REPORT

MOUNT KEITH SATELLITE OPERATIONS STYGOFAUNA ASSESSMENT

PREPARED FOR BHP NICKEL WEST

November 2017

Atopobathynella sp. OES9

MWH® now part of Stantec

This document has been prepared for the benefit of BHP Nickel West. No liability is accepted by this company or any employee or sub-consultant of this company with respect to its use by any other person.

This disclaimer shall apply notwithstanding that the report may be made available to other persons for an application for permission or approval to fulfil a legal requirement.

QUALITY STATEMENT

PROJECT MANAGER	PROJECT TECHNICAL LEAD
Brooke Hay	Dr Nicholas Stevens

PREPARED BY		
Dr Nicholas Stevens	....	28/09/2017
CHECKED BY		
Dr Nicholas Stevens	....	28/09/2017
REVIEWED BY		
Dr David Jasper	....	29/09/2017
APPROVED FOR ISSUE BY		
Dr Nicholas Stevens	....	02/10/2017

This document is confidential. Neither the whole nor any part of this document may be disclosed to any third party without the prior written approval of Stantec and BHP Nickel West.

Stantec Australia Pty Ltd undertook the work, and prepared this document, in accordance with specific instructions from BHP Nickel West to whom this document is addressed, within the time and budgetary requirements of BHP Nickel West. The conclusions and recommendations stated in this document are based on those instructions and requirements, and they could change if such instructions and requirements change or are in fact inaccurate or incomplete.

Stantec Australia Pty Ltd has prepared this document using data and information supplied to Stantec Australia Pty Ltd by BHP Nickel West and other individuals and organisations, most of whom are referred to in this document. Where possible, throughout the document the source of data used has been identified. Unless stated otherwise, Stantec Australia Pty Ltd has not verified such data and information. Stantec Australia Pty Ltd does not represent such data and information as true or accurate, and disclaims all liability with respect to the use of such data and information. All parties relying on this document, do so entirely at their own risk in the knowledge that the document was prepared using information that Stantec Australia Pty Ltd has not verified.

This document is intended to be read in its entirety, and sections or parts of the document should therefore not be read and relied on out of context.

The conclusions and recommendations contained in this document reflect the professional opinion of Stantec Australia Pty Ltd, using the data and information supplied. Stantec Australia Pty Ltd has used reasonable care and professional judgment in its interpretation and analysis of the data. The conclusions and recommendations must be considered within the agreed scope of work, and the methodology used to carry out the work, both of which are stated in this document.

This document was intended for the sole use of BHP Nickel West and only for the use for which it was prepared, which is stated in this document. Any representation in the document is made only to BHP Nickel West. Stantec Australia Pty Ltd disclaims all liability with respect to the use of this document by any third party, and with respect to the use of and reliance upon this document by any party, including BHP Nickel West for a purpose other than the purpose for which it was prepared.

Stantec Australia Pty Ltd has conducted environmental field monitoring and/or testing for the purposes of preparing this document. The type and extent of monitoring and/or testing is described in the document.

Subject to the limitations imposed by the instructions and requirements of BHP Nickel West, the monitoring and testing have been undertaken in a professional manner, according to generally-accepted practices and with a degree of skill and care which is ordinarily exercised by reputable environmental consultants in similar circumstances. Stantec Australia Pty Ltd makes no other warranty, express or implied.

Maps produced by Stantec Australia Pty Ltd may be compiled from multiple external sources and therefore Stantec Australia Pty Ltd does not warrant that the maps provided are error free. Stantec Australia Pty Ltd does not purport to represent precise locations of cadastral corners or the surveyed dimensions of cadastral boundaries. Stantec Australia Pty Ltd gives no warranty in relation to mapping data (including accuracy, reliability, completeness or suitability) and accepts no liability for any loss, damage or costs relating to any use of the data.

PERTH
41 Bishop Street, JOLIMONT, WA 6014
TEL +61 (08) 9388 8799

REVISION SCHEDULE

Rev No.	Date	Description	Signature or Typed Name (documentation on file)			
			Prepared by	Checked by	Reviewed by	Approved by
1	28/09/2017	Draft	N.Stevens	N.Stevens		N.Stevens
2	29/09/2017	Internally Reviewed Draft	N.Stevens	N.Stevens	D.Jasper	N.Stevens
3	5/10/2017	Client Reviewed Final	N.Stevens	N.Stevens	Marc Morris (BHP)	N.Stevens
4	16/10/2017	Client Reviewed Final	N.Stevens	N.Stevens	Annette Latto (BHP)	N.Stevens
5	13/11/2017	Peered Reviewed Final	N.Stevens	N.Stevens	S. Halse (Bennelongia)	N.Stevens

Executive Summary

BHP 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 Northeastern Goldfields region of Western Australia. Stantec (formerly MWH) was commissioned to complete a stygofauna assessment of the proposed Project. A previous subterranean fauna assessment completed by Stantec had found that troglofauna did not represent a key environmental factor, but further work was required to complete a Level 2 stygofauna assessment.

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 operation. Waste rock will be directed to a waste rock landform adjacent to the mining operations.

The objective of the study reported here was to complete a Level 2 stygofauna assessment and to assess the potential environmental impacts and conservation risks posed by the removal or modification of potential stygofauna habitat to any stygofauna species recorded within the Project's Study Area. The scope of this study encompassed a literature review, database searches and stygofauna sampling of the Study Area.

Stygofauna Sample Effort

The stygofauna survey effort, summarised in **ES Table 1**, involved 221 net haul samples from 61 bores collected over eight sample rounds, 2006 (Biota), November 2010, March 2011 June 2011 February 2012, March, May and August 2017 by Stantec.

ES Table 1: Stygofauna survey effort

Area		2006 - 2012	2017	No. Samples	No. Bores
Inside Proposed Pit Boundaries	Goliath	12	9	21	6
	Six Mile Well	4	18	22	7
Outside Pits	<500m	8	45	53	15
	>500m, <1km	22	50	72	18
	>1km	18	35	53	15
Totals		**64**	**157**	**221**	**61**

Stygofauna Results

Ten taxa from four higher level taxonomic groups (Amphipoda, Bathynellacea, Oligochaeta, and Ostracoda) were collected in 12 of the 221 samples taken from eight of the 61 bores sampled. Only two bores (SMW18 and GOL20) recorded multiple species and yielded stygofauna specimens on more than one occasion. The remaining six bores only ever had one species recorded, and only on one occasion despite repeated sampling.

The Bathynellacea was represented by four species, *Atopobathynella* sp. OES8, *A*. sp. OES9, *A*. sp. OES11, and Bathynellidae sp. OES2. The Oligochaeta were represented by two semi-aquatic enchytraeid species, Enchytraeidae sp. OES10 and Enchytraeidae sp. OES23, and a stygobitic worm, Phreodrillidae sp. OES23. An indeterminate oligochaete specimen collected by Biota in 2006 could not be substantiated and taxonomically aligned with other oligochaete species recorded from the Study Area. However, the habitat from which it was collected indicates it is likely to be a semi-aquatic enchytraeid species. The Ostracoda was represented by a single species, *Gomphodella* sp. IK2, recorded from one sample only. The Amphipoda material was collected by Biota in 2006 and could not be located for further examination and so remains as an indeterminate taxa.

Atopobathynella sp. OES8 was found to be the most widespread species, with a range found to extend for over 4 km from the Six Mile Well pit area (SMW18) to the Goliath non-impact area (GOL20). *Atopobathynella* sp. OES11 was the only other stygofauna species to have been collected from more than one bore location;

SMW18 inside the proposed Six Mile Well pit as well as SMW22 from outside the proposed pit boundary but within the modelled groundwater drawdown associated with Six Mile Well pit dewatering. Genetic analysis revealed *Atopobathynella* sp. OES11 to exhibit a relatively high CO1 haplotype diversity within a very limited geographical area, indicating the presence of a larger and more widespread population than shown by location records.

The remaining eight species were each recorded from single bore locations only: Five species, *Atopobathynella* sp. OES9, Bathynellidae sp. OES2, Enchytraeidae sp. OES10, Neoniphargidae sp. and Phreodrillidae sp. OES23, from single locations outside proposed impact areas; one species, *Gomphodella* sp. IK2 from within the Six Mile Well modelled groundwater drawdown zone; the two remaining taxa, the indeterminate Oligochaeta and Enchytraeidae sp. OES23, have each only been recorded from inside the proposed pits, Goliath and Six Mile Well, respectively.

Species Richness Estimates and Survey Adequacy

The species richness predicted to occur across the Study Area ranged from 11 to 16 species. Five of the seven species richness estimators had reached a plateau or were trending downwards. The sampling completed was estimated to have recorded between 63 to 94 % of the assemblage predicted to exist. The extrapolation to a 100 % increase in survey effort (441 samples) predicts that an additional two to three species would be collected.

The total number of stygofauna samples collected as part of this assessment (221; 94 impact) does provide a reliable characterisation of the stygofauna values present in the Study Area and in relation to the proposed direct impact zones. Additional sampling is highly unlikely to further refine the knowledge of the stygofauna assemblage present when taking into consideration the low number of samples (12 of 221) and bores (8 of 61) that recorded stygofauna. The infrequent collection of stygofauna is further highlighted by the fact that from the repeated sampling of the eight bores that had recorded stygofauna, only two bores (GOL20 and SMW18) yielded stygobitic taxa on more than one occasion. Due to the sporadic and limited collection of stygofauna from bores with positive records, further targeted sampling is not considered warranted as would be unlikely to further elucidate stygofauna values within the Study Area.

Proposed Impacts

The two main direct potential impacts on the stygofauna assemblage 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. Both pit excavation and lower groundwater levels pose varying degrees of risk to the conservation of four of the ten stygofauna species that were only recorded from within the proposed mining areas and/or modelled groundwater drawdown zones.

Stygofauna Distributions and Habitat

The low diversity and sporadic occurrence (both spatially and temporally) of stygofauna collected from the Study Area correlates with the overall hydrogeological assessment that the regolith, alluvial and fractured rock aquifers present are minor and relatively hydraulically isolated, with many portions of the Project Area lacking suitable habitat to support stygofauna. The northern, western and eastern portions of the Six Mile Well Project Area, and the Goliath deposit area and southern Goliath reference areas, were confirmed to not host prospective stygofauna habitat as the saturated strata are entirely fresh bedrock and/or heavily clay dominated with no stygobitic species collected despite repeated sample rounds since 2010.

The southern portion of the Six Mile Well Project Area, between the confluence area of the upper Jones Creek and one of its tributaries, was confirmed to host prospective stygofauna habitat within the unconfined portion of the regolith aquifer present, where no thick confining/semi-confining clay dominated strata existed. Stygobitic taxa were recorded from three bores (SMW18, SMW22 and SMW24) that intercepted the unconfined weathered ultramafic and fractured bedrock near to incised drainage channels. Outside of the Six Mile Well Project area only two bores (GOL08 and GOL20) each located near to drainage lines have confirmed records of stygobitic taxa. Both bores do not intercept weathered ultramafic regolith aquifers demonstrating that stygofauna habitat is not confined to regolith aquifers in the Project Area such as those that occur within each of the deposit areas.

The irregular and patchy nature of the stygofauna habitat present is evident to a high degree in the Study Area. The stygofauna inhabited areas appear to be along narrow pathways in the form of a dendritic network across the Study Area. The inhabited network does appear to mimic the main drainage channels with most of the bores recording stygofauna located near incised water courses. Such locations would likely receive higher surface water infiltration rates (i.e. resource influx) and greater degree of weathering of geological units and structures present leading to higher level of secondary porosity (i.e. habitable space).

The distributions and genetic diversity exhibited by *Atopobathynella* sp. OES8 and *Atopobathynella* sp. OES11 do support the hydrogeological information that the habitable portion of the Six Mile Well regolith aquifer system is hydraulically connected to a network of other regolith and fractured rock aquifers associated with the upper Jones Creek catchment. The distribution of *Atopobathynella* sp. OES8 demonstrates that the hydraulic network extends at least to the non-impact zones within the Goliath Project Area. However, the possibility does exist that the network extends further south along Jones Creek and associated main tributaries. Most of the bores sampled since 2010 that had confirmed positive stygofauna records were set in or adjacent to ephemeral drainage channels 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 middle to upper Jones Creek catchment.

Impact Assessment

The stygofauna results have revealed the stygofauna assemblage to be sparsely distributed and infrequently collected. The low stygofauna abundance and sporadic occurrence (both spatially and temporally) does make it difficult to reliably assess the potential risks posed by the development of the Project to the stygofauna assemblage recorded. However, the biological and hydrogeological evidence available does indicate that the distribution patterns of the stygofauna recorded are dendritic-like, reflecting the habitable groundwater networks closely associated with the main drainage channels, and therefore considered to extend beyond each of their recorded locations as shown by *Atopobathynella* sp. OES8 whose range extends for over 4 km from the Six Mile Well pit area to the Goliath non-impact area.

Of the ten stygofauna taxa recorded from the Study Area, four species of the assemblage have each only been recorded from within proposed pit boundaries and/or modelled groundwater drawdown impact zones.

The development of the Goliath deposit is not considered to pose a long term conservation risk to any stygofauna species, in particular the indeterminate Oligochaeta species, due to the lack of prospective stygofauna habitat present and the likelihood that the Oligochaeta species is a semi-aquatic enchytraeid and not stygobitic, and therefore would have a broader distribution, as demonstrated by many other enchytraeid species from other impact assessments, that would extend beyond the Goliath impact zone.

The development of the Six Mile Well deposit will impact populations of three species that were not recorded from outside the proposed impact areas. Enchytraeidae sp. OES23, has only been collected from within the proposed Six Mile Well pit boundary. However, this species is not considered to be stygobitic and likely to possess a broader distribution as has been shown for many other enchytraeid species from the Yilgarn. *Atopobathynella* sp. OES11 has been recorded from inside and outside the proposed Six Mile Well pit but within the groundwater drawdown. The CO1 haplotype diversity for *Atopobathynella* sp. OES11 indicates the presence of a relatively large and more widespread population than location records may show. *Gomphodella* sp. IK2 has been recorded from outside the proposed Six Mile Well pit but also within the groundwater drawdown that is modelled to remove most of the saturated habitat. All three species are considered to be more broadly distributed and occur outside the impacted habitable portion of the Six Mile Well regolith aquifer system, when taking into account physical and biological information available.

The physical data available from the southern portion of the Six Mile Well Project area shows deeper weathering is present along the southeastern boundary of the Six Mile Well Project Area, likely a result of the fault lines and incised Jones Creek drainage channel present, which is considered to have hydraulic connection to the alluvial and fractured rock aquifer systems associated with Jones Creek to the south. Evidence for this is the relatively flat static groundwater levels exhibited that indicate a degree of groundwater connectivity does occur across much of the Study Area. This is further supported by the broader distribution of *Atopobathynella* sp. OES8 that demonstrates that hydraulic connections do exist between the Six Mile Well and Goliath Project Areas.

The remaining six species recorded from the assemblage in the Study Area are not at risk from the impacts of the proposed Project as they have all been found to occur in non-impact zones.

Conclusion

The hydrogeological and stygofauna data indicate that the stygofauna assemblage present are sparsely distributed in a dendritic nature reflecting the network of habitable regolith, alluvial and fractured groundwater systems present, that appear to be closely associated with Jones Creek and tributaries. The findings indicate that the development of the Project is not likely to propose a long term conservation risk to two stygobitic species, *Atopobathynella* sp. OES11 and *Gomphodella* sp. IK2, recorded from within proposed Six Mile Well groundwater drawdown impact areas. Both species are considered to have distributions that extend beyond the impact zones through a network of hydraulic connections between the southern habitable portion of the Six Mile Well regolith aquifer and the alluvial, regolith and fractured rock groundwater systems associated with the Jones Creek drainage system. The broader distributions of both species is supported by the wider distribution of *Atopobathynella* sp. OES8 and relatively high haplotype diversity of *Atopobathynella* sp. OES11. The remaining eight species recorded are also not considered to be of conservation concern because they were collected from non-impact areas or not considered to be stygobites and therefore likely to possess broader distributions beyond the single bore locations from which they were recorded.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

1. Introduction

1.1 Project Location and Description

BHP Billiton Nickel West (Nickel West) commissioned Stantec Australia (Stantec) (formerly MWH) to undertake a stygofauna assessment in the area of the proposed Mount Keith Satellite Operations (MKSO) (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, dewatering facility, and a primary access road servicing the Project from the south.

1.2 Assessment Scope and Objectives

A previous subterranean fauna assessment completed by Stantec had found that troglofauna did not represent a key environmental factor, but further work was required to complete a Level 2 stygofauna assessment (MWH 2016c). Therefore, the scope of the work reported here was to complete a Level 2 stygofauna assessment and an environmental impact assessment. The main objective being to assess the potential environmental impacts and conservation risks posed by the removal or modification of potential stygofauna habitat to any stygofauna species recorded within the Project's Study Area. The scope of this study encompassed a literature review, database searches and stygofauna sampling of the Study Area.

-

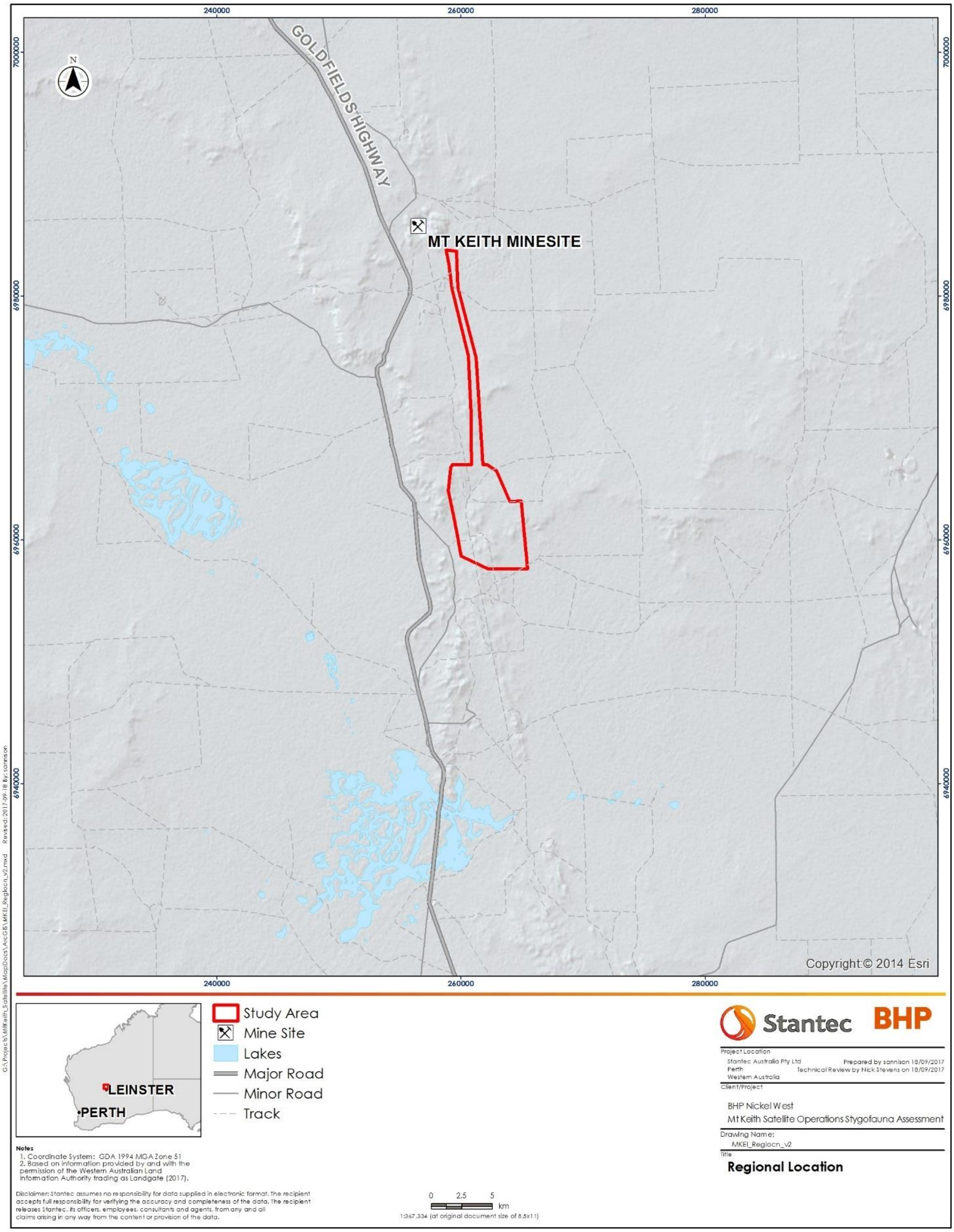

Figure 1-1: Regional location of the Mount Keith Satellite Operations Area.

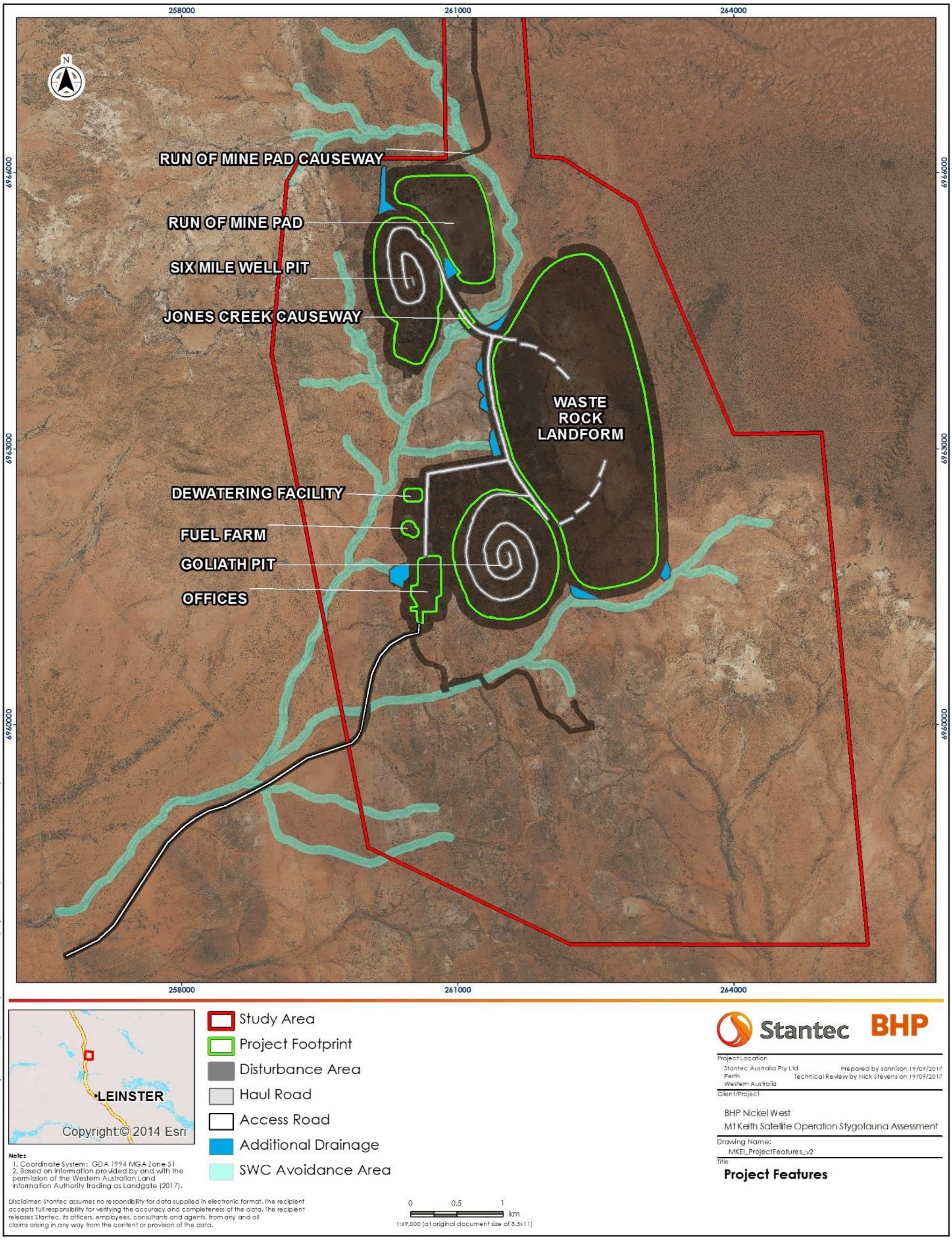

Figure 1-2: The Mount Keith Satellite Operations Area proposed impact footprint.

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, 2011, 2012b, c, d, Subterranean Ecology 2011a).

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).

Conservation estate was reported to make up 1.4% (Australian Natural Resources Atlas 2010) to 1.8% (Cowan 2001) of the Murchison bioregion. More recently, 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 232 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 six times the long term monthly average (Bureau of Meteorology 2017). Rainfall between December 2010 and February 2011 also well exceeded the monthly averages, in response to large, ex-tropical, 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. In 2012, the annual rainfall received (251 mm) was marginally higher than the long term average with no rainfall received over late winter and early spring. In the summer of 2017, there were significant rainfall events that largely contributed to the higher than average annual rainfall received year to date.

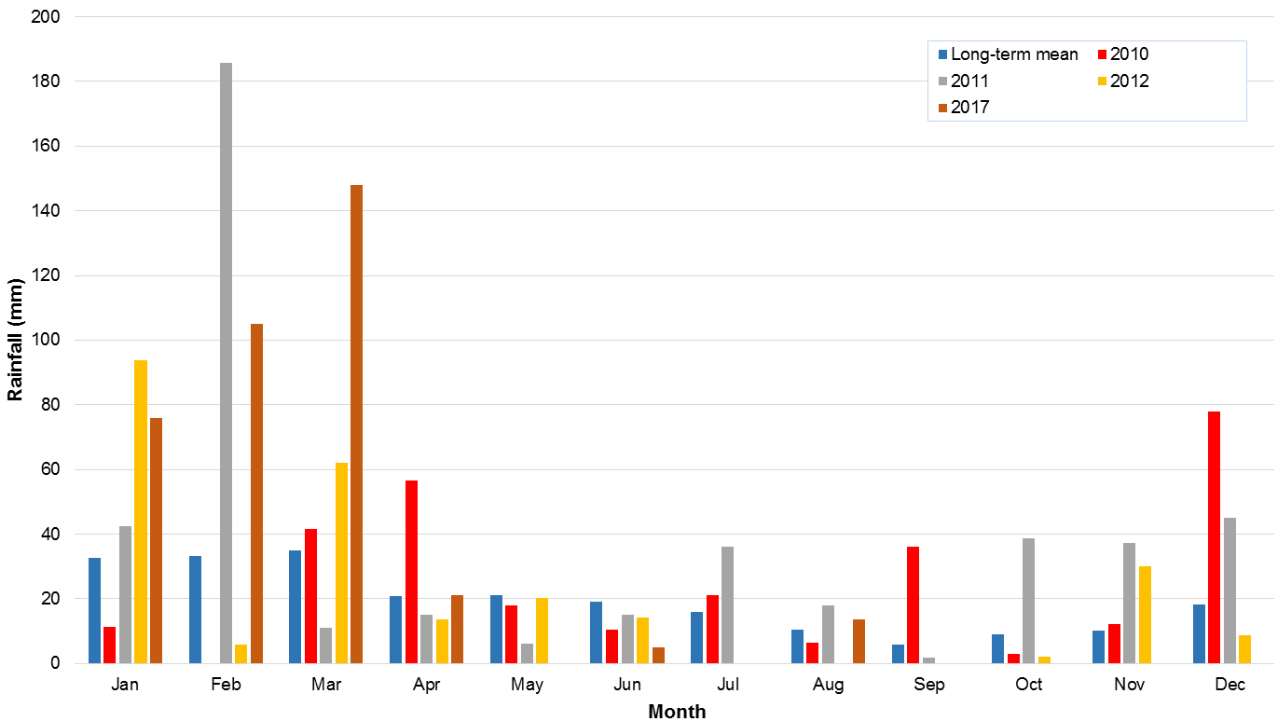

Figure 2-1: Rainfall data collected from Yakabindie Station (Station no. 012088) showing monthly rainfall received during the years (2010, 201, 2012 and 2017) that subterranean fauna sampling was undertaken against the long term average. Long-term data have been calculated from records collected since 1931 to 2017 (Bureau of Meteorology 2017).

2.4 Hydrology

The main drainage system 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 (MWES Consulting 2017a). 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 adcumulate ultramafic or dunite (olivine rich, low aluminium, silica leaching and high porosity upon weathering), which host the nickel sulphide deposits (MWES Consulting 2017a). The local geology is typical of the Yilgarn Craton Archaean greenstone belts that are comprised of faulted and folded NNW-striking, near-vertical layered sequence of high grade metamorphic sediments and volcanics and early felsic intrusives. The dominant geological assemblages present are rocks of the ultramafic, mafic, and felsic sequences (MWES Consulting 2017b).

The regolith profile is relatively shallow, particularly over the felsic-intermediate rock types. There is little alluvial or soil cover. Lateritic weathering comprises duricrust underlain by dense kaolinite clay which overlies saprock, and weathered and fractured bedrock. The lateritic weathering is complex and highly heterogeneous. Thicker weathered profiles (up to 60 m) are present over the dunite bodies and are comprised of: oxide ferruginous (clay altered, local hard pan and nodular iron), underlain by oxide silica-carbonate (complete oxidation, serpentinite, irregular silicification and carbonate alteration), and supergene (partial oxidation towards top, serpentine bleached and porous) (MWES Consulting 2017a). The upper sections of bores drilled in 2017 generally showed high degrees of weathering throughout the saprolite and saprock zones with the lower sections of the bores intercepting fresh bedrock (MWES

Consulting 2017b). The weathering profile is deeper (up to 100 m bgl) along faults and sulphide bearing zones (MWES Consulting 2017a).

The base of oxidation is 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) (MWES Consulting 2017a). At Six Mile Well the upper ferruginous oxide zone is up to 10 m thick with the oxide zone rich in secondary silica-carbonate patchy depending on original parent rock type. There is a very thin regolith transition zone (oxide-sulphide) with base of oxidation at 30-70 m depth. The ultramafic package is larger at Six Mile Well (1,500 x 400 m), and nearly vertical, compared to Goliath, where the ultramafic package is smaller and wedge shaped with the footwall sub-vertical and hanging wall dipping to the west (MWES Consulting 2017a).

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 2011a, Wetland Research and Management 2005). The greenstone landscape that dominates the Project Area is dissected by alluvial drainage lines.

Groundwater in the Project Area and local region is relatively scarce and occurs in surficial deposits and saprolite-weathered regolith, forming shallow aquifers (<100 m deep) of variable size and uneven connectivity (MWES Consulting 2017a). There is no lateral continuous regolith horizon aquifer due to the elevation, depth to water table, and erosional denudation. Most of the fresh bedrock lithology's have practically no primary or secondary porosity and drilling across a majority of the area would generate no groundwater yield (MWES Consulting 2017a, b). Bore locations targeted geological features (i.e. faults, fractures, lineaments and lithological contacts) that were considered to host the most prospective localised zones of higher groundwater yields. Of the 95 bores drilled across the Study Area since 1991, 24 bores have recorded no groundwater yield, while the median and average yield of the remaining 71 bores was 0.25 and 0.5 L/sec, respectively (MWES Consulting 2017a). The 2017 yields from within the proposed Six Mile Well and Goliath pits were low and ranged 0 to 0.5 L/sec and 0.25 to 1 L/sec, respectively.

The most extensive aquifer system considered to occur in the Study Area is associated with the weathered zone present over the dunite (adcumulate) ultramafic pod at Six Mile Well (MWES Consulting 2017a). The weathering of the dunite ultramafic ore has led to the creation of a porous vuggy material, typically at depths of 40-60 metres. On a regional scale this semi-confined regolith aquifer represents a small and localised "caprock aquifer" (MWES Consulting 2017a). The aquifer systems associated with the weathered zone in the Project Area are of limited lateral and vertical extent with permeability and porosity declining with depth as the degree of weathering diminishes below the main aquifer zone (MWES Consulting 2017a). No extensive aquifer is considered to be associated with the Goliath deposit (MWES Consulting 2017a).

Groundwater is also associated with the geological structures that extend throughout much of the Project Area (MWES Consulting 2017a). The permeability along fracture zones may range from moderate to high, however, the fault zones have low porosity and limited lateral extent perpendicular to the fault direction. This means that the storativity of the fractured rock aquifer systems present would be two or more magnitudes lower than the Six Mile Well regolith aquifer system (MWES Consulting 2017a). 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 (MWES Consulting 2017a). The flat gradients indicate that a degree of groundwater connectivity does occur across much of the Project Area that is likely associated with the network of geological structures and regolith aquifers present. The flat gradients also indicate a mature groundwater system that is typical of areas with low rainfall and relatively deep water levels (20 m bgl or more).

3. Subterranean Fauna

3.1 Habitat

The prospective habitat for subterranean fauna (stygofauna and troglofauna) is dependent on the presence of voids of suitable size and connectivity to satisfy biological requirements. Subterranean fauna were previously believed to be mostly restricted to karst landscapes that provide a relatively high degree of secondary porosity, but in more recent times have been found to occur in various types of non-karstic geologies and aquifer systems that exhibit suitable voids for colonisation (Humphreys 2008). Stygofauna are now known to occur in non-karstic aquifers in course alluvial sediments, fractured rock, pisolites and thin rocky regoliths (Halse *et al.* 2014, Humphreys 2006, 2008, MWH 2016c, Outback Ecology 2014). Likewise, recent surveys have identified troglofauna from non-karstic geologies such as vuggy pisolite ore beds, and fractured and weathered rock formations in the Pilbara and Yilgarn regions (Barranco and Harvey 2008, Bennelongia 2009, Halse *et al.* 2002, MWH 2015, Outback Ecology 2011, Subterranean Ecology 2008b).

The extent of stygofauna habitat is dependent on the interconnection of sub-surface crevices, fractures and voids, within suitable hydrogeological units and aquifer systems. In addition to allowing for the movement of stygofauna, adequate interconnected void spaces and associated high permeability can provide pathways for infiltration (vertical or lateral) of resources such as oxygen and carbon, key factors influencing stygofauna persistence and distribution (Humphreys 2008, Strayer 1994). Geological and hydrogeological studies can give an indication of the extent of stygofauna habitat present by providing information on the geological units and structures present, as well as groundwater flow or yield characteristics (aquifer parameters).

3.2 Stygofauna

Stygofauna (groundwater fauna) are predominantly comprised of invertebrates, particularly crustaceans. Other invertebrate stygofauna groups can include gastropods, insects, water mites and worms. In Western Australia, studies have shown that the calcrete and alluvial aquifers associated with palaeodrainage channels of the arid and semi-arid zones can contain rich stygofauna communities. The Pilbara and to a lesser extent the Yilgarn, stand out as global hotspots for stygofauna diversity (Halse *et al.* 2014, Humphreys 2008). Stygofauna can be further classified 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 (and the focus of this stygofauna assessment).

Stygobites are restricted to their subterranean environment and as such are often classified as short range endemics. Short-range endemic species have geographically restricted ranges of less than 10,000 km^2 and are considered more vulnerable to extinction because of their limited distribution range (Harvey et al. 2011, Harvey 2002). Stygobites can often be distinguished from surface or soil dwelling 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, and lower rates of metabolism and fecundity (Cooper et al. 2002, Danielopol and Pospisil 2000).

3.3 Risks and Relevant Legislation

Development and operation of mines in Western Australia pose a number of risks to subterranean fauna and their habitat, which include:

- direct removal of, or disturbance to, habitats through mining excavation;
- lowering the groundwater table through groundwater abstraction for pit dewatering and supply; and

- altering water quality parameters, to levels which may exceed species tolerance limits.

