Rockwater
PROPRIETARY LIMITED

BROWSE LNG DEVELOPMENT

STYGOFAUNA SURVEY FINAL REPORT (2011/2012)

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REPORT FOR
WOODSIDE ENERGY LTD

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1 EXECUTIVE SUMMARY

Woodside, as operator of the proposed Browse LNG Development (the Development), plans to commercialise the Browse Joint Venture's three gas and condensate fields in the Browse Basin, 425 km north of Broome off the Kimberley coast. Gas and liquids from these fields will be extracted using offshore facilities then brought to an onshore LNG plant for processing at the Western Australian Government's Browse LNG Precinct (the Precinct), near James Price Point (JPP), about 60 kilometres north of Broome.

Water requirements for the construction phase of the Downstream (onshore) Development are to be obtained from a proposed borefield in the unconfined Broome aquifer, which is the uppermost aquifer over most of the Dampier Peninsula. The borefield will be located within the proposed Browse LNG Precinct (the Precinct).

As part of the environmental impact studies for the Development, a stygofauna sampling programme was undertaken to identify whether stygofauna is present in the Broome aquifer and to assess the stygofauna values of the Precinct. There are few published studies of stygofauna in the region and the stygofauna of the Kimberley of Western Australia is not well documented.

A desktop review and pilot study was initially undertaken to assess groundwater conditions and confirm the presence or absence of stygofauna at the Precinct (Rockwater 2011, Appendix I). The pilot study identified three potential stygofauna species in the Precinct and was extended into a full survey and regional sampling programme. A total of 68 impact samples and 50 reference samples were taken using pumping and netting techniques over eight sampling rounds. The sampling effort of the study exceeds the requirements of relevant EPA guidelines (EPA 2007).

A total of 684 stygal animals representing at least 18 stygofauna species of six Classes/Orders (Copepoda, Nematoda, Oligochaeta, Syncarida, Gastropoda, Ostracoda and Rotifera) were collected by the survey. Stygofauna diversity was lower at impact sites (9 species) than reference sites (15 species). The abundance of stygal animals was also lower at impact sites.

The stygofauna community of the Precinct comprises nine potential species; two harpacticoid copepods (Family Parastenocaridae), a syncarid (Parabathynellidae), three oligochaetes (Aeolosomatidae, Enchytraeidae and Tubificidae), rotifers, nematodes and an incomplete ostracod (Cyprididae).

Results of regional sampling undertaken as part of the survey indicate that five of the nine species/complexes recorded within the Precinct also occur more widely in the Broome aquifer on the Dampier Peninsula. The reference sites that yielded these species ranged from 46 km

south to 75 km north-east of the Precinct. In addition, two of the species have been recorded by previous studies outside of the Kimberley region.

Of the four species known only from the Precinct, three (*Dussartstenocaris* sp. B04, *Rheomorpha* sp. and *Kimberleybathynella* sp. B1) were collected from multiple sites. The fourth, an unidentified ostracod, was collected as a fragment and is the only singleton record (taxon recorded by collections from a single location) recorded by the survey.

The species of greatest interest from a conservation perspective is the parabathynellid syncarid *Kimberleybathynella* sp. B1. Syncarids typically have small distribution ranges and most are stygobitic. *Kimberleybathynella* sp. B1 is currently known over a range of about 3.5 km and is unlikely to have a wide distribution range; however, based on previous studies, the species can be expected to occur over a range several times larger than the Precinct.

The stygofauna survey for the Development represents the first documented stygofauna on the Dampier Peninsula. Sampling results suggest that groundwater conditions in the Broome aquifer are conducive to stygofauna. Suitable habitat for stygofauna has been shown to be widespread in the Broome aquifer and there are no geological barriers that would restrict dispersal of the stygofauna community. Therefore, in an unconfined, regionally widespread aquifer, it seems unlikely that any stygofauna species would be restricted to an area the size of the Browse LNG Precinct. The fact that four of nine species recorded in the Precinct have only been recorded within the impact area of the Development is likely to be a sampling artefact rather than an indication of restricted distributions. From an impact assessment perspective, implementation of the Development proposal is unlikely to affect the stygofauna values of the area.

2 INTRODUCTION

Woodside, as operator of the proposed Browse LNG Development (the Development), plans to commercialise the Browse Joint Venture's three gas and condensate fields in the Browse Basin, 425 km north of Broome off the Kimberley coast. Gas and liquids from these fields will be extracted using offshore facilities then brought to an onshore LNG plant for processing at the Western Australian Government's Browse LNG Precinct (the Precinct), near James Price Point (JPP), about 60 kilometres north of Broome.

A project water supply for the construction phase is planned to utilise local aquifers and so potential impacts to stygofauna communities that rely on groundwater need to be considered as part of the Environmental Impact Assessment (EIA) process. Construction operations may also present a range of potential environmental impacts to subterranean fauna, which will need to be assessed if such fauna are found to occur within the Precinct.

A stygofauna pilot study was commissioned by Woodside in January 2011. That study confirmed that stygofauna was present in the vicinity of the Development (Rockwater 2011). Consequently, further work was required to fully document the stygofauna community in line with relevant guidelines (EPA 2007).

The pilot study (Rockwater 2011, Appendix I) represents the first recorded stygofauna on the Dampier Peninsula. There are few published studies of subterranean fauna in other parts of the Kimberley of Western Australia. However, consideration of subterranean fauna is required for the Development in accordance with relevant EIA guidelines, which suggest that there is a high probability of rich subterranean fauna assemblages being present in limestone, sandstone and alluvium strata in the Kimberley of Western Australia (Environmental Protection Authority 2007).

The objectives of the second phase of the stygofauna study were to:

1. Increase the sampling effort in line with accepted industry guidelines for stygofauna sampling (EPA 2003, 2007).
2. Identify and sample available sites within the Precinct area that are most likely to provide suitable habitat for stygofauna.
3. Identify any conservation-significant species within aquifers with potential to be impacted by the implementation of the Development.
4. Assess the significance of any stygofauna communities within the Precinct area.
5. Identify potential impacts of the Development on the stygofauna values of the JPP coastal area.

3 PHYSICAL SETTING

3.1 TOPOGRAPHY AND DRAINAGE

The Development is located on the west coast of the Dampier Peninsula (Fig. 1), which is about 150 km wide from the Fitzroy River estuary to JPP. Ground elevations in the area gradually increase inland from the coast to the maximum of 247 m AHD about 35 km east of JPP. This location marks the highest point of a north-northeasterly trending drainage divide on the peninsula that separates westerly drainage to the Indian Ocean from easterly drainage to King Sound or southwesterly drainage towards the Roebuck Plains.

Drainage on the peninsula is ephemeral within shallow and generally sandy channels. The most prominent westerly drainage is Bobby Creek, which drains into Beagle Bay about 80 km northeast of JPP (Fig. 1).

Two small drainage lines, about 8 km and 20 km long (north and south of JPP respectively), trend west-northwestwards towards the coast (Rockwater 2010). The northern drainage flows directly to the ocean through a steep-sided gorge, while the southern drainage terminates at the landwards side of coastal sand dunes. During extreme wet season rainfall, water may pond at the base of the dunes before gradually flowing southwards to an outflow point closer to Quondong Point (SKM 2012). Several very small and localised drainage lines (less than one kilometre in length) are also present. Rainfall runoff flows generally to the coast north of JPP but terminates near the coast with water dissipating in low lying areas and in sand dunes south of JPP.

3.2 CLIMATE

The climate in the Broome area is hot, semi-arid, with mean maximum temperatures ranging from 29°C in June/July to 34°C in December, March and April based on data for Broome airport, the nearest Bureau of Meteorology (BoM) climate station. Summer temperatures are slightly higher inland from the coast.

Monsoonal rainfall predominates in the “wet season” from December to March when, on average, 85 per cent of the annual rainfall at Broome (average 602 mm) is received (Table 1). The rainfall is associated with thunderstorms and occasional tropical cyclones; it shows considerable annual variation. The “dry season” produces very low rainfall averaging between 1 and 27 mm per month.

Average annual rainfall varies considerably over the Dampier Peninsula region, with values of 622 mm for Derby, 896 mm for Country Downs Station and 752 mm for Beagle Bay. Some of the differences in these values are likely to be associated with differing lengths of records for the sites. A weather station was established at JPP in November 2009 and rainfall data for December 2009 to November 2010 are provided in Table 2.

Table 1: Average rainfall at Broome Airport

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Ann
Average Rainfall (mm)	178.5	179.1	100.8	26.7	26.4	17.8	7.3	1.7	1.4	1.4	8.9	56.0	602.1

(BoM data; Station No. 3003; Years 1939-2012)

Table 2: Rainfall at James Price Point meteorological station, December 2009 to November 2010

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec*	Ann
Rainfall (mm)	144.6	12.2	0	13.4	50.8	0	150.4	17.4	2.4	1.2	22.4	206.6	621.4

*2009 data

Comparisons of rainfall and evapotranspiration data by Rockwater (2010) indicate that the average rainfall exceeds average potential evapotranspiration only in February and that average annual potential evaporation is 2.7 times greater than the average annual rainfall.

4 HYDROGEOLOGICAL SETTING

The hydrogeology of the Development has been described in previous reports (Rockwater 2009, 2010; Department of State Development 2010). An extract from Department of State Development (2010) is provided below, with a focus on the Broome Sandstone (Broome aquifer) as most bores sampled by the stygofauna study are screened (or assumed to be screened) within this aquifer:

> *The Browse LNG Precinct lies within the Fitzroy Trough, a structural subdivision of the Canning Basin. The precinct area comprises sedimentary strata which are characterised by two east-west trending structures: the Baskerville anticline to the north, and the Barlee anticline to the south.*
>
> *The stratigraphy of the Fitzroy Trough is summarised as follows (in depth-order from the surface):*
>
> - *Superficial deposits (including Shoonta Hill Sand and Mowanjum Sand) 5 to 20 m thick; Quaternary age;*
> - *Broome Sandstone, up to 280 m thick; early Cretaceous age;*
> - *Jarlemai Siltstone, 260 m thick; late-Jurassic to early Cretaceous age;*
> - *Alexander Formation, 20 m thick; late-Jurassic age;*
> - *Wallal Sandstone, 360 m thick; early- to late-Jurassic age;*
> - *Noonkanbah Formation, 200 m thick; early-Permian age;*
> - *Poole Sandstone, 50 m thick; early-Permian age; and*
> - *Grant Group, 200 m thick; early-Permian age.*

The three formations with the most potential to supply large quantities of groundwater are the Broome Sandstone, the Wallal Sandstone and the Grant Group. For the purposes of this investigation, the Broome Sandstone and Superficial deposits, where saturated, are of primary concern for stygofauna.

4.1 BROOME AQUIFER

The Broome Sandstone contains an unconfined aquifer, the Broome aquifer, which is the uppermost aquifer over most of the region, except for a lobe about 12 km wide on the crest of the Baskerville anticline where the base of the formation is above the water table. Groundwater in the overlying Mowanjum Sand (Pindan) is believed to be in hydraulic connection with the Broome aquifer and is included in the Broome aquifer (J. Moncrieff, Rockwater, *pers comm.*, 2011). The Broome aquifer is interpreted to have a saturated thickness of 100 to 150 m in the vicinity of the Precinct.

The Broome aquifer is the most utilised aquifer on the Dampier Peninsula, being the source of the Broome town water supply, as well as providing water for a range of other uses including agro-forestry, community water supply, petroleum exploration and road infrastructure maintenance by Main Roads (Laws 1991 and DoW 2009). The interpreted extent of the Broome aquifer is shown in Figure 3.

The aquifer is a multi-layered, unconfined aquifer system typically comprised of unconsolidated coarse-grained sandstone and conglomerate with intervening minor lenses of siltstone and claystone, and thin coal seams (Laws 1991). The relatively coarser grained materials produce higher yields and better quality water than the lower-permeability siltstone, claystone and coal seams. Despite the aquifer being composed of several water-bearing zones, there is little vertical difference in groundwater elevations between these water-bearing zones (Laws 1991).

Groundwater levels in the Broome aquifer are about 0 to 2 m AHD near the coast, reflecting an unconfined aquifer with groundwater flow to the sea (Rockwater 2009). Inland, based on sparse data except near Broome, the groundwater levels form a mound in the centre of the Dampier Peninsula where the elevation of the water table is up to 59 m AHD. Groundwater at shallow depths, where it potentially supports phreatophytic vegetation, may be present in the Broome aquifer between the coast and the 10 m AHD topographic contour. It is possible that the Broome aquifer also supports mound springs and perched aquifers in coastal and inland areas of the Dampier Peninsula. Recent hydrogeological data provides no evidence of a perching layer beneath the coastal dune system in the JPP coastal area. However, mounding of groundwater levels beneath the dunes is inferred to occur (SKM 2011).

Groundwater salinity in the Broome aquifer ranges from 250 to 500 mg/L (milligrams per litre) TDS (total dissolved solids) inland from the coast. A wedge of salt water occupies the lower part of the aquifer near the coast. The toe of the saltwater wedge at the Precinct is

estimated to lie about 6 km inland, based on data extrapolated from near Broome (Rockwater 2009).

Groundwater recharge to the Broome aquifer is by:

- direct infiltration of rainfall where the Broome Sandstone outcrops;
- infiltration through or leakage from aquifers in the overlying sediments, e.g. the Shoonta Hill Sand (coastal dune sand); and
- infiltration of surface water from wetlands and drainage systems.

Groundwater recharge is expected to vary throughout the peninsula according to rainfall intensity, depth to water table, location of drainage systems and the local permeability of the aquifer. It is estimated to be 4 to 5% of annual rainfall (Laws 1991).

Regional groundwater flow in the Broome aquifer is influenced by topography and the location of groundwater recharge and discharge areas. At JPP, the direction of regional groundwater flow is interpreted to be in a westerly direction towards the coast. Horizontal hydraulic gradients are reported to be relatively flat at around 4×10^{-4} near the coast (Laws 1991).

Groundwater discharge from the peninsula area typically occurs to the ocean above a saline interface near the coast. Some discharge also occurs via seepage faces along the coast and through evapotranspiration.

4.2 WALLAL AQUIFER

The Wallal aquifer comprises the Wallal Sandstone and the Alexander Formation. It is generally confined or semi-confined above by the Jarlemai Siltstone, which separates it from the Broome aquifer, and is underlain by the sediments of the Liveringa Group, Noonkanbah Formation, Poole Sandstone or Grant Group beneath the JPP area (Rockwater 2009). Here the aquifer is estimated to occur about 400 m below the surface and be about 200 m thick. The Wallal aquifer contains large quantities of brackish to saline groundwater.

No sampling was undertaken from the Wallal aquifer for the stygofauna pilot study and, consequently, it is not discussed further in this report.

5 TERMINOLOGY AND DEFINITIONS

5.1 SUBTERRANEAN FAUNA

Subterranean organisms comprise two main groups; troglofauna and stygofauna. Troglofauna inhabit air chambers in underground cavities and voids above the water table, whereas stygofauna dwell in groundwater. This study considers only stygofauna.

Stygofauna are groundwater-dependent interstitial fauna, largely consisting of crustaceans but also including worms, snails, insects, several other invertebrate groups and blind fish. Stygofauna occur in a range of rock types including, but not restricted to, karstic carbonate rocks, fractured rock aquifers and porous unconsolidated sediments, e.g. alluvium (Eberhard 2007). Stygofauna have been found in most regions of Western Australia, with hotspots in the Pilbara but also recorded in the Goldfields, Kimberley, Murchison and the Yilgarn area (Biota 2007).

Stygofauna are classified into three ecological-evolutionary categories:

(a) Animals which have the ability to spend part of their life cycles in subterranean aquatic habitats '*stygoxenes*'.
(b) Animals which have the capacity to spend their entire life cycle in either underground or surface habitats, but are not confined to this habitat '*stygophiles*'.
(c) Animals which have adapted and restricted exclusively to aquatic subterranean environments, '*stygobites*'.

5.2 OTHER TERMS

Other terms used within this report include:

Impact Area – the area of potential disturbance. For stygofauna, the impact zone includes the areas affected by drawdown of groundwater levels or changes in water quality.
Impact Site – a sample site within the impact area.
Reference Site – a regional sample site outside the defined impact area.

6 DESKTOP STUDY

A desktop study was conducted as part of the Stygofauna Pilot Study (Appendix I). A summary of relevant literature, previous stygofauna studies and data relevant to the stygofauna of the Kimberley region is provided in that report. Site-specific geological data collected during monitoring bore installation and geotechnical investigations at the Precinct were also reviewed as part of the pilot study. Further interpretation of lithological data was not undertaken for site selection purposes as all of the 24 groundwater monitoring bores drilled in the Precinct in 2011 were sampled in Phase II.

7 SAMPLING METHODOLOGY

7.1 GENERAL

The stygofauna sampling methodology outlined herein has been prepared in accordance with the principles outlined in relevant Environmental Protection Authority (EPA) guidance statements (EPA 2003, EPA 2007). The investigation has followed the requirements of the EPA for a full-scale stygofauna study. Samples were collected from aquifers and strata that may be suitable for stygofauna, from an appropriate spread of sampling sites across the Precinct area. In addition, a range of the reference sites sampled in Phase I were re-sampled to provide additional regional contextual information. The sampling effort of the survey exceeds that recommended by the EPA for a full stygofauna study.

Stygofauna sampling for the Development was undertaken in accordance with Regulation 17 Permit No. SF 7676 (Licence to Take Fauna for Scientific Purposes), issued by the Department of Environment and Conservation (DEC).

7.2 STYGOFAUNA SAMPLING

Sampling for Phase II of the stygofauna survey was undertaken in November 2011 (Round 6), April 2012 (Round 7) and June 2012 (Round 8). A total of 68 samples were taken in Phase II using a combination of netting and pumping (Table 3). Where a bore was sampled using both methods, the samples were preserved separately, but the results are combined and included as one sample.

Table 3: Phase II stygofauna sampling (number of samples) for the Browse LNG Development.

	Round 6		Round 7		Round 8		Total Samples*
	Net	Pump	Net	Pump	Net	Pump	
Impact	0	9[1]	26	1	26*	0	**61**
Reference	0	0	5	2	1	1	**6**

*Total number of samples calculated based on combined methods for sampling at each site (i.e. net only sample or a net and pump sample during a single visit being considered a single sample).
[1] Eight of the Round 6 bores were <3 months old

Sixty one samples were taken from 28 bores in the Precinct area during Phase II. Most bores sampled were at least six months old; the exceptions being seven monitoring bores (AE-10, P-17, P-21, P-29, U-10, U-20 and U-31) and one production bore (AP-10) during Round 6.

Following an extensive regional sampling programme in Phase I, only six additional reference samples were taken in Phase II.

At each bore the following measurements and procedures were undertaken:

- prior to biological sampling, measurements were taken of water level and physicochemical water quality parameters (including salinity, conductivity, pH, dissolved oxygen and temperature);
- recordings of total depth, collar heights, diameters and other bore details, where available;
- collection of biological samples using stygofauna sampling nets; and
- preservation of biological samples in 100 % ethanol.

Sampling nets with a diameter of approximately two-thirds of the bore diameter and filter mesh sizes 50 µm and 150 µm were used to sample all bores. Each net consists of a steel collar that supports a filter mesh, tapering to a hollow brass weight. A clear polycarbonate vial with bottom removed and replaced with 50 µm filter mesh was screwed into the brass weight to collect samples filtered by the sampling nets. Nets were suspended by a carabineer and three trace wires attached to the steel collar.

Bores were sampled for stygofauna using the customised sampling nets by lowering the net into the bore using a reel of fishing braid until it reached the bottom of the bore where it was agitated to disturb sediment and any animals that may be present. The biological samples were taken using three net-hauls of the 50 µm stygofauna sampling net and three net-hauls of the 150µm sampling net. The individual samples from each bore were combined and preserved.

A Geotech geosub sampling pump with a 12V power supply was used to obtain pumped samples from several bores. With the exception of the bores sampled in Round 6, those that were pumped were generally netted during the same sampling round. Pumped samples were taken after net samples.

