Biota Environmental Sciences

West Pilbara Iron Ore Project Stygofauna Assessment

Prepared for API Management

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Biota Environmental Sciences

ABN 49 092 687 119
Level 1, 228 Carr Place
Leederville Western Australia 6007
Ph: (08) 9328 1900 Fax: (08) 9328 6138

Project No.: 409

Prepared by: Jason Alexander, Garth Humphreys, Paul Sawers

Checked by: Garth Humphreys, Michi Maier

Approved for Issue: Garth Humphreys

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1.0 Introduction

1.1 Project Background

API Management (API) proposes to develop the West Pilbara Iron Ore Project (WPIOP). The spatial scope of this project is considerable, encompassing several mine deposits and associated infrastructure. The project is located primarily in the vicinity of Red Hill in the western Pilbara, approximately 40 km southwest of Pannawonica (Figure 1.1).

API referred the WPIOP to the Western Australian Environmental Protection Authority (EPA) under Section 38 of the *Environmental Protection Act 1986*. The EPA determined that the proposal would be formally assessed at the level of Public Environmental Review (PER). The project was also referred to the Federal Department of the Environment, Water, Heritage and the Arts (DEWHA) under the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*. DEWHA determined that the project would also be treated as a Controlled Action for the purposes of this latter act. Biota Environmental Sciences (Biota) was commissioned to complete a series of surveys assessing potential development impacts on subterranean, aquatic fauna.

Seven ore bodies are proposed for mining as part of the project, all of which occur on mesa landforms at the western margins of the Hamersley Range (Figure 1.1). The ore bodies comprise:

- Cochrane and Jewell: approximately 9 km to the northeast of Red Hill Station;
- Kens Bore: 15 km southeast of Red Hill Station;
- Cardo Bore North: 25 km southeast of Red Hill Station;
- Cardo Bore East: about 30 km southeast of Red Hill Station;
- Upper Cane: also approximately 30 km southeast of Red Hill Station;
- Trinity Bore: approximately 50 km southeast of Red Hill Station; and
- Catho Well: 52 km south-southeast of Red Hill Station.

Of these deposits, dewatering is proposed for Kens Bore and Cardo Bore East to allow mining access to ore located below the water table at these deposits. The aquifer drawdown associated with dewatering at these locations therefore forms the primary impact of interest to this study.

1.2 Summary Background on Stygofauna

Stygofauna are those fauna that inhabit groundwater, sometimes occurring very close to the surface. They tend to be highly specialised to, and obligate dwellers of, subterranean groundwater habitats ('stygobites'; Humphreys 2000). Stygofauna are known to be present in a variety of rock types including karst (limestones), fissured rock (e.g. granite) and porous rock (e.g. alluvium) (Marmonier et al. 1993). The types of animals that have become stygal (groundwater-inhabiting) in Western Australia include platyhelminthes, oligochaetes, crustaceans, water mites and water beetles, (Humphreys 1999, Watts and Humphreys 1999). Much attention has been directed to the crustacean fauna, which includes ostracods, copepods, bathynellid syncarids, isopods and amphipods (Humphreys 1999, Watts and Humphreys 1999, Biota unpublished data).

1.3 Relevant Previous Studies

While there have been no previous studies completed specifically within the project area, surrounding areas of the Hamersley Range and Robe Valley have been well sampled, including within the nearby Bungaroo Valley (approximately 25 km northeast of Cochrane and Jewell; Biota 2007) and at Mesa A (approximately 35km northwest of Cochrane and Jewell; Biota 2004). Sampling in the locality has also been completed at Yarraloola Station (Biota 2006), Cape Preston (Biota 2008) and Onslow (Biota 2009). Though not yet published, the Department of Environment and Conservation (DEC) Pilbara Biological Survey (PBS) also included stygofauna sampling in the locality.

1.4 Scope of this Study

Dewatering of groundwater aquifers has the potential to affect any stygofauna species or communities that may be present. As part of the assessment of potential impacts of the WPIOP project, Biota was commissioned to undertake surveys for stygofauna in the areas under consideration for development. The scope of the current study was to address the potential impacts on stygofauna arising from the proposed dewatering. The specific aims of the work were to:

- sample available groundwater monitoring sites (drill holes and production bores) within or near the project area for the presence of stygofauna;
- identify the stygofauna collected to species level wherever possible to place them into local and regional context; and
- assess the potential impacts on stygofauna due to the proposed modifications to groundwater systems.

The survey documented in this report was planned and implemented in accordance with:

- EPA Guidance Statement No. 54 "*Sampling of Subterranean Fauna in Groundwater and Caves*" (EPA 2003); and
- Draft EPA Guidance Statement No. 54a "*Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia*" (EPA 2007).

1.5 Terminology

For the purposes of this report, the following terms are used as defined below:

Project area – the overall spatial extent of the WPIOP mine areas, from Cochrane in the north to Catho Well in the south.

Study area – an individual mine area sampling locality (e.g. Kens Bore).

Sample site – a specific bore hole from which specimens were collected.

Stygobite – obligate groundwater fauna.

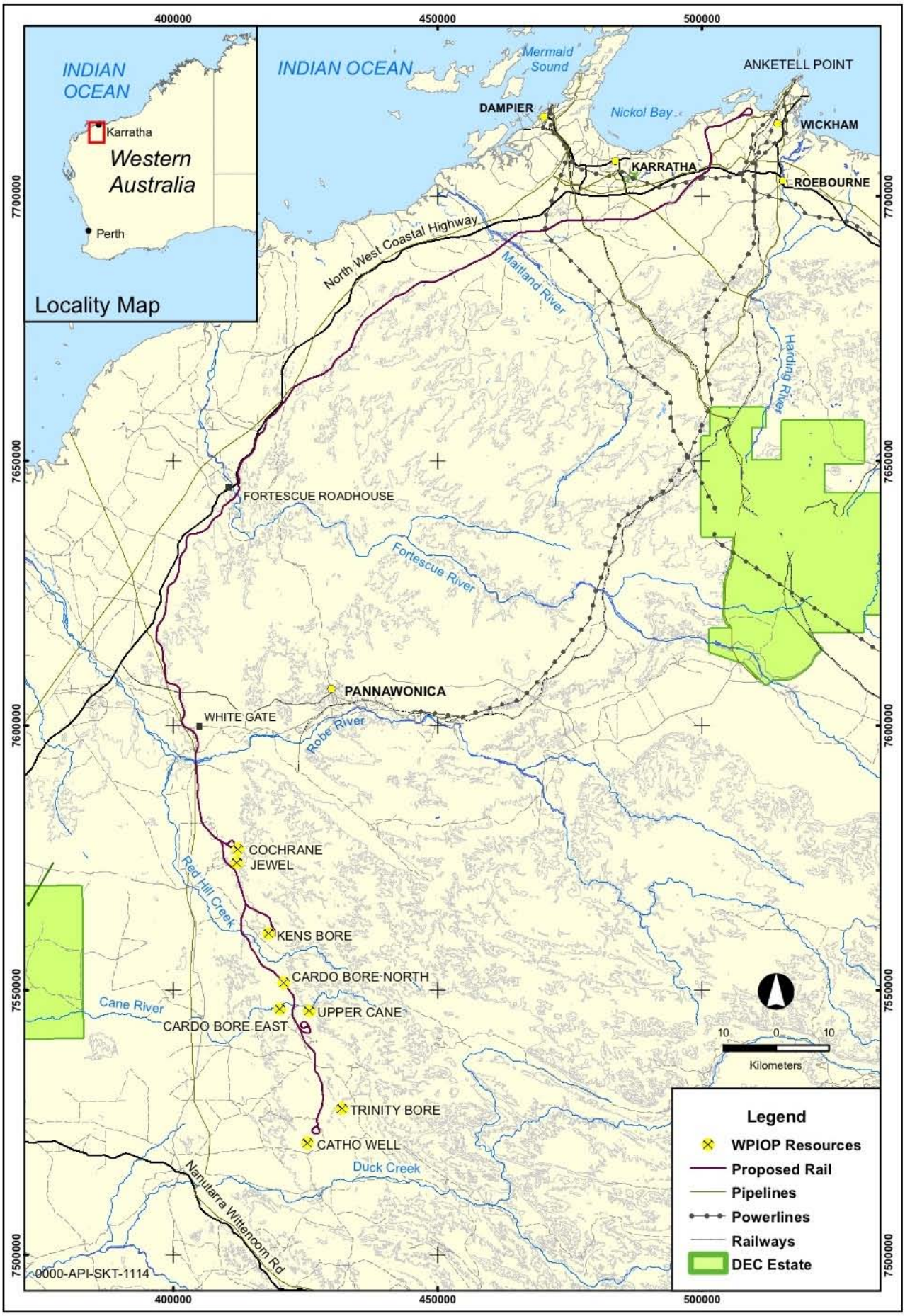

Figure 1.1: Locality map for the West Pilbara Iron Ore Project.

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2.0 Methodology

2.1 Survey Design

Boreholes were selected for sampling in conjunction with API staff to provide spatial coverage of the WPIOP. Sample sites were classified as 'Impact' (within predicted groundwater drawdown extents) or 'Reference' sites (outside of predicted aquifer impacts). Reference sites were selected from a mix of pastoral, water and observation bores.

The design for this project incorporated 58 bores that were sampled over four survey phases between June 2008 and September 2009. A detailed breakdown of sampling by sites and location with respect to Impact or Reference areas is provided in Section 2.3. An overview of the distribution of all boreholes sampled across the multiple-phase survey is provided in Figure 2.1.

2.1.1 Survey Timing and Personnel

All four phases of stygofauna sampling in the WPIOP project area were completed by Biota, with the field survey phases and study teams comprising:

- Pilot Phase - 29th – 30th June 2008: Jason Alexander;
- Phase I - 15th – 19th November 2008: Jason Alexander, Jessica Cairnes;
- Phase II - 23rd – 27th March 2009: Jason Alexander, Jessica Cairnes; and
- Phase III - 25th August – 6th September 2009: Jessica Lynas, Ross Campbell, David Keirle, Chris Cole.

The project was coordinated by Garth Humphreys and managed by Jason Alexander, both of Biota. Jane McRae of Bennelongia completed further taxonomic identifications, with Dr Mark Harvey of the Western Australian Museum and Dr Winston Ponder of the Australian Museum completing more specialist identifications on some taxa.

2.2 Stygofauna Sampling and Data Management

Stygofauna sampling within the WPIOP project area followed a similar format to other stygofauna sampling projects undertaken previously in the Pilbara bioregion. Methodology and approach were consistent with those outlined in the EPA Guidance Statement 54 (EPA 2003) and Draft Guidance Statement 54a (EPA 2007).

Groundwater sampling was undertaken using modified plankton haul nets. These sampling nets were constructed from 70 µm plankton mesh, with 50 mm and 100 mm apertures attached to a weighted catch jar. Each bore was dragged a minimum of four times unless fauna were detected, in which case six hauls were completed. On the final haul the net was agitated gently, which acts to stir the benthos layer and mobilises any fauna present for more effective specimen collecting. On the surface, the net was flushed thoroughly with fresh water and the resulting sample placed in a uniquely labelled container and into a shaded esky in order to preserve the sample until sorting and identification.

Following the completion of a bore, the nets were thoroughly rinsed with water and inspected before using on another hole. This prevented cross-contamination of specimens between aquifers and boreholes.

In addition, prototype leaf-litter traps were installed during the third phase of sampling and left for nine days. These traps target a different suite of fauna rarely collected using conventional haul net techniques, such as gastropods, and work via colonisation. These traps were then retrieved and later sorted in an on-site laboratory.