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 EPA developed the *Technical Guidance Subterranean Fauna Survey* (2016b)(equivalent to EPA (2013) EAG 12 *Environmental Assessment Guideline for Consideration of subterranean fauna in environmental impact assessment in Western Australia*) and the *Technical Guidance Sampling Methods for Subterranean Fauna Survey* (2016a)(equivalent to EPA (2007) *Guidance Statement No. 54A Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia*) 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 EPA (2016a, b) guidance documents.

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.

3.4 Regulatory Survey Adequacy Guidelines

The EPA (2016a) stipulates that the appropriate level of survey 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.

For Level 1 low intensity (pilot) surveys the recommended survey intensity considered to provide a reliable indication of the habitat present hosting subterranean fauna is:

- Troglofauna — 10 to 15 samples; and
- Stygofauna — 6 to 10 samples.

If the findings from a desktop assessment and pilot survey indicate that a project area is not prospective for subterranean fauna then no further survey would be required. If a pilot survey does collect stygofauna and / or troglofauna species, thereby demonstrating that subterranean fauna are a potential environmental factor, then a Level 2 (baseline or comprehensive) survey would be required.

The EPA (2016b) recommends that for Level 2 (baseline) stygofauna surveys in areas that have been demonstrated to host a stygofauna assemblage, a minimum of 40 net haul samples are to be collected over at least two survey seasons from within proposed impact areas. The minimum survey effort is considered to relate to proposed impacts across an interconnected habitat, not a collated impact survey effort of separate habitats that are each likely to host distinct stygofauna assemblages with no, or restricted, gene flow occurring among each system.

For Level 2 (baseline) troglofauna surveys in areas that are likely to host 'significant troglofaunal values', a minimum of 60 litter trap samples deployed over two rounds for a minimum of six weeks each are recommended (EPA 2016b). The definition of 'significant values' is not specified or quantified but has been interpreted to relate to the presence of a relatively diverse troglofauna assemblage in or associated with the proposed development area.

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 Study 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 Study 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 groundwater physicochemical data (electrical conductivity (EC), pH, water temperature, dissolved oxygen (DO), and reduction-oxidation potential (Redox)) were recorded in the field from a water sample collected by a bailer from the upper one to two metres of the bore column using a calibrated YSI water quality meter. SWL (m bgl) was measured using a Solinst 101 water level meter. The end of hole depth (EoH) was estimated using the number of rotations of the stygofauna sampling winch reel required to retrieve stygofauna nets.

4.3 Stygofauna Assessment

4.3.1 Net Haul Sampling

Stygofauna samples were taken from exploration drill holes and bores constructed specifically for stygofauna sampling (collectively referred to hence forth as bores) 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 EPA (2016b) technical document. 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 with a base mesh of 50 µm;
- the 150 µm net was lowered first, to near 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 alternating with three samples with 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 Stantec 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 221 stygofauna net haul samples have been collected from 61 bores over eight sample rounds (**Table 4-3, Appendix A, Appendix B**). The first sample round was undertaken in 2006 with five samples collected by Biota (2006a). The additional seven sample rounds were undertaken by Stantec (as Outback Ecology and MWH): November 2010; March and June, 2011; February 2012; March, May and August, 2017. Prior to 2017, there were only 21 suitable and accessible bores available in the Study Area (**Figure 4-1**). Due to the insufficient number of bores available for the stygofauna assessment, 34 new holes were drilled in February 2017 (**Figure 4-2**).

The number of impact samples collected from within proposed mine pit boundaries are: Goliath — 21 samples from 6 bores; Six Mile Well — 22 samples from seven bore (**Table 4-3**). There were 37 samples collected from within 500 m of the proposed Six Mile Well pit that fall within the modelled groundwater drawdown. Sixteen samples were collected from two bores (GOL12 and GOL13) that are within 200 m of the proposed Goliath pit boundary. However, both bores are not considered to be within the groundwater drawdown zone associated with the mining of the Goliath pit because the Goliath deposit is considered to be associated with an isolated and limited surficial regolith aquifer system (MWES Consulting 2017a). Groundwater drawdown will be highly confined and would not extend an appreciable distance beyond the proposed Goliath pit boundary due to the absence of permeability within and surrounding the deposit. Therefore, the need for modelling groundwater drawdown was considered unecessary (MWES Consulting 2017a). The limited regolith groundwater resource will be completely removed with the development of the Goliath pit.

Table 4-3: Summary of stygofauna survey effort.

Area		Biota 2006	2010 - 2012	March 2017	May 2017	August 2017	No. Samples	No. Bores
Inside Proposed Pit Boundaries	Goliath	3	9	3	3	3	**21**	**6**
	Six Mile Well		4	6	6	6	**22**	**7**
Outside Pits	<500m	2	6	17	14	14	**53**	**15**
	>500m, <1km		22	17	17	16	**72**	**18**
	>1km		18	12	12	11	**53**	**15**
Totals		**5**	**59**	**55**	**52**	**50**	**221**	**61**

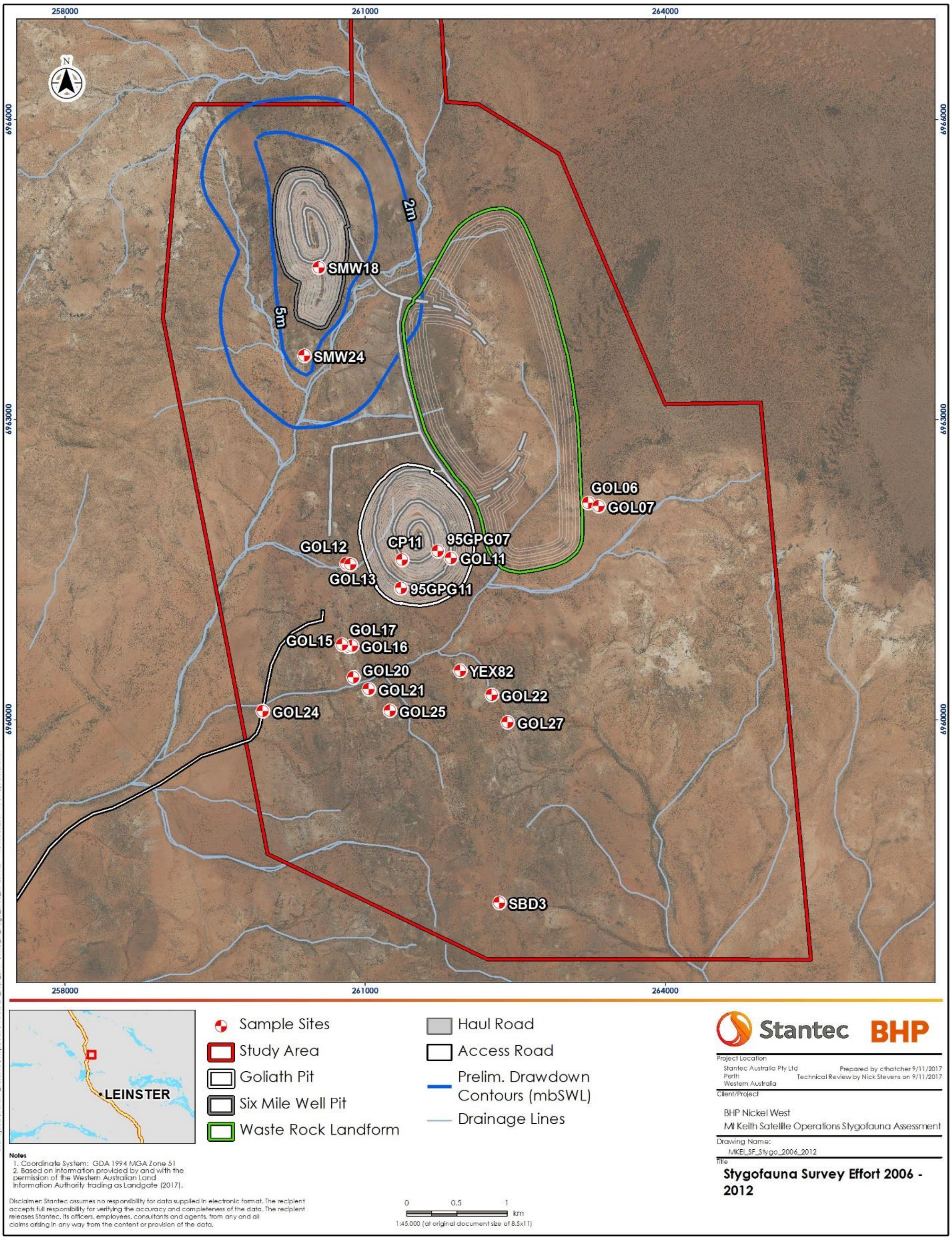

Figure 4-1: Stygofauna 2006 to 2012 survey bore locations in relation to proposed Project footprint.

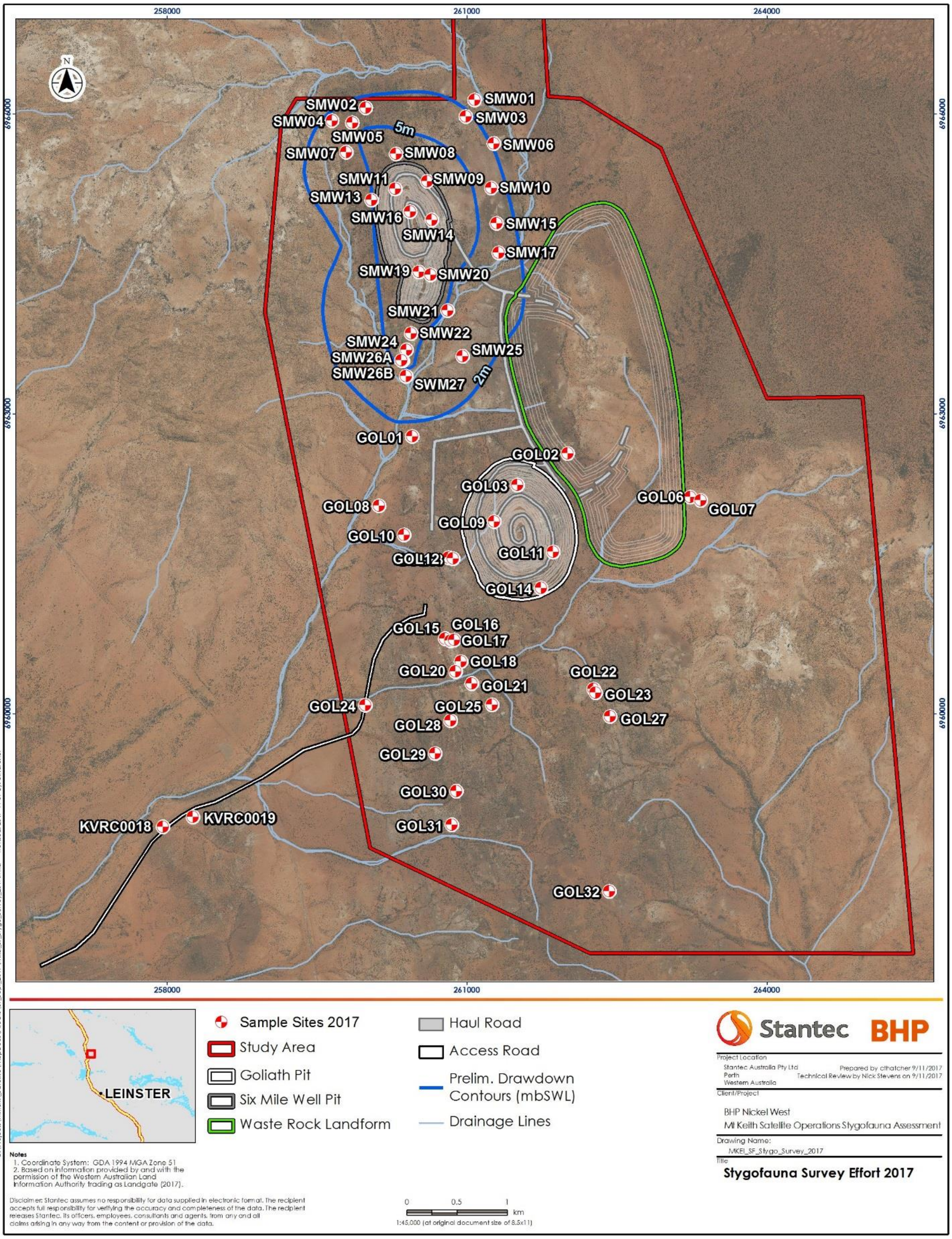

Figure 4-2: Stygofauna 2017 survey bore locations in relation to proposed Project footprint.

4.4 Sorting and Identification of Specimens

Preserved samples were sorted manually using Leica MZ6, MZ7.5, M80 and M205C stereomicroscopes by tala Al-Obaidi, Chris Hofmeester, Syngeon Rodman, Dr Nicholas Stevens 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 STANTEC, 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.

4.5 DNA Sequencing

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

- to compare with material from the surrounding region; e.g. Lake Way, Lake Maitland, and Yeelirrie;
- 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 Study Area.

4.6 Diversity Analysis

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

The species richness analyes provide a statistical evaluation of the proportion of the stygofauna assemblage detected. A range in the number of species predicted to form the assemblage was developed using 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 present only one prediction (Hortal *et al.* 2006).

4.7 Limitations of the Assessment

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

A number of stygofauna surveys have been undertaken in the area surrounding the Project (≤200 km), predominantly within calcrete associated groundwaters (**Table 5-1**). 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). Relatively well studied calcrete systems, Barwidgee, Hinkler Well, Lake Violet, Uramurdah, and Yeelirrie, that have formed in the northern Carey paleodrainage channel in the Project region each host diverse stygofauna assemblages in excess of 30 stygofauna species with more than 70 species recorded from Yeelirrie, the most intensively sampled calcrete system in the region, if not Australia (MWH 2015, Outback Ecology 2012b, d) (Bennelongia 2015b, Subterranean Ecology 2011a).

The Lake Miranda associated calcretes, Lake Miranda East, Lake Miranda West and Yakabindie, are the closest calcrete systems to the Project, located approximately 20 km to the south southwest, and near the terminus of the Jones Creek drainage system. Limited sampling of the Lake Miranda calcretes have collected a few stygofauna species (Watts and Humphreys 2006) and no doubt more intensive sampling would record richer assemblages from the system (**Table 5-1**).

Few surveys in the Project region have sampled non-calcrete associated aquifer systems. Sampling of the weathered and fractured bedrock habitat at Cliffs, 22 km north of the Study Area, did not yield any stygofauna (Sinclair Knight and Merz 2004). Within the current Project Study Area, regolith and fractured rock aquifers were sampled in 2006 (Biota 2006a). Sampling of five bores within the Goliath Project Area collected two amphipod (Neoniphargidae) specimens from GOL13 (previously known as YAKB06), 244 m to the west of the proposed Goliath pit boundary, and a single oligochaete from GOL11 (previously known as CP21) within the proposed Goliath pit (Biota 2006a). Recent sampling of a fractured rock and alluvial aquifer system located within the Raeside paleodrainage channel, more than 170 km to the southeast of the Project, yielded a commonly collected but low species richness stygofauna assemblage dominated by bathynellacean taxa (Stantec, unpublished data). The distribution of stygofauna found occur mostly along the main drainage lines as well as along known fault lines and shear zones.

Within the surrounding northern Goldfields region, genetic studies have indicated that calcrete systems can represent closed 'subterranean islands' in that the species of the stygofauna assemblage present are restricted in distribution to a particular calcrete (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 that surficial alluvial and regolith aquifers associated with the main drainage pathways provided hydraulic connections among the main calcrete aquifer systems. The notion was supported by genetic results reported in Abrams *et al.* (2012) and Outback Ecology (2011, 2012b), that demonstrated the distributions of amphipod, Bathynellacea and dytiscid species extended from Millbillillie Bubble Well calcrete to Lake Violet and Uramurdah calcretes.

There are times when the biological data can seemingly be at odds with the hydrogeological data. Genetic studies have demonstrated that hydraulic connections do exist between aquifers that hydrogeological data had indicated were largely separate systems. Genetic data did show that *Atopobathynella wattsi* has a distribution extending from the Lake Violet calcrete, on the northern shore of Lake Way, to the Hinkler Well calcrete, more than 12 kms away on the western shore of Lake Way (Guzik *et al.* 2008). The Browns Range Metamorphics and Gardiner Sandstone fractured rock aquifer systems each exhibited distinctly different hydrogeological characteristics and were considered to be isolated from one another (Klohn Crippen Berger 2013). However, genetic analysis demonstrated that hydraulic connections did exist between the two fractured rock aquifer systems, with two bathynellicean species clearly shown to be distributed in both (Outback Ecology 2014).

5.2 Database Searches

There were no threatened or priority subterranean fauna noted in the Study 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). Similarly, 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 Study 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 Study Area. The Yakabindie calcrete community was the nearest, 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 Crustacea database identified over 700 records of subterranean taxa in the region surrounding the Study Area (MWH 2016). The closest records (within a radius of approximately 50 km) encompassed stygobitic taxa from groups including amphipods, copepods, isopods, ostracods and syncarids. The only WAM records from within the Study Area were the two *Atopobathynella* species, *A*. OES8 and *A*. OES9, and the ostracod *Gomphodella* sp. IK2 that had been collected as part of the MKSO subterranean fauna assessment. In general, the stygobitic crustaceans recorded in the region were predominantly associated with calcrete habitat in systems such as Yeelirrie, Lake Maitland/Barwidgee, Lake Miranda East and West calcretes and Albion Downs. The differences in the taxon diversity between geological units may be partly attributable to sampling bias. However, it is considered to also reflect the more favourable habitat within calcrete systems relative to regolith and fractured rock systems.

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

Area / Deposit	Distance from Project	Stygofauna	Geology / Habitat	Reference
Yakabindie	Within	Amphipods, oligochaetes, syncarids	Regolith, fractured rock aquifers	Biota 2006a, MWH 2016, current report
Cliffs	22 km north	No stygofauna present	Weathered bedrock	Sinclair Knight Merz 2004
Lake Miranda (East and West)	25 km south	Dytiscid beetles	Calcrete	Watt and Humphreys 2006
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

5.3 Stygofauna Habitats

5.3.1 Aquifer/s Characteristics

Groundwater in the Project Area and local region occurs in saprolite-weathered regolith, surficial alluvial and/or colluvial deposits, and within geological structures (faults, fractures, unconformities) forming shallow aquifers (<100 m deep) of variable size and uneven connectivity (MWES Consulting 2017a). Alluvial, aeolian and/or colluvial deposits which form a surficial cover over the weathered greenstone terrain are only sporadically and partly saturated, as the depth to the water table in the Project Area is typically 25 m bgl or greater. Partial local saturation of these deposits is at least temporarily present along the major drainage lines, which periodically facilitate infiltration of water following high rainfall and surface runoff events (Wetland Research and Management 2005).

In areas hosting nickel ore, the ultramafic dunite with sulphide mineralisation underwent weathering, which provided comparatively extensive permeability and storage as part of the oxidation zone over the dunite, forming a localised regolith caprock aquifer. Similar aquifer development is likely to be present, to varying degrees, in other ultramafic (but also felsic) units, representing the only appreciable aquifer potential of the greenstone terrain in areas for which surficial deposits have no significant saturation. The lateral development of caprock, forming the local aquifer in the Project Area, is expected to be variable, based on the differing ultramafic units present and their individual weathering profiles. Saprolite clays developed over the caprock prevent or reduce vertical connectivity with perched groundwater in sparsely-saturated surficial sediments (where present at the top of saprolite). The saprolite clays will also reduce the presence of oxygen in the underlying caprock. Windows of vertical and lateral connectivity are likely to be present in areas of differential weathering, along fault lines, incised drainage lines, or along sulphide enrichment.

The main aquifer found in the Project Area, the Six Mile Well semi-confined regolith "caprock" aquifer, occurs in the southern portion of the Six Mile Well Project Area only (from SMW14 southwards to beyond SMW27), based on the known bore lithologies and groundwater yields (**Figure 5-1**, **Figure 5-2**) (MWES Consulting 2017b). Within the southern part of the proposed Six Mile Well pit area, the regolith aquifer appears confined to semi-confined with thick clay dominated strata overlying the saturated weathered ultramafic. To the south of the proposed pit boundary (SMW22 to SMW27) the regolith aquifer appears unconfined with the thickness of clay dominated strata decreasing considerably, ranging from absent to a maximum of 8 m thick. 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 more porous central and shallow part of the aquifer (Coffey Partners 1990). The drawdown and recovery patterns indicated relatively higher permeability of the aquifer but with limited extent. The saturated extent of the main regolith aquifer is considered to decline in parts to the south beyond the proposed pit boundary as the more deeply weathered ultamafics give way to less permeable fresh bedrock (BHP Billiton Nickel West 2011) as evidenced by the recorded lithology for bore SMW26 (MWES Consulting 2017b) (**Figure 5-2**). However, the saturated depth of the heavily weathered zone is variable, extending to 38 m bgl (488 AHD) at SMW27, that is located near to confluence of Jones Creek and one of its tributaries (MWES Consulting 2017b) (**Figure 4-2**, **Figure 5-2**). This deeper weathering along the southeastern boundary of the Six Mile Well Project Area is likely a result of the fault lines and incised Jones Creek drainage channel present and would provide a connection to the alluvial and fractured rock aquifer systems associated with Jones Creek to the south.

The northern portion of the Six Mile Well Project Area (from SMW16 northwards) is not considered to host prospective stygofauna habitat as the saturated strata are either entirely fresh bedrock (e.g. SMW16, SMW13) or heavily clay dominated (e.g. SMW08, SMW11), and therefore would not host the porosity or receive the influx of resources (e.g. nutrients, oxygen), due to the thick confining overlying clay layers, required for stygofauna habitation. The low groundwater yields (ranging from 0 to 0.8 L/sec) indicate the low permeability and limited groundwater resource. The stygofauna habitat prospectivity to the east of the proposed Six Mile Well pit is similar to the northern portion of the Six Mile Well Project Area with limited groundwater yields (ranging from 0.05 to 0.6 L/sec) from the confined to semi-confined saturated clay dominated strata overlying mafic basalt saprock to freshrock (MWES Consulting 2017b) indicating limited porosity and resource influx.

Groundwater associated with the thin regolith of the Goliath deposit was not considered a substantial aquifer. Test pumping demonstrated low permeability in the area with a sustainable pump rate of less than 1 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 lithology of bores in (GOL03, GOL09, GOL11) and near

(GOL02, GOL14) the proposed Goliath pit indicate the lack of prospective habitat for stygofauna as the saturated strata are either entirely fresh bedrock or saprolitic clay dominated.

The lithology of most bores present in the Goliath Project Area is not known. In the southern reference areas south of the Goliath deposit the lithology from the four new bores (GOL28, GOL29, GOL30, and GOL31) indicate very low prospectivity for stygofauna habitat with the saturated strata composed entirely of fresh bedrock, with the exception of GOL31 that intercepted weathered ultramafics, with high clay content to the end of hole 65 m bgl (MWES Consulting 2017b). To the west of the Goliath deposit, the lithology from two new bores (GOL08, GOL10) showed contrasting prospectivity for stygofauna habitat. GOL08 is located close to Jones Creek and the lithology is prospective for stygofauna habitat with no thick confining clay layer present and approximately 18 m thick unconfined saturated weathered mafic zone with indication of quartz veins present that would have formed along geological structures (MWES Consulting 2017b). GOL10 is located higher up in the landscape closer to Goliath deposit and has non-prospective stygofauna habitat with the saturated strata composed entirely of fresh bedrock.

Groundwater also occurs, in smaller quantities, within fractured rock aquifers along geological structures in fresh fractured basement, fracture sets, and unconformities forming discrete aquifer units, with low storage and possibly limited connectivity (MWES Consulting 2017a). The permeability of the fractured rock zone can range from moderate to high but the porosity of the fault zones are relatively low and with limited lateral extent. From an economic resource perspective, the regolith and fractured rock aquifer systems present are not considered significant to the groundwater resources of the region because they do not form an extensive regionally continuous aquifer system, instead being relatively minor and hydraulically isolated. However, from an ecological perspective, the spatial and temporal extent of connectivity via the 'interstitial highway' (Ward and Palmer 1994) among the regolith, alluvial and fractured rock aquifers associated with the upper Jones Creek catchment is likely to be dendritic in nature, relatively extensive and sufficient for gene flow to occur among potential stygofauna populations. The groundwater heads across the Project area, in the range of 504 to 510 AHD, are flat with a hydraulic gradient running south along Jones Creek and away from the deposit areas. The flat groundwater heads indicate that a reasonable degree of groundwater connectivity does exist across much of the Project Area (MWES Consulting 2017a), that is considered to be associated with the network of geological structures and regolith and alluvial aquifers present.

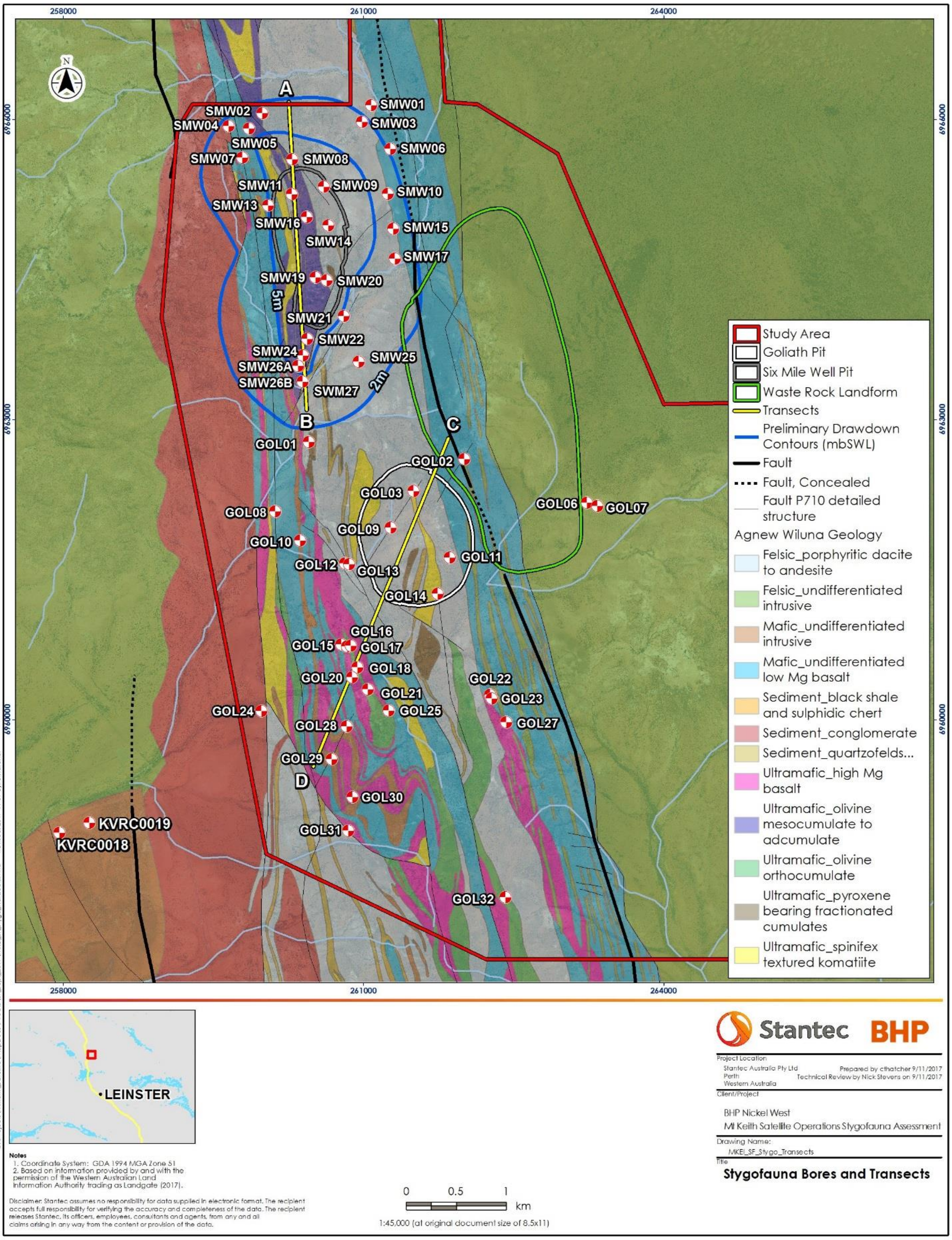

Figure 5-1: The bedrock geology and known geological structures in relation to proposed pits, stygofauna sample sites, and cross-sectional transects shown in Figure 5-2 and Figure 5-3.

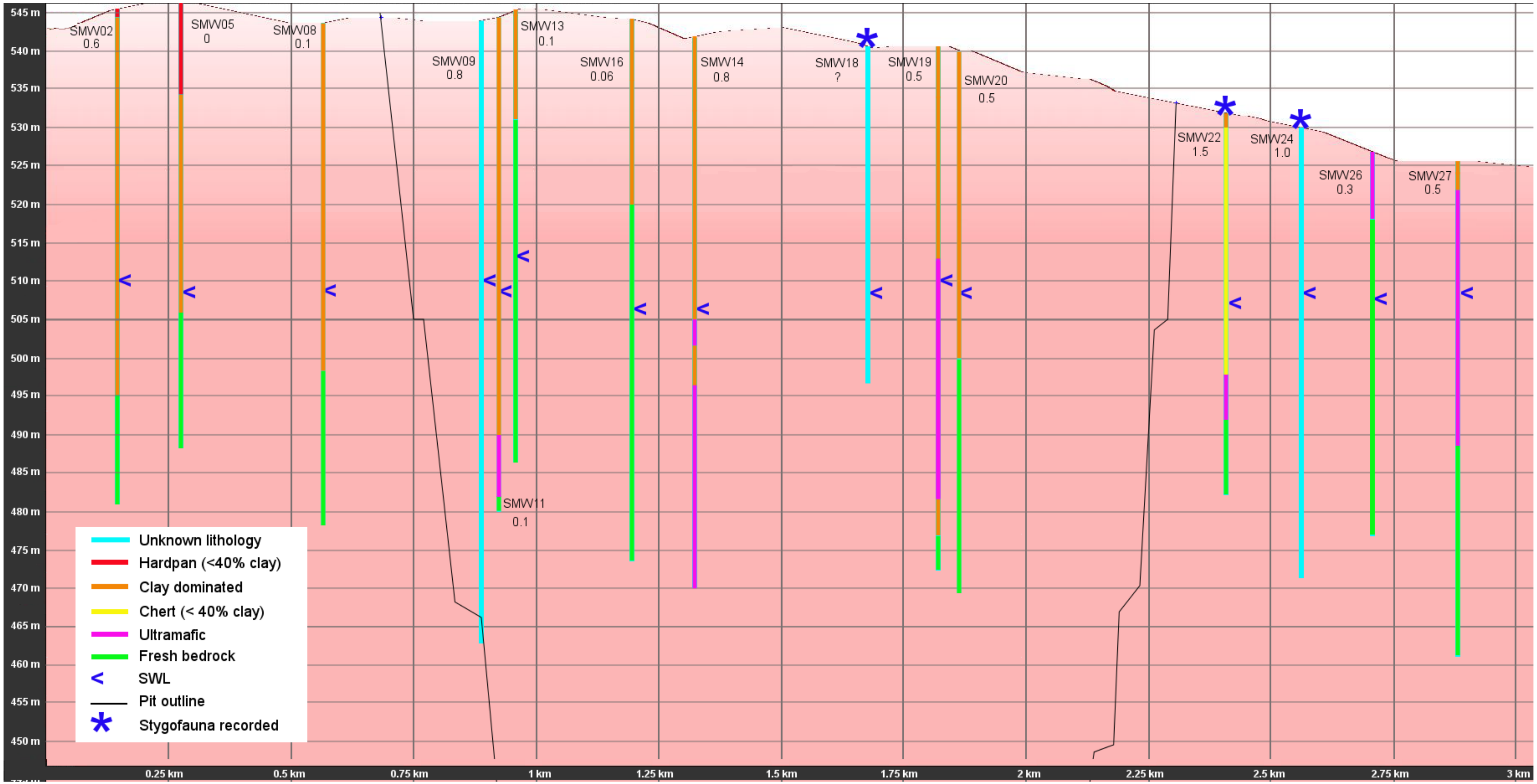

Figure 5-2: Schematic depiction of bore lithologies, standing water levels (SWL), and Six Mile Well pit outline along transect A—B shown in Figure 5-1.

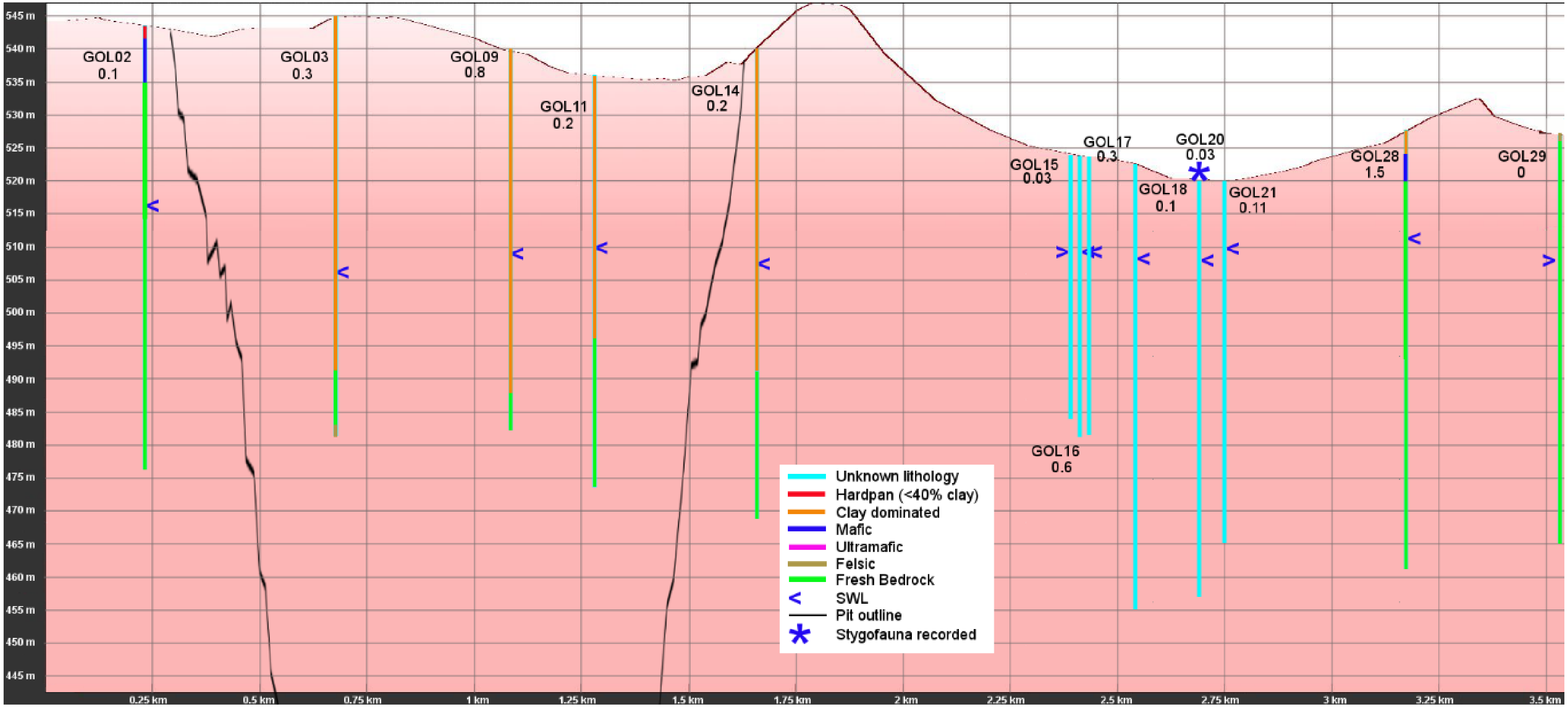

Figure 5-3: Schematic depiction of bore lithologies, standing water levels (SWL), and proposed Goliath pit outline along transect C—D shown in Figure 5-1.

