Waratah Coal

Galilee Coal Project Supplementary EIS
Subterranean Fauna Survey

December 2012

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The objective of this study for the Galilee Coal Project (GCP) was to conduct a stygofauna survey adopting protocols defined in WA guidance statements 54 and 54a (2003 & 2007) and to identify any stygofauna recovered to Order or Family taxonomic rank as described by the scope of work in section 1.4. This study was also limited to the quality and extent of information made available to GHD at the time of undertaking the work.

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This study contains comparisons between results presented in this study and those from other related studies. It has been assumed by GHD that all data contained in those reports that have been referred to in this report are true, accurate and free from error.

Details provided in this report regarding the locations of various monitoring sites sampled as part of this study relative to GCP mine infrastructure are based on information given to GHD in the form of maps provided by Waratah Coal. GHD has assumed that those maps represent the most current mine plan.

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1. Introduction

1.1 Project Background

The Galilee Coal Project (GCP), also known as the China First Project, is a proposed new coal mine and rail link development, for which Waratah Coal is the proponent. The mine Exploration Permit for Coal areas (EPC 1040 and EPC 1079) are located around 30 km north of the township of Alpha.

Waratah Coal proposes to mine 1.4 billion tonnes of coal from MLA 70454. The mine would comprise four x 9 Mtpa longwall underground mines, two x 10 Mtpa open cut mines and two coal preparation facilities (CHPP) with a raw washing capacity of 28 Mtpa. The proposed rail construction associated with the GCP is between the mine and future stockpiling and loading facilities within the Port of Abbot Point and the Abbot Point State Development Area. Due to uncertainty regarding the location of future stockpiling and loading facilities, the limit of assessment is the boundary of the Abbot Point State Development Area. As such, the length of the rail alignment is 453 km. The rail facility would include state of the art, heavy duty standard gauge rail to support 25,000 tonne haul trains. The final rail easement would cover both rail and adjacent service road infrastructure.

An Environmental Impact Study (EIS) was developed and released by Waratah Coal in August 2011 for public comment (henceforth referred to as Waratah Coal, 2011). There were 1842 submissions received (15 from government agencies) indicating significant public interest in the GCP.

Subsequent to those comments being received, Waratah Coal sought to carry out a supplementary EIS (SEIS) to address the comments. To that end, GHD were engaged in March 2012 to carry out additional groundwater fauna monitoring as part of the GCP SEIS.

1.2 Purpose of this report

This report will be a technical report appended to the GCP SEIS. Information presented in this report will be used to address public and agency comments on the EIS with respect to issues relating to the assessment of potential impacts on groundwater fauna associated with the Waratah GCP mine.

1.3 Scope of Work

Overall the broad objective of this study was to develop and implement a study design and sampling approach that would address relevant public submission comments on the GCP EIS and to provide a technical report that could be used to inform the development of the GCP SEIS.

Groundwater fauna (stygofauna and hyporheic fauna) sampling was carried out on two occasions in 2012, from the 23rd – to 27th April and from the 21st to 26th September.

A technical report outlining the results of the above monitoring program (i.e. this report) was required by Waratah Coal. Other requirements for this report include:

- Identifying how specific GCP EIS comments have been addressed by this stygofauna study;

- A comparison of our stygofauna and hyporheic results with those of other relevant studies, in particular the GCP EIS, the AMCI South Galilee Coal Project EIS and the Hancock Coal Alpha Coal Project EIS;
- An assessment of spatial variability;
- Identify any corrections that need to be made with respect to data or statements put forward by E3 Consulting (E3) as part of the GCP EIS report; and
- Recommendations for further monitoring that could assist the development of the GCP SEIS impact assessment and the Environmental Management Plan (EM Plan).

1.4 Project Objectives

As part of the Waratah GCP EIS a baseline assessment of stygofauna was required in accordance with the Project Terms of Reference (TOR) (Queensland Government Coordinator General, 2009). GHD recommended to Waratah that sampling for the SEIS be extended to include hyporheic fauna in addition to stygofauna, as this group of subsurface animals also demonstrates groundwater dependency. By sampling both stygofauna and hyporheic fauna it was considered that the SEIS would provide a more comprehensive indicator of baseline groundwater health and would, therefore, be better able to determine any potential impacts from future mining. This recommendation was adopted by Waratah.

The aim of the baseline stygofauna and hyporheic fauna surveys was to determine if stygofauna and hyporheic fauna were present in groundwater within and adjacent to the Waratah GCP mining lease area, and within the constraints of the study design, determine the range of taxa present, their conservation significance and sustainable management strategies. The need for a comprehensive groundwater fauna survey was enhanced by the fact that the Waratah GCP mining lease area is in close proximity to the Great Artesian Basin eastern recharge area.

The study design adopted by GHD for field events conducted in April and September 2012 was based on the requirement to satisfy the Project TOR for the Galilee Coal Project (Northern Export Facility) EIS (Queensland Government Coordinator General, 2009). These can be defined 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)'. For project areas outside of the mine site, the assessment should be limited to areas where an appropriate risk assessment has determined that the project will have a material impact upon the groundwater resource"…

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"…

1.5 Relevant Project Legislation

1.5.1 Western Australian EPA Guidance Statements 54 and 54a (2003 & 2007)

DEHP requires sampling in areas where stygofauna are 'likely' to occur, and for the GCP, sampling was required to meet the requirements for surveys undertaken for Environmental Impact Assessments in Western Australia, 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).

DEHP do not have any established (published) protocols for sampling stygofauna in Queensland and adopt the WA guidelines (2003 & 2007) by default. The WA Guidance Statements provide information which the WA EPA considers important when assessing proposals where subterranean fauna is considered to be a relevant environmental factor.

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 (e.g. alluvial aquifers). The guidance statement recommends that the most efficient sampling design will include sampling 20 impact bores (i.e. those located 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 Queensland mining companies to find a sufficient number of suitable bores located outside the impact area, a focus on finding sufficient bores within the zone of impact is usually adopted.

The design of the Waratah GCP stygofauna survey conformed to WA Guidelines (2003 & 2007) with the following minor exceptions:

- Order/Family taxonomic resolution was applied as defined by DEHP generic TOR for the Waratah GCP,
- No control bores located outside the Waratah mine lease area (EPC: 1040 and 1079) were selected for sampling,
- Six hauls (where possible) were undertaken when sampling each bore for stygofauna using a 50 micron mesh net of either 40 mm or 50 mm diameter,
- Significant sampling effort was not directed at shallow, quaternary alluvial aquifers, and
- Hydrogeological data was not available prior to sampling to assist with bore selection.

None of these exceptions impacted on the efficacy of the stygofauna sampling program.

WA Guideline Statements 54 and 54a (2003 & 2007) do not include information on the sampling, and analysis of hyporheic fauna and there are no known State or National legislation/protocols that cover hyporheic sampling.

1.5.2 Environmental Protection and Biodiversity Conservation Act (1999)

The *Environment Protection and Biodiversity Conservation Act* (EPBC Act, 1999) is the Australian Government's central piece of environmental legislation. The Act provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places – defined in the Act as matters of national environmental significance. The EPBC Act is relevant to the determination of the ecological value of a Groundwater Dependent Ecosystem (GDE). If a GDE contains a threatened species as listed under this Act, the GDE is then taken to have a higher ecological value.

1.6 GDE's and Stygofauna/Hyporheic Fauna

Groundwater dependent ecosystems or GDE's is a term occurring more frequently in the scientific literature. GDE's represent a vital and significant component of the natural environment (ARMCANZ 1996; ANZECC 1996) and can be simply defined as *'ecosystems that depend on groundwater for their existence and health'* (National Water Commission). Based on this definition, GDE's explicitly include any ecosystem that depends on groundwater at any time or for any duration in order to maintain its composition and condition.

GDE's include a broad range of environments from highly specialised species and ecosystems that possess unique biotic and abiotic characteristics that 'separate' them from other ecosystems that do not rely on groundwater to survive, to more general terrestrial and aquatic ecosystems that have an opportunistic dependence on groundwater, or rely on it during times of drought (Serov *et al*, 2012). The dependence on groundwater can be variable, ranging from partial and infrequent dependence (i.e. seasonal or episodic) to total continual dependence (entire/obligate). It is often difficult, however, to determine the nature of this dependence (Parsons, 2009; Dillon *et al*, 2009). A GDE's sensitivity to change is therefore dependent in part on their reliance on, or access to groundwater as well as their ability to disperse or relocate should the groundwater regime change.

