URS AUSTRALIA

"PILOT SURVEY OF STYGOFAUNA -

RED HILL PROJECT"

February 2012

The ALS Water Sciences Group is part of the Environmental Division of ALS, one of the largest and most geographically diverse environmental testing businesses in the world.

CERTIFICATE OF APPROVAL FOR ISSUE OF DOCUMENTS

Client: URS Australia

Project Title: **Stygofauna Pilot Survey**

Report Title: Pilot Survey of Stygofauna – Red Hill Project

Document No: CQ212625-2011-001

Document Status: Final Version 2

Date of Issue: February 2012

Comments:

	Position	Name	Signature	Date
Prepared by:	Manager ALS Water Sciences QLD	Garry Bennison		08/09/2011
Internal Review by:	Principal Scientist	Jamie Corfield		09/09/2011
Peer Review by:	Senior Ecologist URS Australia	Angus McLeod		21/09/2011
Approved by:	Manager ALS Water Sciences QLD	Garry Bennison		28/09/2011

For further information on this report, contact:

Name: Garry Bennison

Title: Manager - ALS Water Sciences QLD

Address: PO Box 3216 Yeronga QLD 4104

Phone: 07 3859 7802

Mobile: 0407 243 139

E-mail: Garry.Bennison@alsglobal.com

Document Revision Control

Version	Description of Revision	Person Making Issue	Date	Approval
1	Working Draft 1	Garry Bennison	08/09/2011	GLB
2	Working Draft 2	Garry Bennison	28 /09/2011	GLB
3	FINAL	Garry Bennison	10/11/2011	GLB
	FINAL Version 2	Garry Bennison	16/02/2012	GLB

Ecowise Australia Pty Ltd trading as ALS Water Resources Group.

ABN 94 105 060 320

TABLE OF CONTENTS

1 Introduction

Australian Laboratory Services (ALS) was contracted by URS Australia Pty Ltd (URS) in June 2011 to analyse five stygofauna samples collected by URS from the Red Hill Project (the project) in central Queensland and to identify any stygofauna found to Order/Family level. URS required ALS to prepare a report on the findings and to specifically address the following:

- The presence and nature of any stygofauna occurring in groundwater likely to be affected by the project;
- The potential impacts on stygofauna of any changes in the quality and quantity of groundwater;
- Any mitigation measures that may be applied.

1.1 Background to Project

BM Alliance Coal Operations Pty Ltd (BMA) operates the existing Goonyella Riverside and Broadmeadow (GRB) mine complex. Environmental approval for the GRB mine complex is authorised under environmental authority MIN200491507. The mine is currently producing at a rate of approximately 14.5 million tonnes per annum (mtpa) based on a life of mine (LOM) of 57 years.

The Goonyella Riverside Mine (GRM) is an open-cut operation. The Broadmeadow Underground Mine (BRM) is a punch longwall underground mine which has been developed off an existing highwall of the open-cut operation.

In addition to the mining operation, the GRB mine complex includes two coal handling and preparation plants (CHPP) which are located at the Goonyella mine industrial area (MIA) and the Riverside MIA. The CHPP remove the non-coal materials and reduce the coal to the specified size range. Rejects are placed into designated reject dumps. Tailings are pumped to licensed tailings structures and the water is reclaimed for re-use in the CHPP and for dust suppression.

There is also a third MIA at the BRM.

Following processing, product coal is transported by rail to the BMA-owned Hay Point Coal Terminal south of Mackay from where it is shipped to markets around the world.

1.1.1 Overview of the Proposed Expansion Project

BMA proposes to expand its current coal mining operations with a new greenfield underground mine called the Red Hill Mine (RHM). The proposed development, along with increased operational efficiencies at the GRB mine complex, will increase local product coal production rate up to

approximately 32 mtpa over an estimated 25 year LOM. The project will produce a hard coking coal product for the export market.

The key elements of the project include:

- A new underground mine within mining lease application (MLA) 70421, to the east of the GRB mine complex, to target the Goonyella Middle Seam (GMS). The mine layout consists of a main drive extending approximately west to east with longwall panels ranging to the north and south.
- Extension of the existing BRM into MLA70421 involving extension of panels 14, 15 and 16.
- A network of bores and associated surface infrastructure over the underground mine footprint for incidental mine gas pre-drainage and management and goaf methane drainage.
- A ventilation system for ventilation of underground workings.
- A new MIA for the new RHM.
- A new CHPP adjacent to the Riverside MIA. The Red Hill CHPP will consist of three 1,200 tonne per hour modules.
- A conveyor system linking the RHM to the CHPP.
- Associated coal handling infrastructure and stockpiles.
- A new conveyor linking coal stockpiles to a new rail load out facility.
- Upgrades to the existing GRB site water management system to allow integration of the RHM water management. A key component of this upgraded system will be a new water storage dam, the RS1NX dam, located west of the existing GRB mine complex.
- A new accommodation village for the construction and operational workforces with capacity up to 3,000 workers.
- A bridge across the Isaac River for all-weather access. This will be located above the main drive, and will also provide a crossing point for other mine related infrastructure including water pipelines and power supply.