At each site, bore details were measured and the bore volume beneath the water level (i.e. saturated thickness) was calculated. For impact sites, at least three bore volumes were generally filtered for each pumped sample. Where time constraints prevented this (larger volume production bores sampled with a small capacity submersible pump), a sample of 300 L was filtered. For the 50 mm diameter monitoring bores sampled in the Precinct during Round 6, up to 14 bore volumes were pumped and filtered. These bores were being sampled in accordance with water sampling procedures for laboratory analysis as part of a separate work programme and the entire pumped sample was filtered for stygofauna.

Samples were stored in 120 mL polycarbonate vials and preserved using 100% (absolute) ethanol. To avoid contamination, the sampling nets were thoroughly washed with a decontaminant solution and then rinsed with distilled water between sites. All samples were forwarded to specialist stygofauna biologists at the end of each sampling round for sorting and identification.

7.3 WATER QUALITY

Prior to stygofauna sampling at each bore, water quality was measured using a multi-parameter probe (Troll 9500 Pro and Rugged Reader), either *in situ* with the probe connected to a 'down-hole' cable or from a pumped or bailed sample of water from the bore. The probe was lowered down the bore casing to approximately one metre below the water level. Water quality parameter readings were recorded immediately after they had stabilised. Where a pumped water sample was filtered for stygofauna, the water quality readings were generally taken from a pumped water sample collected towards the end of the pumping period at each site.

During early-November 2011, water sampling was undertaken at eight newly-constructed monitoring bores in the BLNG Precinct as part of a separate investigation. Water samples were pumped, preserved and submitted for various analyses and field water quality was measured. The pumped samples were also filtered for stygofauna.

7.4 DATA ANALYSIS & SAMPLING EFFICIENCY

Summary statistics were compiled for the stygofauna sampling results, to compare yields between impact and reference sites. Comparison of data with other Kimberley studies was not possible due to the paucity of stygofauna data from the Kimberley region.

The survey sampling efficiency was assessed using seven common diversity estimators through the EstimateS v8.2.0 software package (Colwell 2009). A species accumulation curve and species diversity estimation were generated for sites within the Precinct area (impact sites) using the default settings, except the following;

- Use of Classic formulas for Chao 1 and Chao 2 for diversity estimators;
- The coverage estimators (ACE, ICE and shared species) were reduced from the default 10 to 5.
- The sample order runs were increased from the default of 50 repetitions to 10,000 runs to smooth the accumulation curve;

8 RESULTS

8.1 PHASE I OVERVIEW

During Phase I of the stygofauna sampling programme, seven impact samples and 44 reference samples were collected to determine whether the Precinct had significant stygofauna values. Sampling of bores in the Precinct and other regional sites on the Dampier Peninsula confirmed that the Broome aquifer provides suitable habitat for stygofauna.

Thirteen potential stygofauna species were collected from six Classes/Orders (Copepoda, Gastropoda, Oligochaeta, Syncarida, Ostracoda and Rotifera). Crustacean orders (Copepoda, Syncarida and Ostracoda) accounted for 63% of all animals recorded, followed by Oligochaeta (Tubificida) with 34%. Syncarids and copepods were the most diverse groups.

One of two impact sites and eleven of 34 reference sites yielded stygofauna. Three species were found within the impact area of the Development, including a copepod (nr. *Parastenocaris* sp. B14), a tubificid worm (Tubificidae group B complex) and a syncarid (*Kimberleybathynella* sp. B1).

Regional stygofauna sampling undertaken as part of the Phase I survey demonstrated that two of three species recorded within the Precinct area also occurred at reference sites. The presence of stygofauna at multiple sites indicated distribution ranges for these species of 46 km (nr *Parastenocaris* sp. B14) to 75 km (Tubificidae group B complex) on the Dampier Peninsula in a regionally widespread aquifer. The Phase I survey report is included as Appendix I.

8.2 PHASE II RESULTS

A total of 67 stygofauna samples were taken in Phase II; 61 from impact sites and six from reference sites. Impact sites included two production bores and 24 monitoring bores installed at the Precinct in 2011 for the dual purposes of groundwater monitoring and stygofauna sampling (Fig. 2). In addition, two bores sampled previously in Phase I were sampled. Reference sites included one bore near Barred Creek on Manari Rd (Bore X1) and the regional bores 4B-10, HCL5A, HCL6 and HCL6A on the Cape Leveque road. The locations of stygofauna sampling sites across the survey area are shown in Figure 3. The sampling effort across three sampling rounds (Rounds 6-8) in Phase II is presented in Appendix II. Site details and available bore construction details are included as Appendix III.

Results for Phase II stygofauna sampling are presented in Table 4. A total of 519 individuals were collected, representing at least nine stygal species of six Classes/Orders (Copepoda, Nematoda, Oligochaeta, Syncarida, Ostracoda and Rotifera). A shift in the composition of the stygofauna community (from Phase I) resulted from the presence of nematodes and oligochaetes in high numbers (63% and 26% of all animals respectively). Crustacean orders

accounted for 8% of all animals recorded (Copepoda (4%), Syncarida (3%) and Ostracoda (<1%)) followed by Rotifera (3%).

Nineteen of 28 impact sites (68%) and three of five reference sites (60%) yielded stygofauna (Figs 2 and 3 respectively). Nine potential species were found within the impact area of the Development (Fig. 2), including four species recorded in Phase I (*Parastenocaris* sp. B14, Tubificidae group B complex, *Kimberleybathynella* sp. B1 and Bdelloidea sp. 2:2).

The majority of specimens collected in Phase II were nematodes and oligochaetes (89%). Stygal and aquatic nematodes were recorded from 13 impact sites and three reference sites. Nematodes, although listed in the EPA guidelines, are not required to be identified to lower taxonomic levels due to limitations in their taxonomic framework.

Oligochaetes were collected from seven Precinct sites and one reference site in Phase II. The tubificid worm Tubificidae group B complex, first recorded at Bore X near JPP and at bore TTM08 near Beagle Bay, was recorded at five additional impact sites in the Precinct during Phase II. At least one other tubificid worm, *Enchytraeus* Pilbara sp. 2 (PSS), and another unidentified oligochaete, Oligochaeta sp. (indet.), were recorded. Identification of the latter species was not possible and specimens were forwarded to Dr Adrian Pinder (DEC) for further taxonomic work. A determination on the specimens has not yet been received from Dr Pinder. Enchytraeidae Pilbara sp. 2 (PSS) was recorded at bore O-10 in the Precinct and bore X1, approximately 15 km to the south. This is a cosmopolitan species and is found throughout Western Australia from the Yilgarn to the Pilbara, and more recently, the Kimberley region.

The syncarid *Kimberleybathynella* sp. B1 (Plate 1) was recorded from two sites (Bore X and U-31) in Phase II, indicating a range of at least 3.6 km for the species.

Harpacticoid copepods were recorded from six impact sites. *Parastenocaris* sp. B14 was recorded at Bore X and two other sites. Another harpacticoid copepod, *Dussartstenocaris* sp. B04 (Plate 2), was recorded from two sites in the Precinct. Incomplete Parastenocaridae collections were made from two additional sites. These collections are likely to represent either *Parastenocaris* sp. B14 or *Dussartstenocaris* sp. B04 given their proximity to sites that yielded these taxa (Figure 2). Copepods were not recorded at reference sites in Phase II.

A pumped sample from Bore X in Phase II contained damaged ostracod specimens (valves only). As the specimens were incomplete, identification beyond ordinal level was not possible. Juvenile and damaged ostracods of the genus *Cyprideis*, which are surface aquatic ostracods, were also recorded from this bore.

Table 4: Results of Phase II Stygofauna Sampling (Rounds 6-8).

Order	Family	Taxon	N	Impact (Number of animals in parenthesis)	Reference
COPEPODA					
Harpacticoida	Parastenocarididae	-	1	AP-32 (1)	-
Harpacticoida	Parastenocarididae	*Dussartstenocaris* sp. B04	9	AP-20 (1), F-14 (8)	-
Harpacticoida	Parastenocarididae	*Parastenocaris* sp.	1	AP-12 (1)	-
Harpacticoida	Parastenocarididae	*Parastenocaris* sp. B14 [I]	12	Bore X (5), AP-36 (2), F-14 (5)	-
SYNCARIDA					
Bathynellacea	Parabathynellidae	*Kimberleybathynella* sp. B1 [1]	16	Bore X (15), U-31 (1)	-
OSTRACODA					
-	-	Ostracoda unident. sp.	2	Bore X (2)	
NEMATODA*					
-	-	Nematoda sp.	327	Bore X (2, 1), AD-16 (1), AP-20 (1, 5), AP-28 (2), AP-32 (2), F-14 (3, 20), I-16 (20, 10), N-4 (1, 1), P-17 (10, 5), P-21 (1), P-29 (4),U-10 (1), U-20 (1)	4B-10 (100), Bore X1 (5, 47, 3), HCL5A (60, 21)
OLIGOCHAETA					
Aphanonura	Aeolosomatidae	*Rheomorpha* sp.	69	AP-20 (4), AP-36 (50), F-14 (2), I-16 (2), O-10 (6), U-10 (4), U-31 (1)	-
Tubificida	Enchytraeidae	Enchytraeus Pilbara sp. 2 (PSS)	33	O-10 (8)	Bore X1 (25)
Haplotaxida	Tubificidae	Tubificidae *cf* spp. WA12/14/22	54	AD-20 (3), AP-20 (6), F-14 (10), I-16 (10), P-21 (5)	Bore X1 (20)
ROTIFERA*					
Bdelloidea	-	Bdelloidea sp. 2:2 [1]	14	AD-20 (3), N-4 (1), V-25 (2)	Bore X1 (8)
		TOTAL	**538**	**249**	**289**

*Denotes taxa not expected to be identified to species level (EPA, 2007)
[1] Denotes taxa also recorded in Phase I

The rotifer Bdelloidea sp. 2:2 was collected from three impact sites and the reference Bore X1 approximately 15 km to the south of the Precinct in Phase II. Bdelloidea are a group of rotifers found commonly in fresh water and the species recorded in the Precinct is not restricted to the groundwater environment or to the Precinct area.

Pumped samples were taken from nine impact sites and three reference sites (Bore X, Bore X1 and HCL5A) during Phase II.

The physico-chemical groundwater data collected at each site sampled for stygofauna are presented in Appendix III. Most bores recorded EC values of 200-880 µS/cm (approximately 130-570 mg/L TDS), indicating that the groundwater is fresh. The exception were bores X1 and AP-32, which had electrical conductivity (EC) values in the range 1,500 to 3,400 µS/cm suggesting that the groundwater at those sites is brackish. Groundwater temperature averaged 31.4^{o}C across the entire study area, ranging from 30.0-32.6^{o}C. Dissolved oxygen readings ranged from 0.3-9.1 mg/L (about 4-75% saturation), with an average of 2.9 mg/L. Field pH values ranged from 4.8 to 8.8 across all sites.

Water quality data for sites that yielded stygofauna in Phase II are presented in Table 5. pH values were generally slightly acidic (4.85) to neutral (7.96) (Phase I range was 5.35-8.47 for Dampier Peninsula bores). Dissolved oxygen concentrations ranged from 0.52-4.01 mg/L. EC readings ranged from 120-3,403 µS/cm. Samples taken for laboratory analysis as part of a parallel study indicate a salinity range of 192-937 mg/L (TDS) and a near neutral pH for all monitoring bores in the Precinct (Rockwater 2012).

Table 5: Water quality parameters for bores that that yielded stygofauna

Site id	Water Quality								Taxonomic Group(s) Recorded
	Method	Depth (m)[#]	Temperature (degrees)	EC (µS/cm)	pH	Turbidity FNU	ORP (mV)	DO (mg/L)	
4B-10	Bailed	-2	31.27	832.2	7.27	210	-	2.15	Nematoda
AD-16	Down-Hole	-0.9	31.70	416.5	5.5	3.5	214	0.956	Nematoda
AD-20	Down-Hole	-1	31.94	417.1	6.53	887	-	0.52	Oligochaeta, Rotifera
AP-12	Down-Hole	-1	31.96	196.6	4.85	279.2	-	3.79	Copepoda.
AP-20	Down-Hole	-1	31.88	320.7	5.51	14.9	-	1.55	Copepoda, Nematoda, Oligochaeta
AP-28	Down-Hole	-0.9	31.62	555.1	5.61	7.0	211	3.877	Nematoda
AP-32	Down-Hole	-1.1	31.67	3403	6.04	759	191	3.601	Copepoda, Nematoda
AP-36	Down-Hole	-0.9	31.46	832.6	6.24	385.6	188	3.764	Copepoda, Oligochaeta
Bore X	Down-Hole	-1	30.65	655	6.05	110.3	-	3.15	Copepoda, Ostracoda, Syncarida,
Bore X1	Down-Hole	-1	31.35	1509	6.16	-	-	0.97	Nematoda, Oligochaeta, Rotifera
F-14	Down-Hole	-1	31.14	172.9	5.55	88.9	-	1.01	Copepoda, Nematoda, Oligochaeta
HCL5A	Bailed	-2	32.63	874.9	6.81	48.3	-	2.36	Nematoda
I-16	Down-Hole	-1	31.51	294.6	5.3	-	-	2.66	Nematoda, Oligochaeta
N-4	Down-Hole	-1	31.65	642.2	7.96	260	-	0.68	Nematoda, Rotifera
O-10	Down-Hole	-1	31.65	282.2	5.60	292.5	-	4.01	Oligochaeta
P-17	Down-Hole	-1	31.26	318	5.86	107.8	-	3.13	Nematoda
P-21	Down-	-1	31.96	120.1	5.06	326.8	-	2.3	Nematoda,

Site id	Water Quality								Taxonomic Group(s) Recorded
	Method	Depth (m)[#]	Temperature (degrees)	EC (µS/cm)	pH	Turbidity FNU	ORP (mV)	DO (mg/L)	
	Hole								Oligochaeta
P-29	Down-Hole	-0.9	31.13	828.0	6.64	18.7	209	3.027	Nematoda
U-10	Down-Hole	-1	31.78	476.7	5.80	8.5	-	1.63	Nematoda, Oligochaeta
U-20	Down-Hole	-1	31.7	765.4	5.62	111.9	-	2.15	Nematoda
U-31	Down-Hole	-0.9	31.41	670.2	6.66	533	141	2.055	Syncarida, Oligochaeta
V-25	Down-Hole	-0.8	30.98	593.5	5.82	5.6	182	2.702	Rotifera

[#] Depth below water level when readings are taken

8.3 COMPLETE RESULTS (PHASES I & II)

The stygofauna sampling programme for the Development comprised of 68 samples from 28 impact sites and 50 samples from 34 reference sites. The sampling effort exceeds the requirements of relevant EPA guidelines (EPA 2007) and provides a suitable dataset against which to assess the stygofauna values of the Precinct.

Overall, 52% of sites sampled contained stygofauna; 19 of 28 impact sites (68%) and 13 of 34 reference sites (38%). All impact sites were sampled on at least two sampling rounds whereas 74% of reference sites were sampled only once. Thirty of 68 impact samples (44%) and 18 of 50 reference samples (36%) yielded stygofauna.

Eighteen stygofauna species in total were collected by the survey, although only nine occurred within the impact area of the Precinct. Stygofauna diversity was lower at impact sites, with nine species compared to 15 from reference sites (Table 6). The capture abundance of stygal animals at sites in the Precinct was also lower; 0.13 animals per sample compared with 0.3 for reference sites.

Table 6: Summary statistics for stygofauna sampling at the Browse LNG Development

	Number of Samples			Total Specimens	Specimens per Sample ($\bar{x}$)	Total Species	Species per Sample ($\bar{x}$)
	Phase 1	Phase 2	Total				
JPP Precinct	7	61	68	283	4.16	9	0.13
Reference	44	6	50	401	8.02	15	0.30

The higher abundance and diversity of stygofauna at reference sites may be explained by the wider range of hydrogeological conditions encountered over a larger spatial extent of sampling sites within the Broome aquifer. Reference sites were taken over an area of 260 km (north-south) by about 90 km (east-west) (Figure 3).

A species accumulation curve (Fig 4) has been generated for samples taken within the Precinct using EstimateS (Colwell 2009). This shows that the rate of new species collected begins to plateau at approximately 20 samples. The observed species richness is within 75-90.5% of the predicted species richness for seven common species richness estimators (Appendix IV) which predict that between 9.9 and 12 species will occur in the Precinct area.

During Phase I, the stygofauna community of the Precinct was dominated by Crustacean orders (Copepoda and Syncarida). These groups were also present in higher numbers in Phase II due to the greater sampling effort; however, high numbers of Oligochaeta and Nematoda in the impact samples altered the composition of the stygofauna community.

The southern-most group of reference sites at Nita Downs Station, 150 km south of Broome yielded five stygofauna species from 15 samples (Fig. 3). The composition of the stygofauna community was similar to the Phase I results at the Precinct, and included three species closely related to those from the Precinct, *Kimberleybathynella* sp. B3, *Kimberleybathynella* sp. B4 and *Parastenocaris* sp.

Stygofauna recorded by the survey (Phases I and II) is presented in Table 7. Of the nine species/complexes recorded in the Precinct, five have been shown to occur at reference sites on the Dampier Peninsula. Two of these, Tubificidae *cf. spp.* WA12/14/22 and *Enchytraeus* Pilbara sp. 2 (PSS), are also known to occur outside the Kimberley region from previous studies (e.g. PBS *in prep.*, Bennelongia 2009).

Table 7: Stygofauna Results for Phase I & II Sampling (Rounds 1-8)

Order	Family	Taxon	n	Impact (Number of animals in parenthesis)[1]	Reference
COPEPODA					
Harpacticoida	Canthocamptidae	nr *Canthocamptus* sp. B1	3	-	Munro Bore (3)
Harpacticoida	Cyclopidae	*Mesocyclops brooksi*	1	-	Mt Phire Bore (1)
Harpacticoida	Parastenocarididae	-	1	AP-32 (1)	-
Harpacticoida	Parastenocarididae	*Dussartstenocaris* sp. B04	9	AP-20 (1), F-14 (8)	-
Harpacticoida	Parastenocarididae	*Parastenocaris* sp.	12	AP-12 (1)	13/85 (5), Schultz Bore (6)
Harpacticoida	Parastenocarididae	*Parastenocaris* sp. B14	38	Bore X (6), Bore X (5), AP-36 (2), F-14 (5)	14/85 (20)
Harpacticoida	Parastenocarididae	*Parastenocaris* sp. B15	1	-	Pauls Bore (1)
NEMATODA*					
-	-	Nematoda sp.	327	Bore X (2, 1), AD-16 (1), AP-20 (1, 5), AP-28 (2), AP-32 (2), F-14 (3, 20), I-16 (20, 10), N-4 (1, 1), P-17 (10, 5), P-21 (1), P-29 (4), U-10 (1), U-20 (1)	4B-10 (100), Bore X1 (5, 47, 3), HCL5A (60, 21)
SYNCARIDA					
Bathynellacea	Parabathynellidae	*Kimberleybathynella* sp. B1	41	Bore X (4, 21), Bore X (15), U-31 (1)	
Bathynellacea	Parabathynellidae	*Kimberleybathynella* sp. B3	1	-	PB01 (1)
Bathynellacea	Parabathynellidae	*Kimberleybathynella* sp. B4	13	-	Munro Bore (13)
Bathynellacea	Parabathynellidae	*Notobathynella* sp. B4	5	-	4/85 (5)
OSTRACODA					
-	-	Ostracoda unident. sp.	2	Bore X (2)	
-	Cyprididae	Bennelongia sp. 3 'kimberleyensis'	2	-	Bore B (2)
GASTROPODA					
Neotaeniglossa	Hydrobiidae	Hydrobiidae sp.	2	-	Bore B (2)
OLIGOCHAETA					
Aphanoneura	Aeolosomatidae	*Rheomorpha* sp.	69	AP-20 (4), AP-36 (50), F-14 (2), I-16 (2), O-10 (6), U-10 (4), U-31 (1)	-
Tubificida	Enchytraeidae	Enchytraeus Pilbara sp. 2 (PSS)	33	O-10 (8)	Bore X1 (25)
Tubificida	Phreodrilidae	*Insulodrilus* sp.	1	-	4/85 (1)
Tubificida	Tubificidae	Tubificidae sp.	1	-	TTM08 (1)
Haplotaxida	Tubificidae	Tubificidae cf spp. WA12/14/22	85	Bore X (2, 1) AD-20 (3), AP-20 (6), F-14 (10), I-16 (10), P-21 (5)	TTM08 (3, 25) Bore X1 (20)
ROTIFERA*					
Bdelloidea	-	Bdelloidea sp. 2:2	37	AD-20 (3), N-4 (1), V-25 (2)	Bore X1 (23) Bore X1 (8)
		TOTAL	**684**	**283**	**401**

[1]Sites in red denote Phase II findings
*Denotes taxa not expected to be identified to species level (EPA, 2007)

9 DISCUSSION

Stygofauna sampling for the Development recorded 18 potential stygofauna species, with nine of these identified from sites in the Precinct near James Price Point (impact sites). This represents a relatively rich stygofauna community from an area of the state where subterranean fauna has been poorly studied.