Stygofauna are entirely groundwater dependent (obligate) and are restricted to locations of groundwater discharge or within aquifers. Due to this dependence, stygofaunal communities are particularly sensitive to, and can be impacted by a range of factors that alter groundwater levels, water pressure, water chemistry and aquifer structure.

Stygofauna communities in Australia consist almost entirely of invertebrates, with the community composition often dominated by crustaceans and oligochaetes, with smaller diversities of molluscs, insects, and other invertebrate groups. The community composition is determined by a range of factors such as type of aquifer, geological/geomorphic history, size of pore spaces, water chemistry and landscape context (i.e. position within the catchment and the association with river systems and the coast). Stygofauna can occur in any aquifer with sufficient pore space and connectivity within the substrate matrix such as limestone karsts and caves, calcrete formations, lava tubes, and fractured rock aquifers, but occur most commonly in alluvial aquifers (Hancock and Boulton, 2008). Within these environments they take on the same roles as surface water aquatic invertebrates in association with the microbial/bacterial community by contributing to water quality through processes such as biochemical processing and filtration (Hancock *et al* 2005). Due to this intrinsic relationship with the physicochemical constraints of the aquifer they are considered as ideal indicators of groundwater health (Gilbert, 1994, Humphreys, 2006, Serov *et al,* 2012). Scientifically, stygofauna are extremely valuable as they have linkages to species with no or very few surface-dwelling representatives. Examples include Bathynellacea, Thermosbaenacea, and Remipedia (Humphreys, 2008). Many stygofauna species are also considered as relictual taxa or living fossils as they are representatives of ancient lineages having evolved from surface-dwelling ancestors with Gondwanan and even Pangaean connections. They are, therefore, critical to improving our understanding of the evolution of the Australian landscape (Humphreys, 2008). Stygofauna also represent a vital and significant component of the natural environment and add to our knowledge of regional, national and global biodiversity.

1.6.1 Hyporheic Fauna

Hyporheic fauna are stygofauna that inhabit the hyporheic zone which is the saturated area of sediment beneath and alongside the main channel of waterways. This zone is subject to the influence of both groundwater and surface water flows to varying degrees. Not all waterways or all sections of waterways have a hyporheic zone, particularly where subsurface geology restricts or eliminates connectivity between surface water and groundwater.

During periods of surface water flow there is extensive hydrological connectivity between surface, riparian and groundwater habitats in vertical and horizontal directions at different spatial and temporal scales (Boulton, 1993; Brunke and Gonser, 1997; Boulton *et al*, 1998). As surface flow disappears, temporary streams are often reduced to a series of isolated pools (Boulton, 1993). However, in streams with a porous substrate, pools may remain connected by subsurface flow through the hyporheic zone (Boulton, 1993; Brunke and Gonser, 1997; Boulton *et al*, 1998). As conditions continue to dry, surface pools may dry up completely, leaving a groundwater-dominated hyporheic zone beneath the stream bed.

Inhabiting the interstitial spaces in the hyporheic zone is a diverse assemblage of invertebrates termed the 'hyporheos' (Williams and Hynes, 1974). The invertebrate community of the hyporheic zone consists of surface water and groundwater fauna, as well as fauna that occur only in the hyporheic zone. As waterways dry and groundwater influence becomes more dominant, there is likely to be a change in the composition of the hyporheic fauna towards a community containing fewer taxa with strong preferences for surface water conditions. However, some more eurytolerant surface species are able to persist in the groundwater-dominated hyporheic zone and use it as a refugial habitat during periods of pool bed drying.

1.7 Terminology Used In This Report

Subterranean fauna can be classified by the degree to which they are dependent on groundwater. Those that are completely dependent on groundwater are termed stygobites/phreatobites (these animals are the focus of this report) and consist predominantly of crustaceans. Those that rely on groundwater to a lesser extent and can live in mixed surface and groundwater are termed stygoxenes or stygophiles (Marmonier *et al,* 1993). The distinction is often ambiguous because it is difficult to know the degree of surface/groundwater mixing in an aquifer (Boulton *et al,* 2003), and the classifications are regularly disputed (Sket, 2010). However, classifications based on affiliation to groundwater can be useful when assessing the conservation status of species and their vulnerability to potential impacts, and in this report we follow the system originally proposed in the mid 1800's for cave-dwelling animals (Hancock *et al*. 2005):

Stygoxenes are organisms that have no affinities with groundwater systems but occur accidentally in caves and alluvial sediments. Some planktonic groups (Calanoida Copepoda) and a variety of benthic crustacean and insect species (Simulid Fly larvae, Caenid Mayflies) may passively infiltrate alluvial sediments (Gilbert *et al*, 1994).

Edaphobites are deep soil dwelling (or endogean) species that frequently display troglomorphisms and may sometimes occur in caves. These animals are not classified as stygofauna.

Stygophiles are facultative subterranean species able to complete their whole life cycles both underground and on the surface. Stygophilic species often have populations above and below ground, with individuals commuting between them and maintaining genetic flow between these populations (Trajano 2001). Examples of stygophiles include some ostracod or copepod species.

Stygobites (Stygobionts) are obligate subterranean species restricted to subterranean environments and typically possessing character traits related to a subterranean existence (stygomorphisms) such as reduced or absent eyes and pigmentation, and enhanced non-optic sensory structures.

Phreatobites are stygobites (obligate subterranean species) restricted to 'deep' groundwater substrata of alluvial aquifers (Gilbert *et al*, 1994). All species within this classification have specialised morphological and physiological adaptations.

Stygofauna is an all-encompassing term for all animals that occur in subsurface waters, including hyporheic fauna (Ward *et al*, 2000).

Hyporheic Zone is the saturated area of sediment beneath and alongside the main channel of waterways. This zone is subject to the influence of both groundwater and surface water flows to varying degrees. Not all waterways or all sections of waterways have a hyporheic zone and the presence of an active hyporheic zone is dependent on the underlying geology which influences hydraulic connectivity.

Hyporheic Fauna are stygofauna that inhabit the hyporheic zone and consist of a diverse assemblage of surface water and groundwater fauna that can move between both aquatic environments (stygophiles), as well as specialised fauna that occur only in the hyporheic zone (stygobites).

Hyporheos is a term that describes the diverse assemblage of invertebrates that inhabit the interstitial spaces of the hyporheic zone (Williams and Hynes, 1974).

From a conservation biology perspective, stygobites/phreatobites usually face a higher risk of extinction because they are frequently short range endemic (SRE) species (Harvey, 2002). As SREs live only in a small geographical area, any impact on their range can severely reduce their population. In assessing the environmental impact of projects on subterranean species it may become important to distinguish stygobites/phreatobites from other ecological categories of subterranean fauna, but it is still critical that the range of non-stygobites also be assessed, especially in areas where few groundwater biological surveys have been conducted and the likelihood of finding new species is high.

1.8 Stygofauna Ecological Requirements

Stygofauna are intricately linked both ecologically and physiologically to the aquifer environment and are adapted to the relative stability of their surroundings. Compared to surface environments, groundwater fluctuates less both in level and 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 (< 20 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 change in community composition (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) and have been recorded at depths of 600 m to 800 m in the Edwards aquifer in Texas and near 800 m from an aquifer in Mexico.

In Australia, stygofauna are known from alluvial, limestone, fractured rock, and calcrete aquifers (Hancock *et al,* 2005; Humphreys, 2008). As yet, few species are known from coal aquifers (although this is changing as further targeted sampling is undertaken in Queensland and NSW). Ham (1982) has reported that coal seams form the major aquifers in the Bowen Basin, with overburden and floor rocks being relatively impermeable. Groundwater flow within individual coal seams is typically higher than that in surrounding sandstone and siltstone with relative hydraulic connection between these geological strata likely to occur. Depending on water quality, surface connectivity and other geological requirements identified above, coal seams can provide suitable habitat for stygofauna.

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.

1.9 Hyporheic Fauna Ecological Requirements

The flow dynamics and behaviour in the hyporheic zone (termed hyporheic flow or underflow) is recognised to be important for surface water/groundwater interactions, as well as fish spawning, among other processes.

As mentioned earlier, hyporheic fauna fall into two groups:

- Those that are episodic inhabitants and use the hyporheic zone as refugia, and
- Those that are obligate groundwater taxa and have adapted to an aquatic subterranean existence.

Despite this generalisation, there are a wide range of hyporheic life history types that fill the range between these extremes.

