Northern Minerals Limited

Browns Range Project

Subterranean Fauna Assessment

June 2014

FINAL REPORT

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Subterranean Fauna Assessment

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Document Control for Job Number: BROW-SF-11001

Document Status	Author	Reviewer	Signature	Date of Issue
Draft Report	Shannon Ross	Nick Stevens	NS	
	Lina Ramlee	D. Jasper	DJ	17/03/2014
	Nick Stevens			
Final Report	Nick Stevens	Greg Barrett		31/03/2014
	Nick Stevens			13/06/2014

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Executive Summary

Northern Minerals commissioned Outback Ecology to undertake a subterranean fauna assessment (stygofauna and troglofauna) for the proposed Browns Range Heavy Rare Earth Elements (HREE) Project (the Project) located in the Tanami Desert of Western Australia (WA), approximately 150 km southeast of Halls Creek. The proposed Project involves open pit mining of HREE-dominant xenotime mineralised ore hosted within the Browns Range Metamorphics from five deposits (Area 5, Gambit Central, Gambit East, Gambit West, and Wolverine) with underground mining associated with Gambit West and Wolverine. Project water supply will be from a proposed borefield in the Gardiner Sandstone.

The objectives of this assessment were to investigate the subterranean fauna values of the Project study area, and to assess if the potential direct impacts associated with the proposed Project will place any species of stygofauna or troglofauna at risk. The scope of this study encompassed a literature review, database searches, assessment of subterranean habitat, and a Level 2 (baseline) stygofauna and troglofauna survey.

Survey Effort

The stygofauna survey effort involved 160 net haul samples from 115 bores taken over five survey periods, conducted from May 2012 to December 2013 (**ES Table 1**).

The troglofauna survey effort involved 59 litter trap samples deployed in 50 uncased bores over three sample periods, conducted from March 2012 to December 2012 (**ES Table 1**). In addition, 150 troglofauna scrape samples were collected from 110 uncased bore holes over five survey periods, conducted from May 2012 to December 2013.

ES Table 1: Subterranean fauna survey effort

Survey Effort		Impact	Non-Impact	Total
Stygofauna	No. Samples	88	72	**160**
	No. Bores	70	45	**115**
Troglofauna	No. Trap Samples	38	21	**59**
	No. Bores	30	20	**50**
	No. Scrape Samples	84	66	**150**
	No. Bores	65	45	**110**

The number of stygofauna and troglofauna samples collected were more than sufficient to achieve a high level of knowledge of the subterranean fauna assemblage present in the Project area and provide a high level of confidence in assessing the potential impacts posed by the proposed Project in accordance with the objectives of the Environmental Protection Authority (EPA) subterranean fauna Environmental Assessment Guidelines and Guidance Statement.

Stygofauna Assessment

A total of 21 stygofauna species were recorded from the Browns Range Metamorphics and Gardiner Sandstone fractured rock aquifer systems within the Project study area. The Bathynellacea were the most diverse order, with genetic analysis determining 15 species to occur. Genetic analyses confirmed that six species had relatively widespread distributions with gene flow demonstrated to occur across much of the Browns Range Metamorphics aquifers as well as extend to the extensive Gardiner Sandstone aquifer. The Wolverine deposit area hosted the highest diversity with six species collected. No stygofauna were recorded from Gambit West. Of the 21 species recorded:

- Fourteen species were recorded from within the Browns Range Metamorphics deposit areas, seven of which were not collected from outside the proposed pit boundaries or the associated modelled groundwater drawdown contours;
- Four species were recorded from the proposed Gardiner Sandstone borefield area, two of which were not collected from outside the proposed 1 m modelled groundwater drawdown contour; and
- Twelve species were found to have distributions that extended beyond the proposed development impact zones.

Of the 21 stygofauna species recorded, nine species were considered of conservation concern because they had not been collected from outside the proposed development impact areas. Of those nine species, seven of them were recorded from within proposed pit boundaries only (Bathynellidae-OES19, Bathynellidae-OES24, Bathynellidae-OES25, *Metacyclops*-OES20, Parabathynellidae-OES18, Parabathynellidae-OES26, and Parabathynellidae-OES27). The proposed mining of the deposits at Area 5, Gambit Central, Gambit East, Gambit West and Wolverine are not considered likely to pose a significant long term conservation risk, when taking the following into consideration:

- widespread distribution patterns of other members of the stygofauna assemblage (many occurring sympatrically) that indicated the:
  - presence of suitable and extensive habitat adjacent to and outside proposed mining impact areas; and
  - likelihood that seemingly restricted species possess broader distribution ranges that extend beyond the proposed pit boundaries and associated modelled groundwater drawdowns.
- limited area of habitat removal associated with mining excavation, relative to the much greater expanse of adjacent habitat remaining within both the Browns Range Metamorphics and the Gardiner Sandstone.

For the remaining two species of conservation concern, *Dussartcyclops*-OES2 and *Parastenocaris*-OES1, the most important factor is the potential drawdown of groundwater in the proposed Borefield.

Groundwater drawdown in excess of one metre, as modelled for the proposed Borefield in the Gardiner Sandstone, is not considered likely to pose a significant long term conservation risk when taking the following into consideration:

- widespread distribution patterns of other members of the stygofauna assemblage occurring sympatrically that demonstrated the:
    - presence of suitable and extensive habitat adjacent to and outside of the modelled 1 m drawdown contour; and
    - likelihood that *Dussartcyclops*-OES2 and *Parastenocaris*-OES1 have broader distribution ranges that extend beyond the modelled 1 m drawdown zone.
- level of modelled groundwater drawdown is less than recorded natural variation in groundwater levels;
- large extent of saturated habitat that would persist in the immediate vicinity of the production bore during the operational life of the borefield; and
- limited area of habitat removal associated with the operation of the proposed borefield, relative to the large expanse of adjacent habitat remaining within both the Gardiner Sandstone and the Browns Range Metamorphics.

Troglofauna Assessment

Only two putative troglofauna species, Nicoletiinae-OES10 and Projapygidae-OES2, were collected indicating that the widespread and contiguous regolith and weathered fractured rock geologies of the Project study area do not harbour a diverse troglofauna assemblage. Both species were collected in scrape samples with no troglofauna collected from any of the litter traps.

Both Nicoletiinae-OES10 and Projapygidae-OES2 are not considered to be of conservation concern because each species was collected from outside proposed pit boundaries and modelled groundwater drawdown zones. The distributions of any potentially undetected troglomorphic species are unlikely to only be restricted to a small area because of the continuity and extent of subsurface habitat present. This notion is supported by the distribution of Projapygidae-OES2 that was found to be relatively widespread having been collected from the Gambit East deposit area and from the North-Western regional area.

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1. INTRODUCTION

Northern Minerals Ltd (formerly Northern Uranium Ltd) (Northern Minerals) commissioned Outback Ecology to undertake a subterranean fauna assessment (stygofauna and troglofauna) for the proposed Browns Range Project (the Project) that is focused on Heavy Rare Earth Elements (HREE). The Project is located in the Tanami Desert of Western Australia (WA), approximately 150 km southeast of Halls Creek, and 15 km west of the Northern Territory (NT) border (**Figure 1**).

Developing the mineral resource could potentially impact subterranean fauna through the physical removal of habitat for pit excavation, and groundwater drawdown required to access the resource and for the Project's water supply. This report presents the findings of stygofauna and troglofauna surveys of these habitats, together with an assessment of the potential risks posed to subterranean fauna by the project, and associated management recommendations.

1.1. Project Background

The Project previously formed part of the Gardiner-Tanami Project, but since 2009 has become a focus for Northern Minerals' HREE development program. The Project covers an area of 400 km^2 located on Gordon Downs Station in the Shire of Halls Creek tenement applications M80/627, L80/76 and L80/77. The southern pastoral boundary passes to the south of the Project area, however, pastoral activity is limited in the project area and focused further to the north. There are no operating mines in the area.

The principal activities planned for the Project include (**Figure 2**):

- Open pit mining of HREE-dominant xenotime mineralised ore from five deposits:
  - Area 5 — proposed pit excavation depth approximately 95 metres below ground level (mbgl);
  - Gambit Central — proposed pit excavation depth approximately 40 mbgl;
  - Gambit East — proposed pit excavation depth approximately 65 mbgl;
  - Gambit West — proposed pit excavation depth approximately 135 mbgl; and
  - Wolverine — proposed pit excavation depth is approximately 200 mbgl.
- Underground mining operations associated with two proposed pits, Gambit West and Wolverine;
- Processing facilities on-site to produce a concentrate of high-purity, mixed rare earth oxides, with concentrate to be transported to a port for export;
- Water supply borefield within the Gardiner Sandstone; and

- Additional associated mining infrastructure such as waste rock landforms (WRL), tailings storage facility (TSF), access and haul roads, water management infrastructure (pipelines, bunds, drains, storage ponds), telecommunications infrastructure, diesel power supply for the mine, plant and support facilities (workshop, fuel and water storage, accommodation village and administration buildings), and an extension of an existing exploration airstrip (**Figure 2**).

1.2. Scope and Objectives

The overarching objectives of this assessment were to assess the subterranean fauna values in the context of the proposed Project footprint and surrounding areas and to investigate if the removal of potential habitat through excavation and groundwater drawdown will place any subterranean fauna within the Project area at risk. The assessment was designed in accordance with the Environmental Protection Authority of Western Australia (EPA) *Environmental Assessment Guideline (EAG) 12* (2013) and EPA *Guidance Statement No. 54A* (2007a), which outline considerations and sampling methods for subterranean fauna in Western Australia.

Specific objectives of the assessment were to:

- document the species richness, abundance and distribution of subterranean fauna species within the Project area
- evaluate the potential of habitat to support subterranean fauna within the Project area;
- consider the conservation significance of any subterranean fauna assemblage or species occurring within the Project area;
- identify potential risks to obligate subterranean fauna from the proposed mining activities; and
- provide an EIA in relation to the proposed Project development;

The scope of this subterranean fauna assessment encompassed a literature review, database searches and a Level 2 Baseline subterranean fauna survey. The terms used in this report to define the various Project areas surveyed within the Project study area as part of this subterranean fauna assessment are:

- *Deposits* — Area 5, Gambit Central, Gambit East, Gambit West (may also be collectively referred to as Gambit deposits or Gambits), and Wolverine, all within the Browns Range Metamorphics;
- *Borefield* — Proposed Borefield, within the Gardiner Sandstone, consisting at present of test bores BRRWS010 and BRRWS007; and;
- *Regional* — Refers to non-impact areas sampled outside the above deposit areas and proposed borefield but within the Project study area and includes Central Regional, North-Western Regional, and Southern Regional.

This report provides the results of the subterranean fauna survey and presents an Environmental Impact Assessment (EIA) for subterranean fauna in the context of the proposed Project.

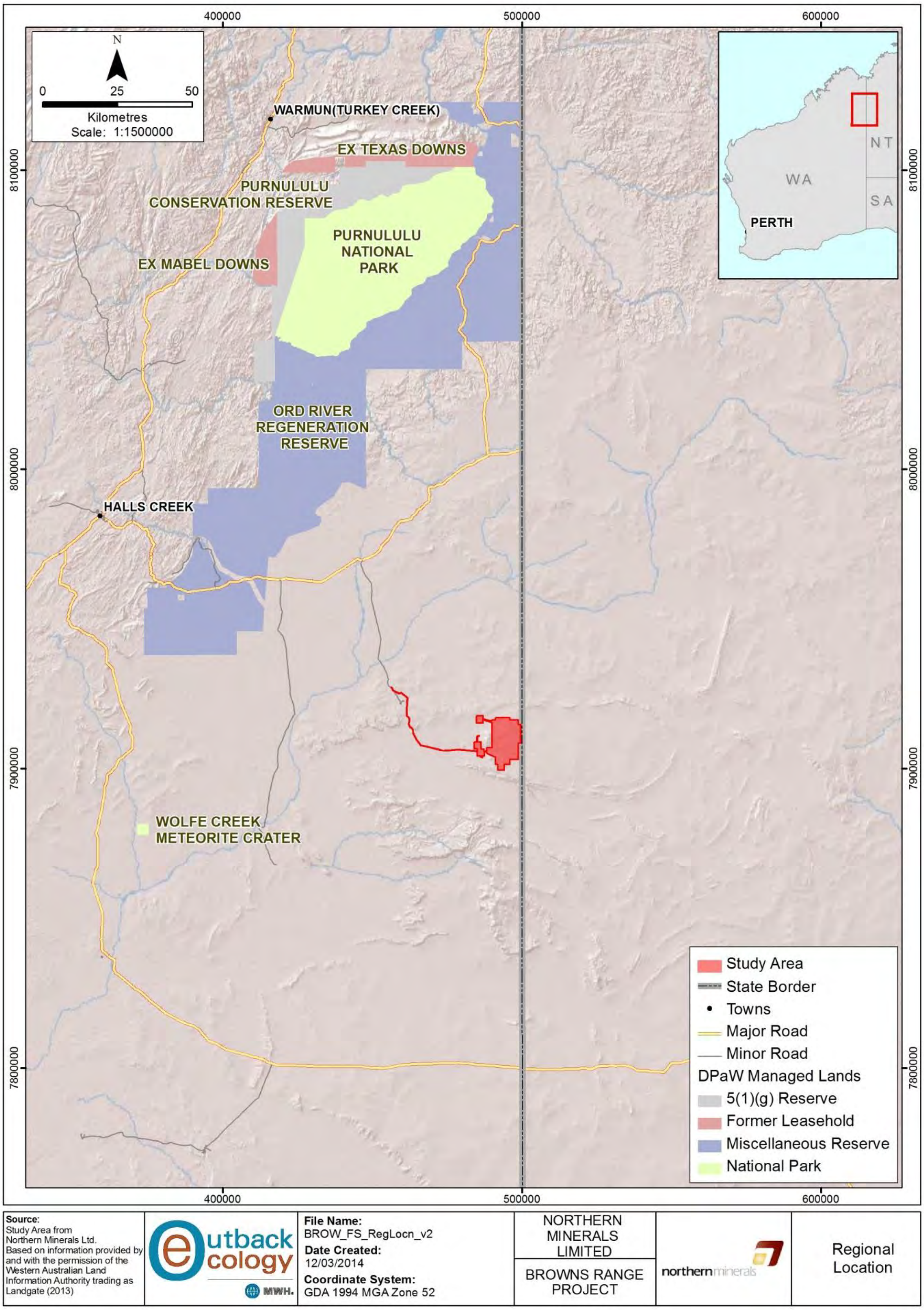


Figure 1: Regional location of the Browns Range Project Study Area

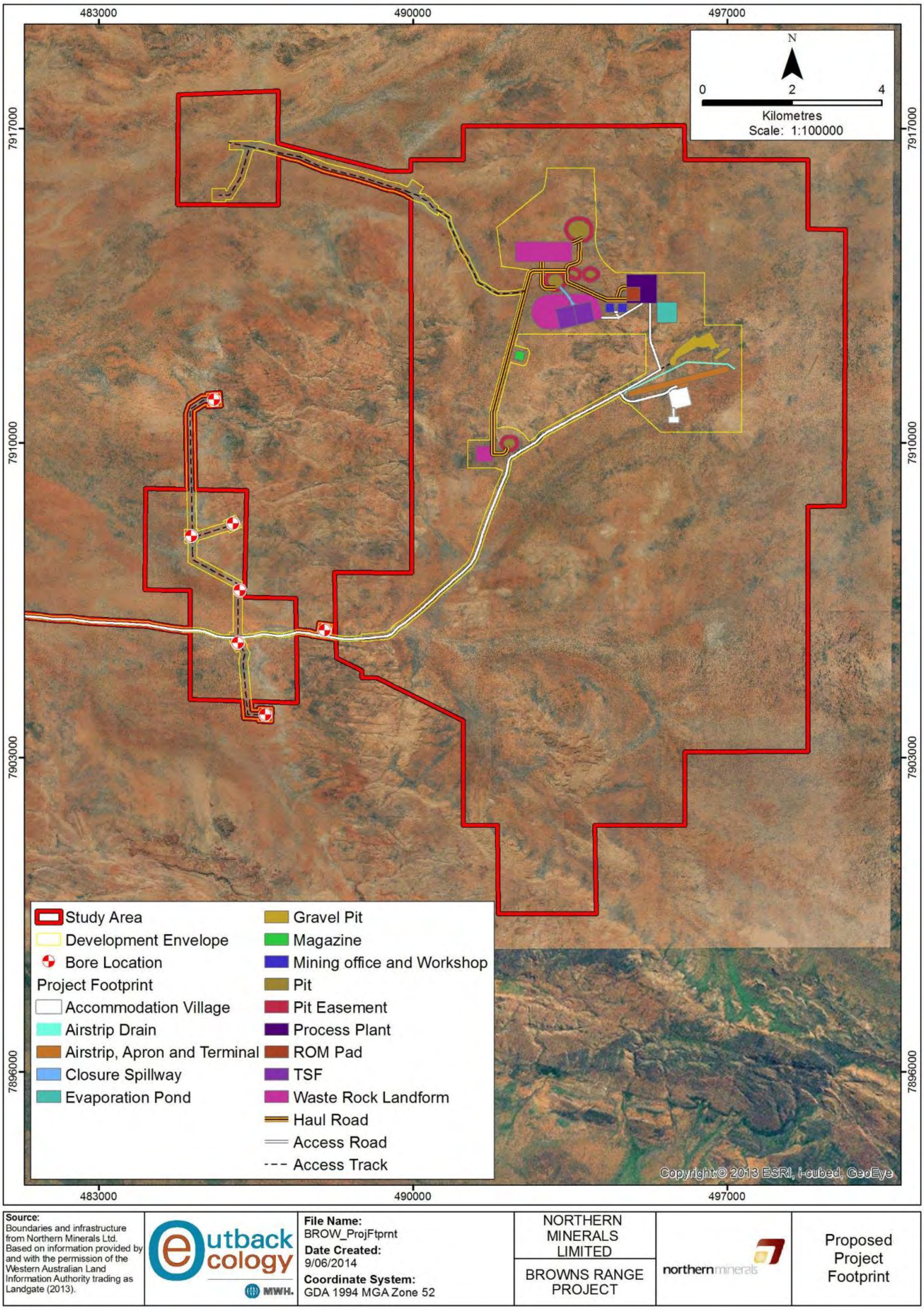


Figure 2: Conceptual layout of proposed Browns Range Project Footprint within the Development Envelope and Project Study Area.

2. EXISTING ENVIRONMENT

2.1. Biogeographic Region

The Project is located within the Tanami bioregion, as defined by the Interim Bioregions of Australia (IBRA) classification system (Graham 2001), within an area of rocky outcrop at the northern edge of the Tanami Desert (**Figure 3**). The majority of the Tanami bioregion extends eastward into the central Northern Territory, but a small portion of the bioregion extends westward into Western Australia and contains the Project Area. The Tanami bioregion is composed of three sub-bioregions: Tanami 1, Tanami 2 and Tanami 3. The Project occurs in Tanami 1, the larger of the three sub-bioregions (**Figure 3**).

The Tanami 1 sub-bioregion covers 3,214,599 ha of red desert sand plains that support mixed shrub steppes and hummock grasslands, as well as hills and ranges that support wattle scrub and hummock grasslands (Graham 2001). Drainage occurs via Sturt Creek (the largest river system in the Tanami bioregion) and other ephemeral watercourses such as the Lander and Hanson Rivers and Winnecke Creek (ANRA: Australian Natural Resources Atlas 2009a, b). The Tanami 1 sub-bioregion incorporates large areas of relatively untouched desert ecological communities, and as such is an important refuge area for biodiversity (ANRA: Australian Natural Resources Atlas 2009a). The sub-bioregion supports a number of threatened fauna species and contains two wetlands of national significance: The Lake Gregory system in Western Australia and Lake Surprise in the Northern Territory (ANRA: Australian Natural Resources Atlas 2009a, b, DSEWPaC: Department of Sustainability 2009). While the sub-bioregion is generally in good ecological condition, significant threatening processes include feral predators, changing fire regimes and weeds (ANRA: Australian Natural Resources Atlas 2009a, Graham 2001). Apart from some vertebrate fauna sampling conducted in the Northern Territory portion of the Tanami 1 sub-bioregion more than 15 years ago, there has been no systematic review of biodiversity within the sub-bioregion (ANRA: Australian Natural Resources Atlas 2009a, Graham 2001). Consequently, little baseline information is available regarding subterranean fauna values of the area.

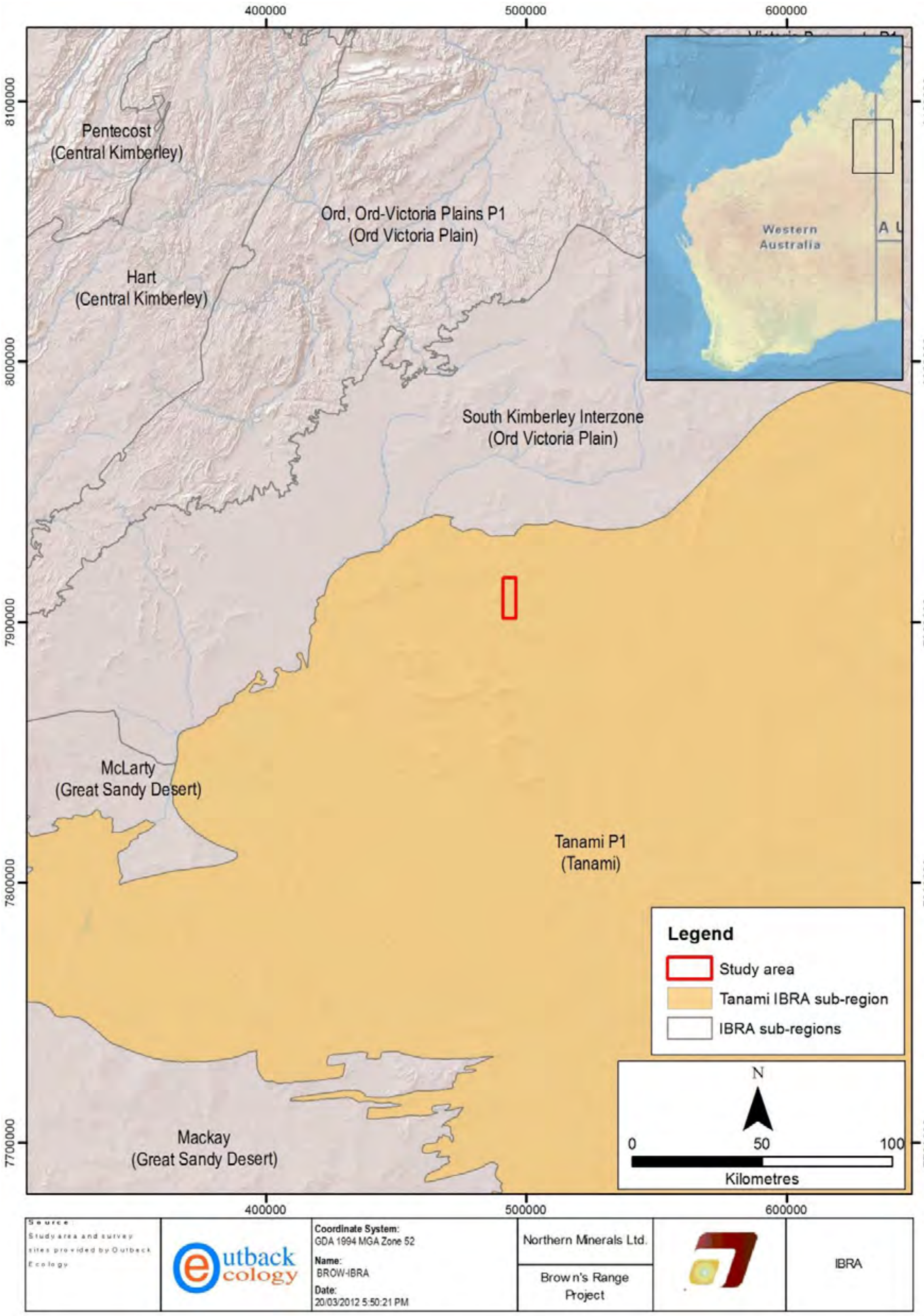


Figure 3: Location of the Study Area relative to the Tanami bioregion and Tanami 1 sub-bioregion

2.2. Climate

The Tanami 1 sub-bioregion experiences an arid-tropical climate with mainly summer rainfall due to a monsoonal influence (Graham 2001). The Bureau of Meteorology (BOM) weather station at Halls Creek Airport, approximately 150 km north-west of the Project, is the closest locality with comprehensive climate data available and consequently provides climate information most relevant to the Project (**Figure 4**). Mean maximum temperatures at Halls Creek Airport range from 27.2°C in July to 38.4°C in November, and peak temperatures are recorded from September to April (**Figure 4**). The mean minimum temperature in winter months ranges from 12.6 to 14.8°C. The majority of rainfall consistently occurs between November and March (the 'wet season'), whereas very little rainfall is typically recorded in winter months (the 'dry season') (**Figure 4**). Halls Creek Airport has a mean annual rainfall of 636 mm and an average of 49 rain days per year (Bureau of Meteorology 2012). An unusually wet dry season was experienced by northern Australia (including the Project Area) in 2010, with many locations in the region measuring their highest dry season rainfall on record (National Climate Centre 2010).

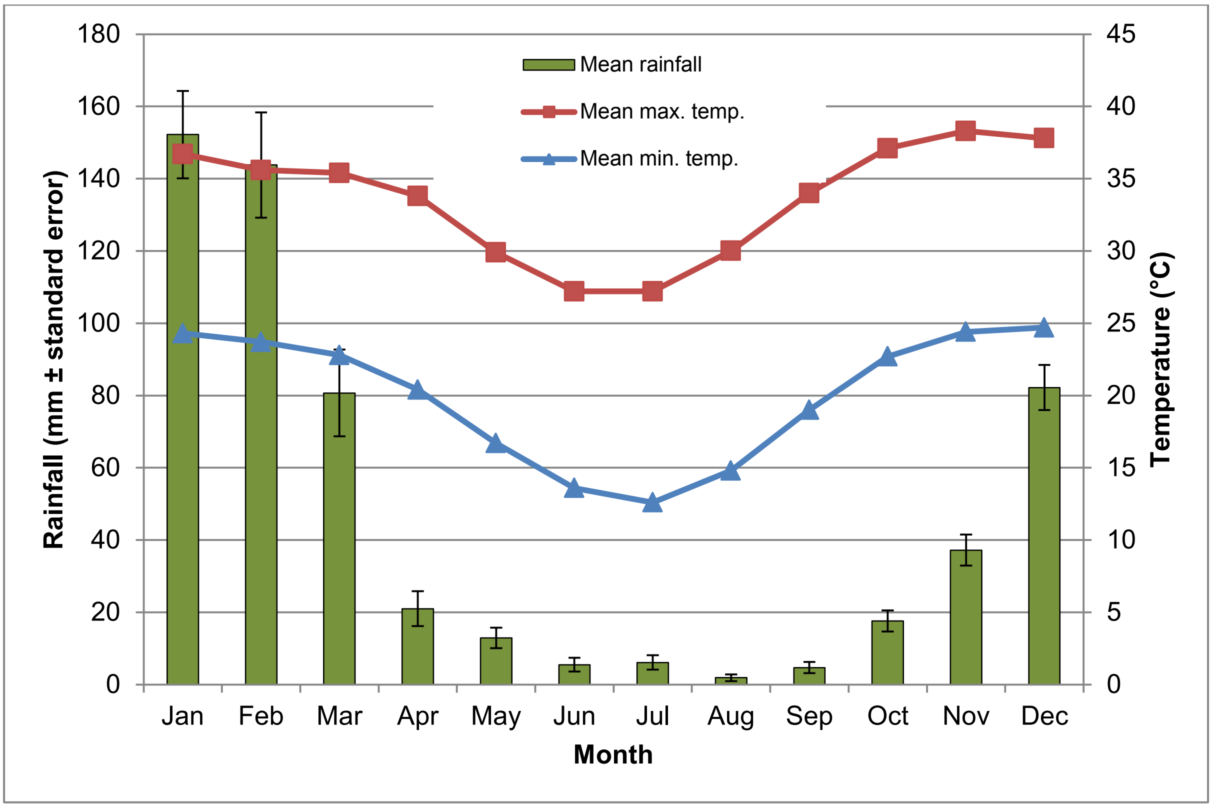


Figure 4: Climate data for Halls Creek Airport weather station (002012)

2.3. Topography and Drainage

The Project area consists of rugged topography with rapid changes in elevation related to metamorphic rocks that form ridges and outcrops. The moderate relief present has elevations that range from around 380 m to 520 (m AHD). Incised drainage systems and numerous drainage lines and ephemeral creek systems are present. Outcrops of the Gardiner Sandstones form rugged outcrops around the western perimeter of the Browns Range Dome. Headwaters and tributaries at the western end of the dome flow to the west towards Sturt Creek and form broad alluvial valleys.

2.4. Geology

The Project area is located on the western side of the Browns Range Dome. The dome has been formed by a granitic core intruding the “Browns Range Metamorphics”. The Browns Range Dome extends across the border into the NT. The dome and its aureole of metamorphics are surrounded by the Gardiner Sandstone (Birrindudu Group). The Gardiner Sandstone is recognised as a regional unit that extends more than 35 km to the west of the Project area beyond Sturt Creek and is estimated to be over 300 m thick (Klohn Crippen Berger 2014).

Northern Minerals summarised the geology of the Project area as primarily overlain with transported soil and low lying vegetation, with rocky outcrops that consist of arkose and meta-arkose that form the dominant geological unit throughout the Project area. Other rock types include quartz mica schists, BIF/quartz pebble conglomerate, dolerite and calc-silicate rocks. Minor occurrences of quartzite, silcrete, ferricrete and iron stone have also been identified. The Gardiner Sandstone is seen to flank the western margins of the Project area and unconformably overlies the older Browns Range metamorphic rocks.

The rare earth deposits with xenotime mineralisation identified within the Project area are hosted within hydrothermal quartz veins and quartz vein breccias associated with the Browns Range Metamorphics. The Project area is also considered prospective for nickel and other electromagnetically conductive massive/semi-massive sulphide mineralisation.

2.5. Hydrogeology

There are no known groundwater users, including pastoral bores, within at least 10 km of the Project area. Pastoral activities are limited in the region surrounding the Project Area due to the land being generally unsuitable for pasture production. No stock are present on the Gordon Downs Station pastoral lease. Riverine pools do not occur in the area and there are no documented groundwater dependant ecosystems (GDE’s) (Johnson 2006).

The location of significant groundwater resources that may provide habitat for stygofauna, irrespective of water quality, is dependent on the presence of suitable groundwater-yielding rock types and site-specific geological conditions, such as the presence of calcrete, fracture or shear zones, or alluvium (Johnson 2006). Regionally, relatively large calcrete systems are present within the Sturt Creek drainage line and extend over areas of 1 km^2 to over 100 km^2. In other parts of arid Western Australia, calcrete is a highly prospective aquifer with large bore yields in excess of 1000 kL/day.

However, calcrete can often contain brackish groundwater due to its low position in the groundwater flow system (Johnson 2006). No areas of calcrete have been identified in drainage lines within the Project study area.

The Gardiner Sandstone is recognised as hosting aquifer systems at a regional scale with a number of registered Department of Water (DoW) bores present within the sandstone unit as well as surface expressions of groundwater such as springs and seeps. Banana Springs, located approximately 10 km to the west of the Project area, is the closest identified water point. Surface runoff and streamlines from Browns Range Dome and outcropping Gardiner Sandstone flow towards this spring. The spring is understood to be situated within Aboriginal Lands and is not accessible (Johnson 2006).

Within the Project study area, the groundwater is considered to be mostly associated with fractured rock aquifers hosted within the Browns Range Metamorphics (including identified deposit areas) and the Gardiner Sandstone (Klohn Crippen Berger 2014). Both the Browns Range Metamorphics and the Gardiner Sandstone units consist of thick sequences with low primary porosity. However, secondary porosity does occur within each unit as a result of geological structures such as faults and shear zones along with associated fracturing. Therefore, for both units the groundwater storage and movement is considered to mostly occur within and along these geological structures and associated fracturing (Klohn Crippen Berger 2014). Bores intercepting these discrete water bearing geological features and fracture zones can provide higher groundwater yields.

Groundwater aquifer systems are considered to be maintained by annual rainfall recharge during the wet season. Recharge rates are difficult to estimate and in the upper parts of drainage lines may be only a small proportion of rainfall. Most of the rainfall is likely to be evaporated or used by native vegetation (Johnson 2006). Any runoff will depend on the intensity and duration of rainfall events, local topography (catchment size and slopes) and the nature of the surface material. Some runoff is expected to be generated from the Gardiner Sandstone outcrops and flow towards the alluvial material in valley floors (Johnson 2006).

The alluvium in drainage lines have not been well described in the local region. However, the saturated thickness may be variable and this can affect the potential for hosting large volumes of groundwater. Deep and extensive alluvial aquifer sections may yield supplies of low salinity water of around 100 kl/day, particularly in areas where recharge occurs below outcrop ridges (Johnson 2006). Within the Project study area there is limited knowledge of the alluvial aquifer system overlying the fractured rock aquifers of the Browns Range Metamorphics and Gardiner Sandstone. However, the alluvial aquifers are not considered to represent significant groundwater sources relative to the fracture rock aquifers but may provide recharge to these underlying systems (Klohn Crippen Berger 2014).

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 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 (Humphreys 2006, 2008). 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, Outback Ecology 2011a, Subterranean Ecology 2008b). A relatively high humidity is considered to be a key requirement for troglofauna existence.

The extent of subterranean habitat is dependent on the interconnection of sub-surface crevices, fractures and voids, within suitable geological units and aquifer systems. Hydrogeological studies can give an indication of the extent of stygofauna habitat present using groundwater flow or yield characteristics (aquifer parameters). For troglofauna, knowledge of the geological facies present can also give an indication of the extent of habitat. .

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 (EPA 2007). 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 distributions. Short-range endemic species are species that 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 metabolisms and fecundity rates (Cooper *et al.* 2002, Danielopol and Pospisil 2000).

3.3. Troglofauna

Troglofauna (air-breathing subterranean fauna) are often relictual forms related to surface dwelling (epigean) groups and can be distinguished by characteristics associated with a below-ground existence (Humphreys 2000). Troglofauna can be divided into:

- troglophiles, which carry out most of their lifecycle underground but are able to survive in epigean habitats;
- trogloxenes, which can enter subsurface habitats passively or incidentally; and
- troglobites (the focus of this assessment), which are obligate or permanent subterranean inhabitants (Thurgate *et al.* 2001) that generally lack pigmentation, are blind (or have reduced eyes), have elongated limbs and may possess enhanced non-visual sensory adaptations (Culver and Sket 2000).

Troglofauna are found worldwide and have been generally classified as cave organisms (Culver and Sket 2000). The most researched areas in Western Australia are the Cape Range and Barrow Island karst cave systems where large, diverse communities have been discovered in extensive cave systems (Hamilton-Smith and Eberhard 2000).

3.4. Risks and Relevant Legislation

Development and operation of new and existing 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, 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 has developed *Environmental Assessment Guideline (EAG) 12* (2013) and EPA *Guidance Statement No. 54A* (2007a) which outline considerations and sampling methods for subterranean fauna in Western Australia. Please note that *Guidance Statement No. 54* (Environmental Protection Authority 2003) was replaced in June, 2013 by EAG 12 (2013). These documents provide advice to proponents and the public on the requirements for environmental impact assessment (EIA) and management of subterranean fauna. The assessment was designed in accordance with both the EPA EAG 12 (2013) and 54A (2007a).

Mining proposals that will potentially impact on groundwater, or hypogean habitats that support subterranean fauna, require a risk assessment to ensure mining operations do not threaten the viability of important species or communities. Proponents must demonstrate that any species existing within potential mine-related impact zones also occur outside this area. For taxa restricted to impact zones, a suitable management plan must be developed, which includes ongoing monitoring of subterranean fauna to ensure the persistence of the species (Environmental Protection Authority 2003).

4. METHODS

4.1. Literature Review

A literature review was undertaken in order to characterise the existing stygofauna and troglofauna 'known' values of the regional area. The information compiled included technical reports, scientific journal articles and government publications.

4.2. Database Searches

Both federal and state database searches were undertaken as part of the desktop review to develop a list of taxa which could potentially occur in the Browns Range area or surrounds, and to identify any priority or threatened ecological communities in the vicinity. Database searches in specified areas were made using the following database and internet tools:

- Western Australian Museum's (WAM) collection database was searched for subterranean crustaceans using a rectangular search area to retrieve records in the Browns Range region;
- Department of Parks and Wildlife (DPaW) Naturemap database was searched for species records within a 40 km radius of Project study area; and
- DPaW Threatened Ecological Communities database was searched for TEC's and PEC's occurring within a 100 km radius of Project study area to obtain TEC and PEC buffer zones in the Browns Range area.

4.2.1. Lists

The following formal lists were checked against the database results, to identify any threatened or priority subterranean fauna that may occur within the search area (**Figure 5**):

- *WC Act* Schedule Species List;
- Department of Parks and Wildlife (DPaW) Threatened Ecological Community (TEC) List;
- DPaW Priority Ecological Community (PEC) List;
- *EPBC Act* TEC List; and
- *EPBC Act* Threatened Fauna List.

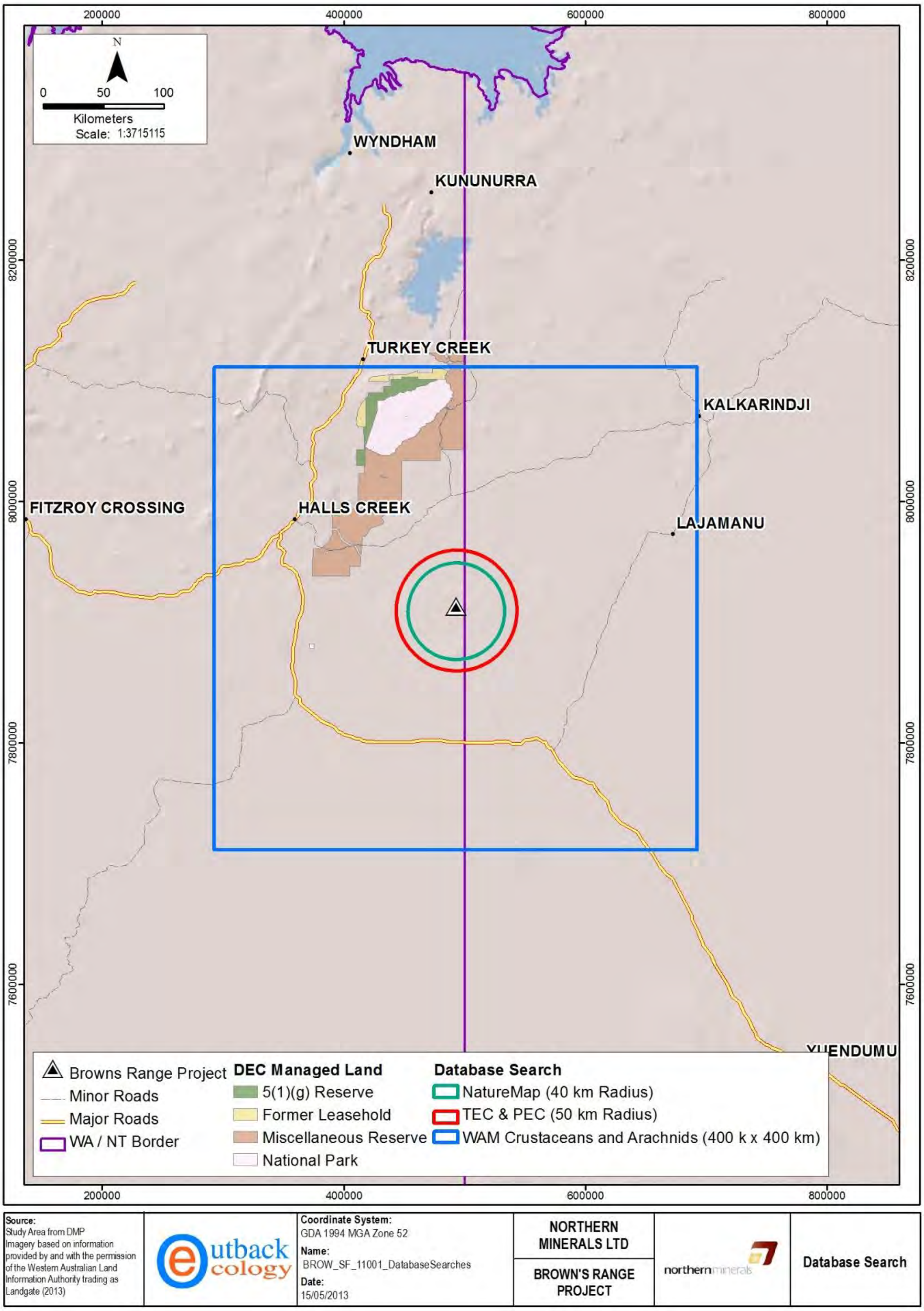


Figure 5: Database search areas carried out for the Browns Range Project.

4.3. Field Personnel and Licences

Licences to take fauna for scientific purposes (*Wildlife Conservation Act 1950*, Regulation 17) were obtained from the DPaW prior to the Browns Range Pilot Subterranean Fauna Survey (Licence Number SF008474). Personnel involved in the field sampling included Nick Stevens, Shannon Ross, Matt Quinn, Shiona Macdonald, Paul Bolton, Mark Carter as well as personnel from Northern Minerals.

4.4. Stygofauna Assessment

4.4.1. Net Haul Sampling

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

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

4.4.2. Stygofauna Survey Effort

A total of 160 stygofauna net haul samples have been collected from 110 uncased exploration bore holes and 5 cased bores slotted below the standing water level (SWL) (**Table 1**, **Figure 6**, **Figure 7**, **Figure 8, Appendix A**). The stygofauna sampling was undertaken across five periods: May 16, 2012; October 21 to 25, 2012; April 9 to 16, 2013; August 15 to 20, 2013; and December 17, 2013. Sampling periods ranged from the early dry season, following large rainfall events, to the late dry season. Sampling was not able to be conducted during the wet season due to heavy rainfall making the area inaccessible.

The total number of samples taken from within proposed impact zones was 88 with 57 samples from within proposed pit shell boundaries and 31 from within modelled groundwater drawdown contours (**Table 2**). The survey effort undertaken does exceed the recommended number of 40 impact zone samples for a Level 2 stygofauna baseline assessment by the Western Australia Environmental Protection Authority (EPA) Guidance Statement 54A (EPA 2007). The survey intensity undertaken is therefore considered to be sufficient to achieve a high level of knowledge of the stygofauna assemblage present in the Project area and provide a high level of confidence in assessing the potential impacts posed by the proposed Project in accordance with EPA EAG 12 (2013).

Table 1: Stygofauna survey effort per sample period.

Sample Period	Net Hauls
May, 2012	2
October, 2012	36
April, 2013	64
August, 2013	50
December, 2013	8
Number of Samples	**160**
Number of Bores	**115**

Table 2: Stygofauna survey effort per Project area and proposed impact from projected groundwater drawdowns (Klohn Crippen Berger 2014).

Project Area	Impact			Non-Impact
	Pit	Groundwater Drawdown	Total Impact	
Area 5	19	4	**23**	6
Central Regional				16
Gambit Central	9	4	**13**	
Gambit East	5	5	**10**	7
Gambit West	3	3	**6**	
North-Western Regional				12
Proposed Borefield (GS)		4	**4**	
Southern Regional				24
Wolverine	21	11	**32**	7
Total	**57**	**31**	**88**	**72**

4.4.3. Groundwater Properties

Basic physicochemical data were collected when taking stygofauna samples (**Appendix B**). The approximate standing water level (SWL) (mbgl) was measured using a Solinst 101 water level meter. A calibrated TPS 90 FLMV multi-parameter field instrument was used to measure pH, water temperature, dissolved oxygen (DO), electrical conductivity (EC), salinity and reduction-oxidation potential (Redox) of the groundwater. The end of hole (EoH) was estimated using the number of rotations of the stygofauna sampling winch reel required to retrieve stygofauna nets. Where this data was not available, EoH measurements were taken from client logs.