5.3.2 Groundwater Properties

Groundwater across the aquifer systems intercepted in the Study Area ranged from fresh to hyposaline (123.5 to 13,345 µS/cm), *sensu* Hammer (1986), with the highest salinities (>10,000 µS/cm) typically recorded from within each of the proposed pit or drawdown areas (e.g., SMW19, SMW22, and 95GPC07) (**Figure 5-4**). 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 C**). 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 mg/L (Coffey Partners 1990) with surrounding isolated fractured rock aquifers generally of lower salinity ranging from 700 to 5,400 (Coffey Partners 1991).

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 recorded (range 2.78 mg/L to >7 mg/L) indicated oxygenated groundwater conditions were present across the Study Area. While concentrations below 5 mg/L may adversely affect surface aquatic biota, stygofauna have been documented from sub-oxic conditions well below 1 mg/L 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 Study Area for the same sample round (**Appendix C**).

The variation in standing water level (SWL) among bores reflected the local topography across the Project Area, particularly within the Goliath region. 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 C**). 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 were greater than 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).

In conclusion, groundwater properties, as represented by the basic suite of physicochemical parameters measured, indicate suitable conditions for stygofauna throughout the Study Area. It is considered unlikely that stygofauna would be precluded from the groundwaters of the Study Areas surveyed on the basis of the conditions recorded.

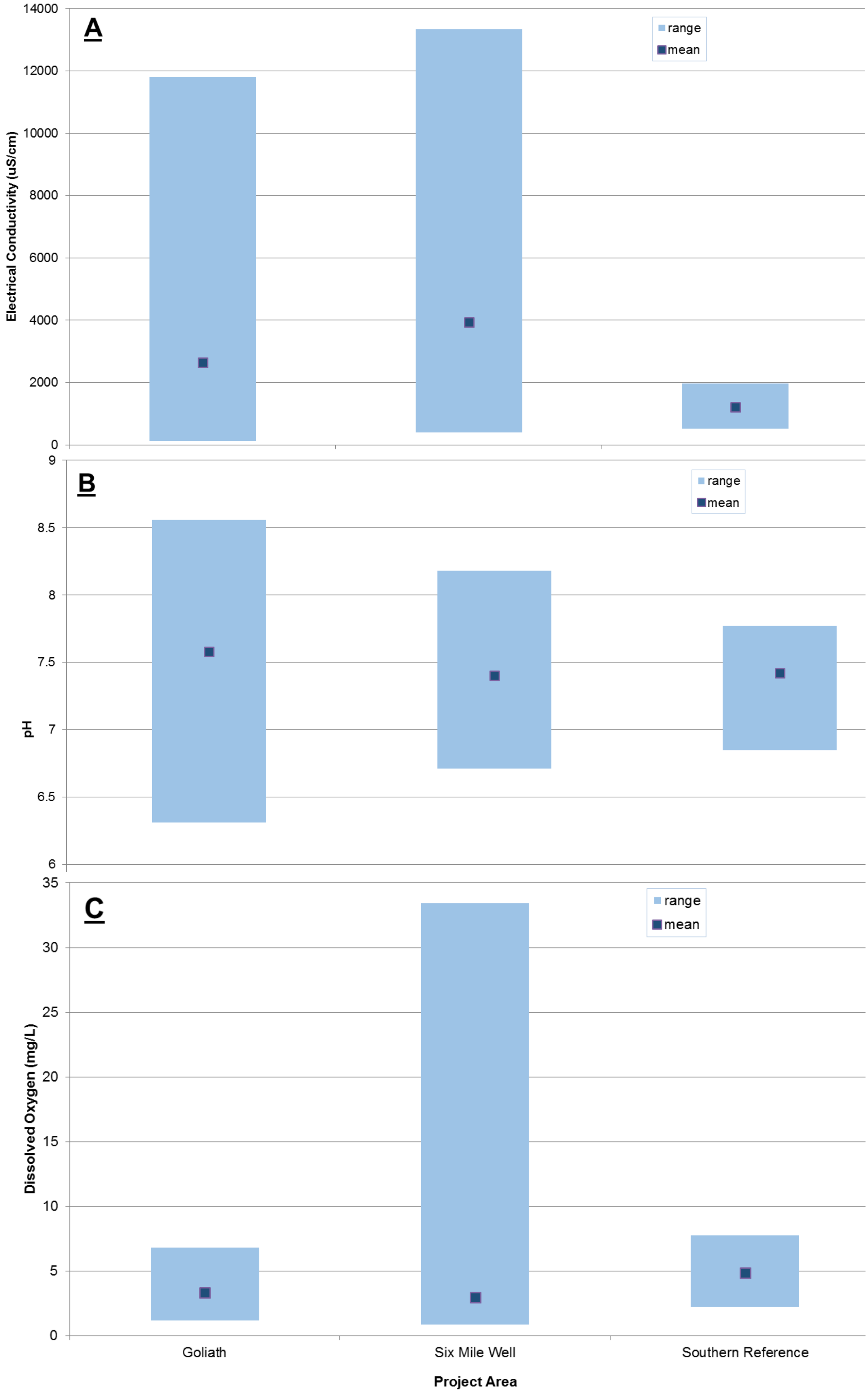

Figure 5-4: Minimum, maximum and mean of groundwater parameters recorded: A) electrical conductivity (EC); B) pH; C) dissolved oxygen (DO).

5.4 Stygofauna Findings

In total, 124 stygofauna specimens, representing 10 taxa from four higher level taxonomic groups (Amphipoda, Bathynellacea, Oligochaeta, and Ostracoda) were collected in 12 of the 221 samples taken from eight of the 61 bores sampled in the Study Area (**Table 5-2**, **Figure 5-5**, **Figure 5-6**, **Appendix D**). Only two bores (SMW18 and GOL20) recorded multiple species and yielded stygofauna specimens on more than one occasion. The remaining six bores only ever had one species recorded, and only on one occasion.

The Bathynellacea was represented by four species, *Atopobathynella* sp. OES8, *A*. sp. OES9, *A*. sp. OES11, and Bathynellidae sp. OES2, identified from 45 specimens. The Oligochaeta was the most abundant group collected with 75 specimens, largely composed of juvenile material. Genetic analysis of the enchytraeid material confirmed the presence of two species, Enchytraeidae sp. OES10 and Enchytraeidae sp. OES23. The Ostracoda was represented by a single species, *Gomphodella* sp. IK2, recorded from one sample only. The Amphipoda and Oligochaeta material collected by Biota in 2006 could not be located for further examination and remain as indeterminate taxa. The single oligochaete specimen could not be substantiated and taxonomically aligned with other oligochaete species recorded from the Study Area so is treated as a separate indeterminate taxon.

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

- <u>Goliath Pit</u> — No stygofauna taxa were collected from within the proposed Goliath pit boundary during the 2010 to 2017 stygofauna sample rounds. Previous sampling by Biota (2006a) did record indeterminate oligochaete material from bore GOL11, within the proposed pit boundary (**Figure 5-7, Appendix D**). There is a high likelihood, due to the habitat characteristics present, the indeterminate material collected represents a semi-aquatic enchytraeid species that may be conspecific with other enchytraeid material recorded, and not represent a stygobitic phreodrillid species.

- <u>Goliath Groundwater Drawdown</u> — No species are considered to have been recorded from within the Goliath groundwater drawdown impact zone. An amphipod, identified as a Neoniphargidae, was recorded in 2006 from bore GOL13 that is located approximately 200 m outside the proposed pit boundary (**Figure 5-7**). 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 considered to extend far beyond the proposed pit boundary. Therefore, the recorded location of the neoniphargid is considered to be outside of the groundwater drawdown impact zone associated with the dewatering of the Goliath pit.

- <u>Six Mile Well Pit</u> — Three species, *Atopobathynella* sp. OES8, *A*. sp. OES11 and Enchytraeidae sp. OES23, were collected from within the proposed Six Mile Well pit boundary from SMW18 during the 2010 to 2012 stygofauna sample rounds (**Figure 5-7**). No species were recorded from within the proposed pit boundary from the three sample rounds undertaken in 2017. However, in 2017 both *Atopobathynella* sp. OES8 and *A*. OES11 were recorded from outside of the proposed Six Mile Well pit boundary. *Atopobathynella* sp. OES8 was recorded in Goliath Project Area from one of the older reference bores, GOL20, approximately 1 km from the proposed Goliath pit boundary and more than 4 km from SMW18 where the species was first recorded. *Atopobathynella* sp. OES11 was recorded from outside the proposed Six Mile Well pit from a newly drilled bore, SMW22, located within the modelled groundwater drawdown impact zone associated with pit dewatering. Enchytraeidae sp. OES23 is the only species to not have been recorded from outside the proposed pit.

- <u>Six Mile Well Groundwater Drawdown</u> — Two species, *Atopobathynella* sp. OES11 and *Gomphodella* sp. IK2, were collected from within the modelled Six Mile Well groundwater drawdown (**Figure 5-7**). *Atopobathynella* sp. OES11 was recorded in 2017 from the new bore SMW22, 150 m south of the pit boundary within the modelled groundwater drawdown impact zone. The Ostracoda species, *Gomphodella* sp. IK2, was collected on a single occasion in 2012 from bore SMW24, 340 m south of the pit boundary within the modelled 5 m bSWL groundwater drawdown impact zone.

Of the ten recorded taxa, six species, *Atopobathynella* sp. OES8, *A*. sp. OES9, Bathynellidae sp. OES2, Enchytraeidae sp. OES10, Neoniphargidae sp. and Phreodrillidae sp. OES23, have been recorded from outside proposed impact areas and do not represent potential conservation concerns in relation to the development of the Project (**Figure 5-7**, **Table 5-2**). *Atopobathynella* sp. OES8 is the only species to have been recorded from both the Six Mile Well and Goliath project areas. The distributions of the four remaining taxa have not been demonstrated to extend beyond proposed impact zones. The indeterminate oligochaete and Enchytraeidae sp. OES23 have only been recorded from inside proposed pit boundaries. *Atopobathynella* sp. OES11 has been recorded from inside and outside Six Mile Well pit, but not from beyond the modelled groundwater drawdown impact zone; and *Gomphodella* sp. IK2 has not been recorded from outside the Six Mile Well pit modelled groundwater drawdown impact zone.

Table 5-2: Stygofauna diversity and distribution. Orange shaded cells — taxa recorded from within the pit outlines only; Yellow shaded cells — taxa recorded from areas of likely groundwater drawdown only.

Taxon	Abundance	Area	Bore ID	Location	Comments
Amphipoda					
indet. Neoniphargidae sp. (Biota 2006)	2	Goliath	GOL13	Near pit (<200m)	Not of potential conservation concern. Indeterminate species collected by Biota (2006a). Specimen could not be found for further examination. No additional amphipod material collected or stygofauna recorded from bore in 2010 to 2017 sample rounds. Doubts do exist that an amphipod does occur in Study Area.
Bathynellacea					
Atopobathynella sp. OES8	2	Goliath, Six Mile Well	GOL20, SMW18	Inside & outside pits (>500m, <1km)	Not of conservation concern. DNA sequencing confirmed morphologically distinction from other *Atopobathynella* species. Most widespread species recorded from Study Area and recorded sympatrically with both *A*. OES9 and *A*. OES11.
Atopobathynella sp. OES9	3	Goliath	GOL20	Outside pits (>500m, <1km)	Not of conservation concern. DNA analysis demonstrated that distinct from other *Atopobathynella* species. Recorded on two occassions from bore since 2010
Atopobathynella sp. OES11	39	Six Mile Well	SMW18, SMW22	Inside & near pit (150m) withhin groundwater drawdown	DNA analysis demonstrated that distinct from other *Atopobathynella* species. The relatively high haplotype diversity and intraspecific CO1 sequence divergence found suggest broader distribution than current location records show
Bathynellidae sp. OES2	1	Goliath	GOL20	Outside pits (>500m, <1km)	Not of conservation concern. Collected on single occasion despite bore being sampled on six occasions since 2010
Oligochaeta					
Enchytraeidae sp. OES10	10	Goliath	GOL24	Outside pits (>1km)	Not considered to be of conservation concern. Enchytraeidae species generally considered widespread in distribution and not stygobitic, more likely to be stygophiles or stygoxenes; Often are semi-aquatic.
Enchytraeidae sp. OES23	60	Six Mile Well	SMW18	Inside pit	Not considered to be of conservation concern. Enchytraeidae species generally considered widespread in distribution and not stygobitic, more likely to be semi-aquatic stygoxenes. Are often collected in troglofauna litter traps
indet. Oligochaeta sp. (Biota 2006a)	1	Goliath	GOL11	Inside pit	Indeterminate material collected by Biota (2006a). Specimen could not be found for further examination. Considered likely to be Enchytraeidae species due to the absence of suitable habitat for stygobitic fauna in recorded location, so unlikely to be Phreodrilidae species. Although this cannot be verified, record not considered to represent a species that would be of conservation concern.
Phreodrilidae sp. OES23	4	Goliath	GOL08	Outside pits (>500m, <1km)	Not of conservation concern. New species recorded in 2017. Specimens sent for DNA failed to PCR.
Ostracoda					
Gomphodella sp. IK2	2	Six Mile Well	SMW24	Near pit (>300m, <500m)	Collected on a single occasion despite bore being sampled on seven occassions since 2010

5.4.1 Amphipoda

Stygobitic amphipods, particulary chiltoniid species, have been relatively commonly recorded from many of the northern Yilgarn calcretes sampled (Bradford *et al.* 2013b, Bradford *et al.* 2010, Cooper *et al.* 2007, Guzik *et al.* 2011, Subterranean Ecology 2011a). However, we are not aware of stygobitic amphipod species being collected from fractured rock aquifer systems that are isolated from calcrete 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.* 2013a, Guzik *et al.* 2011, MWH 2015, Outback Ecology 2012b, d, Subterranean Ecology 2011b). 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 for a stygobitic amphipod in the Yilgarn or Pilbara regions. The molecular analysis did reveal a relatively 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).

Amphipod material collected by Biota (2006a) was submitted to the Western Australian Museum (Garth Humphreys pers comm.) but could not be subsequently found for further examination by Stantec. Further examination of the specimens would have enabled Stantec to determine the taxonomic relationship to other amphipod material from the surrounding region, including material collected by Biota from different areas from the same 2006 survey. No additional amphipod material has been collected in later sample rounds from the Study Area. Interestingly no stygofauna has been recorded from GOL13 (or neighbouring bore GOL12) in 2010 to 2017 sample rounds. Some doubt does exist that the amphipod material does occur in Study Area. This is due to some indiscrepancies in the Biota (2006a) report concerning the bore location (i.e. Albion Downs or Yakabindie) as well as the absence of any stygofauna from multiple rounds of sampling of GOL13 and neighbouring bore GOL12.

5.4.2 Bathynellacea

All species of Bathynellacea globally are specialised stygobites that are considered to have evolved to exploit groundwater systems prior to the breakup of Gondwana (Abrams *et al.* 2012), as opposed to most other stygofauna species from the Pilbara and Yilgarn that are considered to have evolved to be stygobites much later in time with the onset of increasing aridity for the Australian continent. The domination of the stygofauna assemblage within the Study Area by bathynellacean diversity is similar to that reported from north-western and north-eastern Australia where bathynellaceans were the most commonly collected component of 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). The remaining species were recorded infrequently, often known from only one or two samples. Two of the widespread species were found to have distributions that spanned what were considered to be two hydrogeologically distinct and separate fracture rock aquifer systems between the Browns Range Metamorphics and the surrounding Gardiner Sandstone geological unit. Genetic analysis confirmed that there existed subterranean habitat connections between these two distinct geological aquifer units.

The genetic analysis of the bathynellacean taxa collected from the Study Area confirmed that the *Atopobathynella* material, based on morphological characteristics considered important in determining species limits (Cho *et al.* 2006), did represent three distinct but closely related species, exhibiting interspecific CO1 sequence divergence of 10.3 to 11.3 %(**Appendix E**). The *Atopobathynella* species from the Study Area were also found to be divergent from Lake Way, Lake Way South, Barwidgee and Yeelirrie species, exhibiting interspecific CO1 sequence divergence greater than 14.3 % (**Appendix E**).

Both *Atopobathynella* sp. OES8 and *A.* sp. OES11 were recorded from more than one bore: *Atopobathynella* sp. OES8 from the Goliath reference area from one of the older reference bores, GOL20, approximately 1 km from the proposed Goliath pit boundary and more than 4 km from SMW18 within the Six Mile Well proposed pit where the species was first recorded; *Atopobathynella* sp. OES11 was first recorded sympatrically with *Atopobathynella* sp. OES8 from SMW18 and later collected in relatively abundant numbers (38 specimens) from the newly drilled bore SMW22, from just outside the proposed Six Mile Well pit boundary, but still within the modelled groundwater drawdown zone (**Figure 5-7**, **Appendix D**).

Atopobathynella sp. OES9 was only recorded from GOL20 on two of the six occasions the bore was sampled and also collected sympatrically with *Atopobathynella* sp. OES8.

The CO1 sequence data from eight *Atopobathynella* sp. OES11 specimens were analysed to gain further insight into the species' population structure. The maximum intraspecific CO1 sequence divergence among the *Atopobathynella* sp. OES11 specimens analysed was 1.0 % with four separate CO1 haplotypes found to occur from a single bore, SMW22. The co-occurrence of a higher level of haplotype diversity among specimens collected within a limited geographical area, particularly a single bore, is considered to be an indication of a relatively large, stable population with a long evolutionary history that would be more widespread than location records may show (Guzik *et al.* 2011).

5.4.3 Oligochaeta

Phreodrilidae species are commonly associated with groundwater systems and have been recorded in stygofauna assemblages elsewhere (Biota Environmental Services 2010, Halse *et al.* 2002, MWH 2015, Outback Ecology 2012d, 2013, Pinder 2001, 2008, Rockwater 2012, Subterranean Ecology 2012). While some species of Phreodrilidae have only been recorded from aquifers, other species have been recorded from a range of habitats including springs, spring-fed creeks and pools and large surface water systems (Pinder 2008). Although some species are only known from a limited number of sites, other species have been found to have widespread distributions that can occur across disjunct aquifers and drainage catchments (Biota Environmental Sciences 2010, Pinder 2008).

Phreodrillidae OES23 was collected from a new bore, GOL08, in the May 2017 survey round, three months after the bore had been drilled and developed. This species is not of conservation concern as it has been recorded from outside the likely proposed impact zones associated with the proposed Goliath and Six Mile Well pits and associated dewatering drawdown zone.

The taxonomy and ecology of the Enchytraeidae is poorly known, however, no stygobitic species have been 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 2011, 2013, Rota *et al.* 2007, van Vliet *et al.* 1997). Studies in the Goldfields, Pilbara, and Kimberley regions have demonstrated many enchytraeid species to possess relatively broad distributions with a number of species also collected in troglofauna litter traps indicating they are not confined to groundwater but likely semi-aquatic or terrestrial (MWH 2015, Outback Ecology 2013, 2014, Subterranean Ecology 2008a). Genetic analysis of enchytraeids from non-calcrete habitats bordering Lake Austin revealed a relatively diverse assemblage with a number of the species present possessing relatively widespread distributions, one of which was recorded from both north and south of Lake Austin indicating that the hypersaline conditions of the salt lake and associated groundwater system did not pose a barrier to dispersal (Leijs and King (2013) in Outback Ecology (2013)). Other genetic studies have demonstrated within a fractured rock aquifer system that only a single species was present that possessed a relatively widespread distribution throughout the study area exceeding a linear distance of 12 km (Outback Ecology 2014). It is considered likely that the species has a widespread distribution extending beyond the study area throughout the drainage catchment. Genetic analysis of enchytraeids from the Yeelirrie calcrete system uncovered a diverse assemblage and seemed to indicate that each species sequenced possessed a limited distribution (Subterranean Ecology 2011a). However, it is important to note that most enchytraeid material collected was not sequenced and remained as indeterminate. In addition, most locations from which enchytraeids were collected were not represented in the analysis.

Both Enchytraeidae sp. OES10 and Enchytraeidae sp. OES23 are considered to be semi-aquatic stygoxenes and to have much broader distributions than are currently known, as demonstrated by many other enchytraeid species from other impact assessments, and therefore not to be restricted to the immediate areas from which they were each recorded.

5.4.4 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).

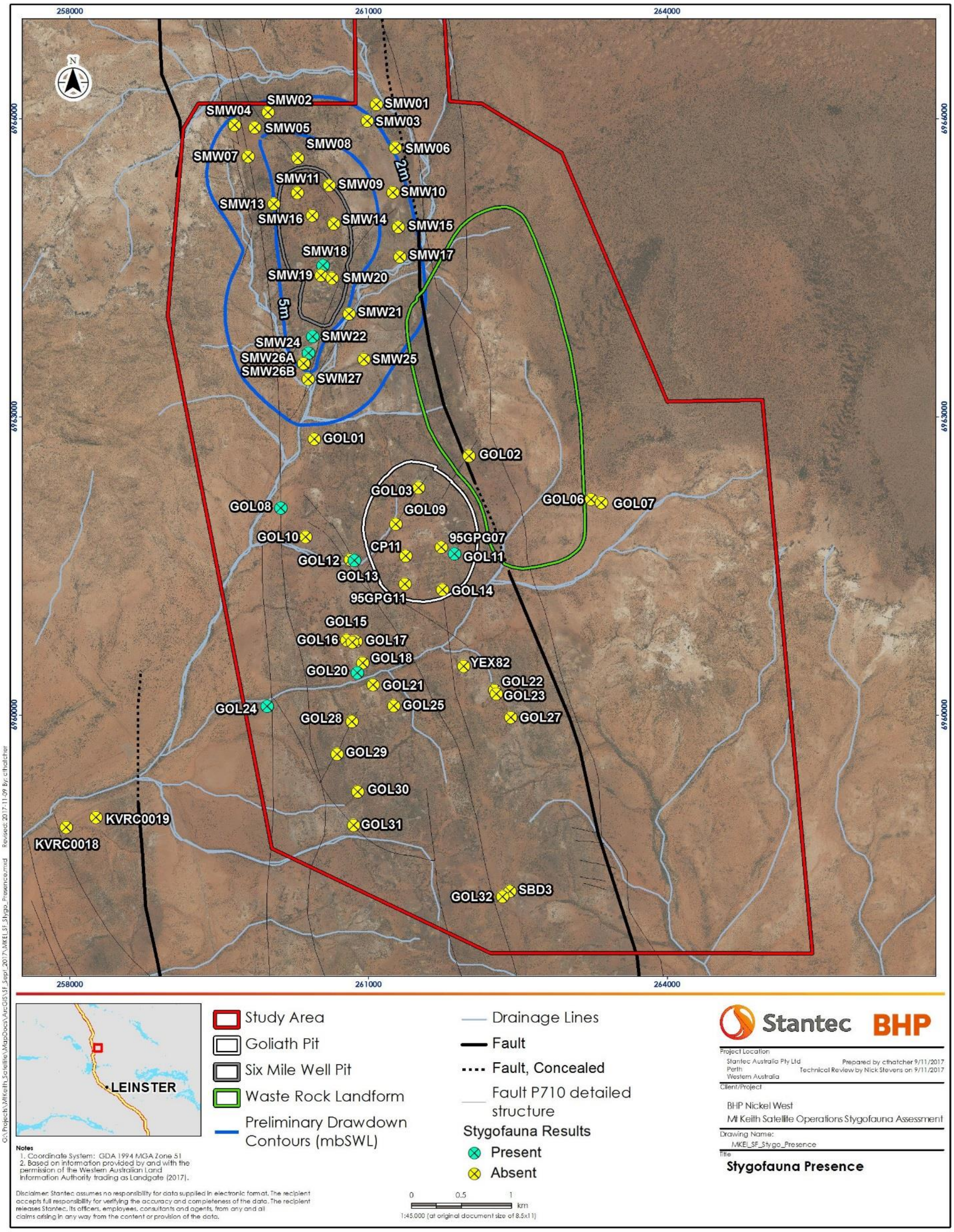

Figure 5-5: Overview of stygofauna sample sites (2006 to 2017) indicating recorded presence or absence.

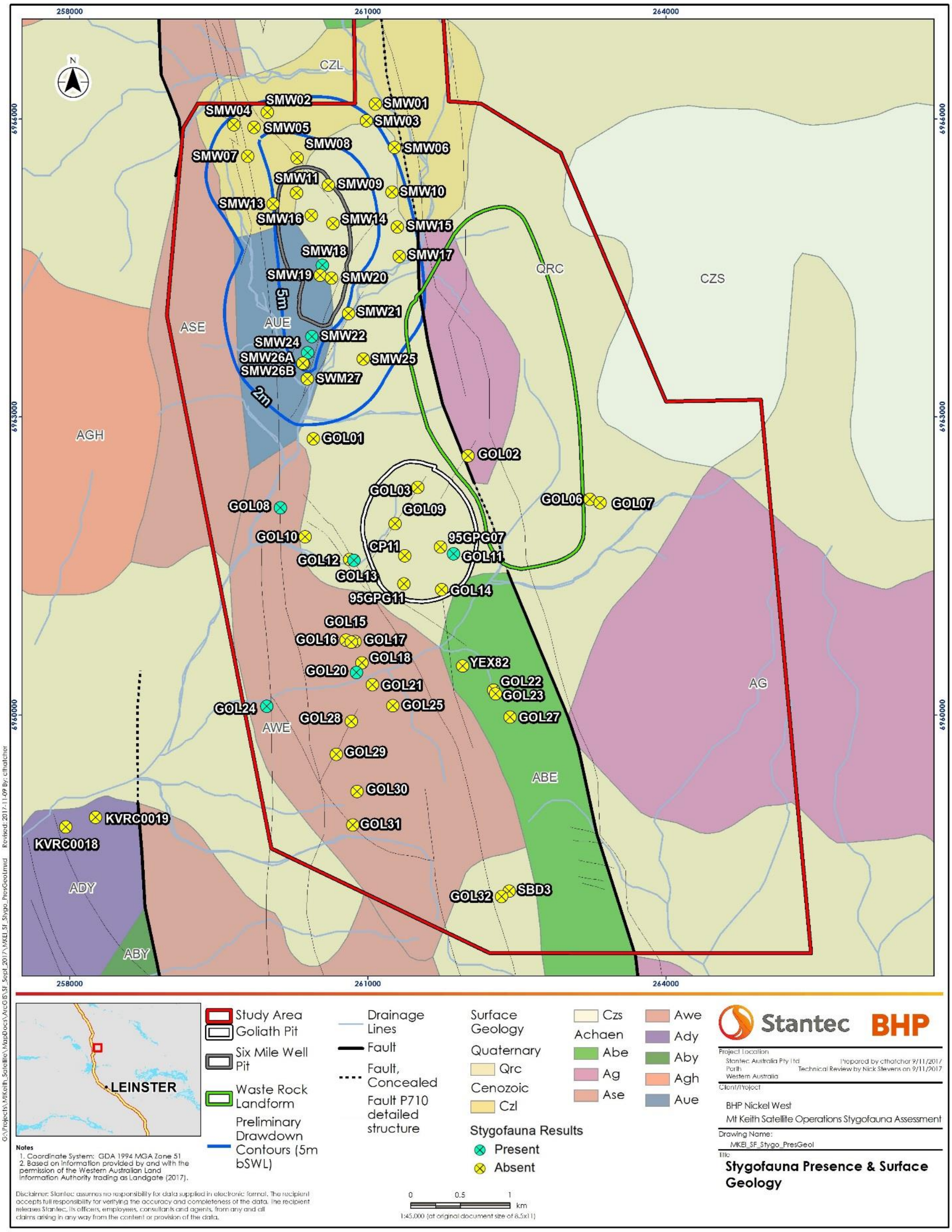

Figure 5-6: Presence or absence of stygofauna records in relation to surface geology.

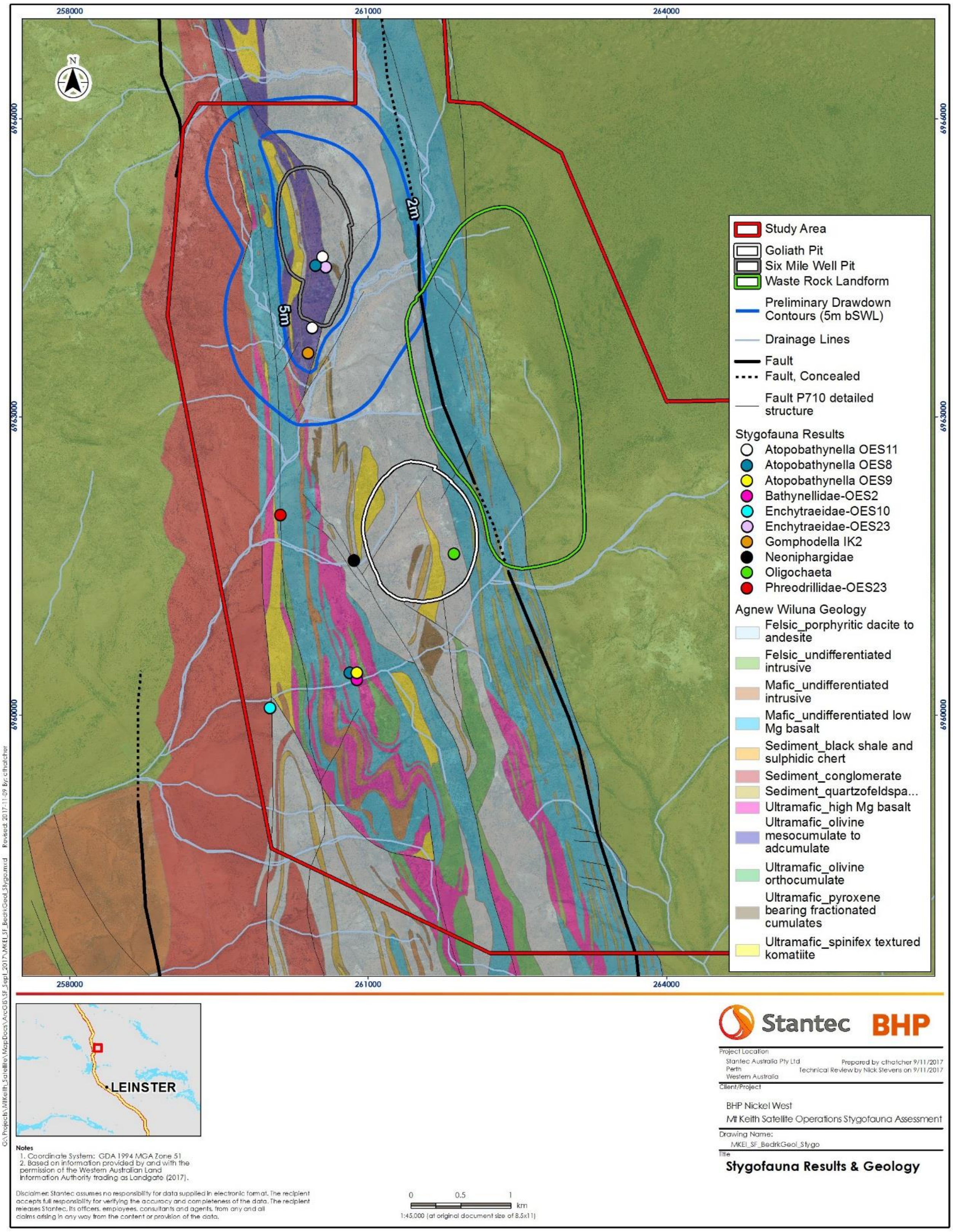

Figure 5-7: Distribution of recorded stygofauna taxa in relation to bedrock geology

5.5 Stygofauna Species Richness Estimates and Survey Adequacy

A total of ten stygofauna taxa were considered to have been collected from the Study Area (treating Oligochaeta sp. as a separate species to other oligochaete taxa recorded). The species richness predicted to occur across the Study Area ranged from 10.7 to 16 species (**Figure 5-8, Table 5-3**). The species accumulation curves for two of the species richness estimators, Bootstrap and Jack 1, are still trending upwards. The remaining five estimators have reached a plateau, with ICE trending downwards. The stygofauna sampling undertaken to date is estimated to have recorded between 62.5 to 93.8 % of the assemblage predicted to exist. The extrapolation to 442 samples predicts that a 100 % increase in survey effort will result in the collection of an additional two to three species from the Study Area.

The species capture rate (10 species from 221 samples at an overall capture rate of 0.05 species per sample) is considerably lower than found for studies of calcrete systems but does fall within the range of findings for other stygofauna assemblages recorded from other fractured rock aquifer systems dominated by Bathynellacea:

- Browns Range — 18 species from 160 samples (capture rate 0.11) (Outback Ecology 2014a);
- Leonora — five species from 100 samples (capture rate 0.05) (Stantec, unpublished data).

The species accumulation curves and comparison of capture rates with other studies of similar aquifer systems indicate that the survey intensity undertaken has been sufficient in providing a reliable level of knowledge of the stygofauna assemblage present in the Study Area and gives a reasonable level of confidence in assessing the potential impacts posed by the proposed Project in accordance with EPA (2016a, b) guidelines. The sampling effort conducted to date within the proposed impact areas (94 samples), has exceeded the recommended minimum requirements of 40 impact samples for a Level 2 stygofauna survey (EPA 2016a, b).

The total number of stygofauna samples collected as part of this assessment (221) does provide a reliable characterisation of the stygofauna values present in the Study Area and in relation to the proposed direct impact zones. Additional sampling is highly unlikely to further refine the knowledge we have of the stygofauna assemblage present when taking into consideration the low number of samples (12 of 221) and bores (8 of 61) that recorded stygofauna (**Appendix B**, **Appendix D**). The infrequent collection of stygofauna is further highlighted by the fact that from the repeated sampling of the eight bores that had recorded stygofauna, only two bores (GOL20 and SMW18) yielded stygobitic taxa on more than one occasion.

The Goliath reference bore GOL20 was sampled six times from 2010 to 2017, and only on two of those occasions were stygofauna collected; *Atopobathynella* sp. OES8 once in May 2017; *Atopobathynella* sp. OES9 twice, June 2011 and May 2017; and Bathynellidae sp. OES2 once in June 2011. The Six Mile Well pit bore SMW18 was sampled four times from 2010 to 2012 (was blocked and unable to be sampled in 2017), and only on two of those occasions were stygobitic taxa collected; *Atopobathynella* sp. OES8 once in November 2010; and *Atopobathynella* sp. OES11 once in February 2012. The stygoxene Enchytraeidae sp. OES23 was collected from SMW18 on three occasions, November 2010, June 2011, and February 2012. Two of the eight bores, GOL11 and GOL13, have unconfirmed records from earlier Biota (2006) work. Despite repeated sampling from 2010 to 2017 (GOL11 sampled six times and GOL13 five) no additional stygofauna were recorded. Two of the eight bores, GOL08 and SMW22, were drilled in February 2017, and yielded stygofauna on one occasion each, in May and August 2017, respectively. Due to the sporadic and limited collection of stygofauna from bores with positive records, further targeted sampling is not considered warranted as would be unlikely to further elucidate stygofauna values within the Study Area.