1.2 Stygofauna

Stygofauna are aquatic animals that live in groundwater. Communities are often dominated by crustacean invertebrates, but also contain oligochaetes, insects, other invertebrate groups, and occasionally fish. Species occur in limestone, calcrete, and fractured rock aquifers, but seem most

abundant in alluvial aquifers (Hancock and Boulton 2008) where they are likely to contribute to water quality through processes such as biochemical filtration (Hancock et al 2005). Scientifically, stygofauna are extremely valuable as they have linkages to species with no or very few surface-dwelling representatives. Examples include Bathynellacea, Thermosbanacea, and Remipeda (Humphreys 2008). Many stygofauna evolved from surface-dwelling ancestors, so are critical to improving our understanding of evolution and can be used to help understand the aridification of Australia (Humphreys 2008).

1.3 Stygofauna Ecological Requirements

Stygofauna are groundwater invertebrates intricately linked to the aquifer environment and are adapted to the relative stability of their surroundings. Compared to surface environments, groundwater fluctuates less in level and in physico-chemical variables such as electrical conductivity, temperature, and pH (Hancock et al. 2005). Groundwater is also generally lower in dissolved oxygen and has less readily available organic matter than surface water environments (Humphreys 2002). As there is no direct photosynthesis in aquifers, stygofauna rely on connections to the land surface to provide them with food. These connections may be hydrological, with infiltrating water bringing dissolved or particulate organic matter to form the basis of subterranean food webs, or it may be more direct, with tree roots that extend below the water table providing leachates or organic carbon or fine rootlets for food (Hancock et al 2005). Generally, stygofauna biodiversity is highest near the water table and declines with depth (Datry et al 2005). Stygofauna biodiversity is also higher in areas of recharge where the water table is close (< 10 m) to the land surface (Humphreys 2000; Hancock and Boulton 2008). This is because the water table is likely to have the highest concentration of oxygen and organic matter. Stygofauna still occur at considerable depth below the water table, but are fewer in number, have lower diversity, and may be different species (Datry et al 2005). In some karstic aquifers, where there is relatively high vertical exchange, or flow does not come into contact with large microbial surface areas (such as occurs in sedimentary aquifers), stygofaunal communities can occur at depths exceeding 100 m (Humphreys 2000).

In Australia, stygofauna are known from alluvial, limestone, fractured rock, and calcrete aquifers (Hancock et al 2005; Humphreys 2008). As yet, no species are known from coal aquifers apart from a copepod from central Queensland that occurred in a shallow seam adjacent to an alluvial aquifer (ALS unpublished). As stygofauna require a space to live, the porosity of the sediments, degree of fracturing, or extent of cavity development must be sufficient, as must the connectivity between the living spaces.

There are three critical factors that threaten stygofauna communities in aquifers impacted by human activity. Many species need stable conditions, and groundwater communities require links to the surface environment to provide organic matter and oxygen. It is likely that stygofauna are able to tolerate natural fluctuations in water level, electrical conductivity (EC), and temperature, and

this has been demonstrated experimentally (Tomlinson unpublished, Hancock unpublished) for stygofaunal amphipods, copepods, and syncarids. However, drawdown that is too rapid, or creates too much separation between the land surface and the water table, could lead to loss of biodiversity. Likewise, an increase in EC could also reduce biodiversity.

The third critical factor that makes stygofauna vulnerable to human activity is their high degree of endemism (Humphreys 2008). This comes about because, unlike many surface-dwelling aquatic invertebrates, stygofauna do not have aerially dispersing life stages. To migrate between areas, stygofauna must be able to swim or crawl, and any barriers to this, such as an area of lower porosity, sections of poor water quality, or other disruptions, prevent natural species migration. This also means that stygofauna are poorly equipped to re-colonise an area once it has been disturbed.

Many species of stygofauna are restricted to small geographical areas. This is particularly the case in non-alluvial aquifers such as some of the calcrete aquifers in Western Australia, where one or more species are known only from a single aquifer, or part of an aquifer (Humphreys 2002). This means that any process that threatens the aquifer, potentially threatens an entire species. There is also a high degree of endemism in alluvial aquifers, even between adjacent systems (Hancock and Boulton 2008). However, providing there is sufficient hydrological connectivity within the aquifer, and physico-chemical conditions are suitable, the distribution of species will not be restricted to small parts of an aquifer.

1.4 Processes That Threaten Stygofauna

Stygofauna are potentially threatened by activities that change the quality or quantity of groundwater, disrupt connectivity between the surface and aquifer, or remove living space. This has become a particular issue for mining proponents over the last decade or so, principally because of the perceived biodiversity value of stygofauna and the fact that little is known of their environmental water requirements.

Mining operations incorporate a range of water affecting activities in their operations, including some or all of the following (SKM 2010):

- Below water table mining;
- Water supply development (e.g. groundwater, dewatering, surface water);
- Dust suppression;
- Tailings disposal;
- Backfilling and rehabilitation works;

- Water diversions and surface sealing;
- Hazardous and dangerous goods storage; and
- Water storages including waste water ponds.