Essential to the survival of all hyporheic fauna is connectivity to surface water for both:

- A range of water quality issues including dissolved oxygen, and
- The supply of food sources as photosynthesis is not possible in the hyporheic zone

Many of the processes that occur and are important in aquifers are also important in the hyporheos, though the hyporheic fauna are subject to more seasonal fluctuations due to their proximity to the surface environment, and to the effects of periodic reductions to surface water flows and levels.

1.10 Other Studies

The National Water Commission (NWC) 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 phylogenetic relictual 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 un-surveyed. 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 surveys (GHD unpublished data) have confirmed the presence of stygofaunal taxa (Copepoda, Bathynellacea, and Amphipoda) in the Bowen Basin including the Central Queensland Coast region. To date, stygofaunal taxa are known from near Clermont, near Collinsville, near Glenden, near Rolleston and near Nebo (GHD unpublished data). 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 electrical conductivity (EC), porosity and connectivity than coal seam aquifers. GHD (unpublished data) has also recovered diverse and abundant stygofaunal communities from the Surat Basin in southern Queensland. Recent surveys in the Galilee Basin (GHD unpublished data) have also recovered stygofauna, however, diversity and abundance has been generally lower than from other Queensland mining regions although this may also reflect the fact that far fewer stygofauna surveys have been undertaken to date in the Galilee Basin. No attempt has yet been made to identify these animals beyond Family level so it is not clear if they represent new species (or even new genera) and what their geographic distribution might be.

Twelve stygofauna taxa have so far been recorded by GHD (unpublished data) from coal seam aquifers in Queensland which strengthens the fact that coal seam aquifers contain stygofaunal communities of significance:

- A species of harpacticoid copepod was collected from the Bowen Basin in Central Queensland (GHD unpublished). This specimen occurred in a shallow coal seam (50 m deep), with low electrical conductivity (< 2 000 µS/cm), a moderate to high amount of fracturing, and a good connection to a small alluvial aquifer,
- A species of *Notobathynella* (Syncarida), a species of Trombidiidae (water mites) and two species of Pezidae (water mites) were collected from a coal seam aquifer (89 m deep with SWL at 38.5 m) in the Galilee Basin in western Queensland. The bore recorded high groundwater quality (EC 1 505 µS/cm; pH 6.28 and DO 2.51 mg/L),
- A species of Amphipoda and a species of Cyclopoid copepod were collected from one bore from the northern Bowen Basin (GHD unpublished). The bore tapped a shallow coal seam aquifer (Fort Cooper Coal Measures 59.5 m deep) with a relatively deep water table at 33.47m and poor groundwater quality with an EC concentration of 9,975 µS/cm, and
- A species of Astigmata (water mite) from a single bore (i.e. 75 m deep and tapping a sub-artesian fractured rock aquifer described as the Cretaceous 'Styx Coal Measures') with poor groundwater quality (i.e. high salinity and low dissolved oxygen concentrations) from the Styx Basin on the Central Queensland Coast (GHD unpublished).
- A species of Astigmata, a species of Prostigmata and two species of Ostracoda from a series of groundwater bores tapping coal seams (Moranbah Coal Measures) in the northern Bowen Basin. The coal seam aquifers ranged in depth from 56 m to 154 m with a SWL ranging from

17.91 m to 64.54 m. Salinities in the bores containing stygofauna were also variable from near fresh at 132 μS/cm to 26,130 μS/cm.

One coal mining area that has a longer history of stygofauna sampling is the Hunter Valley in NSW, 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 was carried out from 2004 to 2008, and surveyed groundwater monitoring bores in agricultural areas and on several mine sites of the upper Hunter Valley (Hancock and Boulton, 2008). The 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.

Surveys were conducted in 2002 and 2003 in the Queensland Pioneer Valley by DEHP (Hancock, 2004). These surveys revealed substantial stygofauna communities with at least 19 taxa from 19 bores in an alluvial aquifer.

Preliminary observations in Queensland (Hancock and Boulton, 2008) suggest that the highest stygofauna diversity and abundance occurs in groundwater with EC less than 5,000 μS/cm, although records of some syncarid species and genera of Koonungidae in Victoria and Tasmania are adapted to exist in naturally high EC waters of 33,000 μS/cm (Serov, P. *pers comm*) and stygofauna have been recorded in salinity up to 60,000 mg/L TDS in Western Australia (Moulds, T. *pers comm*). In Queensland, stygofauna have been collected in bores with EC up to 26,000 μS/cm (GHD unpublished), so it is still quite possible to collect animals in groundwater with EC in excess of 5,000 μS/cm. Other variables thought to be favourable for stygofauna are a shallow water table (<20 m), moderate concentrations of dissolved oxygen (1-5 mg/L), and pH between 6.5 and 7.5 (Hancock and Boulton, 2008), although this range is considered quite narrow (P.Serov, pers comm). Despite these observations, surveys should be conducted across the entire water quality range for baseline studies.

1.11 Previous Stygofauna Surveys Conducted Within Waratah GCP MLA 70454

Stygofauna samples were collected on one occasion in 2010 by E3 as part of the original Waratah GCP EIS. These samples were collected by holding a 0.45 μm mesh net beneath the pumped discharge from six groundwater bores [WAR38-15(New); WAR38-15(63); WAR42-13(new); WAR42-13(80); WAR44-15(New) and WAR44-15(Retro)]. Approximately 300 L of groundwater were passed through the phytoplankton net and all retained material was preserved for later examination.

No stygofauna were recovered from this sampling program, and as the sampling methods employed did not conform with WA Guideline (2003 & 20007) requirements, supplementary stygofauna sampling using an improved study design was requested by DEHP to better inform the EIS.

1.12 Previous Stygofauna Surveys Conducted Adjacent to Waratah GCP MLA 70454

1.12.1 AMCI South Galilee Coal Project

AMCI (Alpha) Pty Ltd and Alpha Coal Pty Ltd (a subsidiary of Bandanna Energy Ltd) have recently completed an EIS for a new mine site located south-west of the township of Alpha (MLA 70453) and immediately south of Waratah GCP MLA 70454. GHD conducted comprehensive surveys of stygofauna, hyporheic fauna and troglofauna in 2011 to inform the AMCI EIS.

Two obligate groundwater species (identified as stygobites) were recovered on one occasion from two bores following the sampling of 38 groundwater bores across two distinct seasons. The study concluded that the AMCI project area did not contain a diverse and abundant (i.e. significant) stygofaunal community and that stygofauna were unlikely to be a relevant environmental factor associated with the AMCI mining project. No troglofauna or hyporheic fauna were recovered from the extensive sampling program.

1.12.2 Hancock Alpha Coal Project

Hancock Prospecting Pty Ltd recently released an EIS for the Alpha Coal Project in the Galilee Basin. The location of the proposed coal mine is approximately 30 km north of the Waratah GCP. A comprehensive stygofauna sampling program was undertaken by Australasian Resource Consultants (AARC) for the project in which 28 groundwater bores were sampled between March and June 2010. GHD undertook the analysis of the stygofauna samples and recorded the presence of one species of cyclopoid copepod from one bore sampled in March 2010. The copepod species was a cosmopolitan, surface-dwelling species that is occasionally collected from groundwater and is a widespread species known from Australia, America and Europe. AARC concluded that a significant stygofauna community was not present within the study area and that proposed mining was unlikely to impact on groundwater dependent fauna.

2. Project Methodology

2.1 Study Area

The Waratah GCP is to be located on Waratah's tenements (MLA 70454) near 'Kia Ora' approximately 13 km west and 35 km north of the town of Alpha (Figure 2-1). Waratah proposes to mine 1.4 billion tonnes of coal on these tenements. In total, Waratah holds exploration tenements over an area of 15,250 km of the Galilee Basin. The mine is expected to be developed to a capacity of 40 million tonnes per annum utilising open cut and underground (longwall) methods. Mine life is expected to be approximately 30 years.

The mine is located within the Belyando catchment, a sub-catchment of the Burdekin River (Figure 2-1). The Belyando catchment encompasses an area of approximately 73,000 km^2 and is the largest sub-catchment of the Burdekin River Basin, comprising nearly 60% of the total area. Some of the major tributaries of the Belyando River are: Mistake, Sandy and Native Companion Creeks.