The stygofauna sampling programme has identified stygofauna communities within the Broome aquifer at the BLNG Precinct near James Price Point and at other regional locations including:

- Barred Creek, 18 km south of the Precinct
- Coconut Well, 33 km south of the Precinct
- Broome townsite, 60 km south of the Precinct
- Nita Downs Station, 180 km south of the Precinct
- Beagle Bay, 75 km north-east of the Precinct
- Kilto Station, 90 km east of the Precinct

Regional sampling, has demonstrated that five of nine species/complexes recorded within the Precinct also occur outside it. The reference sites that yielded these species ranged from 46 km south to 75 km north-east of the Precinct. Three of the remaining four species (*Dussartstenocaris* sp. B04, *Rheomorpha* sp. and *Kimberleybathynella* sp. B1) were collected from multiple sites within the Precinct. The fourth, an unidentified ostracod, was collected as a fragment and is the only singleton record (taxon recorded by collections from a single location) recorded by the survey. Although the ostracod is thought to be a stygal species, it cannot be evaluated further.

Two of three oligochaetes recorded in the Precinct are widespread species and the copepod *Parastenocaris* sp. B14 has been recorded from four sites over a range of about 50 km on the Dampier Peninsula. Nematoda and Rotifera recorded from impact sites were also present at reference sites. Nematodes are a widespread group with few representatives (approximately 20 species) confined to subterranean environments (White and Culver 2012). It is considered unlikely that the Development will affect the conservation status of nematodes recorded by the survey.

The species of greatest interest from a conservation perspective is *Kimberleybathynella* sp. B1. Syncarids typically have small distribution ranges and most are stygobitic (Brusca and Brusca 2003, Eberhard 2005). Relatively little is known about the distribution of species within the Bathynellacea. They occur throughout Western Australia, with collections from the unconfined aquifers of the Swan Coastal Plain, Great Southern, Kimberley, Pilbara and Yilgarn. Cho, Park and Humphreys (2005) described new species of the genus *Kimberleybathynella* from the Kimberley of Western Australia; however, the James Price Point specimens do not match any previously reported species.

The parabathynellid syncarid *Kimberleybathynella* sp. B1 is unlikely to have a wide distribution range. Although it is currently known only from the Precinct (impact area), *K.* sp. B1 has been recorded over a range of about 3.5 km in a regional aquifer system that represents a widespread and connected habitat. Based on previous studies and results of the current survey, the species can be expected to occur over a range several times larger than the Precinct.

A desktop review of published Bathynellidae and Parabathynellidae by Bennelongia (2008) investigated the distribution ranges of species recorded from multiple locations. The review indicated that two thirds of the species had maximum distribution ranges of less than 10 km. Three species of *Kimberleybathynella* had been recorded over distances of up to 6 km; one species of Bathynellidae on the Swan Coastal Plain was shown to occur over a range of at least 50 km; and two European parabathynellids had ranges of several hundred kilometres.

In a review of the global diversity of syncarids, Camacho and Valdecasas (2008) suggested that many apparently restricted species may be shown to have much wider distributions when intensive sampling occurs. The Browse LNG Development stygofauna survey represents the first record of stygofauna communities on the Dampier Peninsula and further sampling would likely increase the ranges of the species recorded.

The presence of *Kimberleybathynella* sp. B1 from only three of 68 impact samples may indicate that the species occurs in low abundance. The fact that it has only been recorded at two sites is likely to be a sampling artefact rather than an indication of a very small distribution range. While two other species (*Dussartstenocaris* sp. B04 and Ostracoda sp. unident.) are known only from the Precinct, this too is most likely a reflection of the low sampling effort on the Dampier Peninsula outside of the present study, to date.

The sampling results and hydrogeological setting suggest that suitable and continuous habitat for stygofauna exists within the Broome aquifer, between Broome and Beagle Bay on the Dampier Peninsula. It is therefore likely that further sampling outside the impact area would demonstrate that all species recorded from the impact area also occur outside it. However, this would require additional bores to be drilled and a significantly greater sampling effort than is required by relevant sampling guidelines (EPA 2007).

For the purposes of impact assessment, the main issue is that none of the stygofauna species recorded by the survey is likely to be restricted to the impact area, which will be defined by the zone of influence on groundwater levels due to pumping from the Broome aquifer for water supply. The Broome aquifer is a highly productive unconfined aquifer that underlies much of the Dampier Peninsula. In the vicinity of the Precinct, it is interpreted to have a saturated thickness of 100 to 150 m. Numerical modelling of the aquifer system to determine the potential water level drawdowns at impact sites had not been completed at the time of

reporting. In the absence of modelled drawdown contours (in prep.), a precautionary approach was adopted to include the entire Precinct in the impact area.

This approach has meant that Bore X near James Price Point, which yielded the highest diversity of stygofauna of all bores sampled, has been included as an impact site. It is understood that pumping of the Broome aquifer for the water supply may result in a localised cone of depression around the borefield, but these effects are likely to be localised. Specific impacts relating to water level declines on sites that yielded stygofauna cannot be assessed at this time, but it is likely that any development-related drawdown in the Broome aquifer near Bore X will be negligible.

The coastal dune area that will form part of the Development has not been included in the stygofauna assessment. No specific geological information is available for this area and little is known about hydrogeological conditions to the west of Manari Rd. The potential presence of limestone formations in the vicinity of the primary dunes would provide additional subterranean habitat in the Precinct that has not been investigated. One site (Bore X) on the eastern side of the Manari Rd has been sampled on six occasions using both pumping and netting techniques. The lithology of this site and bore construction details are not known. An incomplete ostracod specimen collected from this site is the only taxon not recorded elsewhere in the Precinct.

The survey has confirmed the wider distribution of several stygofauna species recorded at the Precinct. Results of the survey, combined with hydrogeological evidence suggest that the Broome aquifer has historically provided pathways for species distribution across the Dampier Peninsula and beyond. There are no geological barriers to stygofauna dispersal in the vicinity of the Precinct and patterns of distribution for the species recorded by the survey indicate that none is likely to be restricted to the impact area.

10 SUMMARY

A comprehensive stygofauna sampling programme was undertaken to assess the stygofauna values of the Browse LNG Development. The survey recorded 18 stygofauna species in total, although only nine occurred within the impact area of the Browse LNG Precinct. This represents a relatively rich stygofauna community and the first such community reported on the Dampier Peninsula.

Regional sampling demonstrated that five of the nine species collected in the Precinct also occur at several regional locations, up to 75 km from the Precinct. Regional stygofauna communities were identified at Barred Creek, Coconut Well, Broome townsite, Nita Downs Station, Beagle Bay and Kilto Station.

Three potential stygofauna species are currently known only from the Precinct, *Dussartstenocaris* sp. B04, *Kimberleybathynella* sp. B1 and an unidentified ostracod. The ostracod was an incomplete specimen and the only singleton record recorded by the survey. Neither the syncarid nor the harpacticoid copepod is likely to be restricted to an area the size of the Precinct in an unconfined, regionally widespread aquifer. Therefore, from an impact assessment perspective, implementation of the Development proposal is unlikely to affect the stygofauna values of the area.

Dated: **19 October 2012** **Rockwater Pty Ltd**

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COLOUR PLATES

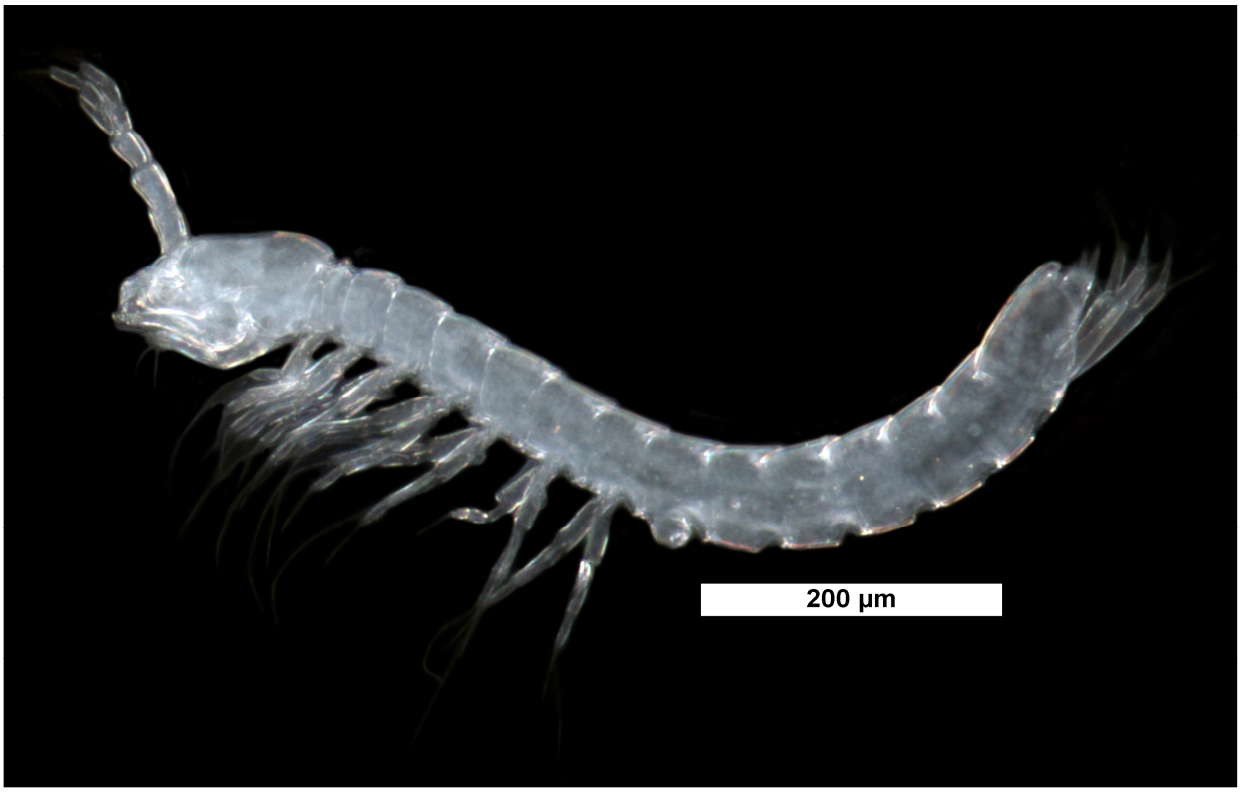


Plate 1: Photomicroscopy of the syncarid *Kimberleybathynella* sp. B01 collected from Precinct site U-31.

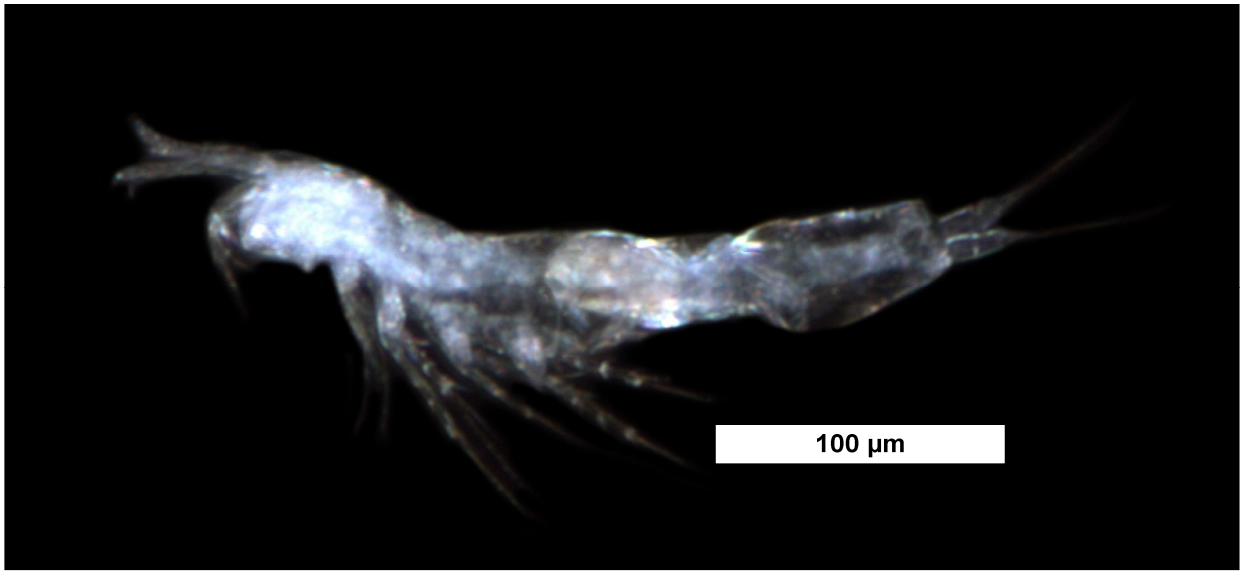
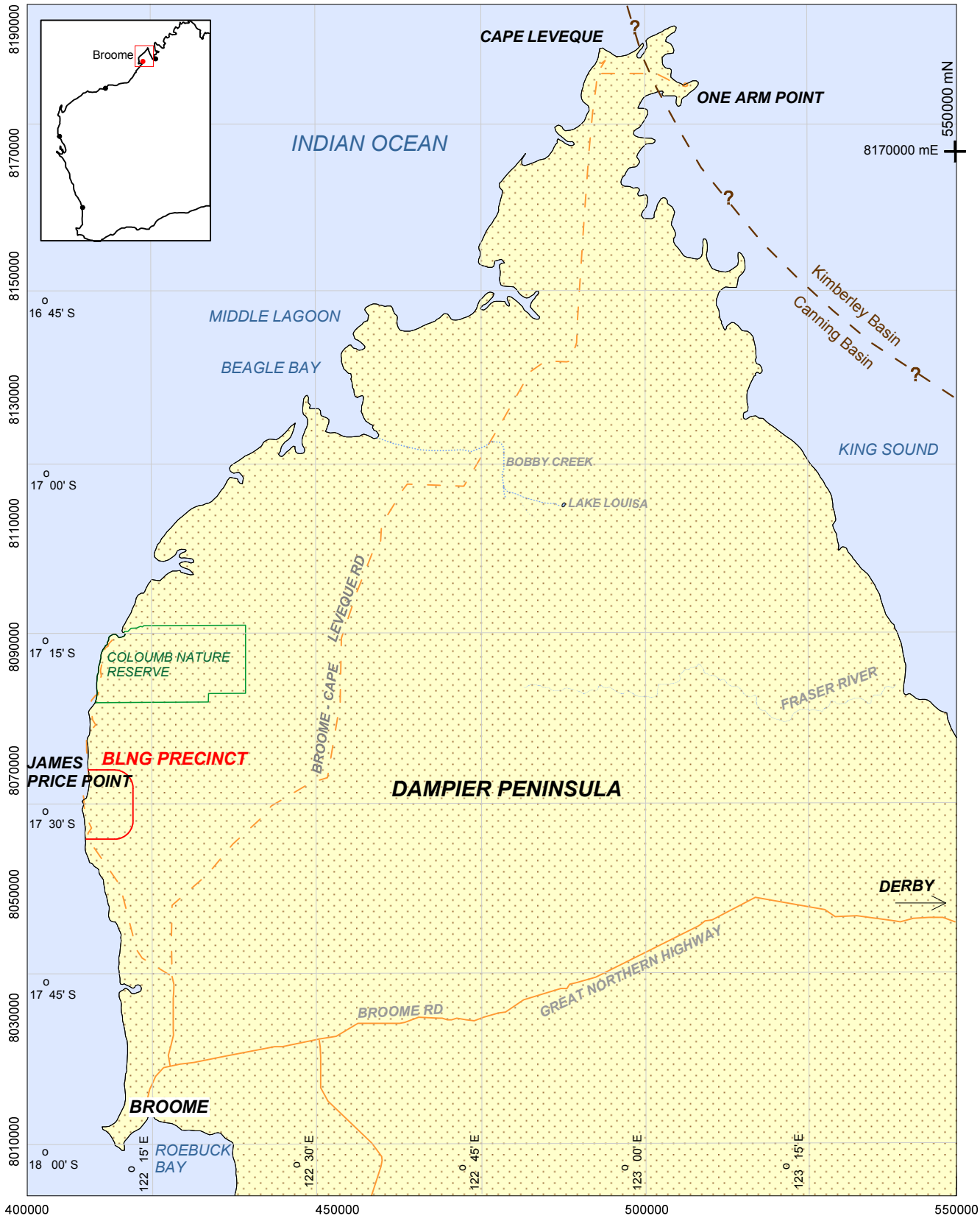


Plate 2: Photomicroscopy of the copepod *Dussartstenocaris* sp. B04 collected from Precinct site F-14.