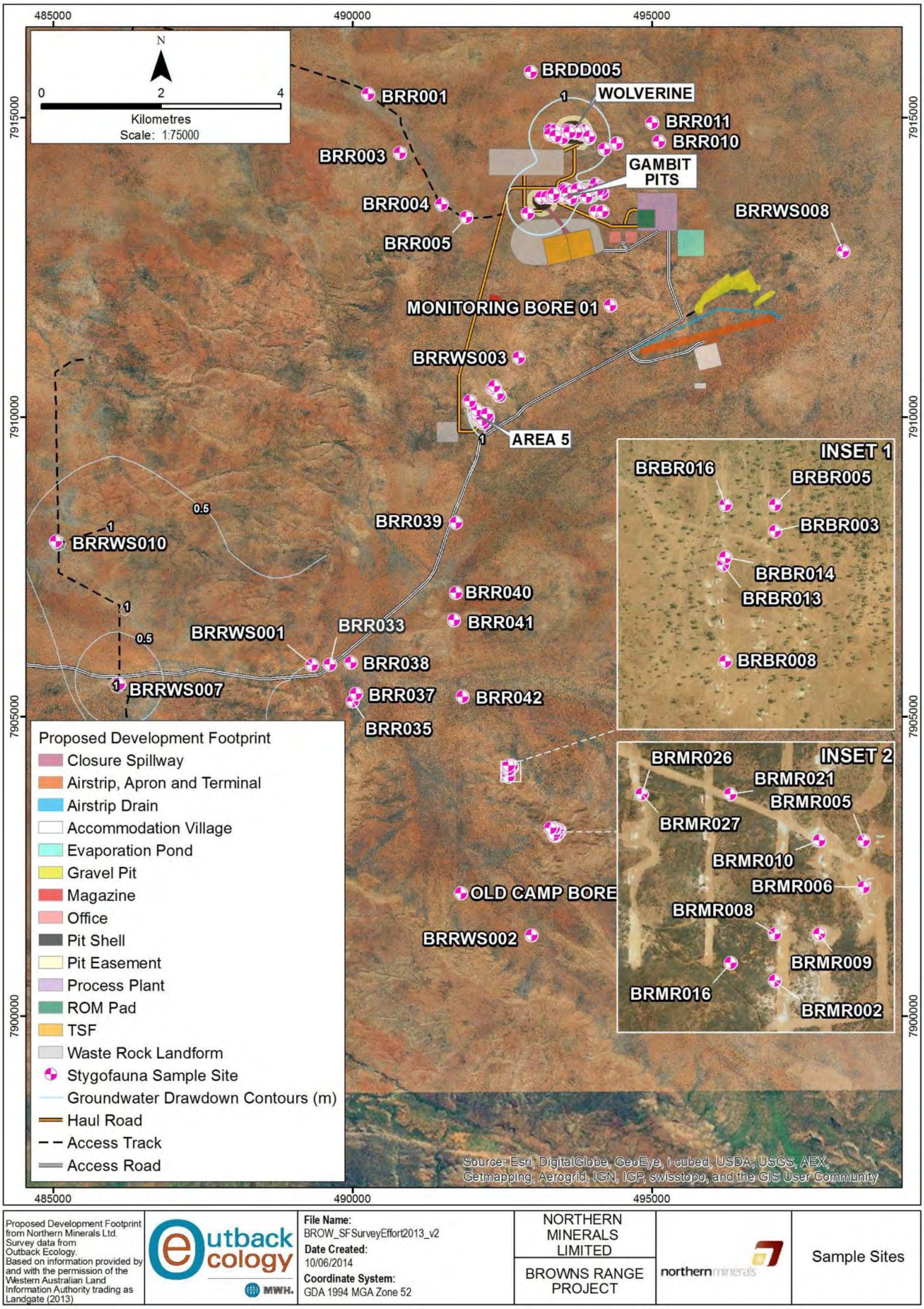


Figure 6: Stygofauna survey bore locations in relation to proposed Project footprint. Refer Figure 7 and Figure 8 for further detail on Gambits and Wolverine, and Area 5 deposit areas, respectively.

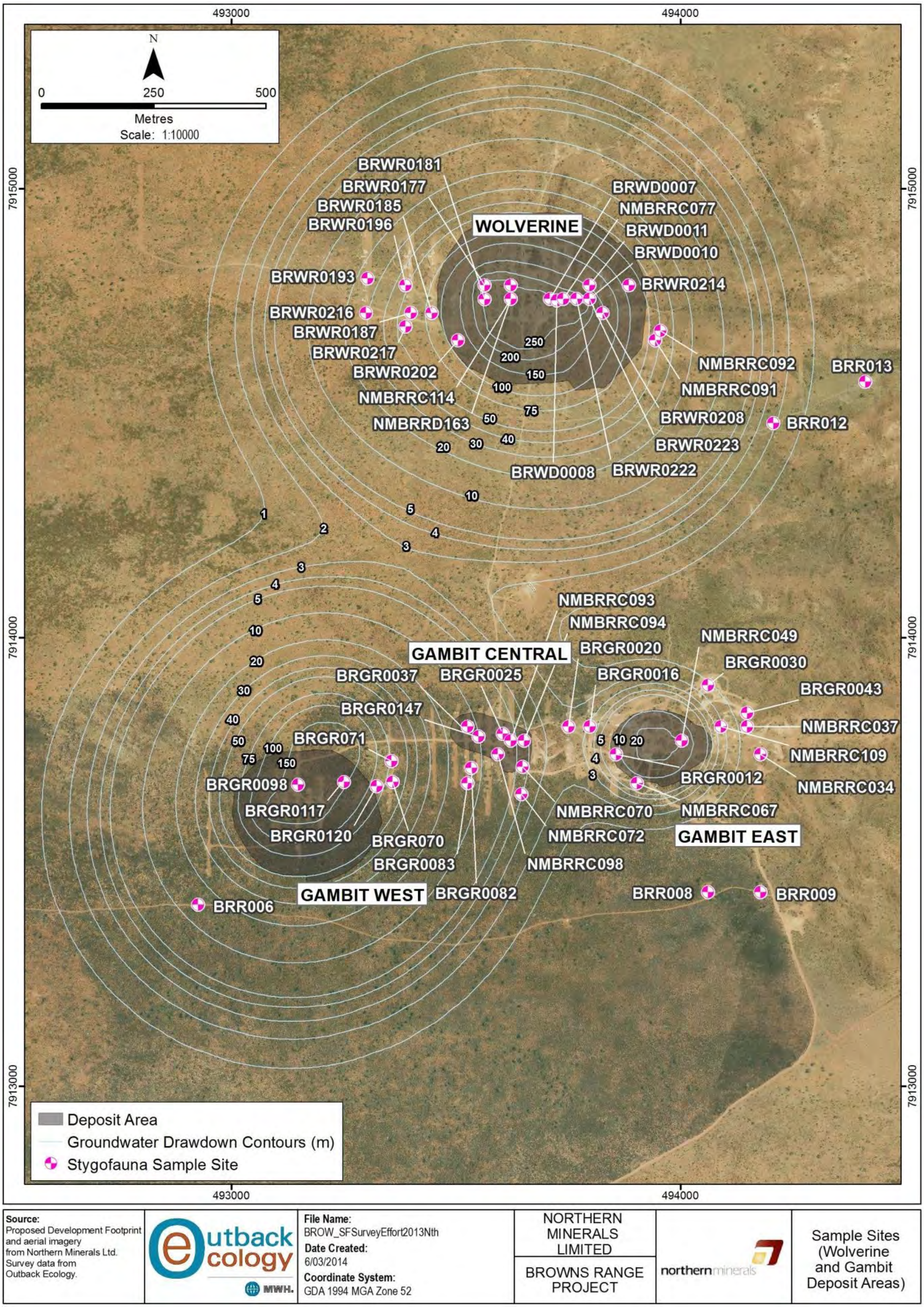


Figure 7: Gambits and Wolverine stygofauna survey bore locations and projected groundwater drawdowns (Klohn Crippen Berger 2014) .

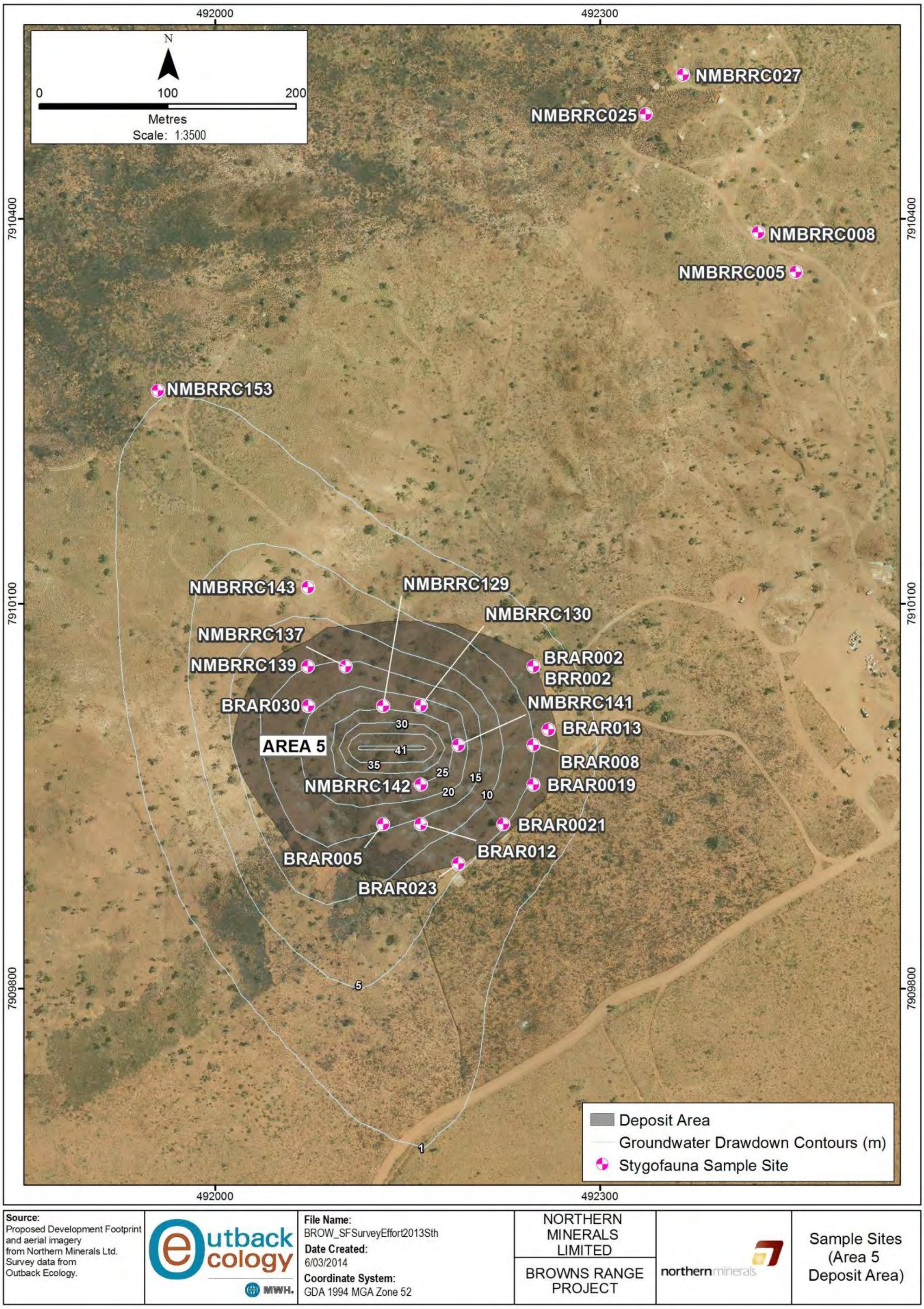


Figure 8: Area 5 stygofauna survey bore locations.

4.5. Troglofauna Assessment

4.5.1. Hypogean Habitat

To record baseline environmental data within the hypogean environment, DS1923 Hygrochron iButtons temperature and humidity loggers (data loggers) were installed in 18 bores in the Browns Range area, with at least one per deposit area, for the second troglofauna trap deployment in October to December 2012. The data loggers were configured to log temperature (±0.0625°C) and humidity (±0.04%) at two-hourly intervals for the duration of troglofauna trap deployment, and were enclosed in protective plastic housing and attached to the troglofauna trap cord, approximately 30 cm above the trap. Upon trap retrieval, the temperature and humidity data were downloaded from the data loggers using the Thermodata Viewer 3.1.14 software package (Thermodata Corporation 2011), and then exported and analysed in Microsoft® Excel®.

The loggers can record definite diurnal fluctuations of exposed environments such as unsealed or opened drill holes. Those datasets consisting of stable humidity and temperature readings were considered to represent the ambient conditions in drill holes that were appropriately sealed. Data that was consistent with unsealed drill holes were removed from the dataset to ensure that temperature and humidity data was a reliable indication of subsurface conditions

4.5.2. Litter Traps

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

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

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

4.5.3. Net Haul Scraping

Net haul scraping has been found to be an efficient method for sampling troglofauna that complements troglofauna trapping (Outback Ecology 2011a, Subterranean Ecology 2008b). Net haul scraping involved:

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

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

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

4.5.4. Survey Effort

A total of 59 troglofauna litter traps were collected from 50 uncased exploration bore holes over three sample periods, each 6 to 8 weeks in length., 14 March to 10 May 2012, 7 August to 25 September 2012 and 21 October to 9 December 2012 (**Table 3**, **Table 4**, **Figure 9**, **Figure 10**, **Figure 11**, **Appendix C**). Seventy litter traps were originally deployed but 11 were lost. In addition to the litter trap samples, 150 troglofauna scrape samples were collected from uncased bore holes.

The recommended number of samples for a Level 2 stygofauna baseline assessment by the Western Australia Environmental Protection Authority (EPA) Guidance Statement 54A (Environmental Protection Authority 2007a) is 60 litter samples for areas considered to host *significant* troglofauna values. The Project study area was found not to host significant troglofauna values so the survey effort undertaken exceeds the recommended number of samples for a Level 2 stygofauna baseline assessment The survey intensity is therefore considered to be sufficient to achieve a high level of knowledge of the troglofauna assemblage present in the Project area and provide a high level of confidence in assessing the potential impacts posed by the proposed Project in accordance with EPA EAG 12 (2013)..

Table 3: Troglofauna survey effort per sample period.

Sample Period	Litter Traps	Net Haul Scrape
March to May, 2012	16	2
August to September, 2012	8	
October to December, 2012	35	36
April, 2013		64
August, 2013		44
December, 2013		4
Number of Samples	**59**	**150**
Number of Bores	**50**	**110**

Table 4: Troglofauna survey effort per Project area and proposed impact.

Project Area	Impact					Non-Impact		
	Pit		Groundwater Drawdown		Total Impact			
	Trap	Scrape	Trap	Scrape		Trap	Scrape	Total Non-Impact
Area 5	5	19	1	4	**29**	4	5	**9**
Central Regional							15	**15**
Gambit Central	9	9	1	4	**23**	0		
Gambit East	4	5	3	5	**17**	2	7	**9**
Gambit West		3		3	**6**			
North-Western Regional							12	**12**
Southern Regional						14	20	**34**
Wolverine	13	21	2	11	**47**	1	7	**8**
Total	**31**	**57**	**7**	**27**	**122**	**21**	**66**	**87**

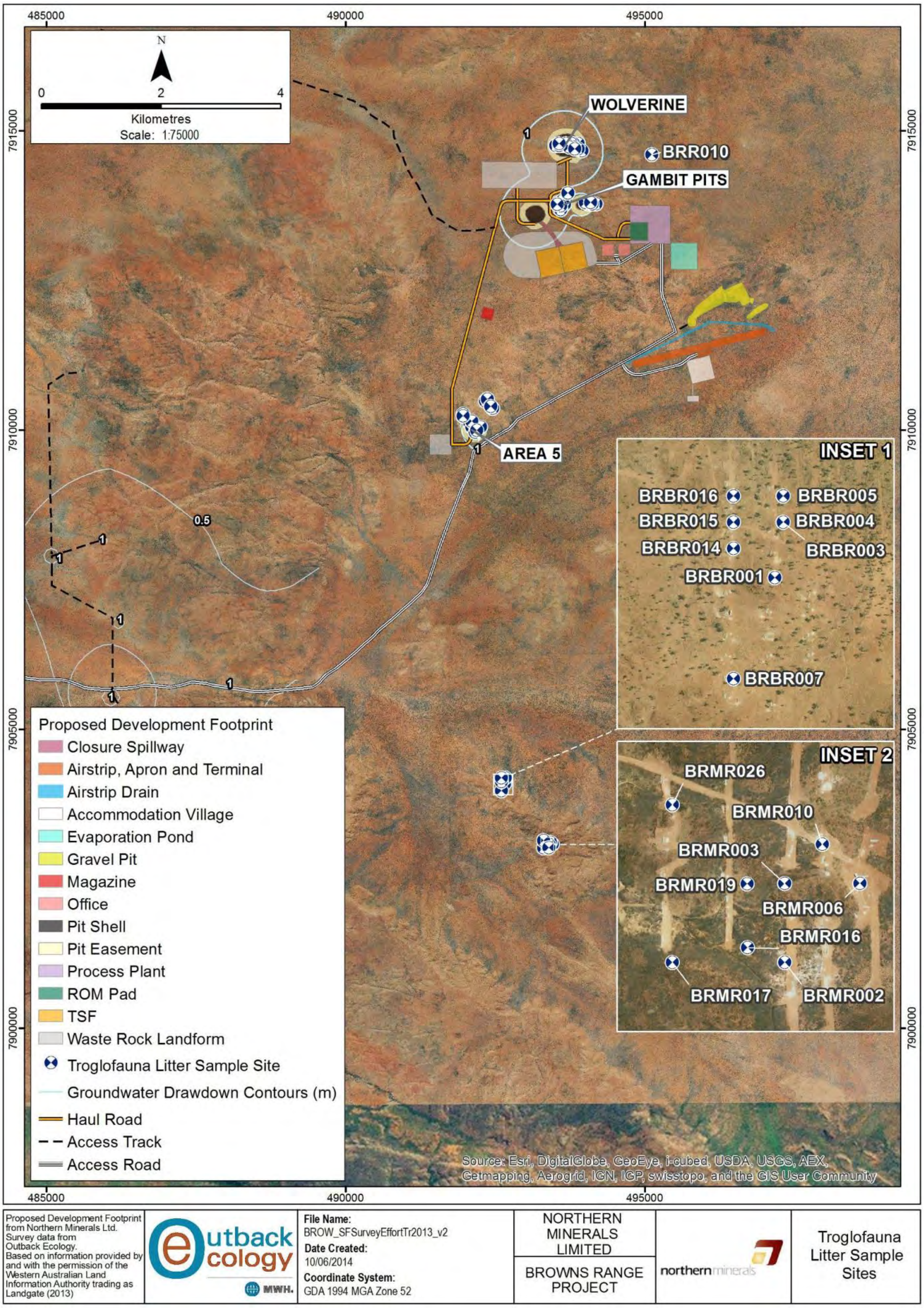


Figure 9: Troglofauna litter trap survey bore locations in relation to proposed Project footprint. Refer Figure 10 and 11 for further detail on Gambits and Wolverine, and Area 5 deposit areas, respectively.

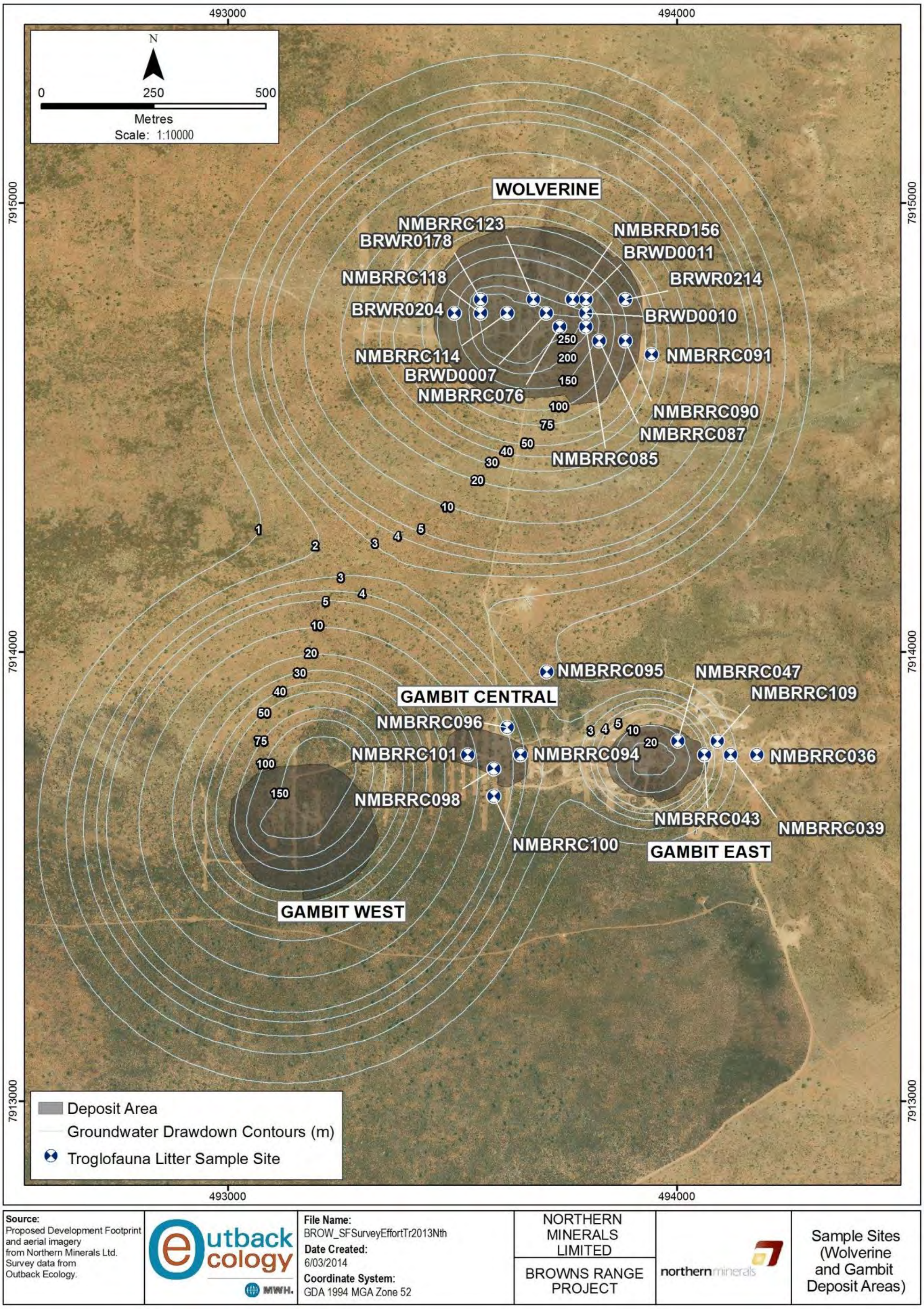
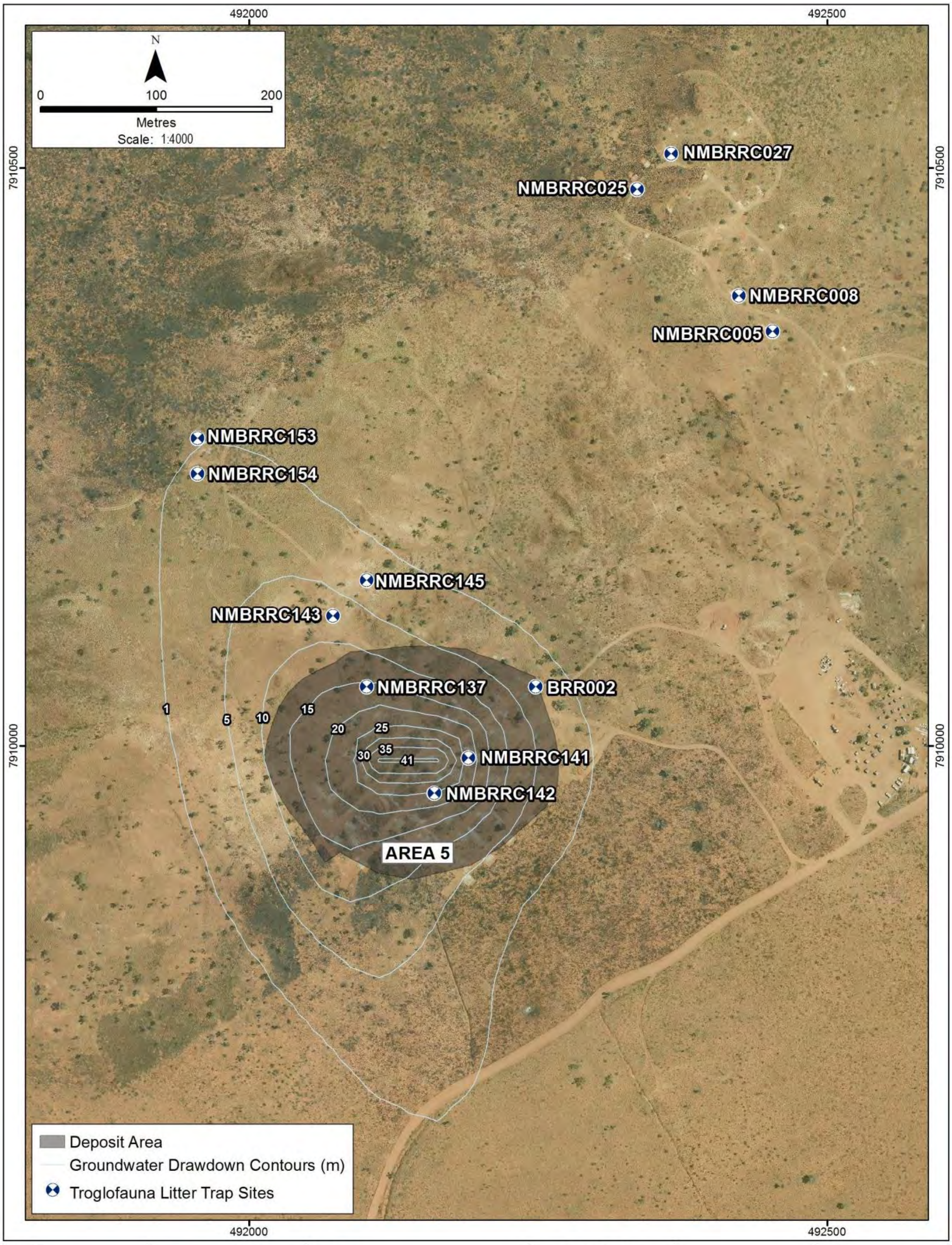


Figure 10: Gambits and Wolverine troglofauna litter trap survey bore locations.



Source: Proposed Development Footprint and aerial imagery from Northern Minerals Ltd. Survey data from Outback Ecology.	outback ecology MWH.	File Name: BROW_SFSurveyEffortTr2013Sth Date Created: 6/03/2014 Coordinate System: GDA 1994 MGA Zone 52	NORTHERN MINERALS LIMITED BROWNS RANGE PROJECT	northern minerals	Sample Sites (Area 5 Deposit Area)

Figure 11: Area 5 troglofauna litter trap survey bore locations.

4.6. Sorting and Identification of Specimens

Preserved samples were sorted manually under Leica MZ6, MZ7.5 and M80 stereomicroscopes. Sub-samples were taken of taxa which were present in high numbers. Sorting was conducted by Syngeon Rodman and Lina Ramlee of Outback Ecology. Once sorted, specimens were preserved in 100% ethanol and kept at approximately 18 to 20°C to ensure viability for future DNA analysis (if required).

Identification was carried out to species or morphospecies level for the majority of taxa, using both published literature and unpublished keys and taxon descriptions. Identifications were undertaken by Dr Erin Thomas and Nicholas Stevens of Outback Ecology. All species determinations have been confirmed with genetic analysis except for copepod material which was examined by specialist taxonomist, Dr Karanovic. Undescribed taxa were assigned morphospecies names. Outback Ecology morphospecies names have also been assigned retrospectively to undescribed taxa that were provisionally named or numbered following DNA analyses or by specialist taxonomists.

Table 5: Specialists involved in the identification of stygofauna from Project area.

Taxa	Specialist Taxonimist/s	Affiliated Institution or Company
Bathynellacea	Dr Rachael King (morphology), Dr Remko Leijs (Genetic analysis)	South Australian Museum (SAM), Adelaide, South Australia
Copepoda	Dr Tomislav Karanovic (morpholy)	Department of Life Science, Hangyang, Korea
Oligocheata	Dr Erin Thomas (morphology), Dr Remko Leijs (Genetic analysis)	Outback Ecology-MWH SAM

4.7. DNA Sequencing

Representative specimens of Bathynellacea and Oligochaeta from the Browns Range were sent to Dr Remko Leijs (South Australian Museum) for genetic analysis. The aims of the analysis were to:

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

4.8. Limitation of the Assessment

All 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
- limitations in taxonomy, in that the current state of taxonomy for a particular group is insufficiently advanced, meaning 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 information may be limited if specialist information was unavailable.

5. RESULTS AND DISCUSSION

5.1. Literature Review

Although the Kimberley region is poorly surveyed for subterranean fauna, there have been some records of stygofauna being found in areas of alluvium, karstic limestone, dolomite and sandstone systems in addition to offshore islands. These communities are not as rich as the Pilbara although comparable sampling effort is lacking. It is also considered likely that troglofauna assemblages are present (EPA 2007). In arid to semi-arid regions, subterranean fauna have generally been found to be more diverse in habitats found within paleodrainages, particularly in groundwater calcretes (Environmental Protection Authority 2003).

The closest recorded subterranean fauna in relation to the Project area were approximately 250 km to the NNW, just south of Lake Argyle. Both the Copepoda, *Metacyclops kimberleyi* and the Parabathynellidae, "*Kimberleybathynella*" were recorded. There are currently seven known species of *Metacyclops* found in Australia with only one species known within the Kimberley region (Karanovic 2004). One of the eight parabathynellids described in Australia, *Kimberleybathynella*, has been recently discovered and is endemic to the Kimberley region (Abrams *et al.* 2012).

5.2. Database Searches

There were no troglofauna or stygofauna records found for the Project area from the WAM Crustacean and Arachnid database or DPAW's NatureMap database. A search of the same area in DPaW's TEC and PEC database did not return any listings of any communities associated with subterranean fauna .

5.3. Stygofauna Habitats

5.3.1. Aquifers

The main habitat for stygofauna in the Project study area is associated with the Browns Range Metamorphics and the Gardiner Sandstone fractured rock aquifer systems. The identified rare earth deposit areas hosted within hydrothermal quartz veins and quartz vein breccias are associated with the Browns Range Metamorphics aquifer system. The lateral and vertical extent of the Browns Range Metamorphics is considerably greater than the deposit areas (**Figure 12**, **Figure 13**, **Figure 14**). The proposed borefield is associated with the Gardiner Sandstone aquifer system. The Gardiner Sandstone unconformably overlies the Browns Range Metamorphics and extends more than 35 km to the west of the Project area beyond Sturt Creek (Klohn Crippen Berger 2014). This recognised regional geological unit is estimated to be over 300 m thick (Klohn Crippen Berger 2014). In both fractured rock systems, the groundwater is considered to mostly exist within and move along discrete geological structures such as faults, shears, fractures, joints and foliation (Klohn Crippen Berger 2014).

Groundwater level tests indicated that both aquifer systems are characterised by semi-confined to confined groundwater flow conditions (Klohn Crippen Berger 2014). The groundwater flow across the Project study area is inferred to run from east to west (**Figure 12**). However, the geological and structural controls present mean that groundwater flow and hydraulic connectivity are likely to be more complex and may likely result in barriers and discrete conduits to groundwater flow (Klohn Crippen Berger 2014). These complexities are likely in turn to be reflected in the distributions of stygofauna species, making it difficult to record and interpret their likely range of extent within the Project area.

Within the Browns Range Metamorphics aquifer, intersection of the groundwater table ranged from around 40 to 50 mbgl. Generally the inflow of groundwater following intersection was minimal, representing seepage (Klohn Crippen Berger 2014). However, two intersections occurred at 140 and 160 mbgl that gave higher groundwater yields of 4 and 5 L/s respectively, and were attributed to discrete groundwater-bearing geological structures (Klohn Crippen Berger 2014). Aquifer tests not associated with the geological structures showed relatively low lateral hydraulic conductivities for Area 5, Wolverine and Gambit deposits but indicated that variations are likely to occur as a result of discrete geological structures being present.

Drill logs and drill core images from Area 5 and Wolverine showed limited voids within mainly massive rock with secondary porosity associated with limited jointing or open shear zones with signs of bearing water evident (**Figure 15**). A number of water bearing geological structures were noted within some deposit areas. Within Area 5, a discrete, steeply-dipping, groundwater-bearing structure, considered to be a shear zone, was identified running across the deposit in a north-west to south-east direction (Klohn Crippen Berger 2014). This shear zone was inferred to extend beyond the deposit area to the north-west and to the south-east but how far is not known (Klohn Crippen Berger 2014). Aerial magnetics and Versatile Time Domain Electro-Magnetics used to interpret geology and structural distributions indicate that shear zone could extend for some kilometres beyond the Area 5 deposit (Northern Minerals 2013). At Gambit East north-south shear or fracture zone with some water was noted to occur through the mineralised zone (Northern Minerals pers comm.). The extent to the north and south is unknown, however, many drill holes either side of the zone are dry. Within Wolverine a sheared or fractured zone similar to Gambit East trends north-east to south-west over a length of at least 150 m (Northern Minerals pers comm.). In addition, two parallel north to south trending wet intersections were also found to occur.

The limited hydraulic testing of the Gardiner Sandstone aquifer within the proposed borefield area indicated water yields and hydraulic conductivity were greater than for the Browns Range Metamorphics aquifer (Klohn Crippen Berger 2014). Groundwater level responses recorded from barometer loggers following the rainfall event (480 mm) in January 2014 indicated that the Gardiner Sandstone was a more extensive aquifer system compared to the Browns Range Metamorphics aquifer with the rise in groundwater level been more gradual (Klohn Crippen Berger 2014). The data recorded also indicated that natural variations in groundwater levels ranged from 1.67 m to 1.72 m in both aquifer systems (Klohn Crippen Berger 2014).

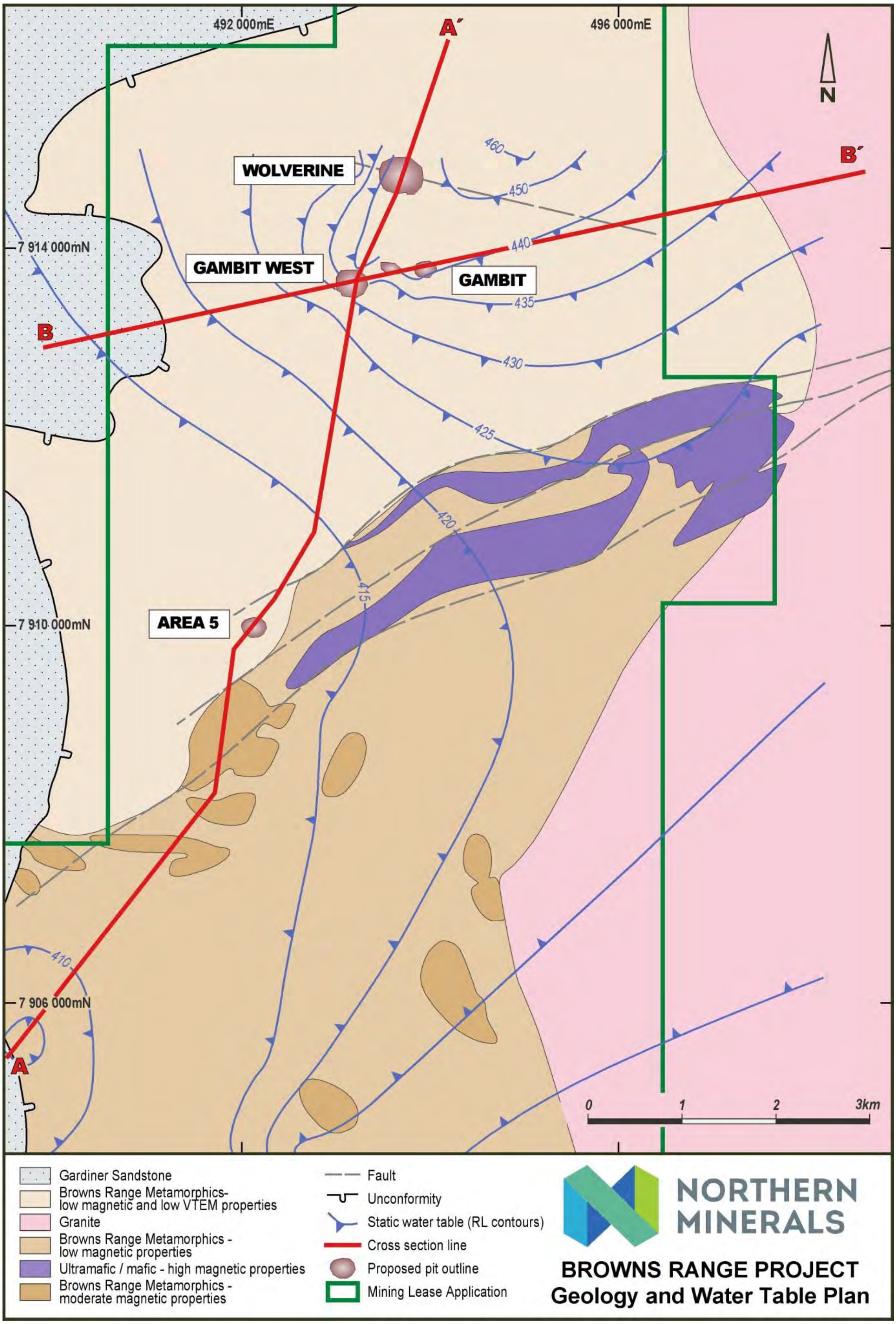


Figure 12: Subsurface geology showing lateral extent of the Browns Range Metamorphics in relation to proposed pit shells and identified faults (Source Northern Minerals).

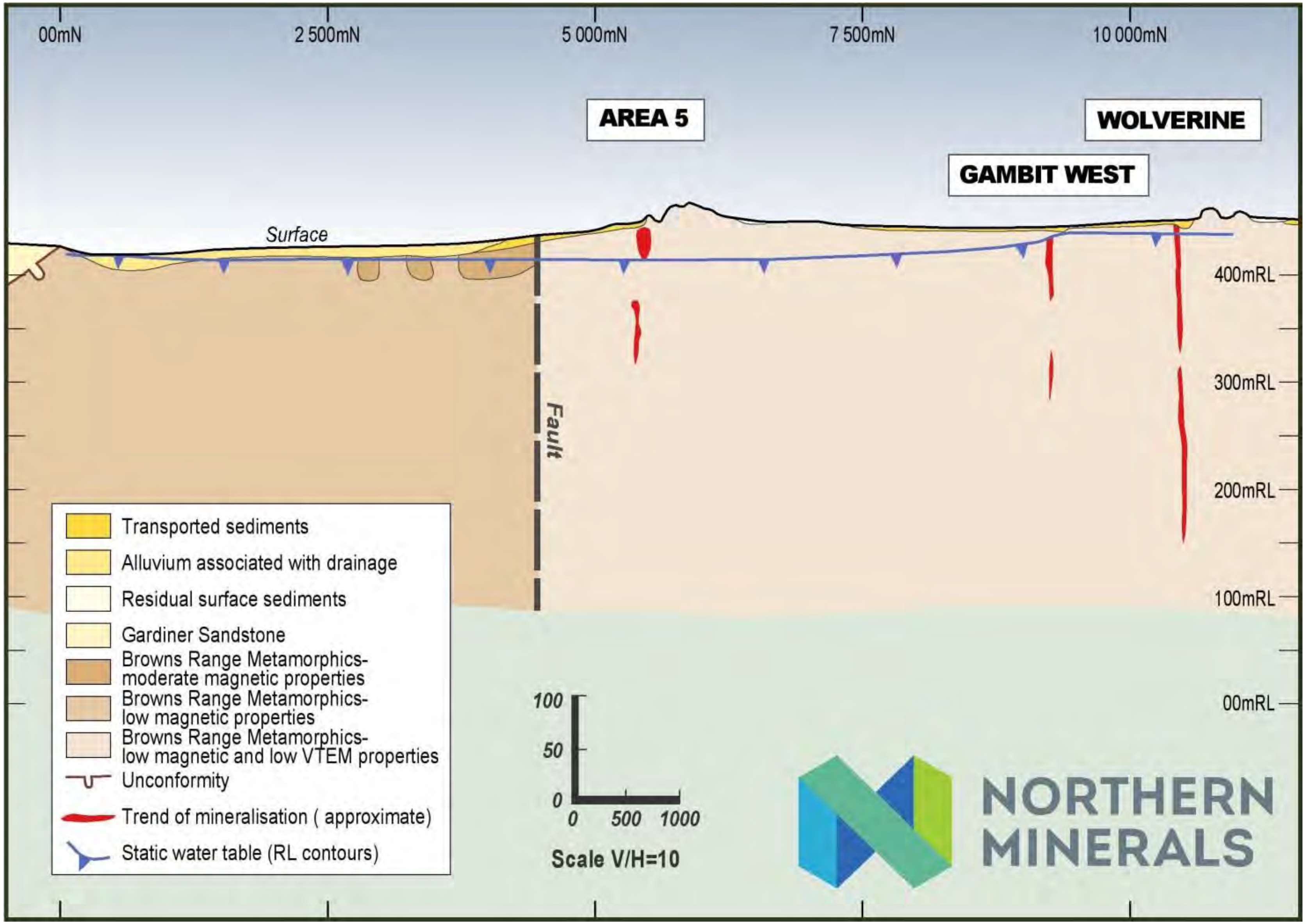


Figure 13: Vertical and lateral extent of the Browns Range Metamorphics in relation to deposits and identified faults along line A — A' indicated in Figure 12 (Source Northern Minerals).

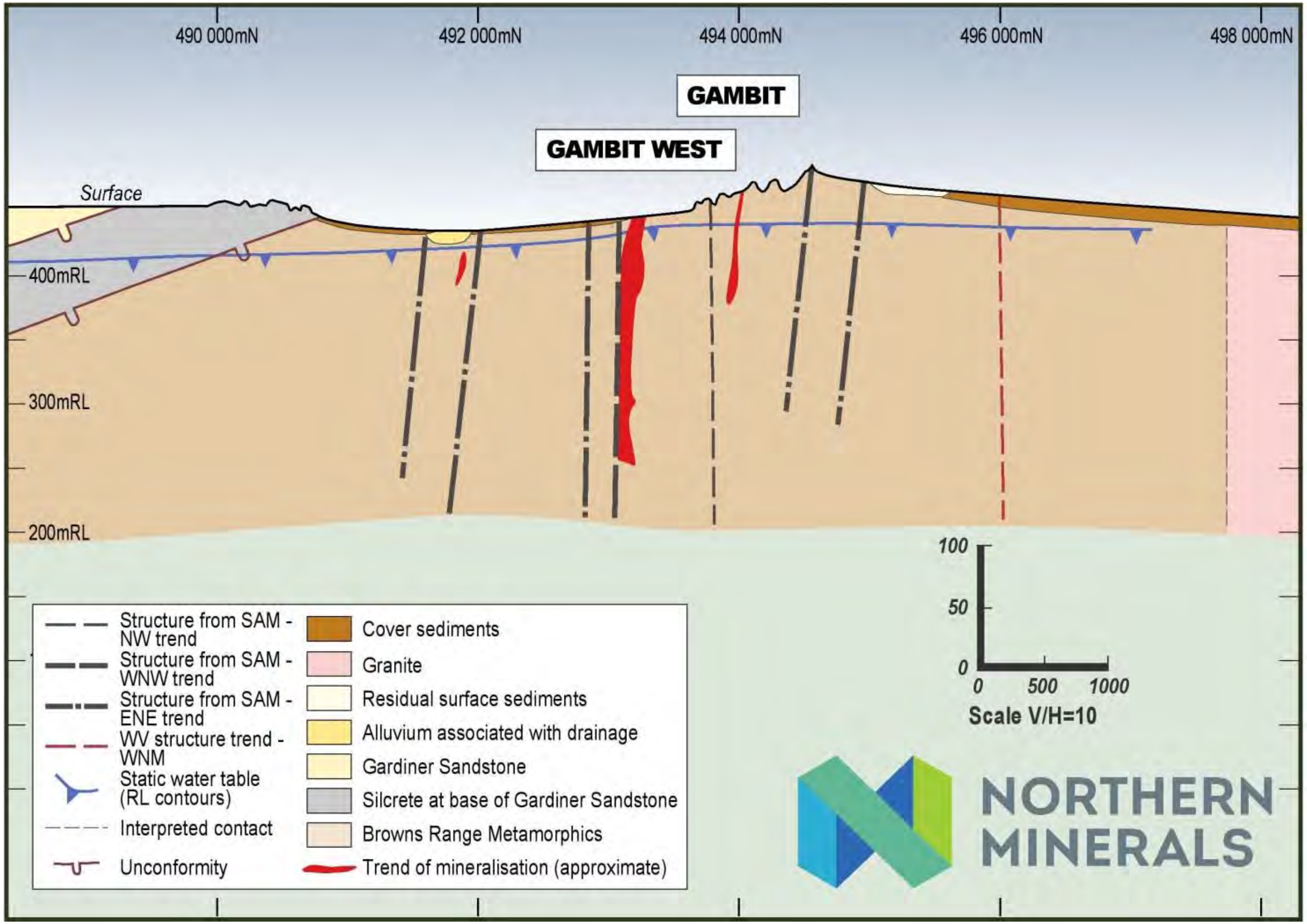


Figure 14: Vertical and lateral extent of the Browns Range Metamorphics in relation to deposits and identified geological structures along line B — B' in Figure 12 (Source Northern Minerals).