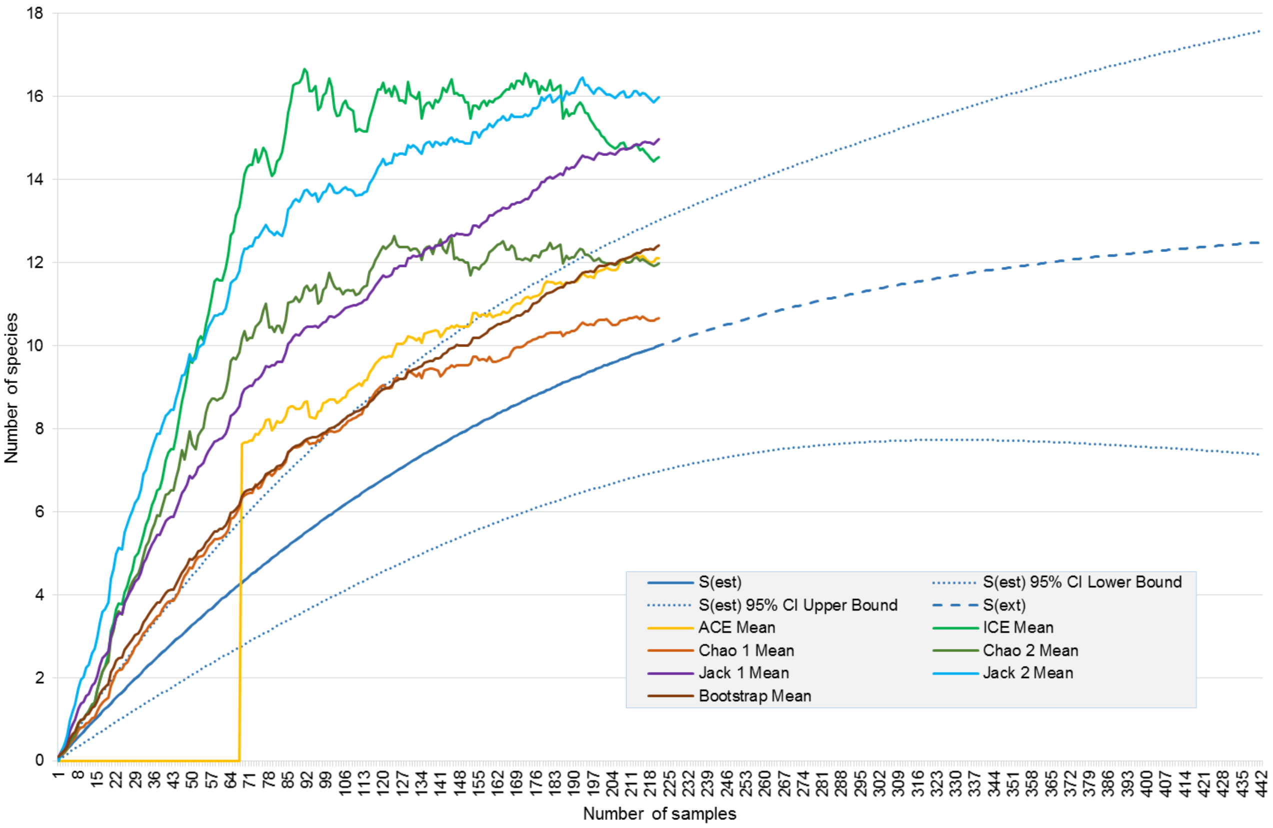

Figure 5-8: Stygofauna species accumulation curves for observed (S(est)), extrapolated (S(ext); to 130 samples), and various diversity estimators (EstimateS (Colwell 2013)) based on all recorded results (including Biota (2006)) from 2006 to 2012 sample rounds for the Mount Keith Satellite Operations Area.

Table 5-3: Observed stygofauna species diversity recorded from 2006 to 2017 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**	**10**	
	Extrapolated (442 samples)	12.5	80.1%
Diversity estimators	Chao 1 Mean	10.7	93.8%
	Chao 2 Mean	12.0	83.4%
	ACE Mean	12.1	82.6%
	Bootstrap Mean	12.4	80.5%
	ICE Mean	14.6	68.7%
	Jack 1 Mean	15.0	66.8%
	Jack 2 Mean	16.0	62.5%
	Range	**10.7 — 16**	**62.5 — 93.8%**

6. Impact Assessment

6.1 Proposed Impacts

The two main direct potential impacts on the stygofauna assemblage 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 species relative to the lowering of the groundwater table only. Both pit excavation and lower groundwater levels pose varying degrees of risk to the conservation of four of the ten stygofauna species that were restricted in distribution to within the proposed mining areas and/or modelled groundwater drawdown zones.

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.

6.2 Stygofauna Distributions and Habitat

The low diversity and infrequent occurrence of stygofauna collected from the Study Area correlates with the overall hydrogeological assessment that the regolith, alluvial and fractured rock aquifers present are minor and relatively hydraulically isolated, with many portions of the Project Area lacking suitable habitat to support stygofauna (refer section 5.3.1). The northern, western and eastern portions of the Six Mile Well Project Area, and the Goliath deposit area and southern Goliath reference areas, were confirmed to not host prospective stygofauna habitat as the saturated strata are entirely fresh bedrock and/or heavily clay dominated with no stygobitic species collected despite repeated sample rounds since 2010.

The southern portion of the Six Mile Well Project Area, between the confluence area of the upper Jones Creek and one of its tributaries, was confirmed to host prospective stygofauna habitat within the unconfined portion of the regolith aquifer present, where no thick confining/semi-confining clay dominated strata existed. Stygobitic taxa were recorded from three bores (SMW18, SMW22 and SMW24) that intercepted the unconfined weathered ultramafic and fractured bedrock near to incised drainage channels. Outside of the Six Mile Well Project area only two bores (GOL08 and GOL20) each located near to drainage lines have confirmed records of stygobitic taxa. Both bores do not intercept weathered ultramafic regolith aquifers demonstrating that stygofauna habitat is not confined to regolith aquifers in the Project Area such as those that occur within each of the deposit areas.

All but two of the stygofauna species recorded from the Study Area, have only been recorded from a single bore each, often on a single occasion despite repeated sampling of the bores (refer section 5.5). It is not possible to reliably assess the distribution range of stygofauna species that are known only from limited records. 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. provision of connected network of habitable cavities), inflow rates of energy resources (e.g. organic carbon, biofilm growth, prey), and water quality parameters such as temperature, pH, dissolved oxygen and organic carbon levels. At the mesohabitat (catchment) scale, factors include surface water flow patterns influencing infiltration zones and influx rates into the groundwater systems of energy resources or dissolved oxygen according to geomorphological features, as well as interactions with riparian vegetation and parafluvial sediments (Boulton *et al.* 1998).

The irregular and patchy nature of the stygofauna habitat present is evident to a high degree in the Study Area. Both bores, SMW18 and GOL20, the only bores to have recorded multiple species on more than one occasion, each have multiple bores drilled within 75 to 300 m of them. However, no stygofauna have been recorded from the close neighbouring bores. This suggests that the stygofauna inhabited areas are not broad expanses, as found in association with calcrete systems, but likely to be along narrow pathways in the form of a dendritic network across the Study Area. The inhabited network does appear to mimic the main drainage channels with most of the bores recording stygofauna located near incised water courses. Such locations would likely receive higher surface water infiltration rates (i.e. resource influx) and greater degree of weathering of geological units and structures present leading to higher level of secondary porosity (i.e. habitable space).

Connectivity among locally saturated surficial alluvial deposits along drainage lines, and from which stygofauna were recorded, would be present, particularly following high rainfall and surface flow events, and are considered to provide a viable pathway for stygofauna movement among the regolith and fractured groundwater systems. Surficial alluvial aquifers are an important ecological component of drainage systems including ephemeral streams (Harvey and Wagner 2000). The hyporheic zone, defined as an ecotone that occurs within the bed and banks of a water course where surface and groundwater interact, forms an important transition zone connecting alluvial aquifer ecosystems to surface aquatic ecosystems (Boulton 2000, Boulton *et al.* 1998, Mugnai *et al.* 2015). Bathynellacean species are known to inhabit the hyporheic zones of water courses, including ephemeral creeks and are considered to likely disperse along such pathways (Abrams *et al.* 2012, Camacho *et al.* 2017, MWH 2016b, Yenumula *et al.* 2015). In arid environments, the hyporheic zone in ephemeral water courses is heavily dependent on associated groundwater within the saturated alluvial sediments and weathered/fractured 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).

Another influential factor contributing to the sporadic nature of the stygofauna results are temporal variations in assemblage diversity when sampling as demonstrated with the continuation of the discovery of new species from previously relatively well sampled areas (Guzik *et al.* 2010) or species only recorded intermittently over the course of an extensive survey program (Karanovic and Cooper 2012, MWH 2015). There was a high degree of temporal variation in the stygofauna results from the study Area as shown by the infrequent collection of stygofauna from bores with positive records despite repeated sampling. Only two bores (GOL20 and SMW18) yielded stygobitic taxa on more than one occasion, and only three stygobitic taxa, *Atopobathynella* sp. OES8, *A.* sp. OES9, *A.* sp. OES11, were collected twice. The semi-aquatic stygoxene Enchytraeidae sp. OES23 was recorded on three occasions. The sporadic and limited collection of stygofauna indicate that further targeted sampling would not further refine the current knowledge of the stygofauna assemblage present within the Study Area.

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, are likely to 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 (MWH 2015, Outback Ecology 2012d). 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). Interconnected with the surficial aquifers would be components of the fractured rock aquifer systems in the Study Area, associated with geological structures such as faults, fractures and shear zones that would likely provide refugia and potentially contribute to the interstitial highway. Molecular analysis demonstrated that many species in Browns Range stygofauna assemblage possessed relatively widespread distributions throughout the fractured rock and associated surficial alluvial aquifer systems present within the Browns Range Metamorphics and surrounding Gardiner Sandstone geological units (Outback Ecology 2014).

The seemingly restricted distribution of a taxon to a single bore, is often an artefact of sampling a species occurring at low population densities that has a patchy, irregular distribution within the groundwater system in response to varying micro- and mesohabitat biotic and abiotic factors, temporal/seasonal fluctuations, 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 results of this study, with 80% of species recorded from a single bore only, have highlighted the difficulties in assessing likely species distributions moreso than other stygofauna studies in the region that had a higher proportion of stygofauna species recorded more commonly from multiple sites.

Reviewing the records of closely-related species, or species collected sympatrically (biological surrogates), as well as considering the expanse of neighbouring geological habitat and hydrogeological data (physical surrogates) can provide further insight and clarification of the potential distribution patterns of species that are known from a few records only and assist in addressing the artefact of sampling difficulties associated with subterranean fauna (Bennelongia 2015a, Environmental Protection Authority 2016b, MWH 2015, 2016d).

The distribution of *Atopobathynella* sp. OES11 from inside the proposed Six Mile Well pit as well as from outside indicates that the portion of the habitable aquifer inside the pit boundary is not hydraulically isolated with connections present to beyond the proposed pit boundary. The relatively high CO1 haplotype diversity exhibited by *Atopobathynella* sp. OES11 (refer section 5.4.1) within a limited geographical area, particularly a single bore, is considered to be indicative of a relatively large and more widespread population than location records may show (Guzik *et al.* 2011). The biological finding are consistent with the hydrogeological information from the area that shows the regolith aquifer system extends beyond the pit boundary to the southern portion of the Six Mile Well Project Area that will be subjected to varying groundwater drawdown extents associated with pit dewatering.

The occurrence of *Atopobathynella* sp. OES8 from within the Six Mile Well pit as well as from the Goliath reference area provides further biological evidence that the Six Mile Well regolith aquifer is not isolated and that a hydraulic connection does exist between the aquifer systems of each area. The broader distribution of *Atopobathynella* sp. OES8 also supports the findings of the relative high haplotype diversity found for *Atopobathynella* sp. OES11. The geological data available from the southern portion of the Six Mile Well Project area did indicate deeper weathering along the southeastern boundary of the Six Mile Well Project Area, likely a result of the fault lines and incised Jones Creek drainage channel present, which is considered to have hydraulic connection to the alluvial and fractured rock aquifer systems associated with Jones Creek to the south (refer section 5.3.1). The relatively flat static groundwater levels exhibited indicates that a degree of groundwater connectivity does occur across much of the Study Area. The distributions and genetic diversity exhibited by *Atopobathynella* sp. OES8 and *Atopobathynella* sp. OES11 do further support that the habitable portion of the Six Mile Well regolith aquifer system is hydraulically connected to a network of other regolith and fractured rock aquifers associated with the upper Jones Creek catchment. The distributions of stygofauna species and gene flow pathways are likely to be dendritic in nature, reflecting the habitable groundwater networks present, that appear to be closely associated with the main drainage channels present.

There is the possibility that the habitat sampled within the Study Area does represent the peripheral upper distribution limits of a more widespread stygofauna assemblage within the Jones Creek catchment. However, a sufficient number of suitable bores were not available along the main Jones Creek line further down the catchment outside the Project's tenement to test if the assemblage was present and more diverse and abundant to the southwest 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. Most of the bores sampled since 2010 that had confirmed positive stygofauna records were set in or adjacent to ephemeral drainage channels that form the very upper extent of the headwaters of the Jones Creek catchment area. Therefore, the habitat sampled may likely represent the outer distribution limits or periphery of the stygofauna assemblage within the middle to upper Jones Creek catchment.

6.3 Stygofauna Recorded From Proposed Impact Areas

The stygofauna results have shown that the stygofauna assemblage in the Study Area are sparsely distributed and infrequently collected (**Figure 5-7**, **Table 5-2**). The low stygofauna abundance and sporadic occurrence (both spatially and temporally) does make it difficult to reliably assess the potential risks posed by the development of the Project to the stygofauna assemblage recorded. However, the biological and hydrogeological evidence available does indicate that the distribution patterns of the stygofauna recorded are dendritic-like, reflecting the habitable groundwater networks closely associated with the main drainage channels, and therefore considered to extend beyond each of their recorded locations as shown by *Atopobathynella* sp. OES8 whose range extends for over 4 km from the Six Mile Well pit area to the Goliath non-impact area.

Of the ten stygofauna taxa recorded from the Study Area, four species of the assemblage have each only been recorded from within proposed pit boundaries and/or modelled groundwater drawdown impact zones (**Figure 5-7**). Two species, the indeterminate oligochaete and Enchytraeidae sp. OES23, have each only been recorded from inside the proposed pits, Goliath and Six Mile Well, respectively. *Atopobathynella* sp. OES11 has been recorded from inside and outside the proposed Six Mile Well pit, but not from beyond the modelled groundwater drawdown impact zone. *Gomphodella* sp. IK2 has not been recorded from outside the Six Mile Well pit modelled groundwater drawdown impact zone. The remaining six species were recorded only from areas outside of proposed impacts, except for *Atopobathynella* sp. OES8 that was also recorded from inside the proposed Six Mile Well pit as well as from non-impact areas in the Goliath Project Area.

The development of the Goliath deposit is not considered to pose a long term conservation risk to any stygofauna species, in particular the indeterminate Oligochaeta species, due to the lack of prospective stygofauna habitat present and the likelihood that the Oligochaeta species is a semi-aquatic enchytraeid and not stygobitic, and therefore would have a broader distribution, as demonstrated by many other enchytraeid species from other impact assessments, that would extend beyond the Goliath impact zone.

The development of the Six Mile Well deposit will impact populations of three species that were not recorded from outside of the proposed impact area. The enchytraeid, Enchytraeidae sp. OES23, has only been collected from within the proposed Six Mile Well pit boundary. However, this species is not considered to be stygobitic and likely to possess a broader distribution as has been shown for many other enchytraeid species from the Yigarn. *Atopobathynella* sp. OES11 has been recorded from inside and outside the proposed Six Mile Well pit but within the groundwater drawdown. The CO1 haplotype diversity for *Atopobathynella* sp. OES11 indicates the presence of a relatively large and more widespread population than location records may show. *Gomphodella* sp. IK2 has been recorded from outside the proposed Six Mile Well pit but also within the groundwater drawdown that is modelled to remove most of the saturated habitat. All three species are considered to be more broadly distributed and occur outside the impacted habitable portion of the Six Mile Well regolith aquifer system, when taking into account physical and biological information available.

The physical data available from the southern portion of the Six Mile Well Project area shows deeper weathering is present along the southeastern boundary of the Six Mile Well Project Area, likely a result of the fault lines and incised Jones Creek drainage channel present, which is considered to have hydraulic connection to the alluvial and fractured rock aquifer systems associated with Jones Creek to the south. Evidence for this is the relatively flat static groundwater levels exhibited that indicate a degree of groundwater connectivity does occur across much of the Study Area. This is further supported by the broader distribution of *Atopobathynella* sp. OES8 that demonstrates that hydraulic connections do exist between the Six Mile Well and Goliath Project Areas.

The remaining six species recorded from the assemblage in the Study Area are not at risk from the impacts of the proposed Project as they have all been found to occur in non-impact zones.

7. Conclusion

The stygofauna assessment reported here has revealed that the Study Area does host a depauperate stygofauna assemblage. The assemblage is dominated by bathynellacean taxa that genetic analysis demonstrated were divergent from other northern Yilgarn bathynellacean fauna assemblages. The hydrogeological and stygofauna data indicate that the stygofauna assemblage present are sparsely distributed in a dendritic nature reflecting the network of habitable groundwater systems present, that appear to be closely associated with Jones Creek and tributaries. The findings indicate that the development of the Project is not likely to propose a long term conservation risk to the two stygobitic species, *Atopobathynella* sp. OES11 and *Gomphodella* sp. IK2, recorded from within proposed Six Mile Well groundwater drawdown impact areas. Both species are considered to have distributions that extend beyond the impact zones through a network of hydraulic connections between the southern habitable portion of the Six Mile Well regolith aquifer and the alluvial, regolith and fractured rock groundwater systems associated with the Jones Creek drainage system. The broader distributions of both species is supported by the distribution of *Atopobathynella* sp. OES8 and haplotype diversity of *Atopobathynella* sp. OES11. The remaining eight species recorded are also not considered to be of conservation concern because were collected from non-impact areas or not considered to be stygobites and therefore likely to possess broader distributions beyond the single bore locations from which they were recorded.

8. References

Abrams, K. M., Guzik, M. T., Cooper, S. J. B., Humphreys, W. F., King, R. A., Cho, J. and Austin, A. D. (2012) What lies beneath: Molecular phylogenetics and ancestral state reconstruction of the ancient subterranean Australian Parabathynellidae (Syncarida, Crustacea). *Molecular Phylogenetics and Evolution* 2012(March 29): Epub ahead of print.

Allford, A., Cooper, S. J. B., Humphreys, W. F. and Austin, A. D. (2008) Diversity and distribution of groundwater fauna in a calcrete aquifer: does sampling method influence the story? *Invertebrate Systematics* 22: 127-138.

Australian Natural Resources Atlas. (2010) *Biodiversity Assessment - Murchison.* Available online at http://www.anra.gov.au/topics/vegetation/assessment/wa/ibra-murchison.html. Accessed on 6/10/2011.

Barranco, P. and Harvey, M. S. (2008) The first indigenous palpigrade from Australia: a new species of Eukoenenia (Palpigradi : Eukoeneniidae). *Invertebrate Systematics* 22: 227-233.

Beard, J. S. (1976) *The vegetation of the Boorabbin and Lake Johnston Areas* Vegmap Publications, Perth, Western Australia.

Beard, J. S. (1990) *Plant Life of Western Australia.* Kangaroo Press, Kenthurst.

Bennelongia. (2009) *Yilgarn Iron Ore Project: Carina Deposit, Subterranean Fauna Assessment.* Report prepared for Polaris Metals NL, Western Australia.

Bennelongia. (2013) *Stygofauna Monitoring: Magellan Lead Carbonate Project, March 2012* Prepared for Magellan Metals Pty Ltd.

Bennelongia. (2015a) *Assessment of Troglofauna at OB32 East* Report prepared for BHP Billiton Iron Ore, Perth, Western Australia.

Bennelongia. (2015b) *Yeelirrie Subterranean Fauna Assessment* Prepared for Cameco Australia.

BHP Billiton Nickel West. (2011) *Report: NDS1 Pits - Mining impacts on groundwater and the ultimate pit voids*.

Biota. (2006a) *BHP Billiton Northern Nickel Projects Stygofauna Assessment* Biota Environmental Science Pty Ltd, Perth Western Australia.

Biota. (2006b) *Magellan Lead Project stygofauna assessment* Prepared for Magellan Metals. April 2006., Perth, Western Australia.

Biota Environmental Sciences. (2010) *Yandicoogina Subterranean Fauna Assessment Phases I - IV.* Prepared for Rio Tinto Iron Ore, Perth.

Biota Environmental Services. (2010) *Yandicoogina Subterranean Fauna Assessment Phases I - IV.* Prepared for Rio Tinto Iron Ore, Perth.

Boulton, A. J. (2000) The Subsurface Macrofauna. In: B. J. Jones and P. J. Mulholland (eds) *Streams and Ground Waters*. Academic Press, San Diego, pp 337-361

Boulton, A. J., Findlay, S., Marmonier, P., Stanley, E. H. and Valett, H. M. (1998) The functional significance of the hyporheic zone in streams and rivers. *Annual Review of Ecology and Systematics* 29: 59-81.

Boulton, A. J. and Stanley, E. H. (1996) Hyporheic processes during flooding and drying in an Sonoran Desert stream. II. Faunal dynamics. *Archiv für Hydrobiologie* 134: 27-52.

Boulton, A. J., Valett, H. M. and Fisher, S. G. (1992) Spatial distribution and taxonomic composition of the hyporheos of several Sonoran Desert streams. *Archiv für Hydrobiologie* 125: 37-61.

Bradford, T., Adams, M., Guzik, M. T., Humphreys, W. F., Austin, A. D. and Cooper, S. J. B. (2013a) Patterns of population genetic variation in sympatric chiltoniid amphipods within a calcrete aquifer reveal a dynamic subterranean environment. *Heredity* 2013: 1-9.

Bradford, T., Adams, M., Guzik, M. T., Humphreys, W. F., Austin, A. D. and Cooper, S. J. B. (2013b) Patterns of population genetic variation in sympatric chiltoniid amphipods within a calcrete aquifer reveal a dynamic subterranean environment. *Heredity*: 1-9.

Bradford, T., Adams, M., Humphreys, W. F., Austin, A. D. and Cooper, S. J. B. (2010) DNA barcoding of stygofauna uncovers cryptic amphipod diversity in a calcrete aquifer in Western Australia's arid zone. *Molecular Ecology Resources* 10: 41–50.

Bureau of Meteorology (2017) *Climate Data Online. Yakabindie Monthly Rainfall.* Available online at http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=139&p_display_type=dataFile&p_startYear=&p_c=&p_stn_num=012088.

Camacho, A. I., Dorda, B. A., Chillón, B. S. and Rey, I. (2017) The collection of Bathynellacea specimens of MNCN (CSIC) Madrid: microscope slices and DNA extract. *ZooKeys* 678: 31-63.

Chapman, D. and Kimstach, V. (1996) Selection of water quality variables. In: D. Chapman (ed) *Water Quality Assessments: A Guide to the Use of Biota, Sediments and Water in Environmental Monitoring.* E and FN Spon London, United Kingdom

Cho, J. and Humphreys, W. F. (2010) Ten new species of the genus *Brevisomabathynella* Cho, Park and Ranga Reddy, 2006 (Malacostraca, Bathynellacea, Parabathynellidae) from Western Australia. *Journal of Natural History* 44(17-18): 993-1079.

Cho, J., Humphreys, W. F. and Lee, S. (2006) Phylogenetic relationships within the genus *Atopobathynella* Schminke (Bathynellacea: Parabathynellidae). *Invertebrate Systematics* 20: 9 - 41.

Clinton, S. M., Grimm, N. B. and Fisher, S. G. (1996) Response of a hyporheic invertebrate assemblage to drying disturbance in a desert stream. *Journal of the North American Benthological Society* 15: 700-712.

Coffey Partners. (1990) *Yakabindie nickel mine: pit dewatering* Report No.: P389/1-DB.

Coffey Partners. (1991) *Yakabindie nickel project: potable water supply* Report No. P389/1-EA.

Colwell, R. K. (2013) *EstimateS: Statistical estimation of species richness and shared species from samples. Version 9*. Available online at User's Guide and application published at: http://purl.oclc.org/estimates.

Cooling, M. P. and Boulton, A. J. (1993) Aspects of the hyporheic zone below the terminus of a South Australian arid-zone stream. *Australian Journal of Marine and Freshwater Research* 44: 411-426.

Cooper, S. J. B., Bradbury, J. H., Saint, K. M., Leys, R., Austin, A. D. and Humphreys, W. F. (2007) Subterranean archipelago in the Australian arid zone: mitochondrial DNA phylogeography of amphipods from central Western Australia. *Molecular Ecology* 16: 1533-1544.

Cooper, S. J. B., Hinze, S., Leys, R., Watts, C. H. S. and Humphreys, W. F. (2002) Islands under the desert: molecular systematics and evolutionary origins of stygobitic water beetles (Coleoptera: Dytiscidae) from central Western Australia. *Invertebrate Systematics* 16: 589-598.

Cooper, S. J. B., Saint, K. M., Taiti, S., Austin, A. D. and Humphreys, W. F. (2008) Subterranean archipelago: mitochondrial DNA phylogeography of stygobitic isopods (Oniscidea: *Haloniscus*) from the Yilgarn region of Western Australia. *Invertebrate Systematics* 22: 195-203.

Cowan, M. (2001) Murchison 1 (MUR1 - East Murchison Subregion). In: *A Biodiversity Audit of Western Australia's 53 Biogeographical Subregions in 2002*

Department of Conservation and Land Management., Kensington, Western Australia

Danielopol, D. L. and Pospisil, P. (2000) Biodiversity in groundwater: a large-scale view. *TREE* 15: 223-224.

De Laurentiis, P., Pesce, G. L. and Humphreys, W. F. (2001) Copepods from ground waters of Western Australia, VI. Cyclopidae (Crustacea: Copepoda) from the Yilgarn Region and the Swan Coastal Plain. *Records of the Western Australian Museum* 64: 115-131.

Department of Environment (2016a) *EPBC Act List of Threatened Ecological Communities*. Available online at https://www.environment.gov.au/cgi-bin/sprat/public/publiclookupcommunities.pl.

Department of Environment (2016b) *EPBC Act List of Threatened Fauna*. Available online at https://www.environment.gov.au/cgi-bin/sprat/public/publicthreatenedlist.pl?wanted=fauna.

Department of Environment and Conservation. (2010) *DEC Managed Lands and Waters within Western Australia.* Prepared by the Department of Environment and Conservation, Information Management Branch, Perth, Western Australia.

Department of Mines and Petroleum. (2010) *Clearing Permit Decision Report. Jaguar Base Metals Deposit* Report prepared for Jabiru Metals Limited, Western Australia.

Department of Parks and Wildlife (2015a) *List of Threatened Ecological Communities endorsed by the Western Australian Minister for Environment*. Available online at http://www.dpaw.wa.gov.au/images/plants-animals/threatened-species/threatened_ecological_communities_endorsed_by_the_minister_for_the_environment_june_2015.pdf.

Department of Parks and Wildlife (2015b) *Priority Ecological Communities for Western Australia - Version 23*. Available online at https://www.dpaw.wa.gov.au/images/documents/plants-animals/threatened-species/priority_ecological_communities_list_wa.pdf.

Department of Parks and Wildlife (2015c) *Threatened and Priority Fauna List* Available online at https://www.dpaw.wa.gov.au/plants-and-animals/threatened-species-and-communities/threatened-animals.

Department of Parks and Wildlife (2015d) *WC Specially Protected Fauna Notice 2015*. Available online at https://www.environment.gov.au/cgi-bin/sprat/public/publicthreatenedlist.pl?wanted=fauna.

Department of Parks and Wildlife (2016a) *NatureMap: Mapping Western Australia's Biodiversity Database search*. Available online at http://naturemap.dec.wa.gov.au./default.aspx.

Department of Parks and Wildlife. (2016b) *Threatened and Priority Ecological Communities Database Search for Yakabindie.* Available online at. Accessed on April 2016.

Department of Parks and Wildlife. (2016c) *Threatened and Priority Fauna Database Search for Yakabindie.* Available online at http://www.dpaw.wa.gov.au/plants-and-animals/threatened-species-and-communities/threatened-animals. Accessed on April 2016.

Department of Sustainability Environment Water Population and Communities (2012a) *Interim Biogeographic Regionalisation for Australia (IBRA) Version 7 - bioregions*. Available online at https://www.environment.gov.au/system/files/pages/5b3d2d31-2355-4b60-820c-e370572b2520/files/bioregions-new.pdf.

Department of Sustainability Environment Water Population and Communities (2012b) *Interim Biogeographic Regionalisation for Australia (IBRA) Version 7 - subregions*. Available online at https://www.environment.gov.au/system/files/pages/5b3d2d31-2355-4b60-820c-e370572b2520/files/bioregions-new.pdf.

Dole-Olivier, M. J., Marmonier, P., Creuze des Chatelliers, M. and Martin, D. (1994) Interstial fauna associated with the alluvial floodplains of the Rhone River (France). In: J. Gibert, D. L. Danielopol and J. A. Stanford (eds) *Groundwater Ecology*. Academic Press, San Diego, pp 313-346

Environmental Protection Authority. (2001) *Mt Margaret Nickel-Cobalt Project, Anaconda Nickel Limited* Report and Recommendations of the Environmental Protection Authority. Bulletin 1025, Perth, Western Australia.

Environmental Protection Authority. (2007) *Guidance for the assessment of environmental factors (in accordance with the Environmental Protection Act 1986). Sampling methods and considerations for subterranean fauna in Western Australia - No. 54a. Technical appendix to guidance statement 54* Environmental Protection Authority, Western Australia.

Environmental Protection Authority. (2013) *Environmental Assessment Guideline (EAG) 12 for consideration of subterranean fauna in environmental impact assessment in Western Australia*.

Environmental Protection Authority. (2016a) *Technical Guidance Sampling Methods for Subterranean Fauna Survey* Environmental Protection Authority, Western Australia.

Environmental Protection Authority. (2016b) *Technical Guidance Subterranean Fauna Survey* Environmental Protection Authority, Western Australia.

Finston, T. and Berry, O. (2011) *Re. Report on the molecular systematics of the Chiltoniidae* Report prepared for Subterranean Ecology

Gentilli, J. (1979) *Western Landscapes.* University of Western Australia Press, Perth, Western Australia.

Golder Associates. (2010) *Lake Maitland Uranium Project. Environmental Scoping Document* Report prepared for Mega Lake Maitland Pty Ltd.

Guzik, M. T., Austin, A. D., Cooper, S. J. B., Harvey, M. S., Humphreys, W. F., Bradford, T., Eberhard, S. M., King, R. A., Leys, R., Muirhead, K. A. and Tomlinson, M. (2010) Is the Australian subterranean fauna uniquely diverse? *Invertebrate Systematics* 24: 407-418.

Guzik, M. T., Cooper, S. J. B., Humphreys, W. F., Ong, S., Kawakami, T. and Austin, A. D. (2011) Evidence for population fragmentation within a subterranean aquatic habitat in the Western Australian desert. *Heredity*: 1-16.

Halse, S. A., Scanlon, M. D. and Cocking, J. S. (2002) *Do springs provide a window to the groundwater fauna of the Australian arid zone?* Department of Conservation and Land Managment, Perth.

Halse, S. A., Scanlon, M. D., Cocking, j. S., Barron, H. J., Richardson, J. B. and Eberhard, S. (2014) Pilbara stygofauna: deep groundwater of an arid landscape contains globally significant radiation of biodiversity. *Records of the Western Australian Museum. Supplement* 78: 443-483.

Hammer, U. T. (1986) *Saline Lake Ecosystems of the World.* Dr. W. Junk Publishers, Dordrecht.

Hancock, P. J. and Boulton, A. J. (2008) Stygofauna biodiversity and endemism in four alluvial aquifers in eastern Australia. *Invertebrate Systematics* 22: 117-126.

Harvey, J. W. and Wagner, B. J. (2000) Quantifying Hydrologic Interactions between Streams and their Subsurface Hyporheic Zones. In: J. B. Jones and P. J. Mulholland (eds) *Streams and Ground Waters*. Academic Press, San Diego, pp 3-44

Harvey, M. E., Rix, M. G., Volker, W. F., Hamilton, Z. R., Johnson, M. S., Teale, R. J., Humphreys, G. and Humphreys, W. F. (2011) Protecting the innocent: studying short-range endemic taxa enhances conservation outcomes. *Invertebrate Systematics* 25: 1-10.

Harvey, M. S. (2002) Short-range endemism among the Australian fauna: some examples from non-marine environments. *Invertebrate Systematics* 16: 555-570.

Hortal, J., Borges, P. and Gaspar, C. (2006) Evaluating the performance of species richness estimators: sensitivity to sample grain size. *Journal of Animal Ecology* 75: 274-287.

Humphreys, W. F. (2006) Aquifers: the ultimate groundwater-dependent ecosystems. *Australian Journal of Botany* 54: 115-132.

Humphreys, W. F. (2008) Rising from Down Under: developments in subterranean biodiversity in Australia from a groundwater fauna perspective. *Invertebrate Systematics* 22: 85–101.

Johnson, S. L., Commander, D. P. and O'Boy, C. A. (1999) *Groundwater resources of the Northern Goldfields, Western Australia.* Water and Rivers Commission, Report HG 2, Perth.

Karanovic, I. (2009) FOUR NEW SPECIES OF GOMPHODELLA DE DECKKER, WITH A PHYLOGENETIC ANALYSIS AND A KEY TO THE LIVING REPRESENTATIVES OF THE SUBFAMILY TIMIRIASEVIINAE (OSTRACODA). *Crustaceana* 82(9): 1133-1176.

Karanovic, T. (2004) *Subterranean copepods from arid Western Australia. Crustaceana Monographs, 3.* Koninkliijke, Brill, Leiden, The Netherlands.

Karanovic, T. and Cooper, S. J. B. (2012) Explosive radiation of the genus Schizopera on a small subterranean island in Western Australia (Copepoda: Harpacticoida): unravelling the cases of cryptic speciation, size differentiation and multiple invasions. *Invertebrate Systematics* 26: 115-192.

King, R., Bradford, T., Austin, A. D., Humphreys, W. F. and Cooper, S. J. B. (2012) Divergent molecular lineages and not-so-cryptic species: the first descriptions of stygobitic chiltoniid amphipods (Talitroidea: Chiltoniidae) from Western Australia. *Journal of Crustacean Biology* 32(3): 465-488.

Klohn Crippen Berger. (2013) *Browns Range Project Groundwater Baseline Characterisation. Draft* Report prepared for Northern Minerals Limited.

Marmonier, P. (1991) Effect of alluvial shift on the spatial distribution of interstitial fauna. *Verhandlungen Internationale Vereinigung fur Theoretische und Angewandte Limnologie* 24: 1613-1616.

Mugnai, R., Messana, G. and Di Lorenzo, T. (2015) The hyporheic zone and its functions: revision and research status in Neotropical regions. *Brazilian Journal of Biology* 75(3): 524-534.

MWES Consulting. (2017a) *Mt Keith Satellite Operations Water Aspects and Impacts Draft Report* Prepared for BHP Billiton- Nickel West.

MWES Consulting. (2017b) *Mt Keith Satellite Pits Stygofauna Bore Drilling – February 2017* Report prepared for BHP Nickel West, Perth, Western Australia.

MWH. (2015) *Wiluna Uranium Project: Millipede Targeted Subterranean Fauna Assessment* Report prepared for Toro Energy Ltd.

MWH. (2016a) *Corunna Downs Subterranean Fauna Assessment* Report prepared for Atlas Iron Ltd, Western Australia.

MWH. (2016b) *Ethel Gorge Stygofauna Monitoring Program: 2016* Report prepared for BHP Billiton Iron Ore.

MWH. (2016c) *Mount Keith Satellite Operations Subterranean Fauna Assessment* Report prepared for BHP Billiton Nickel West.

MWH. (2016d) *Wiluna Extension Uranium Project: MWH responses to OEPA's request for additional information regarding subterranean fauna* Report prepared for Toro Energy, Perth Western Australia.