FIGURES

FIGURE 1



I:368.1/Surfer/Fig 1 - Locality.srf

CLIENT:	Woodside Energy Ltd
PROJECT:	Browse LNG Development Subterranean Fauna Study
DATE:	October 2012
Dwg. No:	368.1/12/2-1

LOCALITY MAP

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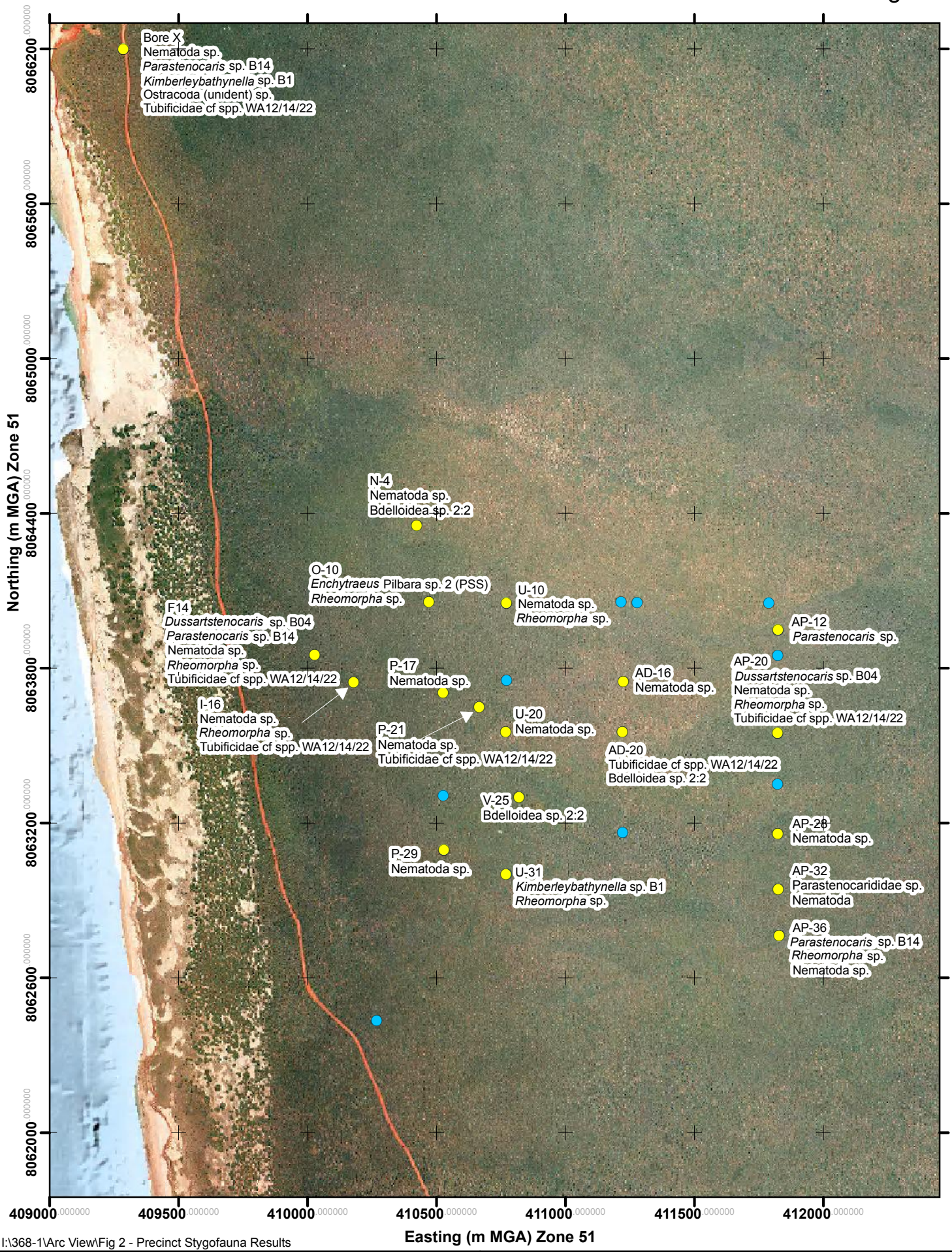
Figure 2



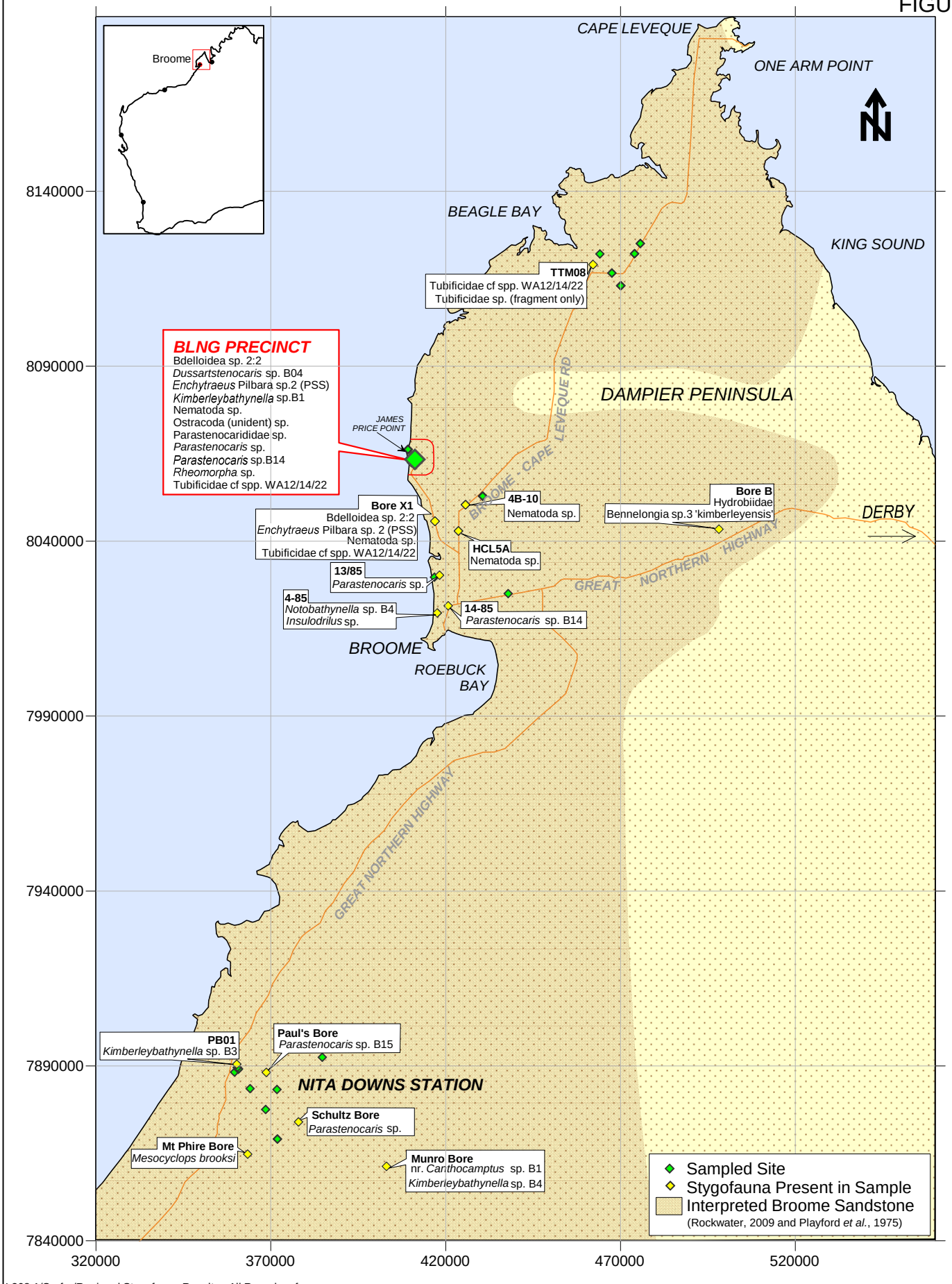
I:\368-1\Arc View\Fig 2 - Precinct Stygofauna Results

CLIENT: Woodside Energy Ltd
PROJECT: Browse LNG Development
DATE: October 2012
Dwg No: 368.1/12/1-2

PHASE II STYGOFAUNA SAMPLING
BROWSE LNG PRECINCT
STYGOFAUNA RESULTS

Rockwater

FIGURE 3



I:368.1/Surfer/Regional Stygofauna Results - All Rounds.srf

CLIENT: Woodside Energy Ltd

PROJECT: Browse LNG Development
Subterranean Fauna Study

DATE: October 2012

Dwg. No: 368.1/12/2-3

REGIONAL STYGOFAUNA SAMPLING LOCATIONS AND RESULTS

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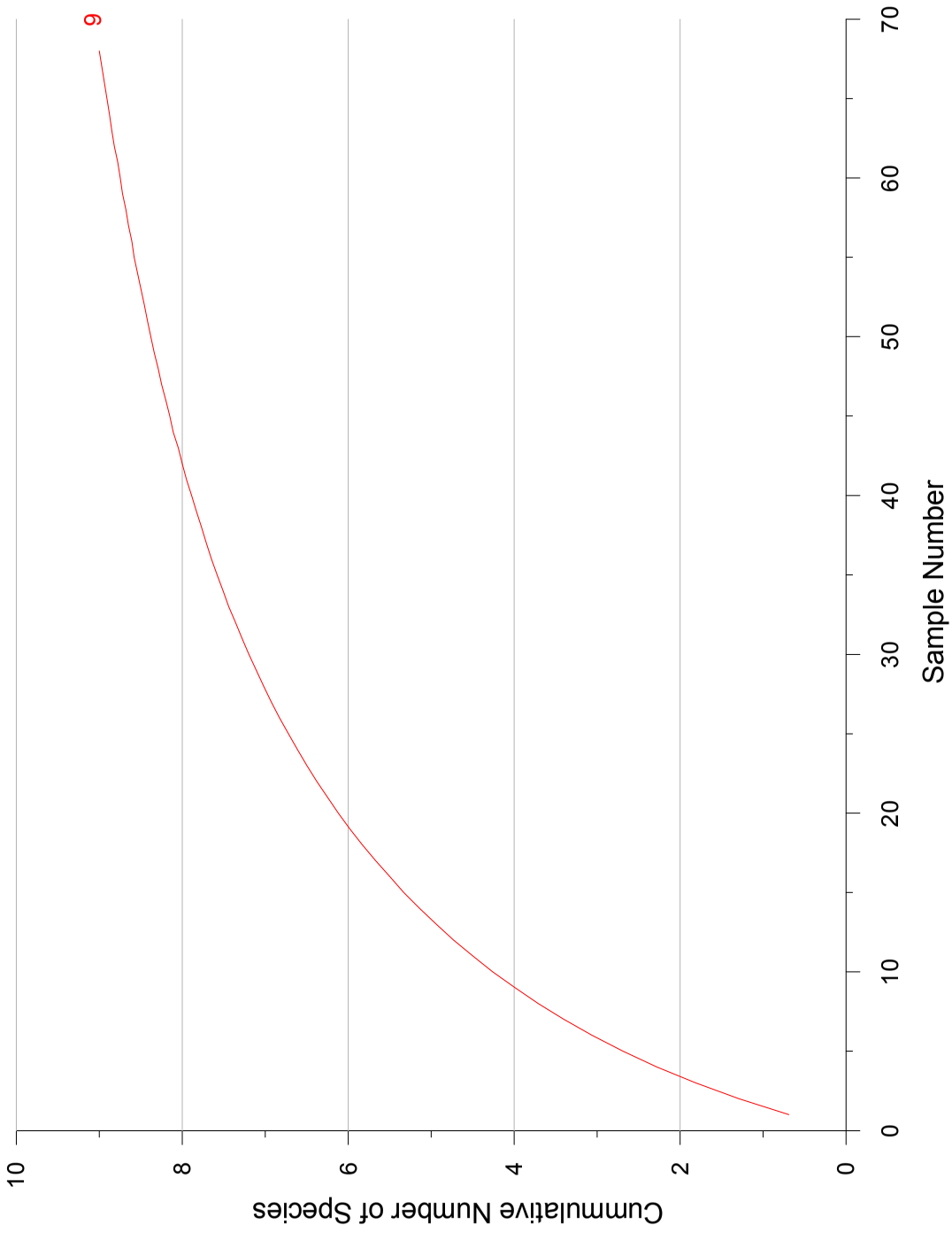
Figure 4



368.1/Grapher/Species Accumulation Curve.grf

Client: Woodside Energy Limited

Project : Browse LNG Development
Subterranean Fauna Survey

Date : October 2012

Dwg. No: 368.1/12/2-4

STYGOFAUNA SPECIES ACCUMULATION CURVE
(Generated by EstimateS (v8.2.0) Colwell 2005)

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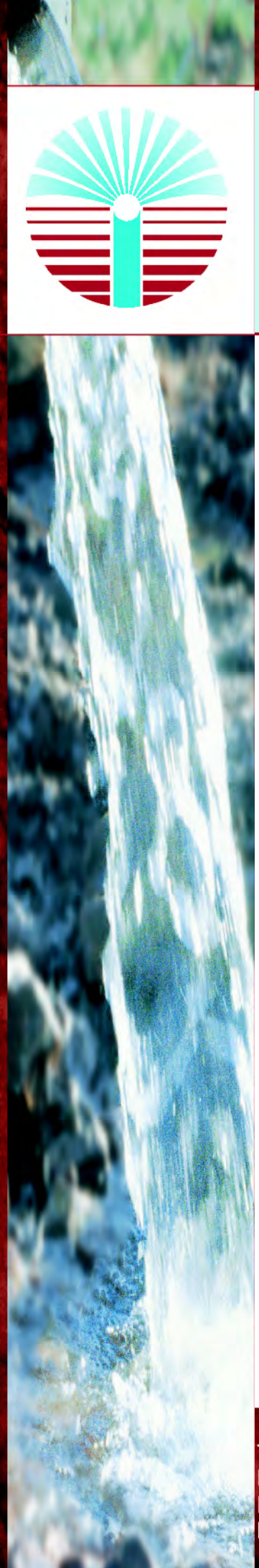
APPENDIX I



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BROWSE DOWNSTREAM PROJECT

RESULTS OF STYGOFAUNA PILOT STUDY AND REGIONAL SAMPLING PROGRAMME

DECEMBER 2011

REPORT FOR
WOODSIDE ENERGY LTD

(Report No. 368.1/11/02)

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1 INTRODUCTION

Woodside Energy Limited (WEL) is preparing a proposal to establish the Browse Downstream Project (the Project), a liquefied natural gas (LNG) processing plant at the Western Australian Government's proposed Browse LNG (BLNG) Precinct (the Precinct) near James Price Point (JPP), approximately 60 km north of Broome (Fig. 1).

A project water supply for the construction phase and operations is planned to utilise local aquifers and so potential project impacts to stygofauna communities that rely on groundwater need to be considered as part of the Environmental Impact Assessment (EIA) process. Construction operations may present a range of potential environmental impacts to subterranean fauna, if such fauna are found to occur at the Project.

There are few published studies of subterranean fauna in the Kimberley and no records of stygofauna from the Dampier Peninsula. However, consideration of subterranean fauna is required during the formal EIA of the Project as there is generally considered to be a high probability of rich subterranean fauna assemblages being present in limestone, sandstone and alluvium strata in the Kimberley of Western Australia (EPA 2007).

Rockwater was commissioned to undertake an assessment of subterranean fauna values for the Project at James Price Point (JPP). The focus of the present investigation is stygofauna. A pilot study, incorporating a desktop study and a preliminary stygofauna sampling programme, was commenced in January 2011. The sampling programme was subsequently extended to align the sampling intensity and seasonality with relevant guidelines for assessment of subterranean fauna (EPA 2003, 2007).

The objectives of the stygofauna pilot study were to:

1. Confirm whether stygofauna are a relevant environmental factor for the Project.
2. Identify and sample available sites within the Project area that are most likely to provide suitable habitat for stygofauna.
3. Identify any conservation-significant species within aquifers or formations likely to be impacted by the implementation of the Project.
4. Assess the significance and conservation status of any stygofauna communities within the project area.
5. Identify potential impacts of the Project on the stygofauna values of the JPP coastal area.

2 PHYSICAL SETTING

2.1 TOPOGRAPHY AND DRAINAGE

The Browse Downstream Project is located on the west coast of the Dampier Peninsula (Fig. 1), which is about 150 km wide from the Fitzroy River estuary to JPP. Ground elevations in the area gradually increase inland from the coast to the maximum of 247 m AHD about 35 km east of JPP. This marks the top of a north-northeasterly trending drainage divide on the peninsula that separates westerly drainage to the Indian Ocean from easterly drainage to King Sound or southwesterly drainage towards the Roebuck Plains.

Drainage on the peninsula is ephemeral within shallow and generally sandy channels. The most prominent westerly drainage is Bobby Creek, which drains into Beagle Bay about 80 km northeast of JPP (Fig. 1).

Two small drainage lines, about 8 km and 20 km long (north and south of the JPP respectively), trend west-northwestwards towards the coast (Rockwater 2010). The northern drainage flows directly to the ocean through a steep-sided gorge, while the southern drainage terminates at the landwards side of coastal sand dunes. Several very small and localised drainage lines (less than one kilometre in length) are also present. Rainfall runoff flows generally to the coast north of JPP but terminates near the coast with water dissipating in low lying areas and in sand dunes south of JPP.

2.2 CLIMATE

The climate in the Broome area is hot, semi-arid, with mean maximum temperatures ranging from 29°C in June/July to 34°C in December, March and April based on data for Broome airport, the nearest Bureau of Meteorology (BoM) climate station. Summer temperatures are slightly higher inland from the coast.

Monsoonal rainfall predominates in the “wet season” from December to March when, on average, 85 per cent of the annual rainfall at Broome (average 602 mm) is received (Table 1). The rainfall is associated with thunderstorms and occasional tropical cyclones; it shows considerable annual variation. The “dry season” produces very low rainfall averaging between 1 and 27 mm per month.

Average annual rainfall varies considerably over the Dampier Peninsula region, with values of 622 mm for Derby, 896 mm for Country Downs Station and 752 mm for Beagle Bay. Some of the differences in these values are likely to be associated with differing lengths of records for the sites. A weather station was established at JPP in November 2009 and rainfall data for December 2009 to November 2010 are provided in Table 2.

Table 1: Average rainfall at Broome Airport

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Ann
Average Rainfall (mm)	175.2	180.2	102.0	26.0	26.8	18.3	5.9	1.7	1.4	1.3	8.3	54.6	602.4

(BoM data; Station No. 3003; Years 1941-2009)

Table 2: Rainfall at James Price Point meteorological station, December 2009 to November 2010

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec*	Ann
Rainfall (mm)	144.6	12.2	0	13.4	50.8	0	150.4	17.4	2.4	1.2	22.4	206.6	621.4

Comparisons of rainfall and evapotranspiration data at the Project were made by Rockwater (2009). Rainfall values were interpolated by multiplying Broome Airport average rainfall data by 1.17 and average areal potential evapotranspiration data were read from maps on the BoM website (BoM, 2011). The data indicate that average rainfall exceeds average potential evapotranspiration only in February and that average annual potential evaporation is 2.7 times greater than the average annual rainfall (Table 3).

Table 3: Extrapolated average rainfall and average areal potential evapotranspiration for the Browse Downstream Project area

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Ann
Average Rainfall (mm)	205	211	119	31	31	21	7	2	2	2	10	64	705
Average Areal Potential Evapo-transpiration (mm)	207	185	191	139	110	88	95	114	149	193	209	220	1900

3 HYDROGEOLOGICAL SETTING

The hydrogeology of the Browse Downstream Project (previously Browse LNG Precinct) has been described in previous reports (Rockwater 2009, 2010; Department of State Development 2010). An extract from Department of State Development (2010) is provided below, with a focus on the Broome Sandstone (Broome aquifer) as most bores sampled by the stygofauna pilot study are screened (or assumed to be screened) within this aquifer:

> *The Browse LNG Precinct lies within the Fitzroy Trough, a structural subdivision of the Canning Basin. The precinct area comprises sedimentary strata which are characterised by two east-west trending structures: the Baskerville anticline to the north, and the Barlee anticline to the south.*
>
> *The stratigraphy of the Fitzroy Trough is summarised as follows (in depth-order from the surface):*
>
> - *Superficial deposits (including Shoonta Hill Sand and Mowanjum Sand) 5 to 20 m thick; Quaternary age;*

- *Broome Sandstone, up to 280 m thick; early Cretaceous age;*
- *Jarlemai Siltstone, 260 m thick; late-Jurassic to early Cretaceous age;*
- *Alexander Formation, 20 m thick; late-Jurassic age;*
- *Wallal Sandstone, 360 m thick; early- to late-Jurassic age;*
- *Noonkanbah Formation, 200 m thick; early-Permian age;*
- *Poole Sandstone, 50 m thick; early-Permian age; and*
- *Grant Group, 200 m thick; early-Permian age.*

The three formations with the most potential to supply large quantities of groundwater are the Broome Sandstone, the Wallal Sandstone and the Grant Group. For the purposes of this investigation, the Broome Sandstone and Superficial deposits, where saturated, are of primary concern for stygofauna.

3.1 BROOME AQUIFER

The Broome Sandstone contains an unconfined aquifer, the Broome aquifer, which is the uppermost aquifer over most of the region, except for a lobe about 12 km wide on the crest of the Baskerville anticline where the base of the formation is above the water table. Groundwater in the overlying Mowanjum Sand (Pindan) is believed to be in hydraulic connection with Broome aquifer and is included in the Broome aquifer (J. Moncrieff, Rockwater, pers comm., 2011). The Broome aquifer is interpreted to have a saturated thickness of 100 to 150 m in the vicinity of the Project.

The Broome aquifer is the most utilised aquifer on the Dampier Peninsula, being the source of the Broome town water supply, as well as providing water for a range of other uses including agro-forestry, community water supply, petroleum exploration and road infrastructure maintenance by Main Roads (Laws 1991 and DoW 2009). The interpreted extent of the Broome aquifer is shown in Figure 2.

The aquifer is a multi-layered, unconfined aquifer system typically comprised of unconsolidated coarse-grained sandstone and conglomerate with intervening minor lenses of siltstone and claystone, and thin coal seams (Laws 1991). The relatively coarser grained materials produce higher yields and better quality water than the lower-permeability siltstone, claystone and coal seams. Despite the aquifer being composed of several water-bearing zones, there is little vertical difference in groundwater elevations between these water-bearing zones (Laws 1991).

Groundwater levels in the Broome aquifer are about 0 to 2 m AHD near the coast, reflecting an unconfined aquifer with groundwater flow to the sea (Rockwater 2009). Inland, based on sparse data except near Broome, the groundwater levels form a mound in the centre of the Dampier Peninsula where the elevation of the water table is up to 59 m AHD. Groundwater at shallow depths, where it potentially supports phreatophytic vegetation, may be present in the Broome aquifer between the coast and the 10 m AHD topographic contour. It is possible that

the Broome aquifer also supports mound springs and perched aquifers in coastal and inland areas of the Dampier Peninsula. Recent hydrogeological data provides no evidence of a perching layer beneath the coastal dune system in the JPP coastal area. However, mounding of groundwater levels beneath the dunes is inferred to occur (SKM 2011).