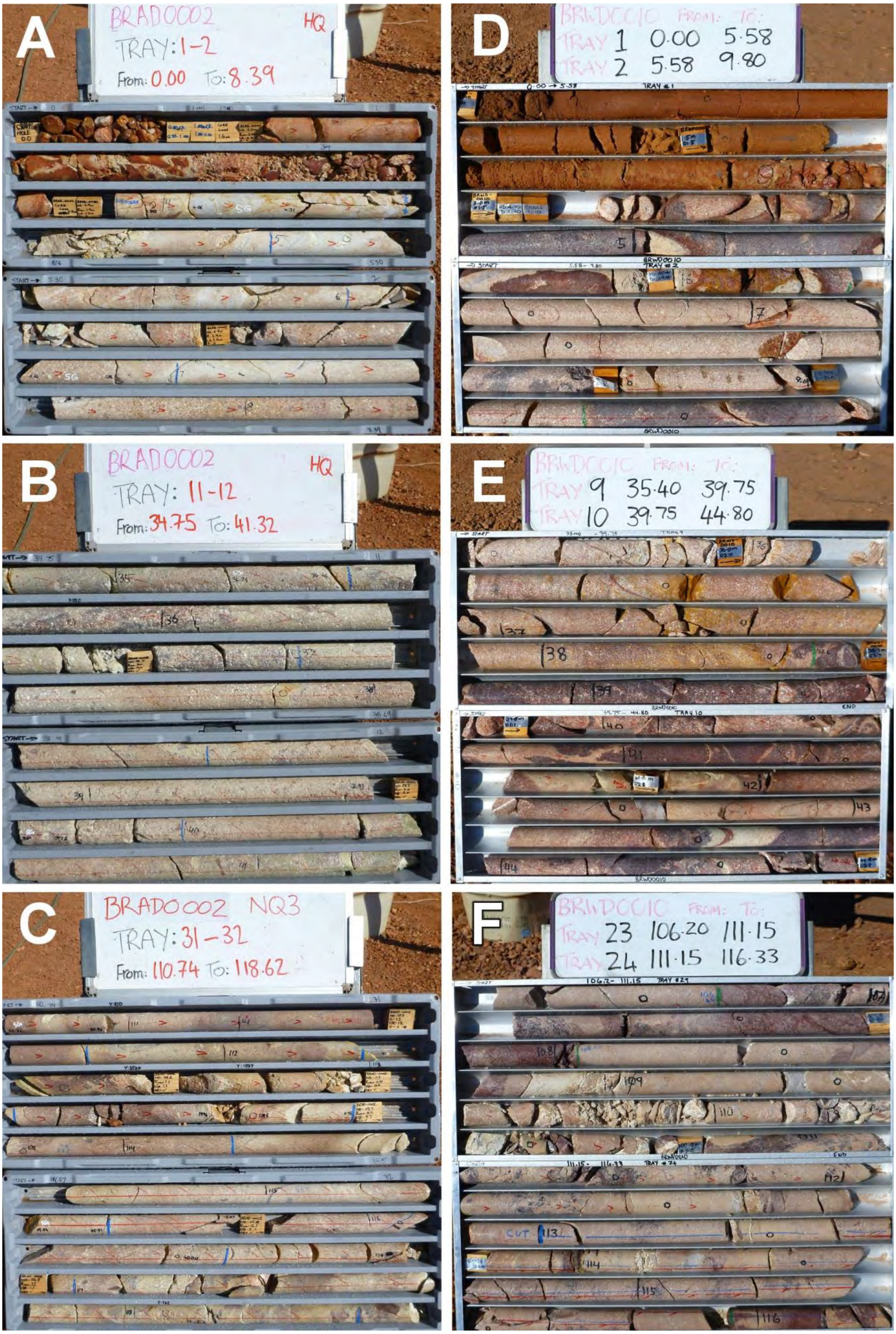


Figure 15: Diamond drill core images within Browns Range Metamorphics; Area 5 drill hole BRAD0002 (close to BRAR0019) — A) 0 to 8.39 mbgl ; B) 34.75 to 41.32 mbgl ; C) 110.74 to 118.62 mbgl; Wolverine drill hole BRWD0010 (close to BRWD0010) — D) 0 to 9.8 mbgl ; E) 35.40 to 44.8 mbgl ; F) 106.2 to 116.33 mbgl.

5.3.2. Groundwater Properties

Groundwater attributes can have an important influence on the occurrence and distribution of stygofauna. A number of basic physicochemical parameters (pH, salinity, dissolved oxygen (DO), redox, temperature, standing water levels (SWL)) were recorded during stygofauna sampling at Browns Range. The three more important parameters in regard to influencing stygofauna habitat are considered to be pH, DO and salinity.

pH

Groundwater pH ranged from 4.48 to 8.97 **(Appendix B),** indicating acidic (pH <6.5) to alkaline (pH > 7.5) conditions within the wider Browns Range Project area *sensu* (Foged 1978). For most areas, pH values commonly fell between pH 6.5 and 7.5 and were classified as circumneutral. An exception was the Potential Borefield. Groundwater in this area, associated with the Gardiner Sandstone, had a mean pH less than 6 (**Figure 16**). Bores within Gambit deposits and Wolverine also tended to have slightly lower groundwater pH (respective means of 6.3). The lower values in the Wolverine and Gambit deposit areas were also documented during sampling for the baseline groundwater characterisation program (Klohn Crippen Berger 2013).

Acidic groundwaters, which are generally associated with igneous and metamorphic sedimentary rocks, provide less suitable conditions for stygofauna (Humphreys 2008). However, stygal ostracods within the Pilbara region have been recorded from acidic groundwaters with pH as low as 4.4, although greater diversity was observed in association with higher pH values (Reeves *et al.* 2007). This suggests that although stygal diversity may decline with increasing acidity, the occurrence of some stygofauna taxa cannot be discounted. The pH values of groundwaters at Browns Range are considered to be within the range suitable for stygofauna.

Salinity

Electrical conductivity, recorded as a measure of groundwater salinity, ranged from 0.07 mS/cm to 39.21 mS/cm **(Appendix B)**, equating with fresh (<5 mS/cm) to mesosaline conditions (30 to 70 mS/cm) *sensu* Hammer (1986). Salinity, where documented, ranged from 0.03 to 17.62 g/L, consistent with the patterns noted for electrical conductivity. Overall, the majority of areas were found to host fresh groundwater conditions. Exceptions to the trend included the North-Western Regional and the Central Regional areas, both of which had comparatively higher mean electrical conductivities in relation to the other project areas (**Figure 17**). The former had a number of bores classified as hyposaline (5 to 30 mS/cm) while the Central Regional bores typically contained hyposaline to mesosaline groundwaters. The large range for the Central Regional area, almost 40 mS/cm (**Figure** 17), reflects a small number of bores with electrical conductivities of less than 1 mS/cm.

Stygofauna are known to occur in conditions ranging from fresh to hypersaline (≥70 mS/cm) *sensu* Hammer (1986). While values below approximately 80 mS/cm are typically associated with significant stygofauna communities (Environmental Protection Authority 2007b), studies have identified some stygofauna species in groundwaters exceeding 100 mS/cm (Outback Ecology 2011a, 2012). With all records falling below 40 mS/cm or 20 g/L, the electrical conductivity and salinity values documented from the various areas of Browns Range are well within the range conducive to stygofauna communities.

Dissolved Oxygen

The level of dissolved oxygen levels in the groundwaters was variable, spanning from 0.09 to 8.59 mg/L across the wider Browns Range Project area (**Appendix B**). With the exception of Wolverine (0.09 mg/L), the minima generally ranged between 0.3 and 1 mg/L, while maximum values tended to exceed 5 mg/L (**Figure 18**).

The mean dissolved oxygen concentrations were similar for most of the areas, typically ranging between 2 and 3 mg/L. In comparison, the Gambit West and the potential Borefield areas had lower ranges and mean concentrations (<1.5 mg/L) (**Figure 18**). However, there are a comparatively low number of records from these project areas.

Dissolved oxygen concentrations are often patchy in the subterranean environment, commonly ranging from suboxic (<0.3 mg/L) to oxic (>3 mg/L) over time, in addition to small and large spatial scales. Given the variability of these environments, stygofauna tend to be more resistant to low levels of oxygen than are surface water species (Malard and Hervant 1999, Strayer 1994). In Australia for example, stygofauna are frequently recorded in association with dissolved oxygen levels of less than 1 mg/L (Humphreys 2008, Watts and Humphreys 2006).

SWL

The approximate standing water levels ranged from less than 2 mbgl at a bore within Wolverine to approximately 41 mbgl at Monitoring Bore 1, Area 5. Consistent with Monitoring Bore 1, standing water levels within Area 5 bores were generally deeper relative to the other prospect areas, with 28 of the 31 records from this area exceeding 30 mbgl. Only one record from the remaining areas (from Wolverine) was deeper than 30 mbgl and a number of bores were found to have standing water levels of less than 20 mbgl (**Appendix B**).

Groundwater Assessment

The groundwater properties as represented by the basic suite of physicochemical parameters measured indicates suitable conditions for stygofauna throughout the Project study area. It is considered unlikely that stygofauna would be precluded from the groundwaters of any the Project areas surveyed on the basis of these parameters.

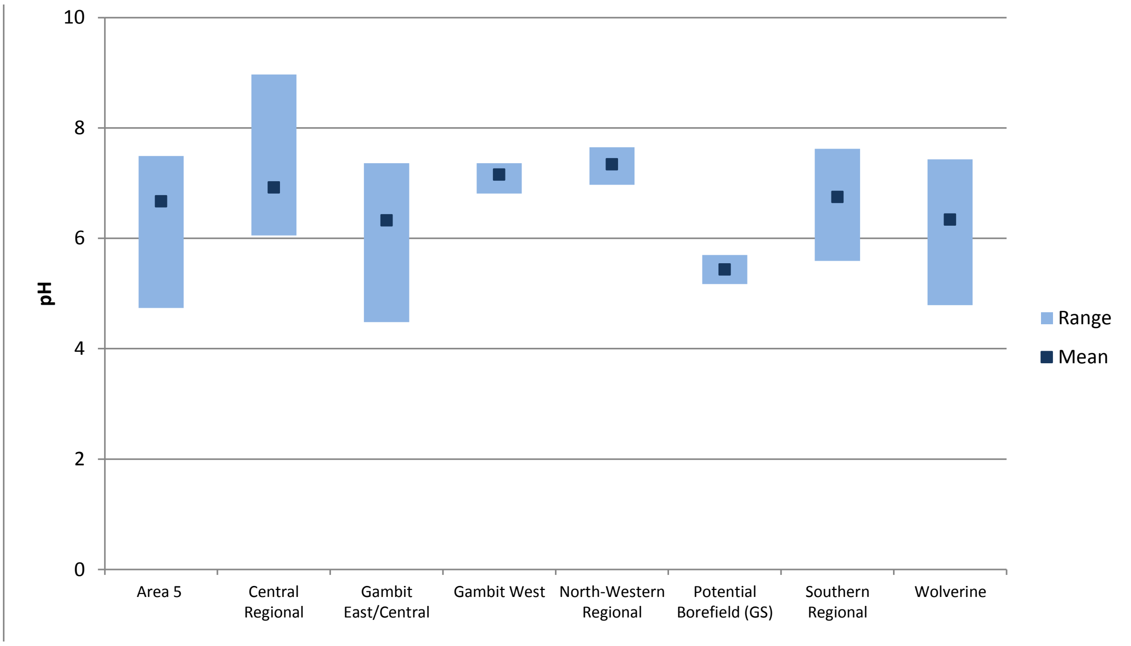


Figure 16: Minimum, maximum and mean pH recorded from Project areas.

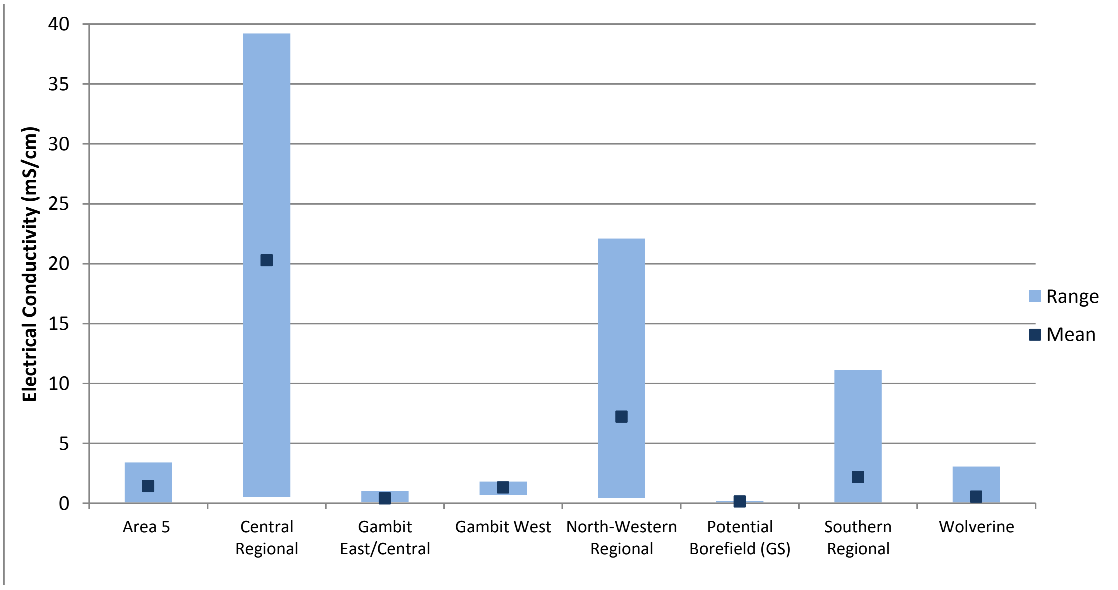


Figure 17: Minimum, maximum and mean electrical conductivity recorded from Project areas.

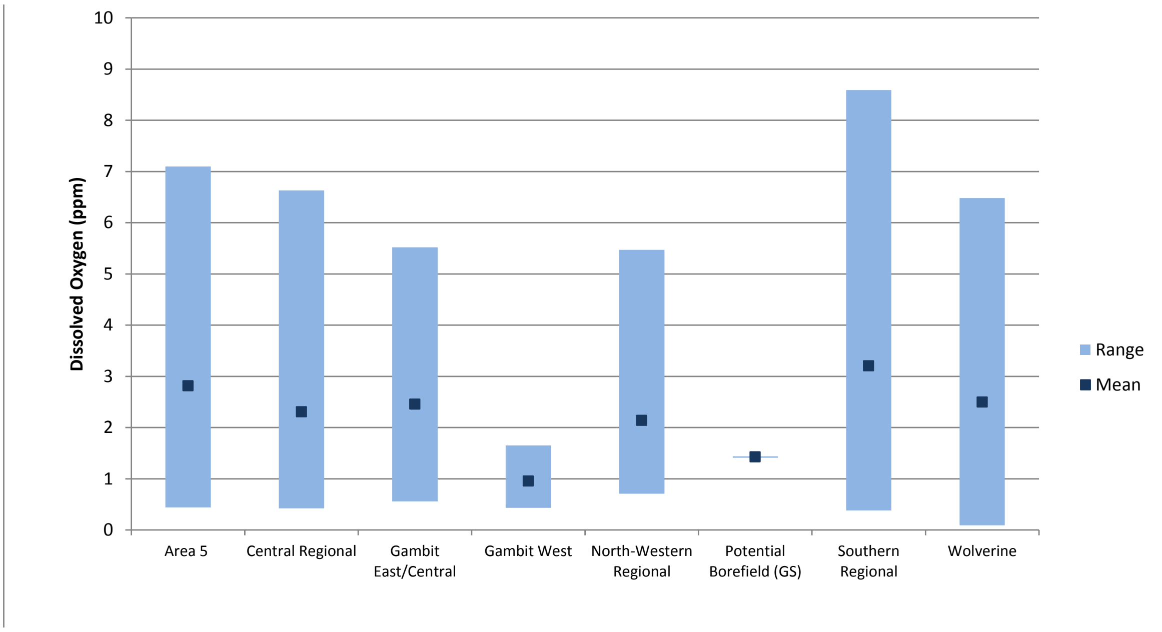


Figure 18: Minimum, maximum and mean dissolved oxygen recorded from the Project areas.

5.4. Troglofauna Habitats

5.4.1. Geology

The geological units that would be most likely to provide the cavities and voids required for troglofauna habitation would be the unsaturated weathered and fractured rock systems associated with the Browns Range Metamorphics and Gardiner Sandstone units (**Figure 12**, **Figure 13**, **Figure** 14). Non-prospective areas for troglofauna would be where the weathered and fractured rock profiles are overlain by relatively deep sand or clay strata with little or no interstitial pore space. Diamond drill core samples from Area 5 drill hole BRAD0002 includes fractured rock overlain by coarse detrital/weathered regolith to approximately two metres down hole with weathered fracture rock to approximately five metres down hole (**Figure** 15). Below five metres, there is secondary porosity associated with minor fracturing. Diamond drill core from Wolverine drill hole BRWD0010 includes fractured rock overlain by finer detrital/colluvial regolith to approximately four metres down hole with weathered fracture rock to approximately 6.5 m down hole (**Figure 15**). Below 6.5 m, secondary porosity associated with minor fracturing.

5.4.2. Subterranean Humidity and Temperature

A total of 20,493 data points were logged for temperature (10,533) and humidity (9,960) in the hypogean environment on the second deployment of troglofauna litter traps (Oct to Dec 2012). Of the 22 data loggers (loggers) deployed, 19 were retrieved with reliable temperature data sets and 18 for humidity. Results from 3 loggers were disregarded as they clearly resembled environments exposed to the elements, analogous to those in surface habitats or unsealed bores. One of the loggers may have been damaged as it did not record sufficient humidity data. By removing these deficient data sets we were able to confidently characterise the baseline humidity and temperature conditions experienced in the hypogean environment of the Project and identify differences, if any, between prospects.

The loggers are sensitive enough to record any break of a seal. This was evident in bore NMBRCC141 where it recorded the bore being opened between 9.30 am and 11.30 am the 15/11/2012, temperatures rose to 49.6 C and humidity dropped to 14 % (**Figure 19**). Afterwards, the bore temperature and humidity settled back to the previous levels recorded. For the purpose of these results that data point was removed.

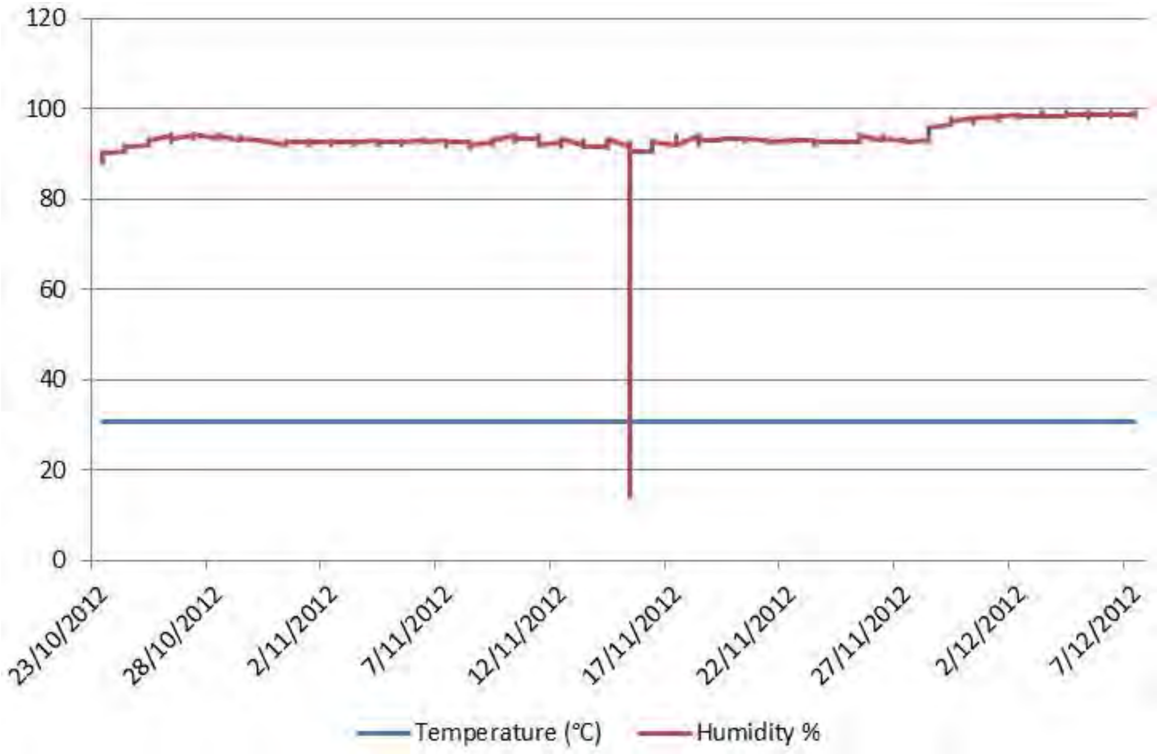


Figure 19: Humidity and temperature readings from inside sealed drill hole, NMBRRC141, Area 5 Browns Range Project.

Results from across the Project indicated favourable conditions for troglofauna. There were a few bores for which temperature and humidity fluctuated considerably, however, most of the bores were characterised by generally high humidity levels (>85 %) and stable temperatures (~30 C). More often than not the temperature is inversely proportional to the humidity. While no troglofauna were collected in the traps deployed this information does provide baseline data on the conditions within bores before mining operations begin. This information could enable these parameters to be measured throughout the mining process if required, to monitor impacts to the subterranean environment.

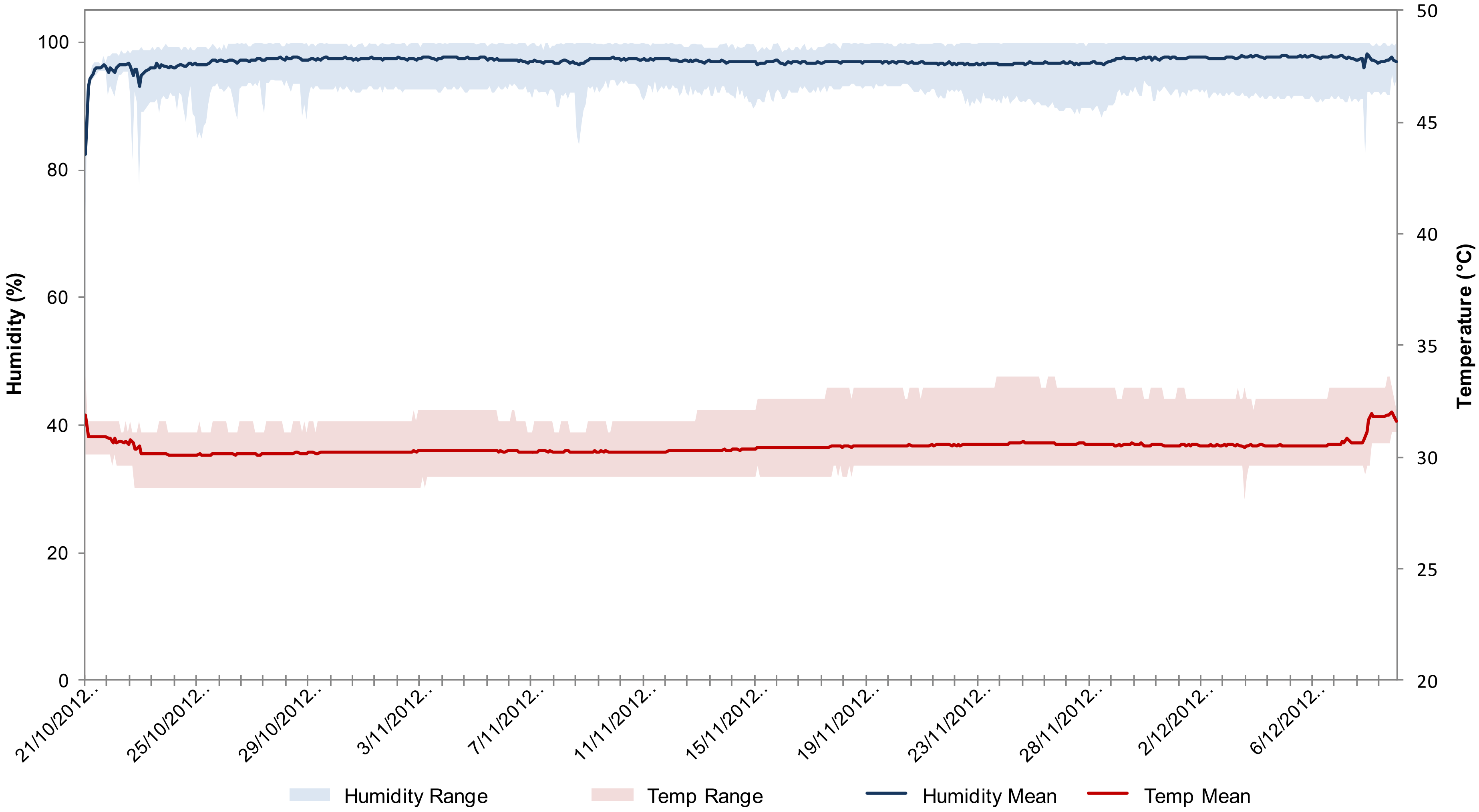


Figure 20: Average (mean) and range of humidity and temperature recorded in the hypogean habitat within the Browns Range Project area.

5.5. Stygofauna Survey

5.5.1. Stygofauna Findings

In total, 1,353 stygofauna specimens, representing 21 species from three higher level taxonomic groups, Bathynellacea, Copepoda and Oligochaeta, were recorded from all Project areas surveyed (**Table 6, Appendix D, Appendix E**). Stygofauna were collected from 33 of the 115 bores sampled and 47 of the 160 net haul samples taken.

The Bathynellacea order was the most diverse group represented with 15 species recorded (**Figure** 23, **Figure 24**). Five of these species are from the family Bathynellidae, and the remaining ten species belong to a new, undescribed genus in the family Parabathynellidae closely related to described genera *Atopobathynella* and *Kimberleybathynella* (Leijs 2013b, c, d, 2014, Leijs and King 2013b) (**Appendix F,** Refer **Appendix G** for alignment among morphospecies names used). The Copepoda were the next most diverse group with five species recorded (**Figure 25**) (Karanovic 2013a, b, 2014) (**Appendix H**). The Oligochaeta was represented by one widely distributed species, Enchytraeidae-OES17 (Leijs 2013b, Leijs and King 2013b) (**Figure 26**).

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

- Wolverine — hosted the greatest diversity with six species recorded (**Table 7**). Three species, Bathynellidae-OES19, Parabathynellidae-OES18, and *Metacyclops*-OES20, were only recorded within proposed pit boundaries and/or modelled groundwater drawdown contours. The remaining three species, Enchytraeidae-OES17, Parabathynellidae-OES17, Parabathynellidae-OES20, were found to have distributions that extended to other Project areas, including Area 5, Gambit Central, Gambit East and the southern regional area.

- Area 5 — was the second most diverse deposit area with five species recorded. Three species, Bathynellidae-OES24, Parabathynellidae-OES26, and Parabathynellidae-OES27, were only recorded within proposed pit boundaries. Parabathynellidae-OES16 was found within the Area 5 deposit area but outside the proposed pit shell and associated modelled groundwater drawdown contours. Only one species, Enchytraeidae-OES17, was found to also occur in other Project areas including non-impact regional areas.

- Gambit Central — recorded three species. One species, Bathynellidae-OES25, was recorded with the proposed pit boundary only. Two species, Bathynellidae-OES26 and Parabathynellidae-OES20 were demonstrated to occur in other Project areas, including North-Western Regional and Wolverine.

- Gambit East — recorded three species all of which were demonstrated to occur outside the proposed impact zone. Two of these species, Parabathynellidae-OES22 and Enchytraeidae-OES17, were also recorded from other Project areas, including the proposed borefield in the Gardiner Sandstone, Area 5, Wolverine and Southern and Western regional areas. Parabathynellidae-OES21 was recorded outside the proposed pit boundary and associated groundwater drawdown as well as from inside the pit boundary.

- Gambit West — No stygofauna species were recorded.
- Borefield — recorded four species. Two species, *Dussartcyclops*-OES2 and *Parastenocaris*-OES1 were recorded within the 1 m modelled groundwater drawdown contour only. Two species, Bathynellidae-OES27 and Parabathynellidae-OES22, were shared with other Project areas, including Gambit East and Wolverine.

Table 6: Stygofauna species diversity and distribution in relation to Project areas. Shaded rows indicate taxa of conservation concern: dark orange — found within proposed pit shell only; lighter orange — found within groundwater drawdown > 0.5 m only.

Taxon	Abundance	Project Area	Impact		Non-impact	Status
			Pit	Drawdown		
Bathynellacea						
Bathynellidae						
Bathynellidae-OES19	101	Wolverine	●	●		Of conservation concern
Bathynellidae-OES24	3	Area 5	●			Of conservation concern
Bathynellidae-OES25	13	Gambit Central	●			Of conservation concern
Bathynellidae-OES26	7	Gambit Central and North-Western Regional		●	●	Not of conservation concern
Bathynellidae-OES27	12	Central Regional and Proposed Borefield (GS)		●	●	Not of conservation concern
Parabathynellidae						
Parabathynellidae-OES16	35	Area 5			●	Not of conservation concern
Parabathynellidae-OES17	156	Southern Regional, Wolverine	●		●	Not of conservation concern. Widespread
Parabathynellidae-OES18	26	Wolverine	●			Of conservation concern
Parabathynellidae-OES20	15	Gambit Central, Wolverine	●		●	Not of conservation concern
Parabathynellidae-OES21	4	Gambit East	●		●	Not of conservation concern
Parabathynellidae-OES22	51	Gambit East and Proposed Borefield (GS)		●	●	Not of conservation concern
Parabathynellidae-OES23	703	Southern Regional			●	Not of conservation concern
Parabathynellidae-OES26	7	Area 5	●			Of conservation concern
Parabathynellidae-OES27	3	Area 5	●			Of conservation concern
Parabathynellidae-OES28	98	Southern Regional			●	Not of conservation concern
Copepoda						
Cyclopoida						
Metacyclops -OES20	23	Wolverine	●			Of conservation concern
Microcyclops varicans	3	Southern Regional			●	Not of conservation concern. Cosmopolitan, eurytopic surface-water stygophile, recorded from Pilbara (Karanovic 2004, 2006).
Dussartcyclops -OES2	1	Proposed Borefield (GS)		●		Of conservation concern
Harpacticoida						
Megastygonitocrella trispinosa	2	Western Regional			●	Not of conservation concern. Widespread species, first recorded from Pilbara region
Parastenocaris -OES1	22	Proposed Borefield (GS)		●		Of conservation concern
Oligochaeta						
Enchytraeidae-OES17	104	Area 5, Gambit East, Southern and Western Regional, Wolverine	●	●	●	Not of conservation concern. Widespread

Table 7: Number of stygofauna species recorded from each Project area with number of species shared amongst or unique to each area indicated. Proportion of species unique to an area indicated in parentheses. Gambit West not included because no species were recorded.

Project area	Total Abundance	Area 5	Gambit Central	Gambit East	Wolverine	Borefield	Regional
Area 5	5	4 (80%)					
Gambit Central	3		1 (33%)				
Gambit East	3	1		1 (33%)			
Wolverine	6	1	1	1	3 (50%)		
Borefield	4			1		2 (50%)	
Regional	8	1	1		1	1	4 (50%)

Note: Total number of species presented for an area in table will not necessarily be the same as sum of individual cells, because widespread species that occur in multiple areas will be accounted for multiple times.

Bathynellacea

All species of Bathynellacea globally are considered to be stygobitic. The domination of the stygofauna assemblage at the Project area by bathynellacean diversity is similar to studies undertaken in north-eastern Australia that have also found bathynellaceans to be most commonly collected component of some aquifers (Hancock and Boulton 2008). Of the fifteen bathynellacean species recorded in this study, five species (Bathynellidae-OES26, Bathynellidae-OES27, Parabathynellidae-OES17, Parabathynellidae-OES20, and Parabathynellidae-OES22) were found to have relatively widespread distributions across the Project areas surveyed. Parabathynellidae-OES17 was the most commonly collected and widespread **(Figure 24**, **Table 6**). This species was collected from nine samples over three survey periods (**Appendix D**). A greater number of individual Parabathynellidiae-OES23 specimens (700) were collected compared to Parabathynellidae-OES17, however, most of those 700 were collected in a single sample. Genetic analysis demonstrated that Parabathynellidae-OES17 has a broad distribution across the Project area that extends from the Wolverine deposit in the north to non-impact regional areas more than 10 km to the south (Leijs and King 2013b) (**Appendix F**).

The genetic divergence displayed between northern and southern specimens of each species was low. Parabathynellidae-OES17 specimen from Wolverine bore NMBRRC091 exhibited only 0.1% divergence from a specimen collected from southern regional bore BRBR016. This indicates that there are no physical barriers preventing this species dispersing among the northern Project areas in and around the Wolverine deposit, down to the southern regional area. Interestingly, the divergence exhibited between Parabathynellidae-OES17 specimens from Wolverine bores NMBRRC091 and NMBRRC114, approximately 300 m apart, was greater at 0.4%. This co-occurrence of a higher level of haplotype diversity among specimens collected sympatrically can be an indication of a relatively large and widespread population.

The distributions of both Bathynellidae-OES27 and Parabathynellidae-OES22 provide evidence that there is subterranean habitat connections between the geological units within the Browns Range Metamorphics and the surrounding Gardiner Sandstone geological unit (**Figure 23, Figure 24**) (Leijs 2014). Bathynellidae-OES27 material collected from bore BRR040 in the central regional Project area displayed only 0.7 to 0.8% genetic divergence with material collected from proposed borefield bore BRRWS010. Of interest regarding the Bathynellidae-OES27 genetic results is that a larger genetic divergence of 1.3% was displayed between the two specimens collected in the same sample from borefield bore BRRWS010 (Leijs 2014). Genetic analysis demonstrated that Parabathynellidae-OES22 material collected from the Gambit East deposit area bore BRR008 was conspecific, with only 1.8% divergence, with specimens collected more than 10 km to the south-west from the proposed borefield bore BRRWS010 within the Gardiner Sandstone (Leijs 2014).

The distributions of both Bathynellidae-OES26 and Parabathynellidae-OES20 provided evidence that gene flow occurs between the Gambit Central and the North-Western regional Project areas as well as between Gambit Central and Wolverine, thereby demonstrating that subterranean habitat connections exist (**Figure 23**, **Figure 24**) (Leijs 2013b, c, Leijs and King 2013b). Bathynellidae-OES26 material from Gambit Central bore BRGR0083 displayed genetic divergence of 1.3% from a sequenced specimen collected approximately three kilometres away at North-Western regional bore BRR003. Parabathynellidae-OES20 material from Gambit Central bore NMBRR093 displayed genetic divergence of 0.7% from a sequenced specimen collected approximately two kilometres to the north at Wolverine bore NMBRRC114.

Of the remaining 10 of the 15 bathynellacean species recorded which did not display widespread distributions, four species were recorded from outside proposed impact areas only, with six species (Bathynellidae-OES19, Bathynellidae-OES24, Bathynellidae-OES25, Parabathynellidae-OES18, Parabathynellidae-OES26, and Parabathynellidae-OES27) been of conservation concern because they have each only been recorded from within proposed pit boundaries and/or modelled groundwater drawdown contours.

Copepoda

Of the five Copepoda species recorded, two species (*Microcyclops varicans* and *Megastygonitocrella trispinosa*) have widespread distributions that extend well beyond the Project area. *Microcyclops varicans* is found in many other parts of the world and can tolerate a broad range of environmental conditions in surface and subterranean aquatic habitats (Karanovic 2005). In Western Australia, *Microcyclops varicans* has also been recorded from the Pilbara region (Karanovic 2013a). *Megastygonitocrella trispinosa* has been found to be widespread throughout many localities in the Pilbara region of Western Australia (Karanovic 2006, Karanovic and Hancock 2009). The remaining three species, *Dussartcyclops*-OES2, *Metacyclops*-OES20, and *Parastenocaris*-OES1, represent new stygobitic species. These three copepod species are of potential conservation concern because they have only been recorded from within proposed impact areas (**Figure 25**, **Appendix D**). *Metacyclops*-OES20 was only recorded in April 2013 from two bores within the proposed Wolverine pit boundaries.

Dussartcyclops-OES2 and *Parastenocaris*-OES1 were each collected in December 2013 in the same sample from a single bore within the 1 m drawdown contour of the proposed borefield in the Gardiner Sandstone.

Oligochaeta

Genetic analyses determined that the Enchytraeidae material commonly collected over multiple survey periods represented one, widely distributed species, Enchytraeidae-OES17 (**Figure 26**, **Appendix D**) (Leijs 2013b, Leijs and King 2013b) (**Appendix F**). Enchytraeidae-OES17 was recorded from five Project areas including two non-impact regional areas with the Project area.

The taxonomy and ecology of the Enchytraeidae is poorly known, with no stygal species described to date (Pinder 2009, Pinder 2007). These worms are commonly recorded in subterranean fauna surveys, and occur in both surface and subterranean aquatic systems (freshwater and marine), or semi-aquatic and terrestrial habitats (Outback Ecology 2011a, Rota *et al.* 2007, van Vliet *et al.* 1997). It is not known whether Enchytraeidae OES17 is an aquatic (inhabiting the aquifer), semi-aquatic or terrestrial oligochaete species. Terrestrial invertebrate fauna are often collected in stygofauna nets having either being dislodged from the soil profile during retrieval of the nets or collected from the water column into which they may have fallen (Outback Ecology 2011a, Outback Ecology unpublished data, Subterranean Ecology 2008a, b). Some Enchytraeidae species have been demonstrated to not be obligate groundwater inhabitants, with genetic data showing material collected in troglofauna traps were conspecific (same species) with material collected from stygofauna net hauls (Leijs 2013a, Outback Ecology 2011b). However, no Enchytraeidae-OES17 material was collected from the relatively substantial trapping effort conducted. It is for this reason that Enchytraeidae OES17 is considered a putative stygofauna species, but not of conservation concern.

5.5.2. Species Diversity Estimates and Survey Adequacy

The species accumulation curve shows a constant rate of decline in the rate of new species found but had not reached a plateau by the end of the sample effort conducted (**Figure 21**). An extrapolation of the curve suggests that a further sample round of approximately 40 to 50 samples might yield an additional one, possibly two, stygofauna species.

The various species diversity estimators (e.g., ACE, Bootsrap, Chao, ICE, and Jacknife) in EstimateS (Colwell 2009) estimated the total richness of the stygofauna assemblage to range from 21 to 28 species (**Figure 22, Table 8**). The Chao 2 diversity estimator showed a notable decrease in the number of species found around the 90 to 95 sample mark. This trend was also evident for diversity estimators ICE and Jack 2, but only decreasing around the 120 to 125 sample mark. The 20 taxa collected represent an estimated 72% to 95% of the total species predicted to occur in the survey area (**Table 8**).

The species accumulation curve and diversity estimators indicate that further sampling is likely to record new stygofauna species in the Project area. However, the sample effort required to attempt to collect all stygofauna species that might be present is estimated to need to be at least twice more intensive to collect possibly another four species. The results are consistent with species accumulation curves for other stygofauna surveys in Australia (e.g. Eberhard *et al.* 2007) and overseas, many of which do not plateau even after many years of intensive survey effort (Pipan and Culver 2007). The 160 net haul samples collected in this assessment of the Project area exceeds the 40 samples recommended by EPA Guidance Statement 54a (2007). The species accumulation curves indicate that the survey intensity undertaken was more than sufficient in providing a high level of knowledge of the stygofauna assemblage present in the Project area and provide a high level of confidence in assessing the potential impacts posed by the proposed Project in accordance with EPA EAG 12 (2013).

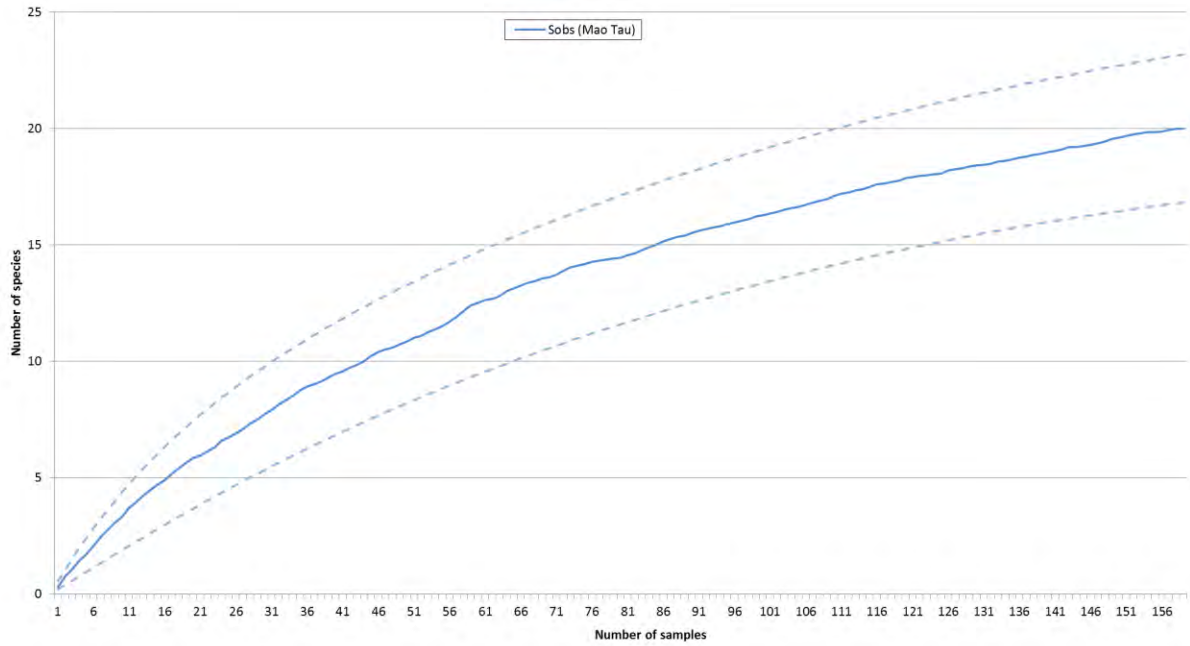


Figure 21: Stygofauna species accumulation curve (Sobs Mao Tau: EstimateS (Colwell 2009)) for the Project. Dashed lines represent Sobs 95% upper and lower confidence intervals.

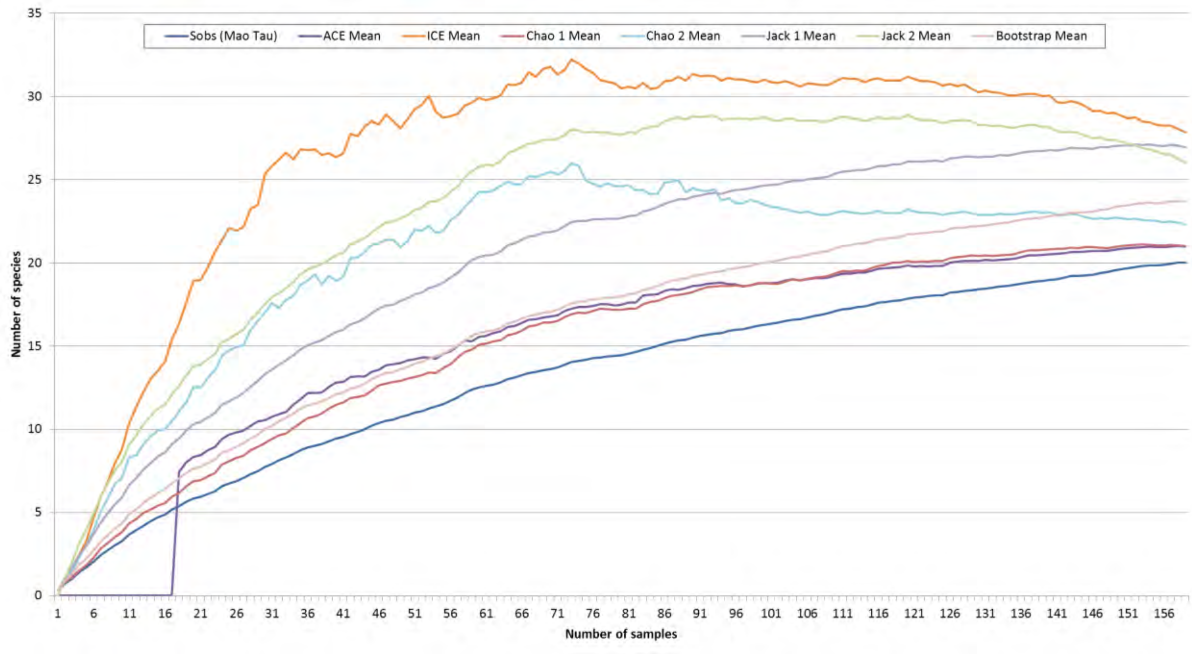


Figure 22: Stygofauna species accumulation curves for various diversity estimators and Sobs Mao Tau (Colwell 2009) for the Project.

