Reed Resources Ltd

Barrambie Vanadium Project

Barrambie Borefield, Stygofauna Assessment.

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DRAFT REPORT

Reed Resources Ltd

outback ecology

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Executive Summary

In 2009 the Definitive Feasibility Studies for the Barrambie Vanadium Project Area (BVPA), 80 km northwest of Sandstone, were completed by Reed Resources Ltd with the project assessed at a PER level. Outback Ecology was commissioned to assess the potential risk of the project to the stygofauna community within the proposed Barrambie borefield as part of these studies.

Four stygofauna surveys (Phases I – IV) were conducted, with 15 sites (bores and pastoral wells) sampled, resulting in 41 samples collected. From the 40 taxa identified, 24 were identified as stygal or potentially stygal taxa, from a total of 40 taxa. The taxon accumulation curve, generated using the data collated from the four phases, suggested that a reasonable proportion of the expected taxa (75 % - 88 %) has been collected.

Some taxa were only collected from impact zone bores and their distribution therefore appears localised. Among these were potentially new taxa including *Pseudectinosoma sp. 1* n. sp. (T. Karanovic), *Halonsicus* nr *longiantennatus*, *Atopobathynella* sp. OE1 (J. McRae), *Atopobathynella* nr sp. OE1, *Atopobathynella* sp. OES3 and *Atopobathynella* sp. OES4. While it appears that these taxa may be at risk from the groundwater abstraction associated with the proposed Barrambie borefield, there are a number of factors which mitigate the risk to these taxa.

The distribution pattern of several groups in the Barrambie borefield indicates a level of connectivity through the borefield. This is further supported by the similarity in groundwater quality measured over four sampling phases. The expected hydraulic connectivity between the calcrete aquifer and the alluvial sediments would also be likely to further improve the ability of the stygofauna to disperse, potentially lessening the risk to stygofauna. Additionally, as a result of the conservative approach undertaken during groundwater modelling and the proposed retention of an average saturated aquifer thickness of 75 % within the borefield area for the first five years, there is likely to be sufficient groundwater habitat maintained in the area of impact. The risk to the stygofauna community from the Barrambie borefield proposal is therefore considered to be low.

The assessment undertaken by Reed Resources has provided valuable information on a Priority Ecological Community (Department of Environment and Conservation 2009) by defining the stygofauna community present. The intended implementation of an annual stygofauna monitoring program for at least the first five years of the project would provide further knowledge on the Barrambie borefield (Cogla Downs) calcrete aquifer while assisting in management efforts.

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1. INTRODUCTION

1.1 Project background

Outback Ecology was commissioned by Aquaterra, on behalf of Reed Resources Ltd, to undertake the stygofauna assessment for the Definitive Feasibility Studies into the production of vanadium from the Barrambie deposit. The Barrambie Vanadium Project Area (BVPA) lies within the Murchison Region of Western Australia, 80 km northwest of Sandstone and 115 km southeast of Meekatharra (**Figure 1**). Reed Resources Ltd propose to mine approximately 3 Mt of vanadium ore per annum over an initial mine life of 12 years. It is estimated that a water supply of 2.5 GL per annum will be required for dust suppression and use in the processing plant and mining camp.

An aquifer located within the Cogla Downs drainage system, 30 km north of the BVPA on the Yarrabubba Station pastoral lease area, was identified as a potential source of water for the project. Cogla Downs is part of an extensive palaeodrainage system, extending some 40 km to the northwest and 30 km to the southwest, with drainage toward Lake Annean. Two main aquifers are associated with the Cogla Downs drainage system; a shallow calcrete aquifer and a deeper palaeochannel aquifer. This study focussed on the shallow calcrete aquifer, referred to as the Barrambie borefield.

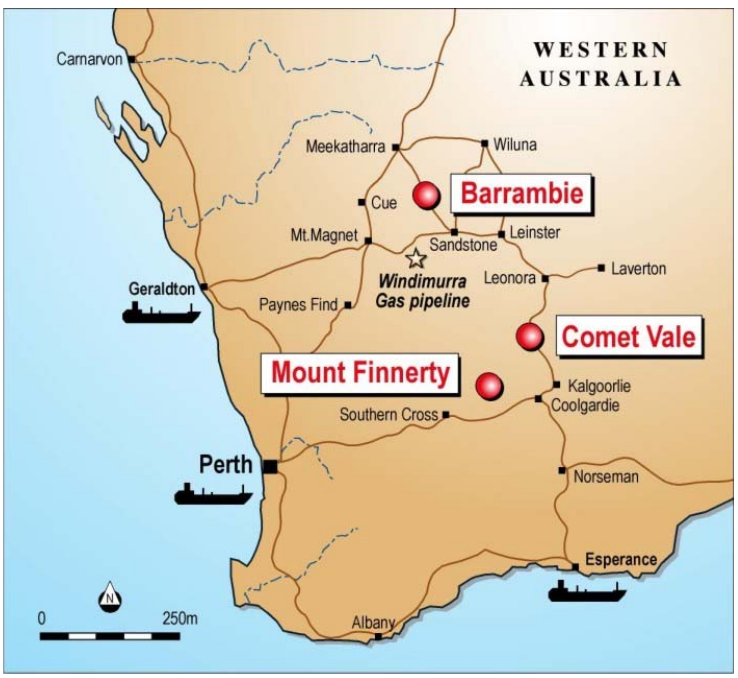

Figure 1: Location of the Barrambie Vanadium Project Area (source: Reed Resources Ltd).

1.2 Climate

The climate of the Murchison Region is classified as arid, characterised by cool winters and dry hot summers (Hall and Milewski 1994, McKenzie *et al.* 2002). The mean annual rainfall for Sandstone (the closest weather station to the Barrambie borefield) is approximately 250 mm, the majority falling between January and July.

Monthly rainfall totals for 2008 were mostly below the long-term averages (**Figure 2**). The exceptions were February and November with totals of approximately 90 and 80 mm, respectively, and potentially contributing to groundwater recharge. Above average falls were also recorded in December 2007 (49.6 mm), prior to the January 2008 (Phase I) survey. Rainfall in this region is driven by localised thunderstorms or, less commonly, cyclonic events in northern coastal Western Australia (Bureau of Meteorology 2009).

Rainfall was found to be more consistent in the months leading up to the Phase IV survey (**Figure 2**). Monthly totals ranged from approximately 3 - 43 mm and generally exceeded the long-term average.

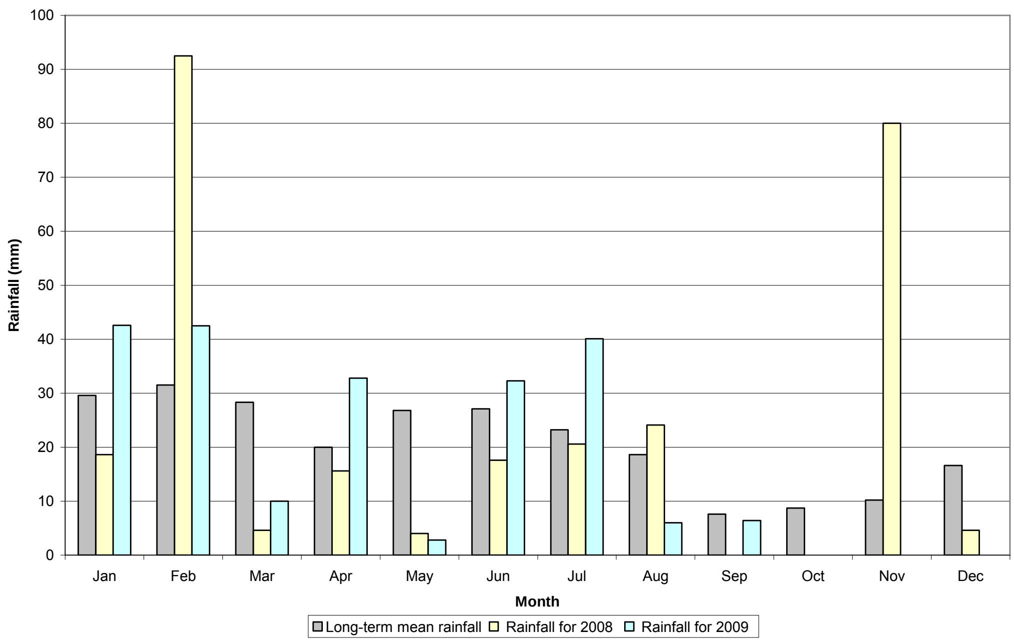

Figure 2: **Monthly rainfall data for Sandstone, Western Australia, 2008 to 2009 compared to the long-term averages. The 2009 data is from January to October only. (Bureau of Meteorology 2009).**

1.3 Hydrogeological context

1.3.1 Aquifer thickness and extent

During water supply investigations the extent of the Barrambie borefield calcrete aquifer was considered to be best represented by the outcrop area as defined by the GSWA 1: 250,000 geology map. Calcrete was absent from some locations within the outcrop area and concomitantly is known to occur outside the outcrop area, suggesting that the calcrete aquifer may be a channelised system rather than a single isotropic homogenous aquifer.

The Barrambie borefield calcrete aquifer is thought to extend to depths of 20 m, though is typically 5 to 15 m in thickness, declining to the north. The depth to the groundwater within the unconfined alluvium and calcrete aquifers range from 2 – 7 mbgl (Aquaterra 2009). Drilling confirmed the calcrete has karstic solution features; porosity is high and secondary permeability is enhanced by numerous fractures and fissures which have been developed and exploited by the groundwater flow. The thin rubbly soils mean that the calcrete aquifer can receive substantial direct recharge from rainfall (Aquaterra 2008), although there is currently insufficient data to quantify the amount (Aquaterra 2009).

1.3.2 Groundwater modelling

Hydraulic pump tests were carried out by Aquaterra in August and October 2007 to assess the extent of the calcrete aquifer and the sustainability of the water supply. Four bores (B8P, B10P, B15P, and Limestone Bore) were test pumped in October 2007 at abstraction rates ranging from 12 L/s to 20 L/s for a period ranging between 4 and 36 hours. Water level drawdown observed at these bores ranged from 0.01 m, atLimestone Bore, to 2.37 m at B15P.

The sustainability of the calcrete aquifer was assessed through the development of a numerical groundwater model (Aquaterra 2008). A preliminary borefield layout was designed incorporating seven production bores and two standby bores to meet the initial water supply demand of 1.24 GL/a (3400 kL/d). The initial numerical model suggested that this level of abstraction could be sustained for the proposed 12 year mine life. An updated groundwater model was developed to evaluate the sustainability of the water supply with an increased project demand of 2.5 GL/a.