2.1.1 Regional Geology Overview

The Waratah GCP is located within the Late Carboniferous-Middle Triassic Galilee Basin. The Galilee Basin has an area of approximately 247,000 km^2 and is a large scale intracratonic basin with predominantly fluvial sediment infill. It can be divided into northern and southern regions with a boundary in the vicinity of the Barcaldine Ridge extension of the Maneroo Platform.

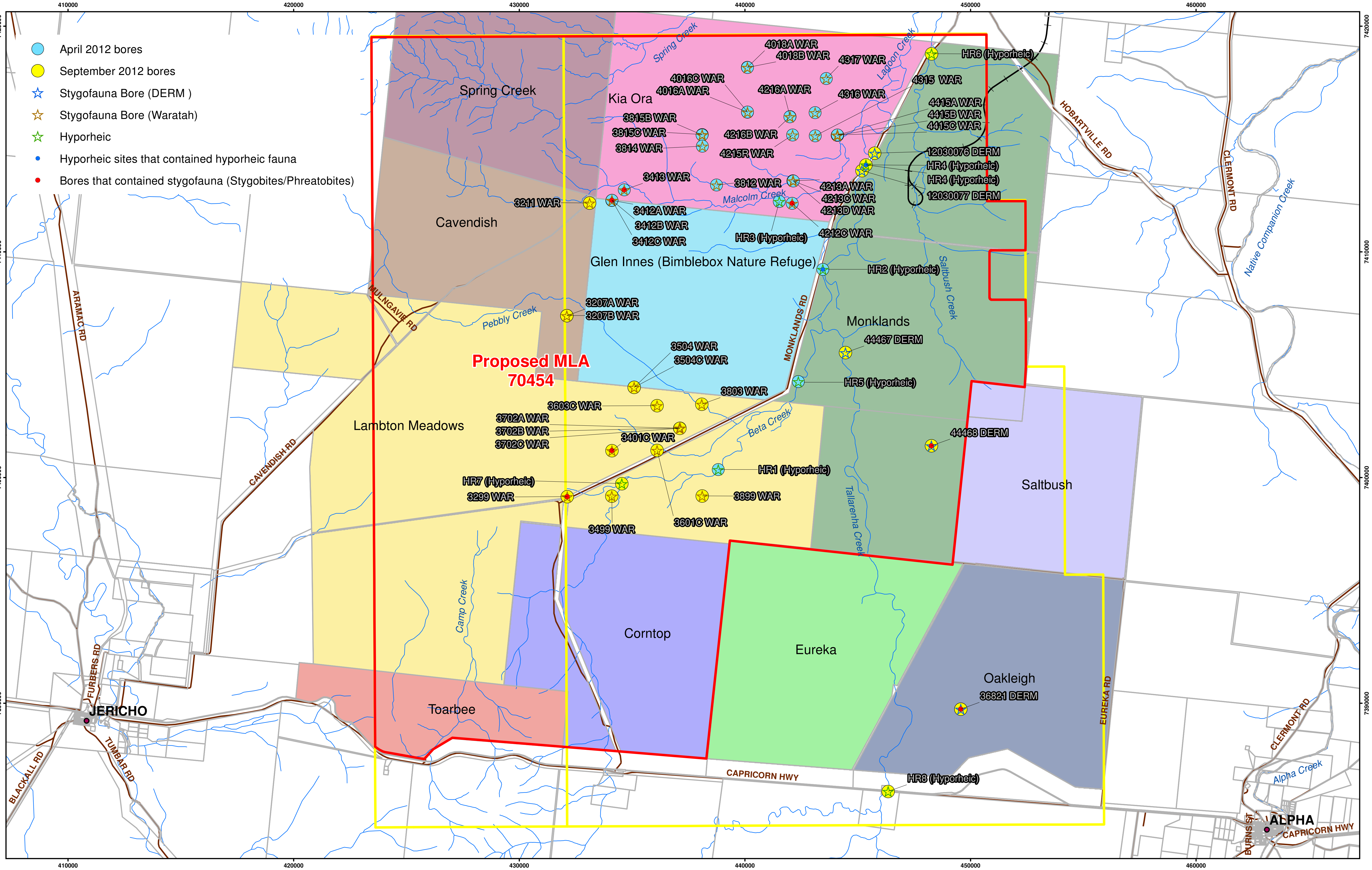
The southern Galilee Basin where the Waratah GCP is located is divided by the Pleasant Creek Arch into two depositional centres: the Powell Depression to the west and the Springsure Shelf to the east.

The rocks of the Galilee Basin are of similar age to those of the Bowen Basin (Late Permian) which are exposed to the east of the Drummond Basin. The Bowen and Galilee Basins are separated along a north-trending structural ridge between Anakie and Springsure, referred to as the Springsure Shelf. Much of the western portion of the Galilee Basin is interpreted as occurring beneath Mesozoic sediments of the Eromanga Basin. The Anakie Inlier comprises older Palaeozoic rocks.

Late Permian, coal-bearing strata of the Galilee Basin sub-crop are found in a linear, north-trending Belt in the central portion of the exposed section of the Basin and are essentially flat lying (dip generally <1º to the west). No major, regional scale fold and fault structures have been identified in regional mapping of the Waratah GCP area.

The Cainozoic unconformably overlies the Rewan Formation and Permian Sequence and the Rewan Formation only occurs in the west of the project area. The Late Permian to Early Triassic Rewan Formation unconformably overlies the Bandanna Formation. The formation is composed of terrestrial alluvial sediments including meandering channel deposits and flood-basin siltstone and sandstone units.

Both the economic and sub-economic coal seams within the project area are contained within the Permian sedimentary deposits comprising the Bandanna Formation and the underlying Colinlea Sandstone. The coal seams are named alphabetically with the uneconomic A and economic B



GALILEE COAL PROJECT (Northern Export Facility)

Waratah Coal
THE NEW ENERGY IN COAL

Mineralogy House, Level 7, 380 Queen Street, Brisbane Qld 4000, Australia

Source:	Cadastral Boundaries: DERM 2012 Roads & Waterways: Geoscience Australia 2010 Geology: Mineral and Energy Resources Location and Information Network (MERLIN) corporate database (DEEDI) 2012 Stygofauna and hyporheic fauna survey sites: GHD - Environmental (Water Resources Group) 2012 Mine Detail: Waratah Coal Pty. Ltd. 2012
Disclaimer:	This plan is based on or contains data provided by others. Waratah Coal Pty. Ltd. gives no warranty in relation to the data (including accuracy, reliability, completness, currency or suiability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to and use of the data. Data must not be used for direct marketing or be used in breach of privacy laws.
File:	File: WAR20-26-SEIS0065a-FIG2-1-STYGOFAUNA-HYPORHEIC-SURVEY-121207 Date: 7/12/2012

0 2,000 4,000 6,000 8,000 10,000
Metres
A3 Scale 1:150,000
Coordinate System: GDA 1994 MGA Zone 55 Projection: Transverse Mercator

MLA 70454
EPC1040 & Part of EPC1079
Proposed Railway Line

FIGURE 2-1: GROUNDWATER BORES & HYPORHEIC SITES USED FOR STYGOFAUNA & HYPORHEIC SAMPLING IN APRIL & SEPTEMBER 2012

seams being uppermost. The major coal seam that will be the target of mining within the deposit is the D seam.

The Late Permian Bandanna Formation ranges from a lacustrine/paludal to a fluvial deposit in the southern region of the Galilee Basin, conformably overlying the Colinlea Sandstone and interfingering with the Black Alley Shale.

The Early to Middle Permian Colinlea Sandstone unconformably overlies the Jochmus formation in the eastern and southern central Galilee Basin. Deposition of the unit occurred in an alluvial environment dominated by peat swamps and easterly and southerly flowing rivers. Sediments were derived from volcanic and metamorphic provinces to the north of the Basin's margins. Strata range from light-medium grey carbonaceous, highly argillaceous siltstone to shale interbedded with minor white to light grey, very fine to fine grained, angular to sub-rounded micaceous quartzose sandstone and coal.

2.1.2 Hydrogeology Overview

The Galilee Basin contains two major sedimentary layers. The upper layer consists of tertiary alluvial sediments and the deeper layers consist primarily of sediments of Permian age. In general, a shallow unconfined aquifer zone is located within the tertiary sediments and a multi-layered semi-confined to confined aquifer system exists within the deeper Permian sediments comprised primarily of sandstone (AMEC, 2010). The aquifers are divided into five major groups (Base of tertiary; A to B sandstone; C to D sandstone; D to E sandstone and E sandstone).