Outback Ecology. (2008) *Stygofauna assessment for the Magellan Lead Project - Wiluna 2008* Report prepared for Magellan Metals Pty Ltd, Perth, Western Australia.

Outback Ecology. (2009) *Assessment of the stygofauna within the Hope Downs 4 study area.* Internal report for Hamersley Hope Management Services Pty Ltd, Perth, Western Australia.

Outback Ecology. (2010) *Magellan Lead Project 2010 stygofauna compliance monitoring* Internal report prepared for Magellan Metals Pty Ltd.

Outback Ecology. (2011) *Wiluna Uranium Project Subterranean Fauna Assessment, March 2011.* Prepared for Toro Energy Ltd, Perth, Western Australia.

Outback Ecology. (2012a) *BHP Billiton Nickel West NDS1 Project: Lake Way Borefield Subterranean Fauna Assessment* Prepared for BHP Billiton NIckel Wes, Perth, Western Australia.

Outback Ecology. (2012b) *Lake Maitland Uranium Project Level 2 Stygofauna Assessment* Prepared for Mega Lake Maitland Pty Ltd, Perth, Western Australia.

Outback Ecology. (2012c) *Lake Maitland Uranium Project Level 2 Troglofauna Assessment* Prepared for Mega Lake Maitland Pty Ltd, Perth, Western Australia.

Outback Ecology. (2012d) *Wiluna Uranium Project Stygofauna Assessment* Prepared for Toro Energy Ltd, Perth, Western Australia.

Outback Ecology. (2013) *Murchison Goldfield: Moyagee Project. Subterranean Fauna Assessment.* Report prepared for Silver Lake Resources, Western Australia.

Outback Ecology. (2014) *Browns Range Project Subterranean Fauna Assessment* Report prepared for Northern Minerals Ltd, Perth, Western Australia.

Pinder, A. (2009) *Tools for identifying selected Australian aquatic oligochaetes (Clitellata: Annelida). Taxonomy Research and Information Network (TRIN) Taxonomic Guide 2 Science Division, Department of Environment and Conservation*, Perth, Western Australia.

Pinder, A. M. (2001) Notes on the diversity and distribution of Australian Naididae and Phreodrilidae (Oligochaeta: Annelida). *Hydrobiologia* 463: 49 - 64.

Pinder, A. M. (2007) Guide to identication of oligochaetes from Pilbara groundwater *CALM*.

Pinder, A. M. (2008) Phreodrilidae (Clitellata: Annelida) in north-western Australia with descriptions of two new species. *Records of the West Australian Museum* 24: 459-468.

Pringle, H. J. R., Van Vreeswyk, A. M. E. and Gilligan, S. A. (1994) *An inventory and condition survey of rangelands in the north-eastern goldfields, Western Australia.* Department of Agriculture, Perth.

Reeves, J. M., De Deckker, P. and Halse, S. A. (2007) Groundwater Ostracods from the arid Pilbara region of northwestern Australia: distribution and water chemistry. *Hydrobiologia* 585: 99–118.

Rockwater. (2012) *Browse LNG Development Stygofauna Survey Final Report (2011/2012).* Report prepared for Woodside Energy Limited, Perth, Western Australia.

Rota, E., Wang, H. and Erseus, C. (2007) The diverse *Grania* fauna (Clitellata: Enchytraeidae) of the Esperance area, Western Australia, with descriptions of two new species. *Journal of Natural History* 41(17-20): 999-1023.

Sinclair Knight and Merz. (2004) WMC Resources Ltd Cliffs Nickel Project Mt Keith, Western Australian - Preliminary Stygofauna Assesment.

Strayer, D. L. (1994) Limits to biological distributions in groundwater. In: J. Gibert, D. L. Danielopol and J. A. Stanford (eds) *Groundwater Ecology*. Academic Press, San Diego, pp 287-310

Subterranean Ecology. (2008a) *Goldsworthy Iron Ore Mining Operations: Cundaline and Callawa Mining Operations Stygofauna Assessment*, North Beach, Western Australia.

Subterranean Ecology. (2008b) *Goldsworthy Iron Ore Mining Operations: Cundaline and Callawa Mining Operations Troglofauna Assessment* North Beach, Western Australia.

Subterranean Ecology. (2011a) BHP Billiton Yeelirrie Development Company Pty Ltd. Yeerlirrie Uranium Project. Subterraean Fauna Survey.

Subterranean Ecology. (2011b) *Yeelirrie Subterranean Fauna Survey* Prepared for BHP Billiton Yeelirrie Development Company Pty Ltd.

Subterranean Ecology. (2012) *Elmatta Project Stygofauna Survey.* Report prepared for Taroom Coal Pty Ltd, Perth, Western Australia.

Taiti, S. and Humphreys, W. F. (2001) New aquatic Oniscidea (Crustacea: Isopoda) from groundwater calcretes of Western Australia. *Records of the Australian Museum* 64: 133 - 151.

Tomlinson, M. and Boulton, A. J. (2010) Ecology and management of subsurface groundwater dependent ecosystems in Australia - a review. *Marine and Freshwater Research* 61: 936-949.

van Vliet, P. C. J., Coleman, D. C. and Hendrix, P. F. (1997) Population dynamics of Enchytraeidae (Oligochaeta) in different agricultural systems. *Biology & Fertility of Soils* 25: 123-129.

Ward, J. V. (1989) The four-dimensional nature of lotic ecosystems. *Journal of the North American Benthological Society* 8: 2-8.

Ward, J. V. and Palmer, M. A. (1994) Distribution patterns of interstitial freshwater meiofauna over a range of spatial scales, with emphasis on alluvial river-aquifer systems. *Hydrobiologia* 287: 147-156.

Watts, C. H. S. and Humphreys, W. F. (2006) Twenty-six new Dytiscidae (Coleoptera) of the genera *Limbodessus* Guignot and *Nirripirti* Watts and Humphreys from underground waters in Australia. *Transactions of the Royal Society of South Australia* 130(1): 123 - 185.

Watts, C. H. S. and Humphreys, W. F. (2009) Fourteen new Dytiscidae (Coleoptera) of the genera *Limbodessus* Guimot, Paroster Sharp, and *Exocelina* Broun from underground waters in Australia. *Transactions of the Royal Society of South Australia* 133(1): 62-107.

Western Australian Museum. (2016a) *Arachnida and Myriapoda Database Search for Yakabindie*.

Western Australian Museum. (2016b) *Crustacea Database Search for Yakabindie*

Wetland Research and Management. (2005) *Baseline aquatic biology and water quality study of Jones Creek, including south-west claypan area* Report prepared for Nickel West, BHP Billiton, Perth, Western Australia.

Woodward Clyde. (1995) *Yakabindie Project - Six Mile and Goliath North dewatering review*.

Yenumula, R. R., Shabuddin, S. and Venkateswara, R. T. (2015) Camachobathynella meghalayaensisn. gen., n. sp., the first Palearctic element of Bathynellacea (Eumalacostraca: Bathynellidae) from northeastern India. *Brill* 35(5): 700-713.

Appendices

Appendix A Bore details

Table A-1: Bore details.

Bore Name	Previous Name	Eastings (GDA: 51 J)	Northings (GDA: 51 J)	Date Drilled	Depth (mbgl)	Slotted Extent (mbgl)	SWL (mbgl)	Yield (L/s)	Saprolitic Clay Strata (mbgl)	Status
GOL01		260452	6962778	09-Feb-17	65	17 to 65	17.4	0.3	3 to 20	Drilled
GOL02		262009	6962609	13-Feb-17	65	17 to 65	29.7	0.1	Absent	Drilled
GOL03		261503	6962290	10-Feb-17	65	23 to 65	40.5	0.3	2 to 59	Drilled
GOL06	YEX162	263235	6962170	-	92	-	24.5	1.0	Unknown	Redeveloped
GOL07	YEX166	263338	6962137	-	100	-	24.3	0.5	Unknown	Redeveloped
GOL08		260119	6962086	08-Feb-17	46	28 to 46	13.7	0.3	2 to 9	Drilled
GOL09		261273	6961925	10-Feb-17	65	23 to 65	29.3	0.8	2.5 to 50	Drilled
GOL10		260368	6961793	07-Feb-17	65	11 to 65	19.0	0.1	2 to 7	Drilled
GOL11	CP21	261862	6961621	11-Feb-17	65	23 to 65	28.9	0.2	2 to 64	Drilled
GOL12	CP53 & YAKB05	260816	6961565	-	44	-	21.6	0.6	Unknown	Redeveloped
GOL13	YAKB06	260859	6961556	-	63	-	21.5	1.0	Unknown	Redeveloped
GOL14		261742	6961261	12-Feb-17	65	23 to 65	27.1	0.2	2 to 45	Drilled
GOL15	SHNP2	260779	6960760	-	40	-	15.8	0.0	Unknown	Redeveloped
GOL16	SHGCN62	260873	6960741	-	44	-	16.2	0.6	Unknown	Redeveloped
GOL17	SHGCN60	260835	6960733	-	44	-	15.8	0.3	Unknown	Redeveloped
GOL18		260939	6960524	-	68	-	15.7	0.1	Unknown	Redeveloped
GOL20	CP22P	260885	6960426	-	63	-	12.3	0.0	Unknown	Redeveloped
GOL21	SHSP1	261046	6960306	-	58	-	13.1	0.1	Unknown	Redeveloped
GOL22	CP6P	262267	6960219	-	65	-	22.3	0.1	Unknown	Redeveloped
GOL23		262285	6960213	-	62	-	22.6	0.2	Unknown	Redeveloped
GOL24	CP13P	259998	6960098	-	77	-	12.0	5.0	Unknown	Redeveloped
GOL25	SHSP2	261252	6960094	-	80	-	20.6	1.0	Unknown	Redeveloped
GOL27	CP5P	262430	6959978	-	59	-	25.8	0.1	Unknown	Redeveloped
GOL28		260833	6959937	06-Feb-17	65	17 to 65	15.6	1.5	2 to 16	Drilled
GOL29		260681	6959606	15-Feb-17	65	17 to 65	58.1	0.0	Absent	Drilled

Table A–1 (cont.): Bore details.

Bore Name	Previous Name	Eastings (GDA: 51 J)	Northings (GDA: 51 J)	Date Drilled	Depth (mbgl)	Slotted Extent (mbgl)	SWL (mbgl)	Yield (L/s)	Saprolitic Clay Strata (mbgl)	Status
GOL30		260891	6959231	05-Feb-17	65	17 to 65	22.9	0.1	2 to 5	Drilled
GOL31		260849	6958892	04-Feb-17	65	29 to 65	24.8	0.2	2 to 4	Drilled
GOL32		262422	6958229	-	82	-	30.0	0.3	Unknown	Redeveloped
SMW01		261076	6966147	20-Feb-17	66	30 to 66	28.6	0.3	9 to 39	Drilled
SMW02		259988	6966066	22-Feb-17	65	47 to 65	36.5	0.6	6 to 29, 47 to 53	Drilled
SMW03		260987	6965978	20-Feb-17	65	29 to 65	30.3	0.2	4 to 41, 45 to 64	Drilled
SMW04		259652	6965939	21-Feb-17	64	58 to 64	43.3	1.0	6 to 60	Drilled
SMW05		259854	6965914	21-Feb-17	65	47 to 65	46.0	0.0	19 to 50	Drilled
SMW06		261268	6965710	17-Feb-17	65	25 to 55	30.6	0.6	2 to 48	Drilled
SMW07		259790	6965622	24-Feb-17	65	29 to 65	50.0	0.0	13 to 28	Drilled
SMW08		260289	6965606	22-Feb-17	65	29 to 65	35.9	0.1	12 to 60	Drilled
SMW09		260602	6965331	-	77	-	30.5	0.8	Unknown	Redeveloped
SMW10		261242	6965262	18-Feb-17	62	40 to 58	25.6	0.3	14 to 55	Drilled
SMW11		260284	6965255	25-Feb-17	65	23 to 65	37.5	0.1	42 to 62	Drilled
SMW13		260046	6965142	24-Feb-17	65	17 to 65	57.7	0.1	2 to 64	Drilled
SMW14		260648	6964946	26-Feb-17	65	23 to 65	28.1	0.8	3 to 32, 39 to 64	Drilled
SMW15		261297	6964911	19-Feb-17	65	29 to 65	32.3	0.1	19 to 50	Drilled
SMW16		260432	6965028	25-Feb-17	65	23 to 65	32.3	0.0	3 to 22	Drilled
SMW17		261316	6964614	18-Feb-17	60	42 to 60	22.7	0.3	6 to 59	Drilled
SMW19		260519	6964425	27-Feb-17	65	23 to 65	30.5	0.5	4 to 56	Drilled
SMW20		260633	6964397	26-Feb-17	65	29 to 65	26.5	0.5	3 to 44	Drilled
SMW21		260805	6964038	02-Mar-17	65	5 to 47	20.0	5.0	No logs	Drilled
SMW22		260438	6963809	27-Feb-17	50	14 to 50	25.7	1.5	2 to 8	Drilled
SMW24	CP52	260394	6963644	-	60	-	22.2	1.0	Unknown	Redeveloped
SMW25		260954	6963581	11-Feb-17	65	17 to 65	20.0	0.5	2 to 41	Drilled
SMW26a		260355	6963534	27-Feb-17	50	14 to 50	19.4	0.3	Absent	Drilled
SMW26b		260345	6963538	-	-	-	-	-	Unknown	Pastoral bore
SMW27		260390	6963381	16-Feb-17	65	17 to 65	17.6	0.5	4 to 12	Drilled

Appendix B Survey Effort: 2006 to 2017

Table A-2: Stygofauna survey effort (including Biota 2006) and bore data recorded. Blue shaded rows indicate stygofauna recorded.

Project Area	Bore Name	Latitude	Longitude	Sample Date	Elevation (AHD)	SWL		EoH		Location
						(m bgl)	(AHD)	(m bgl)	(AHD)	
Goliath	95GPG07	-27.44747222	120.58925	2006	537	NA				Inside pit
Goliath	95GPG07	-27.44747222	120.58925	18/11/2010	537	33.15	503.85	72.9	464.1	Inside pit
Goliath	95GPG07	-27.44747222	120.58925	29/03/2011	537	33.3	503.7	75.6	461.4	Inside pit
Goliath	95GPG11	-27.45075	120.5854722	18/11/2010	530	27.4	502.6	57.6	472.4	Inside pit
Goliath	95GPG11	-27.45075	120.5854722	29/03/2011	530	26.1	503.9	59.4	470.6	Inside pit
Goliath	CP11	-27.44819444	120.5856111	2006	532	NA				Inside pit
Goliath	CP11	-27.44819444	120.5856111	18/11/2010	532	26.06	505.94	58.5	473.5	Inside pit
Goliath	CP11	-27.44819444	120.5856111	29/03/2011	532	26.1	505.9	32.4	499.6	Inside pit
Goliath	CP11	-27.44819444	120.5856111	2/02/2012	532					Inside pit
Goliath	GOL01	-27.43743215	120.5765447	09/08/2017	527	16.53	510.47	65	462	Outside pits (>500m, <1km)
Goliath	GOL01	-27.43743215	120.5765447	15/05/2017	527	16.66	510.34	65	462	Outside pits (>500m, <1km)
Goliath	GOL01	-27.43743215	120.5765447	16/03/2017	527	17.36	509.6	65	462	Outside pits (>500m, <1km)
Goliath	GOL02	-27.43923308	120.592246	10/08/2017	541	29.06	511.94	65	476	Near pit (<200m)
Goliath	GOL02	-27.43923308	120.592246	14/03/2017	541	17.4	523.6	65	476	Near pit (<200m)
Goliath	GOL02	-27.43923308	120.592246	15/05/2017	541	29.02	511.98	65	476	Near pit (<200m)
Goliath	GOL03	-27.44201856	120.5870689	10/08/2017	546	39.82	506.18	65	481	Inside pit
Goliath	GOL03	-27.44201856	120.5870689	14/03/2017	546	40.5	505.5	65	481	Inside pit
Goliath	GOL03	-27.44201856	120.5870689	15/05/2017	546	39.82	506.18	65	481	Inside pit
Goliath	GOL06	-27.44340618	120.6045572	17/06/2011	527	22.99	504.01	49.5	477.5	Outside pits (>1km)
Goliath	GOL06	-27.44340618	120.6045572	14/03/2017	533	24.5	508.5	92	441	Outside pits (>1km)
Goliath	GOL06	-27.44340618	120.6045572	15/05/2017	533	23.1	509.9	92	441	Outside pits (>1km)
Goliath	GOL07	-27.44372168	120.6055922	17/06/2011	566	24.3	541.7	62.1	503.9	Outside pits (>1km)
Goliath	GOL07	-27.44372168	120.6055922	14/03/2017	533	24.3	508.7	100	433	Outside pits (>1km)
Goliath	GOL07	-27.44372168	120.6055922	15/05/2017	533	24.28	508.72	100	433	Outside pits (>1km)
Goliath	GOL08	-27.44361866	120.5730329	09/08/2017	522	12.71	509.29	46	476	Outside pits (>500m, <1km)
Goliath	GOL08	-27.44361866	120.5730329	16/03/2017	522	13.7	508.3	46	476	Outside pits (>500m, <1km)
Goliath	GOL08	-27.44361866	120.5730329	17/05/2017	522	12.77	509.23	46	476	Outside pits (>500m, <1km)

Table A-2 (cont.): Stygofauna survey effort (including Biota 2006) and bore data recorded. Blue shaded rows indicate stygofauna recorded.

Project Area	Bore Name	Latitude	Longitude	Sample Date	Elevation (AHD)	SWL		EoH		Location
						(m bgl)	(AHD)	(m bgl)	(AHD)	
Goliath	GOL09	-27.44527769	120.5846731	10/08/2017	537	28.64	508.36	65	472	Inside pit
Goliath	GOL09	-27.44527769	120.5846731	14/03/2017	537	29.3	507.7	65	472	Inside pit
Goliath	GOL09	-27.44527769	120.5846731	15/05/2017	537	28.6	508.4	65	472	Inside pit
Goliath	GOL10	-27.44630372	120.5755017	09/08/2017	525	17.65	507.35	65	460	Outside pits (>500m, <1km)
Goliath	GOL10	-27.44630372	120.5755017	15/05/2017	525	17.78	507.22	65	460	Outside pits (>500m, <1km)
Goliath	GOL10	-27.44630372	120.5755017	16/03/2017	525	18.98	506	65	460	Outside pits (>500m, <1km)
Goliath	GOL11	-27.44811111	120.590568	2006	532	NA				Inside pit
Goliath	GOL11	-27.44811111	120.590568	18/11/2010	532	29.1	502.9	61.2	470.8	Inside pit
Goliath	GOL11	-27.44811111	120.590568	2/02/2012	532					Inside pit
Goliath	GOL11	-27.44811111	120.590568	10/08/2017	539	28.08	510.92	65	474	Inside pit
Goliath	GOL11	-27.44811111	120.590568	14/03/2017	539	28.86	510.14	65	474	Inside pit
Goliath	GOL11	-27.44811111	120.590568	15/05/2017	539	28.09	510.91	65	474	Inside pit
Goliath	GOL12	-27.44844035	120.5799817	2006	523					Near pit (<200m)
Goliath	GOL12	-27.44844035	120.5799817	18/11/2010	523	20.93	502.07	64.8	458.2	Near pit (<200m)
Goliath	GOL12	-27.44844035	120.5799817	09/08/2017	530	21.1	508.9	44	486	Near pit (<200m)
Goliath	GOL12	-27.44844035	120.5799817	15/05/2017	530	21.09	508.91	44	486	Near pit (<200m)
Goliath	GOL12	-27.44844035	120.5799817	16/03/2017	530	21.59	508.4	44	486	Near pit (<200m)
Goliath	GOL13	-27.44852912	120.5804147	2006	531		531			Near pit (<200m)
Goliath	GOL13	-27.44852912	120.5804147	3/02/2012	531					Near pit (<200m)
Goliath	GOL13	-27.44852912	120.5804147	09/08/2017	531	21.07	509.93	63	468	Near pit (<200m)
Goliath	GOL13	-27.44852912	120.5804147	15/05/2017	531	21.12	509.88	63	468	Near pit (<200m)
Goliath	GOL13	-27.44852912	120.5804147	16/03/2017	531	21.57	509.4	63	468	Near pit (<200m)
Goliath	GOL14	-27.45134862	120.5892885	10/08/2017	534	26.13	507.87	65	469	Near pit (<200m)
Goliath	GOL14	-27.45134862	120.5892885	14/03/2017	534	27.9	506.1	65	469	Near pit (<200m)
Goliath	GOL14	-27.45134862	120.5892885	15/05/2017	534	26	508	65	469	Near pit (<200m)
Goliath	GOL15	-27.45575	120.579449	18/11/2010	515	15.17	499.83	74.6	440.4	Outside pits (>500m, <1km)
Goliath	GOL15	-27.45575	120.579449	28/03/2011	515	16.2	498.8	51.3	463.7	Outside pits (>500m, <1km)
Goliath	GOL15	-27.45575	120.579449	21/06/2011	515	15.22	499.78	38.7	476.3	Outside pits (>500m, <1km)
Goliath	GOL15	-27.45575	120.579449	2/02/2012	515					Outside pits (>500m, <1km)
Goliath	GOL15	-27.45575	120.579449	09/08/2017	524	14.72	509.28	40	484	Outside pits (>500m, <1km)

Table A-2 (cont.): Stygofauna survey effort (including Biota 2006) and bore data recorded. Blue shaded rows indicate stygofauna recorded.

Project Area	Bore Name	Latitude	Longitude	Sample Date	Elevation (AHD)	SWL		EoH		Location
						(m bgl)	(AHD)	(m bgl)	(AHD)	
Goliath	GOL15	-27.45575	120.579449	14/03/2017	524	15.8	508.2	40	484	Outside pits (>500m, <1km)
Goliath	GOL15	-27.45575	120.579449	15/05/2017	524	14.75	509.25	40	484	Outside pits (>500m, <1km)
Goliath	GOL16	-27.45588889	120.5803889	16/11/2010	524	16.24	507.76	59.5	464.5	Outside pits (>500m, <1km)
Goliath	GOL16	-27.45588889	120.5803889	28/03/2011	524	15.3	508.7	81	443	Outside pits (>500m, <1km)
Goliath	GOL16	-27.45588889	120.5803889	21/06/2011	524	16.12	507.88	60.3	463.7	Outside pits (>500m, <1km)
Goliath	GOL16	-27.45588889	120.5803889	3/02/2012	524					Outside pits (>500m, <1km)
Goliath	GOL16	-27.45588889	120.5803889	14/03/2017	525	16.2	508.8	44	481	Outside pits (>500m, <1km)
Goliath	GOL16	-27.45588889	120.5803889	15/05/2017	525	15.7	509.3	44	481	Outside pits (>500m, <1km)
Goliath	GOL17	-27.45594444	120.58001	18/11/2010	519	16	503	60.5	458.5	Outside pits (>500m, <1km)
Goliath	GOL17	-27.45594444	120.58001	28/03/2011	519	15.3	503.7	59.4	459.6	Outside pits (>500m, <1km)
Goliath	GOL17	-27.45594444	120.58001	21/06/2011	519	15.63	503.37	64	455	Outside pits (>500m, <1km)
Goliath	GOL17	-27.45594444	120.58001	3/02/2012	519					Outside pits (>500m, <1km)
Goliath	GOL17	-27.45594444	120.58001	09/08/2017	525	15.1	509.9	44	481	Outside pits (>500m, <1km)
Goliath	GOL17	-27.45594444	120.58001	14/03/2017	525	15.8	509.2	44	481	Outside pits (>500m, <1km)
Goliath	GOL17	-27.45594444	120.58001	15/05/2017	525	15.22	509.78	44	481	Outside pits (>500m, <1km)
Goliath	GOL18	-27.4578487	120.5810155	09/08/2017	523	14.8	508.2	68	455	Outside pits (>500m, <1km)
Goliath	GOL18	-27.4578487	120.5810155	14/03/2017	523	15.7	507.3	68	455	Outside pits (>500m, <1km)
Goliath	GOL18	-27.4578487	120.5810155	15/05/2017	523	14.89	508.11	68	455	Outside pits (>500m, <1km)
Goliath	GOL20	-27.45872222	120.5804722	16/11/2010	526	12.17	513.83	51.3	474.7	Outside pits (>500m, <1km)
Goliath	GOL20	-27.45872222	120.5804722	28/03/2011	526	11.7	514.3	46.8	479.2	Outside pits (>500m, <1km)
Goliath	GOL20	-27.45872222	120.5804722	21/06/2011	526	11.9	514.1	50.5	475.5	Outside pits (>500m, <1km)
Goliath	GOL20	-27.45872222	120.5804722	09/08/2017	520	11.44	508.56	63	457	Outside pits (>500m, <1km)
Goliath	GOL20	-27.45872222	120.5804722	14/03/2017	520	12.3	507.7	63	457	Outside pits (>500m, <1km)
Goliath	GOL20	-27.45872222	120.5804722	15/05/2017	520	11.53	508.47	63	457	Outside pits (>500m, <1km)
Goliath	GOL21	-27.45983689	120.5820594	16/11/2010	529	12.95	516.05	62.1	466.9	Outside pits (>500m, <1km)
Goliath	GOL21	-27.45983689	120.5820594	28/03/2011	529	13.5	515.5	45	484	Outside pits (>500m, <1km)
Goliath	GOL21	-27.45983689	120.5820594	21/06/2011	529	12.77	516.23	38.7	490.3	Outside pits (>500m, <1km)
Goliath	GOL21	-27.45983689	120.5820594	11/08/2017	523	12.32	510.68	58	465	Outside pits (>500m, <1km)
Goliath	GOL21	-27.45983689	120.5820594	14/03/2017	523	13.5	509.5	58	465	Outside pits (>500m, <1km)
Goliath	GOL21	-27.45983689	120.5820594	15/05/2017	523	12.4	510.6	58	465	Outside pits (>500m, <1km)

Table A-2 (cont.): Stygofauna survey effort (including Biota 2006) and bore data recorded. Blue shaded rows indicate stygofauna recorded.

Project Area	Bore Name	Latitude	Longitude	Sample Date	Elevation (AHD)	SWL		EoH		Location
						(m bgl)	(AHD)	(m bgl)	(AHD)	
Goliath	GOL22	-27.46055556	120.5943886	16/11/2010	528	21.84	506.16	33.3	494.7	Outside pits (>1km)
Goliath	GOL22	-27.46055556	120.5943886	28/03/2011	528			31.5	496.5	Outside pits (>1km)
Goliath	GOL22	-27.46055556	120.5943886	21/06/2011	528	21.77	506.23	30.5	497.5	Outside pits (>1km)
Goliath	GOL22	-27.46055556	120.5943886	1/02/2012	528					Outside pits (>1km)
Goliath	GOL22	-27.46055556	120.5943886	10/08/2017	531	21.39	509.61	65	466	Outside pits (>1km)
Goliath	GOL22	-27.46055556	120.5943886	13/03/2017	531	29.7	501.3	65	466	Outside pits (>1km)
Goliath	GOL22	-27.46055556	120.5943886	15/05/2017	531	21.5	509.5	65	466	Outside pits (>1km)
Goliath	GOL23	-27.46089326	120.5945652	13/03/2017	532	22	510	62	470	Outside pits (>1km)
Goliath	GOL23	-27.46089326	120.5945652	15/05/2017	532	21.35	510.65	62	470	Outside pits (>1km)
Goliath	GOL24	-27.46161111	120.57125	18/11/2010	509	11.08	497.92	79.2	429.8	Outside pits (>1km)
Goliath	GOL24	-27.46161111	120.57125	28/03/2011	509	10.8	498.2	59.4	449.6	Outside pits (>1km)
Goliath	GOL24	-27.46161111	120.57125	17/06/2011	509	11.6	497.4	62.4	446.6	Outside pits (>1km)
Goliath	GOL24	-27.46161111	120.57125	2/02/2012	509					Outside pits (>1km)
Goliath	GOL24	-27.46161111	120.57125	10/08/2017	517	11.32	505.68	77	440	Outside pits (>1km)
Goliath	GOL24	-27.46161111	120.57125	15/05/2017	517	11.32	505.68	77	440	Outside pits (>1km)
Goliath	GOL24	-27.46161111	120.57125	16/03/2017	517	12	505	77	440	Outside pits (>1km)
Goliath	GOL25	-27.46178526	120.5841006	16/11/2010	529	20.85	508.15	54.9	474.1	Outside pits (>1km)
Goliath	GOL25	-27.46178526	120.5841006	28/03/2011	529	19.8	509.2	50.4	478.6	Outside pits (>1km)
Goliath	GOL25	-27.46178526	120.5841006	21/06/2011	529	20.7	508.3	36.9	492.1	Outside pits (>1km)
Goliath	GOL25	-27.46178526	120.5841006	2/02/2012	529					Outside pits (>1km)
Goliath	GOL25	-27.46178526	120.5841006	11/08/2017	530	20.13	509.87	80	450	Outside pits (>1km)
Goliath	GOL25	-27.46178526	120.5841006	14/03/2017	530	20.7	509.3	80	450	Outside pits (>1km)
Goliath	GOL25	-27.46178526	120.5841006	15/05/2017	530	20.17	509.83	80	450	Outside pits (>1km)
Goliath	GOL27	-27.46303786	120.5959896	16/11/2010	534	25.25	508.75	69.3	464.7	Outside pits (>1km)
Goliath	GOL27	-27.46303786	120.5959896	28/03/2011	534	25.45	508.55	66.6	467.4	Outside pits (>1km)
Goliath	GOL27	-27.46303786	120.5959896	10/08/2017	534	24.58	509.42	59	475	Outside pits (>1km)
Goliath	GOL27	-27.46303786	120.5959896	13/03/2017	534	26.1	507.9	59	475	Outside pits (>1km)
Goliath	GOL27	-27.46303786	120.5959896	15/05/2017	534	24.64	509.36	59	475	Outside pits (>1km)
Goliath	GOL28	-27.46312846	120.5798327	10/08/2017	526	14.24	511.76	65	461	Outside pits (>1km)
Goliath	GOL28	-27.46312846	120.5798327	14/03/2017	526	16.2	509.8	65	461	Outside pits (>1km)
Goliath	GOL28	-27.46312846	120.5798327	15/05/2017	526	14.41	511.59	65	461	Outside pits (>1km)

Table A-2 (cont.): Stygofauna survey effort (including Biota 2006) and bore data recorded. Blue shaded rows indicate stygofauna recorded.

Project Area	Bore Name	Latitude	Longitude	Sample Date	Elevation (AHD)	SWL		EoH		Location
						(m bgl)	(AHD)	(m bgl)	(AHD)	
Goliath	GOL29	-27.46608719	120.5782341	10/08/2017	530	21.99	508.01	65	465	Outside pits (>1km)
Goliath	GOL29	-27.46608719	120.5782341	14/03/2017	530			65	465	Outside pits (>1km)
Goliath	GOL29	-27.46608719	120.5782341	15/05/2017	530	47.41	482.59	65	465	Outside pits (>1km)
Goliath	GOL30	-27.46950709	120.5802847	10/08/2017	531	20.02	510.98	65	466	Outside pits (>2km)
Goliath	GOL30	-27.46950709	120.5802847	13/03/2017	531			65	466	Outside pits (>2km)
Goliath	GOL30	-27.46950709	120.5802847	15/05/2017	531	20.44	510.56	65	466	Outside pits (>2km)
Goliath	GOL31	-27.4725566	120.5797897	10/08/2017	529	23.03	505.97	65	464	Outside pits (>2km)
Goliath	GOL31	-27.4725566	120.5797897	13/03/2017	529	22.5	506.5	65	464	Outside pits (>2km)
Goliath	GOL31	-27.4725566	120.5797897	15/05/2017	529	23.08	505.92	65	464	Outside pits (>2km)
Goliath	GOL32	-27.47881243	120.5955661	10/08/2017	537	29.41	507.59	81.5	455.5	Outside pits (>3km)
Goliath	GOL32	-27.47881243	120.5955661	13/03/2017	537	29.3	507.7	81.5	455.5	Outside pits (>3km)
Goliath	GOL32	-27.47881243	120.5955661	15/05/2017	537	29.41	507.59	81.5	455.5	Outside pits (>3km)
Goliath	YEX82	-27.45830556	120.5912778	16/11/2010	527	19.8	507.2	66.6	460.4	Outside pits (>500m, <1km)
Goliath	YEX82	-27.45830556	120.5912778	28/03/2011	527			30.6	496.4	Outside pits (>500m, <1km)
Goliath	YEX82	-27.45830556	120.5912778	21/06/2011	527	20.06	506.94	30.5	496.5	Outside pits (>500m, <1km)
Goliath	YEX82	-27.45830556	120.5912778	1/02/2012	527					Outside pits (>500m, <1km)
Southern Reference	KVRC0018	-27.47222222	120.5505556	11/08/2017	510	7.42	502.58			Outside pits (>3km)
Southern Reference	KVRC0019	-27.47138889	120.5536111	13/08/2017	511	8.13	502.87			Outside pits (>3km)
Southern Reference	SBD3	-27.47930556	120.5947778	16/11/2010	534	27.1	506.9	60.3	473.7	Outside pits (>3km)
Southern Reference	SBD3	-27.47930556	120.5947778	28/03/2011	534	26.04	507.96	65.6	468.4	Outside pits (>3km)

Table A-2 (cont.): Stygofauna survey effort (including Biota 2006) and bore data recorded. Blue shaded rows indicate stygofauna recorded.

Project Area	Bore Name	Latitude	Longitude	Sample Date	Elevation (AHD)	SWL		EoH		Location
						(m bgl)	(AHD)	(m bgl)	(AHD)	
Six Mile Well	SMW01	-27.40715797	120.583509	07/08/2017	538	28.4	509.96	66	472	Outside pits (>500m, <1km)
Six Mile Well	SMW01	-27.40715797	120.583509	15/03/2017	538	28.5	509.5	66	472	Outside pits (>500m, <1km)
Six Mile Well	SMW01	-27.40715797	120.583509	15/05/2017	538	28.05	509.95	66	472	Outside pits (>500m, <1km)
Six Mile Well	SMW02	-27.40769575	120.5724976	07/08/2017	546	36.1	509.9	65	481	Outside pits (>500m, <1km)
Six Mile Well	SMW02	-27.40769575	120.5724976	15/03/2017	546	36.5	509.5	65	481	Outside pits (>500m, <1km)
Six Mile Well	SMW02	-27.40769575	120.5724976	15/05/2017	546	35.29	510.71	65	481	Outside pits (>500m, <1km)
Six Mile Well	SMW03	-27.40866319	120.5825743	07/08/2017	538	29.78	508.22	65	473	Outside pits (>500m, <1km)
Six Mile Well	SMW03	-27.40866319	120.5825743	15/03/2017	538	30.28	507.7	65	473	Outside pits (>500m, <1km)
Six Mile Well	SMW03	-27.40866319	120.5825743	15/05/2017	538	29.85	508.15	65	473	Outside pits (>500m, <1km)
Six Mile Well	SMW04	-27.40878448	120.569073	07/08/2017	553	42.9	510.1	64	489	Outside pits (>500m, <1km)
Six Mile Well	SMW04	-27.40878448	120.569073	15/03/2017	553	43.27	509.73	64	489	Outside pits (>500m, <1km)
Six Mile Well	SMW04	-27.40878448	120.569073	15/05/2017	553	42.89	510.11	64	489	Outside pits (>500m, <1km)
Six Mile Well	SMW05	-27.40904038	120.5711168	07/08/2017	553	44.29	508.71	65	488	Outside pits (>500m, <1km)
Six Mile Well	SMW05	-27.40904038	120.5711168	15/03/2017	553	46	507	65	488	Outside pits (>500m, <1km)
Six Mile Well	SMW05	-27.40904038	120.5711168	15/05/2017	553	43.5	509.5	65	488	Outside pits (>500m, <1km)
Six Mile Well	SMW06	-27.41113485	120.5853661	08/08/2017	538	29.6	508.4	65	473	Outside pits (>500m, <1km)
Six Mile Well	SMW06	-27.41113485	120.5853661	15/03/2017	538	30.63	507.4	65	473	Outside pits (>500m, <1km)
Six Mile Well	SMW06	-27.41113485	120.5853661	15/05/2017	538	30.59	507.41	65	473	Outside pits (>500m, <1km)
Six Mile Well	SMW07	-27.41166165	120.5704113	08/08/2017	556	48.41	507.59	65	491	Outside pits (>300m, <500m)
Six Mile Well	SMW07	-27.41166165	120.5704113	15/03/2017	556	50	506	65	491	Outside pits (>300m, <500m)
Six Mile Well	SMW07	-27.41166165	120.5704113	15/05/2017	556	46.4	509.6	65	491	Outside pits (>300m, <500m)
Six Mile Well	SMW08	-27.41189861	120.5754497	08/08/2017	544	35.4	508.6	65	479	Near pit (<200m)
Six Mile Well	SMW08	-27.41189861	120.5754497	15/03/2017	544	35.93	508.1	65	479	Near pit (<200m)
Six Mile Well	SMW08	-27.41189861	120.5754497	15/05/2017	544	35.59	508.41	65	479	Near pit (<200m)
Six Mile Well	SMW09	-27.41443497	120.578561	08/08/2017	540	29.84	510.16	77	463	Inside pit
Six Mile Well	SMW09	-27.41443497	120.578561	15/03/2017	540	30.51	509.5	77	463	Inside pit
Six Mile Well	SMW09	-27.41443497	120.578561	15/05/2017	540	30	510	77	463	Inside pit
Six Mile Well	SMW10	-27.41516847	120.5850151	08/08/2017	534	25.3	508.7	62	472	Outside pits (>300m, <500m)
Six Mile Well	SMW10	-27.41516847	120.5850151	15/03/2017	534	25.6	508.4	62	472	Outside pits (>300m, <500m)
Six Mile Well	SMW10	-27.41516847	120.5850151	15/05/2017	534	25.36	508.64	62	472	Outside pits (>300m, <500m)

Table A-2 (cont.): Stygofauna survey effort (including Biota 2006) and bore data recorded. Blue shaded rows indicate stygofauna recorded.