Groundwater salinity in the Broome aquifer ranges from 250 to 500 mg/L (milligrams per litre) TDS (total dissolved solids) inland from the coast. A wedge of salt water occupies the lower part of the aquifer near the coast. The toe of the saltwater wedge at the Project is estimated to lie about 6 km inland, based on data extrapolated from near Broome (Rockwater 2009).

Groundwater recharge to the Broome aquifer is by:

- direct infiltration of rainfall where the Broome Sandstone outcrops;
- infiltration through or leakage from aquifers in the overlying sediments, e.g. the Shoonta Hill Sand (coastal dune sand); and
- infiltration of surface water from wetlands and drainage systems.

Groundwater recharge is expected to vary throughout the peninsula according to rainfall intensity, depth to water table, location of drainage systems and the local permeability of the aquifer. It is estimated to be 4 to 5% of annual rainfall (Laws 1991).

Regional groundwater flow in the Broome aquifer is influenced by topography and the location of groundwater recharge and discharge areas. At JPP, the direction of regional groundwater flow is interpreted to be in a westerly direction towards the coast. Horizontal hydraulic gradients are reported to be relatively flat at around 4×10^{-4} near the coast (Laws 1991).

Groundwater discharge from the peninsula area typically occurs to the ocean above a saline interface near the coast. Some discharge also occurs via seepage faces along the coast and through evapotranspiration.

3.2 WALLAL AQUIFER

The Wallal aquifer comprises the Wallal Sandstone and the Alexander Formation. It is generally confined or semi-confined above by the Jarlemai Siltstone, which separates it from the Broome aquifer, and is underlain by the sediments of the Liveringa Group, Noonkanbah Formation, Poole Sandstone or Grant Group beneath the JPP area (Rockwater 2009). Here the aquifer is estimated to occur about 400 m below the surface and be about 200 m thick. The Wallal aquifer contains large quantities of brackish to saline groundwater.

No sampling was undertaken from the Wallal aquifer for the stygofauna pilot study and, consequently, it is not discussed further in this report.

4 TERMINOLOGY AND DEFINITIONS

4.1 SUBTERRANEAN FAUNA

Subterranean organisms comprise two main groups; troglofauna and stygofauna. Troglofauna inhabit air chambers in underground cavities and voids above the water table, whereas stygofauna dwell in groundwater. The pilot study considers only stygofauna.

Stygofauna are groundwater-dependent interstitial fauna, largely consisting of crustaceans but also including worms, snails, insects, several other invertebrate groups and blind fish. Stygofauna occur in a range of rock types including, but not restricted to, karstic carbonate rocks, fractured rock aquifers and porous unconsolidated sediments, e.g. alluvium (Eberhard 2007). Stygofauna have been found in most regions of Western Australia, with hotspots in the Pilbara but also recorded in the Goldfields, Kimberley, Murchison and the Yilgarn area (Biota 2007).

Stygofauna are classified into three ecological-evolutionary categories:

(a) Animals which have the ability to spend part of their life cycles in subterranean aquatic habitats '*stygoxenes*'.
(b) Animals which have the capacity to spend their entire life cycle in either underground or surface habitats, but are not confined to this habitat '*stygophiles*'.
(c) Animals which have adapted and restricted exclusively to aquatic subterranean environments, '*stygobites*'.

4.2 OTHER TERMS

Other terms used within this report include:

Impact Area – the area of potential disturbance (see Section 5.3). For stygofauna, the impact zone includes the areas affected by drawdown of groundwater levels or changes in water quality.
Impact Site – a sample site within the impact zone.
Reference Site – a regional sample site outside the defined impact area.

5 DESKTOP STUDY

A desktop study was conducted as part of the Stygofauna Pilot Study, comprising a literature review of other previous subterranean fauna studies in the region, available hydrogeological reports, and maps and data supplied by WEL.

5.1 PREVIOUS STUDIES

There are few published studies of subterranean fauna in the Kimberley and no records of stygofauna from the Dampier Peninsula.

A preliminary assessment of subterranean fauna values at JPP was undertaken for the Project during a 2009 fauna survey at JPP (Biota 2009). The assessment was based on interpretation of the landform and stratigraphic units present in a 24 km stretch of coastline surrounding JPP (Flat Rock to Quondong Point and extending 6 km inland) to determine the likely presence of stygofauna habitat.

During the 2009 assessment, the likelihood of significant stygofauna values in the formations present at JPP was assessed as low. The study suggested that there was potential for smaller stygal forms to be present in the limited habitat spaces offered by saturated clay and sand formations of the site. It also concluded that individual species (if present) were unlikely to be restricted at smaller spatial scales, such as the Project footprint (Biota 2009).

The alluvial aquifers of the Ord River Irrigation Area (ORIA) are known to contain unique stygofauna communities in the northeast of the Kimberley. Humphreys (1999) and Ecowise (2005) identified stygofauna in areas of the Stage 2 (M2) ORIA development, approximately 750 km northeast of JPP. The studies identified syncarids, copepods, ostracods, oligochaetes and oribatid mites from alluvial sediments within the ORIA. Stygofauna sampling for the Argyle Diamond Mine in the northeast Kimberley identified at least 15 species of stygofauna (EPA 2005). Cho, Park and Humphreys (2005) described six species of Parabathynellidae from the Kimberley region, including taxa recorded at Argyle and from the ORIA.

5.2 INTERPRETATION OF SITE-SPECIFIC GEOLOGICAL DATA

A series of groundwater monitoring bores have been installed within the Project area in conjunction with onshore geotechnical investigations. A Rockwater hydrogeologist was present during drilling (continuous rotary coring) and examined most of the core sections in-situ. Following consultation with Rockwater's environmental scientists, the hydrogeologist highlighted sections of the core that represent prospective stygofauna habitat and designed the monitoring bores (screened interval and aperture/slot size) specifically for stygofauna sampling. This is intended to allow future expansion of the stygofauna pilot study into a full study. A selection of lithological data with intervals of suitable stygofauna habitat is shown in Table 3.

Sites flagged with prospective stygofauna habitat have been cased and completed as stygofauna monitoring bores with 3.0 mm aperture slots placed against the most suitable lithologies. Rockwater provided additional specifications for bore construction to minimise the potential for contaminants to be introduced into the bores. These included the use of threaded joints (rather than glued ones), the use of vegetable-based grease on drilling rods,

and no drilling fluids or hydrocarbons used as part of the drilling. Soon after being completed, the bores were developed for several hours by the drilling contractor, by pumping using a small submersible pump.

The drilling results indicate that the Broome Sandstone in the Project area varies between unconsolidated and well cemented, with only minor fractures below the water table. The most prospective stygofauna habitat appears to be fractured sections of well consolidated, medium grained Broome Sandstone with some potential in pore spaces in the unconsolidated sand. Inspection of core and lithological logs from the bores suggests that the overlying superficial deposits (mainly Mowanjum Sand) provide little to no prospective stygofauna habitat.

Table 4 : Potential stygofauna habitat at the Browse Downstream Project.

Bore	Water Level (m btc)*	Depth (m)	Stratigraphy	Lithology	Description	Plates	Suitability for Stygofauna
AP-16	23.94	28.3 – 28.5	Broome Sandstone	Sandstone	Clear, cream, fine to medium grained, subrounded, well sorted. Cream silty bedding. Cavities 1 to 5 mm.	1	**Prospective** 28.3 – 28.5 m
		29.25 – 30.5	Broome Sandstone	Sandstone	Clear, white pink, medium grained, subrounded, well sorted. Fractures from 28.0 – 30.5 m; closed to 2 mm, and cavities, pore space <1mm at 29 m.	1	**Prospective** 29.25 – 30.5 m
		40.0 – 40.3	Broome Sandstone	Sandstone	Clear, white, some yellow brown, medium grained (some coarse), moderately sorted, subrounded to rounded, some white silt, well cemented, hard. Iron staining and minor pore space/cavities >2 mm at 40.2 m and minor fractures.	2	Possibly Prospective
		42.12 – 43.5	Broome Sandstone	Sandstone	Clear, white, orange and red, brown, fine to course grained (predominately medium grained), poor to moderately sorted, subrounded, hard. Minor cavities from 42.5 to 43.5 m.	3	Possibly Prospective
P-21	12.91	43.0 – 50.5	Broome Sandstone	Sandstone	White, medium to coarse grained, very hard. Some yellow staining in parts, weakly consolidated to very hard/well cemented, minor yellow silt. Fracture at 43.5 m.	-	Possibly Prospective 43.5m
U-10	17.91	24.5 – 30.5	Broome Sandstone	Sandstone	Cream, fine to medium grained (predominantly fine), well sorted, subangular, well cemented. Fractured.	4	**Prospective** 24.5 – 30.5 m
U-20	16.21	47.0 – 47.4	Broome Sandstone	Sand	Brown, weathered/oxidised, very hard, some porosity.	-	Possibly Prospective
U-31	13.13	30.2 – 30.5	Broome Sandstone	Sandstone	White, grey, fine to medium grained, moderately sorted, subrounded, some fractures.	-	Possibly Prospective

*Water level on November 2011, m btc = metres below top of casing.

One site, AP-16, showed prospective habitat at a number of intervals from 28 to 44 m, which included cavities of up to 5 mm diameter (Plates 1 – 3). Several other sites showed small intervals of prospective habitat, including U-10, which showed a section of highly-fractured sandstone from 24.5 to 30.5 m (Plate 4). In addition, site P-16 had some cavities (up to 20 mm

diameter) at about 29.3 to 31.3 m depth in the moderately-consolidated lower section of the Mowanjum Sand, near the contact with the Broome Sandstone. P-16 was abandoned and not completed as a stygofauna monitoring bore.

Plate 1: Core from exploration hole AP-16 (27 – 30 m) showing prospective habitat in the fracture zone from 28 – 30.5 m, and cavities up to 5 mm.

Plate 2: Core from AP-16 (39 – 42 m), showing a small zone of fracturing from 40.1 - 40.3 m in the Broome Sandstone.

Plate 3: AP-16 (42 – 45 m), showing potential stygofauna habitat in the fractured zone between 42.1 – 43.5 m.

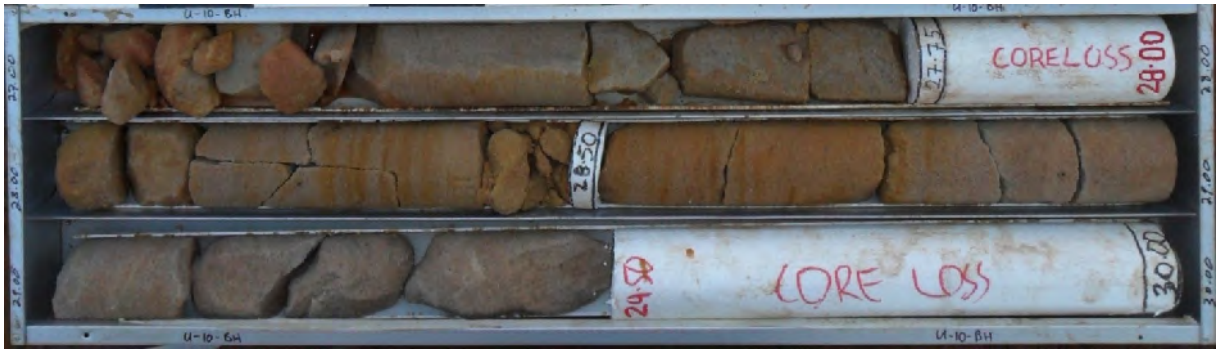

Plate 4: Core photograph from U-10 (27 – 30 m) showing several fractures.

A number of sites show large sections of core loss; however, this is not necessarily indicative of voids or cavities but apparently relates to fracturing of core caused by the drilling. Numerous mechanical breaks present in the core are not necessarily 'fractures' but potentially relate to the fracturing of the core along lines of weakness in otherwise well-cemented strata.

5.3 IDENTIFICATION OF POTENTIAL IMPACT TO STYGOFAUNA

Prior to sampling, aspects of the Project that may potentially impact subterranean fauna were considered as part of the desktop study. Potential impacts comprise two categories: direct and indirect. Direct impacts include aspects of the Project that may result in destruction of habitat and removal of local populations. These direct impacts may potentially result in extinction of any endemic species, if present, at JPP. Indirect impacts include threatening processes that are more likely to lead to reduction in population sizes and secondary impacts to subterranean fauna habitat. The ecological significance of many of the potential indirect impacts to subterranean fauna is not well understood and so it is generally recognised that indirect impacts are difficult to quantify and assess.

Groundwater drawdown and changes in groundwater chemistry associated with dewatering and project water supplies are considered to be the principle potential impacts on stygofauna for the Project. Water sources being considered are the unconfined Broome aquifer during the construction phase and either the deeper, confined Wallal aquifer or desalination of seawater during the operational phase.

As the source and location of construction and operational project water supplies had not been confirmed at the time of the stygofauna investigation, the extent of impacts to local aquifers had not been modelled.

Other aspects of the Project that could potentially affect stygofauna include:

- Vibrations from heavy equipment and piling during construction.
- Groundwater contamination.
- Reduction in organic inputs. Removal of vegetation (clearing) and stockpiling of topsoil may reduce organic material input to subterranean systems.

- Changes to the local surface hydrology, which may alter local recharge/discharge points.
- Hydrocarbon spills/leaks during construction which may lead to surface or groundwater pollution.

It is expected that these effects are unlikely to take place to any significant degree and, consequently, they have not been assessed in the present study.

6 SAMPLING METHODOLOGY

6.1 GENERAL

The subterranean fauna sampling methodology outlined herein has been prepared in accordance with the principles outlined in relevant Environmental Protection Authority (EPA) guidance statements (EPA 2003, EPA 2007). The investigation has followed the requirements of the EPA for a subterranean fauna pilot study, which involved collecting sample sets that are representative of aquifers and strata that may be suitable for stygofauna, from an appropriate spread of sampling sites across the area likely to be impacted by the Project. In addition, a range of reference sites were sampled to allow the findings in the JPP coastal area to be assessed in a regional context. The sampling intensity employed either meets or exceeds that recommended by the EPA for a pilot-scale study.

A Regulation 17 Permit (No. SF 7676) was issued by the Department of Environment and Conservation (DEC) for the purposes of subterranean fauna sampling at the Project.

6.2 STYGOFAUNA SAMPLING

Sampling in the vicinity of JPP for the Browse Downstream Project Stygofauna Pilot Study was undertaken in five rounds between January and October 2011. A total of 50 samples were taken during the sampling programme using a combination of netting and pumping (Table 5). Where a bore was sampled using both methods, the samples were preserved separately, but the results are combined as one sample.

Table 5: Stygofauna sampling (number of samples) over five sampling rounds for the Browse Downstream Project.

	Round 1		Round 2		Round 3		Round 4		Round 5		Total Sites*
	Net	Pump	Net	Pump	Net	Pump	Net	Pump	Net	Pump	
Impact	1	1	0	0	2	2	2	0	2	0	**7**
Reference	1	1	13	0	1	0	5	5	13	10	**44**

*Total number of samples calculated based on combined methods for sampling at each site (i.e. net only sample or a net and pump sample during a single visit being considered a single sample).

Seven samples were taken from two potential impact bores (Bore X and BH6X) in the vicinity of the Project area. Bore X is a disused Main Roads WA production bore located on Manari

Rd, (approximately 300 m from the coast), and BH6X is a monitoring bore situated next to the Woodside meteorological tower in the Project area.

Following the initial sampling at JPP in January 2011, when stygofauna was detected, a programme of regional sampling was initiated to provide some regional contextual information on the local stygofauna community. Reference samples were taken from a range of bores across the Dampier Peninsula between Beagle Bay and Coconut Wells, around the Broome townsite, east of Broome and south of Broome from a range of monitoring bores, irrigation bores and station stock-watering bores. The locations of all bores sampled by the stygofauna investigation are shown in Figure 2.

At each bore the following measurements and procedures were undertaken:

- prior to biological sampling, measurements were taken of water level and physicochemical water quality parameters (including salinity, conductivity, pH, dissolved oxygen and temperature);
- recordings of total depth, collar heights, diameters and other bore details, where available;
- collection of biological samples using stygofauna sampling nets; and
- preservation of biological samples in 100 % ethanol.

Sampling nets with a diameter of approximately two-thirds of the bore diameter and filter mesh sizes 50 µm and 150 µm were used to sample all bores. Each net consists of a steel collar that supports a filter mesh, tapering to a hollow brass weight. A clear polycarbonate vial with bottom removed and replaced with 50 µm filter mesh was screwed into the brass weight to collect samples filtered by the sampling nets. Nets were suspended by a carabineer and three trace wires attached to the steel collar.

Bores were sampled for stygofauna using the customised sampling nets by lowering the net into the bore using a reel of fishing braid until it reached the bottom of the bore where it was agitated to disturb sediment and any animals that may be present. The biological samples were taken using three net-hauls of the 50 µm stygofauna sampling net and three net-hauls of the 150µm sampling net. The individual samples from each bore were combined and preserved.

Pumped samples were taken from the three bores along the Manari Rd between JPP and Barred Creek (Bore X, Bore X1 and BH6X) and from several of the regional bores. A vehicle-mounted Grundfos MP1 sampling pump with a generator power supply was used to sample the bores. Pumped samples generally were taken before net samples due to the sensitivity of the submersible pump to suspended silt and fine sand in the discharge water.

In addition, pumped samples were taken from several regional station bores south of Broome that were equipped with submersible pumps. With the exception of the equipped bores, those that were pumped were generally netted during the same sampling round. At each site, bore

details were measured and the bore volume beneath the water level was calculated. Generally, at least three bore-volumes were filtered for each pumped sample.

Samples were stored in 120 mL polycarbonate vials and preserved using 100% (absolute) ethanol. To avoid contamination, the sampling nets were thoroughly washed with a decontaminant solution and then rinsed with distilled water between sites. All samples were forwarded to specialist stygofauna biologists at the end of each sampling round for sorting and identification.

6.3 WATER QUALITY

Prior to stygofauna sampling at each bore, water quality was measured using a multiparameter probe (Hydrolab minisonde or Troll 9500 Pro and Rugged Reader), either 'down-hole' with the probe connected to a 100 m cable or from a pumped or bailed sample of water from the bore. The probe was lowered down the bore casing to approximately one metre below the water level. Water quality parameter readings were recorded immediately after they had stabilised. Where a pumped water sample was filtered for stygofauna, the water quality readings were generally taken from a pumped water sample collected towards the end of the pumping period at each site.

During early-November 2011, water sampling was undertaken at eight newly-constructed monitoring bores in the BLNG Precinct as part of a separate investigation. Water samples were pumped, preserved and submitted for various analyses and field water quality was measured.

7 STYGOFAUNA RESULTS

A total of 183 stygofaunal animals representing at least 13 potential taxa from six Classes/Orders (Copepoda, Gastropoda, Oligochaeta, Syncarida, Ostracoda and Rotifera) were collected from 12 of 36 sites (33%) during the survey (Table 6). Thirteen potential stygofauna species were collected during the pilot study (Table 6) along with a number of immature/damaged specimens which cannot be indentified further. These specimens have been included in Table 6; however, they are unlikely to represent additional species. One of two impact sites and eleven of 34 reference sites yielded stygofauna. The locations of stygofauna records across the survey area are shown in Figure 2. Site details and available bore construction details are presented in Appendix II.

Crustacean orders (Copepoda, Syncarida and Ostracoda) accounted for 63% of all animals recorded, followed by Oligochaeta (Tubificida) with 34%. Syncarids and copepods were the most diverse groups, each with four species, followed by oligochaetes (two species). An ostracod (Family Cyprididae), hydrobiid snail (dead on collection) and Bdelloid rotifer were present in lower abundance.