The updated numerical model was used to simulate groundwater abstraction from the calcrete aquifer for a period of 20 years, although the initial life of the mine is only 12 years. The model consisted of two runs and adopted a conservative approach that did not incorporate recharge via rainfall (Aquaterra 2008). Furthermore, the modelled calcrete extent did not take into consideration the eastern branch of the Cogla Downs drainage system which would increase the volume of groundwater available in storage. Finally, inflow from adjacent alluvial sediments was not incorporated in the model despite the expectation that the surrounding alluvial sediments are in hydraulic connection with the calcrete aquifer (Aquaterra 2009).

The scenario based on the best estimate of aquifer parameters (Base Case) suggested that the increased water supply (2.5 GL/a) could be provided from a borefield of seven to 10 production bores. However, if conditions were more similar to the “worst case” scenario, the water supply demand may not be sustainable from a borefield of seven to 10 boresfor the predicted mine life of 12 years (Aquaterra 2008).

The extent of the calcrete aquifer drawdown under Base Case aquifer conditions is shown in **Appendices A** and **B.** According to these scenarios the existing pastoral wells, Barlanga, Bedan and South Mill, will retain over 75 % aquifer saturated thickness, with 76 – 78 % and 85 % and 90 %, respectively for each of the wells. Yilby Bore will only have a retention of 55 – 58 % saturation. Similarly, Bore 3 (Obs A) will retain 58 – 62 % of aquifer saturated thickness. The observation bores in the south and centre of the calcrete aquifer (Obs. C and Obs. D) retain 75 - 79 % of aquifer saturation, while the observation bore in the north of the calcrete aquifer (Obs. B) will only retain 69 - 70 % of the aquifer saturated thickness (Aquaterra 2008).

1.4 Stygofauna

The term stygofauna is applied to fauna which inhabit subterranean waters. These organisms can be further categorised according to their level of dependence on the subterranean environment. Animals that enter groundwaters accidentally/passively are referred to as stygoxenes. Those that actively seek resources in groundwater systems on a permanent or temporary basis are known as stygophiles. Organisms that are restricted to subterranean waters (obligate groundwater inhabitants) are termed stygobites. These animals generally display characteristics typical of a subterranean existence which include: a reduction or absence of pigmentation, absence or reduction of eyes, and the presence of extended locomotory and sensory appendages (Gibert *et al.* 1994, Humphreys 2008).

Stygofauna inhabit aquifers containing voids of suitable size for a species' biology. These habitats include voids in karst and pseudokarst, fractured rock, pisolites, alluvial and calcrete aquifers (Humphreys 2009). Distribution is primarily influenced by hydrological stability, groundwater quality, available energy sources, dispersal routes and habitat space (Strayer 1994).

Subterranean surveys over the last decade have revealed that Western Australia harbours an exceptional abundance and diversity of stygofauna (Humphreys 2006, Humphreys *et al.* 2004). Stygofauna diversity is higher within classic karst systems, such as those found in the Cape Range. However, the calcrete aquifers of the arid zone, have also been found to contain diverse stygal populations (Humphreys 2006, Karanovic 2004). Studies in this region have identified a number of endemic stygofauna, some of which are restricted to single aquifers (Karanovic 2004, Watts and Humphreys 1999, Watts and Humphreys 2001, Watts and Humphreys 2003, 2006), potentially representing an important conservation issue (Humphreys 2006).

1.5 Legislation

Stygofauna are protected under the same legislation as that of terrestrial fauna, and are governed under three acts:

1. *Wildlife Conservation Act (1950-1979)* (WA) (WCA);
2. *Environmental Protection Act (1986)* (WA) (EP Act); and
3. *Environment Protection and Biodiversity Conservation Act (1999)* (Cth) (EPBC Act).

The *Wildlife Conservation Act 1950 – 1979* provides protection for all native fauna species, and is administered by the DEC. Special provision is provided for fauna that are considered rare, threatened with extinction or of high conservation value. This includes some species of subterranean biota, which are currently considered to be Schedule 1 taxa (rare or likely to become extinct).

The *Environmental Protection Act (1986)* is administered by the Environmental Protection Authority (EPA) and includes guidelines for reviewing the aspects of proposals that might significantly impact environmental factors. Any operation that has the potential to significantly impact stygofauna habitat may be subject to formal Environmental Impact Assessment (EIA) under the EP Act. Guidance Statement No. 54A (EPA 2007) provides specific assessment and management requirements for subterranean fauna.

The *Environment Protection and Biodiversity Conservation Act (1999)* is administered by the Commonwealth Department of Environment, Water, Heritage and the Arts, to regulate protection of matters of national environmental significance. Any action (including projects, developments, undertakings, activity or series of activities) that is likely to have a significant impact on any matter included in Part 3 of the Act, must be referred to the Minister for decisions on whether the proposed action triggers the EPBC Act and requires assessment and approval under the Act. To date, the EPBC Act list of threatened fauna does not contain any invertebrate stygofauna.

1.6 Potential impacts of mining

The EPA Guidance Statement 54A (GS 54A) (2007) proposes that mining proposals may "impact stygofauna or troglofauna habitat by:

- Lowering the water table sufficiently to dry out the zone in which some species live, or otherwise artificially change water tables, or by
- Changing the water quality (e.g. increasing salinity levels or altering haloclines, increasing nutrient levels or the availability of organic matter, or introducing other pollutants), or by
- Destroying or damaging caves (including changing their temperature and humidity)".

Boulton *et al*. (2003) state that threatening processes for surface waters may also impact upon groundwaters, to the extent that there is a close connection between these two systems. External factors such as mining, water abstraction, land clearing, agriculture and waste disposal are also cited as threats to groundwater ecosystems. The design of sampling programs must take into account the nature and distribution of changes to subsurface habitats associated with mining activities.

The EPA (2003) states that proponents of proposed projects must demonstrate a lack of threat by:

- Showing that species within the potential impact zone also occur outside this area, and are not restricted to the impact zone,
- Providing evidence that likely impacts will not significantly affect species within the potential impact zone, and
- Produce a management plan for the potential impact zone and species within it, to ensure persistence of those species.

In relation to the Barrambie borefield, the greatest potential impact to stygofauna is the lowering of the water table as a result of groundwater abstraction. When designing the stygofauna sampling programs for the borefield the potential impacts of a reduction in the extent, the thickness (depth) or the connectivity of subterranean habitats as a result of changes in groundwater level were taken into account.

1.7 Proposed management strategy

In view of the drawdown estimates and the confirmed presence of a stygal community in the Barrambie borefield (established during the first three phases of sampling), Reed Resources Ltd propose to adopt a strategy of sustainable abstraction, maintaining an average saturated thickness of 75 % across the calcrete aquifer, within the borefield (based on base case water levels). Groundwater quality will also be assessed as part of the program which will aim to monitor and mitigate potential impacts on other groundwater users and the environment. To this end, a plan will be developed to investigate supplementary water sources which can be commissioned prior to the trigger levels for groundwater levels or quality being reached at Barrambie borefield (Aquaterra 2009). As part of the management program, stygofauna sampling will be conducted annually for at least the first five years of the project, incorporating additional sites where possible.

1.8 Report objectives

This report collates the finings of the four stygofauna sampling Phases for the Barrambie borefield. The objective of this study was to assess the potential risk to the stygofauna community posed by groundwater abstraction from the Barrambie borefield (Cogla Downs) calcrete aquifer. This follows the requirements of the EPA Guidance Statement 54 and 54A.

2. SURVEY DESIGN AND SAMPLING EFFORT

2.1 Sampling sites and survey design

Sampling was conducted in four phases between January 2008 and October 2009 (**Table 1**). A total of 15 stygofauna sampling sites were selected, incorporating pastoral wells plus the monitoring and production bores associated with the Cogla Downs calcrete aquifer (proposed Barrambie borefield).

Sites were classified as “impact” and “control” according to the predicted depth of drawdown relative to the pre-disturbance thickness of the aquifer. Sites located in areas where drawdown (under a 12 year “no-recharge” scenario) would exceed one-quarter of the aquifer thickness (< 75 % retention of saturated aquifer thickness) were classified as “impact” sites. Sites situated in areas where the predicted drawdown was less than one-quarter of the pre-disturbance aquifer thickness (> 75% retention of saturated aquifer thickness) were considered “control” sites (**Table 1**).

2.2 Statistical analysis

Extrapolation of “species” (or taxon) accumulation curves provides an indication of the expected increase in richness in relation to additional sampling (Colwell and Coddington 1994). Taxon richness estimators (jackknife and bootstrap) were employed to calculate the expected taxon richness based on the actual (or observed) data. Analyses were conducted using the statistical program Estimate S (Colwell 2006) and cumulative curves of the observed (Sobs Mao Tau) and estimated taxon richness (Bootstrap and Jackknife) were produced using Excel.

Table 1: Details of the sampling sites (bores and wells) and sampling effort for the Barrambie borefield; Phase I (January 2008), Phase II (April 2008), Phase III (November 2008) and Phase IV (October 2009). GPS datum in UTM, WGS84. IBD = internal bore diameter. EoH = end of hole (approximate). X = site sampled; Green cells = sites not sampled.

Bore Code		GPS Coordinates	Casing	IBD (mm)	EoH (mbgl)	Phase			
						I	II	III	VI
Impact	B8P	50 J 687366 6989433	PVC	300	19.0	X			
	B10P	50 J 685610 6993836	PVC	300	15.0	X			
	B1M	50 J 690053 6988467	PVC	50	90.0	X	X	X	
	B3M	50 J 690106 6988486	PVC	50	17.0	X	X	X	X
	B5M	50 J 685625 6993848	PVC	50	15.0	X	X	X	X
	B6M	50 J 686277 6991064	PVC	50	19.0	X			
	B7M	50 J 687360 6989459	PVC	50	20.0	X	X	X	X
	B9M	50 J 685101 6994585	PVC	50	11.5				X
	B14M	50 J 686832 6990937	PVC	50	12.5		X	X	X
	Yilby Bore	50 J 683632 6994441	Logs	2000 x 1000	5.0	X	X	X	X
Control	Barlanga Well	50 J 683678 6991557	Logs	2000 x 1000	5.0	X	X	X	X
	Bedan Well	50 J 685543 6997831	Logs	2000 x 1000	5.0		X	X	X
	Five Mile Well	50 J 700331 6984848	Concrete	1500 x 1000	3.5				X
	South Mill Well	50 J 690811 6984180	Logs	2000 x 1000	4.5	X	X	X	X
	Watson Well	50 J 682419 6997787	Logs	2000 x 1000	11.0		X	X	X