Project Area	Bore Name	Latitude	Longitude	Sample Date	Elevation (AHD)	SWL		EoH		Location
						(m bgl)	(AHD)	(m bgl)	(AHD)	
Six Mile Well	SMW11	-27.41506663	120.5753274	08/08/2017	545	37.11	507.89	65	480	Inside pit
Six Mile Well	SMW11	-27.41506663	120.5753274	15/03/2017	545	37.5	507.5	65	480	Inside pit
Six Mile Well	SMW11	-27.41506663	120.5753274	15/05/2017	545	37.14	507.86	65	480	Inside pit
Six Mile Well	SMW13	-27.41604069	120.5729029	08/08/2017	551	36.65	514.35	65	486	Near pit (<200m)
Six Mile Well	SMW13	-27.41604069	120.5729029	15/03/2017	551	57.7	493.3	65	486	Near pit (<200m)
Six Mile Well	SMW13	-27.41604069	120.5729029	15/05/2017	551	36.72	514.28	65	486	Near pit (<200m)
Six Mile Well	SMW14	-27.41791849	120.5789494	08/08/2017	535	29.5	505.5	65	470	Inside pit
Six Mile Well	SMW14	-27.41791849	120.5789494	15/05/2017	535	27.54	507.46	65	470	Inside pit
Six Mile Well	SMW14	-27.41791849	120.5789494	16/03/2017	535	28.07	506.9	65	470	Inside pit
Six Mile Well	SMW15	-27.41833951	120.5855018	08/08/2017	535	28.12	506.88	65	470	Outside pits (>300m, <500m)
Six Mile Well	SMW15	-27.41833951	120.5855018	15/03/2017	535	32.34	502.7	65	470	Outside pits (>300m, <500m)
Six Mile Well	SMW15	-27.41833951	120.5855018	15/05/2017	535	28.13	506.87	65	470	Outside pits (>300m, <500m)
Six Mile Well	SMW16	-27.41713897	120.576778	08/08/2017	539	32.8	506.2	65	474	Inside pit
Six Mile Well	SMW16	-27.41713897	120.576778	15/05/2017	539	31.83	507.17	65	474	Inside pit
Six Mile Well	SMW16	-27.41713897	120.576778	16/03/2017	539	32.34	506.7	65	474	Inside pit
Six Mile Well	SMW17	-27.4210301	120.5856337	08/08/2017	530	22.4	507.6	60	470	Outside pits (>300m, <500m)
Six Mile Well	SMW17	-27.4210301	120.5856337	15/03/2017	530	22.74	507.26	60	470	Outside pits (>300m, <500m)
Six Mile Well	SMW17	-27.4210301	120.5856337	15/05/2017	530	22.43	507.57	60	470	Outside pits (>300m, <500m)
Six Mile Well	SMW18	-27.42168419	120.5777949	18/11/2010	535	27.54	507.46	38.7	496.3	Inside pit
Six Mile Well	SMW18	-27.42168419	120.5777949	29/03/2011	535	28.8	506.2	38.7	496.3	Inside pit
Six Mile Well	SMW18	-27.42168419	120.5777949	17/06/2011	535	26.35	508.65	36.9	498.1	Inside pit
Six Mile Well	SMW18	-27.42168419	120.5777949	2/02/2012	535					Inside pit
Six Mile Well	SMW19	-27.42259115	120.5775426	08/08/2017	538	27.67	510.33	65	473	Inside pit
Six Mile Well	SMW19	-27.42259115	120.5775426	15/05/2017	538	29.94	508.06	65	473	Inside pit
Six Mile Well	SMW19	-27.42259115	120.5775426	16/03/2017	538	30.47	507.53	65	473	Inside pit
Six Mile Well	SMW20	-27.42286432	120.5786926	08/08/2017	534	26.05	507.95	65	469	Inside pit
Six Mile Well	SMW20	-27.42286432	120.5786926	15/05/2017	534	26.14	507.86	65	469	Inside pit
Six Mile Well	SMW20	-27.42286432	120.5786926	16/03/2017	534	26.53	507.5	65	469	Inside pit

Table A-2 (cont.): Stygofauna survey effort (including Biota 2006) and bore data recorded. Blue shaded rows indicate stygofauna recorded.

Project Area	Bore Name	Latitude	Longitude	Sample Date	Elevation (AHD)	SWL		EoH		Location
						(m bgl)	(AHD)	(m bgl)	(AHD)	
Six Mile Well	SMW21	-27.426132	120.5803547	08/08/2017	528	19.54	508.46	65	463	Near pit (<200m)
Six Mile Well	SMW21	-27.426132	120.5803547	15/05/2017	528	19.59	508.41	65	463	Near pit (<200m)
Six Mile Well	SMW21	-27.426132	120.5803547	16/03/2017	528	20	508	65	463	Near pit (<200m)
Six Mile Well	SMW21	-27.426132	120.5803547	17/03/2017	528	20	508	65	463	Near pit (<200m)
Six Mile Well	SMW21	-27.426132	120.5803547	17/03/2017	528	21.5	506.85	65	463	Near pit (<200m)
Six Mile Well	SMW22	-27.42813318	120.5766024	08/08/2017	532	25.1	506.9	50	482	Near pit (<200m)
Six Mile Well	SMW22	-27.42813318	120.5766024	15/05/2017	532	25.06	506.94	50	482	Near pit (<200m)
Six Mile Well	SMW22	-27.42813318	120.5766024	16/03/2017	532	25.68	506.32	50	482	Near pit (<200m)
Six Mile Well	SMW24	-27.42961376	120.5761251	18/11/2010	525	23.03	501.97	64	461	Outside pits (>300m, <500m)
Six Mile Well	SMW24	-27.42961376	120.5761251	29/03/2011	525	23.4	501.6	60.3	464.7	Outside pits (>300m, <500m)
Six Mile Well	SMW24	-27.42961376	120.5761251	17/06/2011	525	22.42	502.58	60.3	464.7	Outside pits (>300m, <500m)
Six Mile Well	SMW24	-27.42961376	120.5761251	2/02/2012	525					Outside pits (>300m, <500m)
Six Mile Well	SMW24	-27.42961376	120.5761251	09/08/2017	531	22.05	508.95	60	471	Outside pits (>300m, <500m)
Six Mile Well	SMW24	-27.42961376	120.5761251	15/05/2017	531	20.87	510.13	60	471	Outside pits (>300m, <500m)
Six Mile Well	SMW24	-27.42961376	120.5761251	16/03/2017	531	22.2	508.8	60	471	Outside pits (>300m, <500m)
Six Mile Well	SMW25	-27.43028037	120.5817737	09/08/2017	528	20.46	507.54	65	463	Outside pits (>500m, <1km)
Six Mile Well	SMW25	-27.43028037	120.5817737	15/03/2017	528	19.98	508	65	463	Outside pits (>500m, <1km)
Six Mile Well	SMW25	-27.43028037	120.5817737	15/05/2017	528	20.47	507.53	65	463	Outside pits (>500m, <1km)
Six Mile Well	SMW26a	-27.43059905	120.5757092	09/08/2017	527	19.12	507.88	50	477	Outside pits (>300m, <500m)
Six Mile Well	SMW26a	-27.43059905	120.5757092	15/05/2017	527	19.01	507.99	50	477	Outside pits (>300m, <500m)
Six Mile Well	SMW26a	-27.43059905	120.5757092	16/03/2017	527	19.42	507.6	50	477	Outside pits (>300m, <500m)
Six Mile Well	SMW26b	-27.430552	120.575617	16/03/2017	527	20.7	506.3			Outside pits (>300m, <500m)
Six Mile Well	SWM27	-27.43198198	120.5760299	09/08/2017	526	17.1	508.9	65	461	Outside pits (>500m, <1km)
Six Mile Well	SWM27	-27.43198198	120.5760299	15/05/2017	526	17.1	508.9	65	461	Outside pits (>500m, <1km)
Six Mile Well	SWM27	-27.43198198	120.5760299	16/03/2017	526	17.61	508.4	65	461	Outside pits (>500m, <1km)

Appendix C Groundwater Properties Recorded

Table A-3: Groundwater properties recorded.

Bore name	Sample Date	SWL (mbgl)	EoH (mbgl)	pH	Electrical Cond. (uS/cm)	Dissolved Oxygen (mg/L)	Redox (mV)	Water Temp. (C)
95GPG07	Nov 2010	33.15	72.9	7.35	11810	4.66	174	26.5
95GPG07	Mar 2011	33.3	75.6	7.35	-	4.13	135	25.5
95GPG11	Nov 2010	27.4	57.6	7.87	1745	4.91	147	25.7
95GPG11	Mar 2011	26.1	59.4	7.74	-	5.48	87	24.8
CP11	Nov 2010	26.06	58.5	7.84	1381	4.91	159	26
CP11	Mar 2011	26.1	32.4	7.67	-	5.05	24	26.1
GOL01	Mar 2017	17.4	65.0	7.0	3,507	1.48	172.2	26.9
GOL01	May 2017	16.7	69.0	6.9	3,043	1.9	204.3	24.7
GOL01	Aug 2017	16.53	68.4	6.99	2896	1.99	185.2	23.1
GOL02	Mar 2017	17.4	65.0	7.7	1,552	2.05	171.0	28.8
GOL02	May 2017	29.0	72.0	7.7	1,444	1.6	342.6	24.4
GOL02	Aug 2017	29.06		7.76	1342	2.64	401.1	22.3
GOL03	Mar 2017	40.5	65.0	7.5	-	3.69	163.3	27.3
GOL03	May 2017	39.8	64.8	7.4	4,806	1.9	341.6	24.7
GOL03	Aug 2017	39.82		7.52	4624	2.43	424.8	22.1
GOL06	Jun 2011	22.99	49.5	8.23	-	4.09	181	23.1
GOL06	Mar 2017	24.5	-	6.3	385	2.74	165.3	26.8
GOL06	May 2017	23.1	130.0	6.9	124	1.7	311.4	23.0
GOL07	Jun 2011	24.3	62.1	8.25	888	4.05	152	23.9
GOL07	Mar 2017	24.3	-	7.0	579	1.47	163.9	26.6
GOL07	May 2017	24.3	130.0	6.9	387	1.7	286.2	22.8
GOL08	Mar 2017	13.7	46.0	7.2	4,302	1.97	208.3	26.4
GOL08	May 2017	-	69.0	6.5	435	2.9	277.5	24.9
GOL08	Aug 2017	12.71		6.89	493	2.25	319.4	23.2
GOL09	Mar 2017	29.3	65.0	7.6	4,768	2.14	232.2	26.4
GOL09	May 2017	28.6	87.0	7.5	3,777	1.6	330.6	24.8
GOL09	Aug 2017	28.64		7.71	3495	3.08	429.2	22.2
GOL10	Mar 2017	19.0	65.0	7.7	2,607	1.93	240.3	27.0
GOL10	May 2017	17.8	77.0	7.8	1,964	1.9	281.4	24.9
GOL10	Aug 2017	17.65	69.3	7.81	1980	3.12	399.7	23.9
GOL11	Nov 2010	29.1	61.2	7.71	3430	6.75	155	26.1
GOL11	Mar 2017	28.9	65.0	7.6	3,900	2.01	216.7	26.8
GOL11	May 2017	28.1	79.0	7.7	3,971	1.2	331.5	24.5
GOL11	Aug 2017	28.08	68.4	7.8	4024	2.05	435.9	22.1
GOL12	Nov 2010	20.93	64.8	7.39	3640	4.03	149	26.6
GOL12	Mar 2017	21.6	34.2	7.5	3,995	1.73	232.0	26.5
GOL12	May 2017	21.1	46.0	7.5	3,683	1.4	298.3	24.5
GOL12	Aug 2017	21.1	32.4	7.43	3596	1.99	383.2	23.3
GOL13	Mar 2017	21.6	37.8	7.4	7,141	1.54	211.9	26.5
GOL13	May 2017	21.1	41.0	7.4	6,802	1.8	294.9	24.7
GOL13	Aug 2017	21.07	36.9	7.49	6692	1.88	354.6	24
GOL14	Mar 2017	27.9	-	7.8	2,937	3.88	177.5	26.1
GOL14	May 2017	26.0	66.0	7.6	3,389	1.6	315.3	25.1
GOL14	Aug 2017	26.13	68.4	7.73	2872	3.45	430.8	22.9
GOL15	Nov 2010	15.17	81	8	2990	5.62	172	26
GOL15	Mar 2011	16.2	51.3	7.93	-	5	134	25.8
GOL15	Jun 2011	15.22	38.7	8.4	3300	6.82	73	22.6

Table A-3 (cont.): Groundwater properties recorded.

Bore name	Sample Date	SWL (mbgl)	EoH (mbgl)	pH	Electrical Cond. (uS/cm)	Dissolved Oxygen (mg/L)	Redox (mV)	Water Temp. (C)
GOL15	Mar 2017	15.8	40.0	7.8	1,273	4.27	170.9	26.3
GOL15	May 2017	14.8	57.0	8.1	1,248	3.9	296.7	24.9
GOL15	Aug 2017	14.72		7.58	4598	2.66	402.7	24.2
GOL16	Nov 2010	16.24	45	7.51	1845	2.78	121	26.6
GOL16	Mar 2011	15.3	81	7.87	-	4.61	133	26
GOL16	Jun 2011	16.12	60.3	8.14	2640	3.65	74	23.3
GOL16	Mar 2017	16.2	44.0	7.5	2,010	2.02	189.0	26.5
GOL16	May 2017	15.7	53.0	8.1	2,768	1.2	308.8	25.2
GOL17	Nov 2010	16	81.9	7.72	3370	5.09	182	25.2
GOL17	Mar 2011	15.3	59.4	7.68	-	5.55	134	26.2
GOL17	Jun 2011	15.63	64	7.88	3430	6.83	88	22
GOL17	Mar 2017	15.8	44.0	7.8	4,270	3.41	190.7	26.4
GOL17	May 2017	15.2	55.0	7.7	3,032	3.3	306.0	25.3
GOL17	Aug 2017	15.1	39.36	7.79	2605	3.18	424.9	23.8
GOL18	Mar 2017	15.7	68.0	7.1	5,369	1.45	199.1	26.7
GOL18	May 2017	14.9	81.0	7.1	4,934	1.2	126.2	23.2
GOL18	Aug 2017	14.8	73.8	7.17	4980	6.74	363	23.5
GOL20	Nov 2010	12.17	51.3	7.49	2220	3.33	121	26.3
GOL20	Mar 2011	11.7	46.8	7.31	-	6.05	113	25.7
GOL20	Jun 2011	11.9	90	7.51	1956	3.92	63	21.7
GOL20	Mar 2017	12.3	63.0	7.7	1,583	1.86	179.4	26.2
GOL20	May 2017	11.5	63.0	7.5	1,673	1.4	311.3	24.6
GOL20	Aug 2017	11.44		7.51	1765	1.94	431.3	23.7
GOL21	Nov 2010	12.95	62.1	8.33	1924	6.03	87	26.4
GOL21	Mar 2011	13.5	45	8.04	-	4.71	109	26.2
GOL21	Jun 2011	12.77	38.7	8.56	2077	5.8	83	21.7
GOL21	Mar 2017	13.5	-	7.9	3,504	5.23	171.5	25.8
GOL21	May 2017	12.4	68.0	8.0	3,443	3.5	301.5	23.9
GOL21	Aug 2017	12.32		8.14	3403	4.09	357.5	22.5
GOL22	Nov 2010	21.84	33.3	7.46	734	4.35	110	26.1
GOL22	Mar 2011	-	31.5	7.18	-	4.59	176	24.3
GOL22	Jun 2011	21.77	200	7.92	502	5.64	90	21.1
GOL22	Mar 2017	29.7	65.0	7.4	948	4.96	233.6	27.1
GOL22	May 2017	21.5	78.0	7.3	962	2.9	337.4	24.9
GOL22	Aug 2017	21.39	69.3	7.38	915	4.2	435.2	23.4
GOL23	Mar 2017	22.0	65.0	7.5	1,118	2.46	241.2	27.7
GOL23	May 2017	21.4	70.0	7.4	1,092	1.7	319.9	25.0
GOL24	Nov 2010	11.08	79.2	7.93	1427	5.68	188	24.9
GOL24	Mar 2011	10.8	59.4	7.33	-	6.12	156	25.5
GOL24	Jun 2011	11.6	90	7.61	629	6.16	53	24.1
GOL24	Mar 2017	12.0	77.0	7.4	1,040	3.58	226.3	26.2
GOL24	May 2017	11.3	91.0	7.6	1,017	3.6	330.2	24.3
GOL24	Aug 2017	11.32		7.41	1003	3.72	461.3	23.2
GOL25	Nov 2010	20.85	54.9	7.15	2070	4.31	47	26.1
GOL25	Mar 2011	19.8	99	6.98	-	4.14	88	26
GOL25	Jun 2011	20.7	36.9	7.3	2800	3.57	-63	21.9
GOL25	Mar 2017	20.7	-	8.3	1745	1.97	163.1	25.7
GOL25	May 2017	20.2	85.5	7.5	2256	1.4	114.7	23.9
GOL25	Aug 2017	20.13	87.3	7.16	2306	1.76	198.2	22.9
GOL27	Nov 2010	25.25	69.3	7.98	1412	6.64	101	26.8
GOL27	Mar 2011	25.45	66.6	7.4	-	4.65	-	-

Table A-3 (cont.): Groundwater properties recorded.

Bore name	Sample Date	SWL (mbgl)	EoH (mbgl)	pH	Electrical Cond. (uS/cm)	Dissolved Oxygen (mg/L)	Redox (mV)	Water Temp. (C)
GOL27	Mar 2017	26.1	60.3	7.8	1354	5.69	249.5	26.0
GOL27	May 2017	24.6	69.0	7.2	1332	3.9	338.3	25.3
GOL27	Aug 2017	24.58	62.1	7.33	1333	3.1	418.3	24.6
GOL28	Mar 2017	16.2	65.0	7.7	1172	2.18	152.7	25.3
GOL28	May 2017	14.4	76.0	7.6	1148	2.5	348.4	24.0
GOL28	Aug 2017	14.24	67.5	7.65	1128	2.91	441.3	23.5
GOL29	May 2017	47.4	69.3	7.4	914	4.2	339.5	23.3
GOL29	Aug 2017	21.99	67.5	7.33	968	1.67	407.7	24.2
GOL30	Mar 2017	-	65.0	7.5	900	2.31	177.2	26.8
GOL30	May 2017	20.4	67.0	7.6	1252	1.6	304.4	24.9
GOL30	Aug 2017	20.02	68.4	7.49	783	2	395.6	24.3
GOL31	Mar 2017	22.5	65.0	7.6	4907	1.97	190.3	26.9
GOL31	May 2017	23.1	76.0	7.6	4253	1.4	329.3	25.0
GOL31	Aug 2017	23.03	68.4	7.59	4300	1.66	330.5	24
GOL32	Mar 2017	29.3	81.5	7.8	5065	3.35	211.0	26.9
GOL32	May 2017	29.4	89.0	7.6	4923	2.5	341.4	24.9
GOL32	Aug 2017	29.41		7.63	5010	3.03	416.2	24
YEX82	Nov 2010	19.8	66.6	7.99	2180	4.55	109	26.6
YEX82	Mar 2011	-	30.6	8.01	-	4.6	193	24.9
YEX82	Jun 2011	20.06	200	8.06	2140	3	64	18.7
KVRC0018	Aug 2017	7.42	82.73	6.85	510	2.24	7.1	23.3
KVRC0019	Aug 2017	8.13	62.93	7.32	1145	2.74	240.9	24.4
SBD3	Nov 2010	27.1	60.3	7.74	1965	6.63	124	28.1
SBD3	Mar 2011	26.04	90	7.77	-	7.77	132	23.6
SMW01	Mar 2017	28.5	66.0	7.3	2755	1.89	201.8	24.4
SMW01	May 2017	28.1	28.8	7.4	2720	1.2	164.8	25.1
SMW01	Aug 2017	28.4	79	7.34	2899	0.88	228.2	25.5
SMW02	Mar 2017	36.5	65.0	7.3	1732	2.09	261.7	25.6
SMW02	May 2017	35.3	65.7	7.3	1788	1.7	148.8	26.6
SMW02	Aug 2017	36.1		7.46	1870	2.25	202.1	26.1
SMW03	Mar 2017	30.3	65.0	7.4	3690	3.71	213.1	24.7
SMW03	May 2017	29.9	65.7	7.3	3833	33.4	172.1	24.8
SMW03	Aug 2017	29.78		7.28	4053	3.9	254.1	25.3
SMW04	Mar 2017	43.3	64.0	7.4	4140	1.17	206.4	24.8
SMW04	May 2017	42.9	-	7.1	483.5	2.0	126.7	25.1
SMW04	Aug 2017	42.9	66.6	7.17	506	5.46	195.6	24.8
SMW05	Mar 2017	46.0	65.0	7.2	516	1.43	242.5	25.2
SMW05	May 2017	43.5	59.9	7.1	462.2	1.9	104.3	25.4
SMW05	Aug 2017	44.29		7.11	498.5	1.7	207.6	26.3
SMW06	Mar 2017	30.6	65.0	7.5	1,410	2.97	238.6	25.8
SMW06	May 2017	30.6	-	7.5	1,468	2.3	290.9	23.7
SMW06	Aug 2017	29.6		7.43	1295	2.1	332	23.7
SMW07	May 2017	46.4	-	7.8	665	1.7	282.5	22.8
SMW07	Aug 2017	48.41	57.6	7.79	730	1.54	277	23.1
SMW08	Mar 2017	35.9	65.0	7.3	2,311	2.25	232.3	25.5
SMW08	May 2017	35.6	-	7.4	1,835	2.5	291.2	23.4
SMW08	Aug 2017	35.4		7.35	1950	3.88	3140	23.5
SMW09	Mar 2017	30.5	77.0	7.6	5,113	3.48	249.2	25.5
SMW10	Mar 2017	25.6	62.0	7.3	2,421	1.33	263.9	26.3
SMW10	May 2017	25.4	-	7.4	2,182	1.9	288.4	24.0
SMW10	Aug 2017	25.3		7.48	2295	1.28	329.3	24.1

Table A-3 (cont.): Groundwater properties recorded.

Bore name	Sample Date	SWL (mbgl)	EoH (mbgl)	pH	Electrical Cond. (uS/cm)	Dissolved Oxygen (mg/L)	Redox (mV)	Water Temp. (C)
SMW11	Mar 2017	37.5	65.0	7.3	5,230	2.69	253.7	25.9
SMW11	May 2017	37.1	-	7.3	4,149	3.8	225.1	24.7
SMW11	Aug 2017	37.11	70.2	7.25	4035	3.86	297.1	25.2
SMW13	Mar 2017	57.7	65.0	7.9	625	1.67	248.3	25.5
SMW13	May 2017	36.7	-	7.8	693	1.5	105.0	24.7
SMW14	Mar 2017	28.1	65.0	6.9	6,948	3.06	260.4	23.9
SMW14	May 2017	27.5	-	7.1	5,119	1.6	279.9	24.4
SMW14	Aug 2017	29.5	68.4	6.88	3806	2.14	-7.4	25.7
SMW15	Mar 2017	32.3	65.0	7.6	1,706	1.87	259.2	26.3
SMW15	May 2017	28.1	-	7.6	1,983	1.7	280.9	24.4
SMW15	Aug 2017	28.12		7.67	1943	4.08	336.8	25.5
SMW16	Mar 2017	32.3	65.0	8.2	7,442	1.35	244.8	24.1
SMW16	May 2017	31.8	-	7.9	7,479	1.3	280.8	24.7
SMW16	Aug 2017	32.8	68.4	7.87	7865	1.41	148.9	25.9
SMW17	Mar 2017	22.7	60.0	7.8	1,945	1.91	250.6	25.6
SMW17	May 2017	22.4	-	7.7	1,818	2.1	282.9	24.0
SMW17	Aug 2017	22.4		7.63	1888	1.16	332.5	24.4
SMW18	Nov 2010	27.54	38.7	6.87	4080	3.37	136	27.1
SMW18	Mar 2011	28.8	38.7	6.71	-	3.7	119	22.3
SMW18	Jun 2011	26.35	36.9	7.08	4900	5.71	-192	23.8
SMW19	Mar 2017	30.5	65.0	7.4	13,345	2.15	254.1	24.5
SMW19	May 2017	29.9	-	7.2	12,379	2.4	248.5	24.7
SMW19	Aug 2017	27.67		7.13	12470	2.29	269.2	25.2
SMW20	Mar 2017	26.5	65.0	7.5	5,020	2.34	260.6	24.3
SMW20	May 2017	26.1	-	7.5	5,081	1.7	243.0	24.6
SMW20	Aug 2017	26.05	70.2	7.53	5350	2.27	237	25.8
SMW21	Mar 2017	21.5	65.0	7.5	1,971	2.55	255.1	25.0
SMW21	May 2017	19.6	-	7.3	1,626	2.0	311.2	23.0
SMW21	Aug 2017	19.54		7.58	1385	4.26	295	24.8
SMW22	Mar 2017	25.7	49.0	7.1	11,324	2.23	260.9	25.3
SMW22	May 2017	25.1	54.0	7.1	11,374	2.1	317.7	21.8
SMW22	Aug 2017	25.1		7.31	6900	2.24	322.6	24.5
SMW24	Nov 2010	23.03	64	7.28	7540	6.3	154	27.3
SMW24	Mar 2011	23.4	60.3	7.21	-	6.25	71	22.7
SMW24	Jun 2011	22.42	60.3	7.65	6450	5.27	41	24.5
SMW24	Mar 2017	22.2	60.0	7.5	5,276	4.60	258.2	25.3
SMW24	May 2017	20.9	54.0	7.3	9,135	1.9	271.1	23.5
SMW24	Aug 2017	22.05	62.1	7.63	4926	4.69	326.6	
SMW25	Mar 2017	20.0	65.0	7.0	7,826	3.47	187.0	24.9
SMW25	May 2017	20.5	67.5	7.0	10,616	2.2	326.1	24.2
SMW25	Aug 2017	20.46	68.4	7.61	2000	4.02	382.9	23.2
SMW26a	Mar 2017	19.4	49.0	7.6	2,993	1.45	257.3	25.6
SMW26a	May 2017	19.0	-	7.7	2,664	2.0	297.0	23.8
SMW26a	Aug 2017	19.12	54	7.78	2435	1.57	360.6	23.3
SMW26b	Mar 2017	20.7	22.1	7.7	391	2.52	245.3	25.7
SMW27	Mar 2017	17.6	65.0	7.5	1,027	2.3	257.2	25.3
SMW27	May 2017	17.1	69.3	7.4	3,527	1.8	312.5	23.3
SWM27	Aug 2017	17.1		7.57	3520	2.73	385.5	22.6

Appendix D Stygofauna Survey Results: 2006 to 2017

Table A-4: Stygofauna survey results (including Biota 2006) sorted by taxon.

Group	Family	Taxon	Abundance	Project Area	Bore Name	Latitude	Longitude	Location	Sample Date
Amphipoda	Neoniphargidae	Neoniphargidae	2	Goliath	GOL13	-27.44853	120.58041	Near pit (<200m)	2006
Bathynellacea	Bathynellidae	Bathynellidae sp. OES2	1	Goliath	GOL20	-27.45872	120.58047	Outside pits (>500m, <1km)	21/06/2011
Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES8	1	Six Mile Well	SMW18	-27.42168	120.57779	Inside Pit	18/11/2010
Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES8	1	Goliath	GOL20	-27.45872	120.58047	Outside pits (>500m, <1km)	15/05/2017
Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES9	1	Goliath	GOL20	-27.45872	120.58047	Outside pits (>500m, <1km)	21/06/2011
Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES9	2	Goliath	GOL20	-27.45872	120.58047	Outside pits (>500m, <1km)	15/05/2017
Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES11	1	Six Mile Well	SMW18	-27.42168	120.57779	Inside Pit	2/02/2012
Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES11	38	Six Mile Well	SMW22	-27.42813	120.57660	Near pit (<200m)	08/08/2017
Oligochaeta		Oligochaeta	1	Goliath	GOL11	-27.44819	120.58561	Inside Pit	2006
Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES10	7	Goliath	GOL24	-27.46161	120.57125	Outside pits (>1km)	2/02/2012
Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES10	3	Goliath	GOL24	-27.46161	120.57125	Outside pits (>1km)	16/03/2017
Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES23	7	Six Mile Well	SMW18	-27.42168	120.57779	Inside Pit	18/11/2010
Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES23	3	Six Mile Well	SMW18	-27.42168	120.57779	Inside Pit	17/06/2011
Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES23	50	Six Mile Well	SMW18	-27.42168	120.57779	Inside Pit	2/02/2012
Oligochaeta	Phreodrilidae	Phreodrillidae sp. OES23	4	Goliath	GOL08	-27.44362	120.57303	Outside pits (>500m, <1km)	17/05/2017
Ostracoda	Limnocytheridae	*Gomphodella* sp. IK2	2	Six Mile Well	SMW24	-27.42961	120.57613	Near pit (>300m, <500m)	2/02/2012

Table A-5: Stygofauna survey results (including Biota 2006) sorted by Study Area and bore name.

Project Area	Bore Name	Latitude	Longitude	Location	Sample Date	Group	Family	Taxon	Abundance
Goliath	GOL08	-27.44362	120.57303	Outside pits (>500m, <1km)	17/05/2017	Oligochaeta	Phreodrilidae	Phreodrillidae sp. OES23	4
Goliath	GOL11	-27.44819	120.58561	Inside Pit	2006	Oligochaeta		Oligochaeta	1
Goliath	GOL13	-27.44853	120.58041	Near pit (<200m)	2006	Amphipoda	Neoniphargidae	Neoniphargidae	2
Goliath	GOL20	-27.45872	120.58047	Outside pits (>500m, <1km)	21/06/2011	Bathynellacea	Bathynellidae	Bathynellidae sp. OES2	1
Goliath	GOL20	-27.45872	120.58047	Outside pits (>500m, <1km)	21/06/2011	Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES9	1
Goliath	GOL20	-27.45872	120.58047	Outside pits (>500m, <1km)	15/05/2017	Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES8	1
Goliath	GOL20	-27.45872	120.58047	Outside pits (>500m, <1km)	15/05/2017	Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES9	2
Goliath	GOL24	-27.46161	120.57125	Outside pits (>1km)	2/02/2012	Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES10	7
Goliath	GOL24	-27.46161	120.57125	Outside pits (>1km)	16/03/2017	Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES10	3
Six Mile Well	SMW18	-27.42168	120.57779	Inside Pit	18/11/2010	Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES8	1
Six Mile Well	SMW18	-27.42168	120.57779	Inside Pit	18/11/2010	Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES23	7
Six Mile Well	SMW18	-27.42168	120.57779	Inside Pit	17/06/2011	Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES23	3
Six Mile Well	SMW18	-27.42168	120.57779	Inside Pit	2/02/2012	Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES11	1
Six Mile Well	SMW18	-27.42168	120.57779	Inside Pit	2/02/2012	Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES23	50
Six Mile Well	SMW22	-27.42813	120.57660	Near pit (<200m)	08/08/2017	Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES11	38
Six Mile Well	SMW24	-27.42961	120.57613	Near pit (>300m, <500m)	2/02/2012	Ostracoda	Limnocytheridae	*Gomphodella* sp. IK2	2

Appendix E DNA Analysis

Prepared for Outback Ecology, March 2012
by Dr Remko Leijs, Dr Rachael King and Dr Chris Watts, South Australian Museum, March 2012.

Biodiversity assessment of the subterranean fauna of the Lake Way South area using molecular and morphological methods

Summary

- In the Lake Way South area five parabathynellid species are found belonging to three different genera. Only a single species is currently described.
- The Lake Way South area has a diverse isopod fauna that consist of rather divergent lineages. At least eight species are recorded.
- Five species of pseudoscorpions are so far recoded from the Lake Way South area.
- The fact that with further sampling still additional species are found shows that the biodiversity of the area is still not known to its full extent.

Methods

Biodiversity assessment of a selection of the collected fauna (Table 1) included morphological assessement and PCR amplification and sequencing of a 677 bp fragment of CO1, commonly used for DNA barcoding (Hebert et al. 2003). Morphological assessment is indicated in Table 1 in the column "SAM identification". To increase sequencing success rate, PCR's for all specimens were set up with two different sets of primers. The sequences were added to large datasets that consists of related taxa from the region complemented with published (Amphipoda: Cooper et al. 2007; Bathynellidae: Guzik et al. 2008;

Table 1. Overview of the analysed specimens. The first column gives the DNA extraction number, the last column indicates whether the DNA sequencing was successful.