The majority of the coal seams exist within Permian sediments. Existing data on landowners bores in and around the mine indicate that the bores predominantly abstract water from the unconfined Tertiary and semi-confined to confined Permian sandstone aquifers. The shallower tertiary aquifers are not found in all areas of the mine site. Groundwater within the mine area can be broadly grouped into the aquifers specified above (AMEC, 2010), however E3 (2010) report the presence of thinner bands of groundwater in and around the various coal seams.

A data gap analysis report by Bradshaw and Bradshaw (2010) indicated the potential for reservoir storage within the Triassic sandstone sediments and the potential for aquifers to exist within the Bandanna formation. The report also suggests that vertical movement of groundwater occurs between different sedimentary layers and aquifers.

A geophysical survey conducted by E3 (2010) concluded that:

- Groundwater primarily flows in the coal seams and within the overburden/interburden immediately adjacent to the seams. Recharge occurs locally by horizontal flow rather than vertical recharge.
- Tertiary aquifers occur predominantly alongside and below surface water bodies such as wetlands and streambeds and groundwater flows to the east. Tallarenha Creek may recharge the shallow tertiary aquifer during the wet season resulting in a gradient away from the creek.

2.1.3 Great Artesian Basin

The Great Artesian Basin (GAB) is a large hydrogeological basin consisting of the Eromanga, Surat and Carpentaria Basins as well as parts of the Bowen, Surat and Galilee Basins and covers an area of 1.7 million km^2. The GAB consists of confined artesian and sub-artesian groundwater with the confined aquifers of the Basin being bounded by the Rewan Group sediments, which form the basement of the aquifers, with the Winton Formation acting as the upper confining layer. An estimated 8,700 million ML of water are contained within the GAB.

The economic coal seams associated with the Waratah GCP occur below and to the east of the Rewan Formation confining layer. The Rewan Formation aquitard, which is taken to be approximately 175 m thick, exists to the west of the Waratah GCP. It is therefore determined that there is little likelihood of the project impacting on groundwater of the GAB.

2.2 Study Design

Stygofauna sampling conducted by GHD for the Waratah GCP used methods outlined in Western Australian EPA Guidance Statements No. 54 and. 54a (2003 & 2007). There are currently no published guidelines in Australia for sampling hyporheic fauna.

The aim of the survey was to determine if stygofauna and hyporheic fauna were present in groundwater associated with the Waratah GCP, and within the constraints of the study design, determine the range of taxa present and their conservation significance. Established standard sampling techniques used in Australia and overseas (Hancock and Boulton 2008; Dumas and Fontanini 2001) were adopted for this project and all field equipment was of high quality, well maintained, fully calibrated and operated according to manufacturer's specifications. The sampling program was conducted by professionally qualified and experienced GHD aquatic ecologists (refer Section 2.5 of this report).

Two sampling events were undertaken for stygofauna and hyporheic fauna across two seasons spaced 5 months apart as follows:

- The first sampling event was undertaken during the post-wet season between 23 and 27 April 2012 and sampled 27 groundwater bores and 5 hyporheic sites. (Table 2-1).
- The second sampling event was undertaken in the pre-wet season between 21 and 26 September 2012 and sampled 18 groundwater bores and 4 hyporheic sites (Table 2-2).

2.3 Location of Sampling Bores

As indicated above, a total of 45 groundwater bores and 9 hyporheic sites were sampled for stygofauna and hyporheic fauna in April and September 2012 (Table 2-1; Table 2-2; Figure 2-1). The sampling event conducted in April 2012 was largely focused on bores located within the Kia Ora property (i.e. 25 of 27 sites) with two sites sampled on the Glen Innes property as these bores were located next to a public road. The reason that the April sampling event was restricted to the Kia Ora property was that access to bores on properties other than Kia Ora was denied by local landholders. The selection of bores sampled in April 2012 included Waratah geological exploration holes (22 sites) and water monitoring piezometers (5 sites). The GHD field team was escorted to all sites by Kelvin Sypher (Waratah GCP Project Manager and Kia Ora Property Manager).

The second round of sampling conducted in September 2012 included groundwater bores located on Cavendish, Lambton Meadows, Monkland's and Oakleigh properties located within MLA 70454 (Table 2-2). This group of bores provided much greater geographical coverage across the Waratah GCP mining lease area, including a range of different geologies and providing access to different aquifers. None of the bores sampled in April 2012 were re-sampled in September 2012. GHD requested approval through Waratah Coal to sample groundwater bores located on Spring Creek, Glen Innes, Saltbush, Eureka, Corntop and Kia Ora properties, however, access to these bores was denied by the landholders. Of the 18 sites sampled in September 2012, 13 bores were Waratah

Table 2-1: Location of 27 groundwater bores and 5 hyporheic sites (shaded rows) sampled for groundwater quality, stygofauna and hyporheic fauna in April 2012.

Bore/Site ID	Easting	Northing	Latitude	Longitude	Date Sampled	Purpose	Aquifer
4215R WAR	442116	7415183	23.37201	146.4336	24/04/2012	Exploration	Unknown
4315 WAR	443121	7415145	23.37240	146.4434	24/04/2012	Exploration	Unknown
4415A WAR	444091	7415171	23.37220	146.4529	24/04/2012	Piezometer	Unknown
4415B WAR	444115	7415172	23.37220	146.4532	24/04/2012	Piezometer	Unknown
4415C WAR	444106	7415180	23.37211	146.4531	24/04/2012	Exploration	Unknown
4216A WAR	442001	7415993	23.36470	146.4325	24/04/2012	Exploration	Unknown
4216B WAR	441995	7415986	23.36480	146.4325	24/04/2012	Exploration	Unknown
4316 WAR	443116	7416171	23.36310	146.4434	24/04/2012	Exploration	Unknown
4317 WAR	443607	7417686	23.34946	146.4483	24/04/2012	Exploration	Unknown
4016A WAR	440115	7416193	23.36283	146.4141	25/04/2012	Exploration	Unknown
4016C WAR	440114	7416201	23.36275	146.4141	25/04/2012	Exploration	Unknown
4018A WAR	440112	7418180	23.34488	146.4142	25/04/2012	Exploration	Unknown
4018B WAR	440113	7418174	23.34493	146.4141	25/04/2012	Exploration	Unknown
3815C WAR	438109	7415202	23.37170	146.3944	25/04/2012	Exploration	Unknown
3815B WAR	438106	7415183	23.37188	146.3944	25/04/2012	Piezometer	Unknown
3814 WAR	438118	7414689	23.37633	146.3945	25/04/2012	Exploration	Unknown
4213A WAR	442136	7413152	23.39037	146.4337	25/04/2012	Piezometer	Unknown
4213C WAR	442128	7413151	23.39038	146.4337	25/04/2012	Piezometer	Unknown
4213D WAR	442150	7413145	23.39043	146.4339	25/04/2012	Exploration	Unknown
4212C WAR	442097	7412152	23.39938	146.4333	25/04/2012	Exploration	Unknown
3412A WAR	434105	7412281	23.39793	146.3551	25/04/2012	Exploration	Unknown
3412B WAR	434106	7412286	23.39788	146.3551	26/04/2012	Exploration	Unknown
3412C WAR	434106	7412288	23.39787	146.3551	26/04/2012	Exploration	Unknown
3413 WAR	434658	7412750	23.39372	146.3605	26/04/2012	Exploration	Unknown
3812 WAR	438743	7412964	23.39195	146.4005	26/04/2012	Exploration	Unknown
3702A WAR	437099	7402186	23.48923	146.3844	26/04/2012	Exploration	Unknown
3702B WAR	437131	7402198	23.48912	146.3843	26/04/2012	Exploration	Unknown
HR1 (Hyporheic)	438818	7400354	23.50583	146.4007	26/04/2012	Beta Ck	Creek Bed
HR2 (Hyporheic)	4434459	7409225	23.42588	146.4465	26/04/2012	TallarenhaCk	Creek Bed
HR3 (Hyporheic)	441524	7412236	23.39861	146.4277	26/04/2012	Malcolm Ck	Creek Bed
HR4 (Hyporheic)	445365	7413855	23.38413	146.4653	26/04/2012	Lagoon Ck	Creek Bed
HR5 (Hyporheic)	4423368	7404256	23.47071	146.4356	26/04/2012	Beta Ck	Creek Bed

Table 2-2: Location of 18 groundwater bores and 4 hyporheic sites (shaded rows) sampled for groundwater quality, stygofauna and hyporheic fauna in September 2012 (ND = No Data)