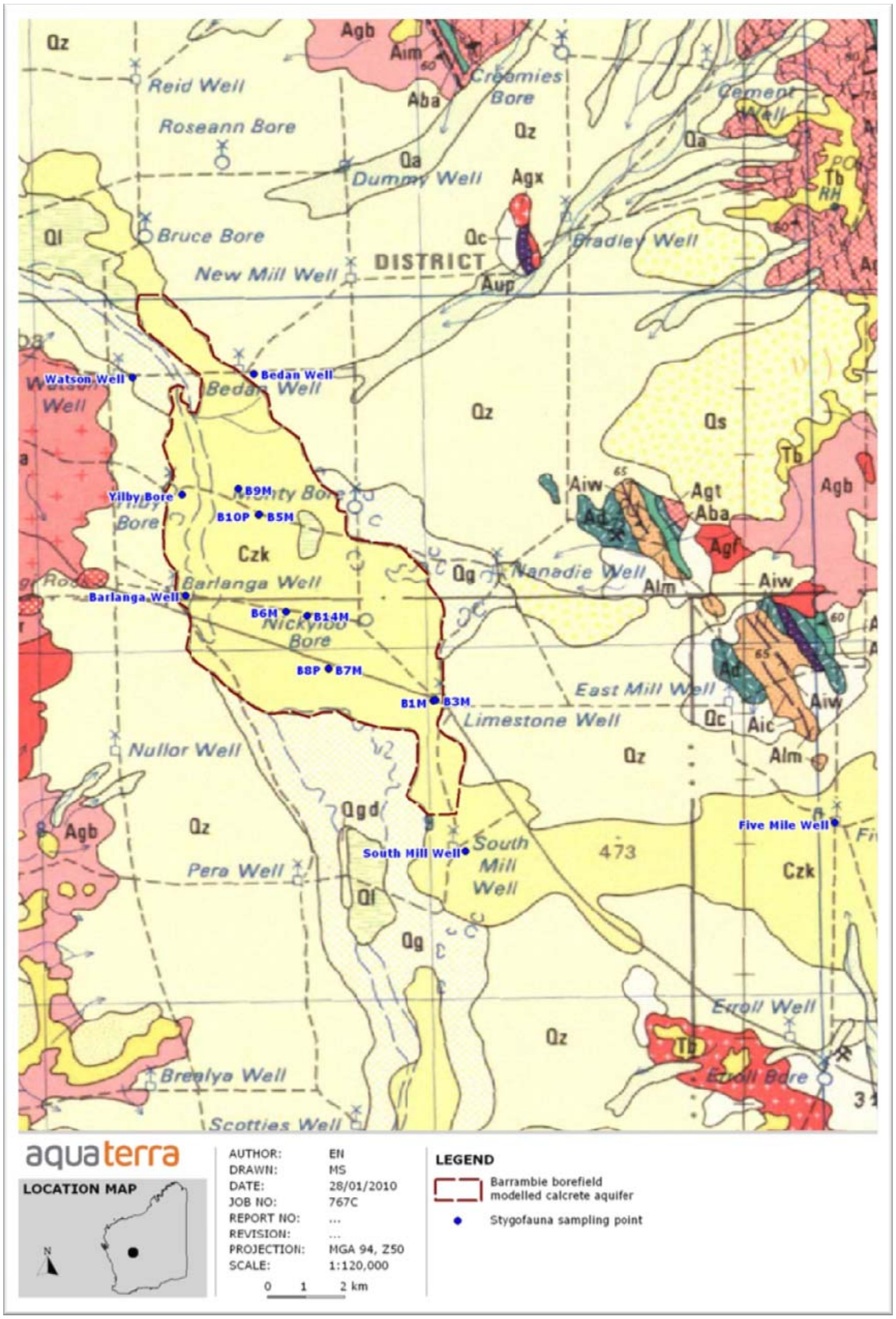

Figure 3: Location of stygofauna sampling sites (blue dots), Barrambie borefield, Cogla Downs. The extent of the calcrete aquifer is outlined in red.

3. METHODS

3.1 Groundwater quality

Basic physicochemical data was collected during each of the sampling phases. The standing water level (SWL) (mbgl) was measured at each site using a Solinst 101 water level meter. Groundwater was then collected just below the SWL with a disposable clear PVC bailer (42 mm x 900 mm), lowered using a winch. A calibrated TPS 90 FLMV multi-parameter field instrument was used to measure the pH, temperature, salinity as electrical conductivity (EC), and dissolved oxygen (DO) of the groundwater retrieved. End of hole (EoH) was estimated for each site using the net hauls.

3.2 Stygofauna sampling

Sampling was consistent with the procedures outlined in the EPA Draft Guidance Statement No. 54A (EPA 2007). Haul nets, found to be the most efficient retrieval method (Allford *et al.* 2008), were used during all four surveys. The sampling method was as follows:

- Samples were collected using two weighted nets with mesh sizes of 150 µm and 50 µm. Each net was fitted with a glass vial with a base mesh of 50 µm.
- The 150 μm net was lowered first to near the bottom of the hole.
- Once at the bottom the net was gently raised up and down three times to agitate the bottom 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 and all the contents emptied into a 120 ml polycarbonate vial and preserved with 100% undenatured ethanol in the field.
- This process was repeated up to five times.
- The same procedure was then repeated using the 50 μm net.
- To prevent cross-contamination, all sampling equipment was washed thoroughly with Decon 90 (detergent) and then rinsed with distilled water after sampling each site.
- Samples were couriered back to Outback Ecology's laboratory in Perth.

A Licence to Take Fauna for Scientific Purposes, *Wildlife Conservation Act 1950*, Regulation 17, was obtained from the DEC for each of the four sampling phases (Lic. Nos. SF006164, SF006342, SF006665, SF007078). An Export License, *Wildlife Conservation Act 1950*, Regulation 18, was also obtained for each batch of samples that were sent to taxonomists interstate (Lic. Nos. ES002008, ES002022 and ES002055). The reports accompanying the licenses have been submitted to the DEC. The field surveys were undertaken by Drs Fiona Taukulis, Veronica Campagna, Nihara Gunawardene, Erin Thomas and Mr Jay Puglisi from Outback Ecology (OES).

3.3 Specimen identification

Preserved samples were sorted manually using a Leica MZ6 stereomicroscope following elutriation of the samples to separate larger sediment particles. Samples were sieved into fractions using 250, 90 and 53 µm mesh sizes, to improve sorting efficiency. Sub-samples were taken for taxa which were present in high numbers. The specimens were then identified to their lowest possible taxonomic rank by Dr Erin Thomas (ET), Dr Nihara Gunawardene (NRG) and Mr Nick Stevens (NS) of OES. Assistance in sorting was provided by Mr Richard de Lange and Ms Kimberley Moiler of OES.

Identifications were undertaken using all available literature, both from scientific publications and that provided by government bodies in the absence of published information. Specialist taxonomists were employed to obtain higher taxonomic resolution where necessary. The specialists and their area of expertise were:

- Dr Tomislav Karanovic (TK), (Subterranean Ecology Pty Ltd) (Copepoda)
- Dr Ivana Karanovic (IK) (Department of Zoology, University of Tasmania) (Ostracoda)
- Dr Stuart Halse (SH) (Bennelongia Pty Ltd) (Ostracoda)
- Ms Jane McRae (JMM) (Bennelongia Pty Ltd) (Syncarida).

3.4 Limitations of the study

All specimens were identified to the lowest taxonomic level possible. However, specimens can not always be identified to species or morphospecies level due to the current state of stygofauna taxonomy and the delicate nature of these invertebrates. To date, descriptions of many new species are yet to be published, hence taxonomic keys are lacking. The loss or damage of certain taxonomic features during collection and/or sorting process also restricts identification.

While every effort has been made to assess the conservation status of the stygofauna collected using in-house data collections, publications, publicly available reports, and information provided by specialist taxonomists, some accounts may be limited if information was unavailable at report submission.

4. RESULTS AND DISCUSSION

Physicochemical parameters such as salinity, pH and dissolved oxygen are known to influence the distribution of stygofauna within the groundwater (Humphreys 2008). To assist in the development of management plans, the collection of baseline data is important. The basic groundwater parameters considered as having the most influence on stygofauna (EPA 2007) were measured during all four surveys for the Barrambie borefield. Variation between sampling phases and sample sites was observed during the assessment, though mostly minor. The differences between impact and control sites were primarily due to the differences between wells and bores and therefore exposure to the external elements, or the aquifer intercepted (calcrete versus palaeochannel). In general the groundwater conditions were found to be similar and consistent with other stygofauna habitats.

The pH of the groundwater was found to be predominantly slightly alkaline (pH of 7.5). The impact bores had pH ranges from 7.21 - 8.02 and were generally considered alkaline (pH >7.5 *sensu* Foged 1978) (**Appendix C**). B1M, which intercepted the palaeochannel aquifer, was the exception with a groundwater pH of 6.59 to 6.95. The pastoral wells displayed greater variability with pH ranges of 6.95 – 8.35, though these waters were exposed to any external factors such as rainfall, dust and so on. Generally, the variation in the groundwater pH was considered to be minimal and pH was considered unlikely to be a limiting factor with the majority of values comparable to those typical of stygofauna-rich calcareous systems (Humphreys 2008).

Using electrical conductivity as a surrogate for salinity, groundwaters were classified as either fresh (< 5 mS/cm) or hyposaline (5 - 30 mS/cm) (*sensu* Hammer 1986 and Williams 1998), the salinity increasing toward the northern section of the aquifer. Again B1M was the exception, with salinities exceeding 110 mS/cm across the phases. The hypersaline conditions (≥ 70 mS/cm) of B1M indicate the bore has intersected the palaeochannel sand aquifer rather than the less saline calcrete aquifer (Aquaterra 2009).

Groundwater temperatures in the enclosed impact bores ranged from 24.0 - 29.9 ºC and were reasonably consistent across the phases, reflecting the relative stability of the subterranean environment. Greater fluctuations were recorded from the open pastoral wells, which ranged from 18.9 - 30.1 ºC and naturally reflected the ambient air temperature.

Groundwaters tend to exhibit temporal variation in dissolved oxygen concentrations (Malard and Hervant 1999). The DO concentrations in both impact and control sites were found to have greater variability between sampling phases rather than between sites. Concentrations were found to be the highest in Phase I across the aquifer (9.48 – 13.59 ppm) (**Table C.** 1) and then decreased in subsequent surveys. The lowest DO was recorded at B1M (0.61 ppm) (**Table C.** 3).

Standing water levels ranged from 2.30 - 8.98 mbgl throughout the aquifer with little fluctuation between sampling phases at most sites. The exception was Watson Well with a decrease in water level from 4.79 mbgl in Phase III to 8.98 mbgl in Phase IV, potentially as a result of water usage. The calcrete aquifer at

Barrambie borefield is relatively shallow and because of this direct recharge is expected during rainfall events (Aquaterra 2008).

The data collected over the four sampling events (Phase I – IV) indicates that the groundwater quality of the Cogla Downs aquifer is suitable for stygal communities. In addition, similarities in the overall water quality of various sites suggest that there is likely be some connectivity within the shallow calcrete aquifer, potentially facilitating movement of stygofauna.

