). Beyond this, drainage becomes increasingly diffuse, before encountering the Yakabindie calcrete and reaching Lake Miranda, located within the Carey Palaeodrainage system (Wetland Research and Management 2005).

2.5 Geology

The general geology of the Project Area is a low porosity peridotite komatite ultramafic located in the Archean Agnew-Wiluna greenstone belt with lozenges of dunite, some of which host the nickel sulphide deposits (BHP Billiton Nickel West 2011b). There is little alluvial or soil cover with the base of oxidation deeper at the Six-mile Well deposit (90 to 170 m below ground level [bgl]) compared to the Goliath deposit (30 to 70 m bgl). The ultramafic package is larger at Six-mile Well (1,500 x 400 m) compared to Goliath (BHP Billiton Nickel West 2011).

2.6 Hydrogeology

The Project is located within the upper section of the Jones Creek catchment that lies within the larger catchment of an ancient river system, the Carey Palaeodrainage, which once flowed south east into the Eucla Basin currently situated beneath the Nullarbor Plain (Johnson *et al.* 1999). Major fresh and hypersaline aquifers are contained within the palaeodrainage ground waters. Groundwater resources within the Carey Palaeodrainage catchment include calcrete, fractured rock and unconfined regolith (alluvial and colluvial) aquifers, a number of which are important in maintaining local stygofauna assemblages (Outback Ecology 2008, 2012a, b, d, Subterranean Ecology 2011b, Wetland Research and Management 2005).

Groundwater in the Project Area and local region occurs predominately in unconfined shallow aquifers of less than 100 m deep that are not well defined (BHP Billiton Nickel West 2011). The groundwaters are mostly associated with alluvial and/or colluvial deposits, that represent transported or weathered regolith horizons created by erosional and depositional processes, that have formed over the dunite ultramafic caprock aquitard that hosts the nickel deposits (BHP Billiton Nickel West 2011, Wetland Research and Management 2005). The overall static water levels across the Project Area are relatively flat with a slight hydraulic gradient running south down Jones Creek away from the deposit areas (BHP Billiton Nickel West 2011).

3 Subterranean Fauna

3.1 Background

3.1.1 Stygofauna

Stygofauna (groundwater fauna) are predominantly comprised of invertebrates, although some vertebrates, for example eels and fish, can also occur. While crustaceans typically dominate stygofauna community structure, other invertebrate groups including gastropods, insects, arachnids and worms may be represented. Stygofauna can be classified into three main groups according to their level of dependency on the subterranean environment:

- stygoxenes are animals that enter groundwaters passively or accidentally;
- stygophiles inhabit groundwaters on a permanent or temporary basis; and
- stygobites are obligate groundwater dwellers

Stygobites can often be distinguished from surface animals by morphological characteristics typical of a subterranean existence, such as a reduction or absence of pigmentation, absence or reduction of eyes, and the presence of extended locomotory and sensory appendages (Humphreys 2008). They can also be defined by ecological parameters such as longer life history stages, lower metabolisms and fecundity rates (Cooper *et al.* 2002, Danielopol and Pospisil 2000).

Stygobites are restricted to their subterranean environment and as such can have locally-restricted distributions. Taxa with such limited geographical ranges may be further categorised as short range endemic species (SREs) and are considered more vulnerable to extinction (Harvey *et al.* 2011). While a range of less than 10,000 km^2 is generally accepted for short-range endemism (Environmental Protection Authority 2013b, Harvey 2002), the potential adoption of smaller range limits, for example 1000 km^2 or lower has been discussed (Eberhard *et al.* 2009, Harvey *et al.* 2011).

Stygofauna occur in various types of aquifers that exhibit voids of a suitable size to meet biological requirements (Humphreys 2008). In Australia, research efforts and improved sampling techniques have revealed a rich stygal community. Although previously thought to be restricted to karst landscapes, stygofauna have now been found in alluvial sediments, fractured rock aquifers, pisolites and thin regoliths (Guzik *et al.* 2011, Humphreys 2006, 2008, Subterranean Ecology 2008a). In Western Australia, studies have shown that the calcrete and alluvial aquifers associated with palaeodrainage channels of the arid and semi-arid zones contain rich stygofauna communities, with the Pilbara and to a lesser extent the Yilgarn, standing out as global hotspots for stygofauna diversity (Environmental Protection Authority 2007, Humphreys 2008).

3.1.2 Troglofauna

Troglofauna are defined as air-breathing subterranean fauna inhabiting voids or caves (Environmental Protection Authority 2013b). They are often relictual forms related to surface-dwelling (epigean) groups, and can be recognised by characteristics associated with a subterranean existence (Humphreys 2000). Similar to stygofauna, troglofauna can be further divided into:

- *trogloxenes*, which are animals that enter subsurface terrestrial habitats passively or incidentally;
- *troglophiles,* which are animals that carry out part of their lifecycle underground, but are also able to survive in epigean habitats; and
- *troglobites,* which are obligate subterranean inhabitants.

As they are restricted to subterranean environments, troglobites generally lack pigmentation, are blind or have reduced eyes, have elongated limbs, and may possess enhanced non-visual sensory adaptations (Culver *et al.* 1995). Troglofauna are found worldwide and until recently had primarily been investigated as cave-dwelling organisms (Culver and Sket 2000). Consistent with this, significant areas for troglofauna in Western Australia are the Cape Range and Barrow Island karst cave systems, where large and diverse communities have been discovered in extensive cave systems (Hamilton-Smith and Eberhard 2000). However, the discovery of diverse troglofauna communities in subsurface rock fractures in non-karst areas in the 1980's prompted broader consideration of potential habitat (Juberthie 2000). More recent surveys have identified troglofauna from non-karstic geologies such as vuggy pisolite ore beds in the Pilbara region, and calcrete and metamorphic mafic rocks in the Yilgarn (Barranco and Harvey 2008, Bennelongia 2009, Outback Ecology 2011a, Subterranean Ecology 2008c). Distributions are typically restricted, with many troglofauna classified as short range endemic (SRE's) (Harvey *et al.* 2011).

3.2 Risks and Relevant Legislation

Development and operation of new and existing mines in Western Australia poses a number of risks to subterranean fauna and habitat, including:

- lowering the water table, which may cause drying of habitats;
- altering water quality, which may exceed species tolerance limits; and
- direct removal of, or disturbance to, habitats .

Subterranean fauna are protected under State and Federal legislation, governed by three Acts:

- Wildlife Conservation Act 1950 (WA) (WC Act);
- Environmental Protection Act 1986 (WA) (EP Act); and
- Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act).

With this legislation in mind, the Environmental Protection Authority (EPA) has developed Environmental Assessment Guideline (EAG) 12 (2013) and Guidance Statement No. 54A (Environmental Protection Authority 2007) which outline considerations and sampling methods for subterranean fauna in Western Australia. These documents provide advice to proponents and the public on the requirements for environmental impact assessment (EIA) and management of subterranean fauna. The assessment reported here was designed in accordance with both the EAG 12 (Environmental Protection Authority 2013a) and 54A (Environmental Protection Authority 2007).

Mining proposals that will potentially impact on groundwater or hypogean habitats that support subterranean fauna, require a risk assessment to ensure mining operations do not threaten the viability of important species or communities. Proponents must demonstrate that any species existing within potential mine-related impact zones also occur outside this area. For taxa restricted to impact zones, a suitable management plan must be developed, which includes ongoing monitoring of subterranean fauna to ensure the persistence of the species (Environmental Protection Authority 2007).

In accordance with these Guidance Statements, potential impacts to subterranean fauna posed by the Project are related to the following:

- Goliath and Six-mile Well deposits. Mining will involve the physical removal of waste and ore material and the lowering of groundwater levels through mine pit dewatering; and
- ·Waste Rock Landform. As a physical structure, the landform may influence the flow of energy into the subterranean habitat in the immediate area. It may also potentially impact the subterranean habitat during construction (e.g. disturbance of surface material).

Potential, indirect impacts on subterranean fauna assemblages may also include an increase in sediment load in run-off from mining activities. Such an increase that could reduce surface-subsurface water exchange during flow periods (e.g., lessen input of resources) and alter groundwater chemistry (Marmonier 1991).

4 Methods

4.1 Desktop Study

4.1.1 Literature Review

A literature review was conducted to gather existing information on subterranean fauna from within the vicinity of the Project Area. The review included technical reports, scientific journal articles and government publications.

4.1.2 Database searches and lists

Database searches were conducted on relevant government databases to identify any subterranean fauna or threatened and priority communities (TEC or PECs) documented from the Project Area or surrounds (**Table 4-1**). Federal and state government lists were also consulted (**Table 4-2**).

Table 4-1: Summary of databases accessed for the Mount Keith Satellite Operations subterranean fauna desktop assessment

Database	GPS Coordinates	Search Radius	Reference
NatureMap	120°35'13"E, 27°24'55"S	20 km	Department of Parks and Wildlife 2016a
Threatened and Priority Ecological Communities	120°35'13"E, 27°24'55"S	50 km	Department of Parks and Wildlife 2016b
Threatened and Priority Fauna	120°35'13"E, 27°24'55"S	50 km	Department of Parks and Wildlife 2016c
WAM Arachnida and Myriapoda	119°34'13"E, 26°30'39"S (NW corner)	NA	Western Australian Museum 2016a
WAM Crustacea	121°35'53"E, S28°19'02"S (SE corner)		Western Australian Museum 2016b

Table 4-2: Summary of federal and state government lists accessed for the Mount Keith Satellite Operations subterranean fauna desktop assessment

List	Authority	Reference
EPBC Act Threatened Ecological Communities List	Federal	Department of the Environment 2016a
EPBC Act Threatened Fauna List		Department of the Environment 2016b
Threatened Ecological Communities List	State	Department of Parks and Wildlife 2015a
Priority Ecological Communities List		Department of Parks and Wildlife 2015b
Threatened and Priority Fauna List		Department of Parks and Wildlife 2015c
WC Specially Protected Fauna Notice 2015		Department of Parks and Wildlife 2015d

4.2 Groundwater Properties

Basic physicochemical data were collected during the stygofauna surveys. The approximate standing water level (SWL) (m bgl) was measured using a Solinst 101 water level meter. A calibrated TPS 90 FLMV multi-parameter field instrument was used to measure pH, water temperature, dissolved oxygen (DO), electrical conductivity (EC), salinity and reduction-oxidation potential (Redox) of the groundwater. The end of hole (EoH) was estimated using the number of rotations of the sampling winch reel required to retrieve stygofauna nets.

4.3 Stygofauna Assessment

4.3.1 Net Haul Sampling

Stygofauna were sampled using haul nets, which have been found to be the most efficient retrieval method (Allford *et al.* 2008). Sampling was consistent with the procedures outlined in the Guidance Statement No. 54a (EPA 2007). The sampling method was as follows:

- Samples were collected using two weighted haul nets with mesh sizes of 150 µm and 50 µm. Each net was fitted with a collection vial;
- The 150 µm net was lowered first, near to the bottom of the hole;
- Once at the bottom, the net was gently raised up and down to agitate the sediments;
- The net was then raised slowly to minimise the 'bow wave' effect that may result in the loss of specimens, filtering the stygofauna from the water column on retrieval;
- Once retrieved, the collection vial was removed, the contents emptied into a 250 ml polycarbonate vial, and preserved with 100 % undenatured ethanol;
- This process was repeated three times with the 150 µm net and three times using the 50 µm net;
- To prevent cross-contamination, all sampling equipment was washed thoroughly with Decon 90 (2 to 5% concentration) and rinsed with potable water after each site;
- In the field, samples were placed into eskies with ice bricks prior to being transferred into a refrigerated environment on-site at the end of each survey day; and
- Samples were couriered back to the MWH laboratory in Perth, where they were stored in 100% ethanol and refrigerated at approximately minus 20°C.

4.3.2 Stygofauna Survey Effort

A total of 64 stygofauna net haul samples have been collected from 21 bores (**Table 4-3, Figure 4-1, Appendix A: Table A-1**). All known suitable and accessible bores available (i.e. not fully cased, were vertical, not inclined) were sampled in the Project Area. Representative images of bores sampled are shown in **Appendix C**. Of the bores sampled, 16 were cased (slotted below standing water level (SWL)), and 5 were uncased.

Stygofauna sampling has occurred over five sample rounds. The first sample round was undertaken in 2006 with five samples collected by Biota (2006a) (**Table 4-3**; **Appendix A: Table A-1**). The additional four sample rounds were undertaken by MWH (as Outback Ecology): November 16 to 18, 2010; March 28 to 29, 2011; June 17 to 21, 2011; and February 1 to 3, 2012.

The number of impact samples collected from within proposed mine pit boundaries are: <u>Goliath pit</u>, 12 samples from 4 bores; <u>Six-Mile pit</u>, four samples from one bore (**Figure 4-1**). The number of groundwater drawdown impact samples collected is not able to be accurately determined. The Goliath deposit is considered to be associated with a surficial regolith aquifer system that will be completely removed with the development of the Goliath pit (Berry 2016). To what extent (lateral and vertical) groundwater drawdown will occur along associated geological structures of the fractured rock aquifer system associated with the regolith aquifer present at Goliath is not able to be accurately determined. Therefore, bores that are close to the proposed Goliath pit (e.g. less than 1km away) are not able to be reliably designated as occurring within groundwater drawdown zone or not. For Six-Mile deposit area, the 5m modelled groundwater drawdown below natural SWL encompasses the only bore (CP52) that is near to, but outside of, the proposed pit boundary. As with Goliath, the extent (lateral and vertical) of groundwater drawdown that will occur along associated geological structures of the fractured rock aquifer system associated with the regolith aquifer present at Six-Mile outside of the proposed pit and modelled 5m bSWL contour is not able to be accurately determined.

Table 4-3 Summary of stygofauna survey effort

Area		Biota 2006	November 2010	March 2011	June 2011	February 2012	No. Samples	No. Bores
Inside Proposed Pit Boundaries	Goliath	3	4	3		2	**12**	**4**
	Six-mile Well		1	1	1	1	**4**	**1**
Outside Pits	<500m	2	2	1	1	2	**8**	**3**
	>500m, <1km		6	6	6	4	**22**	**6**
	>1km		5	5	5	3	**18**	**7**
Totals		**5**	**18**	**16**	**13**	**12**	**64**	**21**

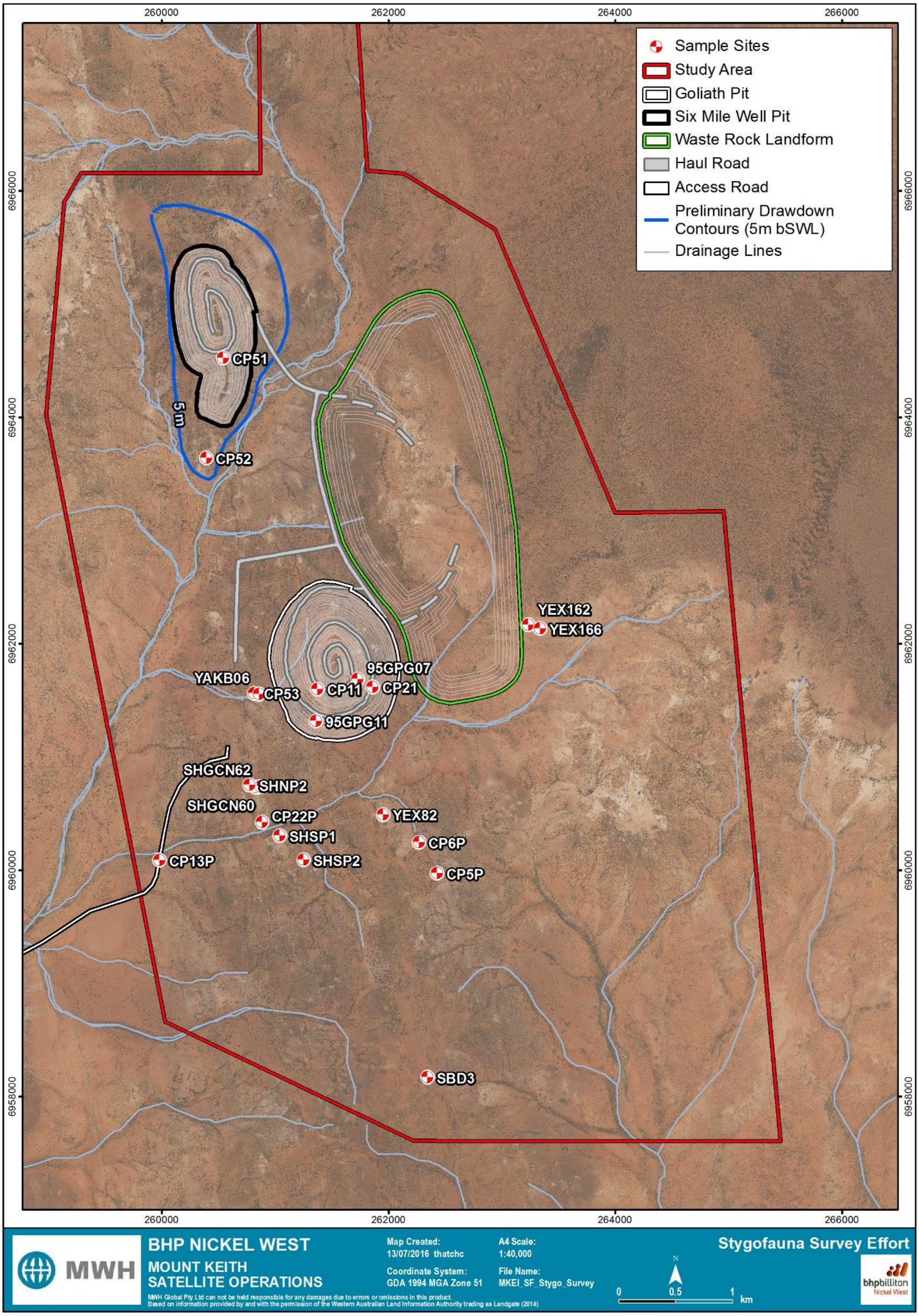

Figure 4-1: Stygofauna survey bore locations in relation to proposed Project footprint.

4.4 Troglofauna Assessment

4.4.1 Litter Trap Sampling

Troglofauna were sampled in accordance with Guidance Statement No. 54a (EPA 2007) using litter traps suspended in bores as follows:

- litter traps were packed with sterilised organic material and sealed to maintain moist, sterile conditions prior to field deployment;
- traps were then wetted with water prior to deployment in bores;
- once installed in the bores, traps were left in place for least six to eight weeks (during each sampling round) to allow adequate time for colonisation by troglofauna; and
- on retrieval, traps were sealed in zip lock bags, labelled, and couriered to the MWH laboratory in Perth for sorting and identification.

In the laboratory, troglofauna specimens were extracted from the litter using Tullgren funnels. Litter was placed into funnels, and light and low heat were applied from overhead lamps to create a temperature gradient of approximately 14°C in the litter. This treatment was applied to encourage any troglofauna, which are light sensitive and prefer humid conditions, to migrate down through the litter as it dried. Troglofauna specimens then fell through a mesh layer into collection vials at the base of the funnels, containing 100% ethanol. After 48 to 72 hours, the litter was removed from the funnels and manually searched under magnification for any remaining troglofauna specimens.

4.4.2 Net Haul Scraping

Net haul scraping has been found to be an efficient method for sampling troglofauna that complements troglofauna trapping (Halse and Pearson 2014, Outback Ecology 2011a, Subterranean Ecology 2008c). Net haul scraping involves:

- lowering a stygofauna net to the bottom of a dry bore, or at least one metre below the standing water level if groundwater was present;
- scraping the net up along the uncased wall surface of the bore on retrieval, with the aim of dislodging and collecting any troglofauna that may be present; and
- repeating the process to a total of four times per borehole, with each scrape sampling a different side of the wall surface of the bore.

In this survey all troglofauna scrape samples were collected as part of stygofauna sampling. Scraping for troglofauna was conducted simultaneously when sampling uncased bores with water present for stygofauna, so that the stygofauna sample also counted as a troglofauna scrape sample. The only difference was that the sample effort was greater, with six net hauls taken per sample rather than four. Stygofauna samples from bores that were fully-cased above the groundwater table were not counted as net haul scrape samples, regardless of whether potential troglofauna taxa may have been collected.

All haul samples were transferred to a 250 ml vial and preserved in 100% ethanol prior to shipment back to MWH's laboratory in Perth for processing. To enhance preservation of specimens and their DNA, samples were kept cool in eskies with ice bricks, then refrigerated at the end of each survey day. All samples were then shipped back to Perth in eskies with ice bricks and placed in freezers to further promote fixation of DNA.

4.4.3 Troglofauna Survey Effort

A total of 81 troglofauna samples (67 litter trap and 14 net haul scrape samples) have been collected from 37 uncased bores (**Table 4-4**, **Figure 4-2**, **Appendix A: Table A-2**). Troglofauna sampling was conducted in refurbished rehabilitated exploration drill holes (referred to herein as bores) that were selected to give good geographical coverage of impact and reference areas within the Project Area. Most of these bores were inclined. Litter trap samples were collected over two trapping rounds conducted from March 26, to May 30, 2011 (9 week duration), and from the May 30, to July 19, 2011 (7 week duration) (**Table 4-4**). Three traps were lost over the entire trapping program due to becoming wedged within bores on retrieval. Representative images of bores sampled are shown in **Appendix B**.

The number of impact samples collected from within proposed mine pit boundaries are: Goliath pit, 15 samples from eight bores; Six-Mile pit, eight samples from four bores (**Table 4-4**). As discussed above, the number of groundwater drawdown impact samples collected is not able to be accurately determined (refer **section 4.3.2**). For Six-Mile deposit area, the 5m bSWL modelled groundwater drawdown encompasses two bores (SMD1187 and SMD1181) that are near to, but outside of, the proposed pit boundary (**Figure 4-2**). For three bores (SMD1178, SMD1180, and YAKAOES03) that are less than 150m from the modelled 5m bSWL groundwater contour, the vertical extent of the potential groundwater drawdown is unknown.