In recognition of the above mining activities, direct effects on groundwater dependent ecosystems may be as follows:

- Quantity (groundwater levels, pressures and fluxes);
- Quality (concentrations of salts and other important water quality constituents);
- Groundwater interactions (interactions between groundwater systems and between groundwater and surface systems); and
- Physical disruption of aquifers (excavation of mining pits and underground workings).

The existence and extent of these water affecting activities, and their potential impact on local to regional scale groundwater resources, will depend largely on the scale of the mining operation, mining method, and process water requirements, as well as climatic and geological setting.

1.5 Other Studies

The National Water Commission (NWC) has reported (NWC Waterlines 2011) that extensive gaps exist in our knowledge of the distribution, composition and biodiversity value of Australian stygofauna. Despite this incomplete inventory it is apparent that stygofauna are present across a variety of Australian subsurface environments and are generally characterised by high diversity and local-scale endemicity. They are also often of high scientific interest; for example, the occurrence of the only known southern hemisphere representatives of several phyletic relict lineages.

In Australia, at least 750 stygofauna species have been described (Humphreys 2008), but this is a conservative estimate of total continental biodiversity as more than 66% of known species come from just two regions of Western Australia (Humphreys 2008) and large parts of Australia remain unsurveyed. In Queensland there are approximately 40 species of stygofauna known, but this estimate will certainly increase as more surveys are conducted and taxonomic knowledge improves.

Several small surveys have confirmed at least 4 stygofaunal taxa (one Copepoda, two Bathynellacea, and one Amphipoda) live in the Bowen Basin. To date, two species are known from near Clermont, one near Collinsville, and one near Nebo. These were collected from alluvial/sedimentary aquifers rather than coal seam aquifers. The likely reason for this is that the water in the alluvial aquifers has lower EC than coal seam aquifers.

Only one stygofauna taxon is known from a coal seam aquifer - a species of harpacticoid collected from central Queensland (ALS unpublished). This specimen occurred in a shallow coal seam (50m deep), with low electrical conductivity (< 2000 uS/cm), a moderate to high amount of fracturing, and a good connection to a small alluvial aquifer.

One coal mining area that has a longer history of stygofauna sampling is the Hunter Valley, where surveys of alluvial aquifers were conducted between 2000 and 2008. Surveys of the groundwater/surface water interface along the Hunter River between Singleton and Glenbawn Dam from 2000 and 2003 found a diverse community of stygofauna (Hancock 2004). A follow-up project from 2004 to 2008 surveyed groundwater monitoring bores in agricultural areas and on several mine sites of the upper Hunter Valley (Hancock and Boulton 2008). This latter work found at least 40 taxa new to science (this number is likely to increase since not all specimens have yet been identified to species) and confirmed that stygofauna can exist in areas dominated by coal mining. It is worth mentioning that although the Hunter Valley has one of the richest known communities of stygofauna in Australia, no animals were collected from coal seams. All of the bores that contained stygofauna were in alluvial aquifers of the Hunter River and its tributaries. This may reflect a sampling bias, since most of the bores surveyed entered alluvium rather than coal seams, and the presence of stygofauna in coal seams should not be ruled out. However, it is likely that the majority of taxa in the Hunter Valley do live in alluvial aquifers, which is also likely to be the case for stygofauna in the QLD Bowen Basin.

1.6 Requirements For Sampling

Under the draft environmental impact statement (EIS) Terms of Reference (ToR) for many new or renewing projects, aquifers need to be sampled for stygofauna as follows:

- *Aquatic biology*

... "The EIS should provide a description to Order or Family taxonomic rank of the presence and nature of stygofauna occurring in groundwater likely to be affected by the Project. Sampling and survey methods should follow the best practice guideline which is currently that published by the Western Australian Environmental Protection Authority - Guidance for the Assessment of Environmental Factors No.54 (December 2003) and No.54a (August 2007)"...

- *Potential impacts and mitigation measures*

... "In any groundwater aquifers found to contain stygofauna, describe the potential impacts on stygofauna of any changes in the quality and quantity of the groundwater and describe any mitigation measures that may be applied"...

DERM requires sampling in areas where stygofauna are 'likely' to occur, and for the current project, it has been assumed that sampling is required to meet the requirements for surveys undertaken for environmental impact assessments in Western Australia (WA), as detailed in the following documents:

- WA EPA Guidance Statement No. 54, Consideration of Subterranean Fauna in Groundwater and Caves during Environmental Impact Assessment in Western Australia (EPA 2003);
- WA EPA Guidance Statement No. 54a, Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia (EPA 2007, or its revision).

DERM do not have any established (published) protocols for sampling stygofauna in QLD and adopt the WA guidelines by default. The WA Guidance Statements (EPA 2003, 2007) provide information which the WA EPA considers important when assessing proposals where subterranean fauna is a relevant environmental factor. By adopting the WA protocols for sampling stygofauna, results should be readily acceptable by DERM.