Bore/Site ID	Easting	Northing	Latitude	Longitude	Date Sampled	Purpose	Aquifer
44467 DERM	444458	7405534	23.45918	146.45620	22/09/2012	Windmill	Tertiary Undefined
44468 DERM	448270	7401410	22.44236	146.49360	22/09/2012	Windmill	Tertiary Undefined
12030077 DERM	445187	7413599	23.38635	146.46360	22/09/2012	Piezometer	Tertiary Undefined
12030076 DERM	445752	7414375	23.38110	146.46820	22/09/2012	Piezometer	Tertiary Undefined
36821 DERM	449573	7389740	23.60208	146.50570	22/09/2012	Production	Unknown
3207B WAR	432106	7407176	23.44397	146.33530	23/09/2012	Exploration	Unknown
3207A WAR	432106	7407176	23.44397	146.33530	23/09/2012	Exploration	Unknown
3211 WAR	433121	7412168	23.39891	146.34550	23/09/2012	Exploration	Unknown
3401C WAR	434111	7401191	23.49811	146.35470	24/09/2012	Exploration	Unknown
3504C WAR	435096	7404003	23.47274	146.36440	23/09/2012	Exploration	Unknown
3504 WAR	435096	7404003	23.47274	146.36440	23/09/2012	Exploration	Unknown
3603C WAR	436106	7403184	23.48018	146.37430	23/09/2012	Exploration	Unknown
3803 WAR	438092	7403249	23.47967	146.39380	23/09/2012	Exploration	Unknown
3702C WAR	437116	7402181	23.48927	146.38420	24/09/2012	Exploration	Unknown
3601C WAR	436112	7401207	ND	ND	24/09/2012	Exploration	Unknown
3299 WAR	432129	7399152	23.51644	146.33520	25/09/2012	Exploration	Unknown
3499 WAR	434105	7399182	23.51624	146.35450	25/09/2012	Exploration	Unknown
3899 WAR	438110	7399186	23.51636	146.39380	25/09/2012	Exploration	Unknown
HR4 (Hyporheic)	445365	7413855	23.38413	146.46530	23/09/2012	Lagoon Ck	Creek Bed
HR6 (Hyporheic)	448277	7418785	23.33969	146.49482	26/09/2012	Saltbush Ck	Creek Bed
HR7 (Hyporheic)	434546	7399733	23.51127	146.35889	26/09/2012	Beta Ck	Creek Bed
HR8 (Hyporheic)	446352	7386091	23.63495	146.47401	26/09/2012	Tallarenha Ck	Creek Bed

geological exploration holes, two were DERM bores attached to windmills, two were DERM piezometers and one DERM bore was an active water production bore. The GHD field team was escorted to all sites by Jochen Schmidt (Waratah GCP Project Geologist). Formal approval was granted to GHD to sample DERM groundwater bores located on MLA 70454 following the submission of an application to DERM for ‘Access to Departmental Groundwater Monitoring Sites’. DERM provided GHD with a groundwater bore access key.

2.3.1 Selection of Groundwater Bores for Stygofauna Sampling

The criteria adopted by GHD for the selection of groundwater bores for stygofauna sampling for the Waratah GCP were as follows:

- Aperture of 50 mm diameter or greater;
- Intersect the water table;
- Lined or unlined, but if lined, then slotted through the water column;
- Vertical (not angled);
- Geographically spread across MLA 70454 and include reference bores outside the potential zone of impact (i.e. water drawdown zone);
- Cover all hydrogeological units present, including a focus on shallower alluvial aquifers (where available);
- Of varying age, in excess of six months, and preferably undisturbed (i.e. not regularly pumped or purged); and
- Include a high number of bores (if possible) with a salinity less than 5,000 µS/cm EC (and preferably less than 1,500 µS/cm EC), a DO of $\geq$1 mg/L and pH within the range 6.5 to 7.5.(Hancock et al 2008).

2.3.2 Selection of Sites for Sampling Hyporheic Fauna

The criteria adopted by GHD for the selection of sites for hyporheic sampling for the Waratah GCP were as follows:

- A substrate of sand or gravel or similar material which allowed connectivity between the surface environment and the hyporheic zone;
- A substrate that did not consist of low or impermeable material, such as clay and/or bedrock;
- A Creek/River that was not flowing
- Areas of creek bed that contained damp sand/gravel, often located on the outside of a bend or in a depression in the sand bed.

2.4 Field Sampling and Sample Processing Methodology

2.4.1 Stygofauna Sampling

A 50 mm diameter phreatobiological net was used for stygofauna sampling in all groundwater bores that were greater than 50 mm in diameter. For bores that were 50 mm in diameter a 40 mm diameter net was used for stygofauna sampling (GHD nets conform to WA guideline [2003 & 2007] specifications). Nets were made of 50 µm nybolt mesh material and weighted at the bottom with a brass fixture and an attached plastic collecting jar. The net was lowered to the bottom of the bore, bounced three to five times to dislodge resting animals, and slowly retrieved (Plate 2-1). At the top of each haul, the collecting jar was rinsed into a 50 µm mesh brass sieve and the net lowered again. Once six hauls were completed (the aim was always to collect between 4 and 6 hauls with all hauls reaching the bottom of the bore), the entire sieve contents were transferred to a labelled sample jar and preserved in 100% AR Grade ethanol (to allow for future DNA analysis if required).

A small amount of Rose Bengal, which stains animal tissue pink, was added to each sample to aid sample processing

The same stygofauna sampling methodology and field equipment was used for both Waratah GCP sampling events conducted in April and September 2012.

Plate 2-1: Stygofauna sampling of a Waratah GCP groundwater bore in September 2012 (**Photo:** GHD Water Sciences).

2.4.2 Hyporheic Sampling

Hyporheic sampling was undertaken using Karaman-Chappuis pits (Malard *et al*, 2001). A Karaman-Chappuis pit consists of a hole excavated into the river bed until the bottom of the hole extends below the water table. The pit is dug using a spade at points considered likely to be near groundwater. The groundwater that fills the pit is then collected and poured through a 50 µm mesh brass sieve and the contents preserved in 100% AR Grade ethanol (Plate 2-2). A small amount of Rose Bengal, which stains animal tissue pink, was added to each sample to aid sample processing.

The same hyporheic sampling methodology and field equipment was used for both Waratah GCP sampling events conducted in April and September 2012.

2.4.3 Laboratory Processing of Field Samples

Stygofauna and hyporheic fauna sample containers were drained of ethanol and stain and washed gently into channelled Sedgwick-Rafter counting 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 plan achromatic 10x objective lenses and a zoom capability of between 6.3x and 60x. All aquatic animals were removed, and identified to Order/Family level (or lower taxonomic rank if possible) in accordance with Waratah GCP TOR and placed in labelled, polyethylene containers filled with 100% AR Grade ethanol for long-term storage at GHD's specialist aquatic ecology laboratory in Brisbane.

Plate 2-2: Hyporheic fauna sampling at Lagoon Creek in September 2012 (**Photo:** GHD Water Sciences)

2.4.4 Groundwater Quality Sampling

Groundwater samples were collected using a bailer lowered by hand to approximately 3 m below the water surface prior to stygofauna sampling. Water was measured for temperature (^{o}C), pH, electrical conductivity (µS/cm) and dissolved oxygen (% saturation) using a YSI 556 multi-parameter water quality meter in order to provide a general estimate of standing groundwater quality. It is understood that water samples collected by hand bailing may not provide as accurate a measurement of true groundwater quality as groundwater samples collected using standard pumping protocols (e.g. AS/NZS 5667.11.1998).

Groundwater sampling preceded biological sampling to ensure the groundwater contained within the bore was undisturbed. The YSI field meter was calibrated in the laboratory prior to its use in the field, with calibrations regularly cross-checked in the field. The meter was used in accordance with the manufacturer's specifications.

In addition to *in-situ* water quality, measurements were also collected from each groundwater bore on depth to water table (using a Solinst electronic dip probe), depth to end of hole (where possible), bore diameter and construction, purpose of bore, GPS location and bore ID, presence of tree roots, surrounding land use, sampling date, time and sampling team. A photographic record of each bore and surrounding land use was also collected. All field data were recorded on specialised GHD recording sheets.