Table 4-4 Summary of troglofauna survey effort

Area		March - May 2011	May - July 2011	February 2012	No. Samples	No. Bores
Inside Proposed Pit Boundaries	Goliath	7	8		**15**	**8**
	Six-mile Well	4	4		**8**	**4**
Outside Pits	<500m	3	5		**8**	**5**
	>500m, <1km	14 (4)	16 (5)	5 (5)	**35 (14)**	**13**
	>1km	6	9		**15**	**7**
	Totals	**34 (4)**	**42 (5)**	**5 (5)**	**81 (14)**	**37**

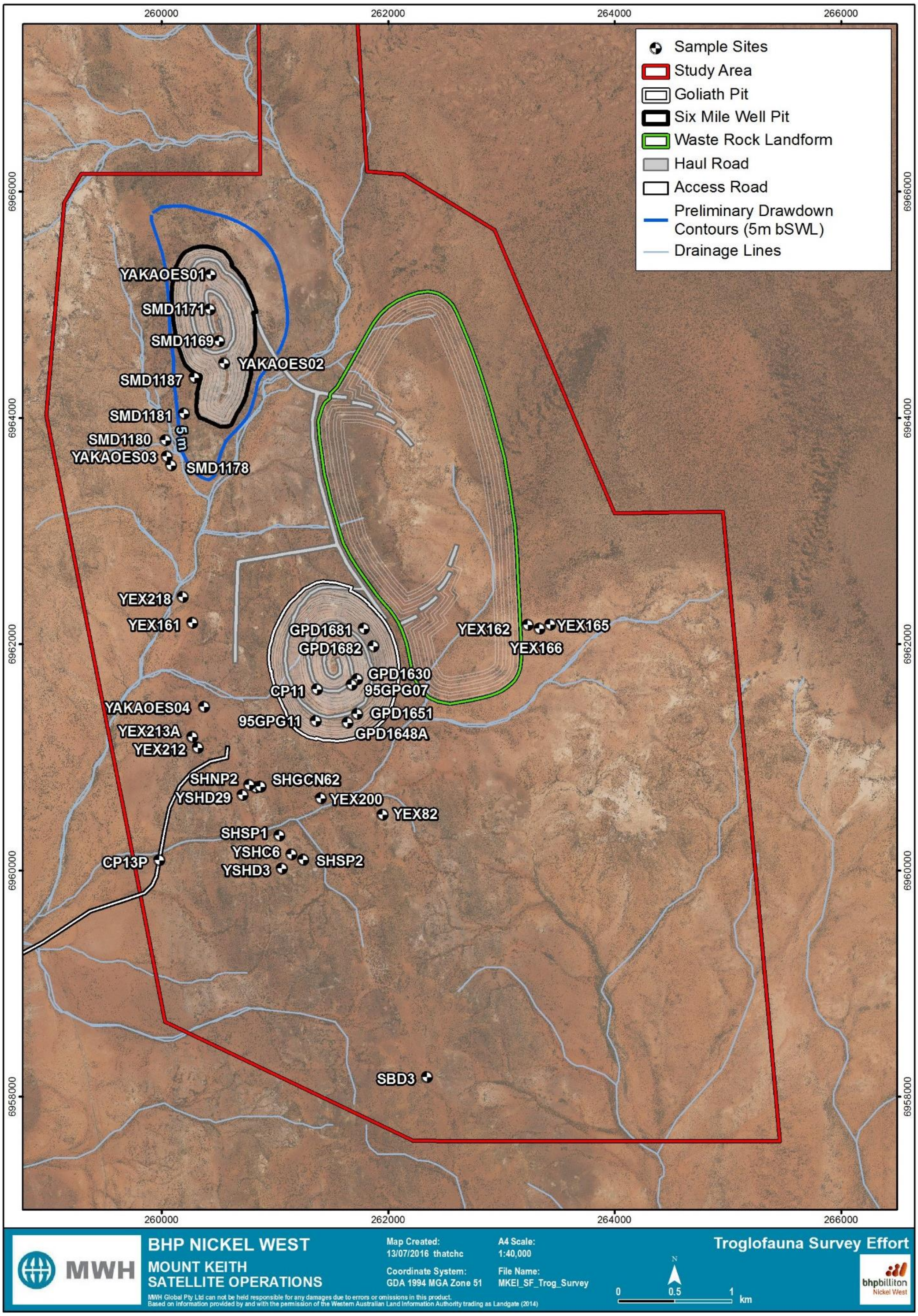

Figure 4-2: Troglofauna survey bore locations in relation to proposed Project footprint.

4.5 Sorting and Identification of Specimens

Preserved samples were sorted manually using Leica MZ6, MZ7.5, M80 and M205C stereomicroscopes by Chris Hofmeester, Syngeon Rodman, and Dr Conor Wilson. Once sorted, any potential subterranean fauna specimens found were preserved in 100% ethanol and stored at approximately minus 18 to 20°C.

Taxa were identified by Dr Jason Coughran, Dr Nicholas Stevens, and Dr Erin Thomas of MWH, using published and unpublished keys and taxon descriptions. Specialist identification for Isopoda and Ostracoda were provided by Dr Rachel King (South Australian Museum) and Prof. Ivana Karanovic (Hanyang University, Seoul), respectively.

4.6 DNA Sequencing

Tissue samples from *Atopobathynella* specimens collected from the Project Area, were sent to Dr Leijs (South Australian Museum) for genetic analyses. The main aims of the molecular analyses were:

- to compare with Lake Way and Lake Maitland material;
- test the robustness of identifications based on morphological characters, including juvenile specimens, and align morphospecies with described and previously sequenced taxa; and
- investigate distribution and phylogeographic patterns of selected taxa to assess the degree of genetic divergence among populations/species across areas sampled within the Project Area.

4.7 Diversity Analysis

The EstimateS software package (Colwell (2013) Version 9.1.0) was used to assess the survey adequacy undertaken by investigating the subterranean fauna diversity recorded in the Project Area. Diversity was analysed using species accumulation rarefaction and extrapolation curves, and species richness estimators (using incidence and abundance data).

The species richness results provide a statistical evaluation of the proportion of the stygofauna and troglofauna assemblages detected. A range in the number of species predicted to form each assemblage was estimated by seven species richness estimators (ACE, Bootstrap, Chao1, Chao2, ICE, Jack 1 and Jack 2). Statistically, it is more robust to show the results of several estimators to provide a range in predicted richness rather than only present one prediction which is not considered statistically sound

4.8 Limitations of the Assessment

Stygofauna sampling was constrained by the lack of suitable holes available throughout the Project Area including within proposed impact zones. The limited number and relatively confined geographical spread of bores can confound the interpretation of sample results of such an intractable habitat, made even more so if the fauna assemblage present exists at low population densities.

Specimens were identified to the lowest taxonomic level where possible. However, specimens could not always be identified to the level of species or morphospecies due to:

- loss or damage of important taxonomic features during collection and/or sorting of specimens;
- lack of adult specimens; or
- limitation in taxonomy, in that the current state of taxonomy for a particular group is insufficiently advanced, and/or relevant taxonomic keys and descriptions are lacking.

While every effort has been made to assess the taxonomy, distribution and conservation significance of the subterranean fauna collected using in-house data collections, publications, publicly available reports, and information provided by specialist taxonomists, some accounts may be limited if specialist information was unavailable.

5 Results and Discussion

5.1 Literature Review

5.1.1 Stygofauna

A number of stygofauna surveys have been undertaken in the area surrounding the Project (≤200 km), predominantly within calcrete associated groundwaters. Calcrete aquifer systems are recognized as providing optimal habitat for stygofauna in the Pilbara and Yilgarn, generally hosting more diverse and abundant assemblages than regolith or fractured rock associated aquifers (Allford *et al.* 2008, Environmental Protection Authority 2007, Humphreys 2008, Outback Ecology 2012d).

Within the surrounding northern Goldfields region, genetic studies have indicated that hydrogeological isolated calcrete systems can represent closed ‘subterranean islands’ in terms of the species of the stygofauna assemblage present are restricted in distribution to a particular calcrete system only (Cooper *et al.* 2002, Cooper *et al.* 2008, Guzik *et al.* 2008). The Lake Way calcrete systems have been shown to be unique in that genetic data has indicated that for some taxa gene flow does occur among the close neighbouring calcrete systems, particularly among the northern lake associated calcretes, Lake Violet and Uramurdah, and with Millbillillie Bubble Well calcrete. The genetic data was consistent with the hydrogeological assessment. The notion was supported by genetic results reported in Abrams *et al.* (2012) and Outback Ecology (2011, 2012b), that demonstrated the distribution of amphipod, Bathynellacea and dytiscid species to extend from Millbillillie Bubble Well calcrete to Lake Violet and Uramurdah calcretes. In addition, molecular data has shown that *Atopobathynella wattsi* has a distribution extending from the Lake Violet calcrete to the Hinkler Well calcrete (Guzik *et al.* 2008). However, there are instances where hydrogeological data may be inconsistent with the biological data. An example was the molecular investigation of the Browns Range stygofauna assemblage that demonstrated that there was a physical connection between two hydrogeologically distinct fractured rock aquifer systems that were considered isolated from one another, with two bathynellicean species clearly shown to occur in both (Outback Ecology 2014).

Comparative to the diverse calcrete aquifers, few surveys in the area have focused on other aquifer types. Of those, sampling at Cliffs, 22 km north of the Project Area, did not yield any stygofauna from the weathered bedrock zone (Sinclair Knight and Merz 2004). The Project Area specifically, associated with regolith and fractured rock aquifers, was sampled in 2006 (Biota 2006a). Sampling of five bores within the Goliath Project Area collected two amphipod (Neoniphargidae) specimens from YAKB06, 244 m to the west of the proposed Goliath pit boundary (near CP53), and a single oligochaete from CP21 within the proposed Goliath pit (Biota 2006a).

5.1.2 Troglofauna

Information on troglofauna from the area surrounding the Project (≤200 km) is limited in comparison to stygofauna (**Table 5-2**). Most of these troglofauna studies have occurred in calcrete associated habitats and have shown troglofauna to occur in relatively low abundance and diversity compared to stygofauna (Outback Ecology 2011a). This is highlighted by the findings of the current study which identified a low diversity of troglofauna from sampling within the regolith and weathered fractured rock geological facies of the Project Area. In comparison, calcretes in surrounding area including Barwidgee, Yeelirrie and the Lake Way associated calcretes were found to host more diverse troglofauna assemblages (MWH 2015, Outback Ecology 2011a, 2012c, Subterranean Ecology 2011b).

Surveys of non-calcrete associated geologies from the broader Yilgarn region have collected troglofauna from weathered and fractured banded ironstone formations (BIF) and mafic units (Bennelongia 2009, ecologia Environment 2008a, b, Environmental Protection Authority 2010). In Europe, the Azores, and the Canary Islands relatively rich troglofauna assemblages have been found to occur in the 'Milieu Souterrain Superficiel' or mesovoid shallow substratum (MSS) that is characterised as superficial underground compartments beneath the soil profile formed from the cracks and fissures of the weathered bedrock and interstitial spaces within collapsed slopes (Borges 1993, Camacho 1992, Juberthie 1983, Lopez and Oromi 2010).

5.2 Database Searches

There were no threatened or priority subterranean fauna noted in the Project Area or surrounds from a search of the Department of Parks and Wildlife's threatened and priority fauna database (Department of Parks and Wildlife 2016c). A search of the Department of Parks and Wildlife's threatened and ecological communities database did not identify any priority subterranean fauna communities within the Project Area (Department of Parks and Wildlife 2016b). The nearest priority subterranean communities occurred in conjunction with calcrete aquifers to the west and to the south of the Project Area. The Yakabindie calcrete community was the most proximal, the associated buffer zone commencing approximately 16 km south of the proposed pit outlines. The Albion Downs calcrete community and Lake Miranda east and west calcrete communities were each located over 20 km away from the proposed pit outlines, to the west and south, respectively.

A search of the Western Australian Museum's Arachnida and Myriapoda database found close to 100 subterranean fauna records within the region surrounding the Project Area. A sub-set of the most proximal records (occurring within a radius of approximately 50 km) (**Appendix C**) included 40 entries from across eight groups. Araneae (spiders) and pseudoscorpions were well represented with four and nine troglomorphic taxa respectively. Three troglomorphic spider taxa, *Prethopalpus callani* and undescribed species of *Opopaea* and *Desognanops* were recorded from Yeelirrie, approximately 45 km north-west of the Project Area.

The pseudoscorpions primarily belonged to *Tyrannochthonius*, a typically troglobitic genus occurring in calcrete or fractured rock geological facies (Edward and Harvey 2008, Harrison *et al.* 2014). Up to seven undescribed species of *Tyrannochthonius* were collected during sampling in the vicinity of the Miranda East calcrete on Yakabindie Station (25 km south of the Project Area), Lake Maitland/Barwidgee calcrete (45 km north-east of the Project Area) and Yeelirrie. A further two pseudoscorpion taxa, undescribed species of *Austrohorus* and *Beierolpium*, were also collected from Yeelirrie.

Other taxa collected from within the area surrounding the Project and identified as troglofauna included representatives of Cephalostigmata (Symphyla) (Yakabindie Station), geophilid and scolopendrid centipedes (Yeelirrie and Albion Downs, respectively). Troglomorphic palpigrades, particularly *Eukoenenia* sp. and polyxenid millipedes were also recorded from Yeelirrie.

A search of the Western Australian Museum Crustacea database identified over 700 records of subterranean taxa in the region surrounding the Project Area. The closest records (within a radius of approximately 50 km) (**Appendix D**) encompassed stygobitic taxa from groups including amphipods, copepods, isopods, ostracods and syncarids. Records from within the Project Area specifically were limited, comprising two undescribed *Atopobathynella* species (syncarids) and an ostracod (Western Australian Museum 2016b). In general however, subterranean crustaceans in the region were predominantly associated with calcrete habitat in systems such as Yeelirrie, Lake Maitland/Barwidgee, Lake Miranda East and West and Albion Downs. The most proximal of these were troglomorphic

Paraplatyarthrus isopods approximately 25 km south of the Project, within the Lake Miranda calcrete area (Western Australian Museum 2016b).

Differences in taxon diversity between geological units may be partly attributable to sampling bias. However, it is considered to also reflect the more optimal habitable environment hosted within calcrete systems relative to regolith and fractured rock systems.

Table 5-1: Summary of stygofauna surveys undertaken within the region surrounding the Project Area

Deposit / Area	Distance from Yakabindie Project	Stygofauna	Geology / Habitat	Reference
Yakabindie	Within	Amphipods, oligochaetes, syncarids	Regolith	Biota 2006a, current report
Cliffs	22 km north	No stygofauna present	Weathered bedrock	Sinclair Knight Merz 2004
Albion Downs	30 km north	Amphipods, copepods, mites	Calcrete	Biota 2006a
Lake Maitland/ Barwidgee	55 km north-east	Amphipods, copepods, isopods, oligochaetes, ostracods, syncarids	Surficial aquifers, often calcrete	Golder Associates 2010, Cooper *et al* 2007, Outback Ecology 2012a
Lake Way South	60 km north	Amphipods, copepods, oligochaetes, syncarids	Alluvium and dune deposits	Biota 2006a, Outback Ecology unpublished data
Lake Darlot	65 km south-east	Copepods	Specific geology unknown	Western Australian Museum 2016b
Depot Springs	75 km south-west	Amphipods, syncarids, copepods	Colluvium and calcrete	Environmental Protection Authority 2001, Cooper *et al* 2007
Lake Way (Hinkler Well)	75 km north-west	Amphipods, dytiscid beetles, copepods, isopods, oligochaetes, syncarids	Calcrete	Taiti and Humphreys 2001, Karanovic 2004, Cho *et al* 2006, Cooper *et al* 2007, Cooper *et al* 2008, Watts and Humphreys 2009, Cho and Humphreys 2010, Outback Ecology 2012c, MWH 2015
Lake Way (Lake Violet)	90 km north-west			
Lake Way (Uramurdah)	90 km north-east			
Lake Way (Millbillillie)	135 km north			
Yeelirrie	85 km north-west	Amphipods, annelids, copepods, dytiscid beetles, isopods, ostracods, syncarids	Calcrete	Subterranean Ecology 2011, Bennelongia 2015
Jaguar	110 km south	No stygofauna recorded during preliminary investigations	Specific geology unknown	Department of Mines and Petroleum 2010
Marshall Creek Borefield	110 km south	Copepods	Silcrete and alluvial sand	Environmental Protection Authority 2001
Sandstone South Borefield	125 km south-west	Copepods	Highest numbers - calcrete/silcrete	
Sturt Meadows	140 km south	Amphipods, copepods, dytiscid beetles, oligochaetes	Calcrete	Environmental Protection Authority 2001, Bradford *et al* 2010, King *et al* 2012
Paroo Station	160 km north	Amphipods, aphanoneurans, dytiscid beetles, copepods, isopods, oligochaetes, ostracods, rotifers, syncarids	Calcrete, chert	De Laurentiis et al 2001, Cho et al 2006, Cooper *et al* 2007, Watts and Humphreys 2009, Biota 2006b, Outback Ecology 2008, 2010, Bennelongia 2013

Table 5-2: Summary of troglofauna surveys undertaken within the region surrounding the Project Area

Deposit / Area	Distance from Yakabindie Project	Troglofauna	Geology / Habitat	Reference
Yakabindie	Within	Isopods	Regolith, fractured rock	Current report
Lake Miranda (East and West)	25 km south	Isopods	Calcrete	Javidakar 2014, Western Australian Museum 2016b
Yakabindie Station	25 km south	Pseudoscorpions, symphylans	Specific geology unknown - likely calcrete	Western Australian Museum 2016a
Lake Maitland/Barwidgee	45 km north-east	Chilopods, hemipterans, isopods, pauropods, pseudoscorpions	Calcrete, alluvium, colluvium	Outback Ecology 2012b
Lake Way (Hinkler Well)	75 km north-west	Diplurans, pauropods, pseudoscorpions, isopods, polyxenid millipedes, silversfish, spiders, symphylans	Calcrete/alluvium	Platnick 2008, MWH 2015, Western Australian Museum 2016a
Lake Way (Lake Violet)	90 km north-west			
Lake Way (Uramurdah)	90 km north-east			
Millbillillie Bubble Well	110 km north-west	Pseudoscorpions	Specific geology unknown - likely calcrete	Western Australian Museum 2016a
Depot Springs	70 km south-west	Spiders	Specific geology unknown	Western Australian Museum 2016a
Yeelirrie	85 km north-west	Diplurans, hemipterans, isopods, myriapods, palpigrades, pseudoscorpions, spiders, silverfish	Calcrete	Subterranean Ecology 2011, Bennelongia 2015
Sturt Meadows	140 km south	Palpigrades, pseudoscorpions	Calcrete	Barranco and Harvey 2008, Edward and Harvey 2008

5.3 Stygofauna Habitats

5.3.1 Aquifers

Groundwater in the Project Area and local region occurs predominately in unconfined shallow aquifers of less than 100 m deep that are not well defined (BHP Billiton Nickel West 2011). The groundwaters are mostly associated with alluvial and/or colluvial deposits, that represent transported or weathered regolith horizons created by erosional and depositional processes, that have formed over the dunite ultramafic caprock aquitard that hosts the nickel deposits (BHP Billiton Nickel West 2011, Wetland Research and Management 2005). To a lesser degree, groundwater is also present within deeper isolated fractured rock aquifers occurring at structurally controlled locations (BHP Billiton Nickel West 2011). From an economic resource perspective, these groundwater bodies were not considered of significance to the groundwater resources of the region because they did not form a regionally continuous aquifer system, being minor and hydraulically isolated (Wetland Research and Management 2005). However, from an ecological perspective, the spatial and temporal extent of connectivity via the 'interstitial highway' (Ward and Palmer 1994) among the surficial regolith and fractured rock aquifers within the upper Jones Creek catchment could be relatively extensive and sufficient for gene flow to occur among potential stygofauna populations.

The groundwater associated with the thin regolith of the Goliath deposit was not considered a substantial aquifer. Test pumping demonstrated a low permeability in the area with a sustainable pump rate of less than one litre per second (L/sec) estimated (Coffey Partners 1990, Woodward Clyde 1995). Testing of the deeper, sub-regolith aquitard, showed water take was generally very low with yields of greater than 1 lugeon (1 L/min/metre/1000kPa) only recorded once.

The regolith aquifer associated with the Six-mile Well deposit forms the main aquifer in the Project Area and is estimated to contain one to two orders of magnitude more in water storage than the fractured rock aquifers in the proposed pit area (BHP Billiton Nickel West 2011). Within the main surficial aquifer, high permeability and porosity extends to 44 m below the ground surface (BHP Billiton Nickel West 2011). Low to moderate permeability may occur to depths of 60 m and in highly weathered materials formed in other ultramafic lithologies (BHP Billiton Nickel West 2011). The permeability of the fractured rock zone can range from moderate to high but the porosity of the fault zones are low and with limited lateral extent (BHP Billiton Nickel West 2011). Pump testing in the southern area of the Six-mile Well deposit recorded a constant rate of 9.6 L/sec and indicated a total storage of about 100 megalitres (ML) within the highly porous central and shallow part of the aquifer (Coffey Partners 1990). The drawdown and recovery patterns indicated high permeability of the aquifer but with limited extent. The saturated extent of the main regolith aquifer declines to the south outside of the proposed pit boundary as the more deeply weathered ultamafic ore-bodies gives way to less permeable fresh bedrock (BHP Billiton Nickel West 2011).

The overall static water levels across the Project Area are relatively flat with a slight hydraulic gradient running south down Jones Creek away from the deposit areas (BHP Billiton Nickel West 2011). The static water levels within the Six-mile Well deposit range from 16 to17 m bgl within the bed of Jones Creek, and

25 to 35 m bgl outside of the creek beds (BHP Billiton Nickel West 2011). Within the Goliath deposit, static water levels range from approximately 25 to 35 m bgl.