WA Guidance Statement 54 (2003) specifies that sampling should occur in at least two seasons and bores should encompass the full range of aquifer types present, with the more prospective habitats assigned significant sampling effort. The guidance statement recommends that the most efficient sampling design will include sampling 20 impact bores (i.e. those within the zone of mining impact) in two seasons spaced at least 3 months apart. This equates to a total of 40 impact bores across two sampling events within the mine footprint. An equal sampling effort using comparable methods should be expended on control bores located outside the zone of influence of the mine. As it can be difficult for mining companies to find a sufficient number of bores outside the impact area, a focus on finding sufficient bores inside the expected zone of impact is recommended. A small mesh size (50 micron) is required for stygofauna sampling to ensure the reliable collection of the smaller species of stygofauna. If stygofauna species are collected from these bores that are not known from elsewhere (e.g. previous surveys, published literature and reports), then further efforts will be needed to find these species from areas not affected by mining.

The WA guidelines do allow for the conduct of Pilot Studies where it is considered that the likelihood of finding stygofauna is very low (e.g. poor groundwater quality, historic sampling of the local area has not recovered stygofauna, lack of groundwater etc.). In the event that a Pilot Study does find stygofauna, additional survey effort is required to satisfy the full WA Guideline requirements.

2 Methodology

2.1 Sampling Protocol

Stygofauna were sampled using a purpose built plankton net with 150 micron mesh. The plankton net was lowered to the bottom of each bore and moved up and down over a distance of approximately 1 m, 3 to 5 times. The plankton net was then slowly retrieved and the entire contents of the net washed into the sampling sieve (150 micron mesh). This process was repeated up to six times where possible. The sample collected was then transferred to a sample jar filled with ethanol (100% AR Grade). ALS analysed 5 stygofauna samples 'as received' from URS at its Brisbane Laboratory.

2.2 Bore Characteristics and Sampling Sites

Eighteen groundwater monitoring bores were selected for stygofauna sampling by URS (Table 1). Only 5 of the 18 bores were able to be sampled due to a combination of landholder access issues, dry bores, piezometers installed in bores and wet ground conditions.

Table 1: Five groundwater bores were sampled for stygofauna (see highlighted rows below).

Monitoring Bore ID	Easting (m)	Northing (m)	Aquifer	Screen Interval (mbgl)	Casing Diameter (mm)	Installation Date	Depth to Water (mbgl)	Sampling Notes
GW1	600214.417	7581417.76	Moranbah Coal Measures	59-65	50	2009	12.06	Sampled with **four** retrievals due to increasing turbidity blocking net with agitation
GW2	604622.09	7590557	Tertiary Sediments	23-29	50	2009	21.84	Sampled with **three** retrievals due to increasing turbidity blocking net with agitation
GW3	596942.9	7600280	Back Creek Group	30-36	50	2009	Not measured	No access to bore due to wet ground conditions
GW6	596744.5	7596096	Back Creek Group	41-47	50	2009	Not measured	Sampled with **six** retrievals
GW7	595291.8	7592354	Quaternary Alluvium	7-10	50	2009	Not measured	No access to bore due to land access restrictions
GW9	595763.3	7588781	Back Creek Group	21-24	50	2009	Not measured	No access to bore due to land access restrictions

GW10	592738.6	7590604	Back Creek Group	21-24	50	2009	Not measured	No access to bore due to land access restrictions
39211	602622.84	7583440.4	Moranbah Coal Measures	~54-60	50	1995	14.45	Sampled with **six** retrievals
39512	601932.77	7582378.8	Moranbah Coal Measures	~54-60	50	1995	Not measured	Bore Dry
39514	601845.23	7583554.8	Moranbah Coal Measures	~54-60	50	1995	Not measured	Blockage within bore @ 3mbgl prevented sampling
40448S	603253.28	7589353.7	Moranbah Coal Measures	81-87	50	1998	Not measured	Vibrating wire piezometer installed in bore not able to be removed blocking sampling access
40942	605397.95	7589587	Moranbah Coal Measures	282-291	50	1998	Not measured	Vibrating wire piezometer installed in bore not able to be removed blocking sampling access
40952	603722.1	7589367.1	Moranbah Coal Measures	237-246	50	1998	Not measured	Vibrating wire piezometer installed in bore not able to be removed blocking sampling access
43840	605109.13	7587460.2	Quaternary Alluvium	4.05-14.35	50	2006	Not measured	Bore Dry
43841	605082.28	7587287.1	Quaternary Alluvium	9.05-15.05	50	2006	13.31	Sampled with **six** retrievals
45318	599755.33	7584383.2	Moranbah Coal Measures	55-61	50	2003	Not measured	No access to bore due to wet ground conditions
45319	599750.49	7584387.4	Tertiary Basalt	36.7-38	50	2003	Not measured	No access to bore due to wet ground conditions
45320	599919.03	7583738	Moranbah Coal Measures	46.5-55.5	50	2003	Not measured	No access to bore due to wet ground conditions

2.3 Geology

The Permo-Triassic sediments of the Bowen Basin are overlain by poorly consolidated sediments of the Tertiary Suttor Formation and by a veneer of unconsolidated Quaternary alluvium and colluvium (Table 2). Locally, the Permo-Triassic sequence comprises, in ascending stratigraphic order: the upper part of the late Permian German Creek Formation of the marine influenced Back Creek Group; and the Moranbah Coal Measures, Fort Cooper Coal Measures and Rangal Coal Measures of the late Permian Blackwater Group. All units of the Permo-Triassic sequence dip from west to east at between 3 and 5 degrees in the vicinity of the EIS study area. The target coal seams for mining in the EIS study area are contained within the Moranbah Coal Measures.