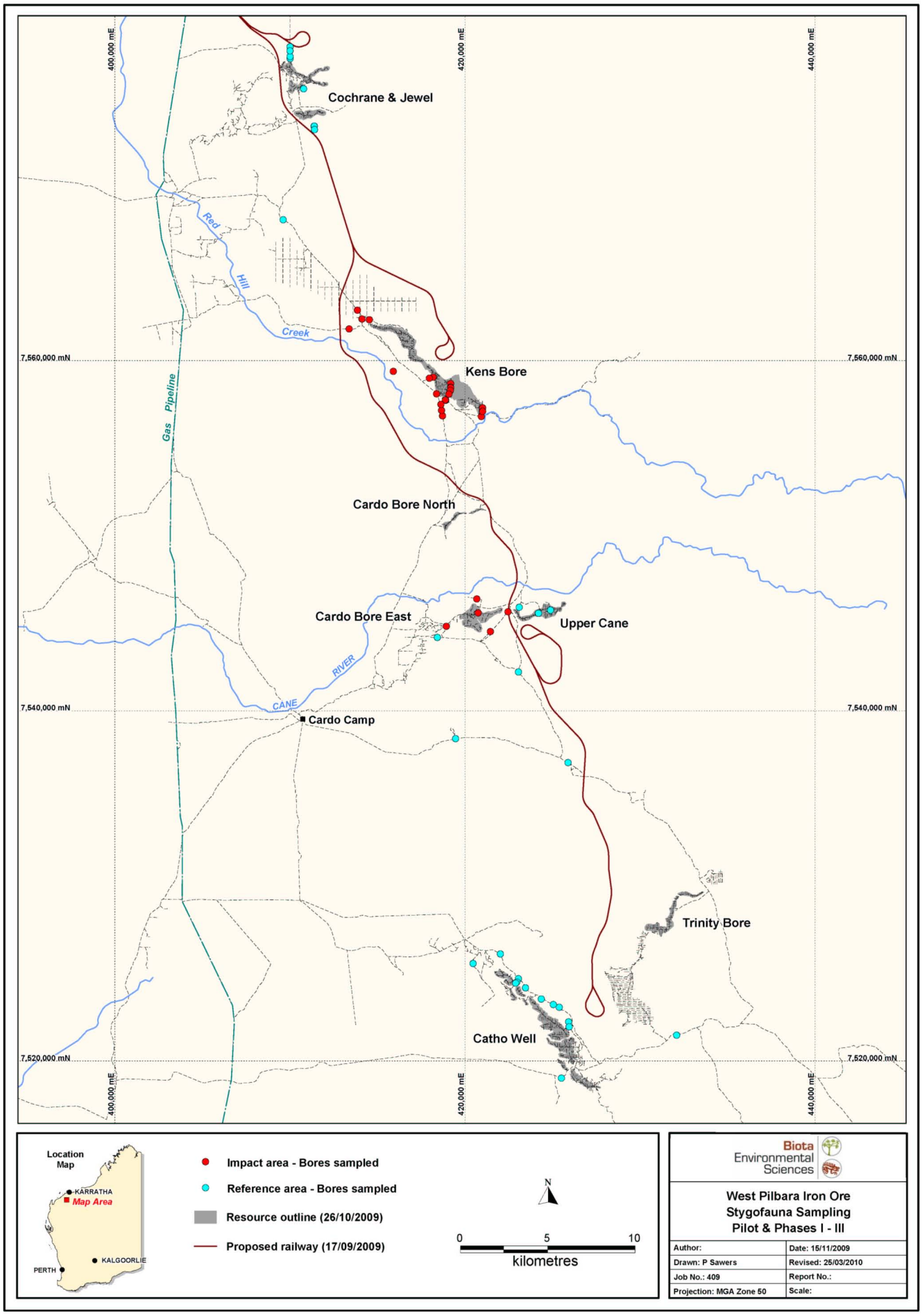

Figure 2.1: Overview of the 58 boreholes sampled for stygofauna during this study.

Sorting and identification of specimens to order level was completed in an on-site laboratory under a dissecting microscope (Olympus SZ40 and SZ61, magnification up to 40x) with the exception of the pilot phase, in which water samples were transported back to the Perth-based laboratory for sorting. Stygofauna specimens were tracked using Biota's standard tracking forms and preserved in 100% ethanol (which provides for both morphological and molecular analysis). Specimens were sent to relevant experts for further identification to the lowest possible taxonomic level.

2.3 Sampling Effort

Three phases of sampling have been completed to-date at the WPIOP project area, in addition to an initial pilot phase. This sampling effort encompassed 58 bores in total. An effort was made to maintain continuity in sampling between phases, with 17 bores being sampled on three occasions and six bores sampled during all four phases (Table 2.1).

The primary aquifer impact areas for the WPIOP survey area associated with the Kens Bore and Cardo Bore study areas (Section 1.1; Figure 2.2 and Figure 2.3; Aquaterra 2009). Maximum groundwater drawdown at Kens Bore will occur at the end of the 15-year mine life, and will result in a lowering of the water table by up to 52 m below current levels at the centre of the pit (Figure 2.2; Aquaterra 2009). A maximum pit drawdown of 18 m below current groundwater levels will occur at Cardo Bore East (Figure 2.3; Aquaterra 2009). For the purposes of this study then, all Kens Bore and Cardo Bore East sample sites within the modelled drawdown contours represented Impact sites, with the balance of the survey sites effectively Reference locations. Following this classification, 29 of the 58 boreholes sampled were Impact sites (Figure 2.2 and Figure 2.3; Table 2.1), with 29 Reference sampling locations across the project area (Table 2.1; Figure 2.1).

Table 2.1: Bores successfully sampled during the four phases of the stygofauna survey (WSG84, zone 50).

Bore Name	Status	Easting (m E)	Northing (m N)	Sampled Successfully				Comments
				Pilot	I	II	III	
CBWB002	Reference	423057	7542219		√	√	√	
CEPZ1	Impact	422458	7545660				√	
CEPZ3	Reference	418423	7544191				√	
CEPZ2	Impact	421455	7544527				√	
CE1-1	Impact	420754	7545594	√				Dry (Phase II)
CE1-4a	Impact	420676	7546390				√	
CBRC076	Impact	418937	7544826		√	√	√	
CWPZ1	Reference	425387	7523067		√	√		
CWPZ2	Reference	425050	7523222		√	√		
CWPZ3	Reference	423457	7524180		√	√	√	
CWPZ4	Reference	422024	7526117		√	√	√	
CWPZ5	Reference	420465	7525572		√	√	√	
CWWB003	Reference	425510	7519020		√		√	
CWWB004	Reference	432090	7521474		√		√	
CW1	Reference	424362	7523540	√	√	√	√	
CW2	Reference	425921	7522238	√				
CW3	Reference	425952	7521954	√	√	√	√	
CW3-1	Reference	423055	7524702	√	√	√		
CW3-2	Reference	422963	7524513	√	√	√		
CW3-3	Reference	422893	7524446	√	√	√	√	
KBRC052	Impact	421001	7557201		√	√	√	
KBRC132	Impact	419080	7558099	√	√	√	√	
KBPB1	Impact	418899	7557735				√	
KBPZ1	Impact	418717	7556848				√	
KBPZ2	Impact	418660	7557165				√	
KBPZ3	Impact	418375	7558103				√	
KBPZ4	Impact	418190	7559056		√	√	√	
KBPZ5	Impact	417965	7558996		√	√	√	
KBPZ6	Impact	414115	7562378				√	
KBPZ7	Impact	414539	7562336				√	
KB1-1	Impact	413858	7562882				√	
KB1-8	Impact	413386	7561811				√	

Table 2.1: Bores successfully sampled during the four phases of the stygofauna survey (WSG84, zone 50).

Bore Name	Status	Easting (m E)	Northing (m N)	Sampled Successfully				Comments
				Pilot	I	II	III	
KB2-1A	Impact	420936	7556808				√	
KB2-5A	Impact	415907	7559387				√	
KB3-1	Impact	419183	7558692	√	√	√	√	
KB3-2	Impact	419180	7558483	√	√	√	√	
KB3-2A	Impact	419189	7558458				√	
KB3-3	Impact	419169	7558299				√	
KB3-4	Impact	419079	7558089				√	
KB3-6	Impact	418880	7557750		√	√		
KB3-8	Impact	418627	7557504				√	
KB4-1A	Impact	421007	7557304	√	√	√		
KB4-2A	Impact	421009	7557105	√	√	√		
KB4-3A	Impact	420936	7556808		√	√	√	
RHNPB1	Reference	411382	7573385				√	
RHNPZ1	Reference	410782	7575524				√	
RHN-1	Reference	410013	7577256				√	
RHN-2	Reference	410011	7577372				√	
RHN-3A	Reference	411395	7573397				√	
RHN3-1A	Reference	410009	7577926				√	
RHN3-3A	Reference	410006	7577693				√	
RHN-4	Reference	411406	7573196				√	
RHWB001	Reference	409616	7568049		√			Piping down bore
UCRC150	Reference	424888	7545750		√	√	√	
UCRC164	Reference	424200	7545571		√	√	√	
UCWB001	Reference	423100	7545913	√	√	√		
URWB001	Reference	419466	7538412		√	√		Windmill attached
URWB002	Reference	425887	7537043		√	√	√	
			Total	**13**	**30**	**27**	**46**	

A summary of each sampling phase follows in Sections 2.3.1 to 2.3.4.

2.3.1 Pilot Phase

The initial pilot phase of stygofauna sampling took place on the 29th and 30th of June 2008. Thirteen bores were successfully sampled. At the time of sampling, only UCWB001 and KBRC132 had been installed for longer than the six-month period after drilling recommended by EPA Draft Guidance Statement 54a (EPA 2007).

2.3.2 Phase I

The Phase I survey ran from the 15th – 19th of November 2008. Thirty bores were successfully sampled from the 47 bores initially selected for this first phase of sampling (Table 2.1), with a number of selected bores either not intersecting the water table or having headworks attached. Bores sampled included 12 that had been previously sampled during the pilot phase.

2.3.3 Phase II

Sampling was completed from the 23rd – 27th of March 2009, with a total of 27 bores successfully sampled (Table 2.1). All bore sites had been previously sampled.

2.3.4 Phase III

Phase III of the WPIOP was completed in two stages, the first of which ran from the 25th – 27th of August 2009 and the second from the 3rd – 6th of September 2009. Forty-six bores were sampled successfully using haul nets. Six of the 10 leaf litter traps deployed during the first stage of the survey were successfully collected and sorted during the November sampling stage.