5.3.2 Groundwater Properties

Recorded groundwater quality parameters across the Project Area during the 2010/11 surveys were suitable for stygofauna habitation. Salinity ranged from fresh (280 parts per million [ppm]) to hyposaline (7,730 ppm), sensu Hammer (1986), and was particularly variable within the Goliath area (**Table 5-3**). There was seasonal variation in salinity among bores, with the lower salinity levels recorded corresponding with recharge from winter rainfall and the higher concentrations occurring in the drier months of March and June (**Appendix E**). The ranges recorded were generally consistent with salinity levels previously recorded for the area. The salinity of the main regolith aquifer at Six-mile Well mostly ranged from 3,000 to 8,000 ppm (Coffey Partners 1990) with surrounding isolated fractured rock aquifers generally of lower salinity ranging from 700 to 5,400 ppm (Coffey Partners 1991). Overall, the groundwater pH ranged from circumneutral (6.5-7.5) to alkaline (>7.5). The most diverse stygal communities inhabit calcareous environments between pH 7.2 and 8.2 (Humphreys 2008), and while low pH can restrict distribution, some ostracods have been documented from pH as low as 4.4 (Reeves *et al.* 2007).

Dissolved oxygen levels ranged from anoxic (2.78 ppm) to oxygenated (7.77 ppm). While concentrations below 5 ppm may adversely affect surface aquatic biota, stygofauna have been documented from sub-oxic conditions well below 1 ppm in coastal environments (Chapman and Kimstach 1996, Humphreys 2008). Groundwater temperature fluctuated with seasonal variations (ranging from 18.7 to 28.1°C) with minimal differences across the Project Area for the same sample round (**Appendix E**).

The variation in standing water level (SWL) among bores reflected the local topography across the Project Area, particularly within the Goliath region (**Table 5-3**). Generally the SWL were closer to the surface to the south of Goliath at Serpentine Hill (15 m bgl), with the area situated within a valley floor. The remaining bores were situated within regions of higher elevation, where the distance to groundwater was greater, averaging SWL's between 20 to 25 m bgl. On the whole, there was little variation in SWL among sample rounds, with most fluctuations less than 0.5 m (**Appendix E**). The greatest fluctuations recorded were between 0.5 to 1.5 m. Fluctuations were inconsistent among sample rounds. In many instances, the November 2010 and/or June 2011 SWL's recorded were greater than recorded for March 2011 despite the large amount of rainfall in February 2011. In other instances, the March SWL's were greater. The standing water levels measured against the Australian Height Datum (AHD) were shown to be relatively flat across the Project Area (range: Six-mile Well deposit 502.9 to 505 m AHD; Goliath deposit 503.6 to 506.8 m AHD) with a slight hydraulic gradient running south down Jones Creek away from the deposit areas (499.2 m AHD) (BHP Billiton Nickel West 2011b).

Table 5-3 Summary of groundwater properties within the Project Area. DO = dissolved oxygen; EoH – end of hole; m bgl = metres below ground level; n = number of samples; SWL = standing water level.

Project Area	Value	D.O. (ppm)	Temp (°C)	Salinity (ppm)	pH (unit)	Redox (mV)	SWL (m bgl)	EoH (m bgl)
Goliath	Min	3	18.70	283.00	7.18	24	8.45	30.60
	Max	6.75	26.80	7730.00	8.06	193	45	200
	Mean	4.87	25.09	1636.00	7.68	124.87	25.90	69.46
	n	16	12	12000	16	15	17	19
Six-mile Well	Min	3.37	23.80	2360.00	6.71	-192	10	36.90
	Max	6.30	27.30	4860.00	7.65	154	28.80	78.30
	Mean	5.10	25.68	3395.00	7.13	54.83	21.84	53.79
	n	6	4	4000	6	6	9	8
Waste Rock Landform	Min	4.05	23.10	482.00	8.23	152	20	49.50
	Max	4.09	23.90	482.00	8.25	181	24.30	81
	Mean	4.07	23.50	482.00	8.24	166.50	22.43	61.65
	n	2	2	1000	2	2	3	4
Serpentine Hill	Min	2.78	21.70	4.390	6.98	-63	10.80	36.90
	Max	6.83	26.60	2070.00	8.56	188	20.85	99
	Mean	5.04	24.71	1389.27	7.75	102.67	14.86	61.89
	n	21	20	16000	21	21	22	21
Sheba	Min	6.63	28.10	1176.00	7.74	124	26.04	90
	Max	7.77	28.10	1176.00	7.77	132	27.10	99
	Mean	7.20	28.10	1176.00	7.76	128	26.57	95
	n	2	1	1000	2	2	2	2
Overall	Min	2.78	18.70	4.390	6.71	-192	8.45	31
	Max	7.77	28.10	7730.00	8.56	193	45	200
	Mean	5.04	24.83	1735.05	7.67	107.54	20.46	63.80
	n	47	46	30000	47	46	53	55

5.4 Stygofauna Survey

5.4.1 Stygofauna Findings

In total, 75 stygofauna specimens, representing at least seven species (potentially eight) from four higher level taxonomic groups (Amphipoda, Bathynellacea, Oligochaeta, and Ostracoda) were collected from six of the 21 bores sampled in the Project Area (**Table 5-4**, **Figures 5-1 & 2, Appendix F: Tables F-1 & 2**). The Bathynellacea was the most diverse group with four species recorded, all of which are singletons (known from a single specimen only). The Oligochaeta was the most abundant group with 68 specimens collected. The Oligochaeta may likely to be represented by one morphospecies Enchytraeidae sp. OES10, however, the material collected by Biota in 2006 was not identified to family level and the specimen could not be located for further examination.

The findings for each of the proposed pit areas are summarised as follows:

- Goliath — No stygofauna taxa were collected from within the proposed Goliath pit boundary during the 2010 to 2012 stygofauna sample rounds. Previous sampling by Biota (2006a) did record an unidentified oligochaete species from bore CP21, within the proposed pit boundary (**Figure 5-3 & 4,Table 5-4, Appendix F**). There is a likelihood that this unidentified species could be the same morphospecies as Enchytraeidae sp. OES10 that has also been recorded from within the proposed Six-Mile Well pit boundary as well as from outside likely groundwater drawdown impact area.

  An amphipod, identified as a Neoniphargidae species, was also recorded in 2006 from bore YAKB06 that is located less than 200 m outside the proposed pit boundary (**Figure 5-3**). As discussed above (refer **Section 4.3.2**) the extent of the groundwater drawdown that would be associated with the mining of the Goliath pit is not known. However, it is considered likely that there would be a significant drawdown occurring at this site located close to the pit. Therefore, the only recorded location of the Neoniphargidae species is considered to be within the groundwater drawdown impact zone associated with the dewatering of the Goliath pit.

- Six-Mile Well — Three species, *Atopobathynella* sp. OES8, *Atopobathynella* sp. OES11 and Enchytraeidae sp. OES10, were collected from within the proposed Six-Mile Well pit boundary from Boer CP51 during the 2010 to 2012 stygofauna sample rounds (**Figure 5-3**). The distributions of both *Atopobathynella* sp. OES8 and *Atopobathynella* sp. OES11 have not been demonstrated to occur outside the proposed pit impact area. Enchytraeidae sp. OES10 was the only species to have been recorded from outside the proposed pit having also been collected from within the proposed Goliath pit boundary as well as from outside the likely groundwater drawdown impact area.

  The Ostracoda species, *Gomphodella* sp. IK2, was collected on a single occasion from Bore CP52 within the modelled 5m bSWL groundwater drawdown impact area associated with the dewatering of Six-Mile Well pit (**Figure 5-3**).

Of the seven identified species, three species, *Atopobathynella* sp. OES9, Bathynellidae sp. OES2, and Enchytraeidae sp. OES10, have been recorded from outside proposed impact areas. The remaining four species, *Atopobathynella* sp. OES8, *Atopobathynella* sp. OES11, *Gomphodella* sp. IK2 and Neoniphargidae sp., are of conservation concern as their distributions have not been demonstrated to extend beyond proposed impact areas.

Table 5-4: Stygofauna taxon diversity and distribution. Orange shaded cells indicate taxa recorded from within the pit outlines only; Yellow shaded cells indicate taxa recorded from areas of likely groundwater drawdown only.

Subterranean Fauna	Abundance	Area	Bore ID	Location	Comments
Stygofauna Taxa					
Amphipoda					
Neoniphargidae sp. (Biota 2006)	2	Goliath	YAKB06	Near pit (<200m)	Of conservation concern. Undescribed species collected by Biota (2006a). Specimen could not be found for further examination. No additional amphipod material collected in later surveys.
Bathynellacea					
Atopobathynella sp. OES8	1	Six-mile Well	CP51	Inside pit	Of conservation concern. DNA sequencing failed but morphologically distinct from other *Atopobathynella* species.
Atopobathynella sp. OES9	1	Serp Hill South	CP22P	Outside pits (>500m, <1km)	Not of conservation concern. DNA analysis demonstrated that distinct from other *Atopobathynella* species
Atopobathynella sp. OES11	1	Six-mile Well	CP51	Inside pit	Of conservation concern. DNA analysis demonstrated that distinct from other *Atopobathynella* species.
Bathynellidae sp. OES2	1	Serp Hill South	CP22P	Outside pits (>500m, <1km)	Not of conservation concern. DNA analysis demonstrated that distinct from other Atopobathynella species
Oligochaeta					
Enchytraeidae sp. OES10	67	Six-mile Well, Serp Hill South	CP13P, CP21, CP51	Inside & Outside pits (>1km)	Not considered to be of conservation concern. Enchytraeidae species generally considered widespread in distribution and not stygobitic, more stygophiles or stygoxenes. Can be semi-aquatic.
Oligochaeta sp. (Biota 2006a)	1	Goliath	CP21	Inside pit	Undescribed species collected by Biota (2006a). Specimen could not be found for further examination. There is likelihood that may be same species as Enchytraeidae sp. OES10. However, this cannot be verified. Conservation status not clear.
Ostracoda					
Gomphodella sp. IK2	2	Six-mile Well	CP52	Near pit (>300m, <500m)	Of conservation concern.

Amphipoda

Stygobitic amphipods, particulary chiltoniid species, have been relatively commonly recorded from many of the northern Yilgarn calcretes sampled (Bradford *et al.* 2013, Bradford *et al.* 2010, Cooper *et al.* 2007, Guzik *et al.* 2011, Subterranean Ecology 2011b). However, we are not aware of stygobitic amphipod species been collected from fractured rock aquifer systems in the northern Yilgarn area. Within well studied calcrete systems (e.g. Barwidgee, Lake Way associated calcretes, Laverton Downs, Sturt Meadows, and Yeelirrie), molecular phylogenetic analyses have revealed that many of the commonly collected amphipod species possessed relatively broad distributions (Bradford *et al.* 2013b, Guzik *et al.* 2011, (MWH 2015, Outback Ecology 2012b, d), Subterranean Ecology 2011). The single chiltoniid species commonly recorded from the Yeelirrie calcrete system was shown to have a distribution that ranged for approximately 70 km from the most north-western survey line (P) down through many of the Yeelirrie calcretes to the south-east of the Yeelirrie salt lake playa (Subterranean Ecology 2011). This may represent one of the broadest distributions recorded from a stygobitic amphipod in the Yilgarn or Pilbara regions. The molecular analysis did reveal a relativley high haplotype diversity present and suggested that there is likely to be a degree of gene flow restriction between geographically distant populations (Finston and Berry (2011) in Subterranean Ecology 2011).

Bathynellacea

All species of Bathynellacea globally are considered to be stygobitic. The domination of the stygofauna assemblage at the Project Area by bathynellacean diversity is similar to studies undertaken in north-western and north-eastern Australia that have also found bathynellaceans to be most commonly collected component of other fractured rock and alluvial aquifers (Hancock and Boulton 2008, Outback Ecology 2014). A genetic study as part of the Browns Range Project, in the south eastern Kimberley region, identified 15 bathynellacean species from fractured rock aquifer systems with five species found to be relatively widespread with distributions extending for further than 10 km (Outback Ecology 2014). Two of these widespread species were found to have distributions that spanned what were considered hydrogeologically to be two separate fracture rock aquifer systems within the Browns Range Metamorphics and the surrounding Gardiner Sandstone geological unit. The genetic analysis confirmed that there existed subterranean habitat connections between these two distinct geological units.

Tissue of all bathynellacean taxa collected from the Project Area were sent for molecular analysis. Amplification of DNA sequence from the CO1 gene was successful for all taxa except *Atopobathynella* sp. OES8, which was morphologically distinct from the other *Atopobathynella* species based on morphological characteristics considered important in determining species limits (Cho *et al.* 2006). *Atopobathynella* species from the Project Area were found to be highly divergent from Lake Way, Lake Way South, Barwidgee and Yeelirrie species (Outback Ecology 2012a).

Oligochaeta

The taxonomy and ecology of the Enchytraeidae is poorly known, with no stygal species described to date (Pinder 2009, Pinder 2007). These worms are commonly recorded in subterranean fauna surveys, and occur in both surface and subterranean aquatic systems (freshwater and marine), or semi-aquatic and terrestrial habitats (Outback Ecology 2011a, Rota *et al.* 2007, van Vliet *et al.* 1997). Genetic analyses of Enchytraeidae material commonly collected at Browns Range revealed that it represented one, widely distributed species (Outback Ecology 2012a).

It is not known whether Enchytraeidae sp. OES10 is an aquatic (inhabiting the aquifer), semi-aquatic or terrestrial oligochaete species. Terrestrial invertebrate fauna are often collected in stygofauna nets having either being dislodged from the soil profile during retrieval of the nets or collected from the water column into which they may have fallen (Outback Ecology 2011a, Outback Ecology unpublished data, Subterranean Ecology 2008b, c). Some Enchytraeidae species have been demonstrated to not be obligate groundwater inhabitants, with genetic data showing material collected in troglofauna traps were conspecific (same species) with material collected from stygofauna net hauls (Leijs 2013, Outback Ecology 2011b). However, no Enchytraeidae sp. OES10 material was collected from the relatively substantial trapping effort conducted. It is for this reason that Enchytraeidae sp. OES10 is considered a putative stygofauna species.

Ostracoda

Ostracods are commonly collected in stygofauna surveys with many species considered to be stygophiles or stygoxenes. The genus *Gomphodella* is endemic to Australia and is composed of both surface water and groundwater dwelling species (Karanovic 2009). *Gomphodella* sp. IK2 was identified from juvenile material as a stygobitic species (Outback Ecology 2012a).

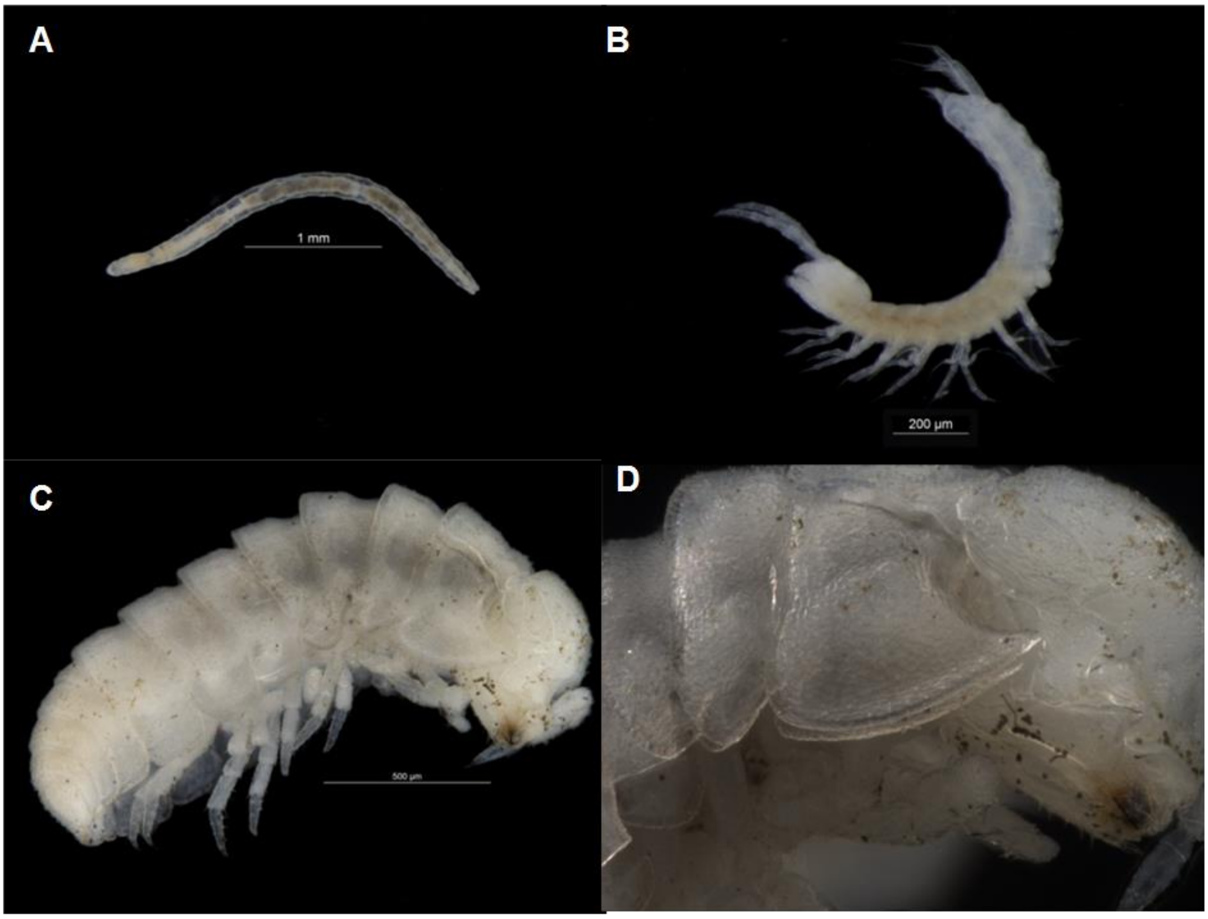

Figure 5-1: Representative stygofauna and troglofauna taxa collected from subterranean fauna sampling. A) Enchytraeidae sp. OES10; B) *Atopobathynella* sp. OES9; C) & D) *Troglarmadillo* sp. OES3.

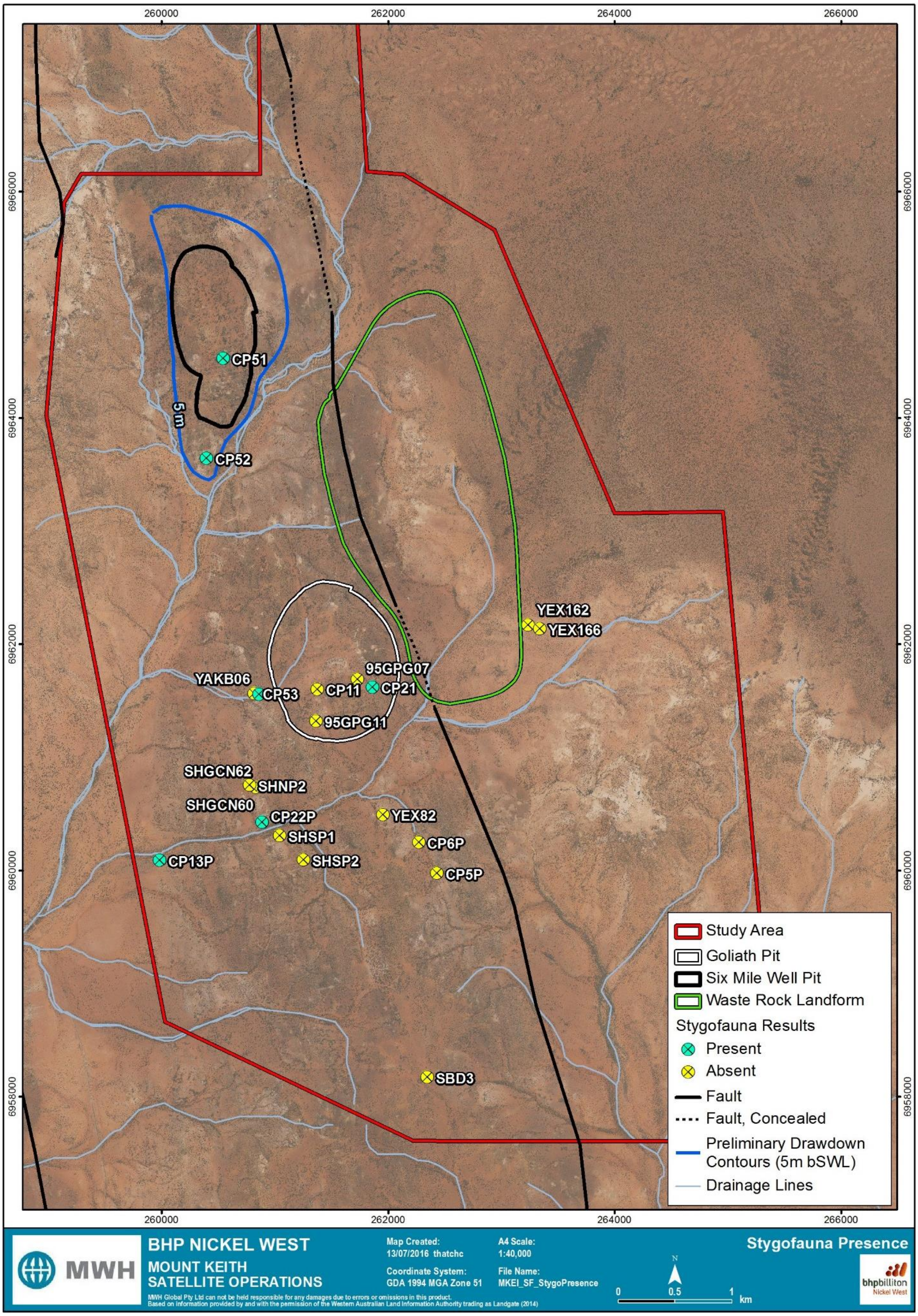

Figure 5-2: Overview of stygofauna sample sites indicating recorded presence or absence.