4.1 Stygofauna

Close to 40 invertebrate taxa were recorded from the Barrambie borefield, with 24 taxa considered either truly stygal or likely to be stygofauna (**Table 2, Table 3, Table 4**). A number of the taxa were classified as terrestrial or surface water forms. They included the Acarina (mites), Collembola (springtails) and Diptera (fly) larvae. As they are not stygofauna, they are presented in the total count tables only and no longer require discussion (**Appendix D - Appendix G**).

4.1.1 Phylum Arthropoda

4.1.1.1 Class Maxillopoda

The class Maxillopoda was represented by the orders Cyclopoida and Harpacticoida (**Table 2**). Four cyclopoid species, *Halicyclops eberhardi, Metacyclops laurentiisae* and *Goniocyclops uniarticulatus* and the common surface water inhabitant, *Apocyclops dengizicus,* were identified. These species are all known to occur outside the Barrambie project area and the majority are well distributed throughout the Murchison Region or beyond (Karanovic 2004). ?*Halicyclops eberhardi,* recorded as a single specimen from impact bore B6M, was likely to be a juvenile *Halicyclops eberhardi.*

Five harpacticoid species were identified in the borefield, four of which have been recorded from other localities within the Murchison (Karanovic 2004). The only harpacticoid found to have a limited range in the Barrambie borefield was *Pseudectinosoma sp. 1* n. sp. (T. Karanovic). This potentially new taxon was recorded from impact sites only (B8P and B5M in Phase I and B14M in Phase III) and as yet has no known distribution outside the Barrambie borefield.

4.1.1.2 Class Malacostraca

Bathynellacea

Bathynellacea and Isopoda were the two malacostracan orders recorded from the groundwaters of the Barrambie borefield (**Table 3**). The order Bathynellacea was represented by Bathynellidae and Parabathynellidae, two families which have been documented from groundwaters in the Pilbara and Yilgarn regions of Western Australia (Eberhard *et al.* 2004, Humphreys *et al.* 2009). Bathynellids were identified from six impact bores over the sampling program. Taxonomic information on the Western Australian Bathynellidae is limited, and identification past family level is not possible. .

Parabathynellids were collected from nine sites, seven of which were in the impact zone. The specimens were identified as *Atopobathynella,* a genus which has been recorded from numerous calcrete aquifers within the Yilgarn region (Cho *et al.* 2006). The only parabathynellid that could not be further identified was a damaged specimen collected from the control site, Barlanga Well, during Phase I. Given the prevalence of *Atopobathynella* in the groundwaters of the Barrambie borefield, the Barlanga Well specimen is highly likely to be *Atopobathynella.*

Atopobathynella gascoyneensis, a taxon first described from a bore at the Gascoyne River in Carnarvon (Cho *et al.* 2006), was present at six of the impact bores. A potentially new taxon, *Atopobathynella* sp. OE1 (J. McRae), was recorded from seven of the impact bores and was found to be sympatric with *Atopobathynella gascoyneensis* in the Barrambie calcrete.

A number of *Atopobathynella* specimens collected from the impact zone were juveniles. They were often collected with mature *Atopobathynella* specimens and therefore it is likely that they belong to one of the taxa already identified. A single juvenile *Atopobathynella* sp. was also recorded from the control site South Mill Well. This indicates movement of these crustaceans throughout the aquifer and a level of connectivty.

On examination of all the *Atopobathynella* specimens, slight variation of the setation of thoracopod VII and the number of spines along the inner margin of the uropodal sympods was noted amongst specimens of similar morphotype. This was considered to be intra-specific variation, a process previously discussed by Schminke (1978) in relation to the parabathynellid *Notobathynella longipes*.

Atopobathynella nr sp. OE1, *Atopobathynella* sp. OES3 and *Atopobathynella* sp. OES4. *Atopobathynella* nr sp. OE1 specimens were separated from *Atopobathynella* sp. OE1 (J. McRae) on account of moderate variation in taxonomic features. *Atopobathynella* sp. OES3 and *Atopobathynella* sp. OES4 were listed as *Atopobathynella* sp. in the previous report. Upon further investigation of taxonomic characteristics, they have now been assigned individual morphospecies.

Isopoda

The order Isopoda was represented by a potentially new taxon; *Halonsicus* nr *longiantennatus* (**Table 3**). Specimens were limited to the area of impact (B8P, B6M and B14M) and were considered to be similar to *Halonsicus longiantennatus,* a species recorded from subterranean waters near Lake Way (Taiti and Humphreys 2001).

4.1.1.3 Class Ostracoda

A single juvenile ostracod of the genus *Strandesia* was collected from a pastoral well, Yilby Bore, located within the potential impact zone. *Strandesia* is associated with surface waters, however the genus is

Comment [VC1]: Isn't it a well?

known to contain a stygal element, *Strandesia kimberleyi* n. sp., recorded from Kimberly groundwaters (Karanovic 2005). Given this was a singleton collected from a well suggests that it may be a surface water inhabitant, rather than stygal.

The other two ostracod taxa identified from the Barrambie borefield, *Candonocypris novaezelandiae* and *Sarscypridopsis ochracea*, are known surface water inhabitants (I. Karanovic *pers. comm.* 2008) and not considered at risk.

4.1.1.4 Class Insecta

Coleopterans (beetles) from the family Dytiscidae (diving beetles) were the only stygal insects collected (**Table 3**). A dytiscid larva (Tribe Bidessini) was recorded from the impact bore B10P during Phase II, however literature on the larval stages of stygal dytiscids is limited and higher level identification of the specimen was not possible. Two adult beetles, also of the Tribe Bidessini, were collected from the impact bore B3M during Phase IV. Both specimens were identified as *Limbodessus microbubba*. This species was first recorded and described from the Yarrabubba Station calcrete aquifer (Watts and Humphreys 2009) which is located within the Cogla Downs pastoral lease.

4.1.2 Phylum Annelida

4.1.2.1 Class Oligochaeta

Tubificidae, Enchytraeidae and Phreodrilidae were the three oligochaete families recorded from the Barrambie borefield (**Table 4**). Tubificidae and Enchytraeidae, two families known to occur in groundwaters of the Pilbara (Eberhard *et al.* 2004) and Yilgarn regions (Outback Ecology unpublished data) were present in control sites and are unlikely to be at risk from groundwater abstraction in the borefield. Phreodrilidae was represented by two morphotypes; (specimens with and without dissimilar chaetae) both of which were collected from impact sites only.

4.1.2.2 Class Aphanoneura

Aeolosoma sp. 2 (PSS DEC) was the only aphanoneuran recorded during the stygofauna assessment. The taxon was present at the control bores Watson Well and Barlanga Well and has previously been identified from groundwaters of the Pilbara region (DEC unpublished data).

4.1.3 Phylum Nematoda

Nematodes, a ubiquitous group which inhabit interstitial spaces within terrestrial and aquatic environments (Ruppert and Barnes 1994), were also recorded from the groundwaters of the Barrambie borefield. While the habitat preferences of this group are difficult to establish, their presence at a control site (Barlanga Well) suggests that they are unlikely to be at risk from proposed drawdown at the Barrambie borefield.

Table 2: Distribution of stygofauna (Arthropoda: Maxillopoda) collected from the Barrambie borefield, (Phase I - IV). * indicates taxa not includedomitted from the final tally of stygal taxa.

Phylum	Class	Order	Lowest Identification	Bore		Distribution and comments
				Impact	Control	
Arthropoda	Maxillopoda	Cyclopoida	*Apocyclops dengizicus*	**Yilby Bore**		Widely distributed species which has been recorded from the Murchison region and surface waters of various countries. [a]
			Goniocyclops uniarticulatus		**Barlanga Well**	Recorded in low numbers from several localities in the Murchison region. [a]
			Halicyclops eberhardi	**B8P, B10P, B3M, B5M, B6M, B7M, B14M,**	**South Mill Well, Bedan Well, Five Mile Well**	Widely distributed in arid Western Australia with possible distribution throughout central Australia. Possible stygophile as opposed to a stygobiont. [b]
			*?Halicyclops eberhardi**	**B6M**		Likely to be *Halicyclops eberhardi* however the immature state of the specimen prevents confirmation. [b]
			Metacyclops laurentiisae		**South Mill Well, Five Mile Well**	This taxon has been recorded from numerous localities in the Murchison region. [a]
		Harpacticoida	*Australocamptus hamondi*		**Barlanga Well, South Mill Well, Five Mile Well**	Well distributed genus throughout Australia. *A. hamondi* has been collected from a number of sites in the Murchison. Potentially a stygophile rather than a stygobite. [b]
			Novanitocrella aboriginesi	**B8P, B10P, B5M, B6M, B7M,**	**South Mill Well**	The species has previously been recorded from Cue water supply bores and the Austin Downs Borefield (Murchison). [a]
			Parastenocaris solitaria	**B8P, B10P, B3M, B7M, B14M,**	**Bedan Well**	This species was first described from Depot Springs (Murchison). [a]
			Pseudectinosoma sp. 1 n. sp. (T. Karanovic)	**B5M, B14M, B8P**		This is only the second representative of the genus *Pseudectinosoma* in Australia. The first was described from the Pilbara region. Potentially new species [b]
			Schizopera oldcuei	**B8P, B10P, B3M, B5M, B6M, B7M, B14M, Yilby Bore,**	**Barlanga Well, Bedan Well, South Mill Well**	This species was first described from the Old Cue water supply bore in the Murchison region. The January 2008 collection represented the second record of the species and the first record of a male. Sampling in April and November 2008 collected both males and females from various sites within the Barrambie borefield. [b]

a (Karanovic 2004), **b** (T. Karanovic *pers. comm.*)

Table 3: Distribution of stygofauna (Arthropoda: Insecta, Malacostraca and Ostracoda) collected from the Barrambie borefield (Phase I - IV). * indicates taxa omitted from the final tally of stygal taxa.