Table 2: Local Stratigraphic Sequence.

Age	Group	Unit	Lithology	Thickness (m)
Quaternary		Alluvial deposits	Residual soils and colluvium units include all blanketing sandy, loamy and clay soils	0 – 30
Tertiary		Suttor Formation	Mainly unconsolidated sand and clay alluvial deposits, minor basalt flows	
Late Permian	Blackwater	Rangal Coal Measures	Grey sandstone and siltstone, with interbedded mudstone, carbonaceous mudstone and coal	70
		Fort Cooper Coal Measures	Lithic grey sandstone, siltstone and mudstone, with thick inferior coal interbedded with carbonaceous mudstone	400
		Moranbah Coal Measures	Labile grey sandstone and siltstone, mudstone, carbonaceous mudstone and coal seams including: • Goonyella Upper Seams (GUS); • Goonyella Middle Seam (GMS); and • Goonyella Lower Seams (GLS).	200 – 300
	Back Creek	German Creek Formation	Predominantly quartzose sandstones, silty sandstone, mudstone, carbonaceous mudstone and coal	Unknown

2.3.1 Moranbah Coal Measures

The Moranbah Coal Measures, which contain the target coal seams, conformably overlie the German Creek Formation and are conformably overlain by the Fort Cooper Coal Measures. The Moranbah Coal Measures were deposited in a predominantly fluvial flood plain environment.

The lithology of the Moranbah Coal Measures is generally characterised by interbedded fine-grained lithic sandstone, siltstone, mudstone, claystone, and coal, which is uniform across the entire EIS study area. The Moranbah Coal Measures show regular grading of lithological sequences from sandstone to siltstone and mudstone to coal, then tending back to sandstone, typical of depositional flood plain / river systems.

The Moranbah Coal Measures are characterised by several laterally persistent thick coal seams interspersed with several thin minor seams, which split and coalesce. Coal occurs in four distinct horizons within the EIS study area:

- Goonyella Upper Seam (GUS);
- P seams;
- Goonyella Middle Seam (GMS); and
- Goonyella Lower Seam (GLS).

Coal of a suitable thickness and quality to be mined is confined to the GUS, GMS, and GLS, which sub-crop within the mining area.

2.3.2 Tertiary and Quaternary Formations

The EIS study area is covered by a 0.5 to 30 m thick layer of poorly consolidated Tertiary and Quaternary sediments unconformably overlying an irregular erosion surface of Permian strata. These sediments consist of lenses of river channel gravels and sands separated by sandy silts, sandy clays and clays. The Tertiary silts and clays are densely compacted and hard. Lag deposits of sand and gravel are found directly on the Tertiary/Permian unconformity, and can also be present related to recent Quaternary deposition from the Isaac River.

2.4 Geomorphology

Features of subsurface geomorphological significance have not been found in the EIS study area. The Quaternary and Tertiary formations that cover the mining area are predominantly sediments which hold no geomorphological significance. The Tertiary basalt that occurs in the west of the mining area is generally thin and extensively weathered, therefore no surface lava tubes or similar geomorphologically significant volcanic features are known to be present. Exploration drilling through basalt has not encountered voids that could be interpreted as lava tubes or lava caves.

There are no limestone or similar carbonate units on site, therefore no karst or cave systems are present.

2.5 Aquifer Occurrence

The groundwater regime in the area of the proposed project comprises Quaternary alluvial aquifers associated with the creeks and river in the area, Tertiary sediment aquifers, Tertiary basalt aquifers and Permian sedimentary rock aquifers.

The occurrence and continuity of the aquifers will be highly dependent on the spatial distribution of the corresponding geological units in the area. In general, the occurrence of the Quaternary and Tertiary aquifers is not well defined. These aquifers are summarised in more detail below.

2.5.1 Quaternary Alluvial Aquifers

Quaternary alluvial deposits in the region occur predominantly along creeks and the Isaac River. The Quaternary alluvial deposits associated with the Isaac River consist of 2-8 m of clay and sandy clay at the surface underlain by up to 15 m of sand and gravel with varying proportions of clay and silt. Potential for groundwater exists within sandy and gravelly sections of alluvium, and represents an unconfined to semi-confined aquifer. Groundwater movement within the alluvium will be predominantly via inter-granular flow.

Recharge to the shallow alluvial aquifer is likely to come from two main sources:

- seepage from creek beds and banks during strong surface water flow or flooding; and
- surface infiltration of rainfall and overland flow, where alluvium is exposed and no substantial clay barriers occur in the shallow sub-surface.