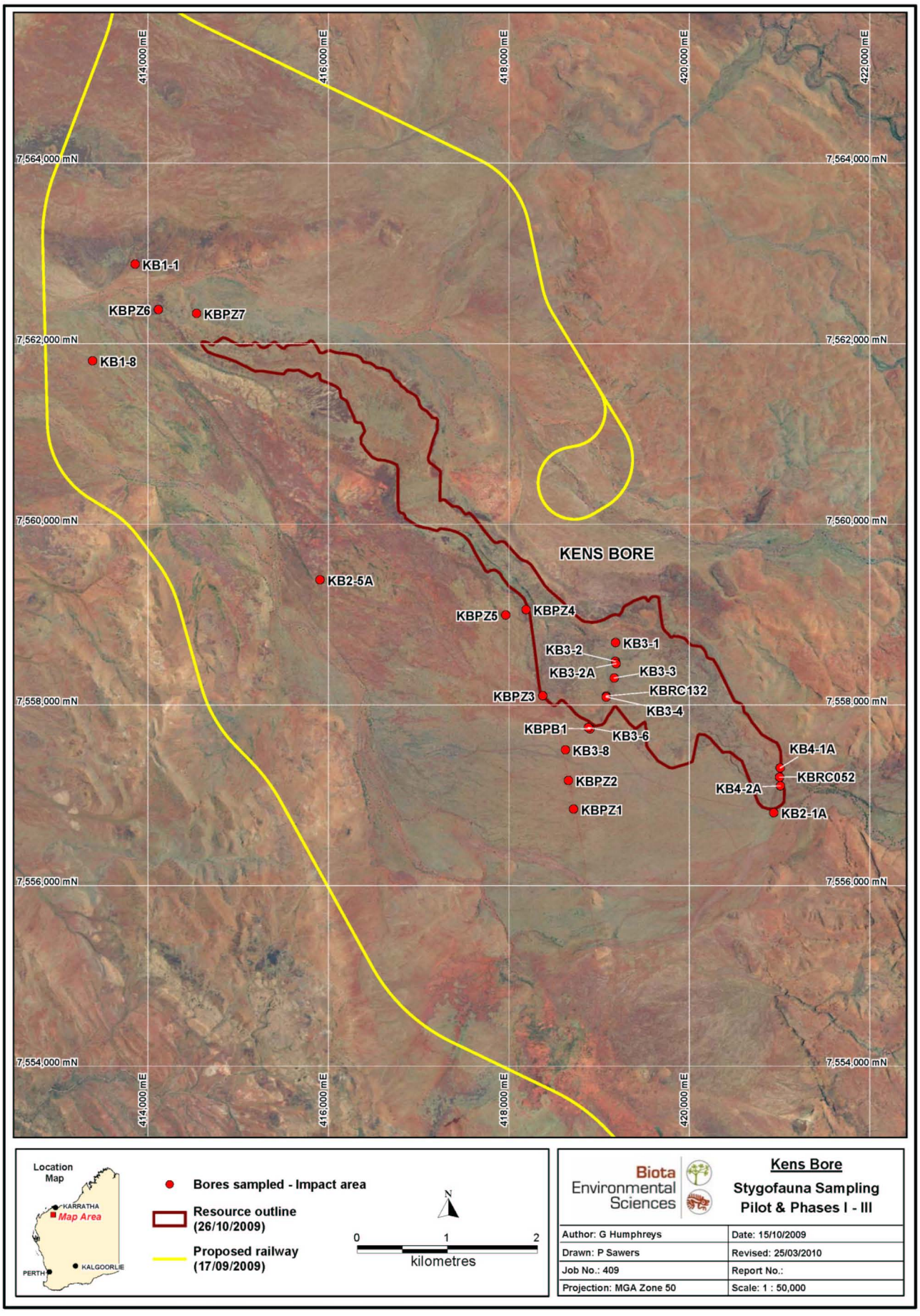

Figure 2.2: Impact area boreholes sampled for stygofauna in the Kens Bore study area.

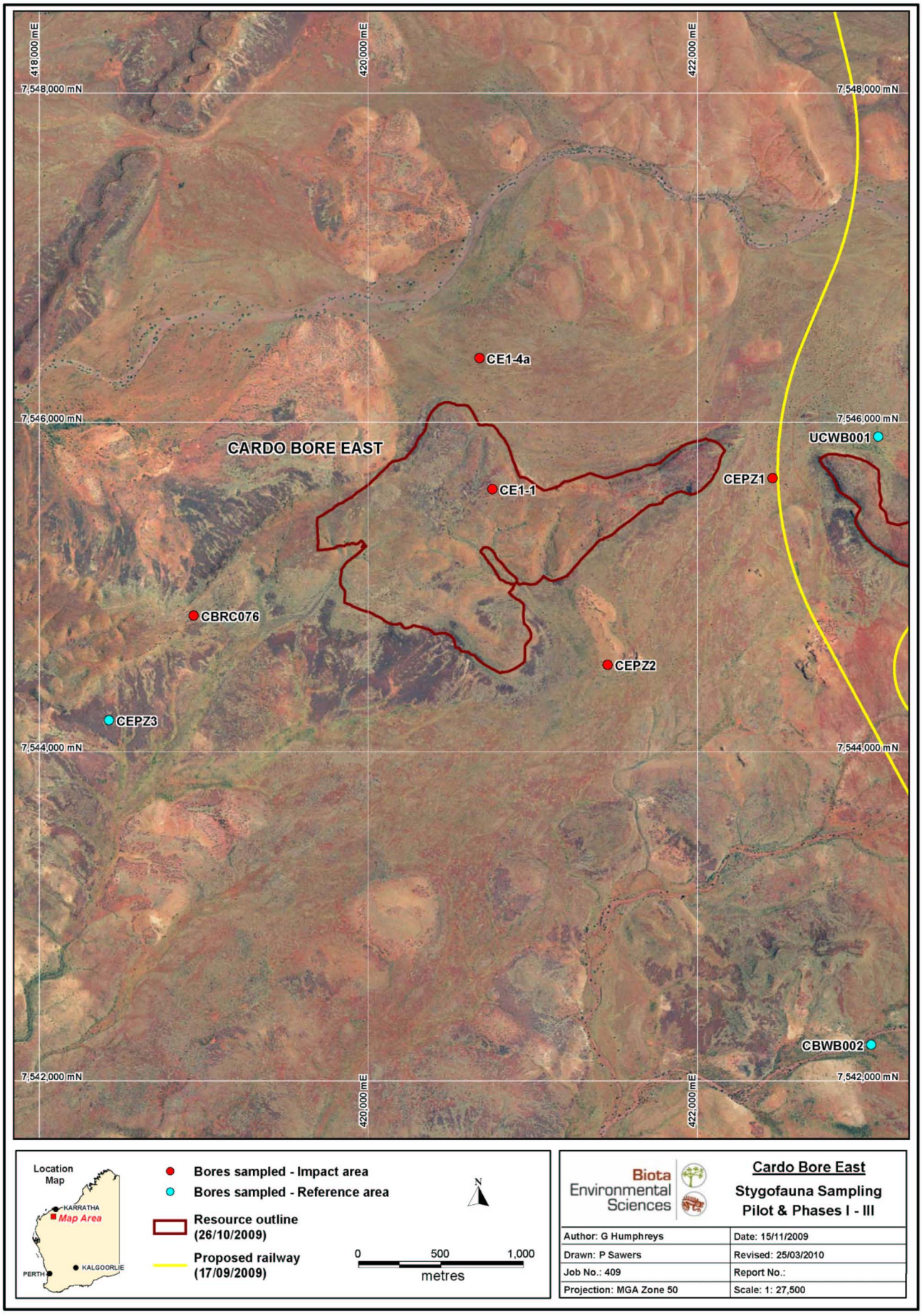

Figure 2.3: Impact area boreholes sampled for stygofauna in the Kens Bore study area.

2.4 Study Limitations

A number of limitations should be recognised by the reader of this report. Many are common functions of working on subterranean fauna, rather than functions of this specific study. These limitations include:

- There is a lack of adequate taxonomic framework and specialist expertise for some of the faunal groups, both within Australia and internationally. This limited the conclusiveness of some of the findings on specific taxa.
- As is commonly the case, there was a high frequency of juvenile specimens compared to adults amongst the collected specimens. For most taxa, only adults can be determined to species level based on morphology, so this limited the level to which many specimens could be identified.
- The spatial extent of the sampling was limited by the availability of viable boreholes, which may have resulted in habitat and geology sampling bias.

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3.0 Hydrogeology and Stygofauna Habitat

The hydrogeology of the Kens Bore study area was assessed by Aquaterra (2009), as the primary dewatering area for the project. While other parts of the WPIOP project area were not studied in detail, it is likely that the conceptual hydrogeology documented by Aquaterra (2009) for Kens Bore is broadly similar to the other study areas.

Aquaterra (2009) identified three types of aquifers in the Kens Bore study area:

- superficial aquifers;
- chemically deposited aquifers; and
- fractured rock aquifers.

A conceptual cross section showing the relationship between these aquifers, groundwater flow and the geological formations present is shown in Figure 3.1.

- **Superficial Alluvial Aquifers**

Drilling conducted in the study area indicated that a superficial aquifer occurs from between 10 m below ground level (mbgl) to 60 mbgl (Aquaterra 2009). Geologically, this unit consists of Tertiary deposits (alluvium and colluvium) (e.g. Red Hill Creek on Figure 3.1). Most of the shallow bores drilled for the project and all of the existing pastoral bores on Red Hill station intersect this aquifer (Aquaterra 2009). Recharge to these Tertiary deposits is by direct percolation of rainfall and by throughflow from surface drainage in contemporary surface creek systems (Aquaterra 2009). Data from two cyclone seasons indicate that the water table fluctuates by at least 3 m seasonally, rising after sustained intense rainfall events and declining during periods of reduced rainfall (Aquaterra 2009). The shallow nature of the sediments and recent recharge means that water quality is good in this virtually freshwater aquifer system, with Total Dissolved Solids (TDS) values ranging from 240 to 530 mg/L (Aquaterra 2009).

- **Chemically Deposited Aquifers**

Two types of chemically deposited aquifers occur: calcrete and pisolitic limonite aquifers, where chemically deposited within Tertiary drainages. Both aquifers are characterised by secondary permeability (Aquaterra 2009). The pisolitic Channel Iron Deposits (CID) formations only form aquifers where below the water table, with much of this unit unsaturated (Aquaterra 2009; Figure 3.1). Recharge to the CID is by direct percolation of rainfall (or indirectly through the overlying hardcap), and by throughflow from the adjacent Red Hill Creek and the surrounding alluvial deposits (Aquaterra 2009).

Minor calcrete deposits occur within drainages as localised exposed mounds, and are characterised by secondary porosity with karstic features, developed through the partial dissolution of calcrete via water interactions (Aquaterra 2009). The calcrete is mostly unsaturated, but is often in hydraulic connection with the alluvium along the drainage channels such that they behave as a single aquifer in some places (Aquaterra 2009).

- **Fractured Rock Aquifers**

Groundwater in fractured rock aquifers only occurs where secondary porosity has developed in fractured and weathered zones, and this rock type otherwise holds no groundwater (Aquaterra 2009). Two types of aquifer occur: dolomite and basement, underlying the other two groundwater systems (Figure 3.1). Groundwater recharge is episodic and affected by direct infiltration of rainfall over areas where the rocks are fractured, jointed and weathered (Aquaterra 2009).

Based on previous studies (e.g. Biota 2004 and 2006), the superficial aquifer unit is the mostly likely to provide core habitat for stygofauna in the study area, particularly where in contact with portions of the chemically deposited calcrete aquifer.