Phylum	Class	Order	Lowest Identification	Bore		Distribution and comments
				Impact	Control	
Arthropoda	Insecta	Coleoptera	*Limbodessus microbubba*	**B3M**		First described from the Yarrabubba Station calcrete aquifer. [c]
			Bidessini (larva)*	**B10P**		Bidessine species have been recorded from calcretes in the Yilgarn region of Western Australia and the Ngalia Basin in central Australia. [c]
	Malacostraca	Isopoda	*Haloniscus* nr *longiantennatus*	**B8P, B6M, B14M**		Similar to *Haloniscus longiantennatus,* a species which has been collected from the Murchison region.
		Bathynellacea	Bathynellidae	**B8P, B10P, B3M, B5M, B7M, B14M**		Family previously recorded from groundwaters within the Pilbara and Yilgarn regions. Taxonomic information is currently limited, restricting further identification. [d,e]
			Atopobathynella gascoyneensis	**B8P, B10P, B5M, B6M, B7M, B14M**		Previously recorded and described from a bore in the Gascoyne region. [f]
			Atopobathynella sp. OE1 (J. McRae)	**B8P, B10P, B3M, B5M, B6M, B7M, B14M**		The morpohology of this taxon differed from the *Atopobathynella* species previously described from the Murchison and Gascoyne regions of Western Australia. May represent a new species. [g]
			Atopobathynella sp. OES3	**B3M**		The morphological characteristics of these specimens differed from the other *Atopobathynella* specimens. Potentially new species.
			Atopobathynella sp. OES4	**B3M**		
			Atopobathynella nr sp. OE1	**B8P, B10P, B3M, B5M**		These specimens were generally similar to *Atopobathynella* sp. OE1 described from other bores within the Barrambie Borefield. Differed slightly in morphological characteristics.
			Atopobathynella sp. (juvenile)*	**B10P, B3M, B5M, B14M,**	**South Mill Well**	Likely to belong to one of the *Atopobathynella* species identified from adult specimens.
			Parabathynellidae*		**Barlanga Well**	Damaged specimen, missing key morphological features. Likely to belong to one of the *Atopobathynella* species identified from intact specimens.
	Ostracoda	Podocopida	*Strandesia* sp.	**Yilby Bore**		This genus mostly occurs in surface waters of the southern hemisphere. One species has been described from subterranean waters in the Kimberley. The specimen collected from the Barrambie borefield was a juvenile and could not be identified further. [h, i]

[c] (Watts and Humphreys 2009), [d] (Eberhard *et al.* 2004), [e] (Outback Ecology unpublished data), [f] (Cho *et al.* 2006), [g] (J. McRae *pers. comm*. 2009), [h] (Karanovic 2005), [I] (I. Karanovic *pers. comm*. 2008).

Table 4: Distribution of stygofauna (Annelida and Nematoda) collected from the Barrambie borefield (Phase I - IV).

Phylum	Class	Order	Lowest Identification	Bore		Distribution and comments
				Impact	Control	
Annelida	Aphanoneura		*Aeolosoma* sp. 2 (PSS DEC)		**Watson Well, Barlanga Well**	This taxon has previously been documented from subterranean waters in the Pilbara region.[j]
	Oligochaeta	Tubificida	Enchytraeidae		**Barlanga Well, South Mill Well, Watson Well**	Enchytraeids are known to occur in subterranean waters of the Pilbara and Yilgarn regions.[d, e]
			Phreodrilidae with similar chaetae	**B3M**		The family Phreodrilidae has been previously been documented from the groundwaters in the Pilbara region.[k]
			Phreodrilidae with dissimilar chaetae	**B14M**		
			Tubificidae		**Bedan Well**	Tubificids have been recorded from groundwaters in the Pilbara and Yilgarn regions.[d, e]
Nematoda			Nematoda		**Barlanga Well**	Nematodes are commonly represented in terrestrial and aquatic habitats[l]. Conservation status is difficult to establish.

[d] (Eberhard *et al.* 2004), [e] (Outback Ecology unpublished data), [j] (DEC unpublished data), [k] (Pinder 2008), [l] (Ruppert and Barnes 1994).

4.2 Sampling effort

Taxon accumulation curves based on the lowest taxonomic classification were generated from the stygofauna data collated from the four sampling phases (**Figure 4**). The observed number of stygal taxa (Sobs Mao Tau) over the four phases of sampling was 24 taxa. According to the taxon richness estimators, Bootstrap (Bootstrap mean) and Jackknife (Jack 1 mean between 75 % and 88 % of the expected taxa were collected. In terms of sampling effort, according to the Guidance Statement 54A (EPA 2007) this was met, with 40 samples collected over four sampling phases.

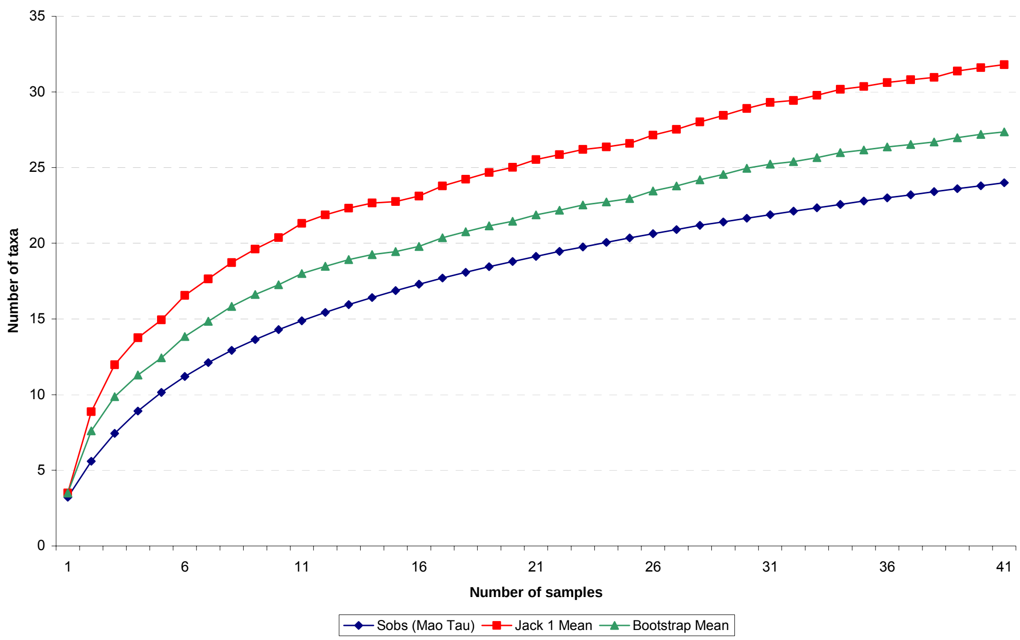

Figure 4: Stygal "taxon" accumulation curve for Barrambie borefield sampling phases I – IV.

4.3 Risk assessment for stygofauna at Barrambie borefield

4.3.1 Priority ecological community

The groundwater assemblage of the Cogla Downs calcrete aquifer has been listed as a Priority Ecological Community (PEC) (Department of Environment and Conservation 2009). The assemblage has been classified as Priority 1. This category is assigned to assemblages that are considered to be of high priority for survey and/or definition of the community, and evaluation of conservation status. Assemblages that have been proposed as threatened ecological communities (TEC) by the Threatened Ecological

Community Scientific Committee and are yet to be classified as "threatened" in Western Australia, are also listed as Priority 1 ecological communities (Department of Environment and Conservation 2009).

The Cogla Downs calcrete aquifer groundwater community is not currently listed as a threatened ecological community under the EPBC Act list of threatened ecological communities. The assessment of the Barrambie borefield has identified, and defined, the stygofauna community within a section of the calcrete.

4.4 Potential risk to taxa

A high portion of the stygal, or potentially stygal, taxa collected from the Barrambie borefield were from the impact zone. Ten of the 15 sites sampled, however, were from the impact zone. Of these groups, the *Apocyclops dengizicus* and *Limbodessus microbubba* have known distributions outside the Barrambie borefield and are not at risk from proposed groundwater drawdown from the Barrambie Project.

New species were found to occur only within the impact zone. *Pseudectinosoma sp. 1* n. sp. (T. Karanovic), *Halonsicus* nr *longiantennatus*, *Atopobathynella* sp. OE1 (J. McRae), *Atopobathynella* nr sp. OE1, *Atopobathynella* sp. OES3 and *Atopobathynella* sp. OES4. While there appears to be limited distribution of these new species their distribution is limited due to sampling efficiency.

A lack of accessible control bores outside the area of impact necessitated the use of pastoral wells as control sites. Wells, which have previously been noted as poor sites for stygofauna sampling (Humphreys 2008), represent a more open environment than bores. This is supported by the differences in community structure between the control and impact sites with a low number of stygal taxa collected from Yilby Bore, the only pastoral well classified as an impact site.

Secondly, the presence of various taxa in both impact and control sites suggests that there may be movement throughout the aquifer, potentially lessening the threat to stygofauna posed by the drawdown in the area of impact. Examples include the frequent overlap of harpacticoid copepod species between the impact and control sites and the *Atopobathynella* juveniles recorded from control sites despite the apparent restriction of adult specimens to impact bores. Similarities in water quality across some sites may also indicate that there is a level of connectivity within the calcrete aquifer.

Moreover, the movement may not be restricted to the calcrete aquifer, with a hydraulic connection expected between the calcrete and the surrounding alluvial sediments (Aquaterra 2009). While research on various stygal groups inhabiting Yilgarn calcretes suggest that most species are restricted to a single calcrete (Cooper *et al.* 2007, Cooper *et al.* 2002, Guzik *et al.* 2008), the potential for stygofauna to move between calcrete aquifers via interstitial spaces in alluvia cannot be ruled out (Cooper *et al.* 2007). For example, work by Watts and Humphreys has identified a small number dytiscid beetle species which occur in more than one calcrete aquifer (Watts and Humphreys 2009). This is supported by the collection of the dytiscid *Limbodessus microbubba* from the groundwaters of the Barrambie borefield (Cogla Downs), a species first described from the nearby Yarrabubba Station calcrete aquifer.

The conservative approach taken during the groundwater modelling must also be considered. As previously noted, the numerical model used to predict drawdown and therefore impact sites, did not take rainfall recharge into account, a factor considered likely to contribute a substantial amount of the recharge to the aquifer. In addition, the modelling did not take into account the eastern branch of the Cogla Downs drainage system, a factor which would increase the volume of water available in storage (Aquaterra 2009). Accordingly, groundwater drawdown is likely to be less than predicted, in turn reducing the potential risk to stygofauna.

Finally, along with the implementation of a comprehensive groundwater monitoring program, it is intended that an average of 75 % of the aquifer storage capacity in the area of impact (which represents approximately 15 % of the aquifer) will be maintained for the first five years of the project. These steps in addition to the other factors discussed, are likely to result in the retention of sufficient groundwater habitat for stygofauna. Furthermore, an annual stygofauna monitoring program will be undertaken for at least the first five years with additional bores incorporated where available. This measure will provide information on the stygal communities and assist in management efforts to ensure stygal populations are not adversely affected.

5. CONCLUSIONS AND RECOMMENDATIONS

The calcrete aquifers of arid Australia are known to have diverse stygal communities (Humphreys *et al.* 2009). In keeping with this, the groundwaters of the Barrambie borefield were found to support 24 stygal taxa. Many of the stygal taxa have a known distribution outside the area of impact. They occur either in the control sites, and/or outside the Barrambie borefield area. Some taxa were only collected from impact zone bores and their distribution therefore appears localised. Among these were potentially new taxa including *Pseudectinosoma sp. 1* n. sp. (T. Karanovic), *Halonsicus* nr *longiantennatus*, *Atopobathynella* sp. OE1 (J. McRae), *Atopobathynella* nr sp. OE1, *Atopobathynella* sp. OES3 and *Atopobathynella* sp. OES4. While it appears that these taxa may be at risk from the groundwater abstraction associated with the proposed Barrambie borefield, there are a number of factors which mitigate the risk to these taxa.