Due to their shallow depth, lack of continuity and thickness, the Quaternary alluvium is not considered a significant aquifer. However, during periods of creek flow, the alluvium may become fully saturated and discharge to sub-cropping coal seams.

2.5.2 Tertiary Sediment Aquifers

The Tertiary sediments of the region consist of lenses of palaeochannel gravels and sands separated by sandy silts, sandy clays and clays. The Tertiary sediments vary in thickness from 15 to 80 m. The silts and clays are densely compacted, hard and generally dry. Potential for groundwater exists within sandy and gravelly sections of the sediment pile, and represents an unconfined to confined aquifer depending on location. Most of the clean sand and gravel lenses are permeable but are of limited lateral and vertical extent. Groundwater movement within the Tertiary sediment will be predominantly via inter-granular flow.

Recharge to the Tertiary sediment aquifers is likely to come from surface infiltration of rainfall and overland flow, where the Tertiary sediments are exposed and no substantial clay barriers occur in the shallow sub-surface. Recharge may also occur by vertical seepage from overlying Quaternary alluvial aquifers.

The nature of the Tertiary sediment aquifers, and hence its permeability and porosity, is likely to be highly variable, depending on the proportion of fine material. A review of borehole logs for the EIS study area showed that the Tertiary stratigraphy is dominated by clays and sandy clays with isolated areas of loose sand. Historically mining issues with Tertiary sediment derived groundwaters appear to have been limited to pit wall stability rather than ongoing problems with groundwater inflow, indicating the limited lateral extent of the more permeable areas.

2.5.3 Tertiary Basalt Aquifers

Tertiary basalt exists as small discontinuous remnants to the south and in the west of the EIS study area, with a larger continuous unit to the north. The basalt is predominantly highly to extremely weathered, clayey and dry. The distribution of less-weathered, fractured and vesicular water-bearing basalt is variable. The Tertiary basalt aquifers are classed as a secondary porosity aquifer and are expected to represent unconfined to confined aquifers depending on location. Groundwater is principally stored and transmitted in the fractures, joints and other discontinuities within the rock mass.

The nature of the Tertiary basalt, and hence its permeability and porosity, is highly variable, depending on the degree of weathering and the intensity and interconnectedness of fracturing. Where the basalt is less weathered and more fractured or vesicular, the unit may have local zones of moderate to high hydraulic conductivity. Hydraulic testing at Moranbah North mine (JBT 2010) indicated the Tertiary basalt to be moderately permeable with hydraulic conductivity values ranging from one to four metres per day and storage coefficient between 1 x 10-2 and 1 x 10-4. Onsite, interpreted hydraulic conductivity values of 1.21 and 0.48 metres per day were obtained from the variable head test for the existing southern extension of the Airstrip Pit (AGE 2004) located in the southwest of the EIS study area. The drilling program undertaken as part of this Airstrip Pit groundwater study showed that the Tertiary basalt appears to be highly heterogeneous and discontinuous locally. In the area of the Airstrip Pit, the basalt intersected during drilling was generally not water-bearing; however for the few holes that did intersect measurable groundwater flows, airlift yields were at most 1.25 litres per second (L/s).

2.5.4 Permian Strata Aquifers

Primary porosity in the Permian strata is likely to be limited, as even the sandstone beds have a significant clay content. Excluding the larger scale discontinuities, such as faults, flow in this unit is therefore likely to be predominantly via fracture flow.

In common with other areas in the Bowen Basin the coal seams constitute the main aquifers in the Permian, but the jointed sandstone overburden and interburden may also be important, locally, for storage and transmittal of water. The vertical anisotropy in the Permian strata may restrict upward/downward leakage, both between layers within the Permian and from the overlying Tertiary formations and alluvium.

Recharge of coal seams is generally by direct infiltration of rainfall and overland flow in subcrop areas, and by downward leakage from overlying aquifers in the Cainozoic formations. It is considered that due to the clayey nature of the Tertiary formations unconformably overlying the coal seams, recharge from rainfall infiltration will be limited.

Testing indicates that with depth the cleats and joints in the coal are less open, with a corresponding decrease in permeability. Historically mining issues with the Permian strata derived groundwaters appear to have been limited to pit wall stability rather than ongoing problems with groundwater inflow, indicating the generally low permeability of the Permian strata on site.

Hydraulic testing of the interburden aquifers reveals that they have highly variable hydraulic conductivity from relatively pervious to highly impervious. This is evidence that the water bearing zones are heterogeneous over short distances and the very low hydraulic conductivity in some parts would isolate more conductive parts of these zones.

2.6 Laboratory Processing

Rose Bengal, which stains animal tissue pink, was added to each sample before processing to allow stygofauna (if present) to be distinguished from sediments and other organic matter and to speed up the sorting process. For initial sorting, samples were elutriated to remove most of the mineral component of the sample, and poured through a 50 µm sieve. The sieve contents, consisting of fine sediments, were spread thinly over the base of a channelled sorting tray and carefully picked to ensure all stygofauna (if present) were detected.