Table 8: Observed stygofauna species diversity from Project compared to estimated diversity using EstimateS (Colwell 2009) diversity estimators.

Observed versus Diversity Estimators		**Obs. & Pred. spp richness**	**% Predicted collected**
Observed	Sobs (Mao Tau)	20	
Diversity estimators	ACE Mean	21.0	95.4%
	Chao 1 Mean	21.0	95.2%
	Chao 2 Mean	22.8	87.6%
	Bootstrap Mean	23.7	84.4%
	Jack 2 Mean	26.0	76.9%
	Jack 1 Mean	27.0	74.2%
	ICE Mean	27.9	71.8%
Range		21 - 27.9	71.8 - 95.4%

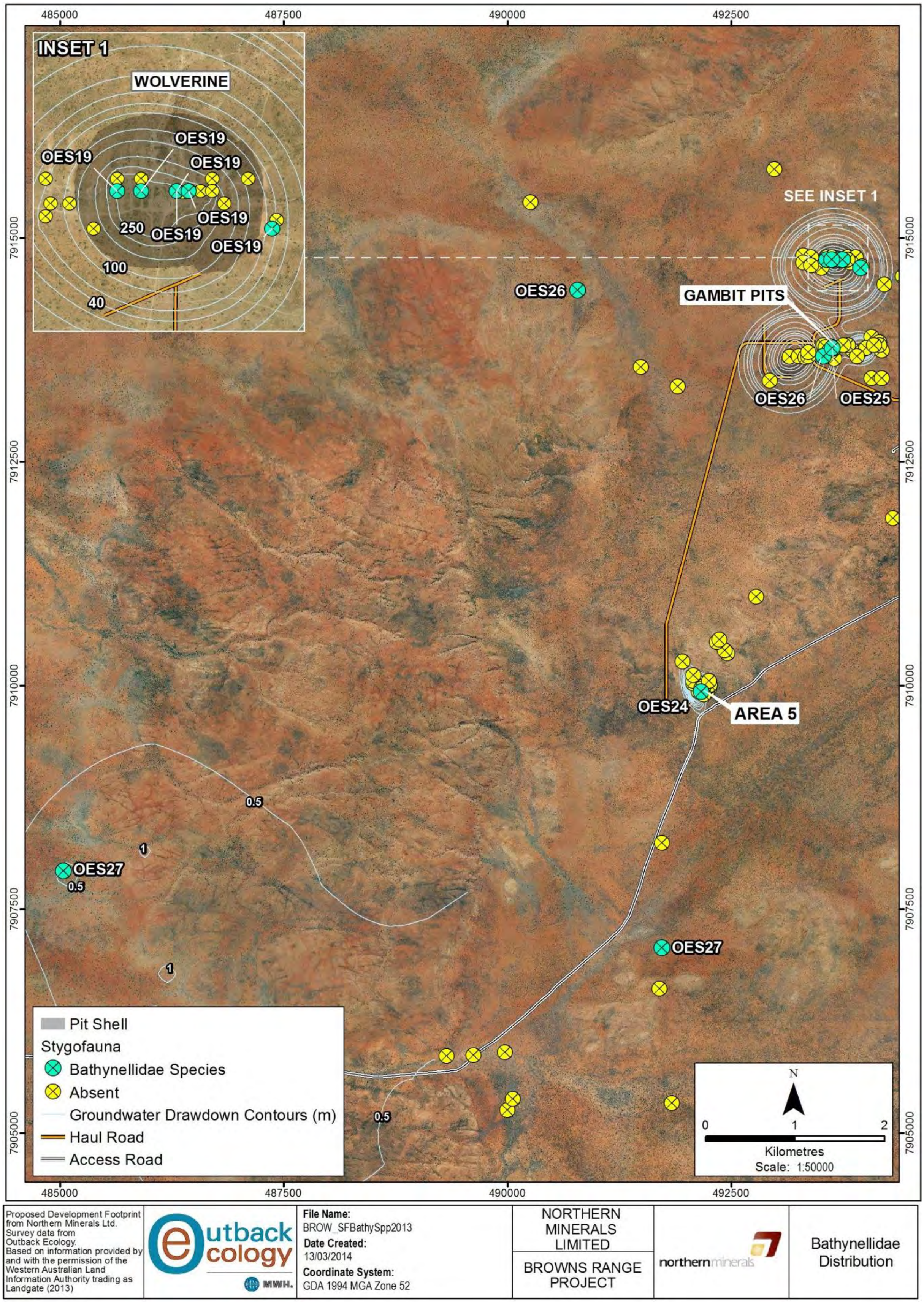


Figure 23: Distribution of Bathynellidae species recorded.

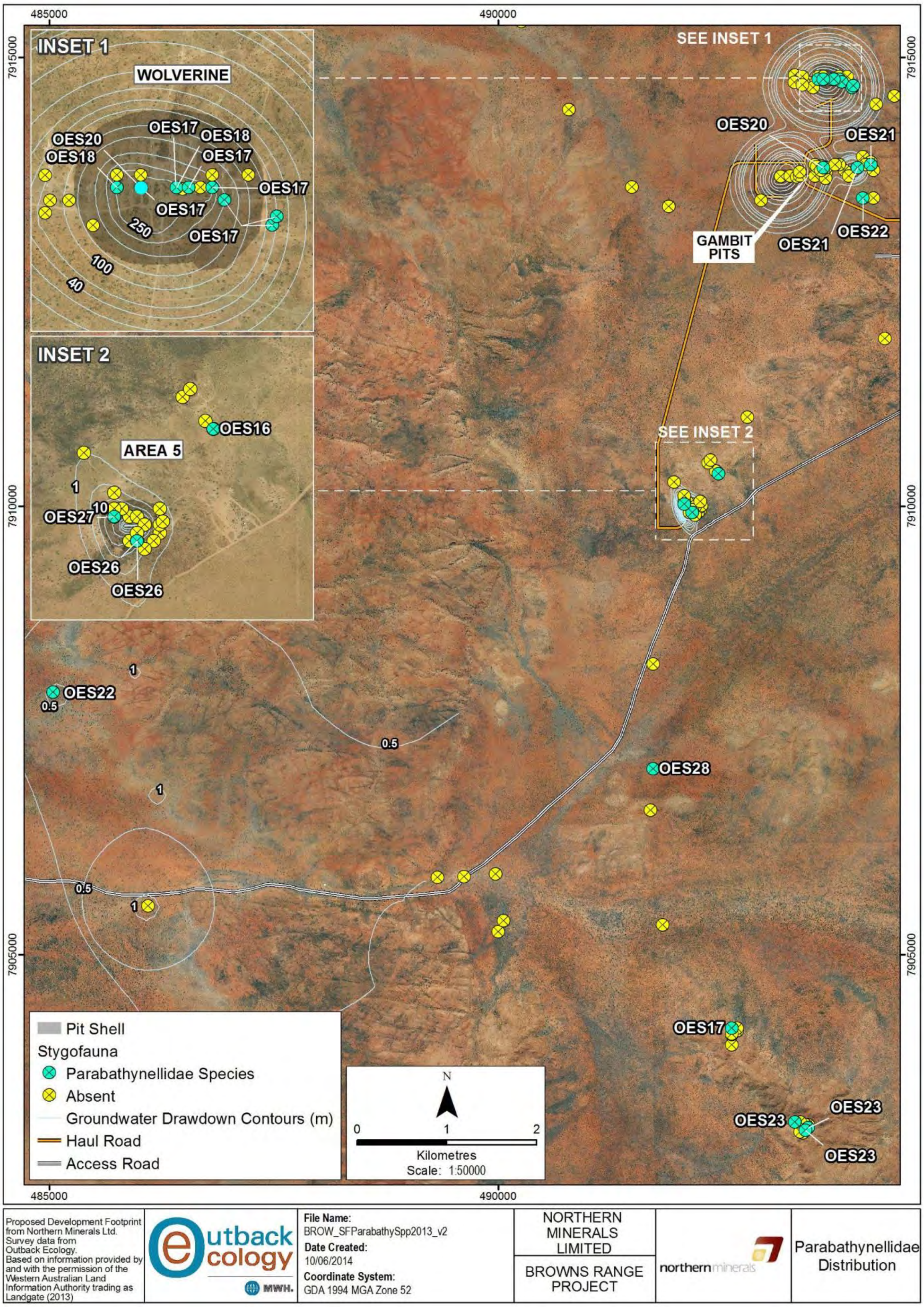


Figure 24: Distribution of Parabathynellidae species recorded.

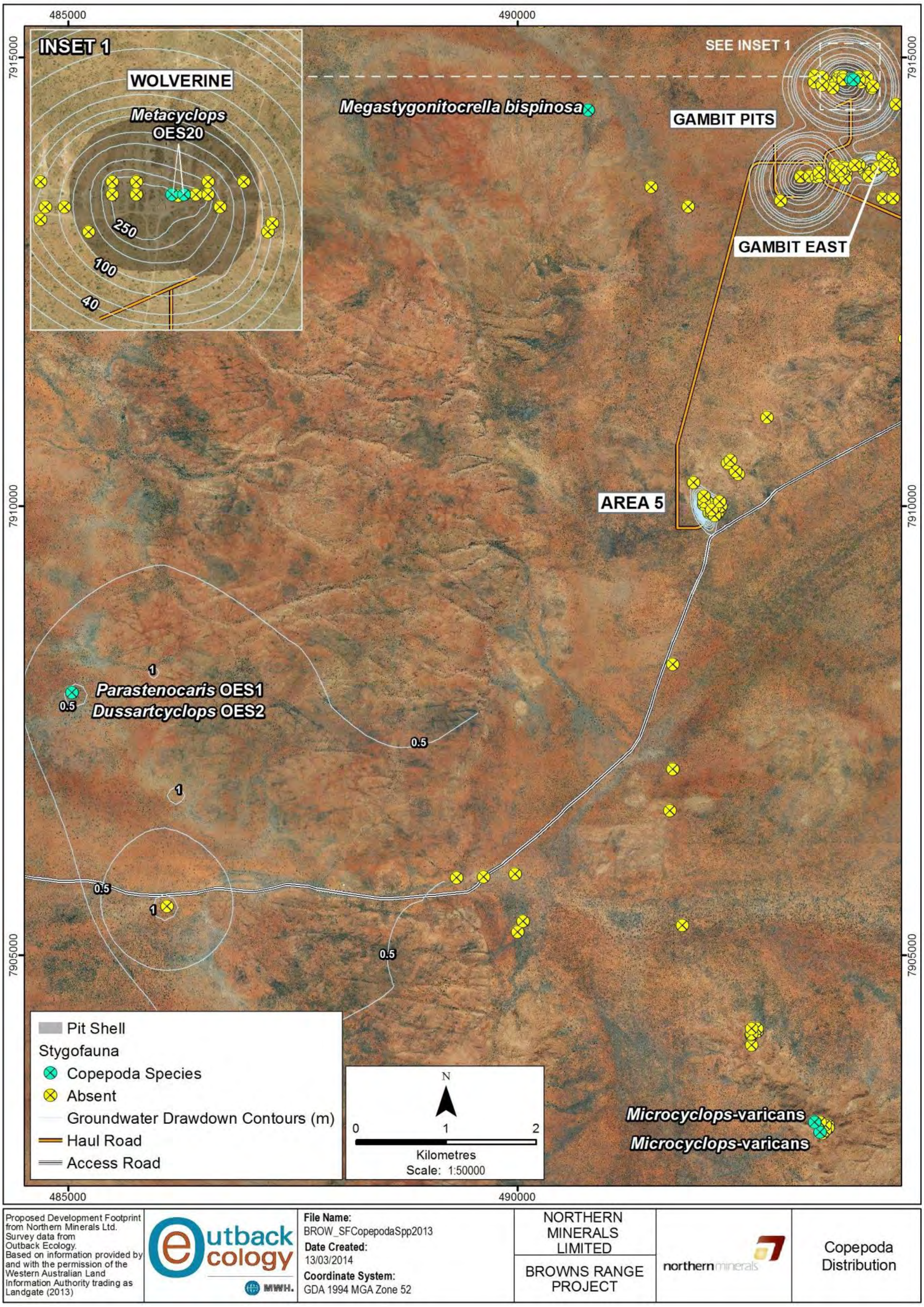


Figure 25: Distribution of Copepoda taxa collected.

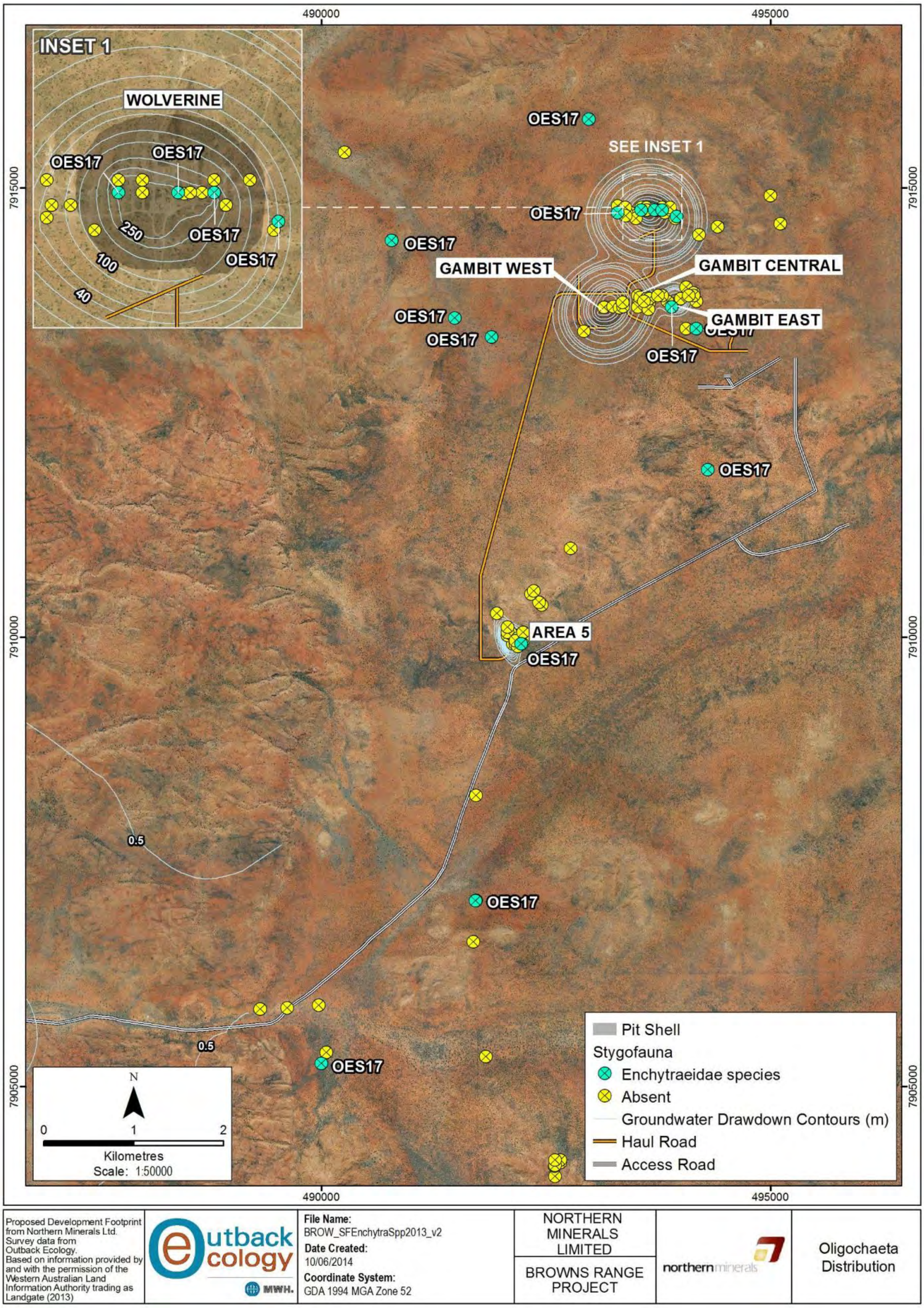


Figure 26: Distribution of Enchytraeidae-OES17 collected.

5.6. Troglofauna Survey

5.6.1. Troglofauna Findings

The troglofauna values of the Project area are low with only two putative troglofauna species, Nicoletiinae-OES10 and Projapygidae-OES2, collected from three of the 150 net haul scrape samples (**Table 9**, **Figure 29, Appendix E**). Neither species are considered to be of conservation concern because each was collected from outside proposed pit boundaries and modelled groundwater drawdown zones. No troglofauna specimens were collected from any of the 59 litter trap samples successfully retrieved.

The results of the troglofauna survey demonstrated that the regolith and weathered fractured rock geologies of the Project study area do not harbour a diverse troglofauna assemblage. The potential habitats associated with these subsurface geologies are widespread and contiguous throughout the Project study area and surrounding region. Therefore, the distributions of potentially undetected troglomorphic species are unlikely to be restricted. This is supported by the distribution of Projapygidae-OES2 that was collected from the Gambit East deposit area and from the North-Western regional area.

Table 9: Over all troglofauna species diversity and distribution in relation to Project areas.

Taxon	Project Area	Impact	Non-impact	Status
Diplura				
Projapygidae				
Projapygidae-OES2	Gambit East and North-Western Regional		●	Not of conservation concern
Thysanura (Zygentoma)				
Nicoletiidae				
Nicoletiinae-OES10	Central Regional		●	Not of conservation concern

5.6.2. Species Diversity Estimates and Survey Adequacy

The species accumulation curve for the Project area showed a relatively constant decline in the rate of new species found which had not reached a plateau by the end of the sample effort conducted (**Figure 27**). An extrapolation of the curve suggests that a further sample round (80 to 90 samples) might yield an additional troglofauna species.

The various species diversity estimators (e.g., ACE, Bootstrap, Chao, ICE and Jacknife) in EstimateS (Colwell 2009) estimated the total richness of the troglofauna assemblage to range from two to three species (**Figure 28**). The diversity estimators Jack 2 and Chao 2 displayed a decline in the number of new species found towards the end of the sampling effort; Bootstrap, Chao 1, and ICE showed relatively linear rates of species predicted as sampling progressed, similar to Sobs (Mao Tau); and ACE predicted species being collected only around the 128 sample point, which continued to increase as sampling progressed. The two taxa collected represent 64% to 100% of the total species predicted to occur in the survey area (**Table 10)**.

These analyses indicate that further extensive sampling is likely to record more troglomorphic species. However, the sample effort to attempt to collect another one to two species that might be present is estimated to need to be at least twice more intensive. The results are consistent with species accumulation curves for other troglofauna surveys in Australia (e.g. Eberhard *et al.* 2007) and overseas, many of which do not plateau, even after many years of intensive survey effort (Pipan and Culver 2007). Sampling occurred both within and outside footprint area, and exceeds the 60 samples within the impact area recommended by EPA Guidance Statement 54a (2007) for areas considered to host *significant* troglofauna values. The species accumulation curves indicate that the survey intensity undertaken was more than sufficient in providing a high level of knowledge of the troglofauna assemblage present in the Project area and provide a high level of confidence in assessing the potential impacts posed by the proposed Project in accordance with EPA EAG 12 (2013).

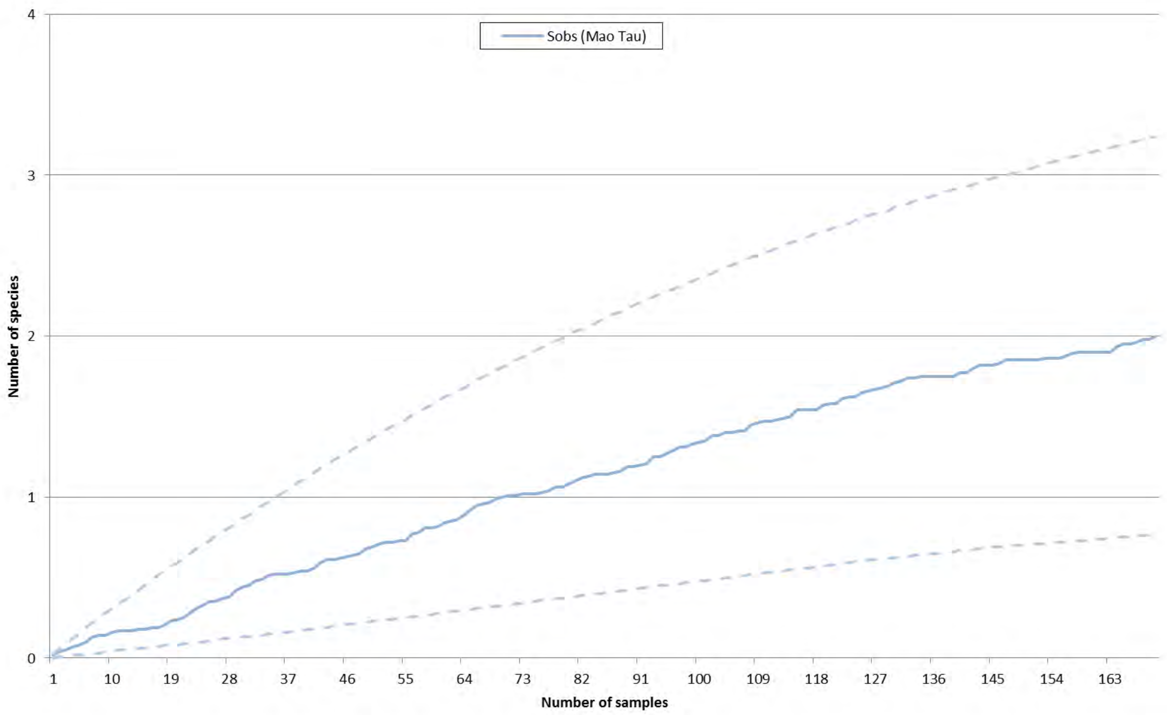


Figure 27: Troglofauna species accumulation curve (Sobs Mao Tau: EstimateS (Colwell 2009)) for the Project. Dashed lines represent Sobs 95% upper and lower confidence intervals.

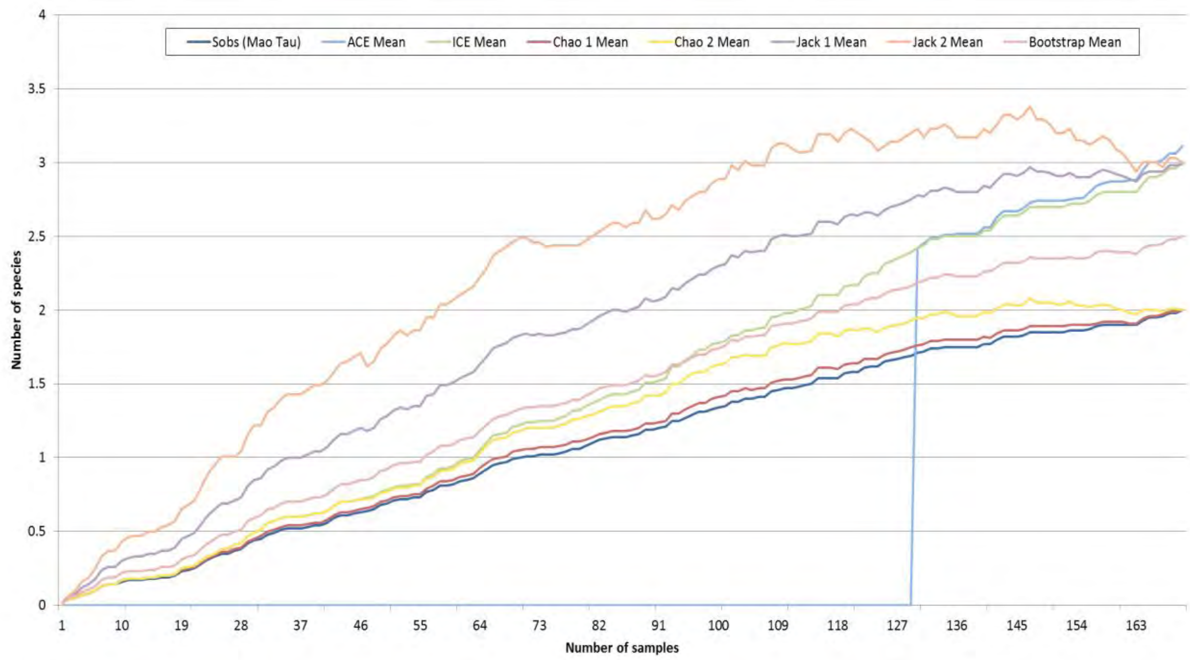


Figure 28: Troglofauna species accumulation curves for various diversity estimators and Sobs Mao Tau (Colwell 2009) for the Project.

Table 10: Observed troglofauna species diversity from Project compared to estimated diversity using EstimateS (Colwell 2009) diversity estimators.

Observed versus Diversity Estimators		Obs. & Pred. spp richness	% Predicted collected
Observed	Sobs (Mao Tau)	2	
Diversity estimators	Chao 1 Mean	2.0	100.0%
	Chao 2 Mean	2.0	100.0%
	Bootstrap Mean	2.5	80.0%
	Jack 1 Mean	3.0	66.9%
	ICE Mean	3.0	66.7%
	Jack 2 Mean	3.0	66.7%
	ACE Mean	3.1	64.3%
Range		2 - 3.1	64.3 - 100%

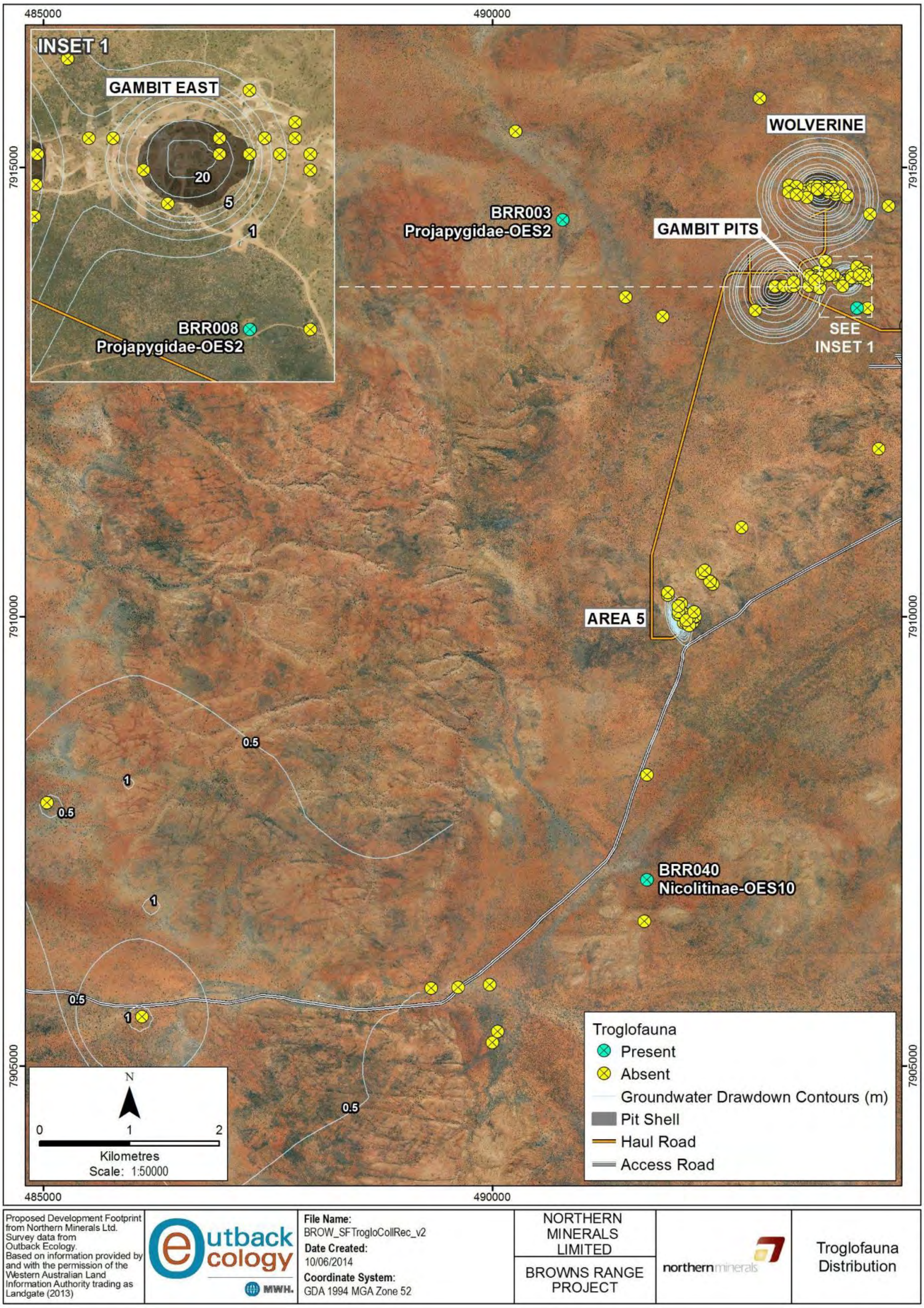


Figure 29: Distribution of troglofauna collected.

6. RISK ASSESSMENT

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

- removal of habitat through excavation of the proposed mining pits Area 5, Gambit Central, Gambit East, Gambit West and Wolverine; and
- drying out of habitat through the lowering of the groundwater table associated with mine pit dewatering, and groundwater extraction from the proposed borefield.

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

Both pit excavation and lower groundwater levels pose varying degrees of risk to the conservation of nine of 21 stygofauna species (**Table 6**) that were restricted in distribution to within the proposed mining areas or modelled groundwater drawdown exceeding one metre below standing water level (m bSWL). The risk assessment outlined below focuses on stygofauna, as no species of troglofauna were found to be of conservation concern in the context of the development of the proposed Project.

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

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

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

6.1. Species of Conservation Concern

Of the 21 stygofauna species recorded from the surveyed Project areas, nine (43%) species of the assemblage are of conservation concern because they have each only been recorded from within proposed pit boundaries and/or modelled groundwater extraction drawdown zones.

The direct removal of habitat through mining excavation within proposed pit boundaries and the associated groundwater drawdowns poses a risk to seven species. These seven species of conservation concern within proposed mining areas are as follows:

- Area 5 — Bathynellidae-OES24, Parabathynellidae-OES26, and Parabathynellidae-OES27.
- Gambit Central — Bathynellidae-OES25.
- Wolverine — Bathynellidae-OES19, Parabathynellidae-OES18, and *Metacyclops*-OES20.

For both Gambit East and Gambit West mining areas no species are of conservation concern. Both species recorded from Gambit East were found to have distributions that extended beyond the proposed impact zones into neighbouring non-impact areas as well as into the Gardiner Sandstone aquifer system. No species were recorded within the proposed Gambit West pit boundary. The absence of stygofauna species is considered to be a reliable indication of the stygofauna values for Gambit West because hydrogeological pump testing revealed this deposit area to have considerably lower permeability with horizontal hydraulic conductivity two to three orders of magnitude less than other neighbouring deposit areas (Klohn Crippen Berger, pers comm.). This lower permeability indicates that the secondary porosity associated with discrete geological structures is unlikely to be sufficient to enable stygofauna colonisation.

The removal of habitat through groundwater drawdown within the proposed borefield area in the Gardiner Sandstone poses a low risk to two species that were found only from within the modelled 1 m drawdown contour. The modelled level of groundwater drawdown is less than the recorded natural variation in groundwater levels. The two species of low conservation concern are:

- *Dussartcyclops*-OES2 and *Parastenocaris*-OES1.

Of the nine species of conservation concern, six species have been recorded from one bore only and two species from two bores only. Bathynellidae-OES19 is the only species of conservation concern that has been collected from more than two bores over multiple sample periods at relatively high levels of abundance on three of the five occasions collected (**Appendix D**). It is not possible to reliably assess the distribution range of stygofauna species that are known from only one or two bores. The seemingly restricted distribution of a species to a single bore is likely to be an artefact of that species occurring at low population densities and/or possessing an irregular distribution in response to varying habitat factors, biological interactions and availability of energy resources (Boulton 2000, Boulton et al. 1998, Humphreys 2009). It is considered unlikely that the actual species distribution is confined to such a limited area that was intercepted by a single bore. The vagaries of assessing stygofauna distributions is typified by the results recorded for the Central regional bore

BRR040 that was sampled on four occasions. On the first three occasions Parabathynellidae-OES28 and Enchytraeidae-OES17 were consistently recorded. On the fourth occasion neither species were collected but instead a new species, Bathynellidae-OES-27, was recorded for the first time.

Biological and physical surrogates can assist in determining likely species distributions and addressing the artefact of sampling difficulties associated with subterranean fauna (Environmental Protection Authority 2013). Reviewing records of closely-related species, or species collected sympatrically (biological surrogates), and expanse of neighbouring geological habitat (physical surrogate) can provide further insight into the potential distribution patterns of species that are known from a few records only.

Biological evidence indicating the likely wider distribution of species with seemingly limited ranges is as follows:

- Gambit Central — Bathynellidae-OES25, that has only been recorded from Bore NMBRRC093 was collected sympatrically with Parabathynellidae-OES20 that has been demonstrated to have a distribution that extends beyond the Gambit Central deposit area to Wolverine. In addition, Bathynellidae-OES26 that was collected from neighbouring bore BRGR0083 was also found to occur within the North-Western Regional area.

- Borefield — Both *Dussartcyclops*-OES2 and *Parastenocaris*-OES1 have only been recorded on the one occasion from borefield bore BRRWS010. Both species were collected sympatrically with two widely distributed species, Bathynellide-OES27 and Parabathynellidae-OES22 whose distributions extend from the Gardiner Sandstone aquifers into the Browns Range Metamorphic aquifers as far as Gambit East.

- Wolverine — Both Parabathynellidae-OES18 and *Metacyclops*-OES20 are each known from two bores and are each known to occur sympatrically with widespread species Parabathynellidae-OES17 and Enchytraeidae-OES17. In addition, Parabathynellidae-OES20 has also demonstrated to have a distribution that extends beyond the Wolverine deposit area to Gambit Central. Bathynellidae-OES19 has been recorded from five bores on two sample periods from within the proposed Wolverine pit boundary as well as outside the pit boundary from bore NMBRRC091 within the modelled 40 to 50 m drawdown contour. From four of the five bores, including NMBRRC091, Bathynellidae-OES19 has been collected sympatrically with widespread species Parabathynellidae-OES17 as well as Enchytraeidae-OES17.

The geological evidence indicates that a large expanse of neighbouring and contiguous habitat exists beyond the proposed impact areas (**Figure 12**, **Figure 13**, **Figure 14**). For each of the six species of conservation concern from Gambit Central, the proposed borefield and Wolverine, the wider distribution ranges of sympatric species demonstrate that fractured rock aquifer habitats suitable for stygofauna are not confined to the rare earth deposits but are more extensive and biologically connected to the broader Project study area. The biological evidence supports the geological evidence that groundwater-bearing structures, such as faults, shears or fractures, possibly in combination with ephemeral alluvial aquifers, are relatively extensive and enable stygofauna to disperse among the Browns Range Metamorphics aquifers within the North-Western regional area through to Gambit Central, Wolverine, Gambit East, the Central and Southern Regional areas as well as to the large and extensive Gardiner Sandstone aquifer system. Therefore, the seemingly restricted distributions of these species of potential concern are more likely to be an artefact of sampling limitations rather than these species possessing such confined ranges.

For the three species of conservation concern in Area 5, Bathynellidae-OES24, Parabathynellidae-OES26, and Parabathynellidae-OES27, no sympatric species were recorded that could reliably demonstrate a biological connection to the broader Project study area. The widely-distributed Enchytraeidae-OES17 did also occur from within the proposed Area 5 Pit boundary. However, due to there been some uncertainty regarding the enchytraeids ecological niche (refer 5.5.1), the widespread distribution of this species alone is not a reliable indicator of whether a broader biological connection exists between Area 5 and the surrounding Project area.

Genetic data does indicate that stygofauna colonisation of the Area 5 deposit area has occurred on multiple occasions in the past. The Area 5 Bathynellacea species are more closely related to species from Gambit Central, Gambit East or Wolverine than to each other. The Area 5 species Parabathynellidae-OES26 and Parabathynellidae-OES27 are more closely related to Wolverine species than to each other. Parabathynellidae-OES26 displays only 6% genetic divergence from Wolverine species Parabathynellidae-OES18 for the CO1 gene fragment sequenced compared to more than 14% divergence from Parabathynellidae-OES27 (Leijs 2013c, d). Likewise Parabathynellidae-OES27 exhibits 6% divergence from widely-distributed species Parabathynellidae-OES17. In addition, both Area 5 species Bathynellidae-OES24 and Parabathynellidae-OES16 are closely related to Gambit Central and Gambit East species, respectively (Leijs 2013c, Leijs and King 2013b). The relationships demonstrated by genetic analyses indicate that geological structures have facilitated gene flow between Area 5 and Project areas to the north on numerous occasions and not that all Area 5 species have evolved together in isolation from the rest of the stygofauna assemblage.

The Area 5 aquifer characteristics are considered similar to other deposit areas in that aquifers are hosted within the Browns Range Metamorphics and are controlled by geological-structures (refer section 5.3.1). Similar to Gambit East and Wolverine, a discrete, groundwater-bearing structure, considered to be a shear zone, was identified traversing the Area 5 deposit in a north-west to south-east direction and is likely to extend for some kilometres beyond the deposit area (Klohn Crippen Berger 2014, Northern Minerals 2013). Unfortunately no bore holes were available to sample outside the Area 5 deposit along the shear zone identified.

Targeted sampling of the few bores available to the north of Area 5 deposit failed to extend the distributions of Bathynellidae-OES24, Parabathynellidae-OES26, and Parabathynellidae-OES27 but did collect Parabathynellidae-OES16. The occurrence of Parabathynellidae-OES16 relatively near to the proposed Area 5 pit but outside the impact zone did indicate that suitable stygofauna habitat exists close to the pit but did not demonstrate a biological connection. However, it is considered unlikely that the Area 5 species of conservation concern, Bathynellidae-OES24, Parabathynellidae-OES26, and Parabathynellidae-OES27, are restricted to the immediate vicinity of the proposed Area 5 pit boundary and associated modelled groundwater drawdown contours when taking into account the number of closely-related species that possess relatively widespread distributions that demonstrate the presence of suitable and connected habitat well beyond the proposed Project impact areas.

6.2. Assessment Summary

Of the 21 stygofauna species recorded, nine species (43%) were considered of conservation concern because they were not collected from outside the proposed Project impact areas. However, for seven of these nine species (Bathynellidae-OES19, Bathynellidae-OES24, Bathynellidae-OES25, *Metacyclops*-OES20, Parabathynellidae-OES18, Parabathynellidae-OES26, and Parabathynellidae-OES27), the proposed mining of the Area 5, Gambit Central, Gambit East, Gambit West and Wolverine deposits are not considered likely to pose a significant long term conservation risk when taking the following into consideration:

- Widespread distribution patterns of other members of the stygofauna assemblage (many occurring sympatrically) that indicated the:
  - presence of suitable and extensive habitat adjacent to and outside proposed mining impact areas; and
  - likelihood that seemingly restricted species, possess broader distribution ranges that extend beyond the proposed pit boundaries and associated modelled groundwater drawdowns.
- Limited area of habitat removal associated with mining excavation, relative to the much greater expanse of adjacent habitat remaining within the Browns Range Metamorphics as well as the Gardiner Sandstone.

For the remaining two species (*Dussartcyclops*-OES2 and *Parastenocaris*-OES1) that were considered to be of low conservation concern, the modelled groundwater drawdown greater than 1 m associated with the proposed Borefield in the Gardiner Sandstone is not considered likely to pose a significant long term conservation risk when taking the following into consideration:

- Widespread distribution patterns of other members of the stygofauna assemblage occurring sympatrically that demonstrated the:
  - presence of suitable and extensive habitat adjacent to and outside the modelled one metre drawdown contour; and
  - likelihood that *Dussartcyclops*-OES2 and *Parastenocaris*-OES1 have broader distribution ranges that extend beyond the modelled one metre drawdown zone.

- Level of modelled groundwater drawdown is less than recorded natural variation in groundwater levels;
- Large extent of saturated habitat that would persist in the immediate vicinity of the production bore during the operational life of the borefield; and
- Limited area of habitat removal associated with the operation of the proposed borefield, relative to the large expanse of adjacent habitat remaining within the Gardiner Sandstone as well as the Browns Range Metamorphics.

7. CONCLUSION

The subterranean fauna assessment undertaken has revealed that the fractured rock aquifer systems within the Project study area host a diverse stygofauna assemblage dominated by bathynellacean taxa. Genetic analysis demonstrated that the stygofauna habitat was not confined to deposit areas only. For a number of species, distributions were shown to occur broadly across the Browns Range Metamorphics aquifers within the Browns Range Dome as well as extend to outside the Dome within the extensive Gardiner Sandstone aquifer. In contrast, the Project area was found not to host a diverse troglofauna assemblage.

The findings indicate that the development of the Project is not likely to pose a significant long term conservation risk to any subterranean fauna species as a broad expanse of habitat will remain and not be impacted outside the proposed development impact zones.

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9. GLOSSARY

alluvium – sediment deposited by a stream or river

aquatic – relating to water

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

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

bedrock – consolidated rock attached to the earth's crust

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

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

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

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

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

divergence – degree of separation from a common ancestor

diversity – species richness

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

ecotone – zone of transition among different ecosystems

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

endemic – having a distribution restricted to a particular geographic region

epigean – pertaining to the surface zone

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

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

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

groundwater – water occurring below the ground surface

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

hypogean – pertaining to the subterranean zone

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

invertebrates – animals lacking vertebrae

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

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

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

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

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

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

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

relictual – having survived as a remnant

salinity – the concentration of all dissolved salts in a solution

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

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

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

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

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

stygal, stygo – pertaining to groundwater habitat or biota

stygobite – an obligate aquatic species of groundwater habitats

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

stygofauna – a general term for aquatic groundwater fauna

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

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

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

void – a pore space in the rock or stratum

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

APPENDIX A
Stygofauna Survey Effort and Bore Details

Stygofauna Survey Effort and Bore Details

Project Area	Bore Code	Impact		Non-Impact	Latitude	Longitude	Sample Date (YYYYMMDD)	Stygofauna Present	Inclination (°)	Casing details	Bore development
		Pit	Drawdown								
Area 5	BRAR002		●		-18.9017	128.9264	20130410	No	60	Uncased	Non-purged
Area 5	BRAR0021		●		-18.9028	128.9262	20130817	Yes	60	Uncased	Purged
Area 5	BRAR005	●			-18.9028	128.9253	20130409	No	60	Uncased	Non-purged
Area 5	BRAR008	●			-18.9022	128.9264	20130409	No	60	Uncased	Non-purged
Area 5	BRAR012	●			-18.9028	128.9256	20130409	Yes	60	Uncased	Non-purged
Area 5	BRAR012	●			-18.9028	128.9256	20130815	Yes	60	Uncased	Non-purged
Area 5	BRAR012	●			-18.9028	128.9256	20130820	No	60	Uncased	Purged
Area 5	BRAR013	●			-18.9021	128.9265	20130819	No	60	Uncased	Purged
Area 5	BRAR019	●			-18.9025	128.9264	20130409	No	60	Uncased	Non-purged
Area 5	BRAR023		●		-18.9031	128.9258	20130410	No	60	Uncased	Non-purged
Area 5	BRAR030	●			-18.9019	128.9247	20130410	Yes	60	Uncased	Non-purged
Area 5	BRAR030	●			-18.9019	128.9247	20130815	No	60	Uncased	Non-purged
Area 5	BRAR030	●			-18.9019	128.9247	20130820	No	60	Uncased	Purged
Area 5	BRRWS003			●	-18.8932	128.9314	20130817	No	60	Uncased	Purged
Area 5	Monitoring Bore 01			●	-18.8853	128.9459	20130820	Yes	Vertical	Cased (slotted	Purged
Area 5	NMBRRC005			●	-18.8989	128.9283	20121024	Yes	60	Uncased	Non-purged
Area 5	NMBRRC008			●	-18.8986	128.9281	20121022	No	60	Uncased	Non-purged
Area 5	NMBRRC025			●	-18.8978	128.9272	20121023	No	60	Uncased	Non-purged
Area 5	NMBRRC027			●	-18.8975	128.9275	20121024	No	60	Uncased	Non-purged
Area 5	NMBRRC129	●			-18.9019	128.9253	20130816	No	60	Uncased	Purged
Area 5	NMBRRC130	●			-18.9019	128.9256	20130816	No	60	Uncased	Purged
Area 5	NMBRRC137	●			-18.9017	128.9250	20121023	No	60	Uncased	Non-purged
Area 5	NMBRRC137	●			-18.9017	128.9250	20130409	No	60	Uncased	Non-purged
Area 5	NMBRRC139	●			-18.9017	128.9247	20130409	No	60	Uncased	Non-purged
Area 5	NMBRRC141	●			-18.9022	128.9258	20121023	No	60	Uncased	Non-purged
Area 5	NMBRRC141	●			-18.9022	128.9258	20130409	No	60	Uncased	Non-purged
Area 5	NMBRRC142	●			-18.9025	128.9256	20121023	No	60	Uncased	Non-purged
Area 5	NMBRRC143	●			-18.9011	128.9247	20121022	No	60	Uncased	Non-purged
Area 5	NMBRRC153		●		-18.8997	128.9236	20121022	No	60	Uncased	Non-purged

Stygofauna Survey Effort and Bore Details (cont.)