The distribution pattern of several groups in the Barrambie borefield indicates a level of connectivity through the borefield. This is further supported by the similarity in groundwater quality measured over four sampling phases. The expected hydraulic connectivity between the calcrete aquifer and the alluvial sediments would also be likely to further improve the ability of the stygofauna to disperse, potentially lessening the risk to stygofauna. Additionally, as a result of the conservative approach undertaken during groundwater modelling and the proposed retention of an average saturated aquifer thickness of 75 % within the borefield area for the first five years, there is likely to be sufficient groundwater habitat maintained in the area of impact. The risk to the stygofauna community from the Barrambie borefield proposal is therefore considered to be low.

The assessment undertaken by Reed Resources has provided valuable information on a Priority Ecological Community (Department of Environment and Conservation 2009) by defining the stygofauna community present. The intended implementation of an annual stygofauna monitoring program for at least the first five years of the project would provide further knowledge on the Barrambie borefield (Cogla Downs) calcrete aquifer while assisting in management efforts.

Recommendations for the future sampling program include the incorporation of new sampling sites, with a particular focus on control bores as opposed to pastoral wells. The inclusion of additional sites from the eastern branch of the aquifer and other calcrete aquifers in the vicinity of Barrambie borefield (Cogla Downs) may also be of benefit.

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Appendix A

Predicted drawdown at 12 years,

Run 1 – Base Case, Barrambie borefield.

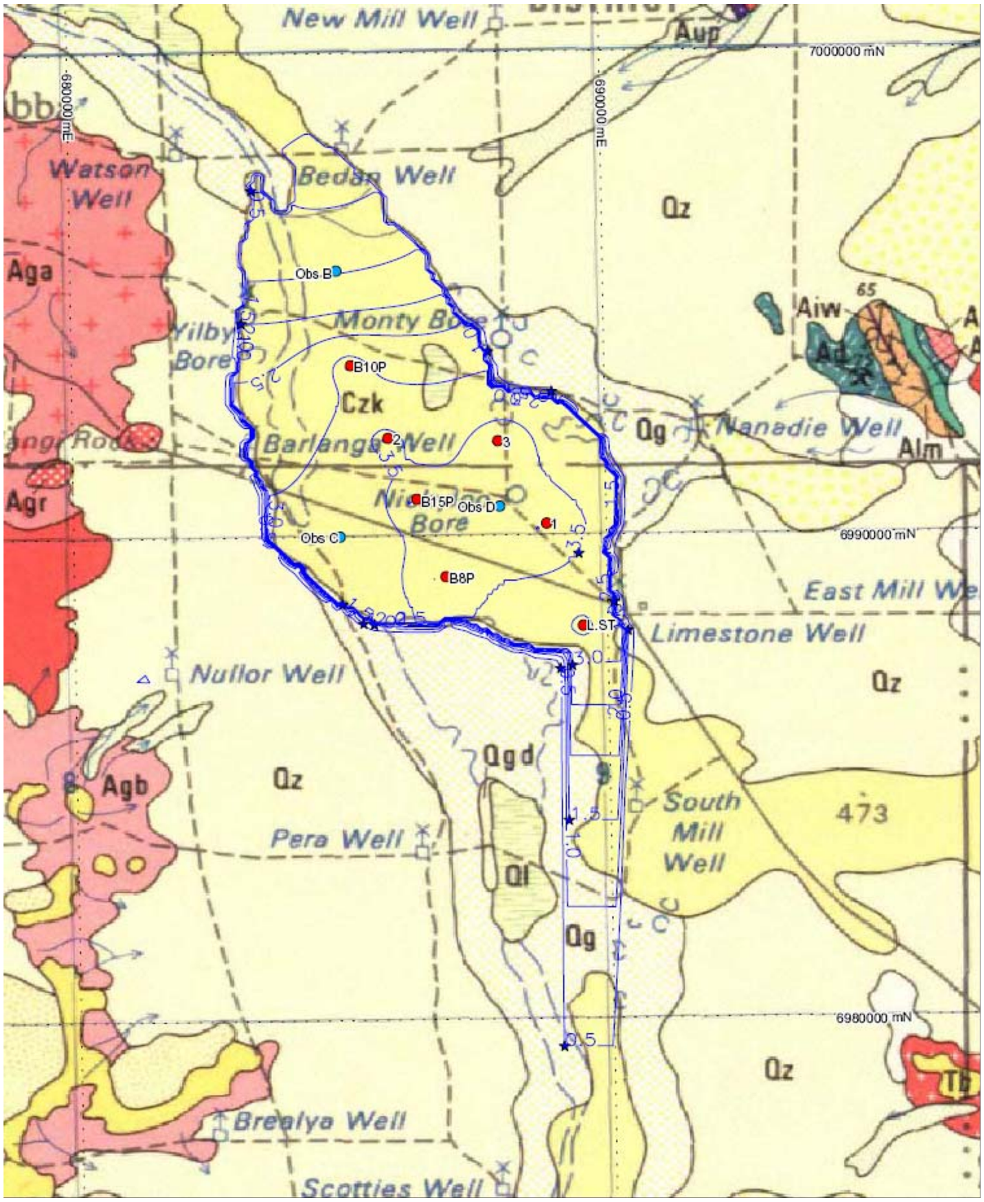

Figure A. 1: Barrambie predicted drawdowns (Run 1 – Base Case) at 12 years (Aquaterra 2008).

Appendix B

Predicted drawdown at 12 years,

Run 2 – Base Case, Barrambie borefield.

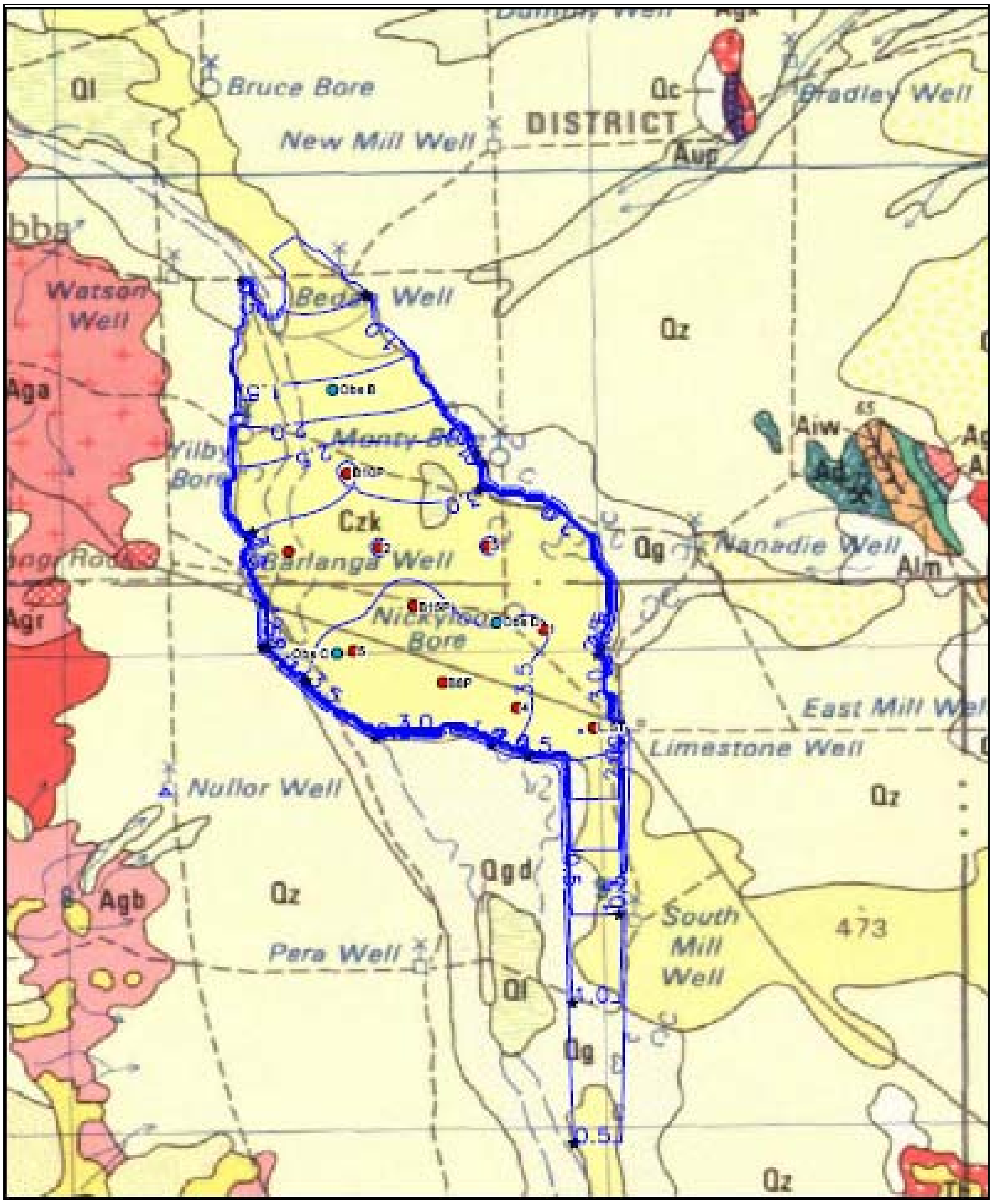

Figure A. 2: Barrambie predicted drawdowns (Run 2 – Base Case) at 12 years (Aquaterra 2008).