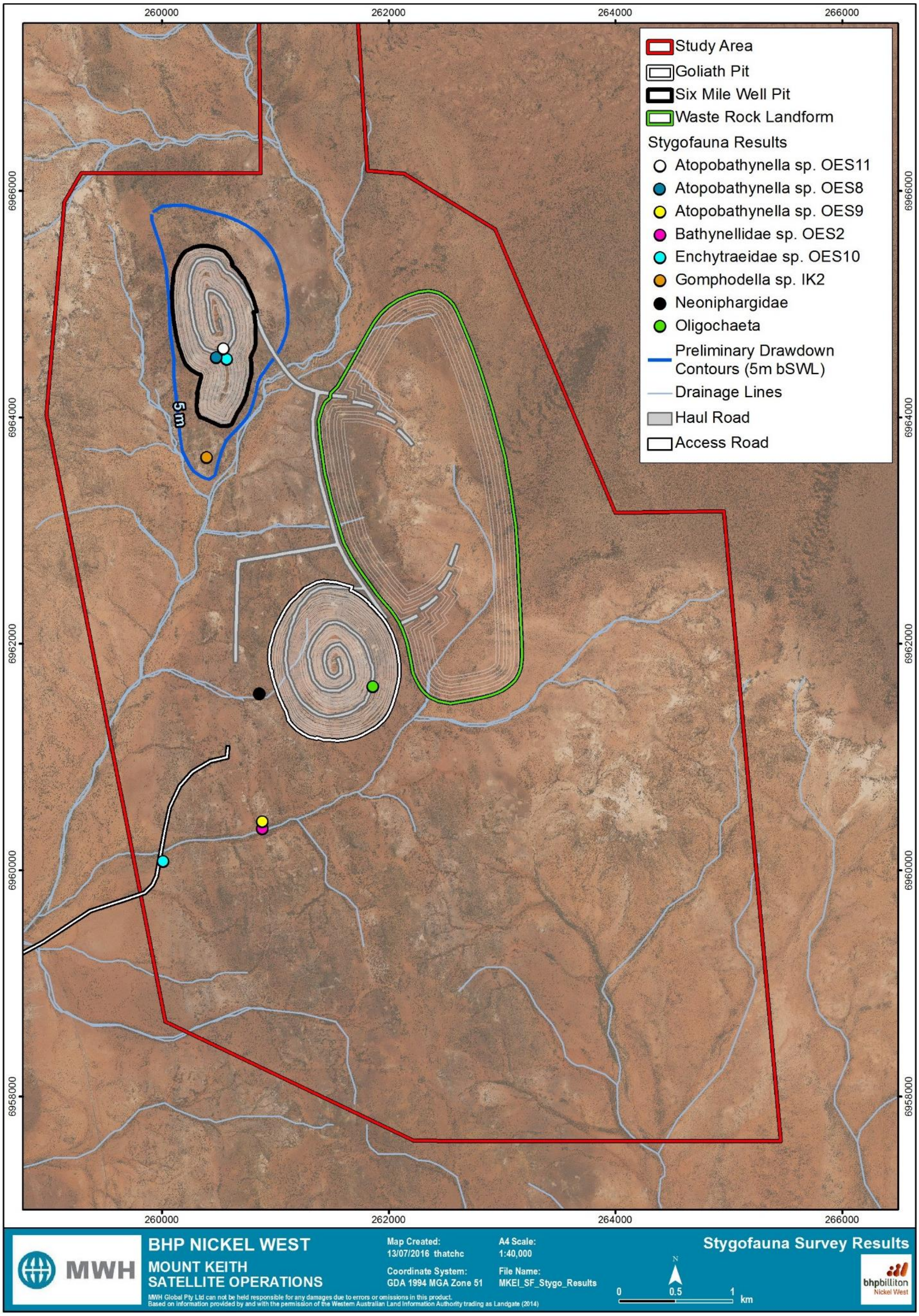

Figure 5-3: Distribution of stygofauna recorded.

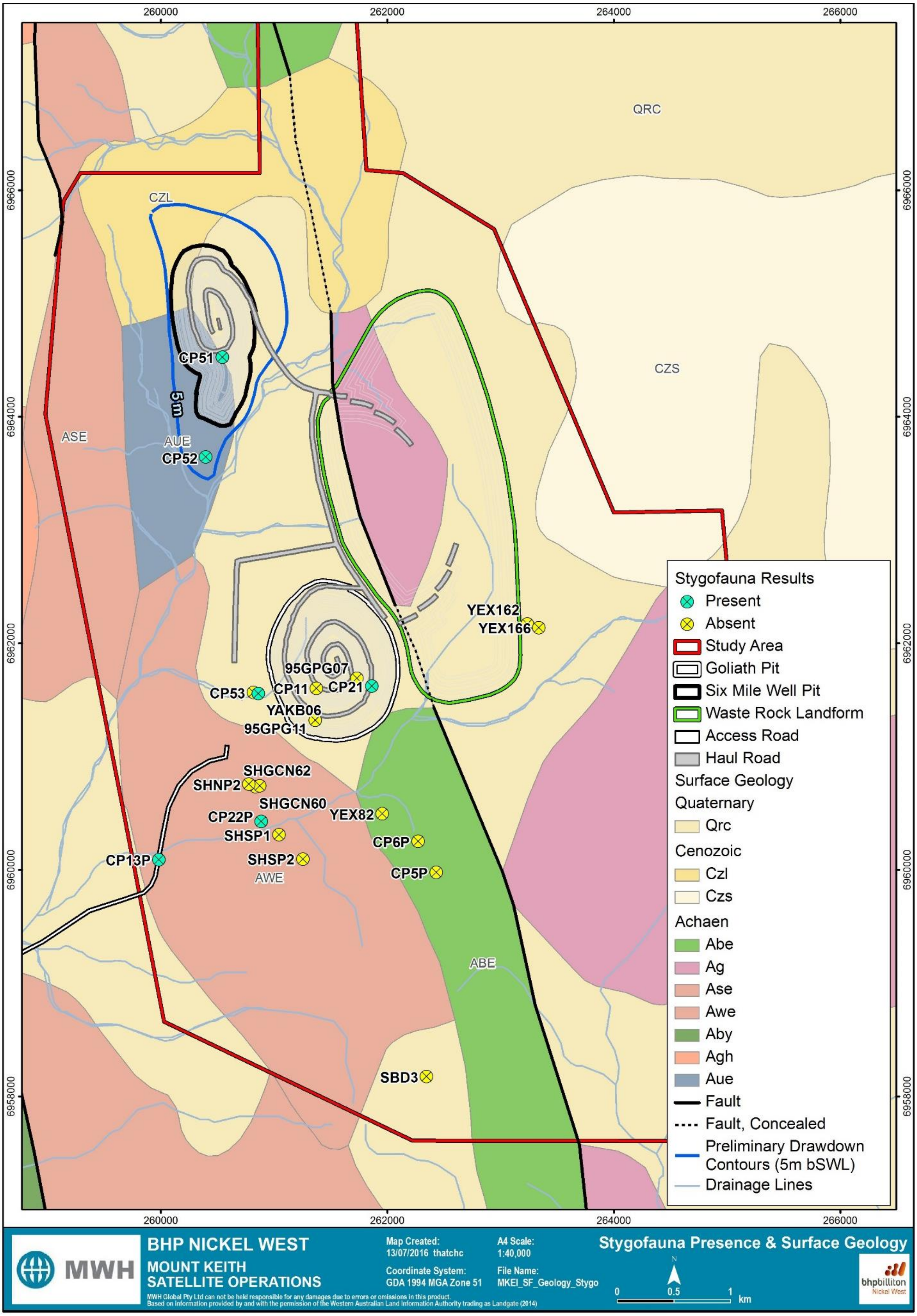

Figure 5-4: Distribution of stygofauna recorded in relation to subsurface geology.

5.4.2 Stygofauna Survey Adequacy

Regulatory Guidelines

The EPA EAG 12 (2013) stipulates that the appropriate level of survey required depends on the likely presence of subterranean fauna, the degree of impact proposed, and adequacy to reliably inform decisions as part of the EIA process as to whether a proposal meets the EPA's objective and is tailored to the circumstances of the proposal. The sampling effort conducted to date has exceeded the minimum requirements of 6 to 10 samples recommended by the EPA Guidance statement 54a (2007) for a Level 1 (pilot) survey and was more than sufficient in providing a reliable indication that stygofauna are present in the Project Area. The presence of stygofauna in the area, in conjunction with the high degree of impact proposed, means that a comprehensive Level 2 (baseline) survey would be required to provide a reliable characterisation of the stygofauna assemblage present in the Project Area and in relation to the proposed direct impact zones (pits associate groundwater drawdown).

The EPA Draft Guidance statement 54a (2007) recommends that in areas that are likely to host 'significant stygofaunal values', a minimum of 40 samples for a comprehensive Level 2 (baseline) survey are required to be collected from at least 10 bores within the proposed impact area. The definition of 'significant values' is not specified but has been interpreted to relate to the species richness present in or associated with the proposed development area. In addition, the minimum survey effort is considered to relate to an impact area on a connected aquifer system (i.e. a single, interconnected habitat), not a collated impact survey effort of separate aquifer systems that are each likely to host distinct stygofauna assemblages with no, or restricted, gene flow occurring among each system.

The number of samples collected for this assessment from within each of the proposed pit areas, and associated groundwater drawdown zone, does not exceed the minimum recommended survey intensity of 40 samples. The survey intensity undertaken to date is considered to be insufficient to achieve a high level of knowledge of the stygofauna assemblage present in the Project Area and, therefore, does not provide a high level of confidence in assessing the potential impacts posed by the proposed Project in accordance with EPA EAG 12 (2013a).

Species Diversity Analysis

A total of eight stygofauna taxa were considered to have been collected from the Project Area (treating Oligochaeta sp. as a separate species to Enchytraeidae sp. OES10). The species richness predicted to occur across the Project Area ranged from 10.6 to 50.8 species (**Figure 5-5, Table 5-5**). The species accumulation curves for all of the species richness estimators are still trending upwards with ICE and Chao 2 approaching exponential increases. None of the estimators are approaching a plateau. The stygofauna sampling undertaken to date is estimated to have recorded between 15.8 to 75.7 percent of the assemblage predicted to exist. The high species richness predicted by ICE (50.8) is considered to be an unreliable estimate as the species richness of many well studied calcrete systems do not come close to exceeding this, with Yeelirrie the only known exception. The extrapolation to 130 samples predicts that a 100 percent increase in survey effort will result in the collection of an additional six species from the Project Area.

The species accumulation curves indicate that the survey intensity undertaken has not been sufficient in providing a high level of knowledge of the stygofauna assemblage present in the Project Area and therefore, does not provide a high level of confidence in assessing the potential impacts posed by the proposed Project in accordance with EPA EAG 12 (2013a).

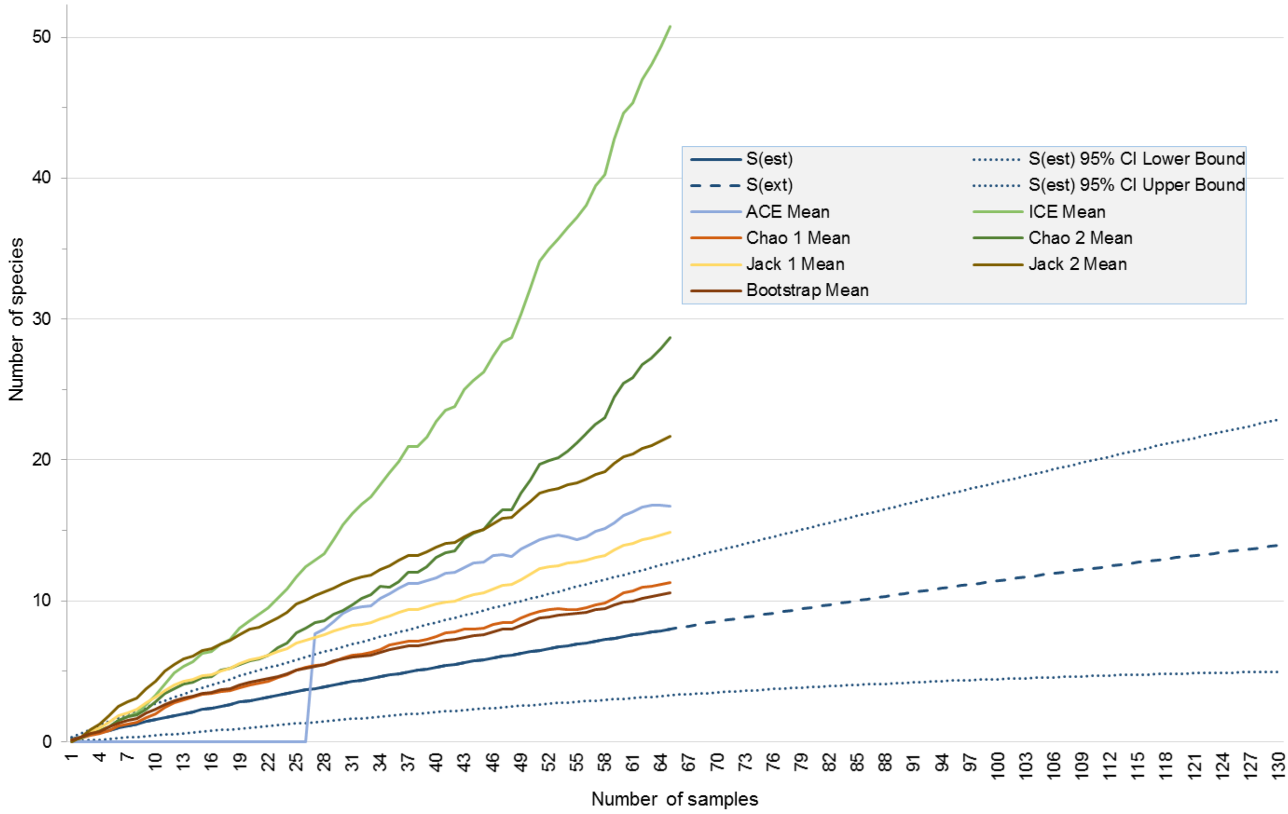

Figure 5-5: Stygofauna species accumulation curves for observed (S(est)), extrapolated (S(ext); to 130 samples), and various diversity estimators (EstimateS (Colwell 2013)) based on all recorded results (including Biota (2006)) from 2006 to 2012 sample rounds for the Mount Keith Satellite Operations Area.

Table 5-5: Observed stygofauna species diversity recorded from 2006 to 2012 sample rounds (including Biota (2006)) of the Mount Keith Satellite Operations Area compared to estimated diversity using EstimateS (Colwell 2013) diversity estimators.

Observed vs Estimated		Obs. & Pred. spp richness	% Predicted collected
Obs.	Sobs	8	
	Extrapolated (130 samples)	14.0	57.2%
Diversity estimators	Bootstrap Mean	10.6	75.7%
	Chao 1 Mean	11.3	70.9%
	Jack 1 Mean	14.9	53.7%
	ACE Mean	16.8	47.8%
	Jack 2 Mean	21.7	36.9%
	Chao 2 Mean	28.7	27.9%
	ICE Mean	50.8	15.8%
	Range	10.6 — 50.8	15.8 — 75.7%

5.5 Troglofauna Survey

5.5.1 Troglofauna Findings

Two troglofauna species, Campodeidae sp. OES2 (Diplura) and *Troglarmadillo* sp. OES3 (Isopoda) were collected from two of the 37 bores sampled (**Table 5-6, Figure 5-1, Figure 5-6, Appendix F: Tables F-1 & 2**). A single specimen of *Troglarmadillo* sp. OES3 was collected in litter traps each sample round from the same bore, YSHD29, within the Serpentine Hill area, more than 900 m to the south west of the proposed Goliath pit boundary (**Figure 5-7**). The dipluran, Campodeidae sp. OES2, was collected in a scrape sample from bore SHGCN62, near to where the isopod was recorded, close to 900 m to the south west of the proposed Goliath pit boundary.

No troglofauna species were collected from within the proposed Goliath and Six-Mile Well pit boundaries or likely associated groundwater drawdown impact areas. Therefore, the proposed Project does not pose a risk to the long-term survival of any known species of troglofauna. The results of the troglofauna survey demonstrated that the interstitial spaces within the regolith and weathered fractured rock geologies in and near to the Project Area do not harbour a diverse or abundant troglofauna assemblage. The potential habitats associated with these subsurface geologies are widespread and contiguous throughout the Project Area and surrounding region (**Figure 5-8**). Therefore, the distributions of potentially undetected troglomorphic species are unlikely to be restricted to a small area only because of the continuity and extent of habitat present.

Table 5-6: Troglofauna taxon diversity and distribution.

Subterranean Fauna	Abundance	Area	Bore ID	Location	Comments
Troglofauna Taxa					
Diplura					
Campodeidae sp. OES2	1	Serp Hill South	SHGCN62	Outside pits (>500m, <1km)	Not of conservation concern.
Isopoda					
Troglarmadillo sp. OES3	2	Serp Hill South	YSHD29	Outside pits (>500m, <1km)	Not of conservation concern.

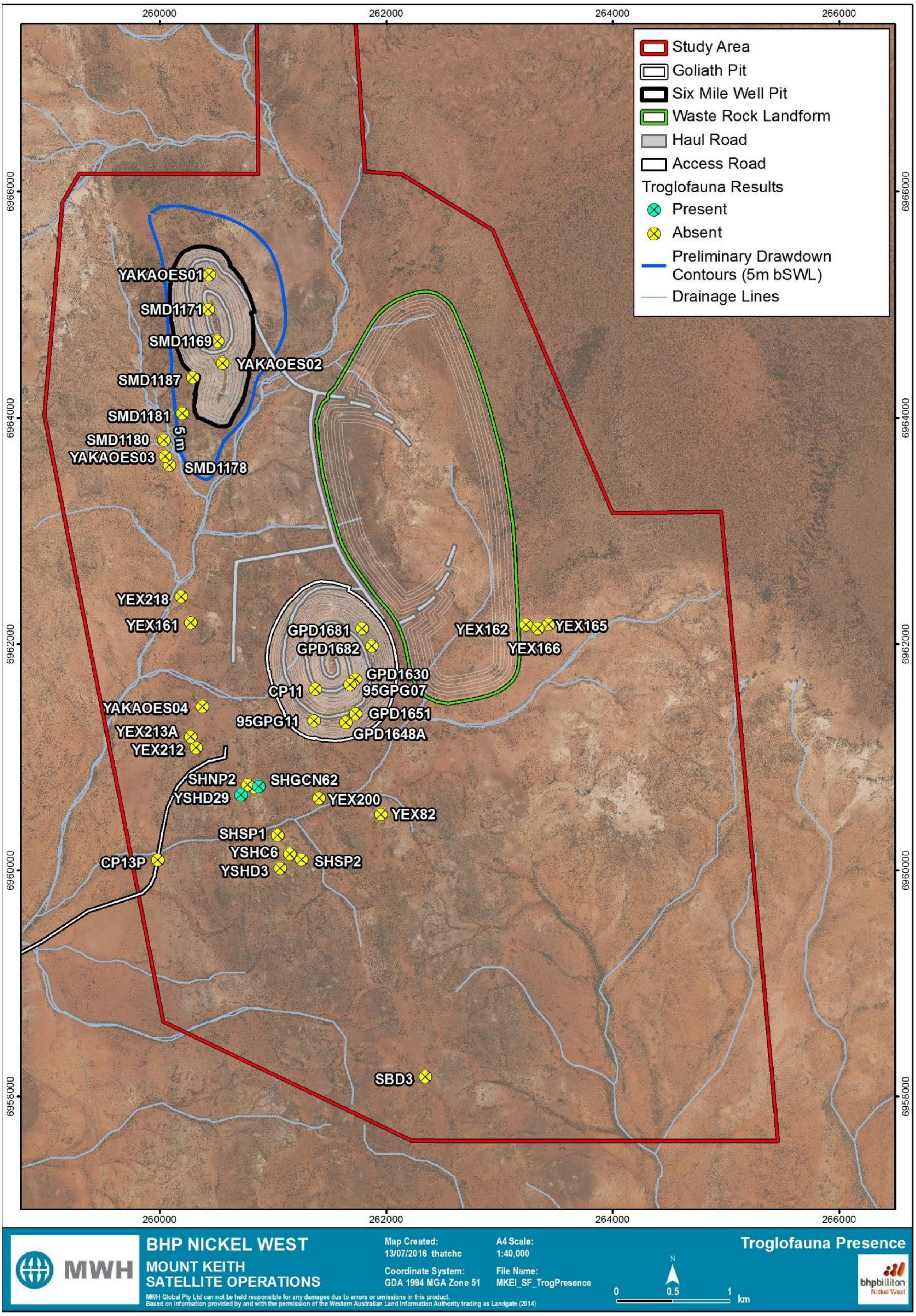

Figure 5-6: Overview of troglofauna sample sites indicating recorded presence or absence.