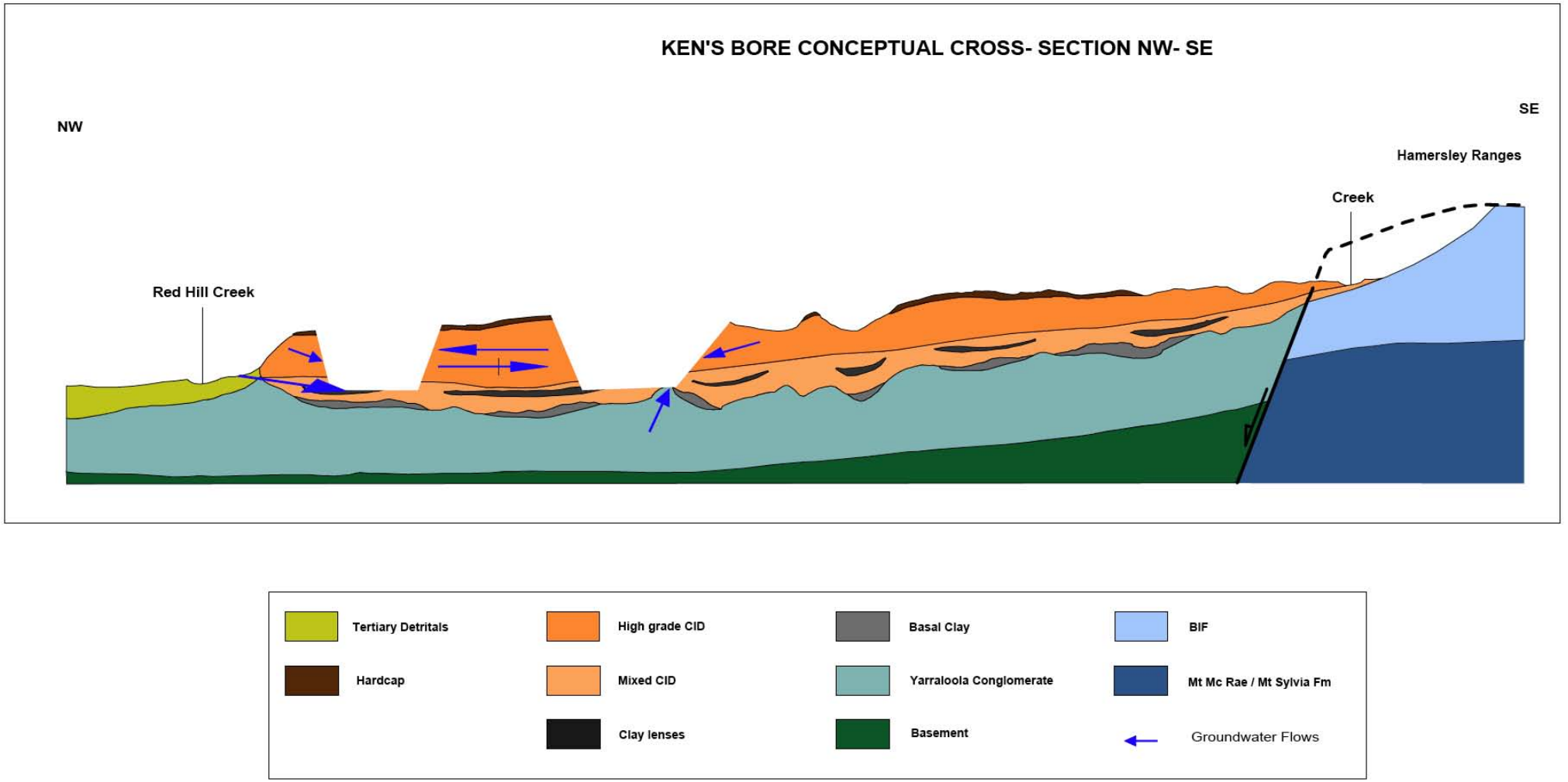

Figure 3.1: Conceptual cross-section showing geological formations and groundwater flows at Kens Bore (source: Aquaterra 2009).

4.0 Results

4.1 Overview

Eight higher-order taxa were represented amongst the fauna collected across the four sampling efforts. A total of 1,486 stygobitic invertebrates were collected from 35 sample sites within the WPIOP project area. Specimens came almost exclusively from crustacean orders, which accounted for 99.6% (1,441) of all the taxa recorded. Of these taxa, the Copepoda, Ostracoda and Amphipoda were the most abundant (Figure 4.1). An overview of the spatial distribution of the stygofauna records and their relative abundance is provided in Figure 4.2.

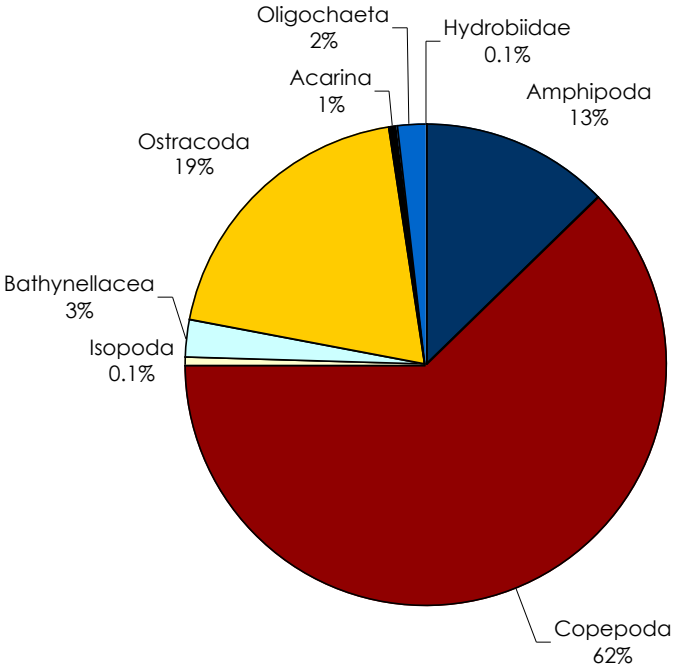

Figure 4.1: Proportional representation of higher order stygal taxa amongst all specimens collected for the WPIOP to date.

A taxonomic summary of higher-order specimens collected, and the number of bores in which they were represented across the project area, is detailed in Table 4.1. In addition to being the largest contributors to the fauna, amphipods, copepods and ostracods were also the most commonly encountered amongst the sample sites (Table 4.1).

Table 4.1: Summary of stygobitic taxa collected from the WPIOP project area.

Taxon				
Phylum	**Class**	**Order**	**Total individuals**	**No. of Sample Sites**
Crustacea	Malacostraca	Amphipoda	182	23
		Bathynellacea	39	8
		Isopoda	7	4
	Copepoda	Cyclopoidea	874	22
		Harpacticoidea	56	7
	Ostracoda	Podocopa	287	8
Chelicerata	Arachnida	Acarina	11	6
Annelida	Oligochaeta	Haplotaxida	29	6
Mollusca	Gastropoda	Sorbeoconcha	1	1
		Total	**1,486**	

A review of the results by each sampling phase follows in Sections 4.2 to 4.5, followed by a detailed account of each taxonomic group in Section 5.0. All raw data are presented in Appendix 1.

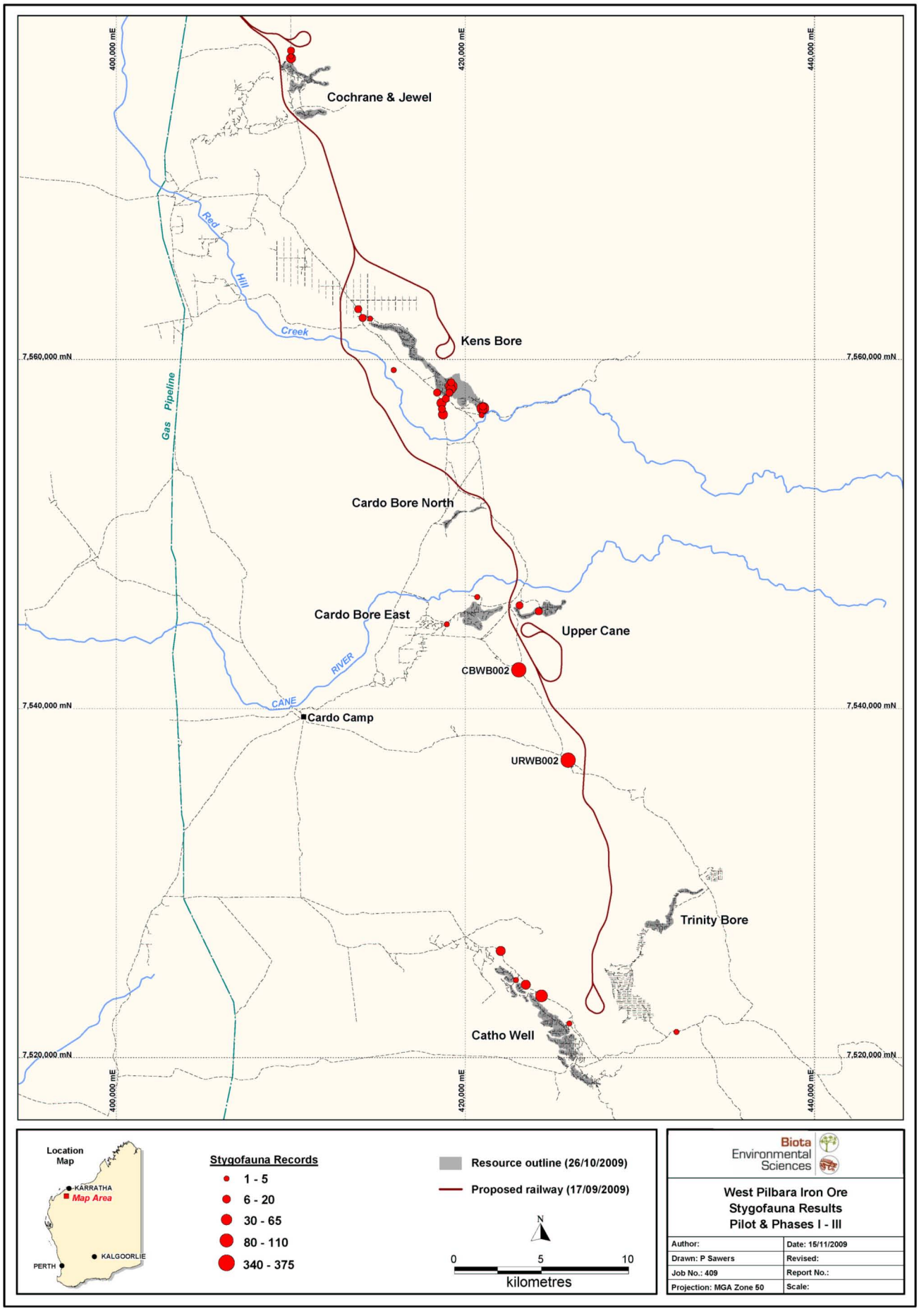

Figure 4.2: Distribution and relative abundance of all stygofauna records from the WPIOP stygofauna survey.

4.2 Pilot Phase

Of the 13 bores sampled during the first phase, three yielded stygofauna: UCWB001, KBRC132 and CW1. UCWB001 had the greatest number of specimens (n=10; 63% of the specimens), while CW1 containing a single amphipod specimen (5%) (Appendix 1). Harpacticoid copepods (*Elaphoidella humphreysi*) and amphipods (Paramelitidae sp. 2 (DEC)) were the most abundant, with four specimens each (21%). The rarely collected isopod family Microcerberidae, as well as the fragmented remains of a bogidiellid amphipod, were the least abundant with only a single specimen of each.

4.3 Phase I

Eleven of the 30 bores successfully sampled during the first phase of WPIOP stygofauna survey contained stygofauna, with a total of 467 specimens collected. Pastoral bores CBWB002 and URWB002 yielded the greatest numbers and diversity with 195 individuals (41%) from eight species, and 122 specimens (26%) from seven species respectively (Appendix 1). The cyclopoid copepod *Diacyclops humphreysi humphreysi* was the most common collected species with 165 specimens (35%) from seven bores.

4.4 Phase II

Stygofauna was recorded in 14 of the 27 bores (52%) sampled. A total of 420 stygobitic specimens were collected with the cyclopoid copepod species *Stygioridgewayia trispinosa* and *Diacyclops humphreysi humphreysi* the most abundant at 170 specimens and 150 specimens respectively (40% and 36%; Appendix 1). A single stygobitic snail specimen belonging to the family Hydrobiidae, as well as an undescribed flabelliferan isopod *Pygolabis* sp. B1, were the least abundant taxa. As for Phase I, pastoral bore URWB002 yielded the greatest diversity with seven species including the hydrobiid snail.

4.5 Phase III

Phase III was completed in early September 2009, with 46 bores successfully sampled using haul nets and six prototype leaf litter traps successfully recovered. Twenty-nine of the 46 bores sampled (63%) contained stygofauna, with a total of 579 specimens collected (Appendix 1). CBWB002 and KBPZ1 yielded the most diversity with five taxonomic groups in each. The Copepoda was the most abundant group, with the cyclopoid copepod species *Diacyclops humphreysi humphreysi* comprising 45% of the total specimens collected. The ostracod species *Humphreyscandona ventosa* was also abundant, accounting for 26% of the specimens. The specimens from the remaining orders (Acarina, Bathynellacea, Isopoda and Oligochaeta) totalled 3% of all specimens collected. Two species, *Diacyclops humphreysi humphreysi* and Paramelitidae sp. 2 (DEC), that had not been collected using haul net techniques during the Phase III sampling were collected using leaf litter traps.