Appendix C

Basic groundwater physicochemical parameters

Phase I – IV

Table C. 1: Basic groundwater measurements; Phase I (January 2008)

	Bore code	pH	EC (mS/cm)	Temp. (°C)	DO (ppm)	SWL (mbgl)
Impact	B8P	7.90	3.82	26.0	12.09	5.1
	B10P	7.85	8.44	26.4	13.02	5.3
	B1M	6.95	113.20	29.9	9.48	5.9
	B3M	7.95	5.31	26.0	11.33	4.5
	B5M	8.02	7.88	26.0	13.59	5.2
	B6M	7.98	4.28	26.0	13.04	4.8
	B7M	7.90	3.95	26.0	12.53	5.4
	B9M	NS	NS	NS	NS	NS
	B14M	NS	NS	NS	NS	NS
	Yilby Bore	7.52	4.68	30.1	10.82	2.7
Control	Barlanga Well	8.35	4.21	27.2	13.29	2.8
	Bedan Well	NS	NS	NS	NS	NS
	Five Mile Well	NS	NS	NS	NS	NS
	South Mill Well	8.30	6.55	28.7	13.39	3.4
	Watson Well	NS	NS	NS	NS	NS

Table C. 2: Basic groundwater measurements; Phase II (April 2008)

	Bore code	pH	EC (mS/cm)	Temp. (°C)	DO (ppm)	SWL (mbgl)
Impact	B8P	NS	NS	NS	NS	NS
	B10P	NS	NS	NS	NS	NS
	B1M	6.90	110.90	26.7	NA	6.20
	B3M	7.83	4.26	27.4	NA	4.90
	B5M	7.81	7.86	24.0	NA	5.40
	B6M	NS	NS	NS	NS	NS
	B7M	7.86	3.81	26.6	NA	5.18
	B9M	NS	NS	NS	NS	NS
	B14M	7.98	4.48	25.8	NA	3.10
	Yilby Bore	7.54	5.51	23.0	NA	3.80
Control	Barlanga Well	6.95	4.05	18.9	15.80	2.77
	Bedan Well	7.98	9.49	24.7	NA	3.20
	Five Mile Well	NS	NS	NS	NS	NS
	South Mill Well	7.80	6.86	24.5	NA	3.35
	Watson Well	7.73	2.59	26.5	NA	5.00

NS = site not sampled during survey; NA = no data

Table C. 3: Basic groundwater measurements; Phase III (November 2008)

	Bore code	pH	EC (mS/cm)	Temp. (°C)	DO (ppm)	SWL (mbgl)
Impact	B8P	NS	NS	NS	NS	NS
	B10P	NS	NS	NS	NS	NS
	B1M	6.59	114.60	26.7	0.61	5.95
	B3M	7.58	4.50	26.8	3.53	4.83
	B5M	7.63	8.04	25.6	6.26	5.24
	B6M	NS	NS	NS	NS	NS
	B7M	7.77	4.96	26.1	4.97	5.13
	B9M	NS	NS	NS	NS	NS
	B14M	7.71	4.37	25.1	3.90	2.96
	Yilby Bore	7.21	6.51	22.1	4.09	2.90
Control	Barlanga Well	8.19	4.37	21.8	5.41	2.71
	Bedan Well	7.47	9.66	22.3	3.15	3.80
	Five Mile Well	NS	NS	NS	NS	NS
	South Mill Well	8.28	7.79	23.7	6.28	2.30
	Watson Well	7.44	2.69	23.2	3.69	4.79

Table C. 4: Basic groundwater measurements; Phase IV (October 2008)

	Bore code	pH	EC (mS/cm)	Temp. (°C)	DO (ppm)	SWL (mbgl)
Impact	B8P	NS	NS	NS	NS	NS
	B10P	NS	NS	NS	NS	NS
	B1M	NS	NS	NS	NS	NS
	B3M	7.73	4.27	26.7	3.38	4.9
	B5M	7.78	7.94	27.4	4.60	5.5
	B6M	NS	NS	NS	NS	NS
	B7M	7.64	4.00	26.7	4.27	5.73
	B9M	7.73	15.09	25.9	3.54	4.59
	B14M	7.77	4.51	25.7	4.99	3.10
	Yilby Bore	7.67	5.35	23.4	4.65	3.10
Control	Barlanga Well	8.27	4.41	25.3	4.97	2.98
	Bedan Well	7.15	9.85	22.1	4.88	3.54
	Five Mile Well	7.58	5.23	24.3	3.69	2.59
	South Mill Well	7.59	7.81	24.7	4.71	3.63
	Watson Well	7.91	2.66	25.3	5.42	8.98

NS = site not sampled during survey; NA = no data

Appendix D

Total invertebrate count

Phase I (January 2008)

Bore Code	Area	Higher Classification	Lowest Identification	Count	Identifier
B8P	Impact	Arachnida	Astigmata	3	NRG
B8P	Impact	Maxillopoda	*Halicyclops eberhardi*	29*	TK
B8P	Impact	Maxillopoda	*Pseudectinosoma sp. 1* n. sp. (T. Karanovic)	2	TK
B8P	Impact	Maxillopoda	*Schizopera oldcuei*	112*	TK
B8P	Impact	Maxillopoda	*Novanitocrella aboriginesi*	4*	TK
B8P	Impact	Maxillopoda	*Parastenocaris solitaria*	34*	TK
B8P	Impact	Malacostraca	*Haloniscus* nr *longiantennatus*	1	JMM
B8P	Impact	Malacostraca	*Atopobathynella gascoyneensis*	4	ET
B8P	Impact	Malacostraca	*Atopobathynella* nr sp. OE1	1	ET
B8P	Impact	Malacostraca	*Atopobathynella* sp. OE1 (J. McRae)	13	ET
B8P	Impact	Malacostraca	Bathynellidae	3	NRG
B10P	Impact	Insecta	Bidessini (larva)	1	ET
B10P	Impact	Collembola	Collembola	1	NRG
B10P	Impact	Maxillopoda	Copepoda (nauplii)	3	NRG
B10P	Impact	Maxillopoda	*Halicyclops eberhardi*	21*	TK
B10P	Impact	Maxillopoda	*Novanitocrella aboriginesi*	1*	TK
B10P	Impact	Maxillopoda	*Schizopera oldcuei*	48*	TK
B10P	Impact	Maxillopoda	*Parastenocaris solitaria*	1	JMM
B10P	Impact	Malacostraca	*Atopobathynella gascoyneensis*	25	ET
B10P	Impact	Malacostraca	*Atopobathynella* sp. OE1 (J. McRae)	7	ET
B10P	Impact	Malacostraca	*Atopobathynella* nr sp. OE1	1	ET
B10P	Impact	Malacostraca	*Atopobathynella* sp. (juvenile)	5	ET
B10P	Impact	Malacostraca	Bathynellidae	1	NRG
B1M	Impact	No Invertebrates			RD
B3M	Impact	Maxillopoda	*Halicyclops eberhardi*	33	TK
B3M	Impact	Maxillopoda	*Parastenocaris solitaria*	4	TK
B3M	Impact	Maxillopoda	*Schizopera oldcuei*	34	TK
B3M	Impact	Malacostraca	*Atopobathynella* sp. OE1 (J. McRae)	2	ET
B3M	Impact	Malacostraca	*Atopobathynella* sp. OES3	1	ET
B3M	Impact	Malacostraca	Bathynellidae	3	ET
B5M	Impact	Maxillopoda	*Halicyclops eberhardi*	2	TK
B5M	Impact	Maxillopoda	*Novanitocrella aboriginesi*	4	TK
B5M	Impact	Maxillopoda	*Pseudectinosoma sp.1* n. sp. (T. Karanovic)	1	TK
B5M	Impact	Maxillopoda	*Schizopera oldcuei*	13	TK
B5M	Impact	Malacostraca	*Atopobathynella gascoyneensis*	3	ET
B5M	Impact	Malacostraca	*Atopobathynella* sp. (juvenile)	1	ET
B5M	Impact	Malacostraca	*Atopobathynella* nr sp. OE1	1	ET
B5M	Impact	Malacostraca	Bathynellidae	1	ET
B6M	Impact	Maxillopoda	*?Halicyclops eberhardi*	1	TK
B6M	Impact	Maxillopoda	*Halicyclops eberhardi*	4	TK
B6M	Impact	Maxillopoda	*Novanitocrella aboriginesi*	8	TK
B6M	Impact	Maxillopoda	*Schizopera oldcuei*	10	TK
B6M	Impact	Malacostraca	*Haloniscus* nr *longiantennatus*	1	JMM

* sub-sample

Bore Code	Area	Higher Classification	Lowest Identification	Count	Identifier
B6M	Impact	Malacostraca	*Atopobathynella gascoyneensis*	2	ET
B6M	Impact	Malacostraca	*Atopobathynella* sp. OE1 (J. McRae)	1	ET
B7M	Impact	Maxillopoda	*Halicyclops eberhardi*	15	TK
B7M	Impact	Maxillopoda	*Parastenocaris solitaria*	1*	TK
B7M	Impact	Maxillopoda	*Schizopera oldcuei*	80*	TK
B7M	Impact	Malacostraca	*Atopobathynella* sp. OE1 (J. McRae)	6	JMM
B7M	Impact	Malacostraca	*Atopobathynella gascoyneensis*	1	JMM
B7M	Impact	Malacostraca	Bathynellidae	5	ET
Yilby Bore	Impact	Collembola	Sminthuridae	1	NRG
Yilby Bore	Impact	Maxillopoda	Copepoda (nauplii)	3	TK
Yilby Bore	Impact	Maxillopoda	*Apocyclops dengizicus*	5	TK
Yilby Bore	Impact	Insecta	Chironomidae (larvae)	3	NRG
Yilby Bore	Impact	Insecta	Diptera (larva)	1	NRG
Yilby Bore	Impact	Maxillopoda	*Schizopera oldcuei*	1	TK
Yilby Bore	Impact	Insecta	Hemiptera (nymph)	5	NRG
Yilby Bore	Impact	Ostracoda	*Candonocypris novaezelandiae*	2 females, 4 valves	IK
Yilby Bore	Impact	Ostracoda	*Sarscypridopsis ochracea*	10 females, 18 valves	IK
Barlanga Well	Control	Arachnida	Acarina (juvenile)	1	NRG
Barlanga Well	Control	Insecta	Ceratopogonidae (larva)	1	ET
Barlanga Well	Control	Maxillopoda	*Australocamptus hamondi*	9	TK
Barlanga Well	Control	Maxillopoda	*Schizopera oldcuei*	1	TK
Barlanga Well	Control	Nematoda	Nematoda	1	RD
Barlanga Well	Control	Oligochaeta	Enchytraeidae	1	ET
Barlanga Well	Control	Ostracoda	*Sarscypridopsis ochracea*	2 females, 24 valves	IK
Barlanga Well	Control	Malacostraca	Parabathynellidae	1	ET
South Mill Well	Control	Maxillopoda	*Halicyclops eberhardi*	2	TK
South Mill Well	Control	Insecta	Ceratopogonidae (larvae)	3	ET
South Mill Well	Control	Maxillopoda	*Australocamptus hamondi*	3	TK
South Mill Well	Control	Maxillopoda	*Schizopera oldcuei*	1	TK
South Mill Well	Control	Insecta	Hemiptera (nymph)	1	NRG
South Mill Well	Control	Ostracoda	*Sarscypridopsis ochracea*	1 female, 12 juv., 24 valves	IK
South Mill Well	Control	Malacostraca	*Atopobathynella* sp. (juvenile)	1	ET

* sub-sample

Appendix E

Total invertebrate count

Phase II (April 2008)