Table 6: Stygofauna species recorded from sites between Beagle Bay and Nita Downs Station for the Browse Downstream Project Stygofauna Pilot Study

Order	Family	Taxon	n*	Impact	Reference
				(Number of animals in parenthesis)	
COPEPODA					
Harpacticoida	Canthocamptidae	nr *Canthocamptus* sp. B1	3	-	Munro Bore (3)
Harpacticoida	Cyclopidae	*Mesocyclops brooksi*	1	-	Mt Phire Bore (1)
Harpacticoida	Parastenocarididae	*Parastenocaris* sp.	5	-	13/85 (5)
Harpacticoida	Parastenocarididae	*Parastenocaris* sp.	6	-	Schultz Bore (6)
Harpacticoida	Parastenocarididae	nr. *Parastenocaris* sp. B14	26	Bore X (6)	14/85 (20)
Harpacticoida	Parastenocarididae	*Parastenocaris* sp. B15	1	-	Pauls Bore (1)
SYNCARIDA					
Bathynellacea	Parabathynellidae	Parabathynellidae sp.	4	Bore X (4)	-
Bathynellacea	Parabathynellidae	*Kimberleybathynella* sp. B1	25	Bore X (4,21)	-
Bathynellacea	Parabathynellidae	*Kimberleybathynella* sp. B3	6	-	PB01 (6)
Bathynellacea	Parabathynellidae	*Kimberleybathynella* sp. B4	13	-	Munro Bore (13)
Bathynellacea	Parabathynellidae	*Notobathynella* sp. B4	5	-	4/85 (5)
OSTRACODA					
-	Cyprididae	*Bennelongia* sp. 3 'kimberleyensis'	30	-	Bore B (30)
GASTROPODA					
Neotaeniglossa	Hydrobiidae	Hydrobiidae sp.	2	-	Bore B (2)
OLIGOCHAETA					
Haplotaxida	Naididae	*Insulodrilus* sp.	1	-	4/85 (1)
Haplotaxida	-	-	2	Bore X (2)	
Haplotaxida	-	-	1		TTM08 (1)
Haplotaxida	Tubificidae	-	25		TTM08 (25)
Haplotaxida	Tubificidae	Tubificidae group B	4	Bore X (1)	TTM08 (3)
ROTIFERA					
Bdelloidea	-	Bdelloidea sp. 2:2	23	-	Bore X1 (23)
		TOTAL	**183**	**38**	**145**

*number of specimens identified

At least three species were found within the Project area, including a copepod (nr. *Parastenocaris* sp. B14), a tubificid worm (Tubificidae group B complex) and a syncarid (*Kimberleybathynella* sp. B1). In addition, damaged or incomplete copepod (*Parastenocaris* sp.), oligochaete (Haplotaxida) and syncarid (Parabathynellidae sp.)

specimens were recovered. All records from the Project area came from a single site, Bore X (Table 6).

Overall, 33% of bores sampled contained stygofauna; however, sampling at regional locations yielded variable results. Twenty three samples from 13 bores located between Broome and JPP yielded at least six species. Eleven samples from seven bores near Beagle Bay, approximately 75 km northeast of the Precinct, yielded one species. Sampling at 15 bores on Nita Downs Station, 150-200 km south of Broome, yielded five species and one sample from a bore approximately 85 km east northeast of Broome yielded two species.

Two of three stygofauna species recorded at JPP (Bore X) were also collected from reference sites during regional sampling. The copepod nr *Parastenocaris* sp. B14 was recorded at reference site 14-85, approximately 46 km to the south of the Precinct and the Tubificidae group B complex worm was recorded at bore TTM08 near Beagle Bay, indicating a range of at least 75 km for the species (Figure 2). The third species recorded at the site, *Kimberleybathynella* sp. B1, was recorded in two of four samples from Bore X. It is likely to represent a new species and is currently only known to occur within the Project area. Singleton and doubleton records provide little information about the distribution of a species and further sampling would be required to demonstrate that the species occurs beyond the Project area.

Parastenocarididae were recorded at four reference sites but specimens from two sites were not able to be identified to species level. Other harpacticoid copepods included *Mesocyclops brooksii* and nr. *Canthocamptus* sp. B1. Syncarids, including two species of *Kimberleybathynella* and one species of *Notobathynella,* were recorded as singletons (species recorded at a single bore) from reference sites between 50 km and 200 km south of Broome. Two species of oligochaete (*Insulodrilus* sp. and Tubificidae Group B complex) were recorded from reference sites at Broome and near Beagle Bay. A Bdelloid rotifer was collected from Bore X1 on Manari Road; however, it is not considered further due to the limitations on taxonomy for this group. An undescribed ostracod (*Bennelongia* sp. 3 'kimberleyensis') and hydrobiid snail were recorded from a reference site 85 km northeast of Broome.

One troglofauna species was collected as by-catch from a stygofauna net sample at reference site 14-85 near Broome (Fig. 2). The isopod *Troglarmadillo* sp. B25 is likely to represent a new species.

The physico-chemical groundwater data collected at each site sampled for stygofauna are presented in Appendix II. With the exception of Bore X1, which had EC values of 1,972-4,342 µS/cm, all bores recorded EC values less than 2,374 µS/cm (approximately 1,550 mg/L TDS). Groundwater temperature averaged 30.4^{o}C across the entire study area, ranging from 20.9-33.1^{o}C. Dissolved oxygen readings ranged from 0.04 to 5.79 mg/L, with an average of 1.81 mg/L. Field pH values ranged from 4.59 to 9.62 across all sites.

Water quality data for sites that yielded stygofauna are presented in Table 4. pH values were typically slightly acidic (5.35-6.96); the exception being bore B (pH=8.47). Dissolved oxygen concentrations ranged from 0.04-5.79 mg/L. EC readings ranged from 100-4342 µS/cm.

Table 7: Water quality parameters for bores that that yielded stygofauna

Site id	Water Quality								Taxonomic Group(s) Recorded
	Method	Depth (m)[#]	Temperature (degrees)	EC (µS/cm)	pH	Turbidity FNU	ORP (mV)	DO (mg/L)	
4/85	Bailed	n/a	21.76	1424	6.19	-	188	0.04	Copepoda, Oligochaeta
13/85	Bailed	n/a	24.37	750	5.76	-	173	0.06	Copepoda
14/85	Bailed	n/a	26.00	1291	6.21	-	208	0.04	Copepoda
Bore B	Down-Hole	-1.03	29.89	100	8.47	45.9	0.18	3.20	Ostracoda, Oligochaeta
Bore X*	Down-Hole	-0.42	30.74	642	5.35	398	59.15	2.04	Copepoda, Syncarida, Oligochaeta
Bore X1	Down-Hole	-0.3	30.91	4342	6.69	5.8	-299	5.14	Rotifera
Mt Phire Bore	Pump	-	33.00	380	5.64	669	0.10	4.27	Copepoda
Munro Bore	Down-Hole	-1	32.07	736	6.85	2.3	0.21	5.79	Copepoda, Syncarida
Pauls Bore	Pump	n/a	31.83	2357	6.53	30.9	0.06	4.45	Syncarida
PB01	Down-Hole	-1.1	32.80	1124	6.96	4.8	0.25	1.49	Syncarida
Schultz Bore	Pump	n/a	32.19	1971	6.67	21.0	0.13	5.03	Copepoda
TTM08	Down-Hole	-1	31.04	2513	6.28	0.1	-0.48	-1.59	Oligochaeta

* Average values across all sampling rounds
[#] Depth below water level when readings are taken

Water quality data from eight monitoring bores within the Project area provide additional ranges for physicochemical parameters (temperature, EC, pH, dissolved oxygen redox and turbidity), which may provide evidence to assess the suitability of groundwater conditions for stygofauna. The data from these bores and other sampled bores in the Project area (Table 8) may be compared with those from sites that yielded stygofauna within the Broome aquifer during the pilot study sampling programme (Table 7). Based on water quality measurement taken during the pilot study, groundwater conditions in all bores sampled for the Project appear to be favourable for stygofauna.

Table 8: Water quality data for bores in the Browse Downstream Project area

Site id	Water Quality							
	Method	Depth (m) #	Temperature (degrees)	EC (µS/cm)	pH	Turbidity FNU	ORP (mV)	DO (mg/L)
Bore X*	Down-hole	n/a	30.74	642	5.35	398.0	59.15	2.04
BH6X*	Down-hole	n/a	31.27	529	5.42	528.6	-0.24	3.77
U-20	Down-hole	-1.425	31.60	874	6.99	336.1	-0.78	0.80
P-29	Down-hole	-1.387	31.28	1021	6.49	32.8	-0.69	1.55
P-21	Down-hole	-1.030	31.49	788	7.68	107.5	-0.78	7.82
P-17	Down-hole	-1.161	31.25	1257	7.90	232.5	-0.76	2.93
U-10	Down-hole	-1.235	32.11	658	8.47	344.5	-0.73	9.07
AE-10	Down-hole	-1.185	32.01	1726	8.81	285.2	-0.82	7.59
AP-10	Down-hole	-1.183	31.46	261	5.68	3.7	-0.49	4.75
AD-10	Pumped	n/a	32.24	234	5.18	188.6	-0.47	4.99

* Average values across all sampling rounds
# Depth below water level when readings are taken

8 DISCUSSION

The Stygofauna Pilot Study recorded 13 potential stygofauna species, with three of these identified from an impact site within the Project area. Stygofauna recorded by this investigation represents the first record of such fauna on the Dampier Peninsula.

The spatial extent of sampling undertaken within the Project area was limited by the number of available groundwater monitoring bores; consequently, two bores were sampled on multiple occasions over a nine month period to obtain a total of seven samples. This represents a sampling intensity that is consistent with the EPA's requirements for a pilot-scale study (EPA 2007).

Three species were recorded from seven samples within the Project area using both pumping and netting methods. Bore X was the highest (stygofauna) yielding bore sampled within the study with 38 animals from three species. Accumulation of species levelled off after just two of four samples from this bore, suggesting that the species richness possibly is low. However, repeat sampling from a greater number and spread of sites across the Project area would be required to confirm this.

Two of three species recorded within the Project area have been shown to occur at reference sites ranging from 46 km (nr *Parastenocaris* sp. B14) to 75 km (Tubificidae group B complex) from the Project on the Dampier Peninsula. The third species, a syncarid (*Kimberleybathynella* sp. B1), was represented by two collections from a bore in the Project area. More intensive sampling would be required to demonstrate that this species occurs more widely in the region.

Syncarids typically have restricted distribution ranges and published data for the genus *Kimberleybathynella* indicate distribution ranges for three species, *K. kimberleyensis, K. argylensis* and *K. pleochaeta,* of 2-6 km (Cho, Park and Humphreys 2005). However, these records relate to habitats associated with groundwater springs and alluvial aquifers in the vicinity of the Argyle Diamond Mine and Ord River Irrigation Area in the northeast Kimberley. Limited sampling for stygofauna has been undertaken beyond these areas in the Kimberley to date and so there is a paucity of regional data with which to compare the stygofauna pilot study results.

A review of bathynellid distribution ranges by Bennelongia (2008) showed an overwhelming picture of very small ranges, with two-thirds of species in the review having ranges of less than ten kilometres. Previous studies in Western Australia have shown ranges of 40-50 km for Parabathynellidae and European studies have shown distribution ranges of up to 430 kilometres for the group (Bennelongia 2008). Based the regional extent of the Broome aquifer that represents potential habitat, it is considered that there is a low likelihood of this species being restricted to an area the size of the Project. It is likely that repeated sampling at a greater intensity than that for a pilot study will increase the distribution ranges of many species recorded within the Broome aquifer by this study.

Hydrogeological evidence provides further justification for a widespread stygofauna community. The Broome aquifer is a highly productive unconfined aquifer that underlies much of the Dampier Peninsula. Historically, it is likely to have provided pathways for species distribution across the Dampier Peninsula and beyond. The pilot study confirms that the Broome aquifer provides suitable habitat for stygofauna on the Dampier Peninsula and across a range of over 300 km, between Beagle Bay and Nita Downs pastoral station, south of Broome.

No comparison is made of the stygofauna yield from pumping versus netting as the pilot study sampling methodology was not designed to test the efficiency of sampling methods. Pumped samples were generally taken before net samples to avoid damaging the submersible pump through pumping of silt and fine sand that the netting method may disturb when nets hit the bases of the bores. Previous studies have suggested that net sampling is likely to collect all species present but in low numbers (e.g. Ecowise 2005). Pumped samples are known to collect groundwater fauna in higher abundances (e.g. Hancock 2006, Ecowise 2005) and the pumping method was used to increase the chance of collecting fauna from the two Project sites and from selected reference sites that were suitable for pumping.

None of the sites sampled to date are assumed to be impact sites for the purposes of EIA as further definition of the potential impact area within the JPP onshore infrastructure footprint is required. Potential project-related impacts to the stygofauna community cannot be assessed at this stage; however, it is understood that excavations for infrastructure during construction of the LNG plant will occur above the water table and there is likely to be no significant drawdown of water levels in the Broome aquifer in the vicinity of Bore X. For the purposes of

stygofauna impact assessment, confirmation of the source and location of project water supplies is required, and potential drawdown of groundwater levels associated with groundwater extraction needs to be quantified.

9 SUMMARY AND RECOMMENDATIONS

A pilot study in line with relevant guidelines was undertaken to assess the subterranean fauna values of the Browse Downstream Project. The pilot study suggests that the Broome aquifer on the Dampier Peninsula contains a stygofauna community of low to moderate diversity, dominated by crustacean orders.

The only stygofauna species not known to occur beyond the Project area, *Kinberleybathynella* sp. B1, is likely to represent a new species. Based on the distribution of other published species within the genus and the regional extent of the Broome aquifer that represents potential stygofauna habitat, there is a low likelihood of this species being restricted to an area the size of the Project.

Additional sampling within the project area will be required to align the sampling intensity with that expected by the EPA for a full survey. It is anticipated that 40 project area samples will be required for impact assessment purposes and that monitoring bores currently under construction will provide future sites for stygofauna sampling. Sampling will focus on areas where impacts are likely to be greatest including sites within the project area and surrounding coastal dunes. Identification of potential impact mechanisms to stygofauna and stygofauna habitat will require further understanding of the potential project-related impacts on local aquifers.

Dated: **23 December 2011** **Rockwater Pty Ltd**

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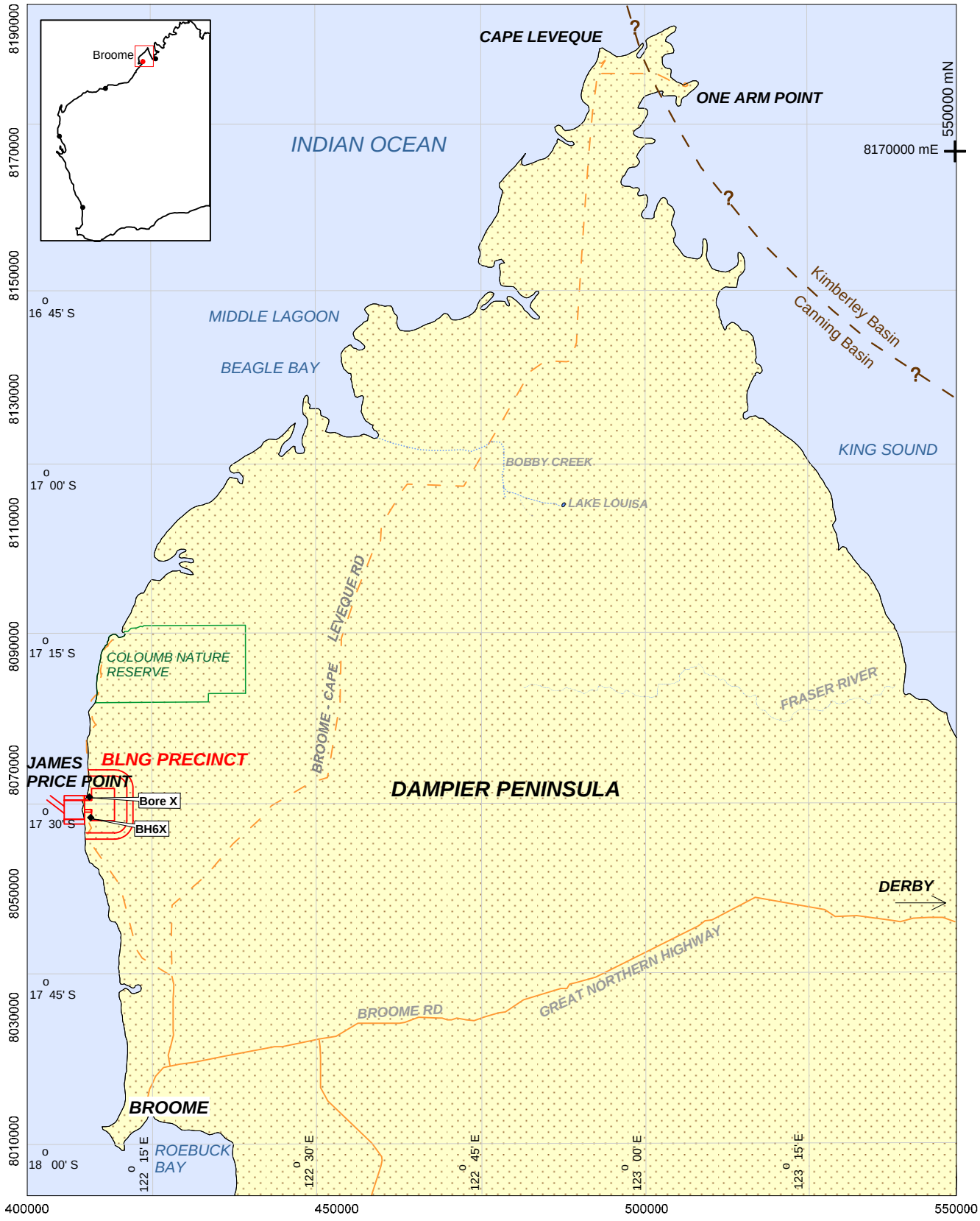
FIGURES

FIGURE 1



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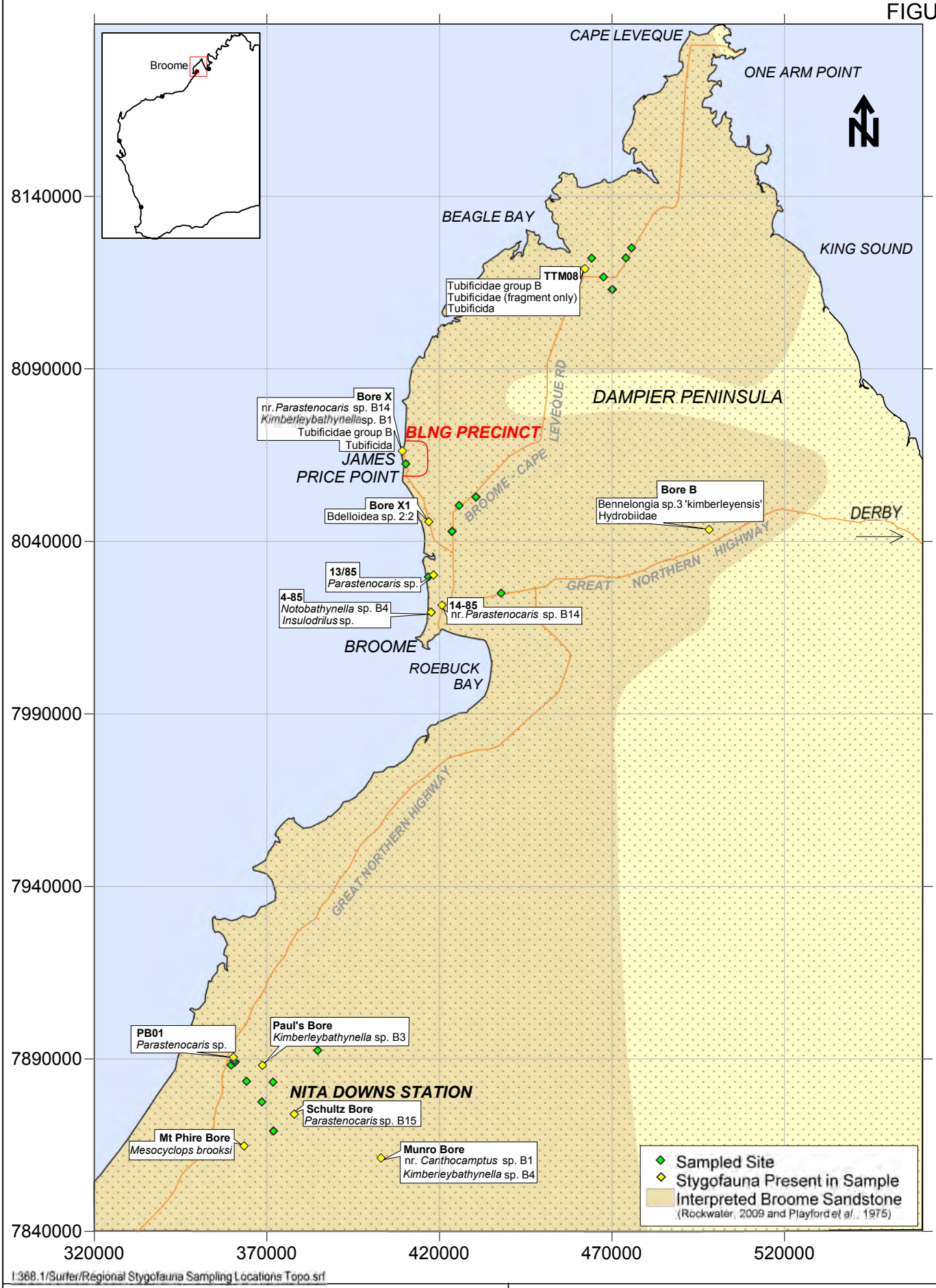
CLIENT:	Woodside Energy Ltd
PROJECT:	BLNG Precinct Stygofauna Sampling Program
DATE:	December 2011
Dwg. No:	368.1/11/2-1