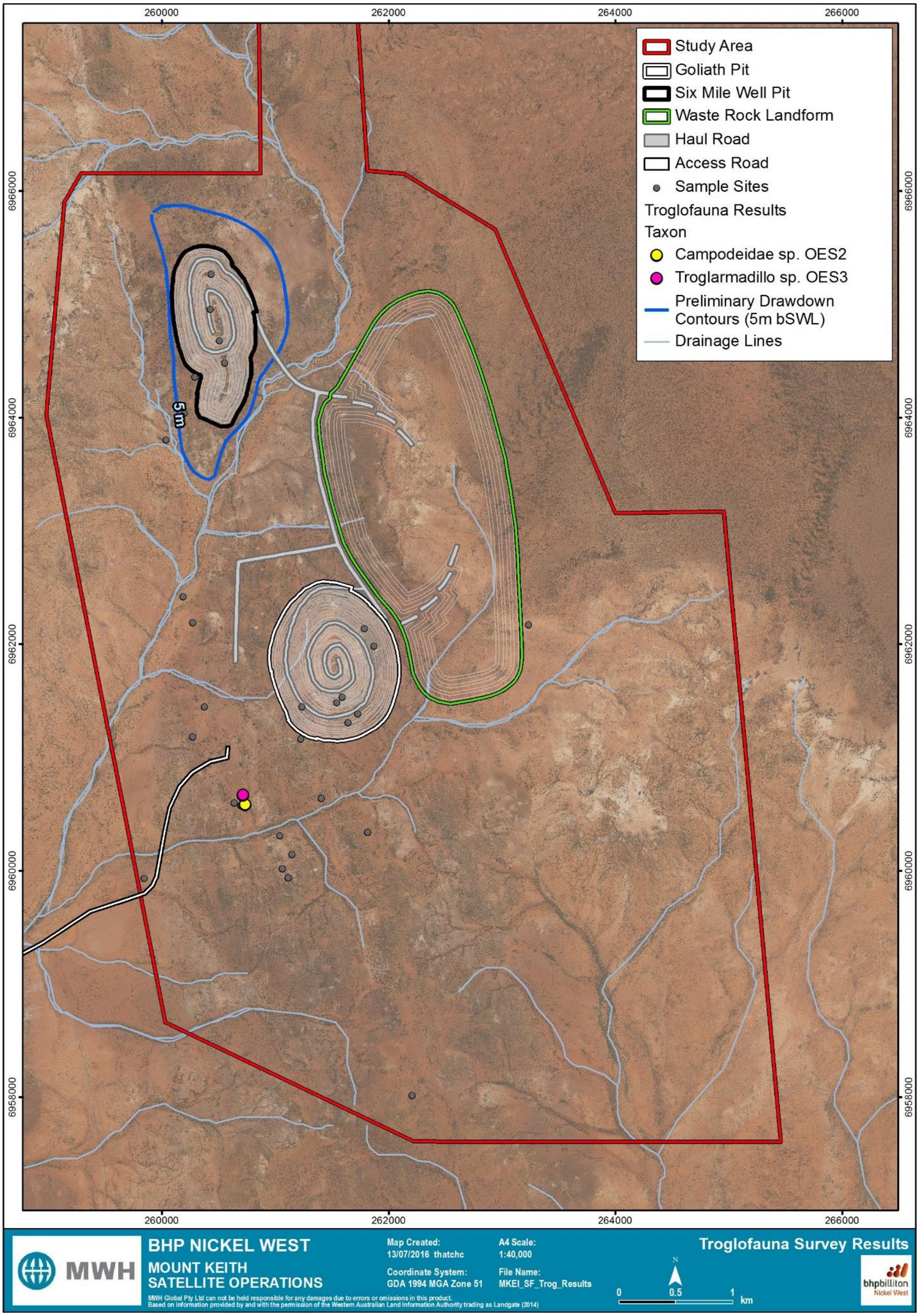

Figure 5-7: Distribution of troglofauna recorded.

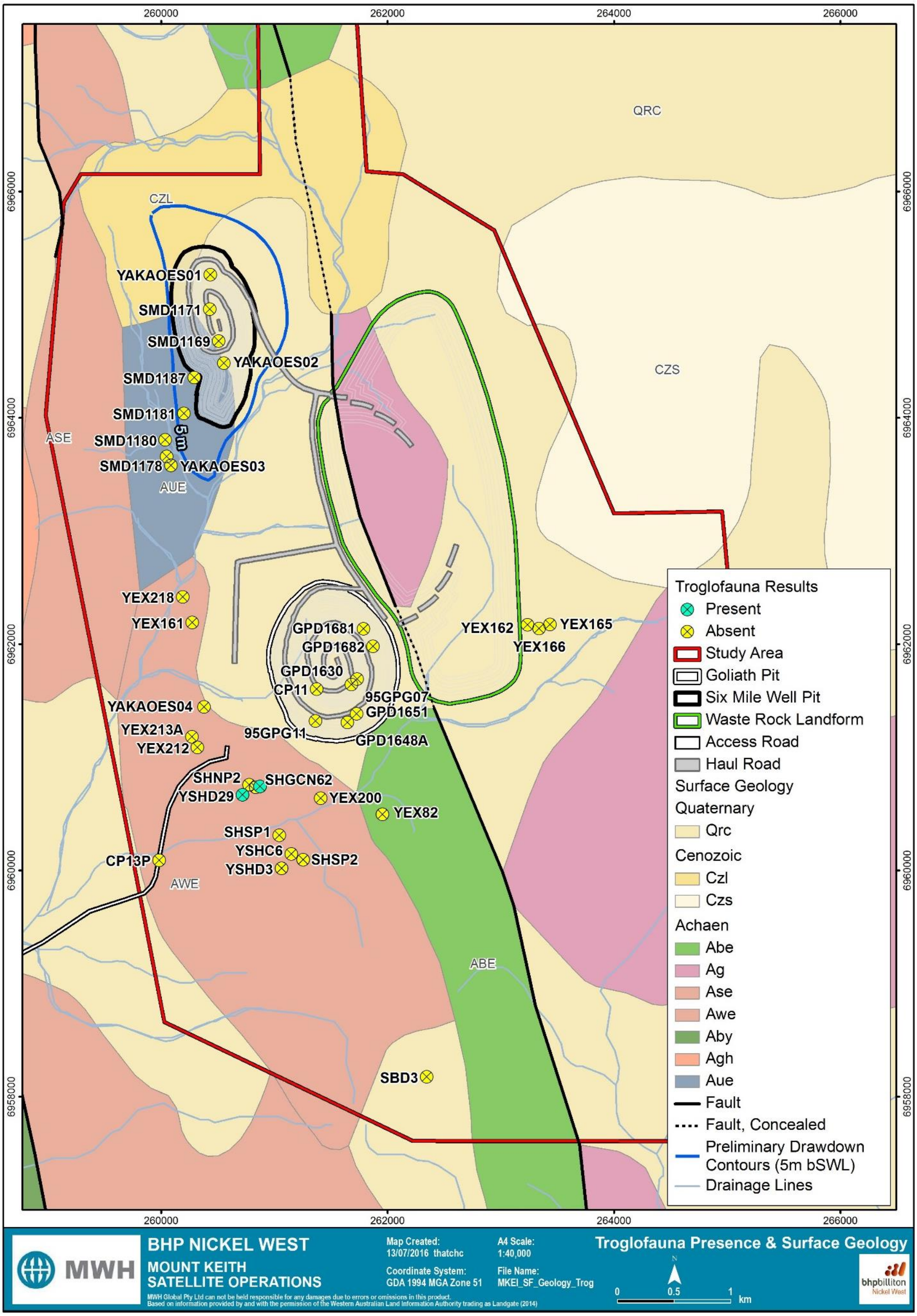

Figure 5-8: Distribution of troglofauna recorded in relation to subsurface geology.

5.5.2 Troglofauna Survey Adequacy

Regulatory Guidelines

The EPA EAG 12 (2013) stipulates that the appropriate level of survey required depends on the likely presence of subterranean fauna, the degree of impact proposed, and adequacy to reliably inform decisions as part of the EIA process as to whether a proposal meets the EPA's objective and is tailored to the circumstances of the proposal. The EPA Guidance statement 54a (2007) recommends that for Level 2 (baseline) surveys in areas that are likely to host 'significant troglofaunal values', a minimum of 60 samples deployed over two rounds for a minimum of six weeks each are required. The sampling effort conducted to date within the proposed pit impact areas has exceeded the minimum requirements of 6 to 10 samples recommended by the EPA Guidance statement 54a (2007) for a Level 1 (pilot) survey. This sample effort was more than sufficient in providing a reliable indication that troglofauna were not present within the proposed pit boundaries. The total number of samples collected as part of this assessment of an area that was demonstrated to have limited prospective habitat for troglofauna, exceeded the recommended baseline minimum with 89 samples. The comprehensive Level 2 (baseline) survey undertaken does provide a reliable characterisation of the troglofauna assemblage present in the Project Area and in relation to the proposed direct impact zones (pits and associate groundwater drawdown).

Species Diversity Analysis

A total of two troglofauna taxa were collected from the Project Area. The species richness predicted to occur across the Project Area ranged from 2 to 3 species (**Figure 5-9, Table 5-7**). The species accumulation curves for five of the seven species richness estimators have reached a plateau or are trending downwards. Only ACE and ICE are still trending upwards. The troglofauna sampling undertaken to date is estimated to have recorded between 66.7 to 100 percent of the assemblage predicted to exist. The extrapolation to 162 samples predicts that a 100 percent increase in survey effort will result in the collection of an additional 0.4 species from the Project Area.

The species accumulation curves indicate that the survey intensity undertaken has been sufficient in providing a high level of knowledge of the stygofauna assemblage present in the Project Area and therefore, does provide a high level of confidence in assessing the potential impacts posed by the proposed Project in accordance with EPA EAG 12 (2013a).

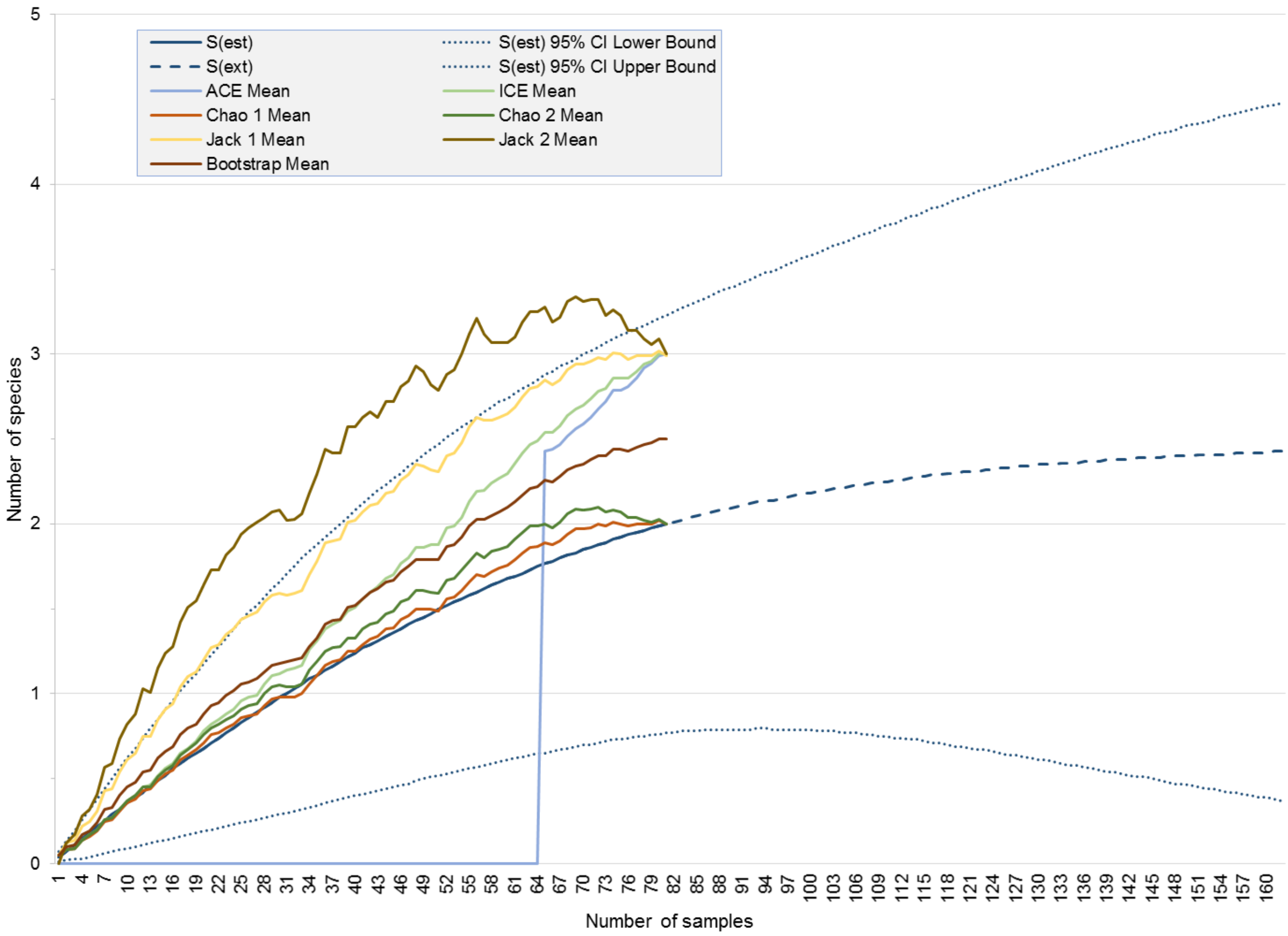

Figure 5-9: Troglofauna species accumulation curves for observed (S(est)), extrapolated (S(ext); to 162 samples), and various diversity estimators (EstimateS (Colwell 2013)) based on all recorded results from 2010 to 2012 sample rounds for the Mount Keith Satellite Operations Area.

Table 5-7: Observed troglofauna species diversity recorded from 2010 to 2012 sample rounds of the Mount Keith Satellite Operations Area compared to estimated diversity using EstimateS (Colwell 2013) diversity estimators.

Observed vs Estimated		Obs. & Pred. spp richness	% Predicted collected
Obs.	Sobs	2	
	Extrapolated (162 samples)	2.4	82.3%
Diversity estimators	Chao 1 Mean	2	100.0%
	Chao 2 Mean	2	100.0%
	Bootstrap Mean	2.5	80.0%
	Jack 1 Mean	2.99	66.9%
	ACE Mean	3	66.7%
	ICE Mean	3	66.7%
	Jack 2 Mean	3	66.7%
	Range	2 — 3	66.7 — 100%

6 Risk Assessment

The two main direct potential impacts on subterranean fauna associated with the development of the Project are:

- removal of habitat through excavation of the proposed mining pits, Goliath and Six-Mile Well; and
- drying out of habitat through the lowering of the groundwater table associated with mine pit dewatering.

The removal of habitat through mining excavation poses the greater risk to the conservation of stygofauna and troglofauna species relative to the lowering of the groundwater table only. Groundwater drawdowns are considered to have greater impacts on stygofauna compared to troglofauna because lowering of the groundwater table can directly reduce the extent of habitat available. In the case of troglofauna, the lowering of the water table may result in portions of saturated geology containing suitable habitable voids becoming unsaturated and potentially available for colonisation.

Both pit excavation and lower groundwater levels pose varying degrees of risk to the conservation of four of the seven identified stygofauna species that were restricted in distribution to within the proposed mining areas or modelled/ likely groundwater drawdown zones. The risk assessment outlined below focuses on stygofauna, as no species of troglofauna were found to be of conservation concern in the context of the development of the proposed Project.

Potential indirect impacts posed by proposed mining developments that could impact on aquifers inhabited by stygofauna include:

- fuel spills; and
- increase in sediment load in run-off from mining activities that could reduce surface-subsurface water exchange during flow periods (e.g., lessen input of resources) and alter groundwater chemistry (Marmonier 1991).

These potential indirect impacts to groundwater quality are not considered further here as part of this risk assessment because they can be greatly reduced or avoided through project design and best practice environmental management procedures. Appropriate management and mitigation measures will need to be addressed in the relevant approvals documentation and related environmental management plan in relation to potential indirect impacts.

6.1 Species of Conservation Concern

Of the seven identified stygofauna species recorded from the Project area, four species of the assemblage are of conservation concern because they have each only been recorded from within proposed pit boundaries or modelled/likely groundwater drawdown zones. The four species of conservation concern within proposed direct impact areas are as follows:

- The direct removal of habitat through mining excavation poses a risk to *Atopobathynella* sp. OES8 and *Atopobathynella* sp. OES11 within the proposed Six-Mile Well pit boundary.
- The direct removal of habitat through groundwater drawdown associated with mine dewatering poses a risk to *Gomphodella* sp. IK2 (Six-Mile Well pit) and Neoniphargidae sp. (Goliath).

Six of the stygofauna species, including all species of conservation concern, were only recorded from one bore with four species identified from a single specimen only (**Table 5-4**). It is not possible to reliably assess the distribution range of stygofauna species that are known only from limited records. Sampling the full extent of their likely range is often not possible as access to the subterranean habitat can often be constrained by the lack of bores available. Ecologically, there are many factors that influence the distribution of stygofauna at a range of habitat and temporal scales (Boulton 2000). Some of the more influential factors at the microhabitat (sediment) scale include suitable interstitial pore size (i.e. pro vision of connected network of habitable cavities), inflow rates of energy resources (e.g. organic carbon, biofilm growth, prey), and water quality parameters such as water temperature, pH, dissolved oxygen and organic carbon levels. At the mesohabitat (catchment) scale, factors include flow patterns along a water course influencing zones of upwelling and downwelling of energy resources or dissolved oxygen according to geomorphological features, as well as interactions with riparian and parafluvial sediments (Boulton *et al.* 1998). In addition, there are temporal variations in assemblage diversity when sampling as demonstrated with the continuation of the discovery of new species from previously relatively well sample areas (Guzik *et al.* 2010) or species only recorded intermittently over the course of an extensive survey program (Karanovic and Cooper 2012, MWH 2015). The seemingly restricted distribution of a taxon to a single bore, may likely be an artefact of sampling a species occurring at low population densities with a patchy, irregular distribution within the aquifer in response to varying micro- and mesohabitat factors, seasonality, biological interactions and availability of energy resources, rather than the actual distribution being confined to one limited area that was intercepted by a single bore.

The low and sporadic incidence of stygofauna present within the Project Area correlates with the overall hydrogeological assessment that the surficial and fractured rock aquifers present in the area are minor and relatively hydraulically isolated (refer Section 5.3.1). To the south of the main Six-mile Well deposit surficial aquifer, outside of the proposed pit boundary along Jones Creek, the more deeply weathered saturated regolith and bedrock layers become much thinner as the geology progresses into less permeable fresh bedrock (BHP Billiton Nickel West 2011a). Beneath and along side Jones Creek, a thin alluvial aquifer of several metres is considered to remain within the weathered zone above the saturated, less permeable bedrock(BHP Billiton Nickel West 2011a). The collection of *Atopobathynella* sp. OES9 and Bathynellidae sp. OES2, from outside the Project impact area, indicates that suitable habitat does exist for stygofauna outside of the regolith aquifers associated with each deposit.

Alluvial aquifers are an important ecological component of river systems including ephemeral streams (Harvey and Wagner 2000). The hyporheic zone forms an important transition zone connecting alluvial aquifer ecosystems to surface aquatic ecosystems (Boulton 2000). The hyporheic zone is defined as an ecotone that occurs within the bed and banks of a water course where surface and groundwater interact (Boulton *et al.* 1998). In arid environments, the hyporheic zone in ephemeral water courses is heavily dependant on associated groundwater within the saturated alluvial sediments and weathered strata, that can provide refugia for many epigean and stygobitic species during not only dry periods but also during flood events (Boulton and Stanley 1996, Boulton *et al.* 1992, Clinton *et al.* 1996, Cooling and Boulton 1993). Through the hyporheic zone, alluvial aquifers can provide an important linkage among rivers and ephemeral streams and can be conceptualised as forming the core of Ward and Palmer's (1994) 'interstitial highway' (Tomlinson and Boulton 2010).

From an ecological perspective, the spatial and temporal dimensions (Dole-Olivier *et al.* 1994, Ward 1989) of the extent of connectivity among the shallow alluvial aquifers associated with Jones Creek and its tributaries, could provide an 'interstitial highway' sufficient for gene flow to occur among stygofauna populations. Molecular sequence data confirmed the wider distribution of stygofauna species *Atopobathynella wattsi* and amphipod Chiltoniidae sp. SAM1, demonstrating that the alluvial aquifers associated with the northern Carey palaeodrainage channel provided interstitial corridors enabling these comparatively large species, to move among multiple calcrete systems over distances of more than 25 km (Outback Ecology 2011a). Similarly, a diverse stygofauna assemblage was found to disperse amongst the alluvial aquifers of the Coondiner Creek drainage system in the south eastern Pilbara (Outback Ecology 2009). In addition, the diverse stygofauna assemblage

Interconnected with the alluvial aquifers, likely providing refugia and potentially contributing to the interstitial highway, would be components of the fractured rock aquifer systems in the project area, associated with geological structures such as faults, fractures and shear zones. Molecular analysis demonstrated that many species in Browns Range stygofauna assemblage possessed relatively widespread distributions throughout the fractured rock and associated alluvial aquifer systems present within the Browns Range Metamorphics and surrounding Gardiner Sandstone geological units (Outback Ecology 2014).

The discussion above regarding potential habitat interconnectedness and extents remains purely conjecture as the survey results to date provide no empirical evidence to support the suppositions proposed. There is the possibility that the habitat sampled represents the peripheral upper distribution limits of a more widespread Jones Creek catchment stygofauna assemblage. However, suitable bores were not available along the main Jones Creek line further down the catchment to test if the assemblage was present and more diverse and abundant to the south of the Project Area. It is unlikely that only sampling the same bores that have already been sampled on multiple occasions as part of this study will provide a much clearer picture of the Jones Creek catchment stygofauna assemblage. These bores are set in or adjacent to minor ephemeral stream beds that form the very upper extent of the headwaters of the Jones Creek catchment area. Therefore, the habitat sampled may likely to represent the outer distribution limits or periphery of the stygofauna assemblage within the Jones Creek catchment. During the 2010 to 2012 surveys there were no known available bores along the main Jones Creek drainage line within the Project Area downstream of Six-mile Well or Goliath impact areas. This prevented further assessment of the stygofauna assemblage within the alluvial aquifers associated with the main channel of the Jones Creek catchment. In addition, there were no published papers nor WAM or DEC database records of stygofauna from the catchment area, including from the large floodplain area at the terminus of Jones Creek and from the calcrete systems associated with Lake Miranda, to provide any additional knowledge regarding species diversity and distribution.

From the stygofauna results collected from the Project Area to date it is not possible to achieve a high level of knowledge of the stygofauna assemblage present in the Project Area. Based on current results the implementation of the proposed Project would put at risk the conservation of four stygofauna species, *Atopobathynella* sp. OES8, *Atopobathynella* sp. OES11, Gomphodella sp. IK2, and Neoniphargidae sp.