Bore Code	Area	Higher Classification	Lowest Identification	Count	Identifier
B1M	Impact	Ostracoda	*Sarscypridopsis ochracea*	1	IK
B3M	Impact	Malacostraca	Bathynellidae	4	ET
B3M	Impact	Malacostraca	*Atopobathynella* nr sp. OE1	2	ET
B3M	Impact	Maxillopoda	Copepoda (nauplii)	1	TK
B3M	Impact	Maxillopoda	*Halicyclops eberhardi*	51*	TK
B3M	Impact	Maxillopoda	*Schizopera oldcuei*	15*	TK
B3M	Impact	Maxillopoda	*Parastenocaris solitaria*	6	TK
B5M	Impact	Malacostraca	*Atopobathynella gascoyneensis*	1	ET
B5M	Impact	Malacostraca	*Atopobathynella* sp. OE1 (J. McRae)	1	ET
B5M	Impact	Maxillopoda	*Halicyclops eberhardi*	2	TK
B5M	Impact	Maxillopoda	*Schizopera oldcuei*	2	TK
B7M	Impact	Malacostraca	*Atopobathynella* sp. OE1 (J. McRae)	1	JMM
B7M	Impact	Malacostraca	Bathynellidae	9	ET
B7M	Impact	Maxillopoda	*Halicyclops eberhardi*	39	TK
B7M	Impact	Maxillopoda	*Novanitocrella aboriginesi*	1*	TK
B7M	Impact	Maxillopoda	*Schizopera oldcuei*	69*	TK
B7M	Impact	Maxillopoda	*Parastenocaris solitaria*	6	TK
B14M	Impact	Arachnida	Mesostigmata	1	NRG
B14M	Impact	Malacostraca	*Atopobathynella* sp. OE1 (J. McRae)	3	JMM
B14M	Impact	Malacostraca	*Atopobathynella* sp. (juvenile)	2	JMM
B14M	Impact	Maxillopoda	Copepoda (nauplii)	2	TK
B14M	Impact	Maxillopoda	*Schizopera oldcuei*	71*	TK
Yilby Bore	Impact	Maxillopoda	Copepoda (nauplii)	2	TK
Yilby Bore	Impact	Maxillopoda	*Apocyclops dengizicus*	1	TK
Yilby Bore	Impact	Ostracoda	*Candonocypris novaezelandiae*	19	IK
Yilby Bore	Impact	Ostracoda	*Sarscypridopsis ochracea*	4	IK
Barlanga Well	Control	Maxillopoda	*Australocamptus hamondi*	1	TK
Bedan Well	Control	Maxillopoda	Copepoda (nauplii)	2	TK
Bedan Well	Control	Maxillopoda	*Schizopera oldcuei*	1	TK
Bedan Well	Control	Maxillopoda	*Parastenocaris solitaria*	3	TK
Bedan Well	Control	Ostracoda	*Sarscypridopsis ochracea*	19	IK
South Mill Well	Control	Arachnida	Acarina (juvenile)	1	NRG
South Mill Well	Control	Maxillopoda	Copepoda (nauplii)	2	RD
South Mill Well	Control	Maxillopoda	*Metacyclops laurentiisae*	1	TK
South Mill Well	Control	Maxillopoda	*Australocamptus hamondi*	3	TK
South Mill Well	Control	Maxillopoda	*Schizopera oldcuei*	1	TK
South Mill Well	Control	Ostracoda	*Sarscypridopsis ochracea*	17	IK
Watson Well	Control	Branchiopoda	Chydoridae	1	ET
Watson Well	Control	Collembola	Collembola	1	NRG

* sub-sample

Appendix F

Total invertebrate count

Phase III (November 2008)

Bore Code	Area	Higher Identification	Lowest Identification	Count	Identifier
B1M	Impact	Insecta	Arthropoda (juvenile)	1	NS
B3M	Impact	Malacostraca	*Atopobathynella* sp. OES4	1	ET
B3M	Impact	Malacostraca	*Atopobathynella* sp. (juvenile)	3	ET
B3M	Impact	Malacostraca	*Atopobathynella* sp. OE1 (J. McRae)	3	ET
B3M	Impact	Malacostraca	Bathynellidae	6	ET
B3M	Impact	Insecta	Culicidae	1	ET
B3M	Impact	Maxillopoda	*Halicyclops eberhardi*	16	TK
B3M	Impact	Maxillopoda	*Parastenocaris solitaria*	7	TK
B3M	Impact	Oligochaeta	Phreodrilidae with similar ventral chaetae	4	NRG
B3M	Impact	Maxillopoda	*Schizopera oldcuei*	4	TK
B5M	Impact	Maxillopoda	*Halicyclops eberhardi*	7	TK
B5M	Impact	Maxillopoda	*Novanitocrella aboriginesi*	1	TK
B7M	Impact	Malacostraca	*Atopobathynella* sp. OE1 (J. McRae)	2	ET
B7M	Impact	Malacostraca	Bathynellidae	3	ET
B7M	Impact	Maxillopoda	*Halicyclops eberhardi*	3	TK
B7M	Impact	Maxillopoda	*Novanitocrella aboriginesi*	2	TK
B7M	Impact	Maxillopoda	*Schizopera oldcuei*	4	TK
B14M	Impact	Malacostraca	*Atopobathynella gascoyneensis*	2	JMM
B14M	Impact	Malacostraca	Bathynellidae	3	ET
B14M	Impact	Maxillopoda	*Halicyclops eberhardi*	3	TK
B14M	Impact	Malacostraca	*Haloniscus* nr *longiantennatus*	1	ET
B14M	Impact	Maxillopoda	*Parastenocaris solitaria*	1	TK
B14M	Impact	Oligochaeta	Phreodrilidae with dissimilar ventral chaetae	1	NRG
B14M	Impact	Maxillopoda	*Pseudectinosoma sp. 1* n. sp. (T. Karanovic)	1	TK
B14M	Impact	Maxillopoda	*Schizopera oldcuei*	38	TK
Yilby Bore	Impact	Maxillopoda	*Apocyclops dengizicus*	3	TK
Yilby Bore	Impact	Maxillopoda	Copepoda (nauplii)	5	RD
Yilby Bore	Impact	Ostracoda	*Sarscypridopsis ochracea*	6 juv., 4 females	IK
Yilby Bore	Impact	Ostracoda	*Strandesia* sp.	1 juv.	IK

* sub-sample

Bore Code	Area	Higher Identification	Lowest Identification	Count	Identifier
Barlanga Well	Control	Arachnida	Astigmata	1	NRG
Barlanga Well	Control	Maxillopoda	*Australocamptus hamondi*	25	TK
Barlanga Well	Control	Maxillopoda	Copepoda (nauplii)	7	RD
Barlanga Well	Control	Maxillopoda	*Goniocyclops uniarticulatus*	1	TK
Barlanga Well	Control	Ostracoda	*Sarscypridopsis ochracea*	1 shell, 6 juveniles	IK
Bedan Well	Control	Ostracoda	*Sarscypridopsis ochracea*	11 shells, 3 juveniles	IK
South Mill Well	Control	Maxillopoda	*Australocamptus hamondi*	2	TK
South Mill Well	Control	Insecta	Ceratopogonidae (larva)	1	ET
South Mill Well	Control	Oligochaeta	Enchytraeidae	1	NRG
South Mill Well	Control	Maxillopoda	*Metacyclops laurentiisae*	2	TK
South Mill Well	Control	Maxillopoda	*Novanitocrella aboriginesi*	1	TK
South Mill Well	Control	Ostracoda	*Sarscypridopsis ochracea*	3 juv., 3 females, 2 shells	IK
Watson Well	Control	Aphanoneura	*Aeolosoma* sp. 2 (PSS DEC)	2	NRG
Watson Well	Control	Arachnida	Astigmata	1	NRG
Watson Well	Control	Insecta	Ceratopogonidae (larva)	1	ET
Watson Well	Control	Collembola	Collembola	4	KM
Watson Well	Control	Oligochaeta	Enchytraeidae	1	NRG
Watson Well	Control	Ostracoda	*Sarscypridopsis ochracea*	1 shell	IK

* sub-sample taken

Appendix G

Total invertebrate count

Phase IV (October 2009)

Bore Code	Area	Higher Identification	Lowest Identification	Count	Identifier
B3M	Impact	Maxillopoda	*Halicyclops eberhardi*	55*	TK
B3M	Impact	Maxillopoda	*Schizopera oldcuei*	50*	TK
B3M	Impact	Maxillopoda	*Parastenocaris solitaria*	30*	TK
B3M	Impact	Dytiscidae	*Limbodessus microbubba*	2	ET
B5M	Impact	Maxillopoda	*Halicyclops eberhardi*	3	TK
B5M	Impact	Syncarida	*Atopobathynella* nr sp. OE1	1	ET
B7M	Impact	Collembola	Collembola	1	KM
B7M	Impact	Maxillopoda	*Halicyclops eberhardi*	2	TK
B7M	Impact	Maxillopoda	*Schizopera oldcuei*	4	TK
B9M	Impact	No Invertebrates			KM
B14M	Impact	Maxillopoda	*Halicyclops eberhardi*	8	TK
B14M	Impact	Maxillopoda	*Schizopera oldcuei*	48*	TK
B14M	Impact	Maxillopoda	*Parastenocaris solitaria*	1*	TK
B14M	Impact	Syncarida	*Atopobathynella* sp. OE1	1	ET
B14M	Impact	Syncarida	*Atopobathynella gascoyneensis*	1	ET
B14M	Impact	Syncarida	Bathynellidae	2	ET
Yilby Bore	Impact	Maxillopoda	*Apocyclops dengizicus*	2	TK
Yilby Bore	Impact	Diptera	Ceratopogonidae	4	ET
Yilby Bore	Impact	Diptera	Culicidae	2	ET
Yilby Bore	Impact	Ostracoda	*Sarscypridopsis ochracea*	2	SH
Barlanga Well	Control	Aphanoneura	*Aeolosoma* sp. 2 (DEC PSS)	19	ET
Barlanga Well	Control	Maxillopoda	*Goniocyclops uniarticulatus*	2	TK
Barlanga Well	Control	Maxillopoda	*Australocamptus hamondi*	51*	TK
Barlanga Well	Control	Ostracoda	*Sarscypridopsis ochracea*	2	SH
Bedan Well	Control	Maxillopoda	*Halicyclops eberhardi*	8	TK
Bedan Well	Control	Diptera	Chironomidae	1	ET
Bedan Well	Control	Oligochaeta	Tubificidae	8	ET
Bedan Well	Control	Ostracoda	*Sarscypridopsis ochracea*	17	SH
Five Mile Well	Control	Maxillopoda	*Halicyclops eberhardi*	1	TK
Five Mile Well	Control	Maxillopoda	*Metacyclops laurentiisae*	2	TK
Five Mile Well	Control	Maxillopoda	*Australocamptus hamondi*	9	TK
Five Mile Well	Control	Culicidae	Culicidae	30	ET
Five Mile Well	Control	Psychodidae	Psychodidae	1	ET
South Mill Well	Control	Collembola	Collembola	1	KM
South Mill Well	Control	Maxillopoda	*Australocamptus hamondi*	37	TK
South Mill Well	Control	Diptera	Culicidae	1	ET
Watson Well	Control	Acarina	Oribatida	1	KM
Watson Well	Control	Diptera	Chironomidae	26	ET
Watson Well	Control	Ostracoda	*Sarscypridopsis ochracea*	1	SH

* sub-sample