WOODSIDE BLNG PROJECT
LOCALITY MAP

Rockwater PROPRIETARY LIMITED

FIGURE 2



I:368.1/Surfer/Regional Stygofauna Sampling Locations Topo.srf

CLIENT: Woodside Energy Ltd

PROJECT: BLNG Precinct
Subterranean Fauna Study

DATE: December 2011

Dwg. No: 368.1/11/2-2

REGIONAL STYGOFAUNA SAMPLING LOCATIONS AND RESULTS

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APPENDIX I

Appendix I: Stygofauna Sites – Rounds 1 - 5

Site id	Easting	Northing	Round 1 June 2011	Round 2 June 2011	Round 3 July 2011	Round 4 August 2011	Round 5 Sept/Oct 2011
Project Area							
Bore X	409285	8066200	✓		✓	✓	✓
BH6X	410267	8062435			✓	✓	✓
Sub-Total (Impact)			1	0	2	2	2
Reference							
Bore X1	416915	8045663	✓		✓	✓	✓
TPB02	470165	8112990		✓			
TTM01	470047	8112999		✓			
TTM02-1	474037	8122102		✓		✓	
TTM03	467559	8116567		✓		✓	
TTM04	464149	8122073		✓			
TTM08	462182	8119032		✓		✓	
TTM09	475705	8125016		✓		✓	
Bore B	498177	8043403					✓
4/85	417615	8019459		✓			
8/85	416825	8029645		✓			
13/85	418310	8030223		✓			
14-85	420746	8021473		✓			
3/90	437912	8024944		✓			
4B-10	425712	8050337		✓		✓	✓
HCL 5	423664	8042883					✓
HCL 5A	423664	8042883					✓
HCL6	430616	8052833					✓
HCL6A	430616	8052833				✓	
Fox's Solar	368588	7877518					✓
HB01	360774	7889042					✓
HB2	360816	7889150					✓
Junction Bore	384779	7892433					✓
MB01	360411	7889497					✓
Mt Phire Bore	363422	7864769					✓
Munro Bore	403110	7861237					✓
No3 Solar	371778	7883217					✓
No5 Bore	364108	7883485					✓
Pauls Bore	368725	7888102					✓
PB01	360307	7890474					✓
Schultz Bore	377955	7873994					✓
Station Yards Bore	359695	7888210					✓
VB01	371932	7869101					✓
VB02	371932	7869096					✓
Sub-Total (Reference)			1	13	1	7	21
Total (All Sites)			**2**	**13**	**3**	**9**	**23**

APPENDIX II

Appendix II: Water quality, site and sampling details for sites sampled in the Browse Downstream Project Pilot Study.

Site Details												Sampling Details				Water Quality									
Site id	Zone	Easting (MGA 94)	Northing (MGA 94)	Status	RL (mAHD[1])	Depth (m bgl[2])	Collar Height (m agl[3])	EOH (mAHD)	Slotted Section (m bgl[2])	WL (m bgl)	Diameter (mm)	Sampled Date	Time	Sampled For[4]	Pumped Volume (L)	Method[5]	Level (m bgl[2])	Temperature (°C)	EC (µS/cm)	Salinity (ppt)	pH	Turbidity FNU	ORP (mV)	DO (mg/L)	DO %
Round 1																									
Bore X	51	409285	8066200	Monitoring	-	25.75	0.79	-	-	15.10	150	9/06/2011	13:00	S (P+N)	160	Down-hole	-0.422	30.75	994.8	-	5.55	12.6	178	-0.78	-70
Bore X1	51	416915	8045663	Monitoring	-	27.25	0.5	-	-	6.98	150	9/06/2011	8:30	S (P+N)	300	Down-hole	-0.3	30.91	4342	-	6.69	5.8	-299	5.14	70.1
Round 2																									
TPB02	51	470165	8112990	Production	65.71	160.5	0.16	-94.63	135.83-160.05	52.04	195	22/06/2011	12:19	S (N)	-	Down-Hole	-1.0	29.53	0.146	0.1	5.43	-	229	0.07	0.9
TTM01	51	470047	8112999	Monitoring	64.5	82.9	0.1	-18.3	71.6-83.6	82.9	50	22/06/2011	6:50	S (N)	-	Down-Hole	-1.0	28.21	0.08	0	5.5	-	164	0.06	0.9
TTM02-1	51	474037	8122102	Monitoring	21.7	80.62	0.1	-58.82	68-62-80.62	10.21	50	22/06/2011	9:55	S (N)	-	Down-Hole	-1.0	28.27	0.241	0.1	5.68	-	187	0.06	0.8
TTM03	51	467559	8116567	Monitoring	44.2	59.8	0.1	-15.5	47.80-59.80	30.86	50	23/06/2011	8:30	S (N)	-	Down-Hole	-1.0	28.64	0.131	0.1	5.32	-	181	0.06	0.7
TTM04	51	464149	8122073	Monitoring	10.1	97.7	0.37	-87.23	79.64-97.64	0.17	50	22/06/2011	7:00	S (N)	-	Down-Hole	-1.0	20.93	0.161	0.1	4.59	-	225	0.07	0.7
TTM08	51	462182	8119032	Monitoring	34	46.5	0	-12.5	-	17.85	250	21/06/2011	15:30	S (N)	-	Down-Hole	-1.0	28.84	0.981	0.5	5.94	-	149	0.04	0.5
TTM09	51	475705	8125016	Monitoring	11	42.3	0.3	-31	-	2.63	150	22/06/2011	8:45	S (N)	-	Down-Hole	-1.0	27.04	0.163	0.1	5.45	-	206	0.07	0.4
4/85	51	417615	8019459	Monitoring	10	-	-	-	-	10.57	44	25/06/2011	7:01	S (N)	-	Bailed	-1.0	21.76	1.424	0.8	6.19	-	188	0.04	0.4
8/85	51	416825	8029645	Monitoring	8	21	-	-	-	10.01	44	24/06/2011	16:05	S (N)	-	Bailed	-1.0	26.32	2.195	1.2	6.17	-	177	0.08	0.8
13/85	51	418310	8030223	Monitoring	28	49.5	0.40	-21.10	-	21.87	44	24/06/2011	16:45	S (N)	-	Bailed	-1.0	24.37	0.75	0.4	5.76	-	173	0.06	0.7
14-85	51	420746	8021473	Monitoring	10	52.84	0.41	-42.43	-	4.88	44	24/06/2011	14:25	S (N)	-	Bailed	-1.0	26	1.291	0.5	6.21	-	208	0.04	0.6
3/90	51	437912	8024944	Monitoring	21	116	0.63	-94.38	-	14.61	50	25/06/2011	5:56	S (N)	-	Down-Hole	-1.0	26.66	0.598	0.3	5.94	-	165	0.06	0.6
4B-10	51	425712	8050337	-	81	83.7	0.20	-2.5	Unknown	71.09	150	23/06/2011	15:20	S (N)	-	Down-Hole	-1.0	29.55	0.604	0.3	7.12	-	-257	0.06	0.7
Round 3																									
Bore X	51	409285	8066200	Monitoring	-	25.75	0.79	-	-	15.32	150	28/07/2011	8:04	S (P+N)	564	Pump	20.0	30.98	414.7	-	4.81	1573	-	4.31	60.2
Bore X1	51	416915	8045663	Monitoring	-	27.25	0.5	-	-	7.28	150	28/07/2011	11:04	S (N)	-	-	-	-	-	-	-	-	-	-	-
BH6X	51	410267	8062435	Monitoring	8.7	47.7	0.615	-39	35.7-47.7	6.64	50	28/07/2011	15:28	S (P+N)	453.6	Pump	40	32.27	468.8	-	5.07	2848.3	-	4.73	68.5
Round 4																									
Bore X	51	409285	8066200	Monitoring	-	25.75	0.79	-	-	14.83	150	29/08/2011	9:00	S (N)	-	Down-Hole	-1.0	30.53	718.7	-	5.65	1.6	-0.75	3.09	-
Bore X1	51	416915	8045663	Monitoring	-	27.25	0.5	-	-	6.58	150	29/08/2011	11:40	S (P + N)	296	Pump	-24	32.66	3189	-	6.08	2365.8	-1.34	0.34	-
BH6X	51	410267	8062435	Monitoring	8.7	47.7	0.615	-39	35.7-47.7	6.805	50	29/08/2011	10:15	S (N)	-	Down-Hole	-1.0	30.81	681.5	-	5.78	2.1	-0.73	3.21	-
4B-10	51	425712	8050337	Monitoring	81	83.7	0.20	-2.50	Unknown	71.09	150	30/08/2011	7:00	S (N)	-	Down-Hole	-0.795	31.57	1324	-	8.01	23.1	-0.78	3.73	-
HCL6A	51	430616	8052833	Monitoring	-	177	-	-	163-175	>100	150	30/08/2011	9:15	S (N)	-	-	-	-	-	-	-	-	-	-	-
TTM02-1	51	474037	8122102	Monitoring	21.67	76.4	0.1	-54.63	68.62-80.62 (1mm)	10.21	50	31/08/2011	12:06	S (P)	378	Pump	-50	32.57	60.71	-	6.09	2864.4	-0.48	0.71	-
TTM03	51	467559	8116567	Monitoring	44.22	59.8	0.1	-15.48	47.8-59.8 (1mm)	30.86	50	31/08/2011	9:52	S (P + N)	186	Down-Hole	-1.0	31.83	288.8	-	5.47	3.7	-0.46	-0.64	-
TTM08	51	462182	8119032	Monitoring	31.07	46.5	0	-15.43	-	17.85	250	30/08/2011	14:28	S (P + N)	273	Down-Hole	-1.0	31.04	2513	-	6.28	0.1	-0.48	-1.59	-
TTM09	51	475705	8125016	Monitoring	12.58	42.3	0.3	-29.42	-	2.63	150	31/08/2011	13:09	S (P)	150	Pump	-35	33.14	376.9	-	5.75	6.4	-0.52	-1.48	-
Round 5																									
Bore X	51	409285	8066200	Monitoring	-	25.75	0.79	-	-	15.26	150	27/09/2011	7:23	S (N)	-	Down-Hole	-1.0	30.71	441.4	-	5.4	4.9	0.2	1.54	-
Bore X1	51	416915	8045663	Monitoring	-	27.25	0.5	-	-	7.485	150	27/09/2011	10:34	S (N + P)	303.6	Down-Hole	-1.023	30.78	1972	-	6.1	3.0	0.19	0.86	-
BH6X	51	410267	8062435	Monitoring	8.7	47.7	-	-39	35.7-47.7	6.82	50	27/09/2011	8:40	S (N)	-	Down-Hole	-1.111	30.72	435.6	-	5.42	22.5	0.25	3.37	-
4B-10	51	425712	8050337	Monitoring	81	83.7	0.20	-2.50	Unknown		150	26/09/2011	12:45	S (N)	-	-	-	-	-	-	-	-	-	-	-
Bore B - HMGB1	51	498177	8043403	Monitoring	73	70.03	0.70	2.97	-	6.155	160	1/10/2011	11:21	S (N + P)	322.5	Down-Hole	-1.026	29.89	100.4	-	8.47	45.9	0.18	3.2	-
HCL 5	51	423664	8042883	Monitoring	57	240	0.36	-183	160-172	34.81	155	26/09/2011	11:30	S (N)	-	Down-Hole	-1.0	31.83	315	-	9.62	1.6	0.12	1.19	-
HCL 5A	51	423664	8042883	Monitoring	57	52	0.89	5.0	46-52	34.81	80	1/10/2011	11:45	S (N)	-	Down-Hole	-0.95	31.91	943.3	-	7.29	30.0	-0.18	0.91	-

Site Details											Sampling Details				Water Quality									
Site id	Zone	Easting (MGA 94)	Northing (MGA 94)	Status	RL (mAHD[1])	Depth (m bgl[2])	Collar Height (m agl[3])	EOH (mAHD)	Slotted Section (m bgl[2])	WL (m bgl)	Diameter (mm)	Sampled Date	Time	Sampled For[4]	Pumped Volume (L)	Method[5]	Level (m bgl[2])	Temperature (°C)	EC (µS/cm)	Salinity (ppt)	pH	Turbidity FNU	ORP (mV)	DO (mg/L)	DO %
HCL 6	51	430616	8052833	Monitoring	-	213	0.83	-	125-131	>93	80	1/10/2011	12:15	S (N)	-	-	-	-	-	-	-	-	-	-	-
Fox's Solar	51	368588	7877518	Production	43	22	-	21	-	18.00		29/09/2011	8:31	S (P)	1200	Pump	-	32.05	1039	-	6.49	-	0.12	3.2	-
HB01	51	360774	7889042	Monitoring	35	23.13	0.37	11.87	-	18.18	140	28/09/2011	13:00	S (N)	-	Down-Hole	-1.607	32.54	1462	-	7.07	29.6	-0.23	1.42	-
HB2	51	360816	7889150	Production	36	27.4		8.6	-	18.64	170	28/09/2011	16:00	S (P)	880	Pump	-	32.51	1719	-	6.78	29.09	0.13	4.64	-
Junction Bore	51	384779	7892433	Production	83	82.5	0.30	0.5	-	53.62	155	30/09/2011	10:02	S (N)	-	Down-Hole	-0.894	33.07	286.1	-	4.78	0.1	0.28	3.91	-
MB01	51	360411	7889497	Monitoring	44	50	0.015	-6	-	17.15	145	28/09/2011	16:45	S (N)	-	Down-Hole	1.393	32.74	1702	-	6.72	150.9	-0.22	1.47	-
Mt Phire Bore	51	363422	7864769	Production	58	-	-	-	-	29.16	150	29/09/2011	9:25	S (P)	900	Pump	-	33	379.7	-	5.64	668.7	0.1	4.27	-
Munro Bore	51	403110	7861237	Monitoring	57	39.4	0.25	17.6	-	7.07	150	29/09/2011	16:45	S (N)	-	Down-Hole	-1.0	32.07	736.1	-	6.85	2.3	0.21	5.79	-
No3 Solar	51	371778	7883217	Production	47	27	0.17	20	-	~18	170	29/09/2011	14:30	S (P)	480	Pump	-	33.08	2374	-	6.22	4.4	0.19	3.96	-
No5 Bore	51	364108	7883485		33	16.5	0.17	16.5	-	11.64	120	29/09/2011	7:30	S (N)	-	Down-Hole	-1.513	32.38	1162	-	7.45	5.1	-0.21	1.31	-
Pauls Bore	51	368725	7888102	Production	47	31	0.24	16	-	27.29	120	30/09/2011	7:15	S (P)	306	Pump	-	31.83	2357	-	6.53	30.9	0.06	4.45	-
PB01	51	360307	7890474	Production	47	126	0.145	-79	33-123 (1mm)	19.26		30/09/2011	14:30	S (N + P)	20	Down-Hole	-1.1	32.8	1124	-	6.96	4.8	0.25	1.49	-
Schultz Bore	51	377955	7873994	Production	78	34.77	0.20	43.23	-	14.91	150	29/09/2011	11:45	S (P)	1053	Pump	-	32.19	1971	-	6.67	21.0	0.13	5.03	-
Station Yards Bore	51	359695	7888210	Production	38	?31.7	0.00	-	-	14.53	150	28/09/2011	16:00	S (P)	1040	Pump	-	32.75	1007	-	6.85	213	0.02	3.98	-
VB01	51	371932	7869101	Monitoring	55	28.05	0.32	26.95	-	18.49	120	29/09/2011	10:35	S (N)	-	Down-Hole	-1.1	32.05	597.1	-	8.02	38.0	-0.21	2.26	-
VB02	51	371932	7869096	Production	54	?25	0.17	-	-	18.32	170	29/09/2011	10:45	S (P)	1860	Pump	-	32.39	268.8	-	5.79	6.4	0.16	3.46	-

[1] m AHD = metres above Australian Height Datum
[2] m btc = metres below ground level
[3] m agl = metres above ground level
[4] S = Stygofauna, Sampling method in parenthesis (N = Net, P = Pump)
[5] Pumped samples have been taken by a representative 2L sample, therefore DO levels may not be accurate.

APPENDIX II

Appendix II: Stygofauna Sampling Effort – Rounds 6- 8

Site id	Easting	Northing	Round 6 Nov 2011	Round 7 April 2012	Round 8 June 2012
IMPACT SITES					
Bore X	409285	8066200		✓	✓
BH6X	410267	8062435		✓	✓
AD-10	411215	8064057	✓		
AD-16	411223	8063749		✓	✓
AD-20	411220	8063554		✓	✓
AD-28	411221	8063164		✓	✓
AE-10	411278	8064055	✓	✓	✓
AP-10	411788	8064054	✓		
AP-12	411824	8063949		✓	✓
AP-14	411823	8063850		✓	✓
AP-20	411822	8063550		✓	✓
AP-24	411822	8063350		✓	✓
AP-28	411823	8063159		✓	✓
AP-32	411825	8062943		✓	✓
AP-36	411828	8062763		✓	✓
F-14	410027	8063852		✓	✓
I-16	410178	8063746		✓	✓
N-4	410423	8064353		✓	✓
O-10	410470	8064057		✓	✓
P-17	410525	8063705	✓	✓	✓
P-21	410524	8063502	✓	✓	✓
P-25	410526	8063307		✓	✓
P-29	410528	8063097	✓	✓	✓
U-10	410770	8064054	✓	✓	✓
U-16	410771	8063754		✓	✓
U-20	410768	8063553	✓	✓	✓
U-31	410769	8063002	✓	✓	✓
V-25	410819	8063300		✓	✓
Sub-Total (Impact)			**9**	**26**	**26**
REFERENCE SITES					
Bore X1	416915	8045663		✓	✓
HCL 6	430616	8052833		✓	
HCL6A	430616	8052833		✓	
4B-10	425712	8050337		✓	
HCL 5A	423664	8042883		✓	
Sub-Total (Reference)			**0**	**5**	**1**
Total (All Sites)			**9**	**31**	**27**

APPENDIX III

Appendix III: Water quality, site and sampling details for sites sampled in the Browse LNG Development Phase II Stygofauna Survey.