7 Conclusion

The subterranean fauna assessment undertaken has revealed that the Project study area does host a low stygofauna and troglofauna diversity with the stygofauna assemblage dominated by bathynellacean taxa. Genetic analysis demonstrated that the bathynellacean taxa were highly divergent from other northern Yilgarn bathynellacean fauna assemblages. Four of the seven stygofauna species recorded were found from within proposed impact areas only and so are of conservation concern. The two troglofauna species recorded were from non-impact areas only so are not of conservation concern. An assessment of survey adequacy found that further stygofauna sampling is required but that no further troglofauna sampling is needed.

The current findings indicate that the development of the Project will pose a significant conservation risk to four stygofauna species through the removal of habitat by mining excavation and pit dewatering. .

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9 Glossary

alluvium – sediment deposited by a stream or river

aquatic – relating to water

aquifer – a body of permeable rock or sediment capable of storing groundwater

arid – a region characterised by a severe lack of available water, to the extent that the growth and development of biota is hindered or prevented

bedrock – consolidated rock attached to the earth's crust

biodiversity – the diversity of biota in a particular environment or region

calcrete – carbonate deposits that form in arid environments, as a result of groundwater evaporation

cave – a subsurface cavity of sufficient size that a human could enter

dissolved oxygen – a measure of the amount of gaseous oxygen dissolved in a solution

distribution range – the overall geographic area that a species is known to occur in

divergence – degree of separation from a common ancestor

diversity – species richness

drawdown – the lowering of the adjacent water table or piezometric surface as a result of groundwater extraction

ecotone – zone of transition among different ecosystems

electrical conductivity – an estimate of the total dissolved salts in a solution, or salinity

endemic – having a distribution restricted to a particular geographic region

epigean – pertaining to the surface zone

fractured rock – a rock formation characterized by separation or discontinuity, usually as a result of geological stress (e.g. faulting)

freshwater – salinity less than 5,000 µS/cm (3,000 mg/L)

geological ages (e.g. Cainozoic) – distinct time periods within the geological history of the earth

groundwater – water occurring below the ground surface

habitat – an ecological or environmental area that is inhabited by a particular animal or plant species

hypogean – pertaining to the subterranean zone

hyporheic zone – spatially fluctuating ecotone within the bed of a river or stream between surface and groundwater. Considered important component of groundwater ecosystems and involved in the 'interstitial highway', forming hyporheic corridor linking associated aquifers.

invertebrates – animals lacking vertebrae

karst – a region of limestone or other soluble rock, characterized by distinctive features such as caves, caverns, sinkholes, underground streams and springs

lineage – a group of organisms related by descent from a common ancestor

molecular – pertaining to the genetic characteristics of an organism or group

morphology – the specific form and structure of an organism or taxon

morphospecies – a general grouping of organisms that share similar morphological traits, but is not necessarily defined by a formal taxonomic rank

palaeoriver, palaeochannel, palaeodrainage – a remnant of a stream or river channel cut in older rock and filled by the sediments of younger overlying rock

pH – a measure of the hydrogen ion concentration of a soil or solution (values below pH of 6.5 are 'acidic', and those above pH 7.5 are 'alkaline')

relictual – having survived as a remnant

salinity – the concentration of all dissolved salts in a solution

semi-arid – a climatic region that receives low annual rainfall (250 – 500 mm)

species – a formal taxonomic unit defining a group or population of organisms that share distinctive characters or traits, are reproductively viable and/or are otherwise identifiable as a related group

species diversity – the number of species present in a particular habitat, ecosystem or region

species accumulation curve – a model used to estimate species diversity or richness

standing water level – the depth to groundwater from a particular reference point (e.g. in a monitoring bore)

stygal, stygo – pertaining to groundwater habitat or biota

stygobite – an obligate aquatic species of groundwater habitats

stygobiont – another term used to describe obligate inhabitants of groundwater systems

stygofauna – a general term for aquatic groundwater fauna

stygophile – an aquatic species that temporarily or permanently inhabits groundwater habitats

stygoxene – an aquatic species that has no fixed affinity with groundwater habitats, but may nonetheless occur in groundwater habitats

taxon – an identifiable group of organisms, usually based on a known or inferred relationship or a shared set of distinctive characteristics

troglobite – an obligate terrestrial species of subterranean habitats

troglofauna – a general term for terrestrial subterranean fauna

troglomorphic features – morphological characteristics resulting from an adaptation to subterranean habitats (e.g. a reduction in pigment)

troglophile – a terrestrial species that temporarily or permanently inhabits subterranean habitats

trogloxene – a terrestrial species that has no fixed affinity with subterranean habitats, but may nonetheless occur in subterranean habitats

void – a pore space in the rock or stratum

Yilgarn – pertaining to the Yilgarn Craton, a 65,000 km^2 body of the earth's crust in south-western Australia that dates back to the Archaean period, 2.6 to 3.7 million years ago

Appendix A Survey Effort and Bore Data

Table A-1: Stygofauna survey effort (including Biota 2006) and bore data recorded. Blue shaded rows indicate stygofauna recorded.

Project Area	Bore Code	Latitude (DMS)	Longitude (DMS)	UTM (51J: GDA)		Sample Date	Elevation	SWL		EoH		Location	Stygofauna Recorded?
				Easting	Northing		(AHD)	(m bgl)	(AHD)	(m bgl)	(AHD)		
Goliath	95GPG07	27°26'56"S	120°35'16"E	261729	6961690	2006	537	NA				Inside pit	No
Goliath	95GPG07	27°26'56"S	120°35'16"E	261729	6961690	18-Nov-10	537	33.15	503.85	72.9	464.1	Inside pit	No
Goliath	95GPG07	27°26'56"S	120°35'16"E	261729	6961690	29-Mar-11	537	33.3	503.7	75.6	461.4	Inside pit	No
Goliath	95GPG11	27°27'08"S	120°35'03"E	261363	6961319	18-Nov-10	530	27.4	502.6	57.6	472.4	Inside pit	No
Goliath	95GPG11	27°27'08"S	120°35'03"E	261363	6961319	29-Mar-11	530	26.1	503.9	59.4	470.6	Inside pit	No
Goliath	CP11	27°26'59"S	120°35'03"E	261373	6961602	2006	532	NA				Inside pit	No
Goliath	CP11	27°26'59"S	120°35'03"E	261373	6961602	18-Nov-10	532	26.06	505.94	58.5	473.5	Inside pit	No
Goliath	CP11	27°26'59"S	120°35'03"E	261373	6961602	29-Mar-11	532	26.1	505.9	32.4	499.6	Inside pit	No
Goliath	CP11	27°26'59"S	120°35'03"E	261373	6961602	2-Feb-12	532					Inside pit	No
Goliath	CP21	27°26'58"S	120°35'21"E	261862	6961621	2006	532	NA				Inside pit	Yes
Goliath	CP21	27°26'58"S	120°35'21"E	261862	6961621	18-Nov-10	532	29.1	502.9	61.2	470.8	Inside pit	No
Goliath	CP21	27°26'58"S	120°35'21"E	261862	6961621	2-Feb-12	532					Inside pit	No
Goliath	CP53	27°26'59"S	120°34'43"E	260816	6961565	2006	523					Near pit (<200m)	No
Goliath	CP53	27°26'59"S	120°34'43"E	260816	6961565	18-Nov-10	523	20.93	502.07	64.8	458.2	Near pit (<200m)	No
Goliath	YAKB06	27°26'55"S	120°34'50"E	260859	6961556	2006	531		531			Near pit (<200m)	Yes
Goliath	YAKB06	27°26'55"S	120°34'50"E	260859	6961556	3-Feb-12	531					Near pit (<200m)	No
Goliath South	CP5P	27°27'52"S	120°35'40"E	262430	6959976	16-Nov-10	534	25.25	508.75	69.3	464.7	Outside pits (>1km)	No
Goliath South	CP5P	27°27'52"S	120°35'40"E	262430	6959976	28-Mar-11	534	25.45	508.55	66.6	467.4	Outside pits (>1km)	No
Goliath South	CP6P	27°27'52"S	120°35'40"E	262270	6960250	16-Nov-10	528	21.84	506.16	33.3	494.7	Outside pits (>1km)	No
Goliath South	CP6P	27°27'52"S	120°35'40"E	262270	6960250	28-Mar-11	528			31.5	496.5	Outside pits (>1km)	No
Goliath South	CP6P	27°27'52"S	120°35'40"E	262270	6960250	21-Jun-11	528	21.77	506.23	30.5	497.5	Outside pits (>1km)	No
Goliath South	CP6P	27°27'52"S	120°35'40"E	262270	6960250	1-Feb-12	528					Outside pits (>1km)	No
Goliath South	YEX82	27°27'35"S	120°35'23"E	261954	6960494	16-Nov-10	527	19.8	507.2	66.6	460.4	Outside pits (>500m, <1km)	No
Goliath South	YEX82	27°27'35"S	120°35'23"E	261954	6960494	28-Mar-11	527			30.6	496.4	Outside pits (>500m, <1km)	No
Goliath South	YEX82	27°27'35"S	120°35'23"E	261954	6960494	21-Jun-11	527	20.06	506.94	30.5	496.5	Outside pits (>500m, <1km)	No
Goliath South	YEX82	27°27'35"S	120°35'23"E	261954	6960494	1-Feb-12	527					Outside pits (>500m, <1km)	No
Serp Hill South	CP13P	27°27'47"S	120°34'11"E	259982	6960089	18-Nov-10	509	11.08	497.92	79.2	429.8	Outside pits (>1km)	No
Serp Hill South	CP13P	27°27'47"S	120°34'11"E	259982	6960089	28-Mar-11	509	10.8	498.2	59.4	449.6	Outside pits (>1km)	No
Serp Hill South	CP13P	27°27'47"S	120°34'11"E	259982	6960089	17-Jun-11	509	11.6	497.4	62.4	446.6	Outside pits (>1km)	No
Serp Hill South	CP13P	27°27'47"S	120°34'11"E	259982	6960089	2-Feb-12	509					Outside pits (>1km)	Yes
Serp Hill South	CP22P	27°27'36"S	120°34'45"E	260885	6960426	16-Nov-10	526	12.17	513.83	51.3	474.7	Outside pits (>500m, <1km)	No
Serp Hill South	CP22P	27°27'36"S	120°34'45"E	260885	6960426	28-Mar-11	526	11.7	514.3	46.8	479.2	Outside pits (>500m, <1km)	No
Serp Hill South	CP22P	27°27'36"S	120°34'45"E	260885	6960426	21-Jun-11	526	11.9	514.1	50.5	475.5	Outside pits (>500m, <1km)	Yes

Table A-1 (cont.): Stygofauna survey effort (including Biota 2006) and bore data recorded. Blue shaded rows indicate stygofauna recorded.

Project Area	Bore Code	Latitude (DMS)	Longitude (DMS)	UTM (51J: GDA)		Sample Date	Elevation	SWL		EoH		Location	Stygofauna Recorded?
				Easting	Northing		(AHD)	(m bgl)	(AHD)	(m bgl)	(AHD)		
Serp Hill South	SHGCN60	27°27'26"S	120°34'43"E	260835	6960733	18-Nov-10	519	16	503	60.5	458.5	Outside pits (>500m, <1km)	No
Serp Hill South	SHGCN60	27°27'26"S	120°34'43"E	260835	6960733	28-Mar-11	519	15.3	503.7	59.4	459.6	Outside pits (>500m, <1km)	No
Serp Hill South	SHGCN60	27°27'26"S	120°34'43"E	260835	6960733	21-Jun-11	519	15.63	503.37	64	455	Outside pits (>500m, <1km)	No
Serp Hill South	SHGCN60	27°27'26"S	120°34'43"E	260835	6960733	3-Feb-12	519					Outside pits (>500m, <1km)	No
Serp Hill South	SHGCN62	27°27'26"S	120°34'44"E	260873	6960741	16-Nov-10	524	16.24	507.76	59.5	464.5	Outside pits (>500m, <1km)	No
Serp Hill South	SHGCN62	27°27'26"S	120°34'44"E	260873	6960741	28-Mar-11	524	15.3	508.7	81	443	Outside pits (>500m, <1km)	No
Serp Hill South	SHGCN62	27°27'26"S	120°34'44"E	260873	6960741	21-Jun-11	524	16.12	507.88	60.3	463.7	Outside pits (>500m, <1km)	No
Serp Hill South	SHGCN62	27°27'26"S	120°34'44"E	260873	6960741	3-Feb-12	524					Outside pits (>500m, <1km)	No
Serp Hill South	SHNP2	27°27'26"S	120°34'41"E	260775	6960755	18-Nov-10	515	15.17	499.83	74.6	440.4	Outside pits (>500m, <1km)	No
Serp Hill South	SHNP2	27°27'26"S	120°34'41"E	260775	6960755	28-Mar-11	515	16.2	498.8	51.3	463.7	Outside pits (>500m, <1km)	No
Serp Hill South	SHNP2	27°27'26"S	120°34'41"E	260775	6960755	21-Jun-11	515	15.22	499.78	38.7	476.3	Outside pits (>500m, <1km)	No
Serp Hill South	SHNP2	27°27'26"S	120°34'41"E	260775	6960755	2-Feb-12	515					Outside pits (>500m, <1km)	No
Serp Hill South	SHSP1	27°27'35"S	120°34'55"E	261042	6960308	16-Nov-10	529	12.95	516.05	62.1	466.9	Outside pits (>500m, <1km)	No
Serp Hill South	SHSP1	27°27'35"S	120°34'55"E	261042	6960308	28-Mar-11	529	13.5	515.5	45	484	Outside pits (>500m, <1km)	No
Serp Hill South	SHSP1	27°27'35"S	120°34'55"E	261042	6960308	21-Jun-11	529	12.77	516.23	38.7	490.3	Outside pits (>500m, <1km)	No
Serp Hill South	SHSP2	27°27'47"S	120°34'58"E	261252	6960094	16-Nov-10	529	20.85	508.15	54.9	474.1	Outside pits (>1km)	No
Serp Hill South	SHSP2	27°27'47"S	120°34'58"E	261252	6960094	28-Mar-11	529	19.8	509.2	50.4	478.6	Outside pits (>1km)	No
Serp Hill South	SHSP2	27°27'47"S	120°34'58"E	261252	6960094	21-Jun-11	529	20.7	508.3	36.9	492.1	Outside pits (>1km)	No
Serp Hill South	SHSP2	27°27'47"S	120°34'58"E	261252	6960094	2-Feb-12	529					Outside pits (>1km)	No
Sheba	SBD3	27°28'51"S	120°35'36"E	262345	6958173	16-Nov-10	534	27.1	506.9	60.3	473.7	Outside pits (>3km)	No
Sheba	SBD3	27°28'51"S	120°35'36"E	262345	6958173	28-Mar-11	534	26.04	507.96	65.6	468.4	Outside pits (>3km)	No
Six-mile Well	CP51	27°25'23"S	120°34'35"E	260542	6964526	18-Nov-10	535	27.54	507.46	38.7	496.3	Inside pit	Yes
Six-mile Well	CP51	27°25'23"S	120°34'35"E	260542	6964526	29-Mar-11	535	28.8	506.2	38.7	496.3	Inside pit	No
Six-mile Well	CP51	27°25'23"S	120°34'35"E	260542	6964526	17-Jun-11	535	26.35	508.65	36.9	498.1	Inside pit	Yes
Six-mile Well	CP51	27°25'23"S	120°34'35"E	260542	6964526	2-Feb-12	535					Inside pit	Yes
Six-mile Well	CP52	27°25'52"S	120°34'29"E	260394	6963644	18-Nov-10	525	23.03	501.97	64	461	Near pit (>300m, <500m)	No
Six-mile Well	CP52	27°25'52"S	120°34'29"E	260394	6963644	29-Mar-11	525	23.4	501.6	60.3	464.7	Near pit (>300m, <500m)	No
Six-mile Well	CP52	27°25'52"S	120°34'29"E	260394	6963644	17-Jun-11	525	22.42	502.58	60.3	464.7	Near pit (>300m, <500m)	No
Six-mile Well	CP52	27°25'52"S	120°34'29"E	260394	6963644	2-Feb-12	525					Near pit (>300m, <500m)	Yes
Waste Rock Landform	YEX162	27°26'36"S	120°36'16"E	263235	6962170	17-Jun-11	527	22.99	504.01	49.5	477.5	Outside pits (>1km)	No
Waste Rock Landform	YEX166	27°48'16"S	120°35'52"E	263338	6962137	17-Jun-11	566	24.3	541.7	62.1	503.9	Outside pits (>1km)	No

Table A-2: Troglofauna survey effort undertaken and bore data recorded. Orange shaded rows indicate troglofauna recorded.

Project Area	Bore Code	Latitude (DMS)	Longitude (DMS)	UTM (51J: GDA)		Sample Start Date	Sample End Date	Trap Depth (mbgl)	Location	Troglofauna Recorded?
				Easting	Northing					
Goliath	95GPG07	27°26'56"S	120°35'16"E	261729	6961690	29-Mar-11	30-May-11	25	Inside pit	No
Goliath	95GPG07	27°26'56"S	120°35'16"E	261729	6961690	23-May-11	19-Jul-11	25	Inside pit	No
Goliath	95GPG11	27°27'08"S	120°35'03"E	261363	6961319	29-Mar-11	30-May-11	20	Inside pit	No
Goliath	95GPG11	27°27'08"S	120°35'03"E	261363	6961319	23-May-11	19-Jul-11	20	Inside pit	No
Goliath	CP11	27°26'59"S	120°35'03"E	261373	6961602	23-May-11	19-Jul-11	16	Inside pit	No
Goliath	GPD1630	27°26'52"S	120°35'19"E	261680	6961642	29-Mar-11	30-May-11	12	Inside pit	No
Goliath	GPD1630	27°26'52"S	120°35'19"E	261680	6961642	23-May-11	19-Jul-11	12	Inside pit	No
Goliath	GPD1648A	27°27'03"S	120°35'18"E	261644	6961307	26-Mar-11	30-May-11	31	Inside pit	No
Goliath	GPD1648A	27°27'03"S	120°35'18"E	261644	6961307	23-May-11	19-Jul-11	29	Inside pit	No
Goliath	GPD1651	27°27'01"S	120°35'21"E	261726	6961383	26-Mar-11	30-May-11	6	Inside pit	No
Goliath	GPD1651	27°27'01"S	120°35'21"E	261726	6961383	23-May-11	19-Jul-11	6	Inside pit	No
Goliath	GPD1681	27°26'37"S	120°35'24"E	261787	6962135	26-Mar-11	30-May-11	9	Inside pit	No
Goliath	GPD1681	27°26'37"S	120°35'24"E	261787	6962135	23-May-11	19-Jul-11	9	Inside pit	No
Goliath	GPD1682	27°26'42"S	120°35'27"E	261870	6961980	26-Mar-11	25-May-11	9	Inside pit	No
Goliath	GPD1682	27°26'42"S	120°35'27"E	261870	6961980	23-May-11	19-Jul-11	9	Inside pit	No
Goliath South	YEX82	27°27'35"S	120°35'23"E	261954	6960494	28-Mar-11	30-May-11	15	Outside pits (>500m, <1km)	No
Goliath South	YEX82	27°27'35"S	120°35'23"E	261954	6960494	30-May-11	19-Jul-11	15	Outside pits (>500m, <1km)	No
Serp Hill North	YAKAOES04	27°26'58"S	120°34'32"E	260377	6961444	25-Mar-11	30-May-11	15	Outside pits (>500m, <1km)	No
Serp Hill North	YAKAOES04	27°26'58"S	120°34'32"E	260377	6961444	23-May-11	19-Jul-11	15	Outside pits (>500m, <1km)	No
Serp Hill North	YEX212	27°27'10"S	120°34'30"E	260320	6961085	23-May-11	19-Jul-11	10	Outside pits (>500m, <1km)	No
Serp Hill North	YEX213A	27°27'07"S	120°34'28"E	260271	6961180	26-Mar-11	30-May-11	10	Outside pits (>500m, <1km)	No
Serp Hill North	YEX213A	27°27'07"S	120°34'28"E	260271	6961180	23-May-11	19-Jul-11	12	Outside pits (>500m, <1km)	No
Serp Hill South	CP13P	27°27'47"S	120°34'11"E	259982	6960089	28-Mar-11	30-May-11	10	Outside pits (>1km)	No
Serp Hill South	CP13P	27°27'47"S	120°34'11"E	259982	6960089	30-May-11	19-Jul-11	10	Outside pits (>1km)	No
Serp Hill South	SHGCN60	27°27'26"S	120°34'43"E	260835	6960733	18-Nov-10		Scrape	Outside pits (>500m, <1km)	No
Serp Hill South	SHGCN60	27°27'26"S	120°34'43"E	260835	6960733	28-Mar-11		Scrape	Outside pits (>500m, <1km)	No
Serp Hill South	SHGCN60	27°27'26"S	120°34'43"E	260835	6960733	28-Mar-11	30-May-11	14	Outside pits (>500m, <1km)	No
Serp Hill South	SHGCN60	27°27'26"S	120°34'43"E	260835	6960733	30-May-11		Scrape	Outside pits (>500m, <1km)	No
Serp Hill South	SHGCN60	27°27'26"S	120°34'43"E	260835	6960733	30-May-11	19-Jul-11	14	Outside pits (>500m, <1km)	No
Serp Hill South	SHGCN60	27°27'26"S	120°34'43"E	260835	6960733	21-Jun-11		Scrape	Outside pits (>500m, <1km)	No
Serp Hill South	SHGCN60	27°27'26"S	120°34'43"E	260835	6960733	03-Feb-12		Scrape	Outside pits (>500m, <1km)	No

Table A-2 (cont.): Troglofauna survey effort undertaken and bore data recorded. Orange shaded rows indicate troglofauna recorded.