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5.0 Annotated List of Stygal Taxa

5.1 Order Amphipoda

A total of 182 amphipod specimens were recorded during the multiple phase survey (Table 5.1, Figure 5.1). These specimens were identified further as representing eight taxa, the majority of which (n=113 or 62%) belonged to the paramelitid genus *Nedsia,* and mostly came from site URWB002 (Appendix 1). Many of the specimens collected were juvenile or damaged, which limited the level of identification possible (see Section 2.4) (e.g. *Nedsia* 'sp. indet.' in Table 5.1).

Table 5.1: Summary of stygal amphipod taxa collected from Impact and Reference sites during Pilot to Phase III sampling at the WPIOP project area.

Order	Family	Taxa	n	Impact	Reference
Amphipoda	Bogidiellidae	Bogidiellidae sp. indet	1	-	UCWB001
	Melitidae	Melitidae sp. 1 (PBS) (nr *Norcapensis*)	6	KB2-5b	URWB002, UCWB001,
		Nedsia sp. indet.	108	KB3-1, KBPZ1, KB1-1, KB3-3, KB3-4, KB2-5b, KB3-2a	CBWB002, URWB002, CE1-4a, RHN-3a,
		Nedsia nr. *hurlberti* (DEC)	5	-	RHN-1
	Paramelitidae	Paramelitidae sp. indet.	15	KB2-5b, KB3-3	CW3-3, CW1, CWPZ4, CW1-3, UCRC164,
		Paramelitidae sp. 2 (DEC)	40	KB4-1a, KB4-3a, KBPZ1, KB3-8,	UCWB001, CW1, CWPZ3, CWPZ4, CW3-3, CBWB002, URWB002
		Paramelitidae sp. 6 (DEC)	5	-	CW1, CWPZ4
		Pilbarus nr. *millsi*	2	-	URWB002

While four of the amphipod taxa were restricted to Reference areas (Bogidiellidae sp. indet, *Nedsia* nr. *hurlberti* (DEC), Paramelitidae sp. 6 (DEC) and *Pilbarus* nr. m*illsi;* Table 5.1, Figure 5.1), none of the identified taxa were recorded only from Impact area bores (Table 5.1).

5.2 Order Bathynellacea

Forty specimens belonging to the order Bathynellacea were collected from WPIOP during this study (Table 5.2). The existing taxonomic framework for this order does not allow for most bathynellid identifications to be completed to species level. Thirty bathynellids of indeterminate family made up the majority of the collected fauna.

Table 5.2: Summary of stygal bathynellid taxa collected from Impact and Reference sites during Pilot to Phase III sampling at the WPIOP project area.

Order	Family	Taxa	n	Impact	Reference
Bathynellacea	Indet.	Bathynellacea sp. indet.	30	KBRC052, KB4-2a	RHN-3a
	Parabathynellidae	*Billibathynella* sp. B1	5	KBRC132	UCWB001
		Hexabathynella sp.	1	KB3-1	-
		Notobathynella sp.	4	KB3-4	CW1

Most bathynellid taxa were collected from both Impact and Reference sites, however one taxon (*Hexabathynella* sp.) was only recorded as a single specimen from Impact bore KB3-1 (Table 5.2).

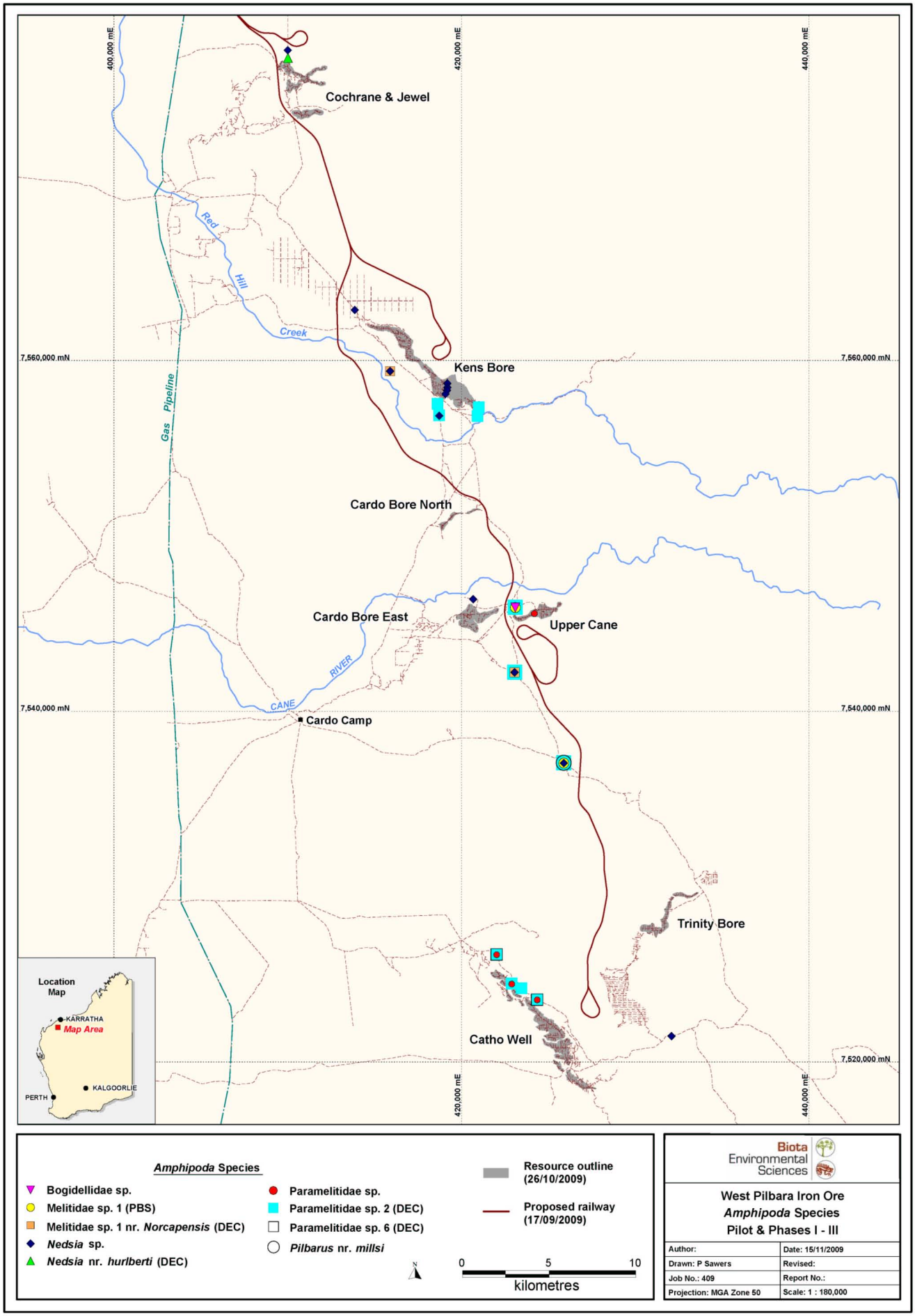

Figure 5.1: Distribution of amphipod taxa collected from the WPIOP project area during the survey.

5.3 Order Isopoda

Seven specimens belonging to the crustacean order Isopoda were collected from the WPIOP project area during Phases I to III (Table 5.3).

Table 5.3: Summary of stygal isopod taxa collected from Impact and Reference sites during Pilot to Phase III sampling at the WPIOP project area.

Order	Family	Taxa	n	Impact	Reference
Isopoda	Amphisopodidae	*Pilbarophreatoicus platyarthricus*	3	KBRC132	-
	Cirolanidae	*Kagalana tonde*	2	-	URWB002
	Microcerberidae	Microcerberidae sp. indet.	1	-	UCWB001
	Tainisopidae	*Pygolabis* sp. B1	1	-	CBWB002

The collected isopods included a previously undescribed species *Pygolabis* sp. B1 (collected from Reference bore CBWB002), as well as a member of the small, rarely collected family Microcerberidae (from UCWB001; Table 5.3). The Microcerberidae is a small group of minute (less than 2 mm), blind Isopods predominantly recorded from interstitial environments and freshwater caves (Barnes 1987). The cirolanid isopod *Kagalana tonde* (Plate 5.1) was also only recorded from Reference areas (site URWB002; Table 5.3).

Plate 5.1: Stygobitic isopod *Kagalana tonde* collected during Phase I (Photo: Jane McRae).

One isopod species was only recorded from Impact sites during this study: *Pilbarophreatoicus platyarthricus* from KBRC132 (Table 5.3). This species has, however, been previously described from a tributary of the Robe River (Knott and Halse 1999), and is not restricted to Kens Bore or the WPIOP project area.

5.4 Class Copepoda

The class Copepoda accounted for the majority of the specimens collected with 930 individuals from two orders (Cyclopoida and Harpacticoida) (Table 5.4). The cyclopoids were relatively common and represented 94% of the copepods collected. All cyclopoid copepods belonged to a single family: the Cyclopidae. The harpacticoid copepods collected during the survey contained representatives from two families: the Canthocamptidae and the Paristenocarididae (Table 5.4).

The most common copepods collected were the cyclopoids *Diacyclops humphreysi humphreysi* (n=572 from 23 sites) and *Stygioridgewayia trispinosa* (n=290) (Table 5.4). Overall, the copepods were the most diverse stygal group with nine taxa collected from three families. The distribution of the copepod taxa is shown in Figure 5.2.

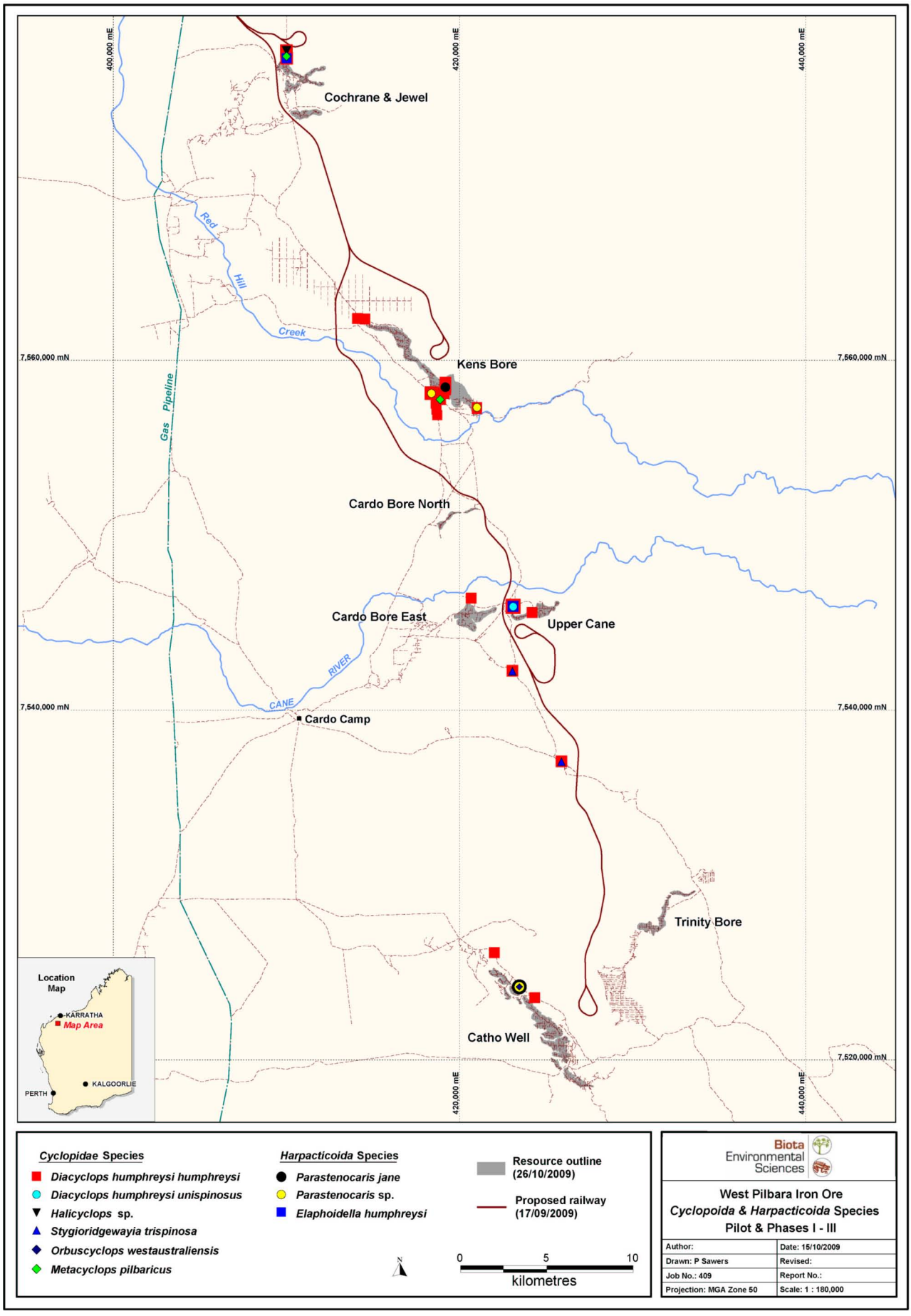

Figure 5.2: Distribution of copepod taxa collected from the WPIOP project area during the survey.