Extraction	Code	OE identification	SAM identification	molecular id	Coll.Date	locality	Site	CO1
ST1563	LN4972	Amphipoda	chitoniid sp 3; 1 female, 1 juv		18/11/2011	Barwidgee calcrete	LT107	seq failed
ST1564	LN4971	Amphipoda	chiltoniid sp 3; 1 male		18/11/2011	Barwidgee calcrete	LT104	seq failed
ST1565	LN4969	Amphipoda	chitoniid sp 3; 1 male, 3 females, 1 juv.		18/11/2011	Barwidgee calcrete	LT105	seq failed
ST1566	LN3231	Amphipoda	chiltoniid sp 3; juvenile	sp.nov. 3	22/09/2011	Barwidgee calcrete	LT107	seq
ST1567	LN3825	Dytiscidae	*Limbodessus barwidgeensis*	*barwidgeensis*	22/09/2011	Lake Way South	LT104	seq
ST1568	LN5563	Dytiscidae	*Limbodessus barwidgeensis*	*barwidgeensis*	18/11/2011	Lake Way South	LT105	seq
ST1569	LN4418	Isopoda: Halonisus sp.?	Platyarthridae, *Trichorhina* sp.	lineage 5 sp.2	20/09/2011	Lake Way South	LWSF148	contam.
ST1570	LN4432	Isopoda	Armadillidae - undescribed genus		21/09/2011	Lake Way South	LWSF156	seq
ST1571	LN2556	Isopoda: Buddelundia sp. OES3	Armadillidae, *Buddelundia* sp.	lineage 9 sp.1	19/07/2011	Lake Way South	YSHD29	seq
ST1572	LN3569	Isopoda: Buddelundia sp. OES3	Armadillidae, *Buddelundia* sp.	lineage 9 sp.1	30/05/2011	Lake Way South	YSHD29	seq
ST1573	LN4209	Parabathynellidae	*Brevisomabathynella?*		19/06/2011	Lake Way South	SP2-3	seq
ST1574	LN2703	Parabathynellidae	*Atopobathynella*	sp.nov. 2	18/06/2011	Lake Way South	1020D	seq
ST1575	LN3821	Parabathynellidae	*Brevisomabathynella*	sp.nov. 3	22/09/2011	Lake Way South	SP6-1A	seq
ST1576	LN3236	Parabathynellidae	too small to ID		22/09/2011	Lake Way South	TB7-7	no PCR
ST1577	LN3247	Parabathynellidae	*Atopobathynella*	sp.nov. 2	22/09/2011	Lake Way South	1020D	seq
ST1578	LN3819	Parabathynellidae	*Atopobathynella*	sp.nov. 2	22/09/2011	Lake Way South	1020D	seq
ST1579	LN3221	Parabathynellidae	*Atopobathynella*	sp.nov. 2	22/09/2011	Lake Way South	1020D	seq
ST1580	LN5547	Syncarida	*Brevisomabathynella*	sp.nov. 3	16/11/2011	Lake Way South	SP2-3	seq
ST1581	LN2450	Parabathynellidae	*unknown genus*	sp. nov	21/06/2011	Yakabindie Deposit	CP22P	seq
ST1582	LN4428	Trichorhina sp. OES6	Platyarthridae, *Trichorhina* sp.		22/09/2011	Lake Way South	LT104	contam.
ST1583	LN4966	Tyrannochthonius sp. OES4	*na*		22/09/2011	Lake Way South	LT107	contam.
ST1584	LN4967	Tyrannochthonius sp. OES4	na	sp.7	22/09/2011	Lake Way South	LT105	seq

Dytiscidae: Leijs et al. 2003, Leijs & Watts 2008, Leijs et al 2012; Isopoda: Cooper et al. 2008), data from Genbank and unpublished sequence data at the South Australian Museum.
Phylogenetic analyses using neighbour joining of uncorrected sequence distances in PAUP* (Swofford 1998) were used to estimate the number of species among the received specimens from each of the areas, as well as for checking whether these species were found at other localities in the region. Results of phylogenetic analyses are presented as partial phylogenetic trees showing the target species with some closest related species as well as a matrix of uncorrected ("p") pairwise distances between target species and relevant taxa in the phylogenetic trees. The target species are highlighted in yellow in the phylogenetic trees. In the distance matrices *intra*-specific distances are highlighted in yellow, relevant *inter*-specific distances in pink and distances of which the states are unclear because of insufficient data are in orange.

Amphipoda – Chiltoniidae

A large unpublished sequence dataset of chiltoniid amphipods including data from 29 different Yilgarn calcrete aquifers exist at the SA-Museum. This dataset was used to compare the chiltoniid amphipods of this project. Apart from recent work at one calcrete aquifer (Sturt Meadows, King (in press)), no other Yilgarn chiltoniid amphipods are presently described. Morphological examination showed that the chiltoniid amphipods from the three sites at Lake Maitland all belonged to the same species. All four specimens available for molecular assessment produced successful PCRs but only one resulted in a good sequence. Phylogenetic analysis shows that specimen ST1566 grouped with specimens that were collected before at Lake Maitland's Barwidgee Station calcrete aquifer (Figure 1). The pairwise sequence divergences among the taxa of <1.673% (Table 2: yellow area) indicate that they are conspecific.

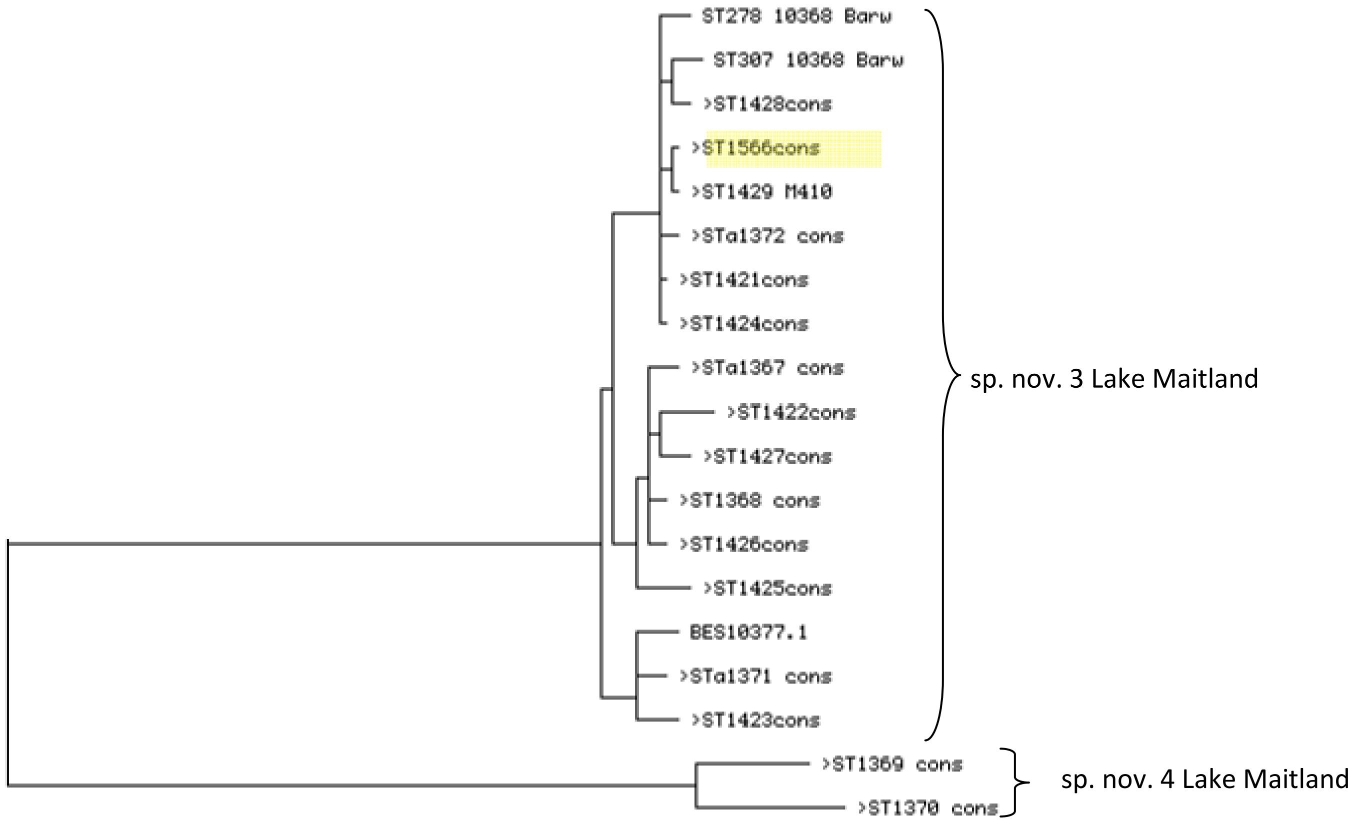

Figure 1.

Uncorrected ("p") distance matrix

	152	185	232	357	358	359	360	366	367	368	369	370	371
152 ST278 10368 Barw	-												
185 ST307 10368 Barw	0.00539	-											
232 BES10377.1	0.01554	0.01235	-										
357 >STa1367 cons	0.01054	0.01365	0.01389	-									
358 >ST1368 cons	0.01223	0.01221	0.00926	0.00603	-								
359 >STa1371 cons	0.01514	0.01202	0.00619	0.01506	0.00898	-							
360 >STa1372 cons	0.00452	0.00447	0.01382	0.01354	0.01048	0.01347	-						
366 >ST1566cons	0.00420	0.00720	0.01394	0.00920	0.01071	0.01372	0.00306	-					
367 >ST1421cons	0.00302	0.00297	0.01232	0.01058	0.00901	0.01202	0.00150	0.00156	-				
368 >ST1422cons	0.01647	0.01645	0.01697	0.00910	0.00752	0.01653	0.01502	0.01530	0.01353	-			
369 >ST1423cons	0.01673	0.01360	0.00772	0.01513	0.01051	0.00751	0.01501	0.01527	0.01353	0.01805	-		
370 >ST1424cons	0.00302	0.00297	0.01232	0.01058	0.00901	0.01202	0.00150	0.00156	0.00000	0.01353	0.01353	-	
371 >ST1425cons	0.01224	0.01532	0.01539	0.00756	0.00901	0.01502	0.01351	0.01066	0.01203	0.01353	0.01654	0.01203	-
372 >ST1426cons	0.00940	0.01101	0.00939	0.00313	0.00153	0.01093	0.00927	0.00951	0.00776	0.00627	0.01250	0.00776	0.00779
373 >ST1427cons	0.01344	0.01341	0.01389	0.00304	0.00451	0.01353	0.01201	0.01224	0.01053	0.00602	0.01504	0.01053	0.01053
374 >ST1428cons	0.00303	0.00317	0.01538	0.01056	0.01202	0.01503	0.00451	0.00150	0.00301	0.01654	0.01654	0.00301	0.01203
375 >ST1429 M410	0.00160	0.00487	0.01144	0.00798	0.00799	0.01123	0.00320	0.00000	0.00160	0.01448	0.01281	0.00160	0.00966
383 >ST1369 cons	0.14398	0.14388	0.14463	0.14283	0.13760	0.14362	0.14212	0.14766	0.14121	0.14266	0.13969	0.14121	0.14269
384 >ST1370 cons	0.14559	0.14241	0.14613	0.14893	0.14372	0.14520	0.14523	0.14868	0.14429	0.14877	0.14125	0.14429	0.14880

Uncorrected ("p") distance matrix (continued)

	372	373	374	375	383	384
372 >ST1426cons	-					
373 >ST1427cons	0.00310	-				
374 >ST1428cons	0.01088	0.01353	-			
375 >ST1429 M410	0.00828	0.01118	0.00164	-		
383 >ST1369 cons	0.13827	0.13817	0.14122	0.14177	-	
384 >ST1370 cons	0.14448	0.14428	0.14430	0.14504	0.02368	-

Table 2.

Parabathynellidae

Morphological examination indicated that the collected Parabathynellidae were species belonging to the genera *Atopobathynella*, *Brevisomabathynella* and an unknown genus. Nine parabathynellid specimens were available for molecular analysis of which seven resulted in good sequences. Four specimens (ST1574, ST1577-79) were conspecific and grouped with specimens of an undescribed species of *Atopobathynella* sp. nov. 1 (Figure 2). Neighbour joining analysis places these specimens within a clade containing species in the genus *Atopobathynella* as recognized in Guzik et al. 2008 (Figure 2). The pairwise sequence divergences among these specimens <1.00% (Table 4) indicate that they are conspecific. The sequence divergences between *A.* sp. nov. 1 and the currently sequenced specimens of 9.2-9.35% indicate intra-specific distances (Table 3, pink area), therefore the specimens are belong to a new species.

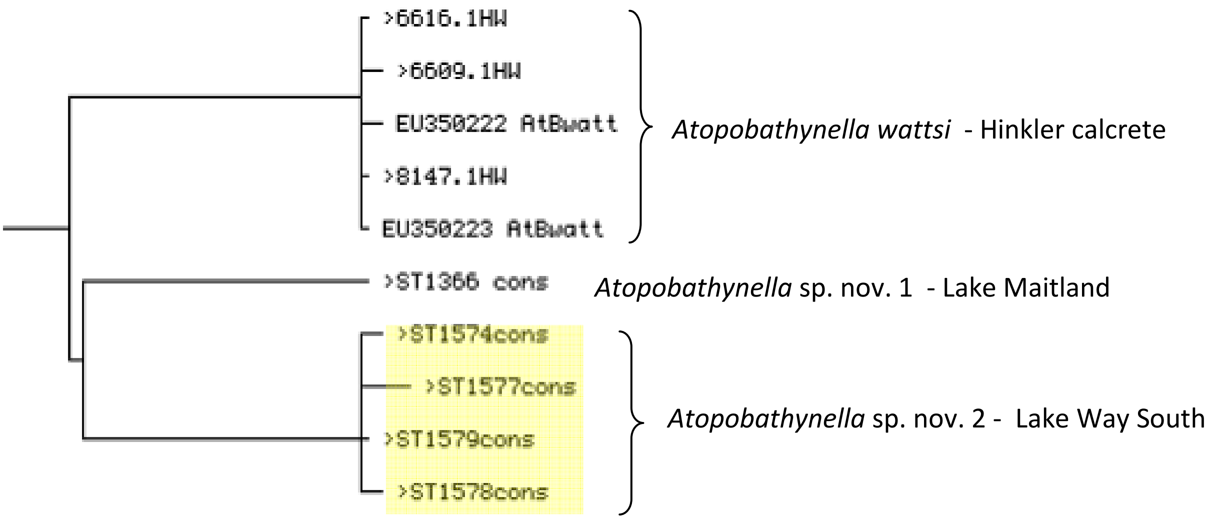

Figure 2.

Uncorrected ("p") distance matrix

		209	210	222	265	267	268
209	EU350223 AtBwatt	-					
210	EU350222 AtBwatt	0.00158	-				
222	>ST1366 cons	0.09523	0.09527	-			
265	>ST1574cons	0.09861	0.09868	0.09204	-		
267	>ST1577cons	0.10506	0.10512	0.09344	0.00714	-	
268	>ST1578cons	0.10253	0.10259	0.09345	0.00570	0.00997	-
269	>ST1579cons	0.09652	0.09659	0.09198	0.00143	0.00571	0.00427

Table 3.

Two specimens ST1575 and ST1580 from Lake Way South were conspecific with a specimen collected previously from Lake Way: pairwise sequence divergence <1.93% (Figure 3, Table 4: yellow area). The specimens are found in the same clade as other described and undescribed species of *Brevisomabathynella* and pairwise divergences with the sister clade *B.* sp. nov. 2 of 5.91-8.43% (Table 4: pink area) indicate intra-specific distances, therefore the specimens belong to a new species.

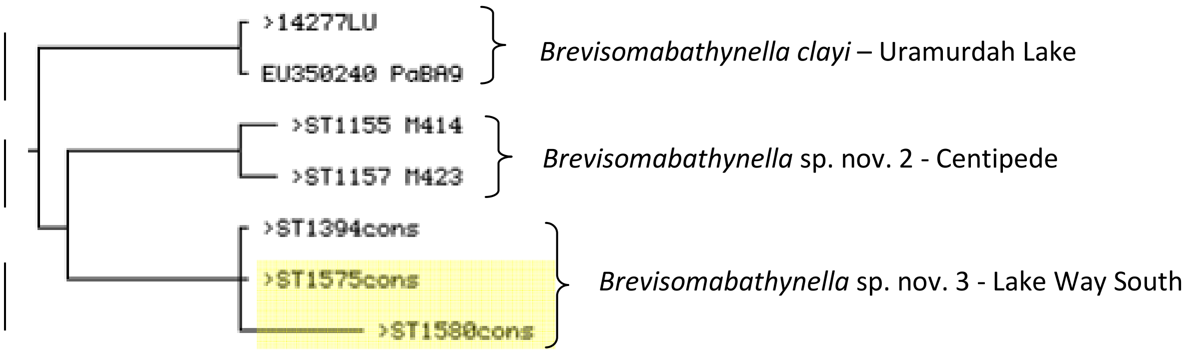

Figure 3.

Uncorrected ("p") distance matrix

		14	190	215	216	223	266
14	>14277LU	-					
190	EU350240 PaBA9	0.00000	-				
215	>ST1155 M414	0.06453	0.06546	-			
216	>ST1157 M423	0.07055	0.07140	0.00832	-		
223	>ST1394cons	0.06182	0.06474	0.06332	0.05909	-	
266	>ST1575cons	0.06180	0.06473	0.06332	0.05910	0.00000	-
270	>ST1580cons	0.08798	0.09043	0.08428	0.06213	0.01922	0.01923

Table 4.

Neighbour joining analysis including specimen ST1581 from the Yakabindi calcrete, places the specimen as distance sister species of a species from the Yeelirrie calcrete: inter-specific distances >14.0% (Figure 4, Table 5: pink area). These species are in a group of Parabathynellidae of which none of the species are currently described and generic status is unkown as well.

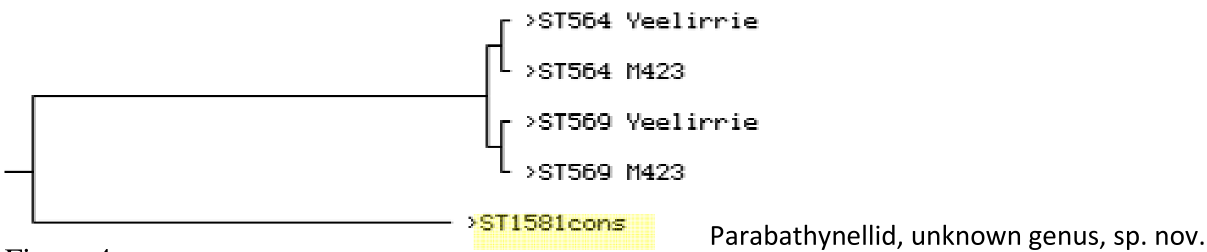

Figure 4.

Uncorrected ("p") distance matrix

		94	95	118	119
94	>ST564 Yeelirrie	-			
95	>ST569 Yeelirrie	0.00465	-		
118	>ST564 M423	0.00000	0.00465	-	
119	>ST569 M423	0.00465	0.00000	0.00465	-
271	>ST1581cons	0.14089	0.14018	0.14089	0.14018

Table 5.

Coleoptera – Dytiscidae – *Limbodessus*

Two specimens ST1567 and ST1568 were identified using morphology by Dr. Chris Watts and verified using DNA sequencing. The specimens are conspecific with specimens in the DNA database of the SA-Museum, and belong to *Limbodessus barwidgeensis* (Figure 5, Table 6: yellow area).

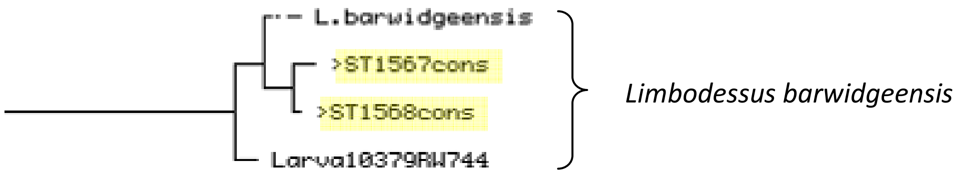

Figure 5.

Uncorrected ("p") distance matrix
35 characters are excluded

		183	201	324
183	L.barwidgeensis	-		
201	Larva10379RW744	0.00063	-	
324	>ST1567cons	0.00127	0.00249	-
325	>ST1568cons	0.00000	0.00123	0.00122

Table 6.

Isopoda

Morphological analysis showed that one of the four identified isopod samples was Platyarthridae genus *Trichorhina* (LN4418) and three were Armadillidae *Buddelundia* sp. (LN2556 and LN3569) and an undescribed genus (LN4432). Three out of four available specimens produced good sequences. The sequences are compared with the DNA database at the SA-Museum that also contain specimen previously analysed from the Lake Way area. One specimen ST1569 groups with specimen ST1187 collected at Lake Way (Figure 6). The pairwise sequence divergence between the specimens of 9.42% (Table 7: pink value) indicates that they are different species belonging to the family Platyarthridae, genus *Trichorhina*.

Figure 6.

Uncorrected ("p") distance matrix

	89	91	92	93	98	99	107
89 >ST1185 M423	-						
91 >ST1187cons	0.17792	-					
92 >ST1186 M414	0.15761	0.19095	-				
93 >ST1188 M423	0.15790	0.18749	0.00000	-			
98 >ST1376 M423	0.20335	0.16838	0.20100	0.19844	-		
99 >ST1377 M414	0.20147	0.16670	0.19377	0.19864	0.01123	-	
107 >ST1554cons	0.15764	0.18997	0.00000	0.00000	0.20136	0.19465	-
109 >ST1569cons	0.19034	0.09422	0.18614	0.18268	0.17449	0.17589	0.18541

Table 7.

Two specimens ST1571 and ST1572 had identical sequences (Table 7: yellow value) and were grouping with a species from lake Maitland (ST1379). The pairwise distances between the two lineages are high: 20.4-22.3% (Table 8: pink area) indicating that they may belong to different genera.

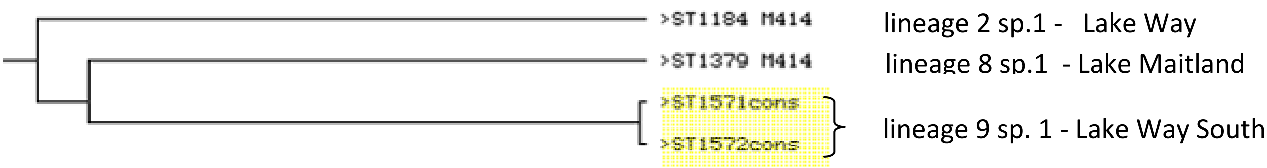

Figure 7.

Uncorrected ("p") distance matrix

	88	101	110
88 >ST1184 M414	-		
101 >ST1379 M414	0.21914	-	
110 >ST1571cons	0.22270	0.20423	-
111 >ST1572cons	0.22270	0.20423	0.00000

Table 8.

Pseudoscorpionida

The single specimen that was available for molecular assessment resulted in a clear sequence. Specimen ST15584 grouped with specimen ST1381 from Lake Maitland (Figure 8, see also report April 2011). The pairwise sequence value of 7.78% (Table 9, pink area) indicate that the specimen is a different species probably in the same genus.

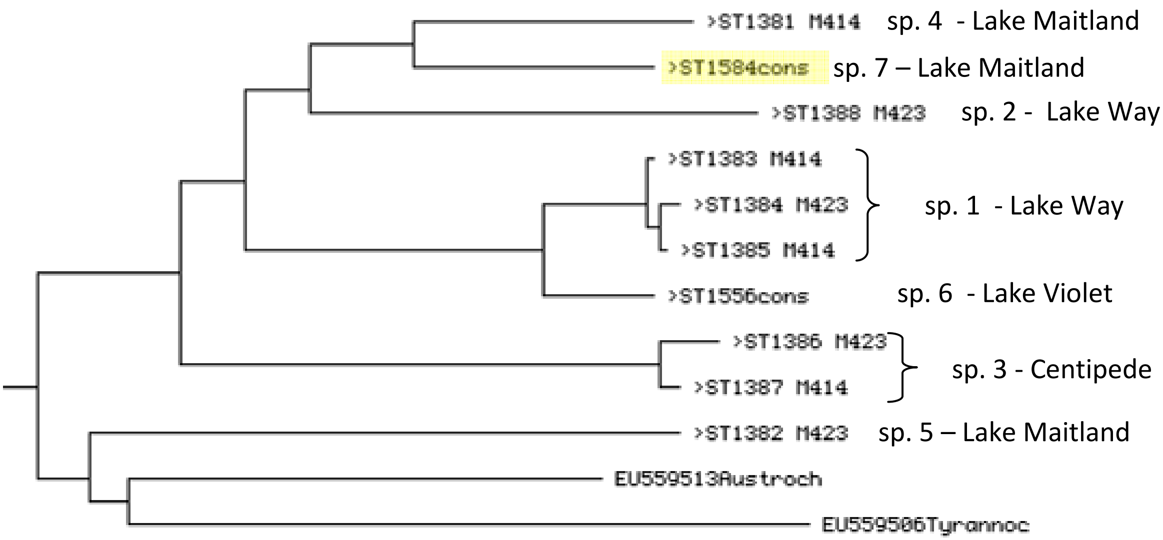

Figure 8.

Uncorrected ("p") distance matrix

	128	129	130	131	132	133	134	135	136	137	154
128 >ST1381 M414	-										
129 >ST1383 M414	0.12674	-									
130 >ST1384 M423	0.12450	0.00346	-								
131 >ST1385 M414	0.12543	0.00153	0.00169	-							
132 >ST1386 M423	0.15439	0.14967	0.14839	0.14812	-						
133 >ST1387 M414	0.15111	0.14672	0.14427	0.14524	0.00817	-					
134 >ST1388 M423	0.12803	0.13953	0.13393	0.13793	0.17236	0.16966	-				
135 >ST1382 M423	0.19069	0.19421	0.18874	0.19418	0.18559	0.18383	0.20288	-			
136 EU559513Austroch	0.20999	0.20263	0.20389	0.20259	0.19814	0.19414	0.22321	0.16978	-		
137 EU559506Tyrannoc	0.21436	0.21186	0.21082	0.21180	0.22180	0.20959	0.23722	0.19800	0.17325	-	
154 >ST1584cons	0.07774	0.12223	0.11777	0.12092	0.14402	0.13736	0.11234	0.19117	0.20284	0.19861	-
155 >ST1556cons	0.12958	0.03509	0.02875	0.03359	0.15317	0.14481	0.14319	0.18812	0.20604	0.20338	0.12201

Table 9.

Figure 9. Armadillid isopod, new genus (LN4432)

Figure 10. Chiltoniid amphipod (LN4969).

References

Cooper SJB, Bradbury JH, Saint KM et al. (2007). Subterranean archipelago in the Australian arid zone: mitochondrial DNA phylogeography of amphipods from central Western Australia. *Molecular Ecology* **16**: 1533–1544.

Cooper SJB, Saint KM, Taiti S et al. (2008). Subterranean archipelago: mitochondrial DNA phylogeography of stygobitic isopods (Oniscidea:*Haloniscus*) from the Yilgarn region of Western Australia. *Invertebrate Systematics*. **22**: 195–203.

Guzik MT, Cooper SJB, Humphreys WF et al. (2008). Phylogeography of the ancient Parabathynellidae (Crustacea: Bathynellacea) from the Yilgarn region of Western Australia. *Invertebrate Systematics* **22**: 205–216.

Hebert PDN, Cywinska A, Ball SL & deWaard JR. (2003). *Proc. R. Soc. London Ser. B* **270**: 313–321.

King, RA, Bradford T, Austin A, Humphreys WF, Cooper SJB (in press) Divergent molecular lineages and not-so-cryptic species: the first descriptions of stygobitic chiltoniid amphipods (Talitroidea: Chiltoniidae) from Western Australia. *Journal of Crustacean Biology* 23(3).

Leijs R & Watts CHS (2008). Systematics and evolution of the Australian subterranean Hydroporine diving beetles (Dytiscidae), with notes on *Carabhydrus*. *Invertebrate Systematics* **22**: 217-225.

Leijs R, Watts CHS, Cooper SJB et al. (2003). Evolution of subterranean diving beetles (Coleoptera: Dytiscidae: Hydroporini, Bidessini) in the arid zone of Australia. *Evolution* **57**: 2819–2834.

Leijs, R., van Nes, E.H., Watts, C.H., Cooper, S.J.B., Humphreys, W.F. & Hogendoorn, K. (2012). Evolution of blind beetles in isolated aquifers: a test of alternative modes of speciation. PlosOne doi: plos.org/10.1371/journal.pone.0034260.

Swofford DL. (1998). PAUP*:Phylogenetic Analysis Using Parsimony (and other methods). Sinauer Associates: Sunderland MA, USA.

Prepared for Outback Ecology, May 2012

by Dr Remko Leijs, Dr Rachael King and Dr Chris Watts, South Australian Museum, March 2012.

. Biodiversity assessment of the subterranean fauna of the LakeWay South area using molecular and morphological methods - 2

Summary

- In the Lake Way South parabathynellid species are found belonging to three different genera. Two new species are reported here
- The Lake Way South area has a diverse isopod fauna that consist of rather divergent lineages. Two new species are reported here.
- The fact that with further sampling still additional species are found shows that the biodiversity of the area is still not known to its full extent.

Methods

Data from the current molecular biodiversity assessment are added to the report on the Wiluna Area presented to Outback Ecology in March 2012. For the methods used here we refer to the report of March 2012. Biodiversity assessment of a selection of the collected fauna included morphological assessment and PCR amplification and sequencing of CO1 (Table 1). Morphological assessment is indicated in Table 1 in the column "SAM identification". To increase sequencing success rate, PCR's for all specimens were set up with two different sets of primers. In the phylogenetic trees the target species are highlighted in yellow. In the distance matrices *intra*-specific distances are highlighted in yellow, relevant *inter*-specific distances in pink and distances of which the states are unclear because of insufficient data are in orange.

Table 1. Overview of the analysed specimens. The first column gives the DNA extraction number, the last column indicates whether the DNA sequencing was successful. Yellow highlighted specimens indicate newly found species.

Extraction	Code	OE identification	SAM identification	molecular id	Coll.Date	locality	Site	CO1
ST1640	LN0971	Amphipoda	*chiltoniid sp. 3* (from last report) , 1f		31/01/2012	Barwidgee calcrete	LT104	contam.
ST1641	LN2847	Amphipoda	chiltoniid juvenile - can't ID, whole to DNA		31/01/2012	Barwidgee calcrete	LT105	contam.
ST1642	LN0968	Amphipoda	chiltoniid juvenile - can't ID, whole to DNA		31/01/2012	Barwidgee calcrete	LT107	contam.
ST1643	LN3295	Trichorhina sp. OES6 (Isopod	Trichorhina sp. (small eyes)	lineage 5 sp. 3	31/01/2012	Lake Way South	LWSF148	seq
ST1644	LN2866	Trichorhina sp. (Isopoda)	Trichorhina sp. (small eyes)	lineage 5 sp. 4	31/01/2012	Lake Way South	LWSF215	seq
ST1645	LN0976	Syncarida	Atopobathynella sp.	sp. nov. 2	1/02/2012	Lake Way South	1020D	seq
ST1646	LN2851	Syncarida	Atopobathynella sp.	sp. nov. 3	31/01/2012	Lake Way South	LT104	seq
ST1647	LN3432	Syncarida	Brevisomabathynella sp.	sp. nov. 3	1/02/2012	Lake Way South	SP2-3	seq
ST1648	LN3285	Atopobathynella sp. OES10	unknown genus sp.	sp. nov. 2	2/02/2012	Yakabindie	CP51	seq
ST1649	LN2273	Tyrannochthonius sp.		sp. 7	31/01/2012	Lake Way South	LWSF164	seq
ST1675	LN2276	Limbodessus sp.	*Limbodessus usitatus*	*L. usitatus*	31/01/2012	Barwidgee calcrete	LT105	seq
ST1676	LN2277	Limbodessus sp.	larva	*L. barwidgeensis*	31/01/2012	Barwidgee calcrete	LT105	seq

Amphipoda – Chiltoniidae

Unfortunately only one of the three Chiltoniid specimens could be identified. Specimen ST1640 was identified using morphology as belonging to species sp. nov. 3, known from previous collections. The other two specimens appeared to be juveniles. Molecular analysis of all three specimens was unsuccessful due to very weak PCR amplification.

Isopoda - *Trichorhina*

Morphological analysis showed that the two identified isopod specimens are Platyarthridae genus *Trichorhina sp.* Both specimens (ST1643 and ST1644) available for molecular analyses produced good sequences. The sequences are compared with the DNA database at the SA-Museum that also contain specimen previously analysed from the Lake Way area. The two specimens are two closely related species (Figure 1) with intra-specific sequence divergence of 6.68% (Table 2). These species group with other species from the Lake Way area (see also report March 2012). The pairwise sequence divergence among the new specimens and earlier analysed specimens are: 11.86-17.03% (Table 2) indicating species belonging to one or two different genera.

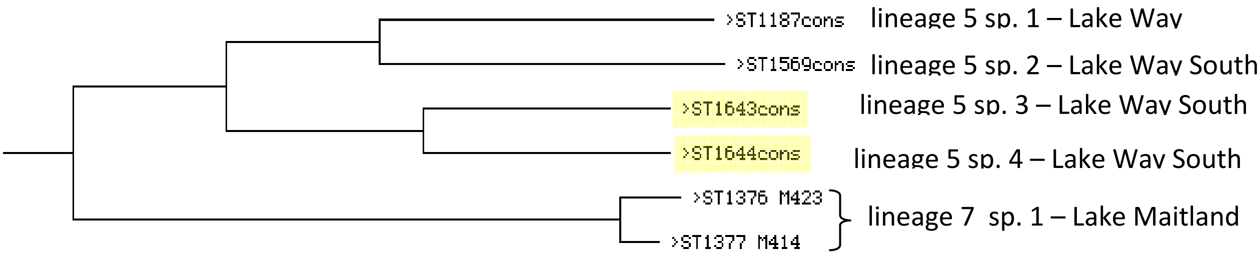

Figure 1.

Uncorrected ("p") distance matrix

		91	98	99	108	352
91	>ST1187cons	-				
98	>ST1376 M423	0.16838	-			
99	>ST1377 M414	0.16670	0.01123	-		
108	>ST1569cons	0.09422	0.17449	0.17589	-	
352	>ST1643cons	0.13380	0.17034	0.16647	0.13528	-
353	>ST1644cons	0.13831	0.16586	0.16806	0.11857	0.06676

Table 2.

Parabathynellidae

Morphological examination indicated that the collected Parabathynellidae were species belonging to three different genera *Atopobathynella*, *Brevisomabathynella* and an unknown genus. Four parabathynellid specimens were available for molecular analysis that all resulted in good sequences. Of the two *Atopobathynella* specimens one (ST1645) belonged to species A. sp. nov. 2 collected before. Uncorrected pairwise divergence < 0.98% (Table 3: yellow area). The other specimen (ST1646) goups with the previous one, but the pairwise sequence divergence values of 10.0-10.29% (Table 3: pink area) indicates that it is separate, new species. Specimen (ST1647) was identified as *Brevisomabathynella* and the molecular analysis indicates that it belongs to a species encountered before (Figure 3): intra-specific sequence divergence ≤1.923%. (Table 4: yellow area). Specimen ST1648 from the Yakabindi calcrete groups with another species collected from Yakabindi (Figure 4). The pairwise sequence divergence of 10.29% (Table 5: pink value) and the long connecting branches (Figure 4) indicates that it is a different species.

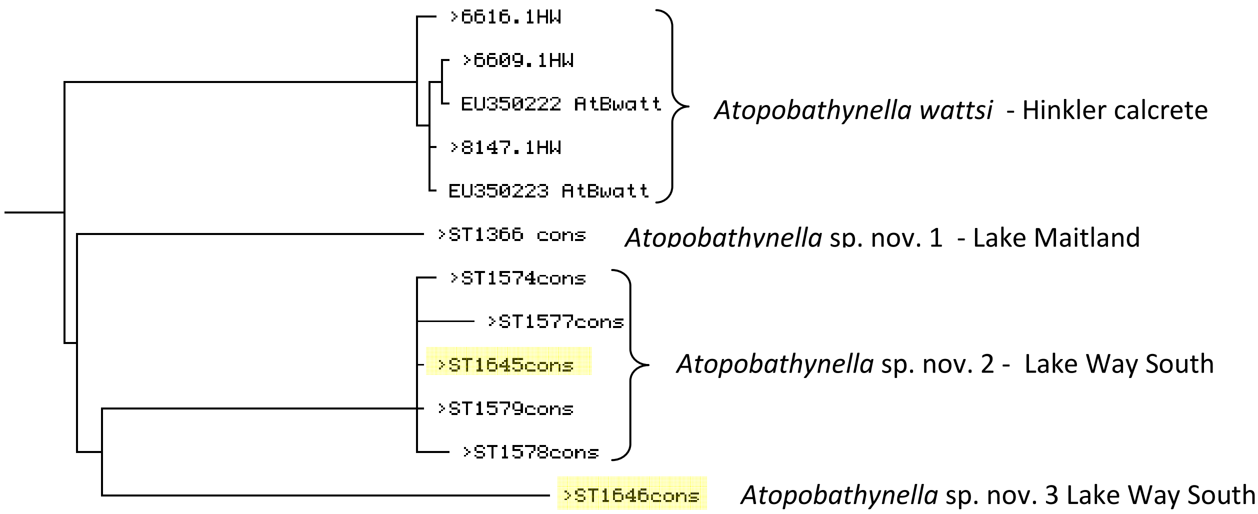

Figure 2.