Project Area	Bore Code	Latitude (DMS)	Longitude (DMS)	UTM (51J: GDA)		Sample Start Date	Sample End Date	Trap Depth (mbgl)	Location	Troglofauna Recorded?
				Easting	Northing					
Serp Hill South	SHGCN62	27°27'26"S	120°34'44"E	260873	6960741	16-Nov-10		Scrape	Outside pits (>500m, <1km)	No
Serp Hill South	SHGCN62	27°27'26"S	120°34'44"E	260873	6960741	28-Mar-11		Scrape	Outside pits (>500m, <1km)	No
Serp Hill South	SHGCN62	27°27'26"S	120°34'44"E	260873	6960741	28-Mar-11	30-May-11	15	Outside pits (>500m, <1km)	No
Serp Hill South	SHGCN62	27°27'26"S	120°34'44"E	260873	6960741	30-May-11	19-Jul-11	10	Outside pits (>500m, <1km)	No
Serp Hill South	SHGCN62	27°27'26"S	120°34'44"E	260873	6960741	21-Jun-11		Scrape	Outside pits (>500m, <1km)	No
Serp Hill South	SHGCN62	27°27'26"S	120°34'44"E	260873	6960741	03-Feb-12		Scrape	Outside pits (>500m, <1km)	Yes
Serp Hill South	SHGCN62	27°27'26"S	120°34'44"E	260873	6960741	03-Feb-12		Scrape	Outside pits (>500m, <1km)	No
Serp Hill South	SHNP2	27°27'26"S	120°34'41"E	260775	6960755	18-Nov-10		Scrape	Outside pits (>500m, <1km)	No
Serp Hill South	SHNP2	27°27'26"S	120°34'41"E	260775	6960755	28-Mar-11		Scrape	Outside pits (>500m, <1km)	No
Serp Hill South	SHNP2	27°27'26"S	120°34'41"E	260775	6960755	21-Jun-11		Scrape	Outside pits (>500m, <1km)	No
Serp Hill South	SHNP2	27°27'26"S	120°34'41"E	260775	6960755	02-Feb-12		Scrape	Outside pits (>500m, <1km)	No
Serp Hill South	SHSP1	27°27'26"S	120°34'41"E	261042	6960308	16-Nov-10		Scrape	Outside pits (>500m, <1km)	No
Serp Hill South	SHSP1	27°27'26"S	120°34'41"E	261042	6960308	28-Mar-11		Scrape	Outside pits (>500m, <1km)	No
Serp Hill South	SHSP1	27°27'26"S	120°34'41"E	261042	6960308	21-Jun-11		Scrape	Outside pits (>500m, <1km)	No
Serp Hill South	SHSP2	27°27'26"S	120°34'41"E	261252	6960094	16-Nov-10		Scrape	Outside pits (>500m, <1km)	No
Serp Hill South	SHSP2	27°27'26"S	120°34'41"E	261252	6960094	28-Mar-11		Scrape	Outside pits (>500m, <1km)	No
Serp Hill South	SHSP2	27°27'26"S	120°34'41"E	261252	6960094	28-Mar-11	30-May-11		Outside pits (>500m, <1km)	No
Serp Hill South	SHSP2	27°27'26"S	120°34'41"E	261252	6960094	30-May-11		Scrape	Outside pits (>500m, <1km)	No
Serp Hill South	SHSP2	27°27'26"S	120°34'41"E	261252	6960094	30-May-11	19-Jul-11	9	Outside pits (>500m, <1km)	No
Serp Hill South	SHSP2	27°27'26"S	120°34'41"E	261252	6960094	21-Jun-11		Scrape	Outside pits (>500m, <1km)	No
Serp Hill South	SHSP2	27°27'26"S	120°34'41"E	261252	6960094	02-Feb-12		Scrape	Outside pits (>500m, <1km)	No
Serp Hill South	YEX200	27°27'25"S	120°35'09"E	261407	6960636	26-Mar-11	30-May-11	10	Outside pits (>500m, <1km)	No
Serp Hill South	YEX200	27°27'25"S	120°35'09"E	261407	6960636	30-May-11	19-Jul-11	10	Outside pits (>500m, <1km)	No
Serp Hill South	YSHC6	27°27'41"S	120°34'59"E	261148	6960143	26-Mar-11	30-May-11	14	Outside pits (>1km)	No
Serp Hill South	YSHC6	27°27'41"S	120°34'59"E	261148	6960143	30-May-11	19-Jul-11	9	Outside pits (>1km)	No
Serp Hill South	YSHD29	27°27'24"S	120°34'44"E	260717	6960666	26-Mar-11	30-May-11	15	Outside pits (>500m, <1km)	Yes
Serp Hill South	YSHD29	27°27'24"S	120°34'44"E	260717	6960666	30-May-11	19-Jul-11	15	Outside pits (>500m, <1km)	Yes
Serp Hill South	YSHD3	27°27'45"S	120°34'56"E	261062	6960016	26-Mar-11	30-May-11	14	Outside pits (>1km)	No
Serp Hill South	YSHD3	27°27'45"S	120°34'56"E	261062	6960016	30-May-11	19-Jul-11	14	Outside pits (>1km)	No
Sheba	SBD3	27°28'51"S	120°35'36"E	262345	6958173	28-Mar-11	30-May-11	25	Outside pits (>3km)	No
Sheba	SBD3	27°28'51"S	120°35'36"E	262345	6958173	28-Mar-11	30-May-11	25	Outside pits (>3km)	No
Sheba	SBD3	27°28'51"S	120°35'36"E	262345	6958173	30-May-11	19-Jul-11	20	Outside pits (>3km)	No

Table A-2 (cont.): Troglofauna survey effort undertaken and bore data recorded. Orange shaded rows indicate troglofauna recorded.

Project Area	Bore Code	Latitude (DMS)	Longitude (DMS)	UTM (51J)		Sample Start Date	Sample End Date	Trap Depth (mbgl)	Location	Troglofauna Recorded?
				Easting	Northing					
Six-mile Well	YEX161	27°26'34"S	120°34'29"E	260272	6962189	25-Mar-11	30-May-11	10	Outside pits (>500m, <1km)	No
Six-mile Well	YEX161	27°26'34"S	120°34'29"E	260272	6962189	23-May-11	19-Jul-11	10	Outside pits (>500m, <1km)	No
Six-mile Well	YEX218	27°26'26"S	120°34'26"E	260187	6962417	25-Mar-11	30-May-11	9	Outside pits (>500m, <1km)	No
Six-mile Well	YEX218	27°26'26"S	120°34'26"E	260187	6962417	23-May-11	19-Jul-11	9	Outside pits (>500m, <1km)	No
Six-mile Well	SMD1169	27°25'13"S	120°34'39"E	260507	6964678	25-Mar-11	30-May-11	20	Inside pit	No
Six-mile Well	SMD1169	27°25'13"S	120°34'39"E	260507	6964678	23-May-11	19-Jul-11	20	Inside pit	No
Six-mile Well	SMD1171	27°25'04"S	120°34'36"E	260427	6964954	25-Mar-11	30-May-11	25	Inside pit	No
Six-mile Well	SMD1171	27°25'04"S	120°34'36"E	260427	6964954	23-May-11	19-Jul-11	25	Inside pit	No
Six-mile Well	SMD1178	27°25'49"S	120°34'23"E	260084	6963579	23-May-11	19-Jul-11	8	Near pit (>300m, <500m)	No
Six-mile Well	SMD1180	27°25'41"S	120°34'21"E	260035	6963804	25-Mar-11	30-May-11	19	Near pit (>300m, <500m)	No
Six-mile Well	SMD1180	27°25'41"S	120°34'21"E	260035	6963804	23-May-11	19-Jul-11	19	Near pit (>300m, <500m)	No
Six-mile Well	SMD1181	27°25'34"S	120°34'27"E	260200	6964039	25-Mar-11	30-May-11	17	Near pit (<200m)	No
Six-mile Well	SMD1181	27°25'34"S	120°34'27"E	260200	6964039	23-May-11	19-Jul-11	17	Near pit (<200m)	No
Six-mile Well	SMD1187	27°25'24"S	120°34'31"E	260291	6964355	23-May-11	19-Jul-11	8	Near pit (<200m)	No
Six-mile Well	YAKAOES01	27°24'54"S	120°34'37"E	260433	6965265	25-Mar-11	30-May-11	14	Inside pit	No
Six-mile Well	YAKAOES01	27°24'54"S	120°34'37"E	260433	6965265	23-May-11	19-Jul-11	14	Inside pit	No
Six-mile Well	YAKAOES02	27°25'20"S	120°34'40"E	260552	6964483	25-Mar-11	30-May-11	6	Inside pit	No
Six-mile Well	YAKAOES02	27°25'20"S	120°34'40"E	260552	6964483	23-May-11	19-Jul-11	5	Inside pit	No
Six-mile Well	YAKAOES03	27°25'46"S	120°34'21"E	260046	6963658	25-Mar-11	30-May-11	14	Near pit (>300m, <500m)	No
Six-mile Well	YAKAOES03	27°25'46"S	120°34'21"E	260046	6963658	23-May-11	19-Jul-11	14	Near pit (>300m, <500m)	No
Waste Rock Landform	YEX162	27°26'36"S	120°36'16"E	263235	6962170	26-Mar-11	30-May-11	9	Outside pits (>1km)	No
Waste Rock Landform	YEX162	27°26'36"S	120°36'16"E	263235	6962170	23-May-11	19-Jul-11	9	Outside pits (>1km)	No
Waste Rock Landform	YEX165	27°26'36"S	120°36'24"E	263434	6962172	26-Mar-11	30-May-11	18	Outside pits (>1km)	No
Waste Rock Landform	YEX165	27°26'36"S	120°36'24"E	263434	6962172	23-May-11	19-Jul-11	18	Outside pits (>1km)	No
Waste Rock Landform	YEX166	27°48'16"S	120°35'52"E	263338	6962137	26-Mar-11	30-May-11	16	Outside pits (>1km)	No
Waste Rock Landform	YEX166	27°48'16"S	120°35'52"E	263338	6962137	23-May-11	19-Jul-11	16	Outside pits (>1km)	No

Appendix B Representative Survey Area Bores

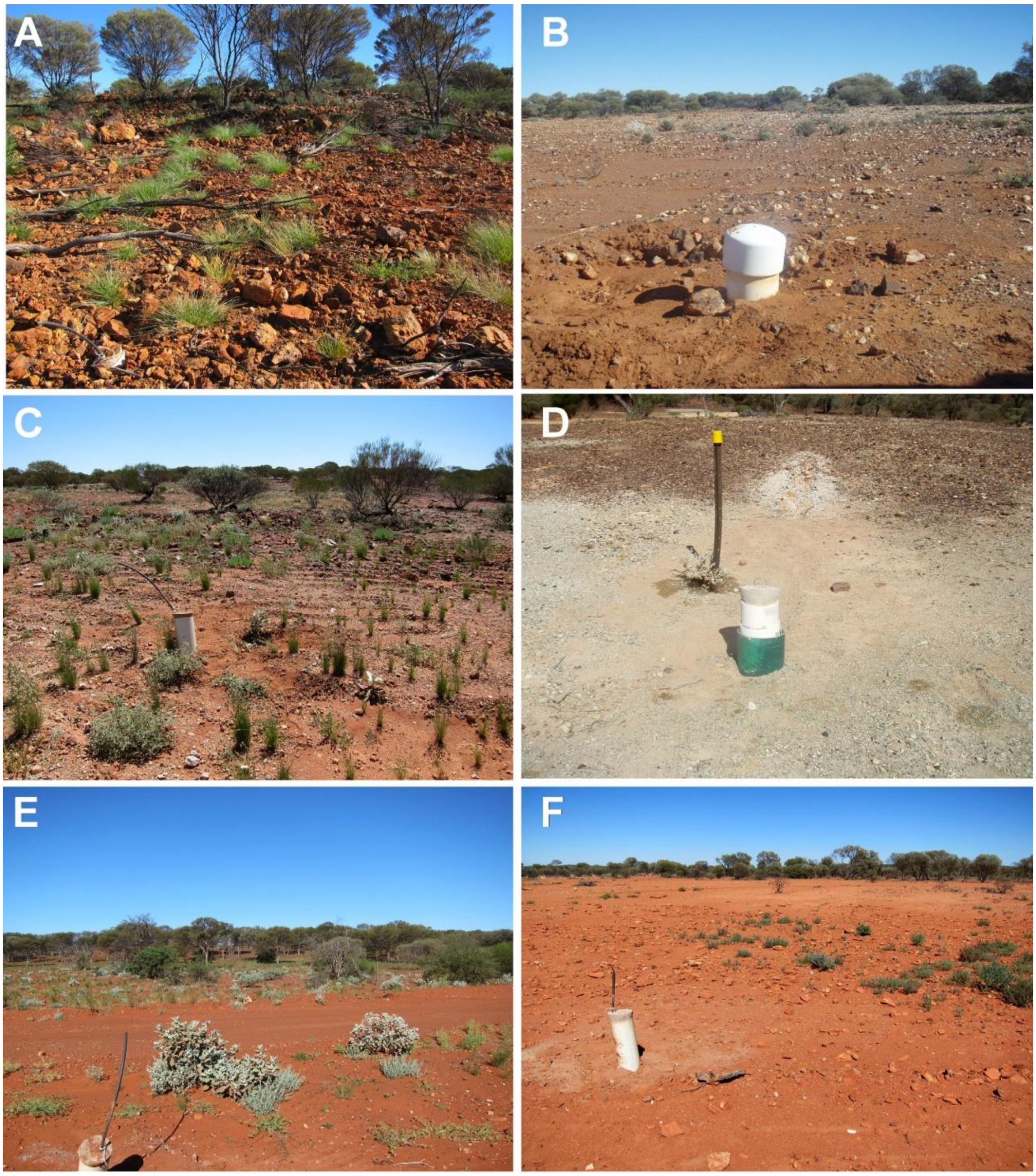

Figure B-1: Representative Project survey area bores; A) GPD1648A, Goliath; B) SHGCN60, Serpentine Hill South; C) YSHD29, Serpentine Hill South; D) CP52, Six-mile Well; E) YEX161, south of Six-mile Well; F) YEX162, Waste Rock Landform.

Appendix C Western Australian Museum (WAM) Arachnida and Myriapoda Database

GROUP	FAMILY	GENUS	SPECIES	SITE	LATITUDE (DECIMAL)	LONGITUDE (DECIMAL)	DATE
				Yeelirrie, 87 km S. of Wiluna	-27.317	120.151	12/01/2010
Araneae	Oonopidae	Opopaea	\`sp. nov.\`	Yeelirrie, 87 km S. of Wiluna, bore YYHC0048H	-27.3166	120.151	17/03/2010
Araneae	Oonopidae	Prethopalpus	callani	Yeelirrie, 87 km S. of Wiluna, bore YYHC0048H	-27.3166	120.151	17/03/2010
Araneae	Sparassidae	Pediana	tenuis	23.7 km SW. of Mt Keith, Albion Downs Borefields, site ADB06B-P6	-27.4025	120.353	/03/2008
Araneae	Trochanteriidae	Desognanops	\`sp. nov. Yeelirrie\`	Yeelirrie Station, bore YYHC0049E	-27.3396	120.151	13/11/2010
Cephalostigmata				Yakabindie Station, MEB site 78	-27.7466	120.524	19/09/2006
Geophilida	Geophilidae			Yeelirrie, 87 km S. of Wiluna	-27.3166	120.151	17/03/2010
Geophilida	Geophilidae			Yeelirrie, 87 km S. of Wiluna	-27.2819	120.111	18/09/2010
Palpigradi				Yeelirrie Station, Yeelirrie Deposit, bore hole SB14-MT (MKC06)	-27.3428	120.242	10/03/2009
Palpigradi	Eukoeneniidae	Eukoenenia	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3444	120.308	18/09/2010
Palpigradi	Eukoeneniidae	Eukoenenia	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3444	120.308	18/09/2010
Palpigradi	Eukoeneniidae	Eukoenenia	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3065	120.218	12/01/2010
Palpigradi	Eukoeneniidae	Eukoenenia	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3444	120.308	12/01/2010
Palpigradi	Eukoeneniidae	Eukoenenia	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3444	120.308	12/01/2010
Palpigradi	Eukoeneniidae	Eukoenenia	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3444	120.308	12/01/2010
Palpigradi	Eukoeneniidae	Eukoenenia	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3444	120.308	12/01/2010
Palpigradi	Eukoeneniidae	Eukoenenia	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3444	120.308	12/01/2010
Palpigradi	Eukoeneniidae	Eukoenenia	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3161	120.151	18/09/2010
Polyxenida				Yeelirrie, 87 km S. of Wiluna	-27.3405	120.151	12/01/2010
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`OES4\`	LT107 / WAM1, 50 km SW. of Wiluna	-27.1374	120.953	20/09/2011
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`OES4\`	LT107, 95 km NE. of Leinster	-27.1374	120.953	18/07/2011
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`OES5\`	LMTF0027 / LMAC0523, 95 km NE. of Leinster	-27.1674	121.084	13/11/2010
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`OES6\`	LT105 / WAM3, 50 km SW. of Wiluna	-27.1377	120.946	20/09/2011
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`OES6\`	LT107, 95 km NE. of Leinster	-27.1374	120.953	18/07/2011
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`sp. indet. (juvenile)\`	Barwidgee Station, bore troglofauna site 105	-27.1375	120.945	20/07/2008
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`sp. nov. Yakabindie Station\`	Yakabindie Station, bore troglofauna site 54	-27.6639	120.61	22/07/2008
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`sp. nov. Yeelirrie\`	Yeelirrie, 87 km S. of Wiluna	-27.3161	120.151	12/01/2010
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3065	120.238	18/09/2010
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3161	120.151	12/01/2010
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3145	120.151	12/01/2010
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3065	120.238	12/01/2010
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3444	120.308	11/03/2010
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3396	120.151	13/11/2009
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3145	120.151	13/11/2009
Pseudoscorpiones	Olpiidae	Austrohorus	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3145	120.151	12/01/2010
Pseudoscorpiones	Olpiidae	Beierolpium	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3145	120.151	12/01/2010
Pseudoscorpiones	Olpiidae	Beierolpium	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3065	120.238	12/01/2010
Pseudoscorpiones	Olpiidae	Beierolpium	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.298	120.168	14/01/2010
Pseudoscorpiones	Olpiidae	Beierolpium	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3145	120.151	18/03/2010
Scolopendrida	Scolopendridae	Scolopendra	morsitans	13.3 km NW. of Mt Keith, Albion Downs Borefields, site ADB17A	-27.2458	120.428	/03/2008

Appendix D Western Australian Museum (WAM) Crustacea Database Search

GROUP	FAMILY	GENUS	SPECIES	SITE	LATITUDE (DECIMAL)	LONGITUDE (DECIMAL)	DATE
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.2479	120.055	18/09/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.2476	120.055	14/01/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.2476	120.055	14/01/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.2476	120.055	20/03/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.2476	120.055	18/03/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.2476	120.055	18/03/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3299	120.151	14/01/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3299	120.151	18/09/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3299	120.151	16/03/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3299	120.151	18/03/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3299	120.151	14/11/2009
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3299	120.151	14/11/2009
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3299	120.151	12/01/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3299	120.151	12/01/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.31	120.15	18/09/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.316	120.151	18/09/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3156	120.151	18/03/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3444	120.308	11/03/2009
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3443	120.308	12/01/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3443	120.308	12/01/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3444	120.308	18/03/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3444	120.308	18/09/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3444	120.308	16/03/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3444	120.308	12/01/2010
Amphipoda	Chiltoniidae		sp. OES1	Leinster	-27.1378	121.034	17/08/2010
Amphipoda	Chiltoniidae		sp. SAM3	Wiluna	-27.1375	120.949	31/01/2012
Amphipoda	Chiltoniidae		sp. SAM4	Leinster	-27.1852	121.066	8/03/2010
Amphipoda	ORDER: Amphipoda			130km south east of Wiluna; WAM1-LT107	-27.1358	120.954	18/07/2011
Amphipoda	ORDER: Amphipoda			130km south east of Wiluna; Little Well	-27.1338	121.004	14/03/2011
Amphipoda	ORDER: Amphipoda			130km south east of Wiluna; LMST008	-27.1377	121.034	14/03/2011
Amphipoda	ORDER: Amphipoda			130km south east of Wiluna; LMST008	-27.1377	121.034	18/07/2011
Amphipoda	ORDER: Amphipoda			130km south east of Wiluna; LMST012	-27.1558	121.036	15/03/2011
Amphipoda	ORDER: Amphipoda			130km south east of Wiluna; LMST012	-27.1558	121.036	18/07/2011
Amphipoda	ORDER: Amphipoda			130km south east of Wiluna; LMST007	-27.1472	121.062	15/03/2011
Amphipoda	ORDER: Amphipoda			130km south east of Wiluna; LMST002	-27.1652	121.064	16/03/2011