2.5 GHD Project Personnel

Both field sampling events (April and September 2012) were supervised by Garry Bennison (BSc.Hons. MAIBiol). Field assistance was provided by Zachariah Billingham in April and Tara Steele in September. Garry Bennison is a Principal Scientist with GHD in Queensland and has in excess of 30 years' experience as an aquatic ecologist and 8 years' experience working specifically on stygofauna, hyporheic fauna and troglofauna projects in WA, NSW, VIC and QLD. Garry has designed, conducted and managed stygofauna projects in Queensland's Bowen, Galilee, Surat and

Styx Basins. Zach Billingham is an Environmental Scientist with GHD in Victoria and has 4 years' experience as an aquatic ecologist including working with both surface water and groundwater ecosystems. Tara Steele is an Environmental Scientist with GHD in Queensland and has 4 years' experience working as an aquatic ecologist with an emphasis on waterway and wetland management.

Laboratory processing of samples, including stygofauna taxonomy, was undertaken by GHD Senior Taxonomist Gavin Williams (Advanced Diploma of Aquatic Resource Management) with independent taxonomic QA/QC provided by Dr Peter Serov (BSc.Hons. PhD) NSW DPI Office of Water. Mark Dahm, GHD Environmental Scientist, prepared the written report for this project.

3. Results

3.1 Groundwater Bore Selection

The bores selected for stygofauna sampling for the Waratah GCP achieved most of the key selection criteria outlined in Section 2.3.1 of this report. The 45 groundwater bores that were sampled across two events in April and September 2012 were geographically well spread across the mine lease area (MLA 70454) (Figure 2-1). As the hydrogeological report for the Waratah GCP SEIS was not complete at the time of bore selection for the stygofauna program, it is not clear what hydrogeological units were present within the mine lease area and what aquifers were intersected by the 45 bores that were selected for stygofauna sampling. Alluvial aquifers, however, were under represented in the makeup of bores chosen for sampling.

Bore age was not an issue for the sampling program with all bores sampled being in excess of three years old, and two DERM bores being in excess of 112 years old. It is recommended, although not totally essential, for bores to be around 6 months old prior to sampling in order to increase the likelihood of collecting stygofauna as it usually takes some time (nominally 6 months) for a bore to stabilise following drilling and purging, for water quality within the bore to reach an equilibrium with the aquifer (i.e. pH, turbidity, breakdown of toxicants etc.) and for stygofauna to fully populate the bore environment (assuming they are present in the aquifer). It is also advantageous to select bores for stygofauna sampling that are not regularly pumped or purged, as this activity can disturb the groundwater bore environment and make it less suitable for stygofauna. In September 2012 two DERM bores (44467 and 44468) had fixed pumps attached which were operating at the time of sampling (see report cover photo).

3.2 Hyporehic Site Selection

Based on the site selection criteria for hyporheic sampling outlined in Section 2.3.2 of this report, waterways within the Waratah GCP mine lease area were first identified that had a porous rocky/gravel/sand substrate that would allow good connectivity between surface and groundwater and which potentially could contain an active hyporheic zone. Five creeks were nominated for sampling (Beta Creek, Tallarenha Creek; Malcolm Creek; Lagoon Creek and Saltbush Creek) and a total of 8 individual sites on these five creeks were sampled in the 2012 post wet (April) and pre-wet (September) seasons. At each selected site up to three Karaman-Chappuis pits (Malard et al, 2001) were dug into the creek bed. Where possible, each pit was dug approximately 60 cm in diameter and 60 cm deep, although local geology often influenced this.

Only one of the eight sites sampled (Lagoon Creek HR4 was sampled in both April and September 2012) contained a true hyporheic zone (Plate 2-2). The remaining seven sites all had a confining (impermeable) layer of clay approximately 30 cm below the creek bed. At these sites there was no standing water indicating that the local water table had receded beneath the clay layer and a hyporheic zone was absent at these locations (Plates 3-1 and 3-2).

Plates 3-1 and 3-2: Karaman-Chappuis pits dug into Beta Creek (left) and Tallarenha Creek (right) showing confining clay layer beneath the creek bed (**Photo:** GHD Water Sciences)

3.2.1 Sampling Effort and Quality of Samples

A total of 45 distinct groundwater bores were sampled for stygofauna across April and September 2012. The quality of stygofauna samples collected is summarised in Table 3-1 and Table 3-2 below. The sampling method aimed to collect between 4 and 6 replicate hauls off the bottom of each bore.

Overall, high quality samples were collected from 35 of 45 bores that were sampled (i.e. 78%) in April and September 2012, which is a good return for a significant sampling effort.

3.3 Groundwater Quality

A total of 45 groundwater bores were sampled for *in-situ* water quality in April and September 2012. All groundwater bores were hand bailed (not purged) with water collected approximately 3 m below the water table level where possible in order to provide an assessment of standing water quality. *In-situ* groundwater chemistry results, therefore, may not provide a totally accurate reflection of aquifer groundwater quality.

The water table varied across the Waratah GCP mine lease with three distinct SWL ranges evident as follows (Tables 3-3 and 3-4):

- 15 bores recorded a SWL <20 m.
- 23 bores recorded a SWL between 25 m and 35 m, and
- 7 bores recorded a SWL >40 m.

Stygofauna in QLD have been reported to prefer shallow water tables, generally less than 20 m (Hancock and Boulton, 2008).

Groundwater temperatures ranged between 23.60°C at site 3412A WAR in April 2012 and 28.84°C at DERM site 12030076 in September 2012, with a mean water temperature across all 45 bores of 26.17°C. These values would be considered normal for groundwater (Tables 3-3 and 3-4).

pH showed little variation across all 45 groundwater bores and ranged between 6.24 at site 3412B WAR in April 2012 and 8.35 at site 3499 WAR in September 2012, with a mean pH across all 45 bores of 7.24 (Tables 3-3 and 3-4). Stygofauna have been reported in QLD to prefer pH in the range of 6.5 to 7.5 (Hancock and Boulton, 2008). A total of 31 groundwater bores (or 69%) recorded a pH within this range.

Electrical Conductivity (EC) was generally low across all 45 groundwater bores and ranged between 476 µS/cm at DERM site 12030077 in September 2012 and 14,412 µS/cm at DERM site 12030076, with a mean EC concentration of 3,475 µS/cm across all 45 groundwater bores (Tables 3-3 and 3-4). Stygofauna have been reported in QLD to prefer an EC concentration less than 5,000 µS/cm (Hancock and Boulton, 2008). A total of 31 groundwater bores (69%) recorded an EC value less than 5,000 µS/cm.

Dissolved oxygen concentrations varied considerably across all 45 bores with a mean concentration of 21.3% saturation which is considered normal for groundwater. DO values should only be used as indicative of true oxygen levels since water was collected using a hand operated bailer and would have received some agitation and artificial oxygenation during collection.

Very little variation was observed in ranges and mean values for SWL, pH, DO, EC and water temperature between sampling events conducted in April and September 2012. No seasonal trends were evident.

Table 3-1: Summary of sampling effort and quality of stygofauna samples collected from Waratah GCP bores in April 2012.

Bore ID	No. of Replicate Samples	Comments
4215R WAR	4	Good sample. All hauls off bottom of bore.
4315 WAR	4	Good sample. All hauls off bottom of bore.
4415A WAR	4	Good sample. All hauls off bottom of bore.
4415B WAR	4	Good sample. All hauls off bottom of bore.
4415C WAR	4	Good sample. All hauls off bottom of bore.
4216A WAR	4	Good sample. All hauls off bottom of bore.
4216B WAR	4	Good sample. All hauls off bottom of bore.
4316 WAR	4	Good sample. All hauls off bottom of bore.
4317 WAR	4	Good sample. All hauls off bottom of bore.
4016A WAR	4	Good sample. All hauls off bottom of bore.
4016C WAR	4	Good sample. All hauls off bottom of bore.
4018A WAR	4	Good sample. All hauls off bottom of bore.
4018B WAR	4	Good sample. All hauls off bottom of bore.
3815C WAR	4	Good sample. All hauls off bottom of bore.
3815B WAR	4	Good sample. All hauls off bottom of bore.
3814 WAR	4	Good sample. All hauls off bottom of bore.
4213A WAR	4	Good sample. All hauls off bottom of bore.
4213C WAR	4	Good sample. All hauls off bottom of bore.
4213D WAR	4	Good sample. All hauls off bottom of bore.
4212C WAR	4	Good sample. All hauls off bottom of bore.
3412A WAR	2	Poor sample. Net jamming. Samples not off bottom of bore.
3412B WAR	4	Good sample. All hauls off bottom of bore.
3412C WAR	6	Good sample. All hauls off bottom of bore.
3413 WAR	4	Good sample. All hauls off bottom of bore.
3812 WAR	4	Good sample. All hauls off bottom of bore.
3702A WAR	4	Average sample. Bore collapsed at ~ 37 m. Only 10m water.
3702B WAR	4	Good sample. All hauls off bottom of bore.