Uncorrected ("p") distance matrix

		208	209	222	266	268	269	270	275
208	EU350223 AtBwatt	-							
209	EU350222 AtBwatt	0.00158	-						
222	>ST1366 cons	0.09523	0.09527	-					
266	>ST1574cons	0.09861	0.09868	0.09204	-				
268	>ST1577cons	0.10506	0.10512	0.09344	0.00714	-			
269	>ST1578cons	0.10253	0.10259	0.09345	0.00570	0.00997	-		
270	>ST1579cons	0.09652	0.09659	0.09198	0.00143	0.00571	0.00427	-	
275	>ST1645cons	0.09666	0.09673	0.09203	0.00143	0.00571	0.00428	0.00000	-
276	>ST1646cons	0.10577	0.10579	0.10364	0.10138	0.10286	0.10286	0.09996	0.10000

Table 3.

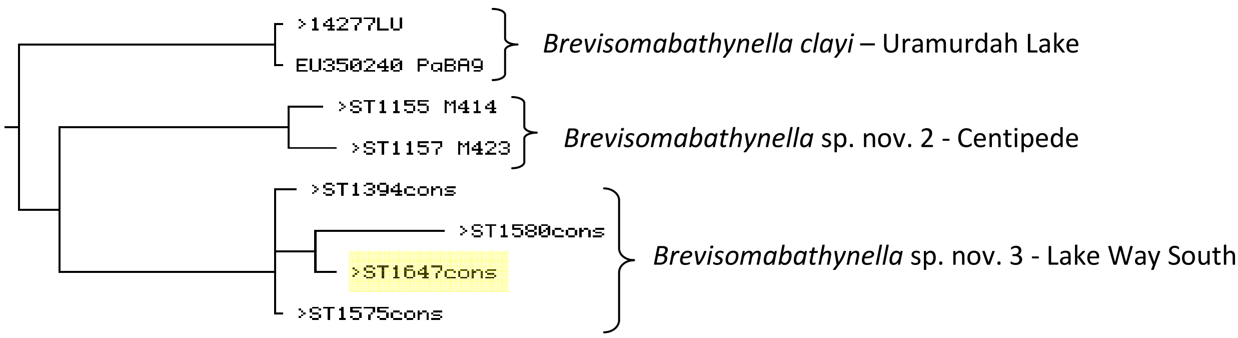

Figure 3.

Uncorrected ("p") distance matrix

		14	189	214	215	223	267	271
14	>14277LU	-						
189	EU350240 PaBA9	0.00000	-					
214	>ST1155 M414	0.06453	0.06546	-				
215	>ST1157 M423	0.07055	0.07140	0.00832	-			
223	>ST1394cons	0.06182	0.06474	0.06332	0.05909	-		
267	>ST1575cons	0.06180	0.06473	0.06332	0.05910	0.00000	-	
271	>ST1580cons	0.08798	0.09043	0.08428	0.06213	0.01922	0.01923	-
281	>ST1647cons	0.06395	0.06681	0.06635	0.06222	0.00431	0.00855	0.01777

Table 4.

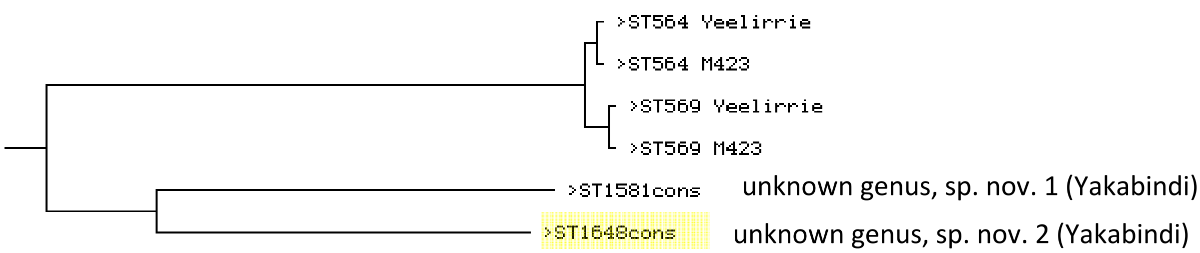

Figure 4.

Uncorrected ("p") distance matrix

		117	118	272
117	>ST564 M423	-		
118	>ST569 M423	0.00465	-	
272	>ST1581cons	0.14089	0.14018	-
283	>ST1648cons	0.14315	0.14681	0.10287

Table 5.

Pseudoscorpionida - *Tyrannochtonius*

The single specimen that was available for molecular assessment resulted in a clear sequence. Specimen ST1649 grouped with specimen ST1584 from Lake Maitland (Figure 5, see also report March 1012). The pairwise sequence value of 0.144% (Table 6, yellow value) indicate that the specimen is conspecific.

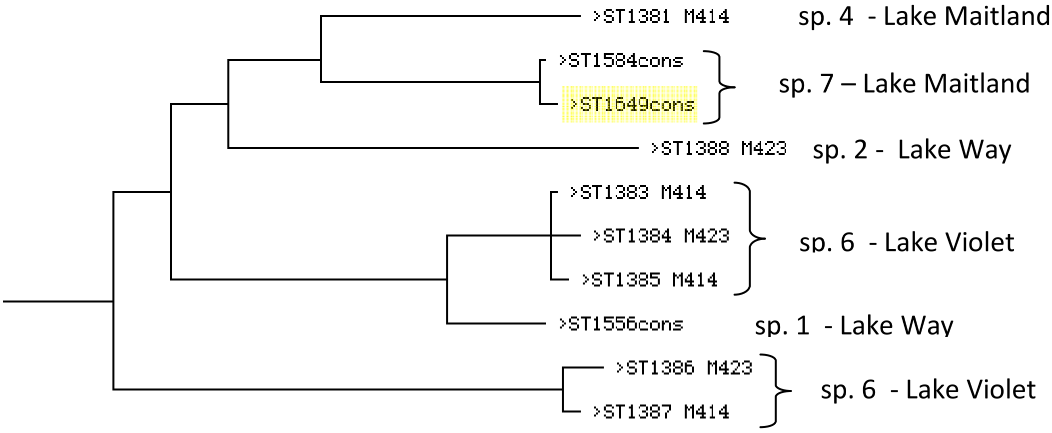

Figure 5.

Uncorrected ("p") distance matrix

		128	129	130	131	132	133	134	135	154	155
128	>ST1381 M414	-									
129	>ST1383 M414	0.12674	-								
130	>ST1384 M423	0.12450	0.00346	-							
131	>ST1385 M414	0.12543	0.00153	0.00169	-						
132	>ST1386 M423	0.15439	0.14967	0.14839	0.14812	-					
133	>ST1387 M414	0.15111	0.14672	0.14427	0.14524	0.00817	-				
134	>ST1388 M423	0.12803	0.13953	0.13393	0.13793	0.17236	0.16966	-			
135	>ST1382 M423	0.19069	0.19421	0.18874	0.19418	0.18559	0.18383	0.20288	-		
154	>ST1584cons	0.07774	0.12223	0.11777	0.12092	0.14402	0.13736	0.11234	0.19117	-	
155	>ST1649cons	0.07929	0.12377	0.11758	0.12246	0.14553	0.13887	0.11385	0.19269	0.00144	-
156	>ST1556cons	0.12958	0.03509	0.02875	0.03359	0.15317	0.14481	0.14319	0.18812	0.12201	0.12368

Table 6.

Coleoptera – Dytiscidae – *Limbodessus*

Two specimens ST1675 and ST1676 were identified using morphology by Dr. Chris Watts and verified using DNA sequencing. The adult specimen ST1675 was identified as *Limbodessus usitatus*, and the larva as *L. barwidgeeensis*, a species that has been found previously.

Report prepared for MWHGlobal, 13 July 2017
by Dr Remko Leijs, South Australian Museum.

Molecular identification of Paramelitidae from Yakabindie, Western Australia

Summary

- One new species from an unknown genus was identified in addition to two other species from Yakabindie that belong to the same unkown genus.

Extraction	Code	MWH identification	SAM identification	Extr.date	Coll.Date	Site	CO1
ST2039	LN11541	Gen nr Atopobathynella OES08	unknown genus, n.sp. YA03	30-May-17	17-May-17	Yakabindie	good seq
ST2040	LN11537	Gen nr Atopobathynella OES09		30-May-17	17-May-17	Yakabindie	no PCR
ST2041	LN11536	Gen nr Atopobathynella OES09		30-May-17	17-May-17	Yakabindie	no PCR

Table 1. Overview of the Parambathynellidae specimens optained from Yakabindie. The first column gives the DNA extraction numbers, the last column indicates whether the DNA sequencing was successful. The Yellow highlighted specimen failed to PCR.

Methods

Biodiversity assessment of the collected fauna (Table 1) was performed using PCR amplification and sequencing in both directions of a 648 bp fragment of CO1, commonly used for DNA barcoding (Hebert et al. 2003). The sequences were added to large datasets that consists of related taxa from other areas complemented with published data from Genbank and unpublished sequence data at the South Australian Museum and the Western Australian Museum.
Phylogenetic analyses using neighbour joining of uncorrected sequence distances in PAUP* (Swofford 1998) were used to match the received specimens with previously identified analysed specimens. Results of phylogenetic analyses are presented as partial phylogenetic trees showing the target species with some closest related species.

Results

Unfortunately only one of the three provided specimens resulted in a good DNA sequence. A neighbour joining analysis showed that specimen ST2039-LN11541 belonged to a sofar unrecognised species within an unknown/undescribed genus. ST2039-LN11541, provisionally named “unknown Parabathynellid genus sp. nov YA03”, appeared as sistergroup to a species from Yeelirrie (inter specific sequence divergence 11.10-11.13%). Interestingly, this group also contained two other species previously collected from Yakabindie: ST1581-LN2450 and ST1648-LN3285 (interspecific sequence divergences > 12.94%) (Figure 1).

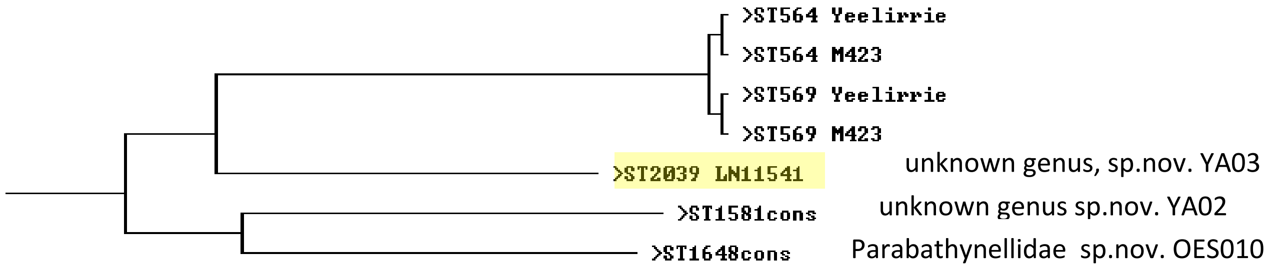

Figure 1. Partial neighbour joining cladogram of Parabathynellidae. Indicated in yellow are the newly sequenced specimens.

Sequences

```
Parabathynellidae-Yakabindie
>ST2039_LN11541
AGTGGTCAACAAATCATAAAGATATTGGAACTATATATTTACTATTTGGCGCTTGAGGTGGTATAGTAGG
AACAGGATTAAGTATAATTATTCGGTTTGAATTAGGGCAACCTGGTCCTTCTATTAACAATGACCAAATC
TATAATGTTCTTGTTACTGCTCATGCATTTATTATAATTTTTTTTATAGTTATACCTATTATAATTGGTG
GATTTGGAAATTGATTAATTCCGTTAATAGTTAATTGTCCTGATATAGCTTTTCCTCGTATAAATAATAT
AAGATTTTGATTATTACCCCCATCTCTTTTACTTTAAGTAATAAGTAGAATAATTGAAAGAGGTGTTGGA
ACTGGATGAACTGTTTACCCTCCTTTGGCTTCAAATGTATTTCATAGCGGACCTTCTATTGATTTAGCTA
TTTTTTCTCTTCATCTTGCAGGGGCATCATCAATTTTAGGAGCTATTAATTTTATTACTACAATTATTAA
CATACGGTCTTTTGGTTTATTAATGGACCGAATACCTTTATTCTGTTGGGCTGTTTTTATTACTGCAATT
TTACTACATATTTCTTTACCAGTTTTAGCTGGAGGATTAACTATGCTTCTTACTGATGGTAATTTAAATA
CATCTTTTTTTGATCCTGCTGGAGGAGGAGATCCAATTCTTTACCAACATTTGTTTTGATTTTTTGGTCA
CCCTGAAGTTTAGTCT
```

Report prepared for Stantec (MWHGlobal), 7 September 2017
by Dr Remko Leijs, South Australian Museum.

Molecular identification of Parabathynellidae and Oligochaeta from Yakabindie, Western Australia

Summary

- Two species of Enchytraeid oligochaetes were identified.
- Seven specimens of a single species of Parabathynellid (Atopobathynella sp.OES11), which include 4 different haplotypes, resulted from the DNA analyses.

Extraction	Code	MWH identification	SAM identification	Extr.date	Coll.Date	Site	CO1
ST2042	LN11371	Atopobathynella OES9	Atopobathynella OES11	29-Aug-17	8/08/2017	Yakabindie	good seq
ST2043	LN30027	Atopobathynella OES9	Atopobathynella OES11	29-Aug-17	8/08/2017	Yakabindie	good seq
ST2044	LN30009	Atopobathynella OES9	Atopobathynella OES11	29-Aug-17	8/08/2017	Yakabindie	good seq
ST2045	LN31177	Atopobathynella OES9	Atopobathynella OES11	29-Aug-17	8/08/2017	Yakabindie	good seq
ST2046	LN30023	Atopobathynella OES11 'lost'		29-Aug-17	8/08/2017	Yakabindie	no PCR
ST2047	LN30608	Atopobathynella OES11	Atopobathynella OES11	29-Aug-17	8/08/2017	Yakabindie	good seq
ST2048	LN31761	Atopobathynella OES11	Atopobathynella OES11	29-Aug-17	8/08/2017	Yakabindie	good seq
ST2049	LN30582	?Atopobathynella OES9	Atopobathynella OES11	29-Aug-17	8/08/2017	Yakabindie	good seq
ST2050	LN31752	Phreodrillidae OES23		29-Aug-17	17/05/2017	Yakabindie	no PCR
ST2051	LN30016	Phreodrillidae OES23		29-Aug-17	17/05/2017	Yakabindie	no PCR
ST2052	LN31762	Enchytraeidae OES10	Enchytraeidae sp.YA01	29-Aug-17	16/03/2017	Yakabindie	weak seq
ST2053	LN31178	Enchytraeidae OES10	Enchytraeidae sp.YA01	29-Aug-17	16/03/2017	Yakabindie	good seq
ST2054	LN31769	Enchytraeidae OES10	Enchytraeidae sp.YA02	29-Aug-17	2/02/2012	Yakabindie	good seq
ST2055	LN31187	Enchytraeidae OES10		29-Aug-17	2/02/2012	Yakabindie	no PCR

Table 1. Overview of the Parabathynellidae and Oligochaeta specimens analysed from Yakabindie. The first column gives the DNA extraction numbers, the last column indicates whether the DNA sequencing was successful. The Yellow highlighted specimen failed to PCR.

Methods

Biodiversity assessment of the collected fauna (Table 1) was performed using PCR amplification and sequencing in both directions of a 648 bp fragment of CO1, commonly used for DNA barcoding (Hebert et al. 2003). The sequences were added to large datasets that consists of related taxa from other areas complemented with published data from Genbank and unpublished sequence data at the South Australian Museum and the Western Australian Museum.
Phylogenetic analyses using neighbour joining of uncorrected sequence distances in PAUP* (Swofford 1998) were used to match the received specimens with previously identified analysed specimens. Results of phylogenetic analyses are presented as partial phylogenetic trees showing the target species with some closest related species.

Results

Parabathynellidae

Seven out of eight samples resulted in a good DNA sequences (Table 1). A neighbour joining analysis showed that all specimens ST2039-LN11541 belonged to the same species which has been recorded from the Yakabindie calcrete before, because they match with specimen ST1648_LN LN3285 (maximum pairwise intra-specific sequence divergence 1.0% between specimens ST1648 and ST2048). In a previous analysis (Yakabindie report July 2017) this clade was provisionally named Parabathynellidae OES10, but because this code was already used for a different taxon, the clade is now (re)named as Parabathynellidae OES11. Four different haplotypes were found in this clade. The sister group to this clade is represented by another species previously collected from Yakabindie: ST1581-LN2450 and ST1648-LN3285 (interspecific sequence divergences 10.29%) (Figure 1).

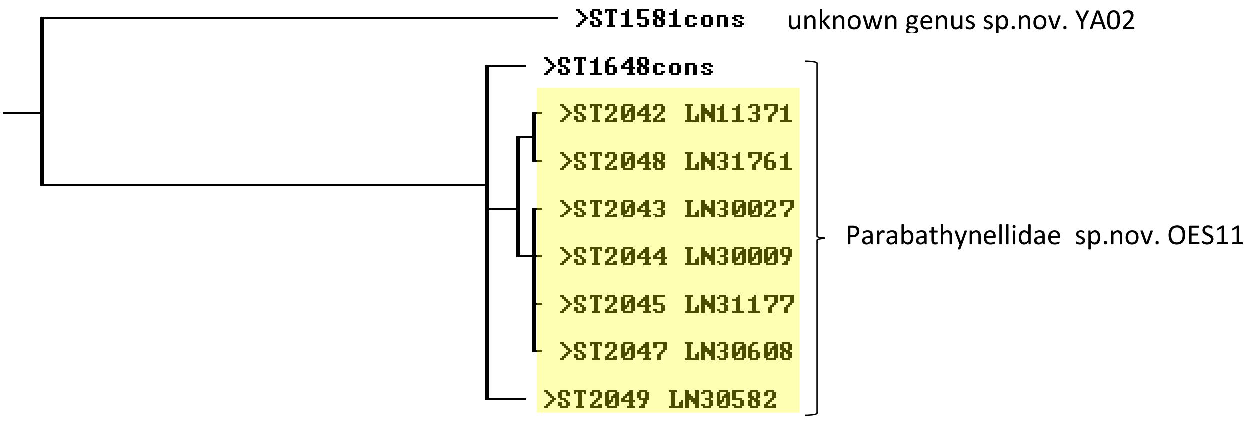

Figure 1. Partial neighbour joining cladogram of Parabathynellidae. Indicated in yellow are the newly sequenced specimens.

Oligochaeta

Three out of six samples produced good DNA sequences (Table 1). The three analysed specimens belonged to two species of Enchytraeidae. Specimen ST2052-LN31762 and ST2053-LN31178 were conspecific, intra-specific pairwise sequence divergence 0.5%. They grouped with specimen ST2054_LN31769, inter-specific pairwise sequence divergence 6.89-6.95%. The closest sister group of the two Yakabindie species in this analysis was found to be ST1200 a Enchytraeid species from the Yeelirrie area (Figure 2).

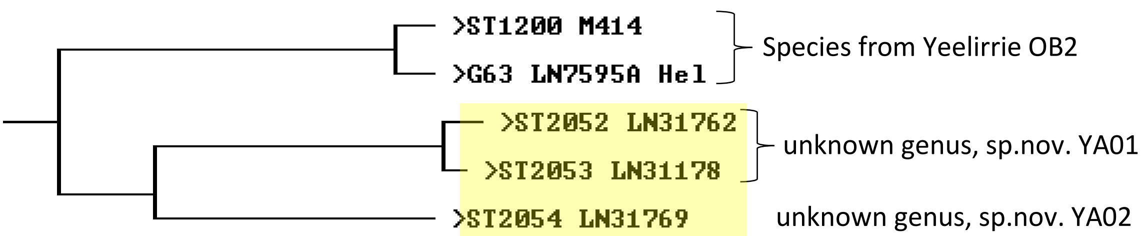

Figure 1. Partial neighbour joining cladogram of Oligochaeta (Enchytraeidae). Indicated in yellow are the newly sequenced specimens.

Sequences

Parabathynellidae
>ST2042_LN11371
AACAAATCATAAAGATATTGGAACATTATATTTACTGTTTGGTGCTTGAGGTGGTATAATCGGCACAGGC
TTAAGTATAATTATTCGATTTGAGTTAGGTCAACCAGGGCCTTTTATTGGAAATGACCAAATTTATAACG
TACTTGTTACTGCACATGCATTTATTATAATTTTTTTTATAGTTATGCCTATTATGATTGGTGGGTTTGG
AAACTGATTAATTCCATTAATACTTAATTGTCCTGATATAGCTTTCCCACGTATAAATAACATAAGGTTT
TGATTATTACCACCATCTCTTTTACTTCTAACGATAAGTGGCATAATTGAAAGAGGAGTTGGAACCGGAT
GAACTGTGTATCCTCCCTTAGCTTTAAATATATATCATAGAGGGCCCTCCGTTGATTTAGCTATTTTTTC
TCTTCATCTTGCAGGAGCTTCTTCAATTTTAGGTGCAATTAATTTTATTAGTACAGTTATTAATATACGA
CCTGCAGGATTATTAATAGATCGAATACCTTTATTCTGTTGAGCTGTATTCATTACTGCAATTTTATTGC
TTGTTTCTTTACCAGTTTTAGCTGGAGGGCTAACCATGCTTCTTACTGATCGTAACTTAAACACATCCTT
TTTTGATCCTGCTGGAGGAGGAGACCCGATTCTTTATCAACATTTATTTTGATTTTTTGGTCACCCTGAA
GTTTA
>ST2043_LN30027
AACAAATCATAAAGATATTGGAACATTATATTTACTGTTTGGTGCTTGAGGTGGTATAGTCGGCACAGGC
TTAAGTATAATTATTCGATTTGAGTTAGGTCAACCAGGGCCTTTTATTGGAAATGACCAAATTTATAACG
TACTTGTTACTGCACATGCATTTATTATAATTTTTTTTATAGTTATGCCTATTATGATCGGTGGGTTTGG
AAACTGATTAATTCCATTAATACTTAATTGTCCTGATATAGCTTTCCCACGTATAAATAACATAAGGTTT
TGATTATTACCACCATCTCTTTTACTTCTAACGATAAGTGGCATAATTGAAAGAGGAGTTGGAACCGGAT
GAACTGTGTATCCTCCCTTAGCTTTAAATATATATCATAGAGGGCCCTCCGTTGATTTAGCTATTTTTTC
TCTTCATCTTGCAGGAGCTTCTTCAATTTTAGGTGCAATTAATTTTATTAGTACAGTTATTAATATACGA
CCTGCAGGATTATTAATAGATCGAATACCTTTATTCTGTTGAGCTGTATTCATTACTGCAATTTTATTGC
TTGTTTCTTTACCAGTTTTAGCTGGAGGGCTAACCATGCTTCTTACTGATCGTAACTTAAACACATCCTT
TTTTGATCCTGCTGGAGGAGGAGACCCGATTCTTTATCAACATTTATTTTGATTTTTTGGTCACCCTGAA
GTTTA
>ST2044_LN30009
AACAAATCATAAAGATATTGGAACATTATATTTACTGTTTGGTGCTTGAGGTGGTATAGTCGGCACAGGC
TTAAGTATAATTATTCGATTTGAGTTAGGTCAACCAGGGCCTTTTATTGGAAATGACCAAATTTATAACG
TACTTGTTACTGCACATGCATTTATTATAATTTTTTTTATAGTTATGCCTATTATGATTGGTGGGTTTGG
AAACTGATTAATTCCATTAATACTTAATTGTCCTGATATAGCTTTCCCACGTATAAATAACATAAGGTTT
TGATTATTACCACCATCTCTTTTACTTCTAACGATAAGTGGCATAATTGAAAGAGGAGTTGGAACCGGAT
GAACTGTGTATCCTCCCTTAGCTTTAAATATATATCATAGAGGGCCCTCCGTTGATTTAGCTATTTTTTC
TCTTCATCTTGCAGGAGCTTCTTCAATTTTAGGTGCAATTAATTTTATTAGTACAGTTATTAATATACGA
CCTGCAGGATTATTAATAGATCGAATACCTTTATTCTGTTGAGCTGTATTCATTACTGCAATTTTATTGC
TTGTTTCTTTACCAGTTTTAGCTGGAGGGCTAACCATGCTTCTTACTGATCGTAACTTAAACACATCCTT
TTTTGATCCTGCTGGAGGAGGAGACCCGATTCTTTATCAACATTTATTTTGATTTTTTGGTCACCCTGAA
GTTTA
>ST2045_LN31177
AACAAATCATAAAGATATTGGAACATTATATTTACTGTTTGGTGCTTGAGGTGGTATAGTCGGCACAGGC
TTAAGTATAATTATTCGATTTGAGTTAGGTCAACCAGGGCCTTTTATTGGAAATGACCAAATTTATAACG
TACTTGTTACTGCACATGCATTTATTATAATTTTTTTTATAGTTATGCCTATTATGATTGGTGGGTTTGG
AAACTGATTAATTCCATTAATACTTAATTGTCCTGATATAGCTTTCCCACGTATAAATAACATAAGGTTT
TGATTATTACCACCATCTCTTTTACTTCTAACGATAAGTGGCATAATTGAAAGAGGAGTTGGAACCGGAT
GAACTGTGTATCCTCCCTTAGCTTTAAATATATATCATAGAGGGCCCTCCGTTGATTTAGCTATTTTTTC
TCTTCATCTTGCAGGAGCTTCTTCAATTTTAGGTGCAATTAATTTTATTAGTACAGTTATTAATATACGA
CCTGCAGGATTATTAATAGATCGAATACCTTTATTCTGTTGAGCTGTATTCATTACTGCAATTTTATTGC
TTGTTTCTTTACCAGTTTTAGCTGGAGGGCTAACCATGCTTCTTACTGATCGTAACTTAAACACATCCTT
TTTTGATCCTGCTGGAGGAGGAGACCCGATTCTTTATCAACATTTATTTTGATTTTTTGGTCACCCTGAA
GTTTA
>ST2047_LN30608
AACAAATCATAAAGATATTGGAACATTATATTTACTGTTTGGTGCTTGAGGTGGTATAGTCGGCACAGGC
TTAAGTATAATTATTCGATTTGAGTTAGGTCAACCAGGGCCTTTTATTGGAAATGACCAAATTTATAACG
TACTTGTTACTGCACATGCATTTATTATAATTTTTTTTATAGTTATGCCTATTATGATTGGTGGGTTTGG
AAACTGATTAATTCCATTAATACTTAATTGTCCTGATATAGCTTTCCCACGTATAAATAACATAAGGTTT
TGATTATTACCACCATCTCTTTTACTTCTAACGATAAGTGGCATAATTGAAAGAGGAGTTGGAACCGGAT
GAACTGTGTATCCTCCCTTAGCTTTAAATATATATCATAGAGGGCCCTCCGTTGATTTAGCTATTTTTTC
TCTTCATCTTGCAGGAGCTTCTTCAATTTTAGGTGCAATTAATTTTATTAGTACAGTTATTAATATACGA

CCTGCAGGATTATTAATAGATCGAATACCTTTATTCTGTTGAGCTGTATTCATTACTGCAATTTTATTGC
TTGTTTCTTTACCAGTTTTAGCTGGAGGGCTAACCATGCTTCTTACTGATCGTAACTTAAACACATCCTT
TTTTGATCCTGCTGGAGGAGGAGACCCGATTCTTTATCAACATTTATTTTGATTTTTTGGTCACCCTGAA
GTTTA
>ST2048_LN31761
AACAAATCATAAAGATATTGGAACATTATATTTACTGTTTGGTGCTTGAGGTGGTATAATCGGCACAGGC
TTAAGTATAATTATTCGATTTGAGTTAGGTCAACCAGGGCCTTTTATTGGAAATGACCAAATTTATAACG
TACTTGTTACTGCACATGCATTTATTATAATTTTTTTTATAGTTATGCCTATTATGATTGGTGGGTTTGG
AAACTGATTAATTCCATTAATACTTAATTGTCCTGATATAGCTTTCCCACGTATAAATAACATAAGGTTT
TGATTATTACCACCATCTCTTTTACTTCTAACGATAAGTGGCATAATTGAAAGAGGAGTTGGAACCGGAT
GAACTGTGTATCCTCCCTTAGCTTTAAATATATATCATAGAGGGCCCTCCGTTGATTTAGCTATTTTTTC
TCTTCATCTTGCAGGAGCTTCTTCAATTTTAGGTGCAATTAATTTTATTAGTACAGTTATTAATATACGA
CCTGCAGGATTATTAATAGATCGAATACCTTTATTCTGTTGAGCTGTATTCATTACTGCAATTTTATTGC
TTGTTTCTTTACCAGTTTTAGCTGGAGGGCTAACCATGCTTCTTACTGATCGTAACTTAAACACATCCTT
TTTTGATCCTGCTGGAGGAGGAGACCCGATTCTTTATCAACATTTATTTTGATTTTTTGGTCACCCTGAA
GTTTA
>ST2049_LN30582
AACAAATCATAAAGATATTGGAACATTATATTTACTATTTGGTGCTTGAGGTGGTATAGTCGGCACAGGC
TTAAGTATAATTATTCGATTTGAGTTAGGTCAACCAGGGCCTTTTATTGGAAATGACCAAATTTATAATG
TACTTGTTACTGCACATGCATTTATTATAATTTTTTTTATAGTTATGCCTATTATAATTGGTGGGTTTGG
AAACTGATTAATTCCATTAATACTTAATTGTCCTGATATAGCTTTCCCACGTATAAATAACATAAGGTTT
TGATTATTACCACCATCTCTTTTACTTCTAACGATAAGTGGCATAATTGAAAGAGGAGTTGGAACCGGAT
GAACTGTGTATCCTCCCTTAGCTTTAAATATATATCATAGAGGGCCCTCCGTTGATTTAGCTATTTTTTC
TCTTCATCTTGCAGGAGCTTCTTCAATTTTAGGTGCAATTAATTTTATTAGTACAGTTATTAATATACGA
CCTGCAGGATTATTAATAGATCGAATACCTTTATTCTGTTGAGCTGTATTAATTACTGCAATTTTATTGC
TTGTTTCTTTACCAGTTTTAGCTGGAGGGCTAACCATGCTTCTTACTGATCGTAACTTAAACACATCCTT
TTTTGATCCTGCTGGAGGAGGAGACCCGATTCTTTATCAACATTTATTTTGATTTTTTGGTCACCCTGAA
GTTTA

Enchytraeidae
>ST2052_LN31762
AACAAATCATAAAGATATTGGTACCTTATATTTCATCTTAGGAGTTTGAGCAGGAATAATAGGGGCTGCC
ATAAGGCTACTAATCCGAATCGAATTAAGACAACCAGGATCATTCCTAGGAAGAGACCAGCTTTACAACA
CTATTGTTACTGGTCATCGATTCTTAATAATTTTTTTCCTGGTTATACCAGTATTCATTGGAGGATTTGG
TAATTGACTTCTCCCACTTATACTAGGAGCACCAGACATAGCTTTCCCCCGTCTCAATAACATAAGATTC
TGACTTCTCCCTCCAGCATTAATATTACTAATTTCTTCAGCAGCAGTAGAAAAAGGAGCTGGCACTGGAT
GAACAGTTTATCCTCCTTTAGCCAGAAATATTGCACATGCAGGACCATCTGTAGACCTTGCAATTTTTTC
TCTTCACTTAGCAGGAGCTTCATCTATTCTAGGTGCAGTTAACTTCATCACCACAGTAATCAATATACGG
TGACAAGGGCTAACACTTGAACGCATCCCATTATTCGTATGAGCTGTAACAATTACTGTAGTTCTTTTAC
TTTTATCCTTACCAGTTTTAGCTGGTGCAATTACAATACTTTTAACAGATCGAAATCTAAATACTT
>ST2053_LN31178
TCATCTTAGGAGTTTGAGCAGGAATAATAGGGGCTGCCATAAGGGTACTAATCCGAATCGAATTAAGACA
ACCAGGATCATTCCTAGGAAGAGACCAGCTTTACAACACTATTGTTACTGGTCATGCATTCTTAATAATT
TTTTTCCTGGTTATACCAGTATTCATTGGAGGATTTGGTAATTGACTTCTCCCACTTATACTAGGAGCAC
CAGACATAGCTTTCCCCCGTCTCAATAACATAAGATTCTGACTTCTCCCTCCAGCATTAATATTASTAAT
TTCTTCAGCAGCAGYAGAAAAAGGAGCTGGCACTGGATGAACAGTTTATCCTCCTTTAGCCAGAAATATT
GCACATGCAGGACCATCTGTAGACCTTGCAATTTTTTCTCTTCACTTAGCAGGAGCTTCATCTATTCTAG
GTGCAGTTAACTTCATCACCACAGTAATCAATATACGGTGACAAGGGCTAACACTTGAACGCATCCCATT
ATTCGTATGAGCTGTAACAATTACTGTAGTTCTTTTACTTTTATCCTTACCAGTTTTAGCTGGTGCAATT
ACAATACTTTTAACAGATCGAAATCTAAATACTTCTTTTTTCGATCCTGCAG
>ST2054_LN31769
AACAAATCATAAAGATATTGGTACCCTATATTTTATCTTAGGAGTTTGAGCGGGAATAATAGGAGCTGCC
ATAAGACTACTAATCCGAATTGAACTAAGACAACCTGGATCATTCCTAGGAAGAGACCAACTTTATAACA
CTATTGTTACTGGTCATGCATTCCTAATAATTTTTTTCCTAGTAATACCAGTATTCATTGGGGGATTTGG
TAATTGACTTCTCCCACTAATACTCGGGGCACCAGATATAGCCTTCCCCCGTCTCAATAATATAAGATTC
TGACTTCTCCCCCCAGCATTAATACTACTAATTTCTTCAGCAGCAGTAGAAAAGGGGGCTGGTACTGGAT
GAACAGTATATCCTCCCCTAGCCAGAAATATTGCGCATGCAGGCCCATCTGTAGACCTTGCAATTTTTTC
TCTTCATTTAGCAGGAGCTTCATCTATTCTAGGTGCAGTTAACTTCATCACTACAGTAATCAATATACGA
TGACAAGGATTAACACTTGAACGCATCCCATTATTTGTATGAGCTGTAACAATTACTGTAGTTCTCTTAC

TCCTATCCTTACCAGTTTTAGCCGGTGCAATTACAATACTTTTAACAGACCGAAATCTAAATACTTCCTT
TTTCGAtCCtGCAG

Perth

41 Bishop Street,
JOLIMONT, WA 6014
Tel +61 (08) 9388 8799

http://au.Stantecglobal.com/

Please visit **www.Stantec.com** to learn more about how Stantec design with community in mind.

MWH® now part of Stantec