Project Area	Bore Code	Impact		Non-Impact	Latitude	Longitude	Sample Date (YYYYMMDD)	Stygofauna Present	Inclination (°)	Casing details	Bore development
		Pit	Drawdown								
Central Regional	BRR033			●	-18.9394	128.9014	20130412	No	Vertical	Uncased	Non-purged
Central Regional	BRR035			●	-18.9450	128.9050	20121024	Yes	Vertical	Uncased	Non-purged
Central Regional	BRR035			●	-18.9450	128.9050	20130412	No	Vertical	Uncased	Non-purged
Central Regional	BRR037			●	-18.9439	128.9056	20130412	No	Vertical	Uncased	Non-purged
Central Regional	BRR037			●	-18.9439	128.9056	20130818	No	Vertical	Uncased	Purged
Central Regional	BRR038			●	-18.9392	128.9047	20121024	No	Vertical	Uncased	Non-purged
Central Regional	BRR038			●	-18.9392	128.9047	20130412	No	Vertical	Uncased	Non-purged
Central Regional	BRR039			●	-18.9181	128.9214	20130816	No	Vertical	Uncased	Purged
Central Regional	BRR040			●	-18.9286	128.9214	20130413	Yes	Vertical	Uncased	Non-purged
Central Regional	BRR040			●	-18.9286	128.9214	20130413	Yes	Vertical	Uncased	Non-purged
Central Regional	BRR040			●	-18.9286	128.9214	20130815	Yes	Vertical	Uncased	Non-purged
Central Regional	BRR040			●	-18.9286	128.9214	20130820	Yes	Vertical	Uncased	Purged
Central Regional	BRR040			●	-18.9286	128.9214	20131217	Yes	Vertical	Uncased	Purged
Central Regional	BRR041			●	-18.9328	128.9211	20130412	No	Vertical	Uncased	Non-purged
Central Regional	BRR042			●	-18.9443	128.9224	20130818	No	Vertical	Uncased	Purged
Central Regional	BRRWS001			●	-18.9395	128.8986	20130816	No	60	Uncased	Purged
Gambit Central	BRGR0020		●		-18.8678	128.9407	20130817	No	60	Uncased	Purged
Gambit Central	BRGR0025	●			-18.8679	128.9393	20130815	No	60	Uncased	Purged
Gambit Central	BRGR0037	●			-18.8678	128.9385	20130817	No	60	Uncased	Purged
Gambit Central	BRGR0082		●		-18.8686	128.9386	20130414	No	60	Uncased	Non-purged
Gambit Central	BRGR0083		●		-18.8689	128.9385	20130817	Yes	60	Uncased	Purged
Gambit Central	BRGR0147	●			-18.8680	128.9388	20130818	No	60	Uncased	Purged
Gambit Central	NMBRRC070	●			-18.8686	128.9397	20130817	No	60	Uncased	Purged
Gambit Central	NMBRRC072		●		-18.8691	128.9397	20130817	No	60	Uncased	Purged
Gambit Central	NMBRRC093	●			-18.8681	128.9394	20130414	Yes	60	Uncased	Non-purged
Gambit Central	NMBRRC093	●			-18.8681	128.9394	20131217	No	60	Uncased	Non-purged
Gambit Central	NMBRRC094	●			-18.8681	128.9397	20121022	No	60	Uncased	Non-purged
Gambit Central	NMBRRC094	●			-18.8681	128.9397	20130414	No	60	Uncased	Non-purged
Gambit Central	NMBRRC098	●			-18.8683	128.9392	20121025	No	60	Uncased	Non-purged
Gambit East	BRGR0012	●			-18.8683	128.9417	20130414	No	60	Uncased	Non-purged
Gambit East	BRGR0016		●		-18.8678	128.9411	20130414	No	60	Uncased	Non-purged
Gambit East	BRGR0016		●		-18.8678	128.9411	20130816	No	60	Uncased	Purged
Gambit East	BRGR0030		●		-18.8669	128.9436	20130414	No	60	Uncased	Non-purged

Stygofauna Survey Effort and Bore Details (cont.)

Project Area	Bore Code	Impact		Non-Impact	Latitude	Longitude	Sample Date (YYYYMMDD)	Stygofauna Present	Inclination (°)	Casing details	Bore development
		Pit	Drawdown								
Gambit East	BRGR0043			●	-18.8675	128.9444	20130414	No	60	Uncased	Non-purged
Gambit East	BRR008			●	-18.8711	128.9436	20130413	Yes	Vertical	Uncased	Non-purged
Gambit East	BRR008			●	-18.8711	128.9436	20130815	Yes	Vertical	Uncased	Non-purged
Gambit East	BRR008			●	-18.8711	128.9436	20130820	Yes	Vertical	Uncased	Purged
Gambit East	BRR009			●	-18.8711	128.9447	20130416	Yes	Vertical	Uncased	Non-purged
Gambit East	NMBRRC034			●	-18.8683	128.9447	20121022	No	Vertical	Uncased	Non-purged
Gambit East	NMBRRC037			●	-18.8678	128.9444	20130413	Yes	60	Uncased	Non-purged
Gambit East	NMBRRC049	●			-18.8681	128.9431	20130413	Yes	60	Uncased	Non-purged
Gambit East	NMBRRC049	●			-18.8681	128.9431	20131217	No	60	Uncased	Non-purged
Gambit East	NMBRRC067	●			-18.8689	128.9421	20130817	Yes	60	Uncased	Purged
Gambit East	NMBRRC100	●			-18.8689	128.9392	20121022	No	60	Uncased	Non-purged
Gambit East	NMBRRC109		●		-18.8678	128.9439	20121022	No	Vertical	Uncased	Non-purged
Gambit East	NMBRRC109		●		-18.8678	128.9439	20130414	No	Vertical	Uncased	Non-purged
Gambit West	BRGR0098	●			-18.8689	128.9349	20130416	No	60	Uncased	Non-purged
Gambit West	BRGR0117	●			-18.8689	128.9359	20130818	No	60	Uncased	Purged
Gambit West	BRGR0120	●			-18.8690	128.9366	20130818	No	60	Uncased	Purged
Gambit West	BRGR070		●		-18.8689	128.9369	20130416	No	60	Uncased	Non-purged
Gambit West	BRGR071		●		-18.8685	128.9369	20130818	No	60	Uncased	Purged
Gambit West	BRR006		●		-18.8714	128.9328	20130817	No	Vertical	Uncased	Purged
North-Western Regional	BRDD005			●	-18.8500	128.9333	20130416	Yes	60	Uncased	Non-purged
North-Western Regional	BRR001			●	-18.8533	128.9075	20121024	No	Vertical	Uncased	Non-purged
North-Western Regional	BRR001			●	-18.8533	128.9075	20130413	No	Vertical	Uncased	Non-purged
North-Western Regional	BRR002			●	-18.8569	128.9127	20130413	No	Vertical	Uncased	Non-purged
North-Western Regional	BRR002			●	-18.8569	128.9127	20130817	No	Vertical	Uncased	Purged
North-Western Regional	BRR003			●	-18.8621	128.9127	20130413	No	Vertical	Uncased	Non-purged
North-Western Regional	BRR003			●	-18.8621	128.9127	20130819	Yes	Vertical	Uncased	Purged
North-Western Regional	BRR003			●	-18.8621	128.9127	20131217	No	Vertical	Uncased	Purged
North-Western Regional	BRR004			●	-18.8700	128.9192	20130413	Yes	Vertical	Uncased	Non-purged
North-Western Regional	BRR004			●	-18.8700	128.9192	20130816	Yes	Vertical	Uncased	Purged
North-Western Regional	BRR005			●	-18.8719	128.9231	20121024	No	Vertical	Uncased	Non-purged
North-Western Regional	BRR005			●	-18.8719	128.9231	20130413	Yes	Vertical	Uncased	Non-purged
Proposed Borefield (GS)	BRRWS007		●		-18.9424	128.8679	20130816	No	Vertical	Cased (slotted)	Purged
Proposed Borefield (GS)	BRRWS007		●		-18.9424	128.8679	20131217	No	Vertical	Cased (slotted)	Purged
Proposed Borefield (GS)	BRRWS010		●		-18.9208	128.8579	20130816	Yes	Vertical	Cased (slotted)	Purged
Proposed Borefield (GS)	BRRWS010		●		-18.9208	128.8579	20131217	Yes	Vertical	Cased (slotted)	Purged

Stygofauna Survey Effort and Bore Details (cont.)

Project Area	Bore Code	Impact		Non-Impact	Latitude	Longitude	Sample Date (YYYYMMDD)	Stygofauna Present	Inclination (°)	Casing details	Bore development
		Pit	Drawdown								
Southern Regional	BRBR003			●	-18.9550	128.9303	20121025	No	60	Uncased	Non-purged
Southern Regional	BRBR005			●	-18.9547	128.9303	20121025	No	60	Uncased	Non-purged
Southern Regional	BRBR008			●	-18.9564	128.9297	20121021	No	60	Uncased	Non-purged
Southern Regional	BRBR013			●	-18.9554	128.9297	20130815	No	60	Uncased	Purged
Southern Regional	BRBR014			●	-18.9553	128.9297	20121024	No	60	Uncased	Non-purged
Southern Regional	BRBR016			●	-18.9547	128.9297	20121024	Yes	60	Uncased	Non-purged
Southern Regional	BRMR002			●	-18.9653	128.9372	20121021	No	60	Uncased	Non-purged
Southern Regional	BRMR002			●	-18.9653	128.9372	20130411	No	60	Uncased	Non-purged
Southern Regional	BRMR005			●	-18.9644	128.9378	20130411	No	60	Uncased	Non-purged
Southern Regional	BRMR006			●	-18.9647	128.9378	20121021	No	60	Uncased	Non-purged
Southern Regional	BRMR006			●	-18.9647	128.9378	20130411	Yes	60	Uncased	Non-purged
Southern Regional	BRMR008			●	-18.9650	128.9372	20130411	No	60	Uncased	Non-purged
Southern Regional	BRMR009			●	-18.9650	128.9375	20130411	Yes	60	Uncased	Non-purged
Southern Regional	BRMR010			●	-18.9644	128.9375	20121021	No	60	Uncased	Non-purged
Southern Regional	BRMR016			●	-18.9652	128.9369	20121021	No	60	Uncased	Non-purged
Southern Regional	BRMR016			●	-18.9652	128.9369	20130412	Yes	60	Uncased	Non-purged
Southern Regional	BRMR021			●	-18.9642	128.9369	20130412	No	60	Uncased	Non-purged
Southern Regional	BRMR026			●	-18.9642	128.9364	20121021	No	60	Uncased	Non-purged
Southern Regional	BRMR026			●	-18.9642	128.9364	20130412	Yes	60	Uncased	Non-purged
Southern Regional	BRMR027			●	-18.9641	128.9364	20130815	No	60	Uncased	Purged
Southern Regional	BRRWS002			●	-18.9803	128.9334	20130816	No	60	Uncased	Purged
Southern Regional	BRRWS002			●	-18.9803	128.9334	20131217	No	60	Uncased	Purged
Southern Regional	Old Camp Bore			●	-18.9740	128.9221	20130815	No	Vertical	Cased (slotted)	Purged
Southern Regional	Old Camp Bore			●	-18.9740	128.9221	20131217	No	Vertical	Cased (slotted)	Purged
Wolverine	BRR010			●	-18.8606	128.9536	20121025	No	Vertical	Uncased	Non-purged
Wolverine	BRR010			●	-18.8606	128.9536	20130414	No	Vertical	Uncased	Non-purged
Wolverine	BRR010			●	-18.8606	128.9536	20130816	No	Vertical	Uncased	Purged
Wolverine	BRR011			●	-18.8577	128.9526	20130819	No	Vertical	Uncased	Purged
Wolverine	BRR012		●		-18.8617	128.9450	20130412	No	Vertical	Uncased	Non-purged
Wolverine	BRR013			●	-18.8608	128.9469	20121025	No	Vertical	Uncased	Non-purged
Wolverine	BRR013			●	-18.8608	128.9469	20130412	No	Vertical	Uncased	Non-purged
Wolverine	BRRWS008			●	-18.8771	128.9828	20130817	No	Vertical	Cased (slotted)	Purged

Stygofauna Survey Effort and Bore Details (cont.)

Project Area	Bore Code	Impact		Non-Impact	Latitude	Longitude	Sample Date (YYYYMMDD)	Stygofauna Present	Inclination (°)	Casing details	Bore development
		Pit	Drawdown								
Wolverine	BRWD0007	●			-18.8592	128.9403	20121022	Yes	60	Uncased	Non-purged
Wolverine	BRWD0007	●			-18.8592	128.9403	20121022	Yes	60	Uncased	Non-purged
Wolverine	BRWD0007	●			-18.8592	128.9403	20130410	Yes	60	Uncased	Non-purged
Wolverine	BRWD0008	●			-18.8592	128.9404	20130815	No	60	Uncased	Non-purged
Wolverine	BRWD0008	●			-18.8592	128.9404	20130820	No	60	Uncased	Purged
Wolverine	BRWD0010	●			-18.8592	128.9411	20121023	Yes	60	Uncased	Non-purged
Wolverine	BRWD0010	●			-18.8592	128.9411	20130411	Yes	60	Uncased	Non-purged
Wolverine	BRWD0011	●			-18.8589	128.9411	20121023	No	60	Uncased	Non-purged
Wolverine	BRWD0011	●			-18.8589	128.9411	20130410	No	60	Uncased	Non-purged
Wolverine	BRWR0177	●			-18.8589	128.9389	20130410	No	60	Uncased	Non-purged
Wolverine	BRWR0181	●			-18.8592	128.9389	20130410	Yes	60	Uncased	Non-purged
Wolverine	BRWR0185		●		-18.8594	128.9378	20130416	No	60	Uncased	Non-purged
Wolverine	BRWR0187		●		-18.8594	128.9373	20130818	No	60	Uncased	Purged
Wolverine	BRWR0193		●		-18.8588	128.9364	20130818	No	60	Uncased	Purged
Wolverine	BRWR0196		●		-18.8589	128.9372	20130410	No	60	Uncased	Non-purged
Wolverine	BRWR0202	●			-18.8600	128.9383	20130416	No	60	Uncased	Non-purged
Wolverine	BRWR0208	●			-18.8594	128.9414	20130411	Yes	60	Uncased	Non-purged
Wolverine	BRWR0214	●			-18.8589	128.9419	20130411	No	60	Uncased	Non-purged
Wolverine	BRWR0216		●		-18.8594	128.9364	20130411	Yes	Vertical	Uncased	Non-purged
Wolverine	BRWR0217		●		-18.8597	128.9372	20130416	No	Vertical	Uncased	Non-purged
Wolverine	BRWR0222	●			-18.8592	128.9408	20130416	No	Vertical	Uncased	Non-purged
Wolverine	BRWR0223	●			-18.8592	128.9411	20130411	No	Vertical	Uncased	Non-purged
Wolverine	NMBRRC077	●			-18.8592	128.9406	20130410	Yes	60	Uncased	Non-purged
Wolverine	NMBRRC091		●		-18.8600	128.9425	20121023	Yes	60	Uncased	Non-purged
Wolverine	NMBRRC091		●		-18.8600	128.9425	20130815	Yes	60	Uncased	Non-purged
Wolverine	NMBRRC091		●		-18.8600	128.9425	20130820	No	60	Uncased	Purged
Wolverine	NMBRRC092		●		-18.8598	128.9426	20130819	Yes	60	Uncased	Purged
Wolverine	NMBRRC114	●			-18.8593	128.9395	20120516	Yes	60	Uncased	Non-purged
Wolverine	NMBRRC114	●			-18.8593	128.9395	20121023	Yes	60	Uncased	Non-purged
Wolverine	NMBRRC121	●			-18.8589	128.9394	20130410	No	60	Uncased	Non-purged
Wolverine	NMBRRD163	●			-18.8594	128.9393	20120516	No	60	Uncased	Non-purged

APPENDIX B

Groundwater Properties Data

Groundwater data.

Area	Site name	Sample Date	SWL (m bgl)	EoH (m bgl)	pH	EC (mS/cm)	Sal (ppt)	DO (mg L^{-1})	Redox (ORP mV)	Water Temp (°C)
Area 5 region	BRAR0019	9 Apr, 2013	31.5	57.6	7.1	0.6	0.26	1.88	111.0	27.3
Area 5 region	BRAR002	10 Apr, 2013	34.5	59.4	7.5	2.84	1.38	1.26	10.4	28.3
Area 5 region	BRAR0021	17 Aug, 2013	30.5	103.5	7.0	1.89	-	1.65	79.8	29.3
Area 5 region	BRAR005	9 Apr, 2013	31.6	136.0	7.2	2.28	1.03	2.19	112.0	31.6
Area 5 region	BRAR008	9 Apr, 2013	32.7	70.0	7.0	3.4	1.55	2.00	73.5	31.0
Area 5 region	BRAR012	9 Apr, 2013	37.3	74.7	7.1	1.6	0.71	2.74	96.7	30.8
Area 5 region	BRAR012	15 Aug, 2013	31.7	47.5	6.4	1.09	-	0.71	79.8	31.4
Area 5 region	BRAR012	20 Aug, 2013	31.6	47.5	6.6	1.27	-	5.12	6.2	30.9
Area 5 region	BRAR013	19 Aug, 2013	31.9	60.0	6.7	1.45	-	1.31	71.7	30.7
Area 5 region	BRAR023	10 Apr, 2013	33.8	65.7	7.4	2.28	1.05	2.11	93.5	29.5
Area 5 region	BRAR030	10 Apr, 2013	38.5	-	7.3	1.04	0.46	2.13	91.2	29.9
Area 5 region	BRAR030	15 Aug, 2013	33.5	56.5	6.9	1.69	-	0.85	-9.3	30.9
Area 5 region	BRAR030	20 Aug, 2013	34.7	56.5	6.9	1.7	-	1.26	100.3	31.1
Area 5 region	BRRWS003	17 Aug, 2013	27.7	150.0	6.8	1.02	-	0.61	60.0	28.2
Area 5 region	NMBRRC005	24 Oct, 2012	25.4	39.6	5.1	0.14	-	6.30	205.6	30.0
Area 5 region	NMBRRC008	22 Oct, 2012	15.8	48.6	4.7	0.07	-	7.02	198.7	31.2
Area 5 region	NMBRRC025	23 Oct, 2012	41.0	56.7	6.1	1.9	-	4.61	126.1	30.9
Area 5 region	NMBRRC027	24 Oct, 2012	39.0	47.7	6.7	0.18	-	7.10	149.1	30.0
Area 5 region	NMBRRC129	9 Apr, 2013	34.9	66.0	7.0	1.89	0.8	1.09	-28.2	31.4
Area 5 region	NMBRRC129	16 Aug, 2013	34.6	66.0	6.8	1.73	-	0.75	-7.9	30.7
Area 5 region	NMBRRC130	9 Apr, 2013	36.5	61.0	6.8	1.66	0.74	1.13	140.1	30.9
Area 5 region	NMBRRC130	15 Aug, 2013	36.4	51.5	6.6	1.77	-	0.44	-168.7	31.0
Area 5 region	NMBRRC137	23 Oct, 2012	39.5	52.2	5.6	0.37	-	3.76	111.8	32.3
Area 5 region	NMBRRC137	9 Apr, 2013	38.3	53.1	6.0	0.49	0.22	3.49	188.0	27.5
Area 5 region	NMBRRC139	9 Apr, 2013	37.2	51.3	6.9	1.04	0.45	0.99	139.9	31.3
Area 5 region	NMBRRC141	23 Oct, 2012	35.5	70.0	6.4	1.25	-	4.61	120.1	31.5
Area 5 region	NMBRRC141	9 Apr, 2013	35.3	63.0	7.0	1.85	0.83	2.15	191.2	31.0
Area 5 region	NMBRRC142	23 Oct, 2012	33.6	53.1	6.7	1.39	-	4.31	-10.9	32.7
Area 5 region	NMBRRC143	22 Oct, 2012	39.3	53.1	6.8	1.7	-	3.66	59.0	30.7
Area 5 region	NMBRRC153	22 Oct, 2012	38.7	56.7	6.8	1.24	-	6.05	80.8	30.6
Area 5 region	Monitoring Bore 01	20 Aug, 2013	40.0	55.5	6.8	1.26	-	3.91	116.0	29.7

Groundwater data (cont.).

Area	Site name	Sample Date	SWL (m bgl)	EoH (m bgl)	pH	EC (mS/cm)	Sal (ppt)	DO (mg L^{-1})	Redox (ORP mV)	Water Temp (°C)
Central Regional	BRR033	12 Apr, 2013	7.63	35.1	7.0	31.91	17.62	1.58	17.9	30.8
Central Regional	BRR035	24 Oct, 2012	11.75	31.5	6.8	24.25	-	4.12	120.6	29.6
Central Regional	BRR035	12 Apr, 2013	9.62	36.9	7.0	24.31	13.12	2.65	114.0	30.6
Central Regional	BRR037	12 Apr, 2013	10.89	40	6.8	28.03	15.94	1.63	140.4	28.8
Central Regional	BRR037	18 Aug, 2013	10.43	30.5	6.1	29.31	-	0.55	61.5	28.5
Central Regional	BRR038	24 Oct, 2012	8.36	22	6.9	31.40	-	5.63	115.5	30.0
Central Regional	BRR038	12 Apr, 2013	7.42	40	9.0	25.12	13.78	2.03	111.8	30.0
Central Regional	BRR039	16 Aug, 2013	16.2	26.5	6.7	19.09	-	1.45	90.5	30.2
Central Regional	BRR040	13 Apr, 2013	13.81	44.1	7.0	0.51	0.23	1.78	45.8	27.9
Central Regional	BRR040	15 Aug, 2013	13.5	40.5	6.9	0.96	-	0.42	49.2	30.5
Central Regional	BRR040	20 Aug, 2013	13.67	40.5	7.0	6.53	-	6.63	-112.5	30.9
Central Regional	BRR041	12 Apr, 2013	18.61	32.4	6.9	22.52	12.03	1.72	121.0	31.1
Central Regional	BRR042	18 Aug, 2013	9.95	48.5	6.7	39.21	-	1.48	105.3	30.5
Central Regional	BRRWS001	16 Aug, 2013	5.4	150	6.2	0.69	-	0.61	11.9	29.6
Gambit West	BRGR0098	15 Aug, 2013	13.2694	21.5	7.1	1.71	-	0.44	73.7	29.9
Gambit West	BRGR0117	18 Aug, 2013	7.8569	47.5	7.2	1.48	-	1.41	45.0	31.0
Gambit West	BRGR0120	18 Aug, 2013	6.73976	120	7.4	1.37	-	1.13	32.8	31.6
Gambit West	BRGR070	16 Apr, 2013	7.63812	11.7	7.2	0.81	0.35	1.65	-18.3	30.4
Gambit West	BRGR071	18 Aug, 2013	6.9	36.5	6.8	0.68	-	0.43	53.4	30.9
Gambit West	BRR006	17 Aug, 2013	16.1	36.5	7.2	1.80	-	0.66	55.1	30.1
Gambit East/Central	BRGR0012	14 Apr, 2013	13.3	20.7	4.8	0.13	0.06	-	234.9	30.6
Gambit East/Central	BRGR0016	14 Apr, 2013	6.4	73.8	5.8	0.32	0.13	2.52	160.4	31.0
Gambit East/Central	BRGR0016	16 Aug, 2013	6.0	38.5	7.2	0.31	-	3.28	50.7	29.2
Gambit East/Central	BRGR0020	17 Aug, 2013	6.0	54.5	6.8	0.42	-	1.13	71.1	30.6
Gambit East/Central	BRGR0025	15 Aug, 2013	9.3	27.9	6.7	0.62	-	0.64	65.5	31.6
Gambit East/Central	BRGR0030	14 Apr, 2013	8.1	118.0	6.4	0.19	0.08	3.06	56.0	30.6
Gambit East/Central	BRGR0037	17 Aug, 2013	9.3	16.0	6.7	0.66	-	3.92	65.5	31.5
Gambit East/Central	BRGR0043	14 Apr, 2013	13.1	38.7	5.3	0.17	0.07	1.96	114.0	29.6
Gambit East/Central	BRGR0082	14 Apr, 2013	8.7	73.8	6.7	0.79	0.34	1.74	131.8	30.6
Gambit East/Central	BRGR0083	17 Aug, 2013	14.3	59.5	7.2	1.03	-	1.17	41.0	31.1

Groundwater data (cont.).

Area	Site name	Sample Date	SWL (m bgl)	EoH (m bgl)	pH	EC (mS/cm)	Sal (ppt)	DO (mg L^{-1})	Redox (ORP mV)	Water Temp (°C)
Gambit East/Central	BRGR0147	18 Aug, 2013	8.7	45.5	7.2	-	-	1.53	44.2	31.1
Gambit East/Central	BRR008	13 Apr, 2013	11.2	46.0	7.2	0.607	0.22	1.88	55.4	30.5
Gambit East/Central	BRR008	15 Aug, 2013	20.1	43.5	6.3	0.52	-	0.82	82.2	30.1
Gambit East/Central	BRR008	20 Aug, 2013	20.1	43.5	6.5	0.7	-	2.28	85.5	30.1
Gambit East/Central	BRR009	16 Apr, 2013	22.0	40.0	7.4	0.4272	0.18	2.00	-94.8	29.9
Gambit East/Central	NMBRRC034	22 Oct, 2012	13.8	39.6	5.2	0.09	-	5.52	165.0	30.7
Gambit East/Central	NMBRRC037	13 Apr, 2013	21.7	36.9	5.9	0.1	0.04	1.84	206.3	31.2
Gambit East/Central	NMBRRC049	13 Apr, 2013	19.8	50.4	6.7	0.15	0.06	1.53	-99.1	29.9
Gambit East/Central	NMBRRC067	17 Aug, 2013	16.6	89.5	6.3	0.34	-	0.56	99.0	30.4
Gambit East/Central	NMBRRC070	17 Aug, 2013	9.8	22.5	5.8	0.21	-	3.28	193.5	30.9
Gambit East/Central	NMBRRC072	17 Aug, 2013	15.2	53.5	7.0	0.43	-	2.24	76.7	30.6
Gambit East/Central	NMBRRC093	14 Apr, 2013	11.7	32.4	6.3	0.25	0.107	1.19	-97.0	28.5
Gambit East/Central	NMBRRC094	22 Oct, 2012	10.3	85.5	6.4	0.55	-	5.47	98.0	30.6
Gambit East/Central	NMBRRC094	14 Apr, 2013	9.7	56.7	6.3	0.56	0.22	2.40	128.0	29.4
Gambit East/Central	NMBRRC098	25 Oct, 2012	8.9	67.5	6.3	0.40	-	2.81	96.3	29.5
Gambit East/Central	NMBRRC100	22 Oct, 2012	8.5	87.3	6.4	0.47	-	4.44	68.4	31.0
Gambit East/Central	NMBRRC109	22 Oct, 2012	20.1	56.7	4.5	0.17	-	4.84	218.3	31.3
Gambit East/Central	NMBRRC109	14 Apr, 2013	20.6	64.8	6.1	0.19	0.08	2.23	189.4	30.3
North-Western Regional	BRDD005	16 Apr, 2013	4.5	158.0	7.4	0.43	0.19	1.92	-59.2	30.7
North-Western Regional	BRR001	24 Oct, 2012	4.1	39.6	7.4	22.10	-	3.87	91.3	30.8
North-Western Regional	BRR001	13 Apr, 2013	6.6	35.1	7.4	9.82	5.06	1.36	73.9	29.1
North-Western Regional	BRR002	13-Apr-13	7.6	35.1	7.7	2.18	1	2.17	60.5	30.1
North-Western Regional	BRR002	17 Aug, 2013	7.3	39.5	7.6	2.07	-	1.28	41.0	31.0
North-Western Regional	BRR003	13 Apr, 2013	10.8	28.8	7.6	8.81	4.04	2.40	67.9	29.4
North-Western Regional	BRR003	19/08/2013	10.8	16.5	7.2	7.95		1.16	-192.2	30.5
North-Western Regional	BRR004	13 Apr, 2013	12.9	27.9	7.4	5.65	2.7	1.31	-174.6	30.9
North-Western Regional	BRR004	16 Aug, 2013	12.1	34.5	7.0	4.56	-	0.71	-91.1	30.3
North-Western Regional	BRR005	24 Oct, 2012	12.4	35.1	7.0	8.03	-	5.47	92.8	30.3
North-Western Regional	BRR005	13 Apr, 2013	13.8	36.0	7.1	7.86	3.8	1.90	44.1	31.2
Potential Borefield (GS)	BRRWS007	16 Aug, 2013	3.1	-	5.7	0.20	-	1.44	68.0	30.8
Potential Borefield (GS)	BRRWS010	16 Aug, 2013	8.9	83.5	5.2	0.07	-	1.41	239.5	30.7

Groundwater data (cont.).

Area	Site name	Sample Date	SWL (m bgl)	EoH (m bgl)	pH	EC (mS/cm)	Sal (ppt)	DO (mg L^{-1})	Redox (ORP mV)	Water Temp (°C)
Southern Regional	BRBR003	25 Oct, 2012	19.6	54.9	6.4	3.87	-	6.87	136.2	29.7
Southern Regional	BRBR005	25 Oct, 2012	23.5	28.8	7.0	11.10	-	4.53	142.4	29.2
Southern Regional	BRBR008	21 Oct, 2012	28.1	54.0	6.1	1.21	-	8.59	122.0	31.5
Southern Regional	BRBR013	15 Aug, 2013	24.7	89.5	6.4	2.54	-	1.68	79.9	31.4
Southern Regional	BRBR014	24 Oct, 2012	24.9	71.1	6.8	8.30	-	5.47	100.0	31.0
Southern Regional	BRBR016	24 Oct, 2012	24.0	71.1	6.9	8.24	-	4.38	101.6	30.2
Southern Regional	BRMR002	21 Oct, 2012	17.6	107.1	5.6	2.92	-	4.68	140.0	31.4
Southern Regional	BRMR002	11 Apr, 2013	16.3	63.0	6.3	0.16	0.07	1.91	110.1	30.3
Southern Regional	BRMR005	11 Apr, 2013	15.2	56.7	7.4	0.37	0.16	1.24	100.1	30.5
Southern Regional	BRMR006	21 Oct, 2012	15.7	67.5	6.6	0.32	-	1.90	110.8	31.5
Southern Regional	BRMR006	11 Apr, 2013	15.6	60.3	7.1	0.26	0.11	2.37	123.6	28.0
Southern Regional	BRMR008	11 Apr, 2013	-	69.3	6.6	0.34	0.14	1.67	38.6	30.2
Southern Regional	BRMR009	11 Apr, 2013	5.3	52.2	5.9	0.08	0.03	1.52	167.4	29.8
Southern Regional	BRMR010	21 Oct, 2012	14.7	96.3	6.7	0.33	-	4.90	107.8	31.4
Southern Regional	BRMR016	21 Oct, 2012	13.8	61.2	6.6	0.42	-	7.66	-71.2	32.1
Southern Regional	BRMR016	12 Apr, 2013	13.1	56.7	6.6	0.14	0.06	0.92	47.7	30.5
Southern Regional	BRMR021	12 Apr, 2013	-	61.0	7.6	0.41	0.18	1.52	57.6	29.6
Southern Regional	BRMR026	21 Oct, 2012	14.0	17.1	7.1	-	-	2.95	105.0	33.6
Southern Regional	BRMR026	12 Apr, 2013	7.5	17.1	6.5	0.19	0.08	1.85	-60.3	29.6
Southern Regional	BRMR027	15 Aug, 2013	12.1	63.0	7.6	0.89	-	0.56	-8.0	31.3
Southern Regional	BRRWS002	16 Aug, 2013	26.6	150.0	7.4	2.01	-	2.91	37.4	31.7
Southern Regional	Old Camp Bore	15 Aug, 2013	22.6	34.5	7.3	1.55	-	0.38	37.2	31.4
Wolverine	BRR010	25 Oct, 2012	23.8	40.5	6.8	1.51	-	3.55	100.1	30.1
Wolverine	BRR010	14 Apr, 2013	10.6	40.5	6.9	1.56	0.71	1.35	113.3	30.0
Wolverine	BRR010	16 Aug, 2013	22.6	37.5	6.8	1.53	-	0.77	64.0	30.2
Wolverine	BRR011	19 Aug, 2013	13.1	38.5	7.1	1.17	-	0.71	-95.3	29.0
Wolverine	BRR012	12 Apr, 2013	2.8	35.1	6.5	0.42	0.18	1.53	105.0	28.8
Wolverine	BRR013	25 Oct, 2012	1.8	2.7	6.0	0.18	-	5.25	1.3	27.3
Wolverine	BRR013	12 Apr, 2013	2.2	-	6.9	0.31	0.13	0.09	-4.5	30.2
Wolverine	BRRWS008	17 Aug, 2013	30.1	150.0	6.7	3.07	-	0.74	-14.5	28.2

Groundwater data (cont.).

Area	Site name	Sample Date	SWL (mbgl)	EoH (mbgl)	pH	EC (mS/cm)	Sal (ppt)	DO (mg L^{-1})	Redox (ORP mV)	Water Temp (°C)
Wolverine	BRWD0007	22 Oct, 2012	3.3	45.9	6.6	0.28	-	6.48	-98.5	28.2
Wolverine	BRWD0007	10 Apr, 2013	3.4	-	6.8	0.32	0.14	1.66	49.1	29.0
Wolverine	BRWD0008	15 Aug, 2013	5.7	47.5	6.6	0.40	-	0.63	-122.9	29.4
Wolverine	BRWD0008	20 Aug, 2013	6.0	47.5	6.5	0.38	-	3.08	44.3	29.5
Wolverine	BRWD0010	23 Oct, 2012	5.4	18.0	6.3	0.27	-	2.63	-3.0	28.6
Wolverine	BRWD0010	11 Apr, 2013	5.9	19.8	5.3	0.14	0.06	1.45	193.7	27.8
Wolverine	BRWD0011	23 Oct, 2012	5.2	28.8	7.0	0.30	-	5.79	-22.1	27.3
Wolverine	BRWD0011	10 Apr, 2013	7.6	26.1	6.3	0.33	0.14	1.53	-84.1	29.1
Wolverine	BRWR0177	10 Apr, 2013	6.1	75.6	6.8	0.59	0.26	2.40	133.8	28.9
Wolverine	BRWR0181	10 Apr, 2013	6.4	17.1	6.4	0.44	0.19	3.95	139.7	29.2
Wolverine	BRWR0185	16 Apr, 2013	6.4	57.6	6.7	0.34	0.14	2.35	117.7	30.4
Wolverine	BRWR0187	18 Aug, 2013	7.6	144.0	7.4	0.43	-	3.08	80.4	28.4
Wolverine	BRWR0193	18 Aug, 2013	14.5	57.5	6.7	0.55	-	1.76	94.6	29.3
Wolverine	BRWR0196	10 Apr, 2013	8.9	14.4	6.6	0.55	0.24	1.43	92.0	30.6
Wolverine	BRWR0202	16 Apr, 2013	6.8	70.0	6.7	0.74	0.33	4.30	100.7	30.9
Wolverine	BRWR0208	11 Apr, 2013	6.3	75.6	4.8	0.10	0.04	1.56	195.9	29.2
Wolverine	BRWR0214	11 Apr, 2013	7.2	85.5	5.8	0.13	0.05	1.38	-58.8	29.8
Wolverine	BRWR0216	11 Apr, 2013	12.0	51.3	6.5	0.73	0.32	3.48	70.5	30.2
Wolverine	BRWR0217	16 Apr, 2013	5.9	40.0	6.4	0.39	0.16	1.49	110.6	31.9
Wolverine	BRWR0222	16 Apr, 2013	9.8	53.1	7.1	0.24	0.10	3.49	117.7	31.6
Wolverine	BRWR0223	11 Apr, 2013	6.1	17.1	6.0	0.16	0.07	1.56	-17.0	27.5
Wolverine	NMBRRC077	10 Apr, 2013	6.2	73.0	5.9	0.15	0.06	1.86	138.6	30.9
Wolverine	NMBRRC091	23 Oct, 2012	14.7	54.0	5.2	0.21	-	3.75	215.2	30.7
Wolverine	NMBRRC091	15 Aug, 2013	15.8	55.6	5.0	0.21	-	1.47	217.5	-
Wolverine	NMBRRC092	19 Aug, 2013	16.2	58.0	5.0	0.17	-	1.88	230.2	31.4
Wolverine	NMBRRC114	23 Oct, 2012	3.0	67.0	5.5	0.06	-	5.48	181.6	28.1
Wolverine	NMBRRC121	10 Apr, 2013	4.9	58.5	6.4	0.47	0.20	3.53	120.8	31.5

APPENDIX D

Troglofauna litter trap and scrape survey effort

Troglofauna litter trap and scrape survey effort

Project Area	Bore Code	Impact		Non-Impact	Latitude	Longitude	Sample Date		Sample Method	Troglofauna Present
		Pit	Groundwater Drawdown				Start (YYYYMMDD)	End (YYYYMMDD)		
Area 5	BRAR002		●		-18.9017	128.9264	20130410	20130410	Scrape	No
Area 5	BRAR0021		●		-18.9028	128.9262	20130817	20130817	Scrape	No
Area 5	BRAR005	●			-18.9028	128.9253	20130409	20130409	Scrape	No
Area 5	BRAR008	●			-18.9022	128.9264	20130409	20130409	Scrape	No
Area 5	BRAR012	●			-18.9028	128.9256	20130409	20130409	Scrape	No
Area 5	BRAR012	●			-18.9028	128.9256	20130815	20130815	Scrape	No
Area 5	BRAR012	●			-18.9028	128.9256	20130820	20130820	Scrape	No
Area 5	BRAR013	●			-18.9021	128.9265	20130819	20130819	Scrape	No
Area 5	BRAR019	●			-18.9025	128.9264	20130409	20130409	Scrape	No
Area 5	BRAR023		●		-18.9031	128.9258	20130410	20130410	Scrape	No
Area 5	BRAR030	●			-18.9019	128.9247	20130410	20130410	Scrape	No
Area 5	BRAR030	●			-18.9019	128.9247	20130815	20130815	Scrape	No
Area 5	BRAR030	●			-18.9019	128.9247	20130820	20130820	Scrape	No
Area 5	BRRWS003			●	-18.8932	128.9314	20130817	20130817	Scrape	No
Area 5	NMBRRC005			●	-18.8989	128.9283	20121024	20121024	Scrape	No
Area 5	NMBRRC008			●	-18.8986	128.9281	20121022	20121022	Scrape	No
Area 5	NMBRRC008			●	-18.8986	128.9281	20121022	20121208	Trap	No
Area 5	NMBRRC025			●	-18.8978	128.9272	20121023	20121023	Scrape	No
Area 5	NMBRRC027			●	-18.8975	128.9275	20121024	20121024	Scrape	No
Area 5	NMBRRC129	●			-18.9019	128.9253	20130816	20130816	Scrape	No
Area 5	NMBRRC130	●			-18.9019	128.9256	20130816	20130816	Scrape	No
Area 5	NMBRRC137	●			-18.9017	128.9250	20121023	20121023	Scrape	No
Area 5	NMBRRC137	●			-18.9017	128.9250	20130409	20130409	Scrape	No
Area 5	NMBRRC139	●			-18.9017	128.9247	20130409	20130409	Scrape	No
Area 5	NMBRRC141	●			-18.9022	128.9258	20121023	20121023	Scrape	No
Area 5	NMBRRC141	●			-18.9022	128.9258	20130409	20130409	Scrape	No
Area 5	NMBRRC142	●			-18.9025	128.9256	20121023	20121023	Scrape	No
Area 5	NMBRRC143	●			-18.9011	128.9247	20121022	20121022	Scrape	No
Area 5	NMBRRC143	●			-18.9011	128.9247	20121022	20121207	Trap	No
Area 5	NMBRRC153			●	-18.8997	128.9236	20121022	20121207	Trap	No
Area 5	NMBRRC137	●			-18.9017	128.9250	20121023	20121207	Trap	No
Area 5	NMBRRC141	●			-18.9022	128.9258	20121023	20121207	Trap	No
Area 5	NMBRRC142	●			-18.9025	128.9256	20121023	20121207	Trap	No
Area 5	NMBRRC145	●			-18.9008	128.9250	20121023	20121207	Trap	No
Area 5	NMBRRC153		●		-18.8997	128.9236	20121022	20121022	Scrape	No
Area 5	NMBRRC154		●		-18.9000	128.9236	20121023	20121207	Trap	No
Area 5	NMBRRC005			●	-18.8989	128.9283	20121024	20121208	Trap	No
Area 5	NMBRRC027			●	-18.8975	128.9275	20121024	20121208	Trap	No

Troglofauna litter trap and scrape survey effort (cont.).

Project Area	Bore Code	Impact		Non-Impact	Latitude	Longitude	Sample Date		Sample Method	Troglofauna Present
		Pit	Groundwater Drawdown				Start (YYYYMMDD)	End (YYYYMMDD)		
Central Regional	BRR033			●	-18.9394	128.9014	20130412	20130412	Scrape	No
Central Regional	BRR035			●	-18.9450	128.9050	20121024	20121024	Scrape	No
Central Regional	BRR035			●	-18.9450	128.9050	20130412	20130412	Scrape	No
Central Regional	BRR037			●	-18.9439	128.9056	20130412	20130412	Scrape	No
Central Regional	BRR037			●	-18.9439	128.9056	20130818	20130818	Scrape	No
Central Regional	BRR038			●	-18.9392	128.9047	20121024	20121024	Scrape	No
Central Regional	BRR038			●	-18.9392	128.9047	20130412	20130412	Scrape	No
Central Regional	BRR039			●	-18.9181	128.9214	20130816	20130816	Scrape	No
Central Regional	BRR040			●	-18.9286	128.9214	20130413	20130413	Scrape	No
Central Regional	BRR040			●	-18.9286	128.9214	20130413	20130413	Scrape	No
Central Regional	BRR040			●	-18.9286	128.9214	20130815	20130815	Scrape	No
Central Regional	BRR040			●	-18.9286	128.9214	20130820	20130820	Scrape	No
Central Regional	BRR040			●	-18.9286	128.9214	20131217	20131217	Scrape	Yes
Central Regional	BRR041			●	-18.9328	128.9211	20130412	20130412	Scrape	No
Central Regional	BRR042			●	-18.9443	128.9224	20130818	20130818	Scrape	No
Gambit Central	BRGR0020		●		-18.8678	128.9407	20130817	20130817	Scrape	No
Gambit Central	BRGR0025	●			-18.8679	128.9393	20130815	20130815	Scrape	No
Gambit Central	BRGR0037	●			-18.8678	128.9385	20130817	20130817	Scrape	No
Gambit Central	BRGR0082		●		-18.8686	128.9386	20130414	20130414	Scrape	No
Gambit Central	BRGR0083		●		-18.8689	128.9385	20130817	20130817	Scrape	No
Gambit Central	BRGR0147	●			-18.8680	128.9388	20130818	20130818	Scrape	No
Gambit Central	NMBRRC070	●			-18.8686	128.9397	20130817	20130817	Scrape	No
Gambit Central	NMBRRC072		●		-18.8691	128.9397	20130817	20130817	Scrape	No
Gambit Central	NMBRRC093	●			-18.8681	128.9394	20130414	20130414	Scrape	No
Gambit Central	NMBRRC093	●			-18.8681	128.9394	20131217	20131217	Scrape	No
Gambit Central	NMBRRC094	●			-18.8681	128.9397	20121022	20121022	Scrape	No
Gambit Central	NMBRRC094	●			-18.8681	128.9397	20130414	20130414	Scrape	No
Gambit Central	NMBRRC095		●		-18.8664	128.9403	20120314	20120508	Trap	No
Gambit Central	NMBRRC098	●			-18.8683	128.9392	20121025	20121025	Scrape	No
Gambit Central	NMBRRC098	●			-18.8683	128.9392	20120314	20120508	Trap	No
Gambit Central	NMBRRC100	●			-18.8689	128.9392	20120314	20120508	Trap	No
Gambit Central	NMBRRC101	●			-18.8681	128.9386	20120314	20120508	Trap	No
Gambit Central	NMBRRC100	●			-18.8689	128.9392	20120807	20120921	Trap	No
Gambit Central	NMBRRC101	●			-18.8681	128.9386	20120807	20120921	Trap	No
Gambit Central	NMBRRC094	●			-18.8681	128.9397	20120810	20120925	Trap	No
Gambit Central	NMBRRC096	●			-18.8675	128.9394	20120810	20120925	Trap	No
Gambit Central	NMBRRC094	●			-18.8681	128.9397	20121022	20121209	Trap	No
Gambit Central	NMBRRC098	●			-18.8683	128.9392	20121025	20121209	Trap	No

Troglofauna litter trap and scrape survey effort (cont.).