Sample jars were drained of ethanol and washed gently into channelled sorting trays to create a thin layer of sediment spread across the bottom of the tray. Samples were then sorted under a Leica MZ9 stereomicroscope with planachromat 10x objective lenses and a zoom capability of between 6.3x and 60x.

3 Results

3.1 Location of Sampling Sites

The groundwater regime in the area of the proposed project comprises Quaternary alluvial aquifers associated with the creeks and river in the area, Tertiary sediment aquifers, and Permian sedimentary rock aquifers. The five bores selected by URS for sampling covered all the major aquifer types located within the EIS study area (Table 1).

3.2 Bore Water Quality

The following water quality data was supplied by URS for the five bores sampled for stygofauna (Table 3). The water quality information provided indicates four of the five bores recorded a relatively low salinity concentration compatible with the existence of stygofauna (GW2 may be marginal). Bore GW6 recorded a high salinity concentration and it is less likely that stygofauna would exist in this environment. The collection method for bore water samples is detailed in the URS Red Hill Project EIS Appendix J.

Table 3: Concentrations of major ions in the five groundwater bores sampled for stygofauna

Monitoring Bore ID	Salinity	Major Ions (mg/L)						
	µS/cm	Na	Ca	K	Mg	Cl	SO4	HCO3 as CaCO3
GW1 Moranbah Coal Measures	1800	77	18	4	9	64	14	151
GW2 Tertiary Sediments	7030	212	62	3	33	165	38	509
43841 Quaternary Alluvium	650	46	35	3	14	59	14	152
39211 Moranbah Coal Measures	400	13	15	8	6	21	1	62
GW6 Back Creek Group	13700	2530	222	82	300	4820	670	434

3.3 Groundwater Fauna

The ALS Brisbane laboratory analysed 5 stygofauna samples collected by URS from within the EIS study area in central Queensland (Table 4). No stygofauna were recorded from any of the samples collected (Table 5). The samples received by ALS were notably lacking in sediment (organic and inorganic).

Table 4 : Details of stygofauna samples collected by URS Australia.

URS Bore Code	Date Collected	Date Received by ALS	Time Collected	Matrix	Collecting Agency	Sample Preservative
GW1	18/06/11	29/06/11	1615hrs	Water	URS Australia	Ethanol
GW2	18/06/11	29/06/11	1240hrs	Water	URS Australia	Ethanol
43841	18/06/11	29/06/11	1520hrs	Water	URS Australia	Ethanol
39211	18/06/11	29/06/11	1100hrs	Water	URS Australia	Ethanol
GW6	19/06/11	29/06/11	1430hrs	Water	URS Australia	Ethanol

Table 5: Results from analysis of stygofauna samples.

URS Bore Code	Date Sample Collected	Stygofauna
GW1	18/06/11	None Found
GW2	18/06/11	None Found
43841	18/06/11	None Found
39211	18/06/11	None Found
GW6	19/06/11	None Found

4 Discussion

Five groundwater samples were collected by URS from within the EIS study area in central Queensland and analysed for stygofauna by the ALS Water Sciences Group in Brisbane. There were no stygofauna present in any of the 5 samples analysed.

The following relevant information was not available to ALS at the time of preparing this report:

- The geographical location of the five groundwater bores sampled in relation to both the EIS study area and the significant local and regional hydrogeological features.
- Details of the proposed operation of the project, particularly as it relates to the local hydrogeology (i.e. proposed drawdown of aquifers).
- Overall compliance with the WA guidelines (2003 & 2007) including QA/QC protocols for sample collection.

To be suitable for stygofauna, aquifers must have sufficient porosity or fractionation for adequate living space, and have a sufficient flux of organic matter (DOC) and dissolved oxygen (Humphreys 2008). Alluvial aquifers adjacent to large permanent rivers often have suitable conditions, and can contain diverse stygofauna communities (Danielopol and Marmonier 1992; Hancock and Boulton 2008). Parts of aquifers with short hydrological transit time, such as those with a shallow water table or close to recharge areas, often have high stygofauna diversity (Datry et al 2005), as do those aquifers with tree roots entering the water table (Hancock and Boulton 2008). Groundwater bore 43841 targeted the Quaternary Alluvium and was sampled as part of this project. This bore was shallow, was low in salinity and would be highly prospective for stygofauna. The quaternary alluvial aquifers located within the EIS study area should have been a key focus of the sampling program with significant effort devoted to sampling these highly prospective aquifers at various locations within the EIS study area. The deeper Permian Strata Aquifers (particularly the Moranbah Coal Measures) also contained groundwater with relatively low salinity. These bores also have potential for containing stygofauna and require a substantial sampling effort in order to be able to conclude with some certainty about the presence/absence of stygofauna.

The absence of stygofauna from any of the project samples may be due to unsuitable geological conditions (low porosity, low hydraulic conductivity), poor water quality or an inappropriate sampling strategy (e.g. net design) or simply by chance that stygofauna were not present or were not captured at the time of sampling (hence the need for replicate sampling across seasons as required by the WA guidelines). A second round of sampling is recommended for the 2012 post-wet season in order to confirm this.