Site Details												Sampling Details				Water Quality								
Site id	Zone	Easting (MGA 94)	Northing (MGA 94)	Status	RL (mAHD[1])	Depth (m bgl[2])	Collar Height (m agl[3])	EOH (mAHD)	Slotted Section (m bgl[2])	WL (m bgl)	Diameter (mm)	Sampled Date	Time	Sampled For[4]	Pumped Volume (L)	Method[5]	Level (m bgl[2])	Temperature (°C)	EC (µS/cm)	Salinity (ppt)	pH	Turbidity FNU	ORP (mV)	DO (mg/L)	DO %
ROUND 6																								
U-20	51	410768	8063553	Monitoring	18.62	24.92	21	0.82	15 - 21	16.21	50	1/11/2011	8:40	S (P)	211.2	Down-hole	-1.425	31.6	874.4	-	6.99	336.1	-0.78	0.8	-
P-29	51	410528	8063097	Monitoring	12.94	26	19.5	0.62	13.5 - 19.5	11.22	50	1/11/2011	11:05	S (P)	231	Down-hole	-1.387	31.28	1021	-	6.49	32.8	-0.69	1.55	-
P-21	51	410665	8063650	Monitoring	14.84	28.32	19	0.61	13 - 19	12.91	50	1/11/2011	13:00	S (P)	168	Down-hole	-1.03	31.49	787.6	-	7.68	107.5	-0.78	7.82	-
P-17	51	410525	8063705	Monitoring	15.4	21.68	20	0.47	14 - 20	13.43	50	2/11/2011	7:20	S (P)	136.5	Down-hole	-1.161	31.25	1257	-	7.9	232.5	-0.76	2.93	-
U-10	51	410770	8064054	Monitoring	20.16	?20.14	30.5	0.55	24.5 - 30.5	17.91	50	2/11/2011	12:20	S (P)	240	Down-hole	-1.235	32.11	657.5	-	8.47	344.5	-0.73	9.07	-
AE-10	51	411278	8064055	Monitoring	24.81	50	26	0.51	20.0 - 26.0	21.97	50	2/11/2011	13:55	S (P)	108	Down-hole	-1.185	32.01	1726	-	8.81	285.2	-0.82	7.59	-
AP-10	51	411788	8064054	Production	26.6	?16.32	~42[#]	0.6	-	23.94	100	3/11/2011	7:30	S (P)	351	Down-hole	-1.183	31.46	261	-	5.68	3.7	-0.49	4.75	-
AD-10	51	411215	8064057	Production	23.9	?15.62	-	-	-	-	100	3/11/2011	14:40	S (P)	1500	Pumped	-	32.24	234.2	-	5.18	188.6	-0.47	4.99	-
U-31	51	410770	8063001	Monitoring	15.25	?11.38	18	-	12 - 18	13.13	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U-20	51	410768	8063553	Monitoring	18.62	24.92	21	0.82	15 - 21	16.21	50	1/11/2011	8:40	S (P)	211.2	Down-hole	-1.425	31.6	874.4	-	6.99	336.1	-0.78	0.8	-
P-29	51	410528	8063097	Monitoring	12.94	26	19.5	0.62	13.5 - 19.5	11.22	50	1/11/2011	11:05	S (P)	231	Down-hole	-1.387	31.28	1021	-	6.49	32.8	-0.69	1.55	-
P-21	51	410665	8063650	Monitoring	14.84	28.32	19	0.61	13 - 19	12.91	50	1/11/2011	13:00	S (P)	168	Down-hole	-1.03	31.49	787.6	-	7.68	107.5	-0.78	7.82	-
P-17	51	410525	8063705	Monitoring	15.4	21.68	20	0.47	14 - 20	13.43	50	2/11/2011	7:20	S (P)	136.5	Down-hole	-1.161	31.25	1257	-	7.9	232.5	-0.76	2.93	-
U-10	51	410770	8064054	Monitoring	20.16	?20.14	30.5	0.55	24.5 - 30.5	17.91	50	2/11/2011	12:20	S (P)	240	Down-hole	-1.235	32.11	657.5	-	8.47	344.5	-0.73	9.07	-
ROUND 7																								
4B-10	51	425712	8050337	Monitoring	81.0	-	83.7	0.20	Unknown	71.07	150	12/04/2012	11:33	S (N)	-	Bailed	-2.00	31.27	832.2	532.9	7.27	210	-898[#]	2.15	30.2
AD-16	51	411223	8063749	Monitoring	23.9	50	44.5	0.55	38.5-44.5	20.76	50	26/04/2012	9:40	S (N)	-	Down-hole	-1	32.02	311.6	199.1	4.91	0.3	-899[#]	2.41	34.3
AD-20	51	411220	8063554	Monitoring	23.2	50	25.6	0.805	19.6-25.6	10.12	50	26/04/2012	10:41	S (N)	-	Down-hole	-1	31.94	417.1	266.6	6.53	887	-905[#]	0.52	7.1
AD-28	51	411221	8063164	Monitoring	21.5	50.5	42.9	0.57	36.9-42.9	18.35	50	26/04/2012	11:30	S (N)	-	Down-hole	-1	31.49	241.9	154.8	5.53	2.00	-894[#]	3.32	46.2
AE-10	51	411278	8064055	Monitoring	24.7	50	26.6	0.65	21.2-27.2	21.71	50	26/04/2012	8:40	S (N)	-	Down-hole	-1	31.73	868.5	554.1	8.22	968	-911[#]	1.17	16.4
AP-12	51	411824	8063949	Monitoring	29.0	50	32.0	0.535	26.0-32.0	25.545	50	26/04/2012	13:50	S (N)	-	Down-hole	-1	31.96	196.6	125.7	4.85	279.2	-890[#]	3.79	53.3
AP-14	51	411823	8063850	Monitoring	30.1	50.5	50.0	0.98	44.0-50.0	26.605	50	27/04/2012	14:30	S (N)	-	Down-hole	-1	31.87	244.3	156.4	5.42	0[#]	-872[#]	3.45	47.0
AP-20	51	411822	8063550	Monitoring	29.0	50	30.7	0.81	24.7-30.7	25.505	50	27/04/2012	13:40	S (N)	-	Down-hole	-1	31.88	320.7	205.4	5.51	14.9	-877[#]	1.55	21.1
AP-24	51	411822	8063350	Monitoring	27.9	52.5	29.6	0.78	23.6-29.6	24.41	50	27/04/2012	12:40	S (N)	-	Down-hole	-1	31.81	553.9	354.9	6.95	15.9	-881[#]	0.44	15.3
AP-28	51	411823	8063159	Monitoring	26.7	50	46.7	0.51	40.7-46.7	23.16	50	27/04/2012	11:03	S (N)	-	Down-hole	-1	31.95	412.2	263.6	4.78	0[#]	-876[#]	3.27	44.8
AP-32	51	411825	8062943	Monitoring	25.4	48.5	26.5	0.74	20.5-26.5	21.91	50	27/04/2012	10:10	S (N)	-	Down-hole	-1	31.78	2519	1661.0	5.71	147.6	-887[#]	3.01	41.3
AP-36	51	411828	8062763	Monitoring	24.7	58.5	26.0	0.805	20.0-26.0	21.17	50	27/04/2012	9:25	S (N)	-	Down-hole	-1	31.53	738.2	471.9	5.84	96.1	-877[#]	2.93	39.7
BH6x	51	410267	8062435	Monitoring	8.7	-	47.7	0.615	35.7-47.7	6.67	50	28/04/2012	8:55	S (N)	-	Down-hole	-1	31.58	337.1	215.8	5.20	0[#]	-870[#]	3.13	42.4
Bore X	51	409285	8066200	Monitoring	-	-	25.8	0.79	Unknown	25.75	50	28/04/2012	10:10	S (N + P)	300	Down-hole	-1	30.65	655.0	419.1	6.05	110.3	-885[#]	3.15	42.2
Bore X1	51	416915	8045663	Monitoring	-	-	27.3	0.5	Unknown	6.58	150	13/04/2012	10:10	S (N + P)	336	Down-hole	-1	31.35	1509	965.5	6.16	0[#]	-893[#]	0.97	12.9
F-14	51	410027	8063852	Monitoring	11.4	51	14.0	0.73	8.0-14.0	8.803	50	24/04/2012	11:00	S (N)	-	Down-hole	-0.9	31.14	172.9	111.1	5.55	88.9	-886[#]	1.01	13.5
HCL 5A	51	423664	8042883	Monitoring	57.0	-	52.0	0.89	46-52	34.80	80	12/04/2012*	13:40	S (N + P)	344	Bailed	-2.00	32.63	874.9	559.9	6.81	48.3	-898[#]	2.36	32.5
HCL 6	51	430616	8052833	Monitoring	130.0	-	213	0.83	125-131	114.65	80	12/04/2012	10:00	S (N)	-	Bailed	-2.00	30.02	304.9	194.0	6.97	195.6	-878[#]	1.9	25.0
HCL6A	51	430616	8052833	Monitoring	130.0	-	177	0.78	163-175	114.66	160	12/04/2012	10:50	S (N)	-	-	-	-	-	-	-	-	-	-	-
I-16	51	410178	8063746	Monitoring	12.6	50	35.0	0.95	29.0-35.0	10.12	50	25/04/2012	10:53	S (N)	-	Down-hole	-1.1	31.51	294.6	188.8	5.3	0[#]	-896[#]	2.66	36.1
N-4	51	410423	8064353	Monitoring	16.0	57	18.9	0.68	13.0-19.0	13.456	50	25/04/2012	10:00	S (N)	-	Down-hole	-0.9	31.65	642.2	410.7	7.96	260	-905[#]	0.68	9.3
O-10	51	410470	8064057	Monitoring	17.1	51	20.2	0.71	14.2-20.2	14.475	50	24/04/2012	12:20	S (N)	-	Down-hole	-1	31.65	282.2	-	5.60	292.5	-887[#]	4.01	55.2
P-17	51	410525	8063705	Monitoring	16.1	50	20.0	0.575	14.0-20.0	13.34	50	24/04/2012	9:02	S (N)	-	Down-hole	-1.1	31.26	318.0	203.4	5.86	107.8	-896[#]	3.13	42.1

Site Details												Sampling Details				Water Quality									
Site id	Zone	Easting (MGA 94)	Northing (MGA 94)	Status	RL (mAHD[1])	Depth (m bgl[2])	Collar Height (m agl[3])	EOH (mAHD)	Slotted Section (m bgl[2])	WL (m bgl[2])	Diameter (mm)	Sampled Date	Time	Sampled For[4]	Pumped Volume (L)	Method[5]	Level (m bgl[2])	Temperature (°C)	EC (µS/cm)	Salinity (ppt)	pH	Turbidity FNU	ORP (mV)	DO (mg/L)	DO %
P-21	51	410524	8063502	Monitoring	15.3	50.5	19.0	0.635	13.0-19.0	12.57	50	24/04/2012	10:00	S (N)	-	Down-hole	-1	31.96	120.1	768.0	5.06	326.8	-888#	2.3	31.4
P-25	51	410526	8063307	Monitoring	14.7	51	35.0	0.8	29.0-35.0	11.977	50	24/04/2012	8:00	S (N)	-	Down-hole	-1.1	31.45	451.2	288.6	5.18	0#	-895#	1.77	24.0
P-29	51	410528	8063097	Monitoring	13.6	58.5	19.5	0.52	13.5-19.5	10.92	50	25/04/2012	8:50	S (N)	-	Down-hole	-1	31.52	589.8	377.2	6.07	0#	-899#	2.31	31.4
U-10	51	410770	8064054	Monitoring	20.4	50	30.5	0.7	24.5-30.5	17.57	50	24/04/2012	13:19	S (N)	-	Down-hole	-0.9	31.78	476.7	304.7	5.80	8.5	-897#	1.63	22.2
U-16	51	410771	8063754	Monitoring	19.0	50	40.5	0.55	34.5-40.5	16.25	50	25/04/2012	12:15	S (N)	-	Down-hole	-1.1	31.90	656.2	419.7	6.85	5.8	-903#	0.64	8.8
U-20	51	410768	8063553	Monitoring	18.7	54	21.2	0.96	15.2-21.2	15.855	50	25/04/2012	13:03	S (N)	-	Down-hole	-1	31.7	765.4	489.8	5.62	111.9	-902#	2.15	29.3
U-31	51	410769	8063002	Monitoring	15.7	51.1	18.0	0.84	12.0-18.0	12.83	50	26/04/2012	12:50	S (N)	-	Down-hole	-1	31.81	780.0	499.4	6.14	239.8	-897#	1.1	15.3
V-25	51	410819	8063300	Monitoring	18.0	50	39.5	0.77	33.5-39.5	15.06	50	25/04/2012	13:45	S (N)	-	Down-hole	-1.1	31.78	451.9	289.2	5.57	20.9	-901#	1.1	19.3
ROUND 8																									
AD-10	51	411215	8064057	Production	23.9	?15.62	-	-	-	21.286	100	14/06/2012	8:32	-	-	Pumped	-	31.28	419.3	-	4.94	1.0	204	5.351	72.9
AD-16	51	411223	8063749	Monitoring	23.9	50	44.5	0.55	38.5-44.5	20.893	50	15/06/2012	9:45	S (N)	-	Down-hole	21.789	31.70	416.5	-	5.5	3.5	214	0.956	13.1
AD-20	51	411220	8063554	Monitoring	23.2	50	25.6	0.805	19.6-25.6	20.202	50	15/06/2012	9:06	S (N)	-	Down-hole	21.202	31.94	495.9	-	6.53	35.3	181	1.503	20.4
AD-28	51	411221	8063164	Monitoring	21.5	50.5	42.9	0.57	36.9-42.9	18.407	50	15/06/2012	8:15	S (N)	-	Down-hole	19.26	30.94	339.8	-	5.88	12.80	171	3.575	48.2
AE-10	51	411278	8064055	Monitoring	24.7	50	26.6	0.65	21.2-27.2	21.775	50	15/06/2012	10:31	S (N)	-	Down-hole	22.693	31.60	836.3	-	8.53	648.5	101	0.338	4.6
AP-10	51	411788	8064054	Production	26.6	?16.32	~42	0.6	-	23.778	100	14/06/2012	14:03	-	-	Down-hole	22.803	31.59	303.5	-	4.79	6.6	250	4.479	61.3
AP-12	51	411824	8063949	Monitoring	29.0	50	32.0	0.535	26.0-32.0	25.61	50	14/06/2012	13:19	S (N)	-	Down-hole	26.524	31.67	242.1	-	5.13	641.9	234	4.957	67.9
AP-14	51	411823	8063850	Monitoring	30.1	50.5	50.0	0.98	44.0-50.0	26.655	50	14/06/2012	12:07	S (N)	-	Down-hole	27.6145	31.76	329.8	-	5.9	10.1	201	3.335	45.7
AP-20	51	411822	8063550	Monitoring	29.0	50	30.7	0.81	24.7-30.7	25.56	50	14/06/2012	11:30	S (N)	-	Down-hole	26.526	31.78	379.8	-	5.85	318.9	198	1.881	25.8
AP-24	51	411822	8063350	Monitoring	27.9	52.5	29.6	0.78	23.6-29.6	24.467	50	14/06/2012	10:45	S (N)	-	Down-hole	25.595	31.75	647.7	-	7.45	1002.2	120	0.300	4.1
AP-28	51	411823	8063159	Monitoring	26.7	50	46.7	0.51	40.7-46.7	23.23	50	14/06/2012	10:02	S (N)	-	Down-hole	24.114	31.62	555.1	-	5.61	7.0	211	3.877	52.9
AP-32	51	411825	8062943	Monitoring	25.4	48.5	26.5	0.74	20.5-26.5	21.966	50	14/06/2012	9:33	S (N)	-	Down-hole	23.079	31.67	3403.0	-	6.04	759	191	3.601	49.2
AP-36	51	411828	8062763	Monitoring	24.7	58.5	26.0	0.805	20.0-26.0	21.225	50	14/06/2012	8:57	S (N)	-	Down-hole	22.135	31.46	832.6	-	6.24	385.6	188	3.764	51.3
BH6x	51	410267	8062435	Monitoring	8.7	-	47.7	0.615	35.7-47.7	6.703	50	12/06/2012	8:00	S (N)	-	Down-hole	8.703	31.37	489.8	-	5.42	4.3	220	1.233	15.2
Bore X	51	409285	8066200	Monitoring	17	-	25.8	0.79	Unknown	15.14	150	12/06/2012	12:23	S (N)	-	Down-hole	16.05	30.56	422.0	-	5.89	5.5	-99	0.535	9.1
Bore X1	51	416915	8045663	Monitoring	17	-	27.3	0.5	Unknown	7.428	150	12/06/2012	13:34	S (N + P)	302	Down-hole	8.625	31.15	1740.0	-	6.87	1.6	-236	0.348	6.2
F-14	51	410027	8063852	Monitoring	11.4	51	14.0	0.73	8.0-14.0	9.13	50	13/06/2012	12:30	S (N)	-	Down-hole	10.54	30.59	338.9	-	6.67	40.8	165	2.764	35.3
I-16	51	410178	8063746	Monitoring	12.6	50	35.0	0.95	29.0-35.0	10.232	50	13/06/2012	10:42	S (N)	-	Down-hole	11.145	31.46	386.9	-	5.62	6.1	199	2.669	36.2
N-4	51	410423	8064353	Monitoring	16.0	57	18.9	0.68	13.0-19.0	13.58	50	16/06/2012	8:45	S (N)	-	Down-hole	14.464	31.02	700.0	-	7.66	689.5	126	0.679	9.1
O-10	51	410470	8064057	Monitoring	17.1	51	20.2	0.71	14.2-20.2	14.63	50	16/06/2012	9:21	S (N)	-	Down-hole	15.64	31.01	367.9	-	6.18	400.4	172	4.245	57.2
P-17	51	410525	8063705	Monitoring	16.1	50	20.0	0.575	14.0-20.0	13.448	50	13/06/2012	10:32	S (N)	-	Down-hole	14.344	31.12	386.1	-	6.35	25.9	189	4.421	60.1
P-21	51	410524	8063502	Monitoring	15.3	50.5	19.0	0.635	13.0-19.0	12.705	50	13/06/2012	10:12	S (N)	-	Down-hole	11.809	31.47	163.0	-	5.76	105	193	5.42	75.0
P-25	51	410526	8063307	Monitoring	14.7	51	35.0	0.8	29.0-35.0	12.078	50	13/06/2012	9:30	S (N)	-	Down-hole	12.976	31.38	563.4	-	5.85	3.6	204	7.283	99.1
P-29	51	410528	8063097	Monitoring	13.6	58.5	19.5	0.52	13.5-19.5	10.985	50	13/06/2012	8:20	S (N)	-	Down-hole	11.918	31.13	828.0	-	6.64	18.7	209	3.027	38.1
U-10	51	410770	8064054	Monitoring	20.4	50	30.5	0.7	24.5-30.5	17.691	50	15/06/2012	11:27	S (N)	-	Down-hole	18.563	31.44	550.5	-	6.39	9.4	182	1.931	26.3
U-16	51	410771	8063754	Monitoring	19.0	50	40.5	0.55	34.5-40.5	16.336	50	15/06/2012	12:45	S (N)	-	Down-hole	17.311	31.59	779.3	-	7.46	15.8	-153	0.537	7.3
U-20	51	410768	8063553	Monitoring	18.7	54	21.2	0.96	15.2-21.2	15.965	50	15/06/2012	13:34	S (N)	-	Down-hole	16.812	31.54	877.1	-	5.96	886.9	178	2.702	37.3
U-31	51	410769	8063002	Monitoring	15.7	51.1	18.0	0.84	12.0-18.0	12.95	50	15/06/2012	14:15	S (N)	-	Down-hole	13.849	31.41	670.2	-	6.66	533	141	2.055	28.1
V-25	51	410819	8063300	Monitoring	18.0	50	39.5	0.77	33.5-39.5	15.194	50	16/06/2012	8:06	S (N)	-	Down-hole	16.017	30.98	593.5	-	5.82	5.6	182	2.702	36.4

[1] m AHD = metres above Australian Height Datum
[2] m btc = metres below ground level
[3] m agl = metres above ground level
[4] S = Stygofauna, Sampling method in parenthesis (N = Net, P = Pump)
[5] Pumped samples have been taken by a representative 2L sample, therefore DO levels may not be accurate.

APPENDIX IV

Appendix IV: Predicted species diversity analysis (EstimateS, Colwell 2009) against observed species richness and percentage of predicted total number of species.

Observed Numbers vs Diversity Estimators		Observed & Predicted sp. Richness	% Predicted Total Number of Species
Obs.	Sobs (Mao Tau)	9	
Diversity estimators	ACE Mean	10.05	89.55
	Bootstrap Mean	9.94	90.54
	Chao 1 Mean	11.0	81.82
	Chao 2 Mean	11.0	81.82
	ICE Mean	10.01	89.91
	Jack 1 Mean	10.97	82.04
	Jack 2 Mean	11.96	75.25
	MMRuns Mean	11.86	75.88
Range		9.94 - 11.96	75.25 - 90.54