Project Area	Bore Code	Impact		Non-Impact	Latitude	Longitude	Sample Date		Sample Method	Troglofauna Present
		Pit	Groundwater Drawdown				Start (YYYYMMDD)	End (YYYYMMDD)		
Gambit East	BRGR0012	●			-18.8683	128.9417	20130414	20130414	Scrape	No
Gambit East	BRGR0016		●		-18.8678	128.9411	20130414	20130414	Scrape	No
Gambit East	BRGR0016		●		-18.8678	128.9411	20130816	20130816	Scrape	No
Gambit East	BRGR0030		●		-18.8669	128.9436	20130414	20130414	Scrape	No
Gambit East	BRGR0043			●	-18.8675	128.9444	20130414	20130414	Scrape	No
Gambit East	BRR008			●	-18.8711	128.9436	20130413	20130413	Scrape	No
Gambit East	BRR008			●	-18.8711	128.9436	20130815	20130815	Scrape	Yes
Gambit East	BRR008			●	-18.8711	128.9436	20130820	20130820	Scrape	No
Gambit East	BRR009			●	-18.8711	128.9447	20130416	20130416	Scrape	No
Gambit East	NMBRRC034			●	-18.8683	128.9447	20121022	20121022	Scrape	No
Gambit East	NMBRRC036			●	-18.8681	128.9447	20120314	20120508	Trap	No
Gambit East	NMBRRC037			●	-18.8678	128.9444	20130413	20130413	Scrape	No
Gambit East	NMBRRC039		●		-18.8681	128.9442	20120314	20120508	Trap	No
Gambit East	NMBRRC043	●			-18.8681	128.9436	20120314	20120508	Trap	No
Gambit East	NMBRRC047	●			-18.8678	128.9431	20120314	20120508	Trap	No
Gambit East	NMBRRC036			●	-18.8681	128.9447	20120807	20120921	Trap	No
Gambit East	NMBRRC039		●		-18.8681	128.9442	20120807	20120921	Trap	No
Gambit East	NMBRRC043	●			-18.8681	128.9436	20120807	20120921	Trap	No
Gambit East	NMBRRC047	●			-18.8678	128.9431	20120807	20120921	Trap	No
Gambit East	NMBRRC049	●			-18.8681	128.9431	20130413	20130413	Scrape	No
Gambit East	NMBRRC049	●			-18.8681	128.9431	20131217	20131217	Scrape	No
Gambit East	NMBRRC067	●			-18.8689	128.9421	20130817	20130817	Scrape	No
Gambit East	NMBRRC100	●			-18.8689	128.9392	20121022	20121022	Scrape	No
Gambit East	NMBRRC109		●		-18.8678	128.9439	20121022	20121022	Scrape	No
Gambit East	NMBRRC109		●		-18.8678	128.9439	20130414	20130414	Scrape	No
Gambit East	NMBRRC109		●		-18.8678	128.9439	20121022	20121209	Trap	No
Gambit West	BRGR0098	●			-18.8689	128.9349	20130416	20130416	Scrape	No
Gambit West	BRGR0117	●			-18.8689	128.9359	20130818	20130818	Scrape	No
Gambit West	BRGR0120	●			-18.8690	128.9366	20130818	20130818	Scrape	No
Gambit West	BRGR070		●		-18.8689	128.9369	20130416	20130416	Scrape	No
Gambit West	BRGR071		●		-18.8685	128.9369	20130818	20130818	Scrape	No
Gambit West	BRR006		●		-18.8714	128.9328	20130817	20130817	Scrape	No

Troglofauna litter trap and scrape survey effort (cont.).

Project Area	Bore Code	Impact		Non-Impact	Latitude	Longitude	Sample Date		Sample Method	Troglofauna Present
		Pit	Groundwater Drawdown				Start (YYYYMMDD)	End (YYYYMMDD)		
North-Western Regional	BRDD005			●	-18.8500	128.9333	20130416	20130416	Scrape	No
North-Western Regional	BRR001			●	-18.8533	128.9075	20121024	20121024	Scrape	No
North-Western Regional	BRR001			●	-18.8533	128.9075	20130413	20130413	Scrape	No
North-Western Regional	BRR002			●	-18.8569	128.9127	20130413	20130413	Scrape	No
North-Western Regional	BRR002			●	-18.8569	128.9127	20130817	20130817	Scrape	No
North-Western Regional	BRR003			●	-18.8621	128.9127	20130413	20130413	Scrape	No
North-Western Regional	BRR003			●	-18.8621	128.9127	20130819	20130819	Scrape	No
North-Western Regional	BRR003			●	-18.8621	128.9127	20131217	20131217	Scrape	Yes
North-Western Regional	BRR004			●	-18.8700	128.9192	20130413	20130413	Scrape	No
North-Western Regional	BRR004			●	-18.8700	128.9192	20130816	20130816	Scrape	No
North-Western Regional	BRR005			●	-18.8719	128.9231	20121024	20121024	Scrape	No
North-Western Regional	BRR005			●	-18.8719	128.9231	20130413	20130413	Scrape	No
Southern Regional	BRBR003			●	-18.9550	128.9303	20121025	20121025	Scrape	No
Southern Regional	BRBR005			●	-18.9547	128.9303	20121025	20121025	Scrape	No
Southern Regional	BRBR007			●	-18.9567	128.9297	20121021	20121208	Trap	No
Southern Regional	BRBR008			●	-18.9564	128.9297	20121021	20121021	Scrape	No
Southern Regional	BRBR013			●	-18.9554	128.9297	20130815	20130815	Scrape	No
Southern Regional	BRBR014			●	-18.9553	128.9297	20121024	20121024	Scrape	No
Southern Regional	BRBR016			●	-18.9547	128.9297	20121024	20121024	Scrape	No
Southern Regional	BRMR002			●	-18.9653	128.9372	20121021	20121021	Scrape	No
Southern Regional	BRMR002			●	-18.9653	128.9372	20130411	20130411	Scrape	No
Southern Regional	BRMR002			●	-18.9653	128.9372	20121021	20121208	Trap	No
Southern Regional	BRMR003			●	-18.9647	128.9372	20121021	20121208	Trap	No
Southern Regional	BRMR005			●	-18.9644	128.9378	20130411	20130411	Scrape	No
Southern Regional	BRMR006			●	-18.9647	128.9378	20121021	20121021	Scrape	No
Southern Regional	BRMR006			●	-18.9647	128.9378	20130411	20130411	Scrape	No
Southern Regional	BRMR006			●	-18.9647	128.9378	20121021	20121208	Trap	No
Southern Regional	BRMR008			●	-18.9650	128.9372	20130411	20130411	Scrape	No
Southern Regional	BRMR009			●	-18.9650	128.9375	20130411	20130411	Scrape	No
Southern Regional	BRMR010			●	-18.9644	128.9375	20121021	20121021	Scrape	No
Southern Regional	BRMR010			●	-18.9644	128.9375	20121021	20121208	Trap	No
Southern Regional	BRMR016			●	-18.9652	128.9369	20121021	20121021	Scrape	No
Southern Regional	BRMR016			●	-18.9652	128.9369	20130412	20130412	Scrape	No
Southern Regional	BRMR016			●	-18.9652	128.9369	20121021	20121208	Trap	No
Southern Regional	BRMR017			●	-18.9653	128.9364	20121021	20121208	Trap	No
Southern Regional	BRMR021			●	-18.9642	128.9369	20130412	20130412	Scrape	No
Southern Regional	BRMR026			●	-18.9642	128.9364	20121021	20121021	Scrape	No
Southern Regional	BRMR026			●	-18.9642	128.9364	20130412	20130412	Scrape	No

Troglofauna litter trap and scrape survey effort (cont.).

Project Area	Bore Code	Impact		Non-Impact	Latitude	Longitude	Sample Date		Sample Method	Troglofauna Present
		Pit	Groundwater Drawdown				Start (YYYYMMDD)	End (YYYYMMDD)		
Southern Regional	BRMR026			●	-18.9642	128.9364	20121021	20121208	Trap	No
Southern Regional	BRMR027			●	-18.9641	128.9364	20130815	20130815	Scrape	No
Southern Regional	BRBR014			●	-18.9553	128.9297	20121024	20121208	Trap	No
Southern Regional	BRBR016			●	-18.9547	128.9297	20121024	20121208	Trap	No
Southern Regional	BRBR001			●	-18.9556	128.9302	20121025	20121208	Trap	No
Southern Regional	BRBR003			●	-18.9550	128.9303	20121025	20121208	Trap	No
Southern Regional	BRBR004			●	-18.9550	128.9303	20121025	20121208	Trap	No
Southern Regional	BRBR005			●	-18.9547	128.9303	20121025	20121208	Trap	No
Wolverine	BRR010			●	-18.8606	128.9536	20121025	20121025	Scrape	No
Wolverine	BRR010			●	-18.8606	128.9536	20130414	20130414	Scrape	No
Wolverine	BRR010			●	-18.8606	128.9536	20130816	20130816	Scrape	No
Wolverine	BRR011			●	-18.8577	128.9526	20130819	20130819	Scrape	No
Wolverine	BRR012		●		-18.8617	128.9450	20130412	20130412	Scrape	No
Wolverine	BRR013			●	-18.8608	128.9469	20121025	20121025	Scrape	No
Wolverine	BRR013			●	-18.8608	128.9469	20130412	20130412	Scrape	No
Wolverine	BRRWS008			●	-18.8771	128.9828	20130817	20130817	Scrape	No
Wolverine	BRWD0007	●			-18.8592	128.9403	20121022	20121022	Scrape	No
Wolverine	BRWD0007	●			-18.8592	128.9403	20121022	20121022	Scrape	No
Wolverine	BRWD0007	●			-18.8592	128.9403	20130410	20130410	Scrape	No
Wolverine	BRWD0008	●			-18.8592	128.9404	20130815	20130815	Scrape	No
Wolverine	BRWD0008	●			-18.8592	128.9404	20130820	20130820	Scrape	No
Wolverine	BRWD0010	●			-18.8592	128.9411	20121023	20121023	Scrape	No
Wolverine	BRWD0010	●			-18.8592	128.9411	20130411	20130411	Scrape	No
Wolverine	BRWD0011	●			-18.8589	128.9411	20121023	20121023	Scrape	No
Wolverine	BRWD0011	●			-18.8589	128.9411	20130410	20130410	Scrape	No
Wolverine	BRWR0177	●			-18.8589	128.9389	20130410	20130410	Scrape	No
Wolverine	BRWR0181	●			-18.8592	128.9389	20130410	20130410	Scrape	No
Wolverine	BRWR0185		●		-18.8594	128.9378	20130416	20130416	Scrape	No
Wolverine	BRWR0187		●		-18.8594	128.9373	20130818	20130818	Scrape	No
Wolverine	BRWR0193		●		-18.8588	128.9364	20130818	20130818	Scrape	No
Wolverine	BRWR0196		●		-18.8589	128.9372	20130410	20130410	Scrape	No
Wolverine	BRWR0202	●			-18.8600	128.9383	20130416	20130416	Scrape	No
Wolverine	BRWR0208	●			-18.8594	128.9414	20130411	20130411	Scrape	No
Wolverine	BRWR0214	●			-18.8589	128.9419	20130411	20130411	Scrape	No
Wolverine	BRWR0216		●		-18.8594	128.9364	20130411	20130411	Scrape	No
Wolverine	BRWR0217		●		-18.8597	128.9372	20130416	20130416	Scrape	No
Wolverine	BRWR0222	●			-18.8592	128.9408	20130416	20130416	Scrape	No
Wolverine	BRWR0223	●			-18.8592	128.9411	20130411	20130411	Scrape	No

Troglofauna litter trap and scrape survey effort (cont.).

Project Area	Bore Code	Impact		Non-Impact	Latitude	Longitude	Sample Date		Sample Method	Troglofauna Present
		Pit	Groundwater Drawdown				Start (YYYYMMDD)	End (YYYYMMDD)		
Wolverine	NMBRRC077	●			-18.8592	128.9406	20130410	20130410	Scrape	No
Wolverine	NMBRRC091		●		-18.8600	128.9425	20121023	20121023	Scrape	No
Wolverine	NMBRRC091		●		-18.8600	128.9425	20130815	20130815	Scrape	No
Wolverine	NMBRRC091		●		-18.8600	128.9425	20130820	20130820	Scrape	No
Wolverine	NMBRRC092		●		-18.8598	128.9426	20130819	20130819	Scrape	No
Wolverine	NMBRRC114	●			-18.8593	128.9395	20120516	20120516	Scrape	No
Wolverine	NMBRRC114	●			-18.8593	128.9395	20121023	20121023	Scrape	No
Wolverine	NMBRRC121	●			-18.8589	128.9394	20130410	20130410	Scrape	No
Wolverine	NMBRRD163	●			-18.8594	128.9393	20120516	20120516	Scrape	No
Wolverine	NMBRRC076	●			-18.8594	128.9406	20120314	20120510	Trap	No
Wolverine	NMBRRC085	●			-18.8594	128.9411	20120314	20120508	Trap	No
Wolverine	NMBRRC087	●			-18.8597	128.9414	20120314	20120510	Trap	No
Wolverine	NMBRRC090	●			-18.8597	128.9419	20120314	20120510	Trap	No
Wolverine	NMBRRC091		●		-18.8600	128.9425	20120314	20120510	Trap	No
Wolverine	NMBRRC118	●			-18.8592	128.9389	20120314	20120510	Trap	No
Wolverine	NMBRRC123	●			-18.8589	128.9400	20120314	20120510	Trap	No
Wolverine	NMBRRD156	●			-18.8589	128.9408	20120314	20120510	Trap	No
Wolverine	BRWD0007	●			-18.8592	128.9403	20121022	20121209	Trap	No
Wolverine	BRWD0010	●			-18.8592	128.9411	20121023	20121209	Trap	No
Wolverine	BRWD0011	●			-18.8589	128.9411	20121023	20121209	Trap	No
Wolverine	BRWR0178	●			-18.8589	128.9389	20121023	20121209	Trap	No
Wolverine	BRWR0204	●			-18.8592	128.9383	20121023	20121209	Trap	No
Wolverine	NMBRRC091		●		-18.8600	128.9425	20121023	20121209	Trap	No
Wolverine	NMBRRC114	●			-18.8592	128.9394	20121023	20121209	Trap	No
Wolverine	BRR010			●	-18.8606	128.9536	20121025	20121209	Trap	No

APPENDIX D

Stygofauna survey results arranged by taxon

Stygofauna results arranged by taxon.

Higher level	Family	Taxon ID	Project Area	Bore Code	Impact?	Sample Date	No. of individuals
Bathynellacea	Bathynellidae	Bathynellidae-OES19	Wolverine	BRWD0007	Yes	10/04/2013	57
Bathynellacea	Bathynellidae	Bathynellidae-OES19	Wolverine	BRWR0181	Yes	10/04/2013	2
Bathynellacea	Bathynellidae	Bathynellidae-OES19	Wolverine	NMBRRC077	Yes	10/04/2013	26
Bathynellacea	Bathynellidae	Bathynellidae-OES19	Wolverine	NMBRRC091	Yes	23/10/2012	1
Bathynellacea	Bathynellidae	Bathynellidae-OES19	Wolverine	NMBRRC114	Yes	23/10/2012	15
Bathynellacea	Bathynellidae	Bathynellidae-OES24	Area 5	BRAR012	Yes	9/04/2013	3
Bathynellacea	Bathynellidae	Bathynellidae-OES25	Gambit Central	NMBRRC093	Yes	14/04/2013	13
Bathynellacea	Bathynellidae	Bathynellidae-OES26	Gambit Central	BRGR0083	Yes	17/08/2013	5
Bathynellacea	Bathynellidae	Bathynellidae-OES26	North-Western Regional	BRR003	No	19/08/2013	2
Bathynellacea	Bathynellidae	Bathynellidae-OES27	Central Regional	BRR040	No	17/12/2013	1
Bathynellacea	Bathynellidae	Bathynellidae-OES27	Proposed Borefield (GS)	BRRWS010	Yes	17/12/2013	11
Bathynellacea	Parabathynellidae	Parabathynellidae-OES16	Area 5	NMBRRC005	No	24/10/2012	35
Bathynellacea	Parabathynellidae	Parabathynellidae-OES17	Southern Regional	BRBR016	No	24/10/2012	1
Bathynellacea	Parabathynellidae	Parabathynellidae-OES17	Wolverine	BRWD0007	Yes	10/04/2013	44
Bathynellacea	Parabathynellidae	Parabathynellidae-OES17	Wolverine	BRWD0010	Yes	11/04/2013	1
Bathynellacea	Parabathynellidae	Parabathynellidae-OES17	Wolverine	BRWR0208	Yes	11/04/2013	6
Bathynellacea	Parabathynellidae	Parabathynellidae-OES17	Wolverine	NMBRRC077	Yes	10/04/2013	58
Bathynellacea	Parabathynellidae	Parabathynellidae-OES17	Wolverine	NMBRRC091	Yes	23/10/2012	4
Bathynellacea	Parabathynellidae	Parabathynellidae-OES17	Wolverine	NMBRRC091	Yes	15/08/2013	10
Bathynellacea	Parabathynellidae	Parabathynellidae-OES17	Wolverine	NMBRRC092	Yes	19/08/2013	1
Bathynellacea	Parabathynellidae	Parabathynellidae-OES17	Wolverine	NMBRRC114	Yes	23/10/2012	31
Bathynellacea	Parabathynellidae	Parabathynellidae-OES18	Wolverine	BRWD0007	Yes	22/10/2012	5
Bathynellacea	Parabathynellidae	Parabathynellidae-OES18	Wolverine	BRWR0181	Yes	10/04/2013	21
Bathynellacea	Parabathynellidae	Parabathynellidae-OES20	Gambit Central	NMBRRC093	Yes	14/04/2013	14
Bathynellacea	Parabathynellidae	Parabathynellidae-OES20	Wolverine	NMBRRC114	Yes	16/05/2012	1
Bathynellacea	Parabathynellidae	Parabathynellidae-OES21	Gambit East	NMBRRC037	No	13/04/2013	1
Bathynellacea	Parabathynellidae	Parabathynellidae-OES21	Gambit East	NMBRRC049	No	13/04/2013	3
Bathynellacea	Parabathynellidae	Parabathynellidae-OES22	Gambit East	BRR008	No	13/04/2013	24
Bathynellacea	Parabathynellidae	Parabathynellidae-OES22	Gambit East	BRR008	No	15/08/2013	21
Bathynellacea	Parabathynellidae	Parabathynellidae-OES22	Gambit East	BRR008	No	20/08/2013	4
Bathynellacea	Parabathynellidae	Parabathynellidae-OES22	Proposed Borefield (GS)	BRRWS010	Yes	16/08/2013	1
Bathynellacea	Parabathynellidae	Parabathynellidae-OES22	Proposed Borefield (GS)	BRRWS010	Yes	17/12/2013	1
Bathynellacea	Parabathynellidae	Parabathynellidae-OES23	Southern Regional	BRMR006	No	11/04/2013	2

Stygofauna results arranged by taxon (cont.).

Higher level	Family	Taxon ID	Project Area	Bore Code	Impact?	Sample Date	No. of individuals
Bathynellacea	Parabathynellidae	Parabathynellidae-OES23	Southern Regional	BRMR009	No	11/04/2013	700
Bathynellacea	Parabathynellidae	Parabathynellidae-OES23	Southern Regional	BRMR026	No	12/04/2013	1
Bathynellacea	Parabathynellidae	Parabathynellidae-OES26	Area 5	BRAR012	Yes	9/04/2013	6
Bathynellacea	Parabathynellidae	Parabathynellidae-OES26	Area 5	BRAR012	Yes	15/08/2013	1
Bathynellacea	Parabathynellidae	Parabathynellidae-OES27	Area 5	BRAR030	Yes	10/04/2013	3
Bathynellacea	Parabathynellidae	Parabathynellidae-OES28	Central Regional	BRR040	No	13/04/2013	95
Bathynellacea	Parabathynellidae	Parabathynellidae-OES28	Central Regional	BRR040	No	15/08/2013	1
Bathynellacea	Parabathynellidae	Parabathynellidae-OES28	Central Regional	BRR040	No	20/08/2013	2
Copepoda: Cyclopoida	Cyclopidae	*Dussartcyclops-OES2*	Proposed Borefield (GS)	BRRWS010	Yes	17/12/2013	1
Copepoda: Cyclopoida	Cyclopidae	*Metacyclops* OES20	Wolverine	BRWD0007	Yes	10/04/2013	18
Copepoda: Cyclopoida	Cyclopidae	*Metacyclops* OES20	Wolverine	NMBRRC077	Yes	10/04/2013	5
Copepoda: Cyclopoida	Cyclopidae	*Microcyclops varicans*	Southern Regional	BRMR016	No	12/04/2013	2
Copepoda: Cyclopoida	Cyclopidae	*Microcyclops varicans*	Southern Regional	BRMR027	No	12/04/2013	1
Copepoda: Harpacticoida	Ameiridae	*Megastygonitocrella bispinosa*	North-Western Regional	BRR003	No	19/08/2013	2
Copepoda: Harpacticoida	Parastenocarididae	*Parastenocaris* -OES1	Proposed Borefield (GS)	BRRWS010	Yes	17/12/2013	22
Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	Area 5	BRAR0021	Yes	17/08/2013	1
Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	Area 5	Monitoring Bore 01	Yes	20/08/2013	1
Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	Central Regional	BRR035	No	24/10/2012	1
Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	Central Regional	BRR040	No	13/04/2013	8
Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	Central Regional	BRR040	No	15/08/2013	8
Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	Gambit East	BRR009	No	16/04/2013	21
Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	Gambit East	NMBRRC067	Yes	17/08/2013	2
Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	North-Western Regional	BRDD005	No	16/04/2013	1
Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	North-Western Regional	BRR003	No	19/08/2013	10
Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	North-Western Regional	BRR004	No	13/04/2013	18
Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	North-Western Regional	BRR004	No	16/08/2013	4
Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	North-Western Regional	BRR005	No	13/04/2013	1
Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	Wolverine	BRWD0007	Yes	22/10/2012	4
Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	Wolverine	BRWD0010	Yes	23/10/2012	2
Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	Wolverine	BRWD0010	Yes	11/04/2013	1
Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	Wolverine	BRWR0181	Yes	10/04/2013	1
Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	Wolverine	BRWR0216	Yes	11/04/2013	6
Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	Wolverine	NMBRRC092	Yes	19/08/2013	14

APPENDIX D

Stygofauna survey results arranged by bore code

Stygofauna results sorted by bore code.

Project Area	Bore Code	Impact?	Sample Date	Higher level	Family	Taxon ID	No. of individuals
Area 5	BRAR019	Yes	9/04/2013				0
Area 5	BRAR002	Yes	10/04/2013				0
Area 5	BRAR0021	Yes	17/08/2013	Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	1
Area 5	BRAR005	Yes	9/04/2013				0
Area 5	BRAR008	Yes	9/04/2013				0
Area 5	BRAR012	Yes	9/04/2013	Bathynellacea	Bathynellidae	Bathynellidae-OES24	3
Area 5	BRAR012	Yes	9/04/2013	Bathynellacea	Parabathynellidae	Parabathynellidae-OES26	6
Area 5	BRAR012	Yes	15/08/2013	Bathynellacea	Parabathynellidae	Parabathynellidae-OES26	1
Area 5	BRAR012	Yes	20/08/2013				0
Area 5	BRAR013	Yes	19/08/2013				0
Area 5	BRAR023	Yes	10/04/2013				0
Area 5	BRAR030	Yes	10/04/2013	Bathynellacea	Parabathynellidae	Parabathynellidae-OES27	3
Area 5	BRAR030	Yes	15/08/2013				0
Area 5	BRAR030	Yes	20/08/2013				0
Area 5	BRRWS003	No	17/08/2013				0
Area 5	Monitoring Bore 01	Yes	20/08/2013	Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	1
Area 5	NMBRRC005	No	24/10/2012	Bathynellacea	Parabathynellidae	Parabathynellidae-OES16	35
Area 5	NMBRRC008	No	22/10/2012				0
Area 5	NMBRRC025	No	23/10/2012				0
Area 5	NMBRRC027	No	24/10/2012				0
Area 5	NMBRRC129	Yes	16/08/2013				0
Area 5	NMBRRC130	Yes	15/08/2013				0
Area 5	NMBRRC137	Yes	23/10/2012				0
Area 5	NMBRRC137	Yes	9/04/2013				0
Area 5	NMBRRC139	Yes	9/04/2013				0
Area 5	NMBRRC141	Yes	23/10/2012				0
Area 5	NMBRRC141	Yes	9/04/2013				0
Area 5	NMBRRC142	Yes	23/10/2012				0
Area 5	NMBRRC143	Yes	22/10/2012				0
Area 5	NMBRRC153	Yes	22/10/2012				0

Stygofauna results sorted by bore code (cont.).

Project Area	Bore Code	Impact?	Sample Date	Higher level	Family	Taxon ID	No. of individuals
Central Regional	BRR033	No	12/04/2013				0
Central Regional	BRR035	No	24/10/2012	Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	1
Central Regional	BRR035	No	12/04/2013				0
Central Regional	BRR037	No	12/04/2013				0
Central Regional	BRR037	No	18/08/2013				0
Central Regional	BRR038	No	24/10/2012				0
Central Regional	BRR038	No	12/04/2013				0
Central Regional	BRR039	No	16/08/2013				0
Central Regional	BRR040	No	13/04/2013	Bathynellacea	Parabathynellidae	Parabathynellidae-OES28	95
Central Regional	BRR040	No	13/04/2013	Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	8
Central Regional	BRR040	No	15/08/2013	Bathynellacea	Parabathynellidae	Parabathynellidae-OES28	1
Central Regional	BRR040	No	15/08/2013	Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	8
Central Regional	BRR040	No	20/08/2013	Bathynellacea	Parabathynellidae	Parabathynellidae-OES28	2
Central Regional	BRR040	No	17/12/2013	Bathynellacea	Bathynellidae	Bathynellidae-OES27	1
Central Regional	BRR041	No	12/04/2013				0
Central Regional	BRR042	No	18/08/2013				0
Central Regional	BRRWS001	No	16/08/2013				0
Gambit Central	BRGR0020	Yes	17/08/2013				0
Gambit Central	BRGR0025	Yes	15/08/2013				0
Gambit Central	BRGR0037	Yes	17/08/2013				0
Gambit Central	BRGR0082	No	14/04/2013				0
Gambit Central	BRGR0083	Yes	17/08/2013	Bathynellacea	Bathynellidae	Bathynellidae-OES26	5
Gambit Central	BRGR0147	Yes	18/08/2013				0
Gambit Central	NMBRRC070	Yes	17/08/2013				0
Gambit Central	NMBRRC072	Yes	17/08/2013				0
Gambit Central	NMBRRC093	Yes	14/04/2013	Bathynellacea	Bathynellidae	Bathynellidae-OES25	13
Gambit Central	NMBRRC093	Yes	14/04/2013	Bathynellacea	Parabathynellidae	Parabathynellidae-OES20	14
Gambit Central	NMBRRC094	Yes	22/10/2012				0
Gambit Central	NMBRRC094	Yes	14/04/2013				0
Gambit Central	NMBRRC098	Yes	22/10/2012				0
Gambit Central	NMBRRC098	Yes	25/10/2012				0

Stygofauna results sorted by bore code (cont.).

Project Area	Bore Code	Impact?	Sample Date	Higher level	Family	Taxon ID	No. of individuals
Gambit East	BRGR0012	No	14/04/2013				0
Gambit East	BRGR0016	Yes	14/04/2013				0
Gambit East	BRGR0016	Yes	16/08/2013				0
Gambit East	BRGR0030	Yes	14/04/2013				0
Gambit East	BRGR0043	Yes	14/04/2013				0
Gambit East	BRR008	No	13/04/2013	Bathynellacea	Parabathynellidae	Parabathynellidae-OES22	24
Gambit East	BRR008	No	15/08/2013	Bathynellacea	Parabathynellidae	Parabathynellidae-OES22	21
Gambit East	BRR008	No	20/08/2013	Bathynellacea	Parabathynellidae	Parabathynellidae-OES22	4
Gambit East	BRR009	No	16/04/2013	Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	21
Gambit East	NMBRRC034	No	22/10/2012				0
Gambit East	NMBRRC037	No	13/04/2013	Bathynellacea	Parabathynellidae	Parabathynellidae-OES21	1
Gambit East	NMBRRC049	No	13/04/2013	Bathynellacea	Parabathynellidae	Parabathynellidae-OES21	3
Gambit East	NMBRRC067	Yes	17/08/2013	Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	2
Gambit East	NMBRRC100	Yes	22/12/2012				0
Gambit East	NMBRRC109	Yes	22/10/2012				0
Gambit East	NMBRRC109	Yes	14/04/2013				0
Gambit West	BRGR0098	Yes	16/08/2013				0
Gambit West	BRGR0117	Yes	18/08/2013				0
Gambit West	BRGR0120	Yes	18/08/2013				0
Gambit West	BRGR070	Yes	16/04/2013				0
Gambit West	BRGR071	Yes	18/08/2013				0
Gambit West	BRR006	No	17/08/2013				0
North-Western Regional	BRDD005	No	16/04/2013	Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	1
North-Western Regional	BRR001	No	24/10/2012				0
North-Western Regional	BRR001	No	13/04/2013				0
North-Western Regional	BRR002	No	13/04/2013				0
North-Western Regional	BRR002	No	17/08/2013				0
North-Western Regional	BRR003	No	13/04/2013				0
North-Western Regional	BRR003	No	19/08/2013	Bathynellacea	Bathynellidae	Bathynellidae-OES26	2
North-Western Regional	BRR003	No	19/08/2013	Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	10
North-Western Regional	BRR003	No	19/08/2013	Harpacticoida	Ameiridae	*Megastygonitocrella bispinosa*	2

Stygofauna results sorted by bore code (cont.).

Project Area	Bore Code	Impact?	Sample Date	Higher level	Family	Taxon ID	No. of individuals
North-Western Regional	BRR004	No	13/04/2013	Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	18
North-Western Regional	BRR004	No	16/08/2013	Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	4
North-Western Regional	BRR005	No	24/10/2012				0
North-Western Regional	BRR005	No	13/04/2013	Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	1
Proposed Borefield (GS)	BRRWS007	Yes	16/08/2013				0
Proposed Borefield (GS)	BRRWS010	Yes	16/08/2013	Bathynellacea	Parabathynellidae	Parabathynellidae-OES22	1
Proposed Borefield (GS)	BRRWS010	Yes	17/12/2013	Bathynellacea	Bathynellidae	Bathynellidae-OES27	11
Proposed Borefield (GS)	BRRWS010	Yes	17/12/2013	Bathynellacea	Parabathynellidae	Parabathynellidae-OES22	1
Proposed Borefield (GS)	BRRWS010	Yes	17/12/2013	Cyclopoida	Cyclopidae	*Dussartcyclops* -OES2	1
Proposed Borefield (GS)	BRRWS010	Yes	17/12/2013	Harpacticoida	Parastenocarididae	*Parastenocaris* -OES1	22
Southern Regional	BRBR003	Yes	25/10/2012				0
Southern Regional	BRBR005	No	25/10/2012				0
Southern Regional	BRBR008	No	21/10/2012				0
Southern Regional	BRBR013	No	15/08/2013				0
Southern Regional	BRBR014	No	24/10/2012				0
Southern Regional	BRBR016	No	24/10/2012	Bathynellacea	Parabathynellidae	Parabathynellidae-OES17	1
Southern Regional	BRMR002	Yes	21/10/2012				0
Southern Regional	BRMR002	No	11/04/2013				0
Southern Regional	BRMR005	No	11/04/2013				0
Southern Regional	BRMR006	No	21/10/2012				0
Southern Regional	BRMR006	No	11/04/2013	Bathynellacea	Parabathynellidae	Parabathynellidae-OES23	2
Southern Regional	BRMR008	No	11/04/2013				0
Southern Regional	BRMR009	No	11/04/2013	Bathynellacea	Parabathynellidae	Parabathynellidae-OES23	700
Southern Regional	BRMR010	No	21/10/2012				0
Southern Regional	BRMR016	No	21/10/2012				0
Southern Regional	BRMR016	No	12/04/2013	Cyclopoida	Cyclopidae	*Microcyclops varicans*	2
Southern Regional	BRMR021	No	12/04/2013				0
Southern Regional	BRMR026	No	21/10/2012				0
Southern Regional	BRMR026	No	12/04/2013	Bathynellacea	Parabathynellidae	Parabathynellidae-OES23	1
Southern Regional	BRMR027	No	12/04/2013	Cyclopoida	Cyclopidae	*Microcyclops varicans*	1
Southern Regional	BRMR027	No	15/08/2013				0
Southern Regional	BRRWS002	No	16/08/2013				0
Southern Regional	Old Camp Bore	No	15/08/2013				0

Stygofauna results sorted by bore code (cont.).

Project Area	Bore Code	Impact?	Sample Date	Higher level	Family	Taxon ID	No. of individuals
Wolverine	BRR010	No	25/10/2012				0
Wolverine	BRR010	No	14/04/2013				0
Wolverine	BRR010	No	16/08/2013				0
Wolverine	BRR011	No	19/08/2013				0
Wolverine	BRR012	No	12/04/2013				0
Wolverine	BRR013	No	25/10/2012				0
Wolverine	BRR013	No	12/04/2013				0
Wolverine	BRRWS008	Yes	17/08/2013				0
Wolverine	BRWD0007	Yes	22/10/2012	Bathynellacea	Parabathynellidae	Parabathynellidae-OES18	5
Wolverine	BRWD0007	Yes	22/10/2012	Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	4
Wolverine	BRWD0007	Yes	10/04/2013	Bathynellacea	Parabathynellidae	Parabathynellidae-OES17	44
Wolverine	BRWD0007	Yes	10/04/2013	Bathynellacea	Bathynellidae	Bathynellidae-OES19	57
Wolverine	BRWD0007	Yes	10/04/2013	Cyclopoida	Cyclopidae	*Metacyclops* OES20	18
Wolverine	BRWD0008	Yes	15/08/2013				0
Wolverine	BRWD0008	Yes	20/08/2013				0
Wolverine	BRWD0010	Yes	23/10/2012	Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	2
Wolverine	BRWD0010	Yes	11/04/2013	Bathynellacea	Parabathynellidae	Parabathynellidae-OES17	1
Wolverine	BRWD0010	Yes	11/04/2013	Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	1
Wolverine	BRWD0011	Yes	23/10/2012				0
Wolverine	BRWD0011	Yes	10/04/2013				0
Wolverine	BRWR0177	Yes	10/04/2013				0
Wolverine	BRWR0181	Yes	10/04/2013	Bathynellacea	Bathynellidae	Bathynellidae-OES19	2
Wolverine	BRWR0181	Yes	10/04/2013	Bathynellacea	Parabathynellidae	Parabathynellidae-OES18	21
Wolverine	BRWR0181	Yes	10/04/2013	Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	1
Wolverine	BRWR0185	Yes	16/04/2013				0
Wolverine	BRWR0187	Yes	18/08/2013				0
Wolverine	BRWR0193	Yes	18/08/2013				0
Wolverine	BRWR0196	Yes	10/04/2013				0
Wolverine	BRWR0202	Yes	16/04/2013				0
Wolverine	BRWR0208	Yes	11/04/2013	Bathynellacea	Parabathynellidae	Parabathynellidae-OES17	6

Stygofauna results sorted by bore code (cont.).

Project Area	Bore Code	Impact?	Sample Date	Higher level	Family	Taxon ID	No. of individuals
Wolverine	BRWR0214	Yes	11/04/2013				0
Wolverine	BRWR0216	Yes	11/04/2013	Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	6
Wolverine	BRWR0217	Yes	16/04/2013				0
Wolverine	BRWR0222	Yes	16/04/2013				0
Wolverine	BRWR0223	Yes	11/04/2013				0
Wolverine	NMBRRC077	Yes	10/04/2013	Bathynellacea	Bathynellidae	Bathynellidae-OES19	26
Wolverine	NMBRRC077	Yes	10/04/2013	Bathynellacea	Parabathynellidae	Parabathynellidae-OES17	58
Wolverine	NMBRRC077	Yes	10/04/2013	Cyclopoida	Cyclopidae	*Metacyclops* OES20	5
Wolverine	NMBRRC091	Yes	23/10/2012	Bathynellacea	Bathynellidae	Bathynellidae-OES19	1
Wolverine	NMBRRC091	Yes	23/10/2012	Bathynellacea	Parabathynellidae	Parabathynellidae-OES17	4
Wolverine	NMBRRC091	Yes	15/08/2013	Bathynellacea	Parabathynellidae	Parabathynellidae-OES17	10
Wolverine	NMBRRC091	Yes	20/08/2013				0
Wolverine	NMBRRC092	Yes	19/08/2013	Bathynellacea	Parabathynellidae	Parabathynellidae-OES17	1
Wolverine	NMBRRC092	Yes	19/08/2013	Oligochaeta	Enchytraeidae	Enchytraeidae-OES17	14
Wolverine	NMBRRC114	Yes	16/05/2012	Bathynellacea	Parabathynellidae	Parabathynellidae-OES20	1
Wolverine	NMBRRC114	Yes	23/10/2012	Bathynellacea	Bathynellidae	Bathynellidae-OES19	15
Wolverine	NMBRRC114	Yes	23/10/2012	Bathynellacea	Parabathynellidae	Parabathynellidae-OES17	31
Wolverine	NMBRRC121	Yes	10/04/2013				0
Wolverine	NMBRRD163	Yes	16/05/2012				0

APPENDIX F

Molecular biodiversity assessments

Prepared for Outback Ecology, January 2013
by Dr Remko Leijs & Dr Rachael King, South Australian Museum.

. Biodiversity assessment of the stygofauna of the Browns Range area using molecular and morphological methods

Summary

- In the Browns Range area six new stygofauna species are identified by molecular biodiversity assessment including:
- 1 new species of Enchytraeid worm;
- 4 new species of Parabathynellidae, belonging to a new genus; and
- 1 new species of Bathynellidae.

Introduction

No previous molecular assessments of the stygofauna of the Browns Range area exist.

Methods

Biodiversity assessment of the collected fauna (Table 1) included morphological assessment 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 other areas complemented with published (Syncarida: Guzik et al. 2008, Abrams et al 2012, 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 the area, as well as for checking whether these species were found at other localities. 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 and relevant *inter*-specific distances in blue.

Extraction	Code	OE identification	SAM identification	Extr.date	Coll.Date	locality	Site	CO1
ST1818	LN2318	Parabathynellidae	new genus sp. BROW 1	20-Dec-12	24-Oct-12	Area 5 North	NMBRRC005	good seq
ST1819	LN2309	Parabathynellidae	new genus sp. BROW 2	20-Dec-12	24-Oct-12	Banshee	BRBR016	good seq
ST1820	LN2320	Oligochaeta	Enchytraeidae sp. BROW 1	20-Dec-12	24-Oct-12	Borefield	BRR035	good seq
ST1821	LN2303	Oligochaeta	Enchytraeidae sp. BROW 1	20-Dec-12	23-Oct-12	Wolverine	BRWD0007	good seq
ST1822	LN2301	Parabathynellidae	new genus sp. BROW 3	20-Dec-12	23-Oct-12	Wolverine	BRWD0007	good seq
ST1823	LN2312	Oligochaeta		20-Dec-12	23-Oct-12	Wolverine	BRWD0010	mult. bands
ST1824	LN2298	Parabathynellidae	new genus sp. BROW 2	20-Dec-12	23-Oct-12	Wolverine	NMBRRC091	good seq
ST1824b	LN2298	Parabathynellidae	Bathynellidae sp. BROW 5	20-Dec-12	23-Oct-12	Wolverine	NMBRRC091	good seq
ST1825	LN5132	Parabathynellidae	new genus sp. BROW 4	20-Dec-12	16-May-12	Wolverine	NMBRRC114	good seq
ST1826	LN2299	Parabathynellidae	new genus sp. BROW 2	20-Dec-12	23-Oct-12	Wolverine	NMBRRC114	good seq

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

Results

Oligochaeta – Enchytraeidae

Two of the three received specimens resulted in good sequences. Specimens ST1820 and ST1821 appeared to belong to a not previously recognized species of belonging to the family Enchytraeidae Figure 1). The pairwise sequence divergence between the specimens of 1.87% (Table 2 yellow highlighted value) indicates an intra-specific distance. The species nearest neighbour is a Enchytraeid species from central Pilbara, inter-specific distances 11.16-12.98% (Table 2 blue highlighted values).

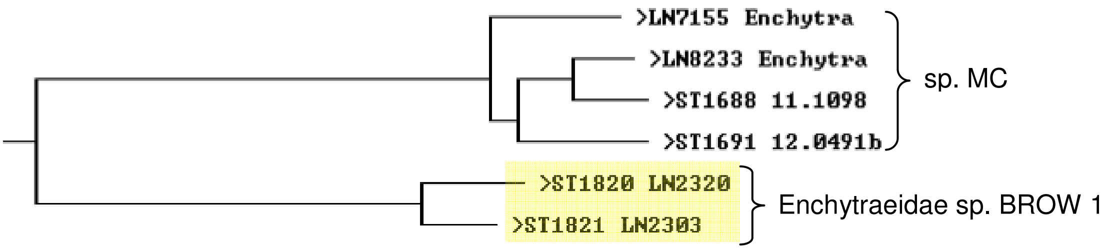

Figure 1. Partial neighbour joining cladogram of Oligochaeta from Browns Range.

Uncorrected ("p") distance matrix

	274	275	324
274 >ST1688 11.1098	-		
275 >ST1691 12.0491b	0.02215	-	
324 >ST1820 LN2320	0.11174	0.12388	-
325 >ST1821 LN2303	0.11157	0.12975	0.01865

Table 2.

Syncarida - Parabathynellidae and Bathynellidae

All seven received specimens resulted in clear sequences (Table 1). The results from the phylogenetic analyses showed that six specimens formed a monophyletic group with four rather divergent species (Figure 2), inter specific distances among these species varied from 9.2-17.5% (Table 3). Three specimens (ST1819,ST1824 and ST1826, sp. BROW2) were con-specific as indicated by pairwise sequence divergences of 0.14-0.57% (Table 3, yellow highlighted values). The species in this monophyletic group are placed as sistergroup of a clade containing described and undescribed species in the genus *Atopobathynella* and a clade that consist of described and undescribed species of which some are classified under *Kimberleybathynella*. This indicates that the four new species from the Browns Range area belong to an undescribed genus.

Site NMBRRC091 which contained new genus sp.BROW2 also contained an undescribed species of Bathynellidae (specimen ST1824b, Figure 3). In the analysis this species is remotely related, pairwise sequence divergence >17.9% (Table 4, blue highlighted values) to a species found in South Australia.

Uncorrected ("p") distance matrix

	177	184	306	307	308	309	310
177 EU350252 AtopoB1	-						
184 EU350245 AtBhinz	0.13766	-					
306 >ST1818 LN2318	0.16916	0.18672	-				
307 >ST1819 LN2309	0.16447	0.17323	0.12900	-			
308 >ST1824 LN2298	0.16168	0.16852	0.12749	0.00142	-		
309 >ST1826 LN2299	0.15999	0.17073	0.13036	0.00429	0.00571	-	
310 >ST1822 LN2301	0.16271	0.18958	0.17486	0.14129	0.13980	0.14272	-
312 >ST1825 LN5132	0.15749	0.18442	0.15774	0.14761	0.14904	0.14903	0.09229

Table 3.

Figure 2. Partial neighbour joining cladogram of Parabathynellidae from Browns Range.

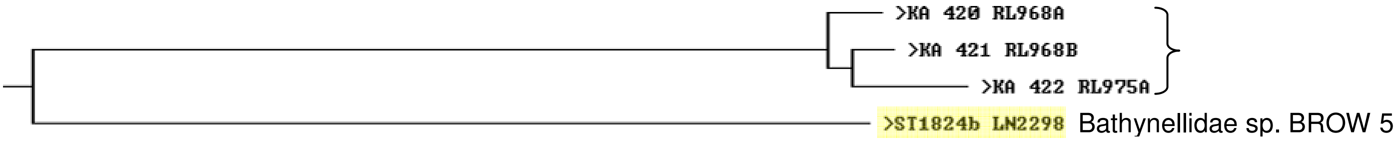

Figure 3. Partial neighbour joining cladogram of Bathynellidae from Browns Range.

Uncorrected ("p") distance matrix

		4	5	6	311
4	>KA 420 RL968A	-			
5	>KA 421 RL968B	0.01183	-		
6	>KA 422 RL975A	0.01889	0.01478	-	
311	>ST1824b LN2298	0.17976	0.18626	0.19534	-

Table 4.

References

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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.

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Prepared for Outback Ecology, June 2013
by Dr Remko Leijs, South Australian Museum.

. Biodiversity assessment of the stygofauna of the Browns Range area using molecular and morphological methods

Summary

- In the Browns Range area five additional new stygofauna species are identified by molecular biodiversity assessment including:
- 3 new species of Parabathynellidae, and
- 2 new species of Bathynellidae
- There is now evidence for 10 species of two new genera of Syncarids and 1 species of Enchytraeid worm.
- The syncarid biodiversity in the Browns Range area is exceptional: no other area of this small size is known to have such a rich syncarid fauna.