Table 5.4: Summary of stygal copepod taxa collected from Impact and Reference sites during Pilot to Phase III sampling at the WPIOP project area.

Order	Family	Taxa	n	Impact	Reference
Cyclopoida	Cyclopidae	*Diacyclops humphreysi humphreysi*	572	KB3-1, KB3-2a, KB3-3, KB3-4, KB3-6, KB3-8, KB4-1a, KBPZ1, KBPZ2, KBPZ3, KBPZ6,KBPZ7, KBRC052, KBRC132	CBWB002, CE1-4a, CW1, CWPZ4, RHN-1, RHN-3a, UCRC164, UCWB001, URWB002
		Diacyclops humphreysi unispinosus	2	-	UCWB001
		Halicyclops sp.	1	-	RHN3-3a
		Metacyclops pilbaricus	2	KB3-6	RHN-2
		Orbuscyclops westaustraliensis	8	-	CWPZ3
		Stygioridgewayia trispinosa	290	-	CBWB002, URWB002
Harpacticoida	Canthocamptidae	*Elaphoidella humphreysi*	9	-	RHN-1, UCWB001
	Paristenocarididae	*Parastenocaris* sp.	4	KB4-1a, KBPZ3	CWPZ3
		Parastenocaris jane	42	KB3-2a	CWPZ3

None of the copepod species recorded were restricted to Impact sampling sites (Table 5.4; Figure 5.2), and most have been previously described from other parts of the Pilbara bioregion.

5.5 Class Ostracoda

The class Ostracoda was represented by a single order and a single family in the collected fauna, and included two taxa belonging to the genus *Humphreyscandona* (Table 5.5). A total of 287 specimens were collected from eight sample sites, with most (71%) belonging to the undescribed species *Humphreyscandona* sp. nov. All specimens of this new taxon were collected from a Reference site: pastoral bore CBWB002 (Table 5.5).

Table 5.5: Summary of stygal ostracod taxa collected from Impact and Reference sites during Pilot to Phase III sampling at the WPIOP project area.

Order	Family	Taxa	n	Impact	Reference
Podocopa	Candonidae	*Areacandona ?undulata*	2	-	RHN3-3a
		Humphreyscandona sp. nov.	80	-	CBWB002
		Humphreyscandona ventosa	203	KB3-1, KB3-2a, KB3-3	CBWB002, CBWB002a, URWB002
		Pilbaracandona rosa	2	KBPZ1	-

One ostracod, *Pilbaracandona rosa*, was only recorded from an Impact site during this study (KBPZ1; Table 5.5). This species has previously been described from elsewhere in the region and is not restricted to the Kens Bore locality.

5.6 Class Gastropoda

A single gastropod from the family Hydrobiidae was recorded from Reference site URWB002 (Plate 5.2; Figure 5.3). The family Hydrobiidae is known as one of the most diverse families of freshwater molluscs represented throughout much of the world and is known from many species within Australia (Ponder et al. 1993). The Hydrobiidae characteristically have little intrinsic ability to disperse outside their immediate habitat (Ponder and Colgan 2002), hence opportunities for accidental dispersal, particularly in subterranean environments, are likely to be limited. Collections of stygobitic snails are uncommon and therefore it is unlikely that the taxonomic framework will allow for species level identification. The specimen was sent to Dr Winston Ponder from the Australian Museum in Sydney, who specialises in aquatic gastropod taxonomy.

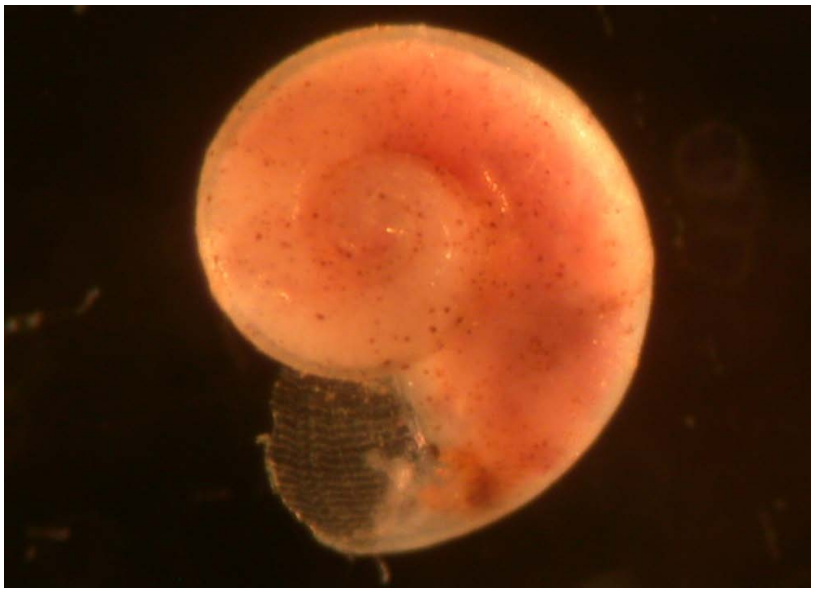

Plate 5.2: Stygobitic hydrobiid snail collected from bore URWB002 during Phase II.

5.7 Order Acarina

A total of 11 aquatic mite specimens were collected from the WPIOP project area during the survey (Table 5.6; Figure 5.3). Four taxa were identified from the collected material, all belonging to the suborder Oribatida. Three of the taxa were unable to be identified to species level.

Table 5.6: Summary of stygal mite taxa collected from Impact and Reference sites during Pilot to Phase III sampling at the WPIOP project area.

Order	Suborder	Taxa	n	Impact	Reference
Acarina	Oribatida	Ameridae sp 1	3	-	CBWB002, URWB002
		Guineaxonopsis sp. S1 (PBS)	1	KBPZ1	-
		Oribatida sp. indet.	4	KBRC052	CBWB002
		Trombidioidea sp.	3	CBRC076	CW3

Two of the Acarina taxa collected were recorded from Impact sites, with one (Oribatida sp. indet.) also collected from Reference site CBWB002 (Table 5.6; Figure 5.3). The other Impact area taxon, *Guineaxonopsis* sp. S1 (PSS), has previously been recorded from elsewhere in the region during the DEC Pilbara Biological Survey and is not restricted to the Kens Bore area.

5.8 Class Oligochaeta

Twenty-nine stygobitic oligochaetes specimens were collected from five bores in the project area (Table 5.7; Figure 5.3). Two families were represented amongst the specimens: the Enchytraeidae and Phreodrilidae. Only five of the oligochaete specimens were sufficiently mature to be identified to species level. Enchytraeidae Pilbara sp.1 was recorded from both Impact site KBRC052 and two Reference sites (Table 5.7; Figure 5.3), in addition to corresponding to a form recorded during the DEC Pilbara Biological Survey. The data suggest that none of the taxa recorded are restricted to Impact areas (Table 5.7).

Table 5.7: Summary of stygal oligochaete taxa collected from Impact and Reference sites during Pilot to Phase III sampling at the WPIOP project area.

Order	Family	Taxa	n	Impact	Reference
Haplotaxida	Enchytraeidae	Enchytraeidae sp. indet.	3	KBRC052	CBRC076
		Enchytraeidae Pilbara sp.1	5	KBRC052	CBWB002, URWB002
	Phreodrilidae	Phreodrilidae sp. dissimilar ventral chaetae	21	KBRC052	CBWB002, UCRC164,

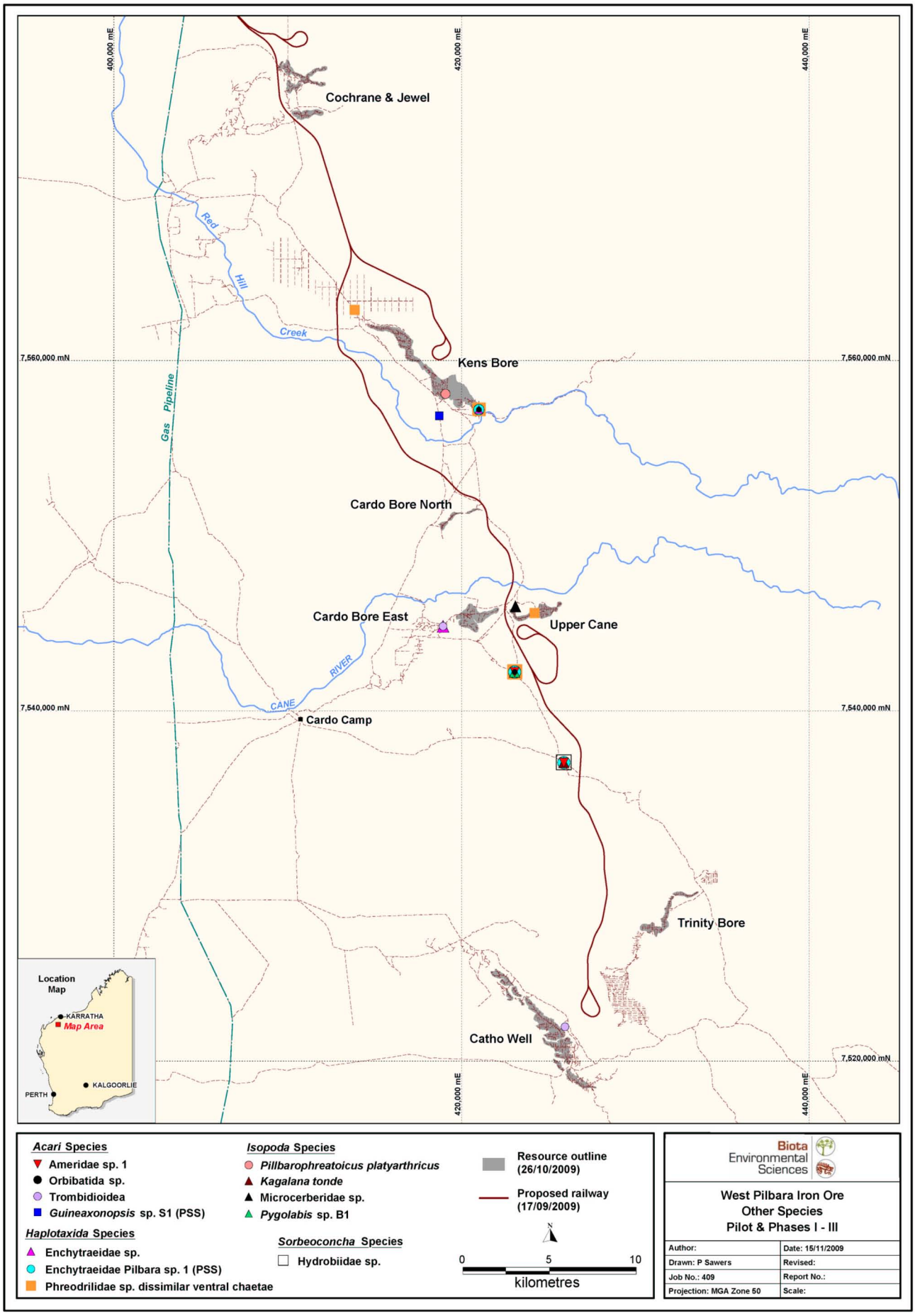

Figure 5.3: Distributions of various other stygal taxa collected from the WPIOP project area during the survey.