GROUP	FAMILY	GENUS	SPECIES	SITE	LATITUDE (DECIMAL)	LONGITUDE (DECIMAL)	DATE
Bathynellecea	Parabathynellidae	Atopobathynella	sp. OES8	Mt. Keith	-27.423	120.576	18/11/2010
Bathynellecea	Parabathynellidae	Atopobathynella	sp. OES9		-27.4587	120.5805	27/03/2011
Copepoda				LMST014	-27.165	121.048	15/03/2011
Copepoda				Lake Way South; 50km SE of Leinster	-26.9849	120.643	18/06/2011
Copepoda				Lake Way South; 50km SE of Leinster	-27.0012	120.745	27/03/2011
Copepoda				Lake Way South; 50km SE of Leinster	-27.0012	120.745	27/03/2011
Copepoda				Lake Way South; 50km SE of Leinster	-27.0011	120.745	18/06/2011
Cyclopoida	Cyclopidae	Halicyclops	microeberherdi n. sp.	LMST008	-27.1333	121.033	17/08/2010
Cyclopoida	Cyclopidae	Halicyclops	microeberherdi n. sp.	LMST014	-27.165	121.048	17/08/2010
Cyclopoida	Cyclopidae	Halicyclops	microeberherdi n. sp.	LMST004	-27.1666	121.05	17/08/2010
Cyclopoida	Cyclopidae	Halicyclops	microeberherdi n. sp.	LMST006	-27.15	121.05	17/08/2010
Cyclopoida	Cyclopidae	Mesocyclops	brooksi	Site 419, "The Other Home Well", Yeeleerie Station	-27.2816	120.093	27/06/2000
Cyclopoida	Cyclopidae	Mesocyclops	brooksi	Townsend Well, Yakabindie Station	-27.655	120.687	29/06/2000
Cyclopoida	Cyclopidae	Microcyclops	varicans	6 Mile Bore	-27.0361	121.062	18/08/2010
Cyclopoida	ORDER: Cyclopoida			130km south east of Wiluna; WAM1-LT107	-27.1358	120.954	18/07/2011
Cyclopoida	ORDER: Cyclopoida			130km south east of Wiluna; Little Well	-27.1338	121.004	18/07/2011
Cyclopoida	ORDER: Cyclopoida			130km south east of Wiluna; LMST012	-27.1558	121.036	18/07/2011
Cyclopoida	ORDER: Cyclopoida			130km south east of Wiluna; LMACW69	-26.9808	121.092	18/07/2011
Cyclopoida				TB18	-26.982	120.676	1/02/2012
Cyclopoida				LMST008	-27.1333	121.033	14/03/2011
Cyclopoida				LMST012	-27.1558	121.036	15/03/2011
Cyclopoida				LT105	-27.1362	120.948	31/01/2012
Cyclopoida				LT104	-27.1361	120.951	31/01/2012
Cyclopoida				LT107	-27.1359	120.954	31/01/2012
Cyclopoida				SCP1111	-26.9849	120.643	17/11/2011
Cyclopoida				TB1-8	-26.982	120.676	17/11/2011
Cyclopoida				Lake Way South	-27.0011	120.745	27/03/2011
Cyclopoida				WAM3	-27.1362	120.948	18/11/2011
Cyclopoida				WAM1	-27.1359	120.954	22/09/2011
Cyclopoida				WAM1	-27.1359	120.954	18/11/2011
Cyclopoida				Little Well	-27.1338	121.004	14/03/2011
Cyclopoida				Little Well	-27.1338	121.004	9/03/2010
Cyclopoida				EH01	-27.1852	121.066	8/03/2010

GROUP	FAMILY	GENUS	SPECIES	SITE	LATITUDE (DECIMAL)	LONGITUDE (DECIMAL)	DATE
Harpacticoida	Ameiridae	Nitocra	lacustris	Little Well	-27.1338	121.004	18/08/2010
Harpacticoida	Ameiridae	Nitokra	esbe	bore SB14-1	-27.3443	120.308	18/03/2010
Harpacticoida	Ameiridae	Nitokra	esbe	bore SB14-1	-27.3443	120.308	18/03/2010
Harpacticoida	Ameiridae	Nitokra	esbe	bore SB14-1	-27.3443	120.308	18/03/2010
Harpacticoida	Ameiridae	Nitokra	yeelirrie	Bore line N, bore YYHC0067B, Yilgarn region	-27.3064	120.225	23/09/2010
Harpacticoida	Ameiridae	Nitokra	yeelirrie	bore YYHC0067B, bore line N	-27.3064	120.225	23/09/2010
Harpacticoida	Ameiridae	Nitokra	yeelirrie	Bore line K, bore YYHC085B	-27.2478	120.055	20/03/2010
Harpacticoida	Ameiridae	Nitokra	yeelirrie n. sp.	Yeelirrie station	-27.3441	120.308	10/03/2009
Harpacticoida	Miraciidae	Schizopera	akation	Yeelirrie station	-27.3441	120.308	18/03/2010
Harpacticoida	Miraciidae	Schizopera	akation sp. nov.	Yeelirrie station	-27.3441	120.308	18/03/2010
Harpacticoida	Miraciidae	Schizopera	akation sp. nov.	Yeelirrie station	-27.3441	120.308	18/03/2010
Harpacticoida	Miraciidae	Schizopera	analspinulosa	Yeelirrie station	-27.3441	120.308	18/03/2010
Harpacticoida	Miraciidae	Schizopera	analspinulosa	Yeelirrie station	-27.3441	120.308	18/03/2010
Harpacticoida	Miraciidae	Schizopera	analspinulosa	Yeelirrie station	-27.3441	120.308	18/03/2010
Harpacticoida	Miraciidae	Schizopera	analspinulosa	Yeelirrie station	-27.3297	120.151	18/03/2010
Harpacticoida	Miraciidae	Schizopera	analspinulosa	Yeelirrie station	-27.3297	120.151	18/03/2010
Harpacticoida	Miraciidae	Schizopera	analspinulosa	Yeelirrie station	-27.3297	120.151	18/03/2010
Harpacticoida	Miraciidae	Schizopera	analspinulosa	Yeelirrie station	-27.3297	120.151	18/03/2010
Harpacticoida	Miraciidae	Schizopera	analspinulosa n. sp.	Yeelirrie station	-27.3441	120.308	18/03/2010
Harpacticoida	Miraciidae	Schizopera	analspinulosa s. str	Yeelirrie station	-27.3441	120.308	18/03/2010
Harpacticoida	Miraciidae	Schizopera	analspinulosa s.str	Yeelirrie station	-27.3441	120.308	18/03/2010
Harpacticoida	Miraciidae	Schizopera	dimorpha n. sp.	LMST011	-27.1472	121.054	18/08/2010
Harpacticoida	Miraciidae	Schizopera	dimorpha n. sp.	LMST006	-27.15	121.05	17/08/2010
Harpacticoida	ORDER: Harpacticoida			130km south east of Wiluna; WAM1-LT107	-27.1358	120.954	18/07/2011
Harpacticoida	ORDER: Harpacticoida			130km south east of Wiluna; Little Well	-27.1338	121.004	18/07/2011
Harpacticoida	ORDER: Harpacticoida			130km south east of Wiluna; LMST008	-27.1377	121.034	18/07/2011
Harpacticoida	ORDER: Harpacticoida			130km south east of Wiluna; LMST012	-27.1558	121.036	18/07/2011
Harpacticoida	Parastenocarididae	Kinnecaris	esbe sp. nov.	SB14-1	-27.3443	120.308	18/03/2010
Harpacticoida	Parastenocarididae	Kinnecaris	esbe sp. nov.	SB14-1	-27.3443	120.308	18/03/2010
Harpacticoida	Parastenocarididae	Kinnecaris	esbe sp. nov.	SB14-1	-27.3443	120.308	18/03/2010

GROUP	FAMILY	GENUS	SPECIES	SITE	LATITUDE (DECIMAL)	LONGITUDE (DECIMAL)	DATE
Harpacticoida	Parastenocarididae	Kinnecaris	lined	bore line D	-27.2828	120.111	23/09/2010
Harpacticoida	Parastenocarididae	Kinnecaris	lined sp. nov.	bore line D	-27.2828	120.111	23/09/2010
Harpacticoida	Parastenocarididae	Kinnecaris	lined sp. nov.	bore line D	-27.2828	120.111	23/09/2010
Harpacticoida	Parastenocarididae	Kinnecaris	lined sp. nov.	bore line D	-27.2828	120.111	23/09/2010
Harpacticoida	Parastenocarididae	Kinnecaris	lined sp. nov.	bore line D	-27.2828	120.111	23/09/2010
Harpacticoida	Parastenocarididae	Kinnecaris	lined sp. nov.	bore line D	-27.2828	120.111	23/09/2010
Harpacticoida	Parastenocarididae	Kinnecaris	lined sp. nov.	bore line D	-27.2828	120.111	23/09/2010
Harpacticoida	Parastenocarididae	Kinnecaris	linel sp. nov.	bore line L, Snake Well	-27.3073	120.151	18/03/2010
Harpacticoida	Parastenocarididae	Kinnecaris	linel sp. nov.	bore line L, Snake Well	-27.3073	120.151	18/03/2010
Harpacticoida	Parastenocarididae	Kinnecaris	linel sp. nov.	bore line L, Snake Well	-27.3073	120.151	18/03/2010
Harpacticoida	Parastenocarididae	Kinnecaris	linel sp. nov.	bore line L, Snake Well	-27.3073	120.151	18/03/2010
Harpacticoida	Parastenocarididae	Kinnecaris	linel sp. nov.	bore line L, Snake Well	-27.3073	120.151	18/03/2010
Harpacticoida	Parastenocarididae	Kinnecaris	linel sp. nov.	bore line L, Snake	-27.3073	120.151	18/03/2010
Harpacticoida	Parastenocarididae	Kinnecaris	uranusi	bore line K	-27.2478	120.055	20/03/2010
Harpacticoida	Parastenocarididae	Kinnecaris	uranusi	bore line K	-27.2478	120.055	20/03/2010
Harpacticoida				LMST012	-27.1558	121.036	17/08/2010
Harpacticoida				SCP1111	-26.9849	120.643	31/01/2012
Harpacticoida				LT105	-27.1362	120.948	31/01/2012
Harpacticoida				LT107	-27.1359	120.954	18/11/2011
Harpacticoida				LT107	-27.1359	120.954	21/09/2011
Harpacticoida				LT107	-27.1359	120.954	31/01/2012
Harpacticoida				1109D	-26.9673	120.638	17/11/2011
Harpacticoida				SCP1111	-26.9849	120.643	17/11/2011
Harpacticoida				TB1-8	-26.982	120.676	17/11/2011
Harpacticoida				Lake Way South	-27.0005	120.745	17/11/2010
Harpacticoida				Lake Way South	-27.0011	120.745	17/11/2010
Harpacticoida				Lake Way South	-27.0011	120.745	27/03/2011
Harpacticoida				TB7-7	-27.0011	120.745	16/11/2011
Harpacticoida				TB7-7	-27.0011	120.745	16/11/2011

GROUP	FAMILY	GENUS	SPECIES	SITE	LATITUDE (DECIMAL)	LONGITUDE (DECIMAL)	DATE
Harpacticoida				WAM3	-27.1362	120.948	18/11/2011
Harpacticoida				WAM2	-27.1361	120.951	18/11/2011
Harpacticoida				Little Well	-27.1338	121.004	9/03/2010
Harpacticoida				EH01	-27.1852	121.066	8/03/2010
Harpacticoida				LMST012	-27.1558	121.036	15/03/2011
Isopoda	Paraplatyarthridae	Paraplatyarthrus	cooperi sp. nov.	Lake Miranda East calcrete	-27.664	120.61	8/08/2011
Isopoda	Paraplatyarthridae	Paraplatyarthrus	cooperi sp. nov.	Lake Miranda East calcrete	-27.664	120.61	8/08/2011
Isopoda	Paraplatyarthridae	Paraplatyarthrus	cooperi sp. nov.	Lake Miranda East calcrete	-27.664	120.61	8/08/2011
Isopoda	Paraplatyarthridae	Paraplatyarthrus	cooperi sp. nov.	Lake Miranda East calcrete	-27.664	120.61	8/08/2011
Isopoda	Paraplatyarthridae	Paraplatyarthrus	cooperi sp. nov.	Lake Miranda East calcrete	-27.664	120.61	8/08/2011
Isopoda	Paraplatyarthridae	Paraplatyarthrus	cooperi sp. nov.	Lake Miranda East calcrete	-27.664	120.61	8/08/2011
Isopoda	Scyphacidae	Haloniscus	sp. OES1	Leinster	-27.1528	121.082	24/05/2007
Isopoda	Scyphacidae	Haloniscus	sp. OES12	Leinster	-27.1566	121.093	24/05/2007
Ostracoda				130km south east of Wiluna; Little Well	-27.1338	121.004	18/07/2011
Ostracoda				CP52	-27.431	120.575	2/02/2012
Ostracoda				WAM3	-27.1362	120.948	18/11/2011
Ostracoda				Little Well	-27.1338	121.004	9/03/2010
Ostracoda				LMST006	-27.15	121.05	17/08/2010
Syncarida				130km south east of Wiluna; WAM3-LT105	-27.1363	120.948	18/07/2011

Appendix E Groundwater Physico-chemical Data

Table E-1: Recorded groundwater parameters. DO = dissolved oxygen; Temp = temperature; SWL = standing water level; EoH = end of hole.

Project Area	Bore ID	Date	D.O. (ppm)	Temp (°C)	Salinity (ppm)	pH	Redox (mV)	SWL (m bgl)	EoH (m bgl)
Goliath	95GPG07	18/11/2010	4.66	26.5	7730	7.35	174	33.15	72.9
Goliath	95GPG07	29/03/2011	4.13	25.5		7.35	135	33.3	75.6
Goliath	95GPG11	18/11/2010	4.91	25.7	1055	7.87	147	27.4	57.6
Goliath	95GPG11	29/03/2011	5.48	24.8		7.74	87	26.1	59.4
Goliath	CP11	18/11/2010	4.91	26	824	7.84	159	26.06	58.5
Goliath	CP11	29/03/2011	5.05	26.1		7.67	24	26.1	32.4
Goliath	CP21	18/11/2010	6.75	26.1	2120	7.71	155	29.1	61.2
Goliath	CP53	18/11/2010	4.03	26.6	2250	7.39	149	20.93	64.8
Goliath South	CP5P	16/11/2010	6.64	26.8	848	7.98	101	25.25	69.3
Goliath South	CP5P	28/03/2011	4.65			7.4		25.45	66.6
Goliath South	CP6P	16/11/2010	4.35	26.1	425	7.46	110	21.84	33.3
Goliath South	CP6P	28/03/2011	4.59	24.3		7.18	176		31.5
Goliath South	CP6P	21/06/2011	5.64	21.1	283	7.92	90	21.77	200
Goliath South	YEX82	16/11/2010	4.55	26.6	1310	7.99	109	19.8	66.6
Goliath South	YEX82	28/03/2011	4.6	24.9		8.01	193		30.6
Goliath South	YEX82	21/06/2011	3	18.7	1180	8.06	64	20.06	200
Serp Hill South	CP13P	18/11/2010	5.68	24.9	857	7.93	188	11.08	79.2
Serp Hill South	CP13P	28/03/2011	6.12	25.5		7.33	156	10.8	59.4
Serp Hill South	CP13P	17/06/2011	6.16	24.1	4.39	7.61	53	11.6	90
Serp Hill South	CP22P	16/11/2010	3.33	26.3	1370	7.49	121	12.17	51.3
Serp Hill South	CP22P	28/03/2011	6.05	25.7		7.31	113	11.7	46.8
Serp Hill South	CP22P	21/06/2011	3.92	21.7	1089	7.51	63	11.9	90
Serp Hill South	SHGCN60	18/11/2010	5.09	25.2	2070	7.72	182	16	81.9
Serp Hill South	SHGCN60	28/03/2011	5.55	26.2		7.68	134	15.3	59.4
Serp Hill South	SHGCN60	21/06/2011	6.83	22	1930	7.88	88	15.63	64
Serp Hill South	SHGCN62	16/11/2010	2.78	26.6	1122	7.51	121	16.24	45
Serp Hill South	SHGCN62	28/03/2011	4.61	26		7.87	133	15.3	81
Serp Hill South	SHGCN62	21/06/2011	3.65	23.3	1490	8.14	74	16.12	60.3
Serp Hill South	SHNP2	18/11/2010	5.62	26	1840	8	172	15.17	81
Serp Hill South	SHNP2	28/03/2011	5	25.8		7.93	134	16.2	51.3
Serp Hill South	SHNP2	21/06/2011	6.82	22.6	1820	8.4	73	15.22	38.7

Project Area	Bore ID	Date	D.O. (ppm)	Temp (°C)	Salinity (ppm)	pH	Redox (mV)	SWL (m bgl)	EoH (m bgl)
Serp Hill South	SHSP1	16/11/2010	6.03	26.4	1168	8.33	87	12.95	62.1
Serp Hill South	SHSP1	28/03/2011	4.71	26.2		8.04	109	13.5	45
Serp Hill South	SHSP1	21/06/2011	5.8	21.7	1148	8.56	83	12.77	38.7
Serp Hill South	SHSP2	16/11/2010	4.31	26.1	1270	7.15	47	20.85	54.9
Serp Hill South	SHSP2	28/03/2011	4.14	26		6.98	88	19.8	99
Serp Hill South	SHSP2	21/06/2011	3.57	21.9	1610	7.3	-63	20.7	36.9
Sheba	SBD3	16/11/2010	6.63	28.1	1176	7.74	124	27.1	60.3
Sheba	SBD3	28/03/2011	7.77	23.6		7.77	132	26.04	90
Six-mile Well	CP51	18/11/2010	3.37	27.1	2550	6.87	136	27.54	38.7
Six-mile Well	CP51	29/03/2011	3.7	22.3		6.71	119	28.8	38.7
Six-mile Well	CP51	17/06/2011	5.71	23.8	2360	7.08	-192	26.35	36.9
Six-mile Well	CP52	18/11/2010	6.3	27.3	4860	7.28	154	23.03	64
Six-mile Well	CP52	29/03/2011	6.25	22.7		7.21	71	23.4	60.3
Six-mile Well	CP52	17/06/2011	5.27	24.5	3810	7.65	41	22.42	60.3
Waste Rock Landform	YEX162	17/06/2011	4.09	23.1		8.23	181	22.99	49.5
Waste Rock Landform	YEX166	17/06/2011	4.05	23.9	482	8.25	152	24.3	62.1

Appendix F Subterranean Fauna Survey Results

Table F-1: Subterranean fauna survey results (including Biota 2006) sorted by taxon.

Group	Family	Taxon	No. Individuals	Project Area	Bore Code	Eastings (51 J: GDA)	Northings (51 J: GDA)	Location	Sample Start Date	Sample End Date	Sampling method
Stygofauna Results											
Amphipoda	Neoniphargidae	Neoniphargidae	2	Goliath	YAKB06	260859	6961556	Near pit (<200m)	2006		Net Haul
Bathynellacea	Bathynellidae	Bathynellidae sp. OES2	1	Serp Hill South	CP22P	260885	6960426	Outside pits (>500m, <1km)	21-Jun-11		Net Haul
Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES11	1	Six Mile Well	CP51	260542	6964526	Inside Pit	2-Feb-12		Net Haul
Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES8	1	Six Mile Well	CP51	260542	6964526	Inside Pit	18-Nov-10		Net Haul
Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES9	1	Serp Hill South	CP22P	260885	6960426	Outside pits (>500m, <1km)	21-Jun-11		Net Haul
Oligochaeta		Oligochaeta	1	Goliath	CP21	261862	6961621	Inside Pit	2006		Net Haul
Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES10	7	Serp Hill South	CP13P	259844	6959931	Outside pits (>1km)	2-Feb-12		Net Haul
Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES10	3	Six Mile Well	CP51	260542	6964526	Inside Pit	17-Jun-11		Net Haul
Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES10	7	Six Mile Well	CP51	260542	6964526	Inside Pit	18-Nov-10		Net Haul
Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES10	50	Six Mile Well	CP51	260542	6964526	Inside Pit	2-Feb-12		Net Haul
Ostracoda	Limnocytheridae	*Gomphodella* sp. IK2	2	Six Mile Well	CP52	260394	6963644	Near pit (>300m, <500m)	2-Feb-12		Net Haul
Troglofauna Results											
Diplura	Campodeidae	Campodeidae sp. OES2	1	Serp Hill South	SHGCN62	260873	6960741	Outside pits (>500m, <1km)	3-Feb-12		Scrape
Isopoda	Amardillidae	*Buddelundia* sp. OES3	1	Serp Hill South	YSHD29	260717	6960666	Outside pits (>500m, <1km)	26-Mar-11	30-May-11	Litter trap
Isopoda	Amardillidae	*Buddelundia* sp. OES3	1	Serp Hill South	YSHD29	260717	6960666	Outside pits (>500m, <1km)	30-May-11	19-Jul-11	Litter trap

Table F-2: Subterranean fauna survey results (including Biota 2006) sorted by Project Area and bore.

Project Area	Bore Code	Eastings (51 J: GDA)	Northings (51 J: GDA)	Location	Sample Start Date	Sample End Date	Sampling method	Group	Family	Taxon	No. Individuals
Stygofauna Results											
Goliath	CP21	261862	6961621	Inside Pit	2006		Net Haul	Oligochaeta		Oligochaeta	1
Goliath	YAKB06	260859	6961556	Near pit (<200m)	2006		Net Haul	Amphipoda	Neoniphargidae	Neoniphargidae	2
Serp Hill South	CP13P	259844	6959931	Outside pits (>1km)	2-Feb-12		Net Haul	Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES10	7
Serp Hill South	CP22P	260885	6960426	Outside pits (>500m, <1km)	21-Jun-11		Net Haul	Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES9	1
Serp Hill South	CP22P	260885	6960426	Outside pits (>500m, <1km)	21-Jun-11		Net Haul	Bathynellacea	Bathynellidae	Bathynellidae sp. OES2	1
Six Mile Well	CP51	260542	6964526	Inside Pit	18-Nov-10		Net Haul	Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES10	7
Six Mile Well	CP51	260542	6964526	Inside Pit	18-Nov-10		Net Haul	Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES8	1
Six Mile Well	CP51	260542	6964526	Inside Pit	17-Jun-11		Net Haul	Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES10	3
Six Mile Well	CP51	260542	6964526	Inside Pit	2-Feb-12		Net Haul	Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES11	1
Six Mile Well	CP51	260542	6964526	Inside Pit	2-Feb-12		Net Haul	Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES10	50
Six Mile Well	CP52	260394	6963644	Near pit (>300m, <500m)	2-Feb-12		Net Haul	Ostracoda	Limnocytheridae	*Gomphodella* sp. IK2	2
Troglofauna Results											
Serp Hill South	YSHD29	260717	6960666	Outside pits (>500m, <1km)	26-Mar-11	30-May-11	Litter trap	Isopoda	Amardillidae	*Buddelundia* sp. OES3	1
Serp Hill South	YSHD29	260717	6960666	Outside pits (>500m, <1km)	30-May-11	19-Jul-11	Litter trap	Isopoda	Amardillidae	*Buddelundia* sp. OES3	1
Serp Hill South	SHGCN62	260873	6960741	Outside pits (>500m, <1km)	3-Feb-12		Scrape	Diplura	Campodeidae	Campodeidae sp. OES2	1