Introduction

The current study builds on to a previous molecular assessment of the stygofauna of the Browns Range area.

Methods

Biodiversity assessment of the collected fauna (Table 1) included morphological assessment 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 other areas complemented with published (Syncarida: Guzik et al. 2008, Abrams et al 2012, 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 the area, as well as for checking whether these species were found at other localities. 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 and relevant *inter*-specific distances in blue.

Extraction	Code	OE identification	SAM identification	Extr.date	Coll.Date	locality	Site	CO1
ST1888	LN8969	Bathynellidae	sp.BROW 8	27-May-13	09-Apr-13	Area 5	BRAR012	good seq
ST1889	LN8965	Bathynellidae	sp.BROW 9	27-May-13	14-Apr-13	Gambit	NMBRRC093	good seq
ST1890	LN8980	Bathynellidae	sp.BROW 5	27-May-13	10-Apr-13	Wolverine	BRWD0007	good seq
ST1891	LN8339	Bathynellidae	sp.BROW 5	27-May-13	10-Apr-13	Wolverine	BRWD0007	good seq
ST1892	LN8346	Bathynellidae	sp.BROW 5	27-May-13	10-Apr-13	Wolverine	BRWR0181	good seq
ST1893	LN8398	Bathynellidae	sp.BROW 5	27-May-13	10-Apr-13	Wolverine	NMBRRC077	good seq
ST1894	LN8329	Parabathynellidae		27-May-13	09-Apr-13	Area 5	BRAR012	noPCR
ST1895	LN8967	Parabathynellidae		27-May-13	10-Apr-13	Area 5	BRAR030	seq failed
ST1896	LN8974	Parabathynellidae		27-May-13	13-Apr-13	Borefield	BRR040	noPCR
ST1897	LN7825	Parabathynellidae	sp.BROW 6	27-May-13	13-Apr-13	Gambit	NMBRRC037	good seq
ST1898	LN8970	Parabathynellidae	sp.BROW 6	27-May-13	13-Apr-13	Gambit	NMBRRC049	good seq
ST1899	LN8968	Parabathynellidae	sp.BROW 4	27-May-13	14-Apr-13	Gambit	NMBRRC093	good seq
ST1900	LN8397	Parabathynellidae	sp.BROW 10	27-May-13	13-Apr-13	Gambit West	BRR008	messy seq
ST1901	LN7830	Parabathynellidae	sp.BROW 10	27-May-13	13-Apr-13	Gambit West	BRR008	messy seq
ST1902	LN8966	Parabathynellidae	sp.BROW 7	27-May-13	11-Apr-13	Mystique	BRMR006	good seq
ST1903	LN8330	Parabathynellidae	sp.BROW 7	27-May-13	11-Apr-13	Mystique	BRMR009	good seq
ST1904	LN8404	Parabathynellidae	sp.BROW 7	27-May-13	12-Apr-13	Mystique	BRMR026	good seq
ST1905	LN8338	Parabathynellidae	sp.BROW 2	27-May-13	10-Apr-13	Wolverine	BRWD0007	good seq
ST1906	LN7827	Parabathynellidae	sp.BROW 2	27-May-13	11-Apr-13	Wolverine	BRWD0010	good seq
ST1907	LN8348	Parabathynellidae	sp.BROW 3	27-May-13	10-Apr-13	Wolverine	BRWR0181	good seq
ST1908	LN8343	Parabathynellidae	sp.BROW 2	27-May-13	11-Apr-13	Wolverine	BRWR0208	good seq
ST1909	LN8399	Parabathynellidae	sp.BROW 2	27-May-13	10-Apr-13	Wolverine	NMBRRC077	good seq
ST1910	LN8978	Enchytraeidae	sp.BROW 1	27-May-13	13-Apr-13	Borefield	BRR040	good seq
ST1911	LN8333	Enchytraeidae	sp.BROW 1	27-May-13	13-Apr-13	Gambit West	BRR004	good seq
ST1912	LN8964	Enchytraeidae	sp.BROW 1	27-May-13	13-Apr-13	Gambit West	BRR004	good seq
ST1913	LN7183	Enchytraeidae	sp.BROW 1	27-May-13	13-Apr-13	Gambit West	BRR005	good seq
ST1914	LN8963	Enchytraeidae	sp.BROW 1	27-May-13	16-Apr-13	Gambit West	BRR009	good seq
ST1915	LN8984	Enchytraeidae	sp.BROW 1	27-May-13	16-Apr-13	Gambit West	BRR009	good seq
ST1916	LN7823	Enchytraeidae	sp.BROW 1	27-May-13	16-Apr-13	Wolverine	BRDD005	good seq
ST1917	LN8328	Enchytraeidae	sp.BROW 1	27-May-13	11-Apr-13	Wolverine	BRWD0010	good seq
ST1918	LN8350	Enchytraeidae	sp.BROW 1	27-May-13	10-Apr-13	Wolverine	BRWR0181	good seq
ST1919	LN8973	Enchytraeidae	sp.BROW 1	27-May-13	11-Apr-13	Wolverine	BRWR0216	good seq
ST1920	LN8972	Enchytraeidae	sp.BROW 1	27-May-13	11-Apr-13	Wolverine	BRWR0216	good seq

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

Results

Oligochaeta – Enchytraeidae

All eleven received specimens resulted in good sequences. The results from the phylogenetic analyses showed that these 11 specimens together with 2 specimens from a previous analysis formed a monophyletic group of a single species. The pairwise sequence divergence among the specimens varies from 0.0-4.12% (Table 2 yellow highlighted values). The cladogram of Figure 2 shows some geographic structure apparent because the clades each have specimens from the same localities. However, each of these localities also have specimens from a number of clades.

The species nearest neighbour is a Enchytraeid species from central Pilbara, inter-specific distances 10.8-13.2% (Table 2 blue highlighted values).

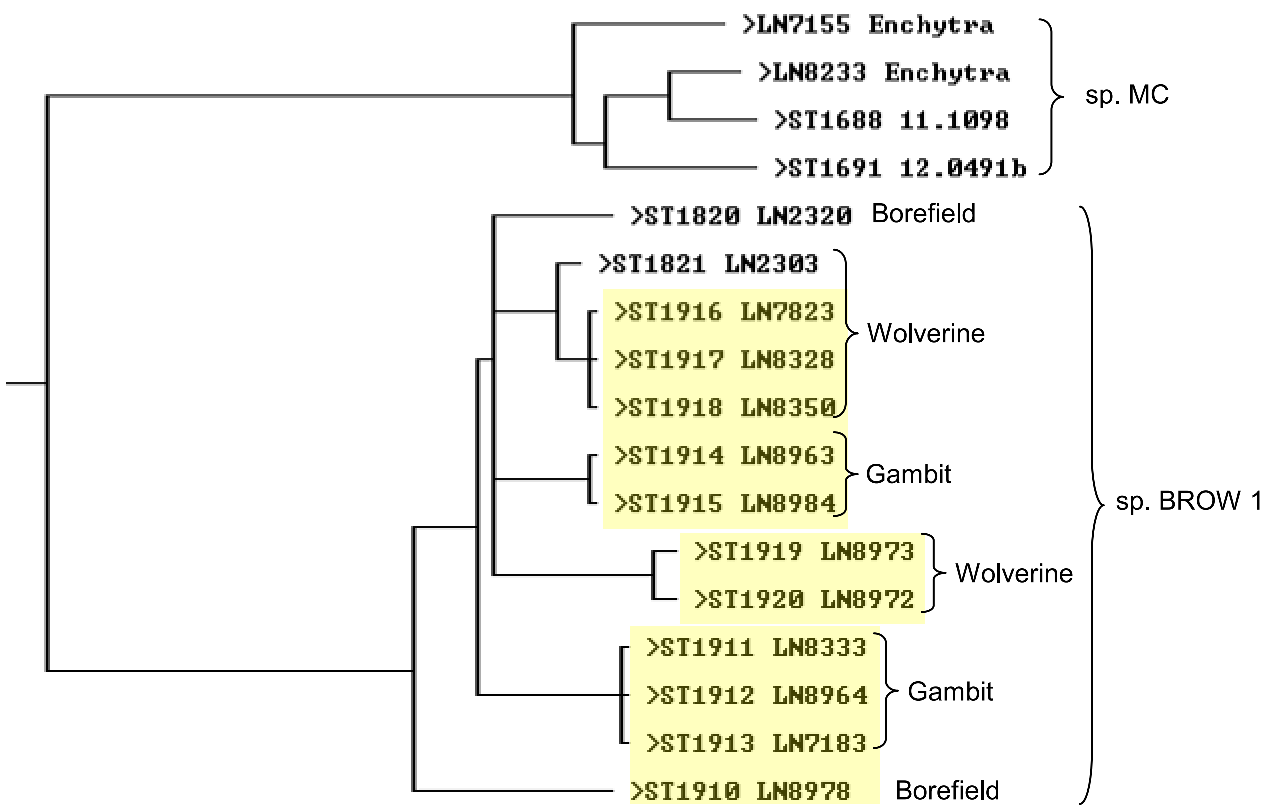

Figure 1. Partial neighbour joining cladogram of Oligochaeta from Browns Range.

Uncorrected ("p") distance matrix

		282	283	332	333	334	335	336	337	338	339
282	>ST1688 11.1098	-									
283	>ST1691 12.0491b	0.02215	-								
332	>ST1820 LN2320	0.11174	0.12388	-							
333	>ST1821 LN2303	0.11157	0.12975	0.01865	-						
334	>ST1916 LN7823	0.11021	0.12766	0.02356	0.00442	-					
335	>ST1917 LN8328	0.11015	0.12766	0.02208	0.00295	0.00147	-				
336	>ST1918 LN8350	0.10998	0.12668	0.02217	0.00296	0.00148	0.00000	-			
337	>ST1914 LN8963	0.10869	0.12621	0.01915	0.01618	0.01762	0.01615	0.01622	-		
338	>ST1915 LN8984	0.10869	0.12621	0.01915	0.01618	0.01762	0.01615	0.01622	0.00000	-	
339	>ST1919 LN8973	0.11505	0.13207	0.02639	0.02200	0.02643	0.02496	0.02504	0.02496	0.02496	-
340	>ST1920 LN8972	0.11498	0.13094	0.02643	0.02202	0.02646	0.02498	0.02504	0.02500	0.02500	0.00000
344	>ST1911 LN8333	0.11790	0.13259	0.02573	0.01723	0.02215	0.02067	0.02071	0.02364	0.02364	0.03088
345	>ST1912 LN8964	0.11790	0.13259	0.02573	0.01723	0.02215	0.02067	0.02071	0.02364	0.02364	0.03088
346	>ST1913 LN7183	0.11790	0.13259	0.02573	0.01723	0.02215	0.02067	0.02071	0.02364	0.02364	0.03088
347	>ST1910 LN8978	0.11313	0.11929	0.03692	0.03095	0.03536	0.03388	0.03387	0.02949	0.02949	0.04126

Uncorrected ("p") distance matrix (continued)

		340	344	345	346	347
340	>ST1920 LN8972	-				
344	>ST1911 LN8333	0.03090	-			
345	>ST1912 LN8964	0.03090	0.00000	-		
346	>ST1913 LN7183	0.03090	0.00000	0.00000	-	
347	>ST1910 LN8978	0.04125	0.03691	0.03691	0.03691	-

Table 2.

Syncarida - Parabathynellidae

Eleven out of the sixteen received specimens resulted in clear sequences and the sequences of two specimens had a number of ambiquities (Table 1). The results from the phylogenetic analyses showed that these 13 specimens together with specimens from a previous analysis formed a monophyletic group with seven rather divergent species among which three additional new species (Figure 2, additional new species in red), inter-specific distances among sister species varied from 8.7-11.8% (Table 3, blue highlighted values), while distances among major clades varied from 11.9-17.4%. Intra-specific pairwise distances were < 1.72% for species BROW2, BROW3, BROW3, BROW6 and BROW7 (Table 3, yellow highlighted values). The intra-specific pairwise distance for species BROW10 is 3.27%, but this value may be inflated due to numerous ambiguities in the sequence reads. As noted in a previous report the

species in this monophyletic group are placed as sistergroup of a clade containing described and undescribed species in the genus *Atopobathynella* and a clade that consist of described and undescribed species of which some are classified under *Kimberleybathynella*. This indicates that the all new species from the Browns Range area belong to an undescribed genus.
Specimens that were sequenced nicely grouped per locality. Although some of the localities (Gambit and Wolverine) have multiple species, these co-occurring species are not closely related, which indicate old speciation processes.

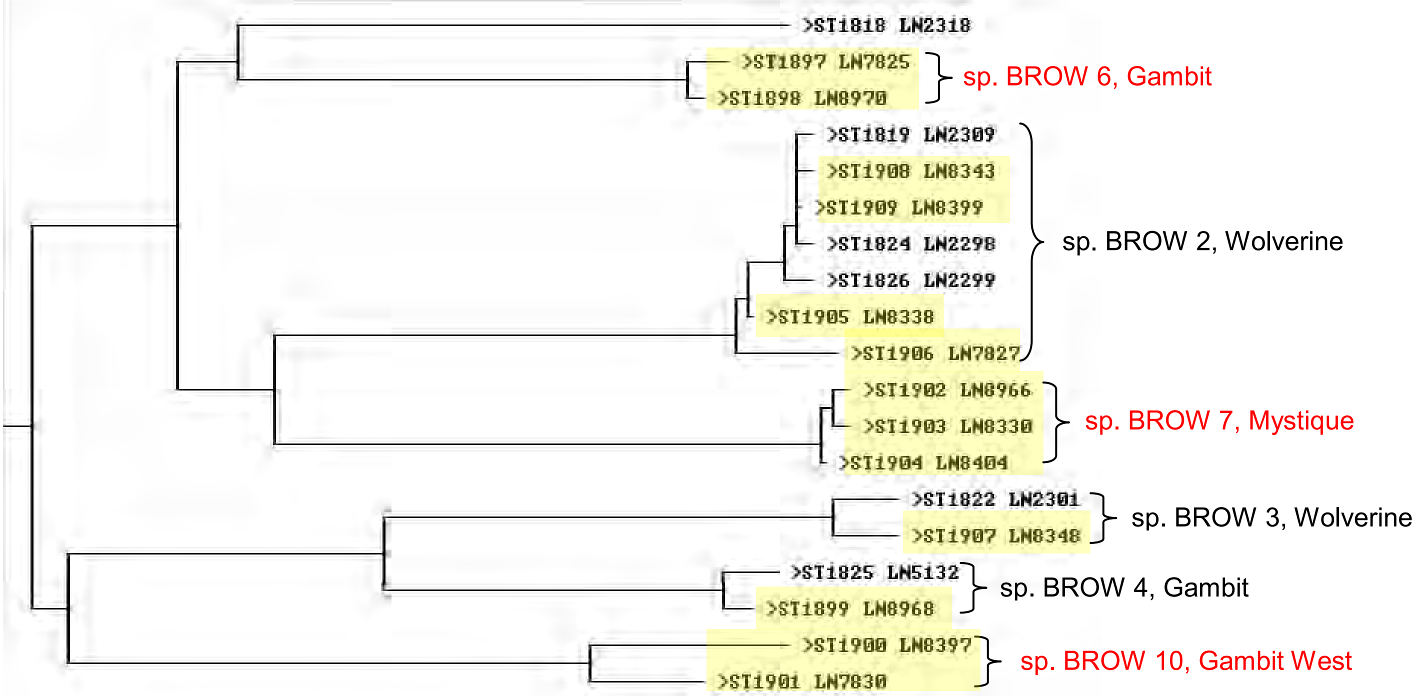

Figure 2. Partial neighbour joining cladogram of Parabathynellidae from Browns Range.

Uncorrected ("p") distance matrix

	177	184	308	309	310	311	312	313	314	315
177 EU350252 AtopoB1	-									
184 EU350245 AtBhinz	0.13766	-								
308 >ST1818 LN2318	0.16916	0.18672	-							
309 >ST1897 LN7825	0.17499	0.18832	0.10977	-						
310 >ST1898 LN8970	0.17130	0.18462	0.10543	0.00434	-					
311 >ST1819 LN2309	0.16447	0.17323	0.12900	0.12573	0.12428	-				
312 >ST1908 LN8343	0.15985	0.16865	0.12892	0.12569	0.12425	0.00000	-			
313 >ST1909 LN8399	0.15985	0.16865	0.12892	0.12569	0.12425	0.00000	0.00000	-		
314 >ST1824 LN2298	0.16168	0.16852	0.12749	0.12713	0.12569	0.00142	0.00143	0.00143	-	
315 >ST1826 LN2299	0.15999	0.17073	0.13036	0.12714	0.12570	0.00429	0.00428	0.00428	0.00571	-
316 >ST1905 LN8338	0.15685	0.16180	0.12468	0.12138	0.11995	0.00292	0.00291	0.00291	0.00436	0.00722
317 >ST1906 LN7827	0.16284	0.17140	0.13608	0.13428	0.13284	0.01293	0.01291	0.01291	0.01435	0.01721
325 >ST1902 LN8966	0.15607	0.17099	0.12036	0.12280	0.12424	0.10704	0.10699	0.10699	0.10842	0.10842
326 >ST1903 LN8330	0.15299	0.16815	0.12130	0.12283	0.12428	0.10839	0.10834	0.10834	0.10978	0.10979
327 >ST1904 LN8404	0.15048	0.16561	0.11969	0.12138	0.12283	0.10678	0.10674	0.10674	0.10818	0.10819
328 >ST1822 LN2301	0.16271	0.18958	0.17486	0.16612	0.16757	0.14129	0.14126	0.14126	0.13980	0.14272
329 >ST1907 LN8348	0.16708	0.18972	0.17341	0.16040	0.16185	0.14163	0.14159	0.14159	0.14014	0.14593
330 >ST1825 LN5132	0.15749	0.18442	0.15774	0.14914	0.14764	0.14761	0.14757	0.14757	0.14904	0.14903
331 >ST1899 LN8968	0.15306	0.17803	0.15186	0.14451	0.14306	0.14192	0.14187	0.14187	0.14331	0.14331
332 >ST1900 LN8397	0.15863	0.17233	0.16972	0.16621	0.16189	0.15048	0.15055	0.15055	0.15288	0.15062
333 >ST1901 LN7830	0.15760	0.16283	0.15664	0.15056	0.15067	0.15106	0.15116	0.15116	0.15247	0.14923

Uncorrected ("p") distance matrix (continued)

	316	317	325	326	327	328	329	330	331	332
316 >ST1905 LN8338	-									
317 >ST1906 LN7827	0.01290	-								
325 >ST1902 LN8966	0.10599	0.11738	-							
326 >ST1903 LN8330	0.10696	0.11841	0.00000	-						
327 >ST1904 LN8404	0.10536	0.11678	0.00145	0.00145	-					
328 >ST1822 LN2301	0.14275	0.14995	0.16314	0.16323	0.16179	-				
329 >ST1907 LN8348	0.14309	0.15021	0.16178	0.16185	0.16043	0.01171	-			
330 >ST1825 LN5132	0.14319	0.15178	0.14903	0.14910	0.14765	0.09229	0.09674	-		
331 >ST1899 LN8968	0.13760	0.14753	0.14329	0.14449	0.14280	0.08755	0.09101	0.00730	-	
332 >ST1900 LN8397	0.14611	0.16612	0.15589	0.15792	0.15517	0.15025	0.15067	0.15046	0.13873	-
333 >ST1901 LN7830	0.14748	0.16360	0.14896	0.14876	0.14631	0.15760	0.15956	0.15017	0.14009	0.03268

Table 3.

Syncarida - Bathynellidae

All six received specimens resulted in clear sequences. The results from the phylogenetic analyses showed that these six specimens together with a specimen from a previous analysis formed a monophyletic group with three rather divergent species among which two additional new species (Figure 3, additional new species in red). The inter-specific distances among the species varied from 8.3-13.1% (Table 4, blue highlighted values). Intra-specific pairwise distances among sp. BROW5 are < 0.59% (Table 4, yellow highlighted values).

The syncarid biodiversity in the Browns Range area is exceptional. To my knowledge there is no other example of such a small range biodiversity hotspot of Bathynellid and Parabathynellid species. Each locality comprises unique species. Several of the localities (Gambit, Wolverine, Area 5) have multiple, up to three, unrelated species.

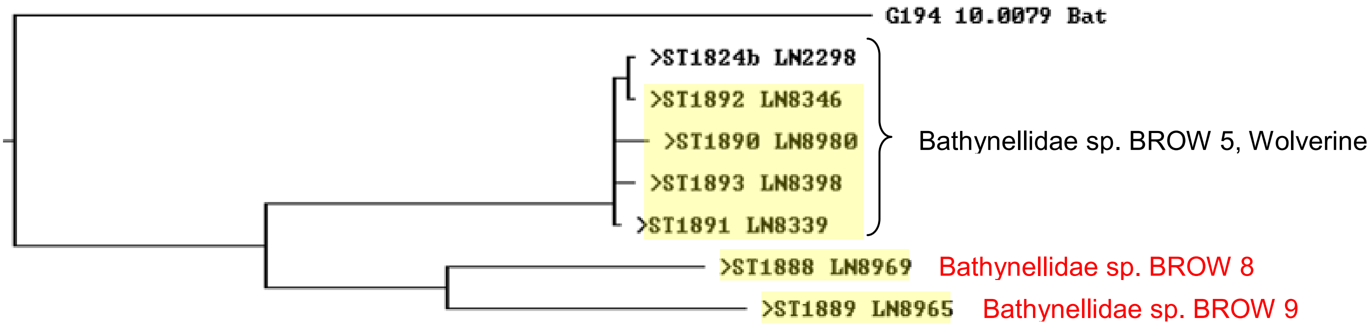

Figure 3. Partial neighbour joining cladogram of Bathynellidae from Browns Range.

Uncorrected ("p") distance matrix

	4	5	6	256	318	319	320	321	322	323
4 >KA 420 RL968A	-									
5 >KA 421 RL968B	0.01183	-								
6 >KA 422 RL975A	0.01889	0.01478	-							
256 G194 10.0079 Bat	0.25589	0.25707	0.26596	-						
318 >ST1888 LN8969	0.19853	0.20164	0.21215	0.21984	-					
319 >ST1889 LN8965	0.21818	0.22144	0.23607	0.24279	0.08453	-				
320 >ST1824b LN2298	0.17976	0.18626	0.19534	0.22853	0.11891	0.12894	-			
321 >ST1890 LN8980	0.18177	0.18835	0.19759	0.22991	0.11855	0.12891	0.00295	-		
322 >ST1891 LN8339	0.18160	0.18811	0.19720	0.22996	0.11891	0.12607	0.00287	0.00589	-	
323 >ST1892 LN8346	0.17979	0.18626	0.19532	0.22993	0.11990	0.12985	0.00000	0.00296	0.00288	-
324 >ST1893 LN8398	0.17962	0.18604	0.19513	0.22993	0.11844	0.13129	0.00144	0.00441	0.00433	0.00145

Table 4.

References

Abrams KM, Guzik MT, Cooper SJB, Humphreys WF, King RA,Cho JL & Austin AD. (2012). What lies beneath: Molecular phylogenetics and ancestral state reconstruction of the ancient subterranean Australian Parabathynellidae (Syncarida, Crustacea) *Mol. Phylogenet. Evol*. **64**:130-144

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.

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

Prepared for Outback Ecology, 23 August 2013
by Dr Remko Leijs, South Australian Museum.

Appendix

Browns Range Parabathynellidae

Summary

- **2 additional Parabathynellidae species were recognised from Area 5.**

Introduction

The current study builds on to a previous molecular assessment of the stygofauna of the Browns Range area.

Methods

Three specimens from Area 5 and Borefield that previously did not result in sequences were PCRed using different sets of (internal) primers.

Extraction	Code	OE identification	SAM identification	Extr.date	Coll.Date	locality	Site	CO1
ST1894	LN8329	Parabathynellidae	sp.BROW 12	27-May-13	09-Apr-13	Area 5	BRAR012	good seq
ST1895	LN8967	Parabathynellidae	sp.BROW 11	27-May-13	10-Apr-13	Area 5	BRAR030	good seq
ST1896	LN8974	Parabathynellidae		27-May-13	13-Apr-13	Borefield	BRR040	seq failed

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

Results

Two out of three specimens resulted in high quality sequences (Table 1). Neighbour joining analyses indicated that these two sequences belong to two different additional species (Figure 1, red highlighted) with pairwise inter-specific sequence divergences of 5.95-8.29% (Table 2, blue highlighted values)

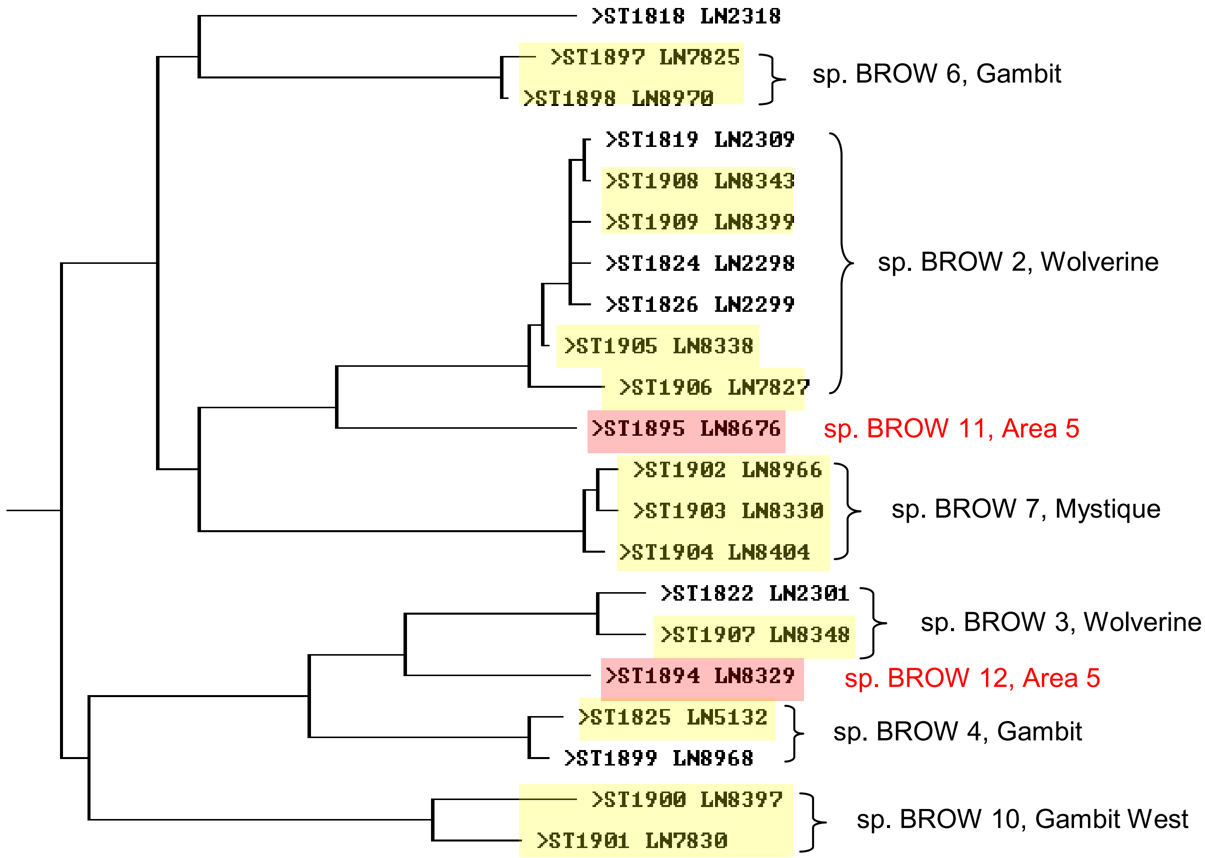

Figure 1. Partial neighbour joining cladogram of Parabathynellidae from Browns Range.

Uncorrected ("p") distance matrix

	177	184	308	309	310	311	312	313	314	315	316
177 EU350252 AtopoB1	-										
184 EU350245 AtBhinz	0.13766	-									
308 >ST1818 LN2318	0.16916	0.18672	-								
309 >ST1897 LN7825	0.17499	0.18832	0.10977	-							
310 >ST1898 LN8970	0.17130	0.18462	0.10543	0.00434	-						
311 >ST1819 LN2309	0.16447	0.17323	0.12900	0.12573	0.12428	-					
312 >ST1908 LN8343	0.15985	0.16865	0.12892	0.12569	0.12425	0.00000	-				
313 >ST1909 LN8399	0.15985	0.16865	0.12892	0.12569	0.12425	0.00000	0.00000	-			
314 >ST1824 LN2298	0.16168	0.16852	0.12749	0.12713	0.12569	0.00142	0.00143	0.00143	-		
315 >ST1826 LN2299	0.15999	0.17073	0.13036	0.12714	0.12570	0.00429	0.00428	0.00428	0.00571	-	
316 >ST1905 LN8338	0.15685	0.16180	0.12468	0.12138	0.11995	0.00292	0.00291	0.00291	0.00436	0.00722	-
317 >ST1906 LN7827	0.16284	0.17140	0.13608	0.13428	0.13284	0.01293	0.01291	0.01291	0.01435	0.01721	0.01290
325 >ST1902 LN8966	0.15607	0.17099	0.12036	0.12280	0.12424	0.10704	0.10699	0.10699	0.10842	0.10842	0.10599
326 >ST1903 LN8330	0.15299	0.16815	0.12130	0.12283	0.12428	0.10839	0.10834	0.10834	0.10978	0.10979	0.10696
327 >ST1904 LN8404	0.15048	0.16561	0.11969	0.12138	0.12283	0.10678	0.10674	0.10674	0.10818	0.10819	0.10536
328 >ST1822 LN2301	0.16271	0.18958	0.17486	0.16612	0.16757	0.14129	0.14126	0.14126	0.13980	0.14272	0.14275
329 >ST1907 LN8348	0.16708	0.18972	0.17341	0.16040	0.16185	0.14163	0.14159	0.14159	0.14014	0.14593	0.14309
330 >ST1825 LN5132	0.15749	0.18442	0.15774	0.14914	0.14764	0.14761	0.14757	0.14757	0.14904	0.14903	0.14319
331 >ST1899 LN8968	0.15306	0.17803	0.15186	0.14451	0.14306	0.14192	0.14187	0.14187	0.14331	0.14331	0.13760
332 >ST1894 LN8329	0.15227	0.15878	0.16145	0.15702	0.15197	0.14315	0.14310	0.14310	0.14588	0.14632	0.13768
333 >ST1895 LN8676	0.15270	0.16264	0.13725	0.11155	0.10660	0.06522	0.06522	0.06522	0.06779	0.06820	0.06038
334 >ST1900 LN8397	0.15863	0.17233	0.16972	0.16621	0.16189	0.15048	0.15055	0.15055	0.15288	0.15062	0.14611
335 >ST1901 LN7830	0.15760	0.16283	0.15664	0.15056	0.15067	0.15106	0.15116	0.15116	0.15247	0.14923	0.14748

Uncorrected ("p") distance matrix (continued)

	317	325	326	327	328	329	330	331	332	333	334
317 >ST1906 LN7827	-										
325 >ST1902 LN8966	0.11738	-									
326 >ST1903 LN8330	0.11841	0.00000	-								
327 >ST1904 LN8404	0.11678	0.00145	0.00145	-							
328 >ST1822 LN2301	0.14995	0.16314	0.16323	0.16179	-						
329 >ST1907 LN8348	0.15021	0.16178	0.16185	0.16043	0.01171	-					
330 >ST1825 LN5132	0.15178	0.14903	0.14910	0.14765	0.09229	0.09674	-				
331 >ST1899 LN8968	0.14753	0.14329	0.14449	0.14280	0.08755	0.09101	0.00730	-			
332 >ST1894 LN8329	0.15469	0.17014	0.17020	0.16703	0.05954	0.06520	0.07822	0.07553	-		
333 >ST1895 LN8676	0.08290	0.12205	0.12517	0.12164	0.15426	0.15771	0.15467	0.14626	0.14781	-	
334 >ST1900 LN8397	0.16612	0.15589	0.15792	0.15517	0.15025	0.15067	0.15046	0.13873	0.13865	0.13788	-
335 >ST1901 LN7830	0.16360	0.14896	0.14876	0.14631	0.15760	0.15956	0.15017	0.14009	0.13725	0.14238	0.03268

Table 2. Additional taxa indicated in red. Inter-specific sequence diverges with closest sister species in blue.

Sequences
(aligned)

>ST1894_LN8329 --

GTTTACCCTCCATTAGCTTTAAACTTATTTCATAGAGGTCCTTCCGTTGATTTAGCAATTTTTTCACTTCATATAGCAGGGGCTTC
ATCAATTTTAGGAGCTATTAATTTTATTACTACTATTATTAATATACGAAACTCAGGATTATTTATAGATCGTATACCATTATTTT
GCTGGGCTGTTTTTATTACAGCTATTCTTTTATTATTATCTCTTCCTGTATTAGCGGGGGGGATTACTATATTATTAACAGATCG
AAATTTAAACACATCATTTTTTGATCCTGCTGGAGGTGGTGATCCTATTTTATATCAGCATTTATTTTGATTTTTTGGTCA--------
----

>ST1895_LN8676 --

GTTTACCCTCCCTTAGCTTTAAATCTATTTCATAGGGGACCTTCAGTAGATTTAGCAATTTTTTCTTTACATATGGCAGGTGCCT
CTTCAATCTTGGGAGCTATTAATTTTATTACAACTATTATTAATATACGTAATTCAGGATTGTTAATAGATCGAATACCTTTATT
TTGTTGAGCAGTTTTTATCACTGCAATTCTTTTATTGTTATCGTTACCTGTTCTTGCAGGAGGAATCACAATATTATTAACTGAT
CGAAATTTAAATACGTCTTTTTTTGATCCAGCAGGAGGGGGAGATCCTATTTTATATCAACATTTATTTTGATTTTTTGGTCACC
CTGAAGTTTAGTC--

Prepared for Outback Ecology, 3 October 2013
by Dr Remko Leijs, South Australian Museum.

Appendix 2

Browns Range Bathynellidae and Parabathynellidae

Summary

- **1 additional Parabathynellidae species was recognised from Borefield.**
- **1 additional Bathynellidae species was recognised from Reginal / Gambit West.**
- **The total number of Bathynellacea species from Browns Range is now 14.**

Introduction

The current study builds on to previous molecular assessments of the stygofauna of the Browns Range area.

Methods

Nine additional specimens from a range of localities within the Browns Range are analysed using the same methods as in earlier molecular biodiversity assessments.

Extraction	Code	OE identification	SAM identification	Extr.date	Coll.Date	locality	Site	CO1
ST1933	LN8317	Parabathynellidae	sp. BROW 13	18-Sep-13	15-Aug-13	Borefield	BRR040	good seq
ST1934	LN7742	Parabathynellidae	sp. BROW 13	18-Sep-13	20-Aug-13	Borefield	BRR040	good seq
ST1935	LN7721	Parabathynellidae	sp. BROW 2	18-Sep-13	19-Aug-13	Wolverine	NMBRRC092	good seq
ST1936	LN6573	Parabathynellidae		18-Sep-13	16-Aug-13	Pot. Borefield	BRRWS010	messy seq
ST1937	LN7733	Parabathynellidae	Bathynellidae sp.BROW 14	18-Sep-13	19-Aug-13	Regional	BRR0003	good seq
ST1938	LN8900	Parabathynellidae	Bathynellidae sp.BROW 14	18-Sep-13	17-Aug-13	Gambit/Gambit West	BRGR0083	good seq
ST1939	LN5976	Parabathynellidae	sp. BROW 2	18-Sep-13	15-Aug-13	Wolverine	NMBRRC091	good seq
ST1940	LN8320	Parabathynellidae	sp. BROW 10	18-Sep-13	20-Aug-13	Gambit West	BRR008	good seq
ST1941	LN8901	Parabathynellidae	sp. BROW 12	18-Sep-13	15-Aug-13	Area 5	BRAR012	good seq

Table 1. Overview of the additional analysed specimens. The first column gives the DNA extraction numbers, the last column indicates whether the DNA sequencing was successful. Yellow highlighted fields indicate successfully analysed specimens, red highlighted field in the SAM identification column indicate newly found species.

Results - Parabathynellidae

Six of the nine received specimens appeared to be Parabathynellidae and resulted in high quality sequences (Table 1). Neighbour joining analyses indicated that these six specimens belong to four different species of which specimens ST1933 and ST1934 appeared to be an additional species (Figure 1, red highlighted), with pairwise inter-specific sequence divergences with nearest neighbour 8.12-8.39% (Table 2, blue highlighted values). Intra specific sequence divergences of species BROW 2, BROW 12 and BROW 13 are < 1.57% (Table 2, yellow highlighted values). Intra specific sequence divergences of species BROW 10, including specimen ST1940 are much higher: 3.26-8.33% (Table 2, yellow highlighted values), but these high values are probably caused by a number of ambiguities in the sequences of specimens ST1900 and ST1901. The conservative approach is to consider these specimens conspecific, also because they are sympatric. Additional data is necessary to test whether the specimens from Gambit West belong to different species.

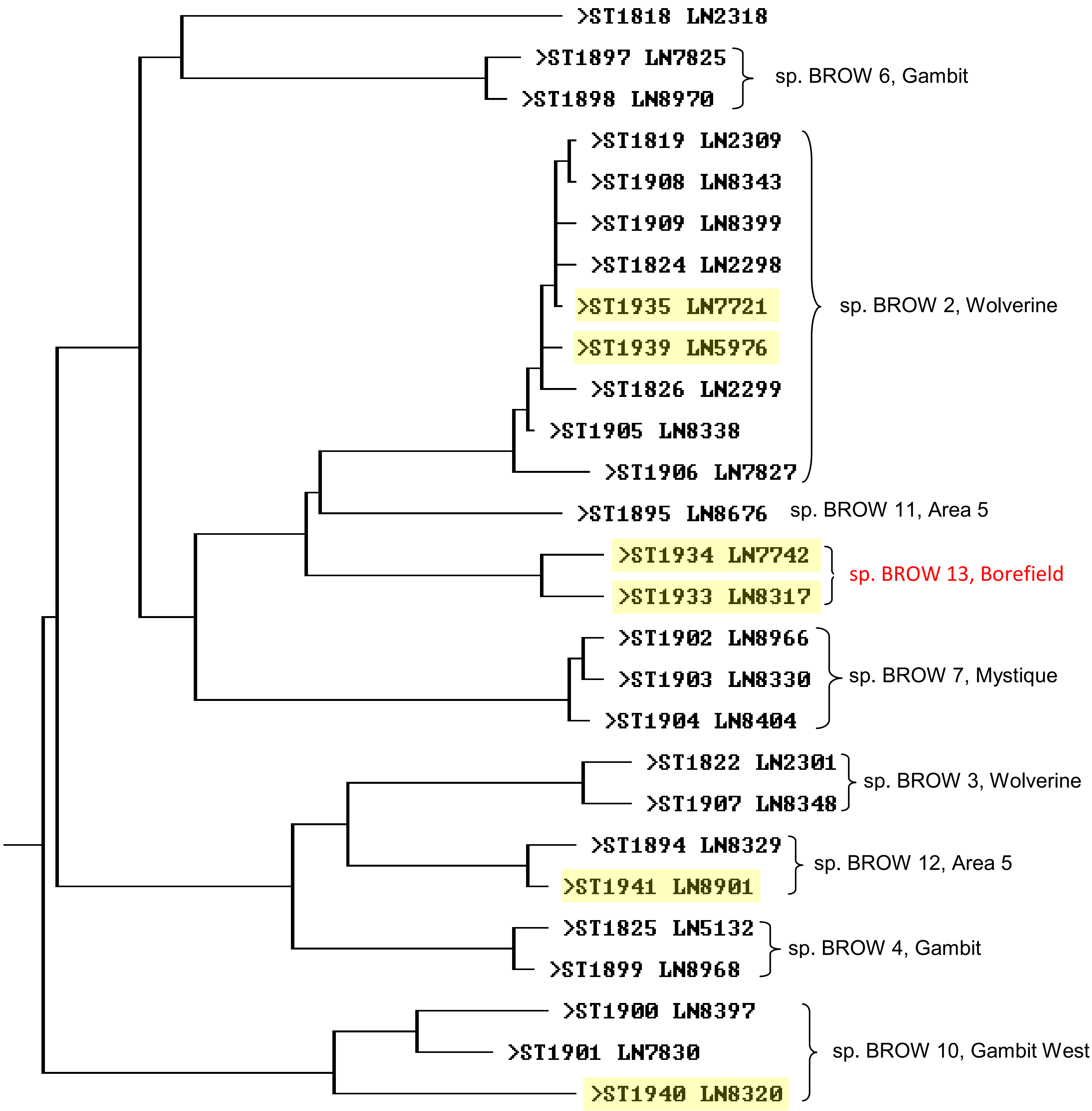

Figure 1. Partial neighbour joining cladogram of Parabathynellidae from Browns Range.

Uncorrected ("p") distance matrix

	177	184	308	309	310	311	312	313	314	315
177 EU350252 AtopoB1	-									
184 EU350245 AtBhinz	0.13766	-								
308 >ST1818 LN2318	0.16916	0.18672	-							
309 >ST1897 LN7825	0.17499	0.18832	0.10977	-						
310 >ST1898 LN8970	0.17130	0.18462	0.10543	0.00434	-					
311 >ST1819 LN2309	0.16447	0.17323	0.12900	0.12573	0.12428	-				
312 >ST1908 LN8343	0.15985	0.16865	0.12892	0.12569	0.12425	0.00000	-			
313 >ST1909 LN8399	0.15985	0.16865	0.12892	0.12569	0.12425	0.00000	0.00000	-		
314 >ST1824 LN2298	0.16168	0.16852	0.12749	0.12713	0.12569	0.00142	0.00143	0.00143	-	
315 >ST1935 LN7721	0.15564	0.16443	0.12929	0.12567	0.12423	0.00000	0.00000	0.00000	0.00144	-
316 >ST1939 LN5976	0.15530	0.16623	0.12771	0.12713	0.12567	0.00144	0.00143	0.00143	0.00287	0.00143
317 >ST1826 LN2299	0.15999	0.17073	0.13036	0.12714	0.12570	0.00429	0.00428	0.00428	0.00571	0.00432
318 >ST1905 LN8338	0.15685	0.16180	0.12468	0.12138	0.11995	0.00292	0.00291	0.00291	0.00436	0.00290
319 >ST1906 LN7827	0.16284	0.17140	0.13608	0.13428	0.13284	0.01293	0.01291	0.01291	0.01435	0.01292
327 >ST1902 LN8966	0.15607	0.17099	0.12036	0.12280	0.12424	0.10704	0.10699	0.10699	0.10842	0.10777
328 >ST1903 LN8330	0.15299	0.16815	0.12130	0.12283	0.12428	0.10839	0.10834	0.10834	0.10978	0.10834
329 >ST1904 LN8404	0.15048	0.16561	0.11969	0.12138	0.12283	0.10678	0.10674	0.10674	0.10818	0.10673
330 >ST1822 LN2301	0.16271	0.18958	0.17486	0.16612	0.16757	0.14129	0.14126	0.14126	0.13980	0.14126
331 >ST1907 LN8348	0.16708	0.18972	0.17341	0.16040	0.16185	0.14163	0.14159	0.14159	0.14014	0.14160
332 >ST1825 LN5132	0.15749	0.18442	0.15774	0.14914	0.14764	0.14761	0.14757	0.14757	0.14904	0.14755
333 >ST1899 LN8968	0.15306	0.17803	0.15186	0.14451	0.14306	0.14192	0.14187	0.14187	0.14331	0.14225
334 >ST1894 LN8329	0.15227	0.15878	0.16145	0.15702	0.15197	0.14315	0.14310	0.14310	0.14588	0.14311
335 >ST1941 LN8901	0.16251	0.15469	0.15497	0.14308	0.14162	0.13926	0.13921	0.13921	0.14065	0.13938
336 >ST1895 LN8676	0.15270	0.16264	0.13725	0.11155	0.10660	0.06522	0.06522	0.06522	0.06779	0.06620
339 >ST1934 LN7742	0.17064	0.18256	0.14370	0.13453	0.13888	0.09018	0.09019	0.09019	0.09162	0.09088
340 >ST1933 LN8317	0.16923	0.18207	0.14045	0.13000	0.13433	0.08133	0.08131	0.08131	0.08274	0.08194
341 >ST1900 LN8397	0.15863	0.17233	0.16972	0.16621	0.16189	0.15048	0.15055	0.15055	0.15288	0.15124
342 >ST1901 LN7830	0.15760	0.16283	0.15664	0.15056	0.15067	0.15106	0.15116	0.15116	0.15247	0.15011
343 >ST1940 LN8320	0.17311	0.18056	0.15924	0.15021	0.14875	0.15787	0.15783	0.15783	0.15927	0.15799

Uncorrected ("p") distance matrix (continued)

	316	317	318	319	327	328	329	330	331	332
316 >ST1939 LN5976	-									
317 >ST1826 LN2299	0.00574	-								
318 >ST1905 LN8338	0.00433	0.00722	-							
319 >ST1906 LN7827	0.01435	0.01721	0.01290	-						
327 >ST1902 LN8966	0.10620	0.10842	0.10599	0.11738	-					
328 >ST1903 LN8330	0.10687	0.10979	0.10696	0.11841	0.00000	-				
329 >ST1904 LN8404	0.10527	0.10819	0.10536	0.11678	0.00145	0.00145	-			
330 >ST1822 LN2301	0.14273	0.14272	0.14275	0.14995	0.16314	0.16323	0.16179	-		
331 >ST1907 LN8348	0.14306	0.14593	0.14309	0.15021	0.16178	0.16185	0.16043	0.01171	-	
332 >ST1825 LN5132	0.14900	0.14903	0.14319	0.15178	0.14903	0.14910	0.14765	0.09229	0.09674	-
333 >ST1899 LN8968	0.14349	0.14331	0.13760	0.14753	0.14329	0.14449	0.14280	0.08755	0.09101	0.00730
334 >ST1894 LN8329	0.14629	0.14632	0.13768	0.15469	0.17014	0.17020	0.16703	0.05954	0.06520	0.07822
335 >ST1941 LN8901	0.14060	0.14065	0.13493	0.14489	0.14352	0.14447	0.14279	0.07585	0.07806	0.07012
336 >ST1895 LN8676	0.06910	0.06820	0.06038	0.08290	0.12205	0.12517	0.12164	0.15426	0.15771	0.15467
339 >ST1934 LN7742	0.09224	0.09163	0.08633	0.09773	0.11873	0.12018	0.11857	0.16489	0.16786	0.15672
340 >ST1933 LN8317	0.08330	0.08274	0.07740	0.08880	0.11555	0.11699	0.11539	0.16022	0.16322	0.15198
341 >ST1900 LN8397	0.15325	0.15062	0.14611	0.16612	0.15589	0.15792	0.15517	0.15025	0.15067	0.15046
342 >ST1901 LN7830	0.14999	0.14923	0.14748	0.16360	0.14896	0.14876	0.14631	0.15760	0.15956	0.15017
343 >ST1940 LN8320	0.15925	0.15640	0.15497	0.16637	0.16500	0.16604	0.16436	0.16457	0.16900	0.16362

Uncorrected ("p") distance matrix (continued)

	333	334	335	336	339	340	341	342	343
333 >ST1899 LN8968	-								
334 >ST1894 LN8329	0.07553	-							
335 >ST1941 LN8901	0.06743	0.00275	-						
336 >ST1895 LN8676	0.14626	0.14781	0.14723	-					
339 >ST1934 LN7742	0.15081	0.17083	0.15234	0.08388	-				
340 >ST1933 LN8317	0.15191	0.17310	0.14784	0.08124	0.01574	-			
341 >ST1900 LN8397	0.13873	0.13865	0.14357	0.13788	0.16840	0.16193	-		
342 >ST1901 LN7830	0.14009	0.13725	0.13704	0.14238	0.14828	0.15013	0.03268	-	
343 >ST1940 LN8320	0.15785	0.14835	0.15495	0.15429	0.15811	0.15642	0.04576	0.08327	-

Table 2. Uncorrected distance matrix. Additional taxa indicated in red. Intra-specific sequence divergences in yellow. Inter-specific sequence divergence with nearest neighbour highlighted in blue.