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6.0 Discussion

6.1 Summary of Findings

This study recorded a total 37 stygal taxa, representing nine orders and 16 families (Section 5.0). The taxonomic composition of the fauna was typical of previous stygofauna surveys completed in the region, being strongly dominated by crustacean groups.

With the exception of the hydrobiid snail, all the orders were represented across the extent of the project area. Many of the species recorded were also collected from large spatial extents, with 15 of the 37 taxa collected from multiple locations. Some taxa were less commonly recorded, and the wider distribution of those recorded from the Kens Bore and Cardo Bore East study areas are of primary interest to this assessment (Section 6.2).

6.2 Potential Impacts

6.2.1 Direct Impacts

Modelling completed by Aquaterra (2009) indicates that the cone of groundwater depression at Kens Bore will extend to a maximum size of approximately 16 km along strike by 12 km across strike at the deepest part of the mine life (15 years) (Figure 6.1). This will result in the desaturation of currently saturated superficial and chemically deposited aquifers at Kens Bore, particularly those associated with the adjoining Red Hill Creek. Dewatering at Cardo Bore East will have lesser impacts, with a maximum groundwater drawdown of 18 m that will extend approximately 1 km radius from the pit (Figure 6.2; Aquaterra 2009). While some local refugia may exist, it is conservatively assumed that these losses of aquatic subterranean habitat will mean that any stygofauna present in the affected areas will also be lost as a result of dewatering.

Twenty-one of the 37 stygal taxa recorded in this study were represented from Impact area sites at Kens Bore and Cardo Bore East (Section 5.0). A summary of the distribution of these taxa is shown in Table 6.1 and Figure 6.1 and Figure 6.2.

Table 6.1: Summary of stygal taxa recorded from within the Kens Bore and Cardo Bore East groundwater Impact areas, and their wider occurrence in Reference areas based on this survey.

Order	Taxa	Impact Sites	No. of Reference Collection Sites
Amphipoda	Melitidae sp. 1 (PBS) (nr *norcapensis*)	KB2-5b	2
	Nedsia sp. indet.	KB3-1, KBPZ1, KB1-1, KB3-3, KB3-4, KB2-5b, KB3-2a, CE1-4a	3
	Paramelitidae sp. indet.	KB2-5b, KB3-3	5
	Paramelitidae sp. 2 (DEC)	KB4-1a, KB4-3a, KBPZ1, KB3-8	7
Bathynellacea	Bathynellacea sp. indet.	KBRC052, KB4-2a	1
	Billibathynella sp. B1	KBRC132	1
	Hexabathynella sp.	KB3-1	-
	Notobathynella sp.	KB3-4	1
Isopoda	*Pilbarophreatoicus platyarthricus*	KBRC132	-
Cyclopoida	*Diacyclops humphreysi humphreysi*	KB3-1, KB3-2a, KB3-3, KB3-4, KB3-6, KB3-8, KB4-1a, KBPZ1, KBPZ2, KBPZ3, KBPZ6, KBPZ7, KBRC052, KBRC132	9
	Metacyclops pilbaricus	KB3-6	1
	Parastenocaris sp.	KB4-1a, KBPZ3	1
	Parastenocaris jane	KB3-2a	1
Podocopa	*Humphreyscandona ventosa*	KB3-1, KB3-2a, KB3-3	3
	Pilbaracandona rosa	KBPZ1	-
Acarina	*Guineaxonopsis* sp. S1 (PSS)	KBPZ1	-
	Oribatida sp. indet.	KBRC052	1
	Trombidioidea sp.	CBRC076	1
Haplotaxida	Enchytraeidae sp. indet.	KBRC052, CBRC076	-
	Enchytraeidae Pilbara sp.1	KBRC052	2
	Phreodrilidae sp. dissimilar ventral chaetae	KBRC052	2

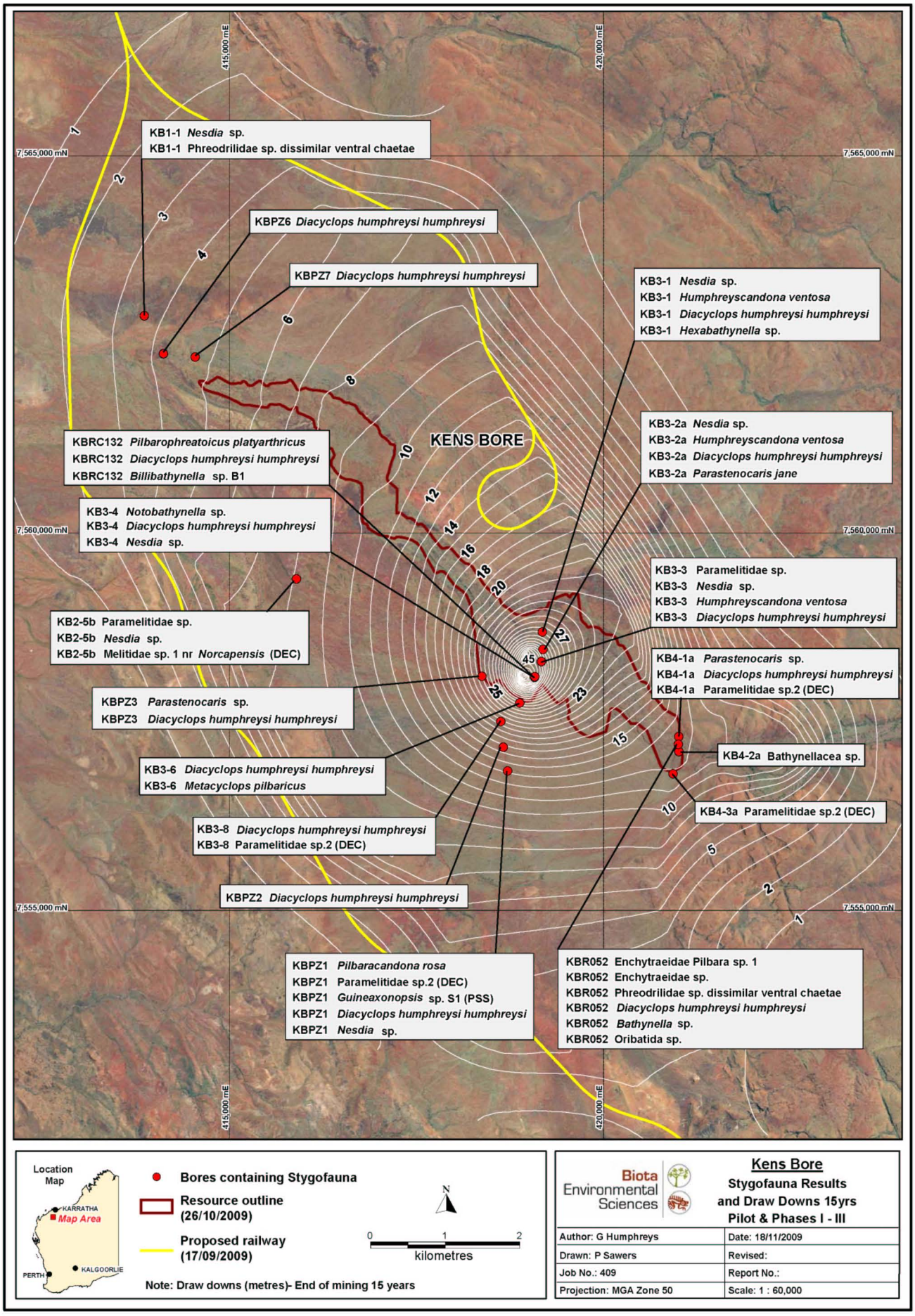

Figure 6.1: Distribution of stygal taxa collected from Kens Bore and predicted aquifer drawdown contours.

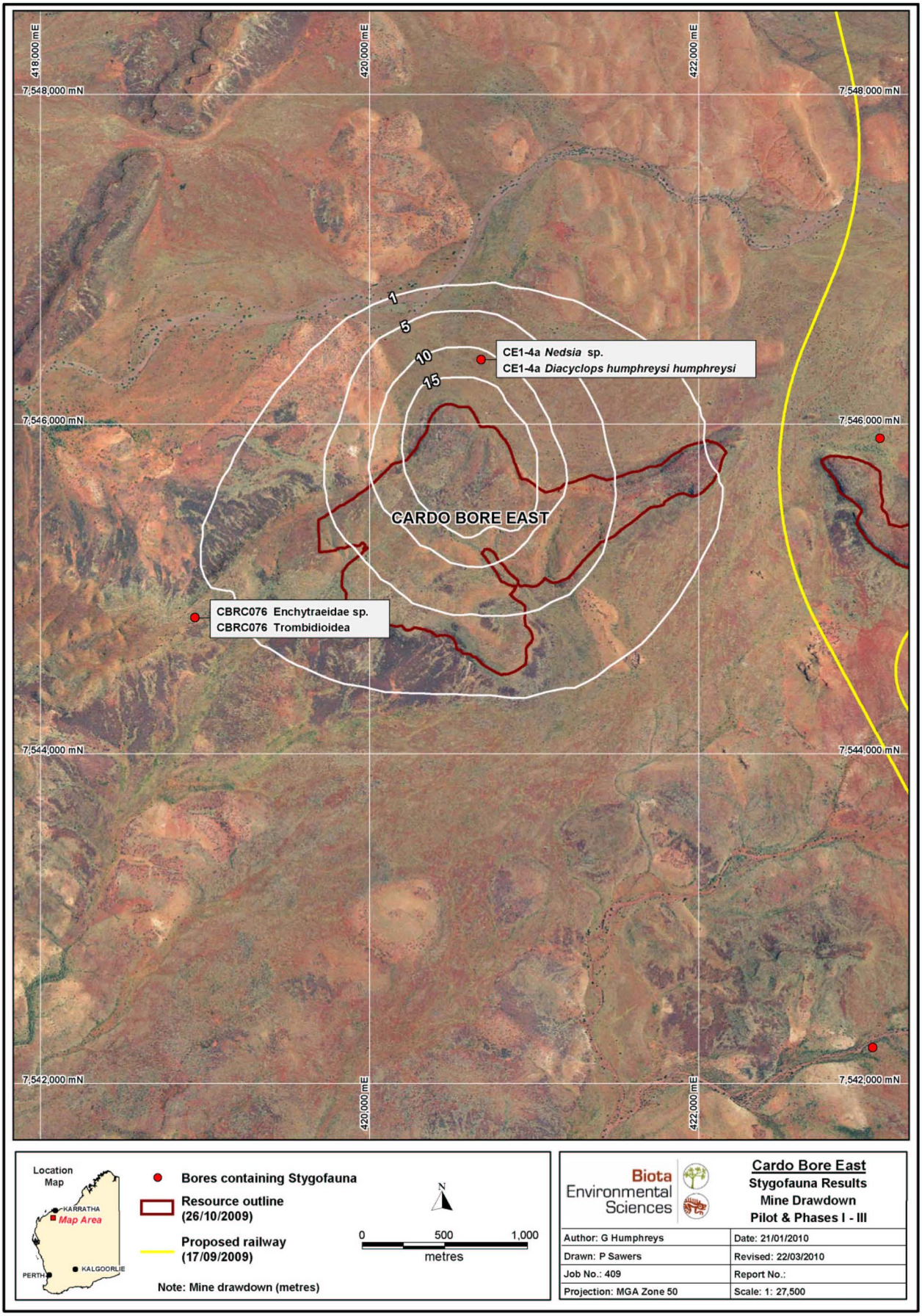

Figure 6.2: Distribution of stygal taxa collected from Cardo Bore East and predicted aquifer drawdown contours.