The WA guidelines do allow for the conduct of Pilot Studies where it is considered that the likelihood of finding stygofauna is very low (e.g. poor groundwater quality, historic sampling of the local area has not recovered stygofauna, lack of groundwater etc.). The project is geographically located between Clermont and Nebo in central Queensland. ALS (unpublished data) has recorded stygofauna in the Clermont region as well as the Collinsville region in addition to south of Nebo, so the presence of stygofauna in the area is established. The project, therefore, lies within a prospective area for stygofauna. The water quality of some of the alluvial and tertiary sediment aquifer bores (GW1, 39211 and 43841) were also conducive to the presence of stygofauna. However, it is considered that these locations offer relatively low opportunities for stygofauna.

Mining proposals, where stygofauna are considered to be a relevant environmental factor, need to be closely assessed with respect to the extent of the proposed groundwater drawdown zone and the likely impacts on groundwater quality. Both of these activities, over time, may cause prospective stygofauna habitat (e.g. alluvial aquifers) to be degraded or lost with the potential for significant impact on stygofauna communities.

The stygofauna sampling equipment used in this project did not conform to WA guideline No.54A (2007) requirements as a 150 micron mesh collection net and sieve was used. Many stygofauna are <0.15mm in diameter (particularly the microcrustacea) and even some of the larger stygofauna (<0.5mm) are elongate in bodyform. The WA guidelines require sampling with a very fine 50 micron mesh for the reliable collection of the smaller species of stygofauna. A larger mesh size of 150 micron may have allowed stygofauna to pass through it and be lost when processing the net sample. The use of the larger mesh net and sieve could also explain why there was very little sediment and organic matter in all five samples collected (refer section 3.3).

5 Conclusions

An initial round of sampling from 5 groundwater bores within the EIS study area found no stygofauna, and it is considered that the EIS study area offers relatively low opportunities for stygofauna. It is however recommended that a review of the stygofauna sampling strategy be undertaken and a second round of post-wet sampling be conducted in 2012. This survey would be undertaken using by experienced samplers using WA Guideline compliant equipment which includes 50 micron mesh and a solid framed net. A minimum of 10 groundwater bores would be sampled that include a focus on shallow alluvial aquifers within the EIS study area. This strategy would conform with a pilot study approach.

6 References

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE), (2004), Groundwater Depressurisation Assessment, Airstrip South Project – Goonyella, Project No. G1201.

Danielopol D.L. & Marmonier P. (1992) Aspects of research on groundwater along the Rhône, Rhine and Danube. Regulated Rivers: Research & Management 7, 5-16.

Datry T., Malard F. & Gibert J. (2005) Response of invertebrate assemblages to increased groundwater recharge rates in a phreatic aquifer. Journal of the North American Benthological Society 24, 461-477.

Hancock P.J. (2004) The effects of river stage fluctuations on the hyporheic and parafluvial ecology of the Hunter River, New South Wales. PhD Thesis, University of New England, Armidale.

Hancock P.J., Boulton A.J. & Humphreys W.F. (2005) Aquifers and hyporheic zones: Towards an ecological understanding of groundwater. Hydrogeology Journal 13, 98-111.

Hancock, P., Boulton, A., and Humphreys, W. (2005) Aquifers and hyporheic zones: toward an ecological understanding of groundwater. Hydrogeology Journal 13, 98-111.

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

Humphreys, W.F. (2000) First in, last out: Should aquifer ecosystems be at the vangard of remediation assessment ? Contaminated Site Remediation Conference, Melbourne, 4-8 December, 2000.

Humphreys, W.F. (2002) Groundwater ecosystems in Australia: an emerging understanding. Keynote address. Proceedings of the International Association of Hydrogeologists Conference, Darwin, 12-17 May, 2002.

Humphreys, W.F. (2008) Rising from Down Under: developments in subterranean biodiversity in Australia from a groundwater perspective. Invertebrate Systematics, 22, 85-102.

JBT Consulting, (2010), Grosvenor Coal Project Environmental Impact Study Groundwater Impact Assessment, Project JBTO1 007 003.

NWC (2011) Evolving Issues and Practices in Groundwater Dependent Ecosystem Management. Waterlines Report Series No.46, May 2011. SKM.

SKM (2010) Framework for Assessing Potential Local and Cumulative Effects of Mining on Groundwater Resources. Report 15: Guidelines for Conducting a Groundwater Effects Statement. Version 3, December 2010. National Water Commission.

WA EPA (2003) Guidance for the assessment of environmental factors (in accordance with the Environmental Protection Act 1986). Sampling of subterranean fauna in groundwater and caves. Guidance Statement 54. Environmental Protection Authority, Western Australia.

WA EPA (2007) Guidance for the assessment of environmental factors (in accordance with the Environmental Protection Act 1986).Sampling methods and survey considerations for Subterranean Fauna in Western Australia. Guidance Statement 54a: Technical appendix for Guidance Statement 54. Environmental Protection Authority, Western Australia.