Results - Bathynellidae

Two of the nine received specimens appeared to be Bathynellidae and resulted in high quality sequences (Table 1). Neighbour joining analyses indicated that the specimens ST1937 and ST1938 belong to an additional species which fit in a different very distant clade compared to the previously encountered Bathynellid species (Figure 2, red highlighted), inter clade distances >22.6% (Table 3, red highlighted values). The intra-specific sequence divergence of ST1937 and ST1938 is 1.29% (Table 3, yellow highlighted value).

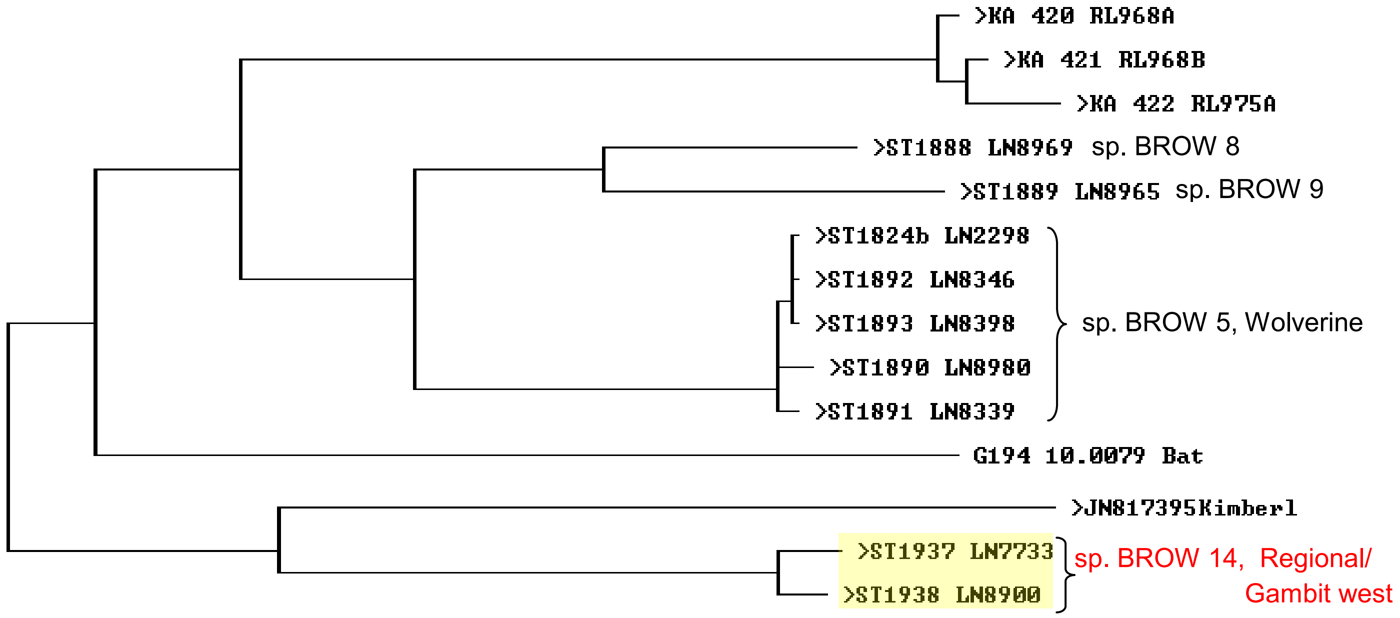

Figure 2. Partial neighbour joining cladogram of Bathynellidae including Browns Range species.

Uncorrected ("p") distance matrix

		4	5	6	255	319	320	321	322	323	324
4	>KA 420 RL968A	-									
5	>KA 421 RL968B	0.01183	-								
6	>KA 422 RL975A	0.01889	0.01478	-							
255	G194 10.0079 Bat	0.25589	0.25707	0.26596	-						
319	>ST1888 LN8969	0.19853	0.20164	0.21215	0.21984	-					
320	>ST1889 LN8965	0.21818	0.22144	0.23607	0.24279	0.08453	-				
321	>ST1824b LN2298	0.17976	0.18626	0.19534	0.22853	0.11891	0.12894	-			
322	>ST1890 LN8980	0.18177	0.18835	0.19759	0.22991	0.11855	0.12891	0.00295	-		
323	>ST1891 LN8339	0.18160	0.18811	0.19720	0.22996	0.11891	0.12607	0.00287	0.00589	-	
324	>ST1892 LN8346	0.17979	0.18626	0.19532	0.22993	0.11990	0.12985	0.00000	0.00296	0.00288	-
325	>ST1893 LN8398	0.17962	0.18604	0.19513	0.22993	0.11844	0.13129	0.00144	0.00441	0.00433	0.00145
336	>JN817395Kimberl	0.26747	0.27354	0.27705	0.29599	0.25876	0.26671	0.27548	0.28333	0.27769	0.27795
337	>ST1937 LN7733	0.26868	0.27628	0.28770	0.25718	0.23265	0.24700	0.23562	0.23825	0.23706	0.23599
338	>ST1938 LN8900	0.26859	0.27614	0.28747	0.25317	0.22573	0.24294	0.22873	0.23378	0.23017	0.23014

Uncorrected ("p") distance matrix (continued)

		325	336	337	338
325	>ST1893 LN8398	-			
336	>JN817395Kimberl	0.27808	-		
337	>ST1937 LN7733	0.23599	0.19583	-	
338	>ST1938 LN8900	0.23014	0.19614	0.01294	-

Table 3. Uncorrected distance matrix. Additional taxa indicated in red. Intra-specific sequence divergences in yellow. Inter-sclade sequence divergences in red.

Sequences aligned :
>ST1933_LN8317
CATAAAGATATTGGAACTCTATATTTACTTTTAGGAGCTTGGGCCGGAATATTAGGAACCGGCTTAAGAATACTTATTCGTTTA
GAATTAGGACAACCTGGGTCTTTTATAGGAAATGATCAAATATATAACGTTATTGTTACTGCCCATGCCTTTGTGATAATTTTT
TTTATAGTAATGCCAATTATGATTGGAGGGTTTGGTAATTGACTTATTCCTTTAATATTAAATTGTCCAGATATAGCTTTTCCTC
GAATAAATAATATAAGATTTTGACTTTTACCTCCTTCTCTTATTCTTTTACTAAGAAGAGGTTTGGTGGAAAGAGGAGTCGGGA
CTGGTTGAACTGTCTATCCTCCTTTAGCTTTAAATTTGTTTCATAGAGGACCTTCAGTTGATTTAGCAATTTTTTCTTTACATATG
GCAGGCGCCTCTTCAATTTTAGGGGCAATTAATTTTATCACAACTATTATTAATATACGTAACTCAGGGTTGTTAATAGACCGA
ATACCTTTATTCTGTTGAGCAGTTTTTATTACTGCAATTCTTTTACTGTTATCGTTACCTGTTCTTGCTGGAGGAATCACAATATT
ATTAACTGACCGAAACCTAAATACATCTTTTTTTGATCCGGCAGGAGGAGGAGACCCTATTCTATACCAACACTTATTTTGATT
TTTTGGTCACCCTGAAGTTTAGTC--

>ST1934_LN7742
CATAAAGATATTGGAACTCTATATTTACTTTTAGGAGCTTGGGCCGGAATAGTAGGAACCGGCTTAAGAATACTTATTCGTTT
AGAATTAGGACAACCTGGGTCTTTTATAGGAAATGATCAAATATATAACGTTATTGTAACAGCCCATGCCTTTGTGATAATTTT
CTTYATAGTAATGCCTATTATAATTGGAGGRTTTGGWAATTGATTTATTCCTTTAATATTAAATTGTCCAGATATAGCTTTTCCT
CGAATAAATAATATAAGATTTTGACTTTTACCTCCTTCTCTTACTCTTTTACTAAGAAGAGGTTTGGTRGAAAGAGGAGTCGGG
ACTGGTTGAACTGTCTATCCTCCTTTAGCTTTAAATTTGTTTCATACAGGACCTTCAGTTGATTTAGCAATTTTTTCTTTACATAT
GGCAGGCGCCTCTTCAATTTTAGGGGCAATTAATTTTATCACAACTATTATTAATATACGTAACTCAGGGTTGTTAATAGACCG
AATACCTTTATTCTGTTGAGCAGTTTTTATTACTGCAATTCTTTTACTGTTATCGCTACCTGTTCTTGCTGGAGGAATCACAATAT
TATTAACTGACCGAAACCTAAATACATCTTTTTTTGATCCGGCAGGAGGAGGAGATCCTATTCTATACCAACACTTATTTTGAT
TTTTTGGTCACCCTGAAGTTTAGTC--

>ST1935_LN7721
CATAAAGATATTGGAACTTTATATCTACTTTTAGGAGCTTGAGCTGGAATATTAGGAACCGGTTTAAGAATACTCATTCGTTTA
GAACTAGGACAACCTGGATCCTTTATAGGAAACGATCAAATATATAATGTTATTGTTACTGCTCATGCTTTTGTAATAATTTTTT
TTATAGTTATGCCAATTATAATTGGAGGGTTTGGTAATTGACTTATTCCTTTAATGTTGAATTGCCCAGATATAGCTTTCCCTCG
AATAAATAATATGAGGTTTTGACTTTTACCCCCTTCTCTTATTCTTTTACTAAGAAGAGGTTTAGTAGAAAGAGGAGTTGGAAC
TGGCTGAACTGTTTATCCTCCTTTAGCTTTAAATTTATTTCATAGAGGGCCTTCAGTTGATTTAGCAATTTTTTCTTTACATATAG
CAGGCGCCTCTTCAATTTTGGGGGCTATTAATTTTATTACAACTATCATTAACATACGTAATTCAGGATTATTAATAGATCGGA
TACCTTTATTTTGTTGAGCGGTTTTTATTACTGCAATTCTTTTATTATTATCGTTACCTGTTCTTGCAGGAGGAATTACAATATTA
CTAACTGACCGAAATTTAAATACGTCTTTTTTTGATCCGGCAGGAGGAGGAGATCCTATTTTATATCAACATCTATTTTGATTTT
TTGGTCACCCTGAAGTT---

>ST1938_LN8900
CATAAAGATATTGGTTCTCTTTATCTCATTTTTGGAGCATGAGCCGGAATGGTAGGAACTGGATTAAGAGTAATTATTCGAAT
AGAACTAGGTCAACCAGGTTTATACATTGGAAATGATCAAATTTATAATACAGTAGTAACAGCTCATGCTTTCGTTATAATTTT
TTTTATAGTTATACCTATTATAATTGGAGGATTTGGAAATTGATTAATTCCTTTAATGTTGAATTGTCCTGATATAGCTTTTCCTC
GAATAAACAACATAAGTTTTTGACTTTTACCTCCTTCATTAATTTTATTATTAACAAGAGGATTGTTAGAAAGAGGAGTAGGAA
CAGGATGAACAGTATATCCTCCCCTAGCTCTTCATCTGTTTCATAGAGGTTCATCGGTTGATTTAGCTATTTTTTCTTTACATTTA
GCTGGAGCTTCTTCTATTATAGGAGCTATTAATTTTATTTCAACTGTTATTAATATGCGATCTTCAGGTTTAAGTATAGATCGGA
TATCTTTATTTTGTTGGGCTGTTTTTATTACAGCTATTTTATTACTTTTGTCATTACCAGTTTTGGCCGGAGGATTAACCATATTG
TTGACTGATCGAAATTTAAATACTTCTTTTTTTGATCCGGCTGGAGGAGGAGACCCGATTTTATATCAACATTTATTTTGATTTT
TTGGTCACCCTGAAGT---

>ST1938_LN8900
CATAAAGATATTGGTTCTCTTTATCTCATTTTTGGAGCATGAGCCGGAATGGTAGGAACTGGATTAAGAGTAATTATTCGAAT
AGAACTAGGTCAACCAGGTTTATACATTGGAAATGATCAAATTTATAATACAGTAGTAACAGCTCATGCTTTCGTTATAATTTT
TTTTATAGTTATACCTATTATAATTGGAGGATTTGGAAATTGATTAATTCCTTTAATGTTGAATTGTCCTGATATAGCTTTTCCTC
GAATAAACAACATAAGTTTTTGACTTTTACCTCCTTCATTAATTTTATTATTAACAAGAGGATTGTTAGAAAGAGGAGTAGGAA
CAGGATGAACAGTATATCCTCCCCTAGCTCTTCATCTGTTTCATAGAGGTTCATCGGTTGATTTAGCTATTTTTTCTTTACATTTA
GCTGGAGCTTCTTCTATTATAGGAGCTATTAATTTTATTTCAACTGTTATTAATATGCGATCTTCAGGTTTAAGTATAGATCGGA
TATCTTTATTTTGTTGGGCTGTTTTTATTACAGCTATTTTATTACTTTTGTCATTACCAGTTTTGGCCGGAGGATTAACCATATTG
TTGACTGATCGAAATTTAAATACTTCTTTTTTTGATCCGGCTGGAGGAGGAGACCCGATTTTATATCAACATTTATTTTGATTTT
TTGGTCACCCTGAAGT---

>ST1939_LN5976
CATAAAGATATTGGAACTTTATATCTACTTTTAGGAGCTTGAGCTGGAATATTAGGAACCGGTTTAAGAATACTCATTCGTTTA
GAACTAGGACAACCTGGATCCTTTATAGGAAACGATCAAATATATAATGTTATTGTTACTGCTCATGCTTTTGTAATAATTTTTT
TTATAGTTATGCCAATTATAATTGGAGGGTTTGGTAATTGACTTATTCCTTTAATGTTGAATTGCCCAGATATAGCTTTCCCTCG
AATAAATAATATGAGGTTTTGACTTTTACCCCCTTCTCTTATTCTTTTACTAAGAAGAGGTTTAGTAGAAAGAGGAGTTGGAAC
TGGCTGAACTGTTTATCCTCCTTTAGCTTTAAATTTATTTCATAGAGGGCCTTCAGTTGATTTAGCAATTTTTTCTTTACATATAG
CAGGCGCCTCTTCAATTTTGGGGGCTATTAATTTTATTACAACTATCATTAACATACGTAATTCAGGATTATTAATAGATCGGA
TACCTTTATTTTGTTGAGCGGTTTTTATTACTGCAATTCTTTTATTATTATCGTTACCTGTTCTTGCAGGAGGAATTACAATATTA
CTAACTGACCGAAATTTAAATACGTCTTTTTTTGATCCGGCAGGAGGAGGAGATCCTATTTTGTATCAACATCTATTTTGATTTT

TTGGTCACCCTGAAGTTT--

>ST1940_LN8320
CATAAAGATATTGGAACCTTATATTTATTGTTAGGAGCTTGGGCAGGAATAGTAGGAACAGGTTTAAGAATAATTATTCGTTT
AGAACTAGGTCAACCAGGTCCATTTATTGGGAACGACCAGATATATAACGTTATTGTAACGGCTCATGCTTTTGTTATAATTTT
TTTTATGGTAATACCTATTATAATTGGAGGCTTTGGTAATTGACTGATTCCCTTAATATTAAATTGTCCAGATATAGCTTTTCCT
CGTATAAATAACATAAGATTTTGATTGTTGCCACCTTCATTAATCTTACTATTAACAAGAGGATTAGTAGAAAGTGGAGTTGG
AACAGGTTGAACTGTTTATCCTCCACTAGCTTTAAATTTGTTTCATAGAGGAGCTTCAGTAGATCTGGCTATTTTTTCGTTACAT
ATAGCAGGAGCTTCATCTATTTTAGGAGCCATTAATTTTATTACTACAATTATCAATATACGAAATTCAGGCCTATTAATAGATC
GAATGCCACTATTTTGTTGGGCCGTTTTTATTACAGCTATTCTTCTTTTGTTATCTTTGCCTGTTTTGGCAGGAGGGATCACTAT
GTTATTAACGGACCGTAATTTAAACACATCCTTTTTTGATCCTGCAGGAGGAGGAGACCCAATTTTATATCAACACTTATTTTG
ATTTTTTGGTCACCCTGAAGTTT--

>ST1941_LN8901
CATAAAGATATTGGAACTCTATATTTACTTTTAGGAGCATGAGCTGGTATATTAGGTACAGGATTAAGTATATTAATTCGTTTA
GAGTTAGGTCAACCAGGACCTTTTATAGGAAATGACCAAATATATAATGTAATCGTTACGGCACATGCTTTTGTAATAATTTTT
TTTATAGTTATACCAATTATGATTGGAGGCTTTGGGAATTGATTAATTCCATTAATATTAAATTGTCCAGATATAGCATTTCCAC
GAATAAATAATATAAGATTTTGACTTCTTCCTCCTTCTCTTATTCTATTATTAGTTAGAGGTTTAGTAGAAAGAGGTGTAGGTA
CAGGTTGAACTGTTTATCCTCCATTAGCTTTAAACTTATTTCATAGAGGTCCTTCCGTTGATTTAGCAATTTTTTCACTTCATATA
GCAGGGGCTTCATCAATTTTAGGAGCTATTAATTTTATTACTACTATTATTAATATACGAAACTCAGGATTATTTATAGATCGTA
TACCATTATTTTGCTGGGCTGTTTTTATTACAGCTATTCTTTTATTATTATCTCTTCCTGTATTAGCGGGGGGGATTACTATATTA
TTAACAGATCGAAATTTAAACACATCATTTTTTGATCCTGCTGGAGGTGGTGATCCTATTTTATATCAGCATTTATTTTGATTTT
TTGGTCACCCTGAAGTTT--

Prepared for Outback Ecology, 5 February 2014
by Dr Remko Leijs, South Australian Museum.

Appendix 3

Browns Range Bathynellidae and Parabathynellidae

Summary

- **1 additional Bathynellidae species was recognised from Borefield.**
- **The total number of Bathynellacea species from Browns Range is now 15!**

Introduction

The current study builds on to previous molecular assessments of the stygofauna of the Browns Range area.

Methods

Four additional specimens from the Borefield area within the Browns Range are analysed using the same methods as in earlier molecular biodiversity assessments.

Extraction	Code	OE identification	SAM identification	Extr.date	Coll.Date	locality	Site	CO1
ST1957	LN5947	Bathynellidae	sp. BROW 15	26-Jan-14	17-Dec-13	Borefield	BRR040	good seq
ST1958	LN6567	Bathynellidae	sp. BROW 15	26-Jan-14	17-Dec-13	Pot. Borefield	BRRWS010	good seq
ST1959	LN6567	Bathynellidae	sp. BROW 15	26-Jan-14	17-Dec-13	Pot. Borefield	BRRWS010	good seq
ST1960	LN6506	Parabathynellidae	sp. BROW 10	26-Jan-14	17-Dec-13	Pot. Borefield	BRRWS010	good seq

Table 1. Overview of the additional analysed specimens. The first column gives the DNA extraction numbers, the last column indicates whether the DNA sequencing was successful. Yellow highlighted fields indicate successfully analysed specimens, red highlighted field in the SAM identification column indicate newly found species.

Results - Parabathynellidae

The received specimen resulted in a high quality sequence (Table 1). Neighbour joining analyses indicated that this specimen belong to a clade previously designated sp. BROW 10.
The new specimen ST1960 is conspecific with ST1940, indicated by a sequence divergence of 1.77% (Table 2, yellow highlighted value). Sequence divergences with specimen ST1900 and ST1901 are much higher (Table 2, blue highlighted values), which would normally indicate inter-specific differences. However, as explained in the previous report (Appendix 2, October 2013) these high values are probably caused by a number of ambiguities in the sequences of specimens ST1900 and ST1901. The conservative approach is to consider these specimens conspecific. Additional specimens from GambitWest would be needed to test whether there are multiple species in this clade.

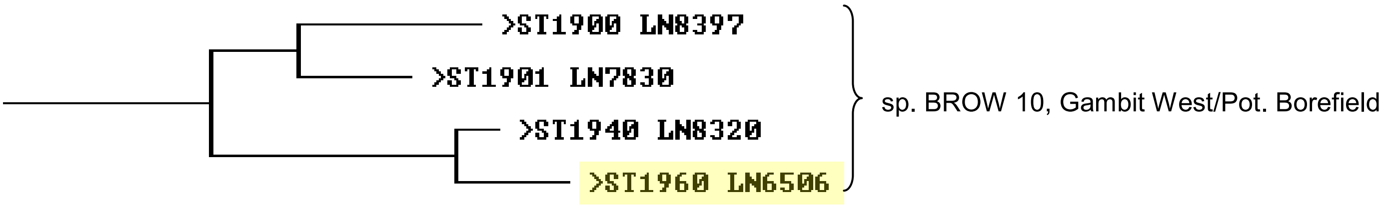

Figure 1. Partial neighbour joining cladogram of Parabathynellidae from Browns Range.

Uncorrected ("p") distance matrix

	341	342	343	347
341 >ST1900 LN8397	-			
342 >ST1901 LN7830	0.03268	-		
343 >ST1940 LN8320	0.04576	0.08327	-	
347 >ST1960 LN6506	0.05137	0.09267	0.01767	-

Table 2. Uncorrected distance matrix. Additional taxa indicated in red. Intra-specific sequence divergences in yellow.

Results - Bathynellidae

All received specimens appeared resulted in high quality sequences (Table 1). Neighbour joining analyses indicated that the specimens ST1957-ST1959 belong to an additional species which fit in a clade containing 3 previously recognised Bathynellid species (Figure 2, red highlighted). The intra-specific sequence divergences among ST1957-ST1958 are 0.72-1.29% (Table 3, yellow highlighted value). Sequence divergences with the other species are 9.66-10.52% (Table 3, blue highlighted values).

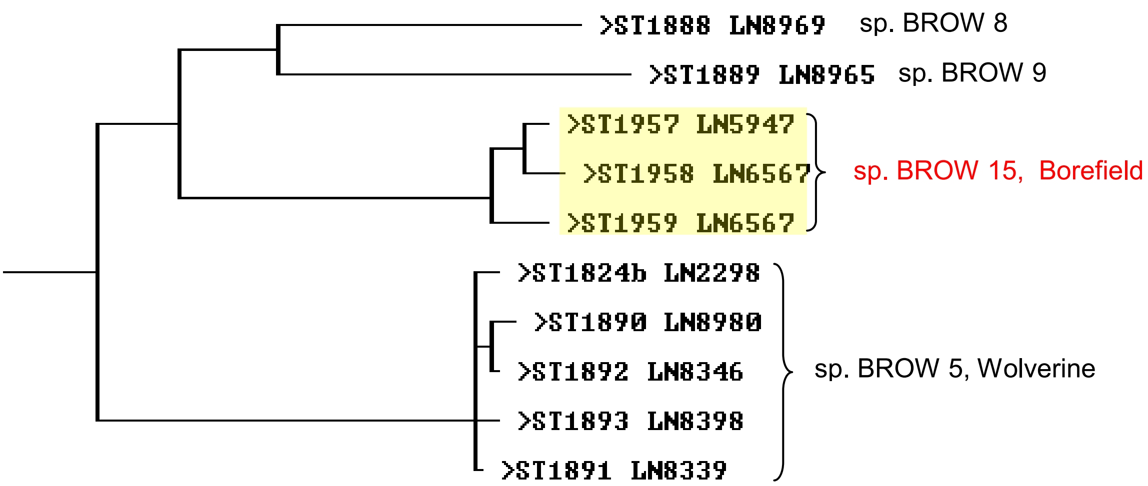

Figure 2. Partial neighbour joining cladogram of Bathynellidae in the Browns Range area.

Uncorrected ("p") distance matrix

	319	320	321	322	323	324	325	344	345
319 >ST1888 LN8969	-								
320 >ST1889 LN8965	0.08453	-							
321 >ST1824b LN2298	0.11891	0.12894	-						
322 >ST1890 LN8980	0.11855	0.12891	0.00295	-					
323 >ST1891 LN8339	0.11891	0.12607	0.00287	0.00589	-				
324 >ST1892 LN8346	0.11990	0.12985	0.00000	0.00296	0.00288	-			
325 >ST1893 LN8398	0.11844	0.13129	0.00144	0.00441	0.00433	0.00145	-		
344 >ST1957 LN5947	0.09659	0.09940	0.10097	0.09977	0.10097	0.10121	0.10266	-	
345 >ST1958 LN6567	0.09660	0.10086	0.10097	0.09982	0.10097	0.10120	0.10264	0.00722	-
346 >ST1959 LN6567	0.10379	0.10516	0.10096	0.09975	0.10096	0.10123	0.10267	0.00866	0.01299

Table 3. Uncorrected distance matrix of Bathynellidae . Additional taxa indicated in red. Intra-specific sequence divergences in yellow.

Sequences aligned :

>ST1957_LN5947

CATAAAGATATTGGAACTTTATACTTGATTCTCGGAGCTTGGGCTGGGTTAGTAGGTACTGGGATAAGAGTAATTATTCGTAT
AGAATTAGGTCAACCAGGGTCTTTAATCGGAGATGACCAAATTTATAATACTATTGTGACCGCCCATGCATTTGTTATAATTTT
CTTTATAGTTATACCTATAATAATTGGTGGATTTGGCAATTGATTAGTGCCATTAATAATTAGTGCACCTGACATATGTTTTCCA
CGAATAAATAACATAAGATTTTGACTACTTCCCCCATCACTTTTATTATTATTAGCTAGAAGGTTTGTGGAAAGAGGTGTAGGA
ACTGGATGAACAGTTTACCCTCCTTTAGCTAGGAATGTTTCACATAGGGGGGCTTCAGTCGATTTAGCTATTTTCTCTTTACAC
ATTGCAGGGGCTTCTTCTATTATGGGGGCTGTCAATTTTATTAGTACATTGAGAAATATGCGGGCTCCTGGCATGCTTTTAGA
ACTAATGCCATTATTCCCATGATCTGTTCTAATAACAGCCCTGTTATTACTTTTTTCATTACCAGTTTTAGCTGGAGGAATTACT
ATACTATTAACTGATCGTAATTTAAATACATCATTTTTTGATCCTGCGGGTGGGGGGGATCCTATCCTTTATCAACACTTGTTTT
GATTTTTTGGTCACCCTGAA--

>ST1958_LN6567

CATAAAGATATTGGAACTTTATACTTGATTCTCGGAGCTTGGGCTGGGTTAGTAGGTACCGGGATAAGAGTAATTATTCGTAT
AGAATTAGGTCAACCAGGGTCTTTAATCGGAGATGACCAAATTTATAATACTATTGTGACCGCCCATGCATTTGTTATAATTTT
CTTTATAGTTATACCTATAATAATTGGTGGATTTGGCAATTGATTAGTGCCATTAATAATTAGTGCACCTGACATATGTTTTCCA
CGAATAAATAACATAAGATTTTGACTACTTCCCCCATCACTTTTATTATTATTAGCTAGAAGGTTTGTGGAAAGAGGTGTAGGA
ACTGGATGAACAGTCTACCCTCCTTTAGCTAGGAATGTTTCACATAGGGGGGCTTCGGTCGATTTAGCTATTTTCTCTTTACAC
ATTGCAGGGGCTTCTTCTATTATGGGGGCTGTCAATTTTATTAGTACATTGAGAAATATGCGGGCTCCTGGCATGCTTTTAGA
ACTAATGCCATTATTCCCGTGATCTGTTCTAATAACAGCCCTGTTATTACTTTTTTCATTACCAGTTTTAGCTGGAGGAATTACT
ATACTATTAACTGATCGTAATTTAAATACATCATTTTTTGATCCTGCGGGTGGGGGAGATCCTATCCTTTATCAACACTTGTTTT
GATTTTTTGGTCACCCTGAA--

>ST1959_LN6567

CATAAAGATATTGGAACTTTATACTTAATTCTCGGAGCTTGGGCTGGGTTAGTAGGTACTGGGATAAGAGTAATTATTCGTAT
AGAATTAGGTCAACCAGGGTCTTTAATCGGAGATGACCAAATTTATAATACTATTGTGACCGCCCATGCATTTGTTATAATTTT
TTTTATAGTTATACCTATAATAATTGGTGGATTTGGCAATTGATTAGTGCCATTAATAATTAGTGCGCCTGACATATGTTTTCCA
CGAATAAATAACATAAGATTTTGACTACTTCCCCCATCACTTTTATTATTATTAGCTAGAAGGTTTGTGGAAAGAGGTGTAGGA
ACTGGATGGACAGTTTACCCTCCTTTAGCTAGGAATGTTTCACATAGGGGGGCTTCAGTCGATTTAGCTATTTTCTCTTTACAC
ATTGCAGGGGCTTCTTCTATTATGGGGGCTATCAATTTTATTAGTACATTGAGAAATATGCGGGCTCCTGGCATGCTTTTAGAA
CTAATGCCATTATTCCCATGATCTGTTCTAATAACAGCCCTGTTATTACTTTTTTCATTACCAGTTTTAGCTGGAGGAATTACTAT
ACTATTAACTGATCGTAATTTAAATACATCATTTTTTGATCCTGCGGGTGGGGGAGATCCTATCCTTTATCAACACTTGTTTTGA
TTTTTTGGTCACCCTGAA--

>ST1960_LN6506 -----------------------------

GTTAGGAGCTTGGGCAGGAATAGTAGGAACAGGTTTAAGAATAATTATTCGTTTAGAACTAGGTCAACCAGGTCCATTTATT
GGGAACGACCAGATATATAACGTTATYGTAACGGCTCATGCTTTTGTTATAATTTTTTTTATGGTGATACCTATTATAATTGGA
GGCTTCGGTAATTGACTAATTCCCTTAATATTAAATTGTCCAGATATAGCTTTTCCTCGTATAAATAACATAAGATTTTGATTGT
TGCCACCTTCATTGATCTTATTATTAACAAGAGGATTAGTAGAAAGTGGAGTTGGAACAGGTTGAACTGTTTACCCTCCACTA
GCTTTAAATTTGTTTCATAGAGGAGCTTCAGTAGATCTGGCCATTTTTTCGTTACATATAGCAGGAGCTTCATCTATTTTAGGA

GCCATTAATTTTATTACTACAATTATTAATATACGAAATTCAGGCCTATTAATAGATCGAATGCCACTATTTTGTTGGGCTGTTT
TTATTACAGCTATTCTTCTTTTGTTATCTTTGCCTGTTTTGGCAGGAGGGATCACTATGTTATTAACGGACCGTAATTTAAACAC
ATCTTTTTTTGATCCTGCAGGAGGAGGAGATCC---

APPENDIX G

Record of Alignments Among Morphospecies Names Used

Record of alignments among morphospecies names used

Higher classification	Outback Ecology morphospecies name	Previous morphospecies or provisional name assigned by taxonomist or DNA specialist
Bathynellacea	Bathynellidae-OES19	Bathynellidae sp. BROW 5
	Bathynellidae-OES24	Bathynellidae sp. BROW 8
	Bathynellidae-OES25	Bathynellidae sp. BROW 9
	Bathynellidae-OES26	Bathynellidae sp. BROW 14
	Bathynellidae-OES27	Bathynellidae sp. BROW 15
	Parabathynellidae-OES16	Parabathynellidae new genus sp. BROW 1
	Parabathynellidae-OES17	Parabathynellidae new genus sp. BROW 2
	Parabathynellidae-OES18	Parabathynellidae new genus sp. BROW 3
	Parabathynellidae-OES20	Parabathynellidae new genus sp. BROW 4
	Parabathynellidae-OES21	Parabathynellidae new genus sp. BROW 6
	Parabathynellidae-OES22	Parabathynellidae new genus sp. BROW 10
	Parabathynellidae-OES23	Parabathynellidae new genus sp. BROW 7
	Parabathynellidae-OES26	Parabathynellidae new genus sp. BROW 12
	Parabathynellidae-OES27	Parabathynellidae new genus sp. BROW 11
	Parabathynellidae-OES28	Parabathynellidae new genus sp. BROW 13
Oligochaeta	Enchytraeidae-OES17	Enchytraeidae sp. BROW 1
Copepoda	*Metacyclops* -OES20	*Metacyclops 'brownsi'* n. sp
	Dussartcyclops -OES2	*Dussartcyclops* sp. 1 n. sp.
	Parastenocaris -OES1	*Parastenocaris* sp. 1 n. sp.

APPENDIX H

Copepoda Morphological Assessment Reports

Browns Ranges Copepoda Morphological Assessment

29th July, 2013

Prepared by
Dr. T. Karanovic Research Professor
Biodiversity Laboratory,
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Seoul 133-791 Korea
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RE:
Job Number: **BROW-SF-11001**
Taxa: Copepods
Region: **Browns Ranges (WA)**
Total Number of Samples: 4 vials

I. RESULTS:

Browns Ranges, Mystique, BRMR016, -18.96517191, 128.9369444, 4/12/2013, Net Haul, Cyclopoida, 2, LN8352, WAM C52558
Microcyclops varicans (G.O. Sars, 1863) – 1 male + 3 females + 6 copepodids (1 female dissected on 1 slide, others in alcohol)

Browns Ranges, Mystique, BRMR026, -18.96416667, 128.9363889, 4/12/2013, Net Haul, Cyclopoida, 1, LN8403, WAM C52556
Microcyclops varicans (G.O. Sars, 1863) – 1 female in alcohol

Browns Ranges, Wolverine, BRWD0007, -18.85916667, 128.9402778, 4/12/2013, Net Haul, Cyclopoida, 18, LN7810, WAM C52557
Metacyclops brownsi n. sp. – 1 male + 6 females + 11 copepodids (1 female dissected on 1 slide, others in alcohol)

Browns Ranges, Wolverine, NMBRRC077, -18.85916667, 128.9405556, 4/12/2013, Net Haul, Cyclopoida, 5, LN8331, WAM C52555
Metacyclops brownsi n. sp. – 1 male + 1 female + 1 copepodid

I. SYSTEMATIC LIST:

Subphylum Crustacea Brünich, 1772
Class Maxillopoda Dahl, 1956
Subclass Copepoda H. Milne Edwards, 1840
Order Cyclopoida Rafinesque, 1815
Family Cyclopidae Rafinesque, 1815
Subfamily Cyclopinae Rafinesque, 1815
Genus *Metacyclops* Kiefer, 1927
1. *Metacyclops brownsi* n. sp.

Genus *Microcyclops* Claus, 1893
2. *Microcyclops varicans* (G.O. Sars, 1863)

II. COMMENTS:

Microcyclops varicans (G.O. Sars, 1863) is a widely distributed surface-water species, already recorded a number of times in Australian subterranean habitats (Karanovic 2004, 2006). It is a stygophile.

Metacyclops brownsi n. sp. is only provisionally placed in the genus *Metacyclops.* Its morphological characteristics would suggest it as a missing link between Australian endemic genera *Pescecyclops* Karanovic, Eberhard & Murdoch, 2011 and *Pilbaracyclops* Karanovic, 2006. Most plesiomorphic characters make this species look quite similar to *Pescecyclops laurentiise* (Karanovic, 2004), including the shape and armature of P4, P5 and A1.

Major differences include: only 6 setae on Enp2A2, 4 setae on Enp2P2 & P3, larger Gsg, slightly shorter Fu & longer dorsal seta on Fu. It is certainly a new species, that I am encountering for the first time in your material.

III. REFERENCES

Karanovic T. (2004): Subterranean Copepoda from arid Western Australia. *Crustaceana Monographs*, 3: 366pp.

Karanovic T. (2006) Subterranean copepods (Crustacea, Copepoda) from the Pilbara region in Western Australia. *Records of the Western Australian Museum, Supplement* 70: 239pp.

Karanovic T., Eberhard S.M., Murdoch A. (2011): A cladistic analysis and taxonomic revision of Australian *Metacyclops* and *Goniocyclops*, with description of four new species and three new genera (Copepoda, Cyclopoida). *Crustaceana* 84: 1-67.

With best wishes,

Tom Karanovic

Seoul, 29 July 2013

Tanami Desert Copepoda Morphological Assessment

17th October, 2013

Prepared by
Dr. T. Karanovic Research Professor
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Department of Life Sciences
Hanyang University
Seoul 133-791 Korea
email: Tomislav.karanovic@utas.edu.au

RE:
Job Number: **BROW-SF-11001**
Taxa: Copepods
Region: **Tanami Desert (WA)**
Total Number of Samples: 1 vial

I. RESULTS:

WA, Browns Ranges, 150 km SE of Halls Creek, bore BRR0003, 18°51'44"S 128°54'45"E, 19 August 2013, leg. S. Lange, Harpacticoida, 2, LN8889, WAM C54556

Megastygonitocrella trispinosa (Karanovic, 2006) – 2 females in alcohol

I. SYSTEMATIC LIST:

Subphylum Crustacea Brünnich, 1772
Class Copepoda Milne-Edwards, 1840
Order Harpacticoida Sars, 1903
Family Ameiridae Monard, 1927
Genus *Megastygonitocrella* Karanovic & Hancock, 2009
Megastygonitocrella trispinosa (Karanovic, 2006)

II. COMMENTS:

Megastygonitocrella trispinosa (Karanovic, 2006)

This species was described as *Stygonitocrella trispinosa* by Karanovic (2006) from several localities in the Pilbara region. It was later reported from numerous localities in the Pilbara region and transferred into the newly erected genus *Megastygonitocrella* by Karanovic & Hancock (2009). It shows significant variability both between and within sites, and also many asymmetries have been reported (including the number of spines on the female baseoendopod of the fifth leg, which is the name bearing feature!). In your sample both female specimens exhibited two spines on this appendage.

REFERENCES

Karanovic T. (2006) Subterranean copepods (Crustacea, Copepoda) from the Pilbara region in Western Australia. *Records of the Western Australian Museum, Supplement* 70: 239pp.

Karanovic T. & Hancock P. (2009) On the diagnostic characters of the genus *Stygonitocrella* (Copepoda, Harpacticoida), with descriptions of seven new species from Australian subterranean waters. *Zootaxa* 2324: 1-85.

With best wishes,

Tom Karanovic

Seoul, 17 October 2013

Browns Ranges Copepoda Morphological Assessment

24th February, 2014

Prepared by
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RE:
Job Number: **BROW-SF-11001**
Taxa: Copepods
Region: **Browns Ranges (WA)**
Total Number of Samples: 2 vials

I. RESULTS:

WA, Browns Range, bore BRRWS010, 18°55'15.0"S 128°51'28.5, 17 December 2013, leg. S. Lange, Net Haul, Harpacticoida, LN6504, WAM C60012

Parastenocaris sp. 1 n. sp. – 12 males + 11 females (1 male dissected on 1 slide, others in alcohol)

WA, Browns Range, bore BRRWS010, 18°55'15.0"S 128°51'28.5, 17 December 2013, leg. S. Lange, Net Haul, Cyclopoida, LN7669, WAM C60013

Dussartcyclops sp. 1 n. sp. – 1 male in alcohol

II. SYSTEMATIC LIST:

Sybphylum Crustacea Brünich, 1772
Class Maxillopoda Dahl, 1956
Subclass Copepoda H. Milne Edwards, 1840
Order Cyclopoida Rafinesque, 1815
Family Cyclopidae Rafinesque, 1815
Subfamily Cyclopinae Rafinesque, 1815
Genus *Dussartcyclops* Karanovic, Eberhard & Murdoch, 2011

1. *Dussartcyclops sp. 1* n. sp.

Order Harpacticoida Sars, 1903
Family Parastenocarididae Chappuis, 1940
Subfamily Parastenocaridinae Chappuis, 1940
Genus *Parastenocaris* Kessler, 1913

2. *Parastenocaris sp 1* n. sp.

III. COMMENTS:

Dussartcyclops sp. 1 n. sp. belongs to the Western Australian endemic genus *Dussartcyclops* established by Karanovic et al. (2011) for two members from Yilgarn (previously identified as members of Goniocyclops) and one from Barrow Island, Pilbara (previously identified as a member of *Allocyclops*). The new species from Browns Range is relatively closely related to *Dussartcyclops uniarticulatus* (Karanovic, 2004), described from the Yilgarn region by Karanovic (2004), but can be distinguished by only two setae on the Enp2P2, dorsal seta on the caudal rami almost as long as the outer apical seta, and much shorter anal operculum. These interesting cyclopoids are probably a very old lineage (with clear Gondwana connections) but are always rare. They are all stygobionts.

Parastenocaris sp 1 n. sp. is very similar to the common Pilbara species *Parastenocaris jane* Karanovic, 2006, which was recorded from numerous bores (unpublished data) in addition to those reported in Karanovic (2006). The new species differs from *P. jane* by a wider urosome, shape of the EnpP4 in male (no setules, etc.), size of the ExpP3 apophysis in male (almost as long as entire Exp), and presence of spiniform process on the male P5 (similar to that in female, but shorter). This species is also a stygobiont.

IV. REFERENCES

Karanovic T. (2004): Subterranean Copepoda from arid Western Australia. *Crustaceana Monographs*, 3: 366pp.

Karanovic T. (2006) Subterranean copepods (Crustacea, Copepoda) from the Pilbara region in Western Australia. *Records of the Western Australian Museum, Supplement* 70: 239pp.

Karanovic T., Eberhard S.M., Murdoch A. (2011): A cladistic analysis and taxonomic revision of Australian *Metacyclops* and *Goniocyclops*, with description of four new species and three new genera (Copepoda, Cyclopoida). *Crustaceana* 84: 1-67.

With best wishes,

Tom Karanovic

Seoul, 24 February 2013

APPENDIX I

Troglofauna Survey Results

Troglofauna results.

Higher level	Family	Taxon ID	Project Area	Bore Code	Impact?	Sample Date	No. of individuals	Collection Method
Diplura	Projapygidae	Projapygidae-OES2	Gambit East	BRR008	No	20130815	1	Scrape
Diplura	Projapygidae	Projapygidae-OES2	North-Western Regional	BRR003	No	20131217	2	Scrape
Thysanura (Zygentoma)	Nicoletiidae	Nicolitinae-OES10	Central Regional	BRR040	No	20131217	1	Scrape