Based on the results of this survey, 19 of the 21 stygal taxa recorded from the project Impact area have been demonstrated to occur more widely in the project area (Table 6.1). Many of these have also been recorded elsewhere in the region during the previous impact assessment surveys

or during the DEC Pilbara Biological Survey (Section 5.0). Some of these taxa, particularly Paramelitidae sp. 2 (DEC), *Diacyclops humphreysi humphreysi* and *Humphreyscandona ventosa*, are clearly widespread (Table 6.1). Three of the remaining four taxa from Kens Bore, *Pilbarophreatoicus platyarthricus*, *Pilbaracandona rosa* and *Guineaxonopsis* sp. S1 (PBS), have also all been recorded more widely in the region (Section 5.0).

Only one of the Cardo Bore East Impact area species, Enchytraeidae sp., was not recorded from a Reference site in this study (Table 6.1). However, this record was from bore CBRC076 which is at the outer limit of the expected drawdown and the aquifer in this location will experience 0.5 m of change (Figure 6.2). This is well within normal seasonal variation for watertables in the region (Finlayson and McMahon 1988). This, combined with the low probability that a stygal oligochaete species would be confined to a small spatial extent (Biota 2009), suggest a low risk of any species' conservation status being affected by the dewatering of Cardo Bore East.

The only remaining Impact area only species left to be considered is the bathynellid crustacean *Hexabathynella* sp. from Kens Bore (bore KB3-1; Table 6.1; Figure 6.1). Considering that:

- 19 of the 20 species collected from the Kens Bore area have been demonstrated to occur more widely in the WPIOP project area or further afield;
- three other more widely-occurring stygal taxa were recorded from the same bore (KB3-1); and
- the overall distributional patterns from this study do not indicate any small-scale geographic barriers or hydrogeological features that could limit this taxon to the Kens Bore area;

it appears very unlikely that *Hexabathynella* sp. only occurs at Kens Bore. It is far more likely that this result is attributable to ecological sampling effects. The fact that only a single specimen was collected from KB3-1 is consistent with this, suggesting that it may be an infrequently collected species.

The outcome of this assessment therefore is that population level impacts on the taxa listed in Table 6.1 are likely to occur due to dewatering at Kens Bore and, to a lesser extent, at Cardo Bore East. However, the data suggest that these are not areas with any particular distributional restrictions in respect of stygal species or communities. Over 90% percent of the species collected have been shown to occur more widely, and it is likely that this is the case for all the species present. This may be a reflection of the general connectivity of regional alluvial systems off this western margin of the Hamersley Range. Given these findings, there appears to be a low risk that groundwater habitat loss at Cardo Bore East and Kens Bore would result in an overall change in conservation status for any of the stygal taxa occurring in the area.

6.2.2 Indirect Impacts

In addition to the primary impact from the WPIOP proposal of dewatering at Kens Bore and Cardo Bore East, other indirect or lower tier impacts could affect stygofauna occurring in the locality. These include:

- clearing and erosion run-off from surface operations, with the potential to create increased sediment loads in the aquifer and reduce habitat space in karstic or fracture strata above the watertable;
- changes to groundwater recharge or discharge areas due to sealing of surface areas, with increase in run-off and reduction in recharge;
- groundwater pollution (e.g. chemical pollutants spills, unlined landfills and direct discharge of waste or different quality water into streams or aquifers; Sket 1999); and/or
- salinisation of groundwater systems due to post-mining pit voids or other intrusion of saline water.

These lower level potential impacts should be able to be ameliorated through project design and/or with best practice environmental management procedures. This will be addressed in the PER to be prepared for the WPIOP project and related environmental management plans.

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Appendix 1

Raw Data (Pilot Phase – Phase III)

Taxonomy				Bores collected from (Number collected)	Total Collected	Comment
Phylum	**Class**	**Order**	**Taxon**			
Pilot Phase						
Crustacea	Malacostraca	Amphipoda	Bogidiellidae sp.	UCWB001 (1)	1	Partial specimen
			Paramelitidae sp. 2 (DEC)	UCWB001 (3), CW1 (1)	4	
		Bathynellacea	*Billibathynella* sp. B1	KBRC132 (1), UCWB001 (1)	2	
		Isopoda	Microcerberidae sp. indet.	UCWB001 (1)	1	
			Pilbarophreatoicus platyarthricus	KBRC132 (3)	3	
	Copepoda	Cyclopoidea	*Diacyclops humphreysi humphreysi*	KBRC132 (1)	1	
			Diacyclops humphreysi unispinosus	UCWB001 (2)	2	
		Harpacticoida	*Elaphoidella humphreysi*	UCWB001 (4)	4	
Phase I						
Crustacea	Malacostraca	Amphipoda	Paramelitidae sp. 2 (DEC)	KB4-1a (1), CWPZ3 (4), CW3-3 (3), CBWB002 (1), URWB002 (1)	10	
			Nedsia sp.	KB3-1 (2), CBWB002 (10), URWB002 (35),	47	
			Pilbarus nr. *millsi*	URWB002 (2)	2	
		Bathynellacea	*Bathynella* sp.	KBRC052 (10)	10	
			Notobathynella sp.	CW1 (3)	3	
		Isopoda	*Kagalana tonde*	URWB002 (1)	1	
	Copepoda	Cyclopoidea	Ameridae sp 1	CBWB002 (2), URWB002 (1)	3	Juvenile
			Diacyclops humphreysi humphreys	KB4-1a (13), KBRC052 (31), KB3-1 (5), CW1 (20), CBWB002 (90), URWB002 (2), KB3-6 (4)	165	
			Metacyclops pilbaricus	KB3-6 (1)	1	
			Orbuscyclops westaustraliensis	CWPZ3 (3)	3	Juvenile male specimen
		Harpacticoidea	*Parastenocaris* sp.	KB4-1a (1)	1	Female
			Parastenocaris jane	CWPZ3 (39)	39	
			Stygioridgewayia trispinosa	CBWB002 (8), URWB002 (80)	88	
	Ostracoda	Podocopa	*Humphreyscandona ventosa*	KB3-1 (7)	7	
			Humphreyscandona n.sp.	CBWB002 (80)	80	Very triangular shell, high dorsal arch, quite tapered dorsally, with strong ventral striations
Chelicerata	Arachnida	Hydracarina	Oribatida	KBRC052 (1), CBWB002 (3)	4	
Annelida	Clitellata	Oligochaeta	Enchytraeidae	KBRC052 (2), CBRC076 (1)	3	
			Phreodrilidae with dissimilar ventral chaetae	KBRC052 (1), CBWB002 (1), UCRC164 (1)	3	

Taxonomy				Bores collected from (Number collected)	Total Collected	Comment
Phylum	**Class**	**Order**	**Taxon**			
Phase II						
Crustacea	Malacostraca	Amphipoda	Melitidae sp. 1 (PBS) (nr *Norcapensis*)	URWB002 (3), UCWB001 (1)	4	
			Nedsia sp.	URWB002 (1), CBWB002 (3)	4	Juvenile
			Paramelitidae sp.	CW3-3 (2), CW1 (1), CWPZ4 (5)	8	Juvenile
			Paramelitidae sp. 2 (DEC)	CBWB002 (2), CWPZ4 (1)	3	
			Paramelitidae sp. 6 (DEC)	CW1 (1), CWPZ4 (4)	5	
		Bathynellidae	*Bathynella* sp.	KBRC052 (11), KB4-2a (7)	18	
			Billibathynella sp. B1	KBRC132 (3)	3	
		Isopoda	*Pygolabis* sp. B1	CBWB002 (1)	1	Unlike any of the described species. Female
	Copepoda	Cyclopoidea	*Diacyclops humphreysi humphreysi*	URWB002 (6), CW1 (54), CWPZ4 (32), KB3-1 (4), KBRC052 (52), KB3-6 (2)	140	
			Stygioridgewayia trispinosa	URWB002 (170)	170	
	Ostracoda	Podocopa	*Humphreyscandona ventosa*	URWB002 (11), CBWB002 (33)	44	
Mollusca	Gastropoda	Sorbeoconcha	Hydrobiidae sp.	URWB002 (1)	1	
Annelida	Oligochaeta	Haplotaxida	Enchytraeidae Pilbara sp. 1	URWB002 (2), KBRC052 (1)	3	
			Phreodrilidae with dissimilar ventral chaetae	UCRC164 (4)	4	Immature.
Phase III						
Crustacea	Malacostraca	Amphipoda	Melitidae sp.1 nr *Norcapensis* (DEC)	CBWB002 (1), KB2-5b (1)	2	
			Nedsia sp.	CWB004 (3), URWB002 (25), CE1-4a (2), KBPZ1 (1), RHN-3a (5), KB1-1 (12), KB3-3 (1), KB3-4 (1), KB2-5b (1), KB3-2a (5)	56	Juvenile
			Nedsia nr. *hurlberti* (DEC)	RHN-1 (5),	5	
			Paramelitidae sp.	CW1-3 (3), CWPZ4 (1), UCRC164 (1), KB3-3 (1), KB2-5b (1)	7	Juvenile
			Paramelitidae sp. 2 (DEC)	CWPZ4 (8), KB4-3a (1), KBPZ1 (2), KB3-8 (1), CWPZ3 (8)	20	
		Bathynellacea	*Bathynella* sp.	RHN-3a (2)	2	
			Hexabathynella sp.	KB3-1 (1)	1	male, very small animal
			Notobathynella sp.	KB3-4 (1)	1	
		Isopoda	*Kagalana tonde*	URWB002 (1)	1	

Taxonomy				Bores collected from (Number collected)	Total Collected	Comment
Phylum	**Class**	**Order**	**Taxon**			
	Copepoda	Cycloipodea	*Diacyclops humphreysi humphreysi*	CW1 (17), CWPZ4 (23), UCWB001 (3), UCRC164 (1), CE1-4a (2), KBRC052 (12), KBPZ1 (30), KBPZ2 (6), KBPZ7 (5), RHN-1 (30), RHN-3a (7), KBPZ6 (17), KB3-3 (30), KB3-4 (11), KB3-8 (30), KBPZ3 (5), KB3-2a (30), KBRC132 (2), CBWB002 (1)	255	
			Elaphoidella humphreysi	RHN-1 (5)	5	
			Halicyclops sp.	RHN3-3a (1)	1	
			Metacyclops pilbaricus	RHN-2 (1)	1	
			Orbuscyclops westaustraliensis	CWPZ3 (5)	5	
		Harpacticoidea	*Parastenocaris jane*	KB3-2a (3)	3	
			Parastenocaris sp.	CWPZ3 (1), KBPZ3 (2),	3	Juvenile
			Stygoridgewayia trispinosa	CBWB002 (2), URWB002 (30)	32	
	Ostracoda	Podocopa	*Areacandona ?undulata*	RHN3-3a (2)	2	shell lacks dorsal undulation
			Humphreyscandona ventosa	CBWB002 (100), KB3-3 (2), KB3-2a (50)	152	
			Pilbaracandona rosa	KBPZ1 (2)	2	
Chelicerata	Arachnida	Acarina	*Guineaxonopsis* sp. S1 (PSS)	KBPZ1 (1)	1	
			Trombidioidea sp.	CBRC076 (1)	1	
Annelida	Oligochaeta	Haplotaxida	Enchytraeidae Pilbara sp. 1 (PBS)	CBWB002 (2)	2	
			Phreodrilidae with dissimilar ventral chaetae	UCRC164 (11), KBRC052 (1), KB1-1 (2),	14	
				Total	**1,477**	