Table 3-2: Summary of sampling effort and quality of stygofauna samples collected from Waratah GCP bores in September 2012.

Bore ID	No. of Replicate Samples	Comments
44467 DERM	1	Poor sample. Fixed operating pump attached to bore. Pump head restricted sampling off bottom of bore. Net jammed and ripped.
44468 DERM	3	Poor sample. Fixed operating pump attached to bore. Pump head restricted sampling off bottom of bore.
12030077 DERM	6	Good sample. All hauls off bottom of bore
12030076 DERM	4	Good sample. All hauls off bottom of bore.
36821 DERM	6	Good sample. All hauls off bottom of bore
3207B WAR	4	Average sample. Bore collapsed at 80m.
3207A WAR	4	Average sample. Bore collapsed at 82m.
3211 WAR	4	Average sample. Bore collapsed at 114.5m.
3401C WAR	6	Good sample. All hauls off bottom of bore.
3504C WAR	4	Average sample. Bore collapsed at ~ 135m.
3504 WAR	4	Average sample. Bore collapsed at ~ 90m.
3603C WAR	6	Good sample. All hauls off bottom of bore.
3803 WAR	4	Good sample. All hauls off bottom of bore.
3702C WAR	6	Good sample. All hauls off bottom of bore.
3601C WAR	6	Good sample. All hauls off bottom of bore.
3299 WAR	4	Average sample. Bore collapsed at ~ 50m.
3499 WAR	6	Good sample. All hauls off bottom of bore.
3899 WAR	4	Good sample. All hauls off bottom of bore.

Table 3-3: Bore depth, SWL and key water quality parameters from 27 Waratah GCP bores sampled in April 2012. (ND = No Data)(est = estimated)

Bore ID	Depth (m)		pH (units)	EC (µS/cm)	Water Temp (°C)	DO (% Satn)	Bore Age (Years)
	EoH	SWL					
3412A WAR	ND	33.97	6.25	550	23.60	10.9	3.3
3412B WAR	est. 50	31.12	6.24	3,684	24.94	13.8	3.3
3412C WAR	est. 100	42.69	7.11	1,911	25.40	16.6	3.3
3413 WAR	est. 100	34.63	6.85	4,447	24.41	14.1	5.0
3702A WAR	est. 40	26.70	6.91	5,335	25.27	14.6	ND
3702B WAR	est. 60	26.29	6.48	1,373	25.38	ND	ND
3812 WAR	est. 100	28.01	7.32	5,826	24.98	38.1	3.5
3814 WAR	62	45.96	7.06	6,366	27.30	17.6	ND
3815B WAR	62	52.42	7.01	4,470	27.80	21.9	3.7
3815C WAR	62	51.51	6.97	3,431	27.47	20.1	3.7
4016A WAR	est. 100	32.18	7.12	7,037	25.60	13.2	3.6
4016C WAR	138	32.34	6.86	6,285	25.40	18.7	3.6
4018A WAR	est. 100	34.62	6.71	3,201	25.90	10.8	3.6
4018B WAR	est. 100	34.67	7.03	2,790	26.30	ND	3.6
4212C WAR	est. 80	17.87	7.93	6,749	25.60	32.6	4.1
4213A WAR	est. 50	16.83	7.35	5,413	26.27	13.6	4.9
4213C WAR	est. 50	15.23	6.91	3,067	25.70	17.6	5.0
4213D WAR	est. 50	16.72	7.61	5,328	25.88	15.3	5.1
4215R WAR	est. 100	20.50	6.71	8,516	26.34	13.3	5.1
4216A WAR	est. 130	24.83	7.42	2,828	26.96	ND	3.8
4216B WAR	64.2	18.89	7.26	3,347	26.15	ND	3.8
4315 WAR	est. 100	16.74	7.37	5,155	26.16	ND	4.1
4316 WAR	ND	19.10	7.11	2,828	26.40	15.9	5.0
4317 WAR	ND	19.74	6.74	2,685	26.31	ND	3.8
4415A WAR	ND	10.78	6.91	10,963	26.15	ND	5.1
4415B WAR	ND	9.48	7.34	2,375	26.45	ND	5.6
4415C WAR	est. 80	9.83	7.31	7,737	26.15	ND	5.1
		SWL (m)	**pH** (units)	**EC** (µS/cm)	**Water Temp** (°C)	**DO** (% Satn)	
Mean Value		**26.80**	**7.03**	**4,581**	**25.94**	**17.7**	
Range		**9.48 to 52.42**	**6.24 to 7.93**	**550 to 10,963**	**23.6 to 27.8**	**10.9 to 38.1**	

Table 3-4: Bore depth, SWL and key water quality parameters from 18 Waratah GCP bores sampled in September 2012. (ND = No Data)(est = estimated).

Bore ID	Depth (m)		pH (units)	EC (µS/cm)	Water Temp (°C)	DO (% Satn)	Bore Age (yrs)
	EoH	SWL					
12030077 DERM	8.2	4.83	6.82	476	25.65	25.9	38.5
44468 DERM	est. 20.0	10.53	6.97	3,219	25.23	46.1	112.8
44467 DERM	est. 20.0	13.95	7.04	4,654	25.87	45.7	112.8
3803 WAR	170	23.34	7.71	1,626	26.72	16.2	4.8
12030076 DERM	28	24.22	7.98	14,412	28.84	3.2	38.5
3702C WAR	150	26.32	7.85	1,435	26.17	29.2	3.0
3601C WAR	140	26.52	8.05	1,345	26.61	18.4	4.8
3499 WAR	est. 190	27.69	8.35	1,349	26.45	19.9	4.7
3899 WAR	est. 180	27.74	7.08	1,525	27.95	19.8	4.7
3299 WAR	ND	29.64	7.61	1,386	25.13	20.3	4.8
36821 DERM	est. 35.0	29.64	7.64	702	26.74	26.5	41.3
3603C WAR	147	30.06	7.01	1,375	26.59	18.1	3.6
3401C WAR	193	31.65	7.85	2,132	26.18	28.2	3.6
3504C WAR	183	32.36	7.54	1,370	26.31	24.1	3.2
3504 WAR	ND	32.80	6.87	1,460	26.11	20.9	3.2
3211 WAR	115	40.96	7.85	1,360	26.57	37.2	4.0
3207A WAR	82	45.63	6.85	1,430	26.41	20.5	3.8
3207B WAR	80	46.95	6.92	1,380	25.61	29.3	4.5
		SWL (m)	**pH** (units)	**EC** (µS/cm)	**Water Temp** (°C)	**DO** (% Satn)	
Mean Value		**28.05**	**7.44**	**2,369**	**26.40**	**24.9**	
Range		**4.83 to 46.95**	**6.82 to 8.35**	**476 to 14,412**	**25.23 to 28.84**	**3.2 to 46.1**	

3.4 Groundwater Fauna

3.4.1 Stygofauna

A total of 45 groundwater bores were sampled for stygofauna in April and September 2012 within the Waratah GCP mine lease area using standard sampling methods described in WA Guidelines 54 and 54a (2003 & 2007). Sample quality was high across all 45 bores (Tables 3-1 & 3-2). Groundwater bores on six properties located within MLA 70454 (Kia Ora, Lambton Meadows, Oakleigh, Monklands, Cavendish and Glen Innes) were sampled for stygofauna in 2012. Stygofauna were recovered from bores located on four of the six properties (Kia Ora, Lambton Meadows, Oakleigh and Monklands) indicating that stygofauna were widely distributed across MLA 70454.

Analysis of the April 2012 stygofauna samples revealed the presence of obligate groundwater fauna (Phreatobites) in three bores (3412B WAR, 4212C WAR and 3413 WAR) located on Kia Ora property (Table 3-5). Stygofauna diversity was very low with only one taxon being recorded which was an Enchytraeid oligochaete (genus/species unknown). Stygofauna abundance was also generally low with the exception of bore 3412B WAR which recorded 290 oligochaete specimens.

Sampling conducted in September 2012 recorded the presence of obligate groundwater fauna (Phreatobites) in four bores (3299 WAR, 3401C WAR, DERM 44468 and DERM 36821) located on Oakleigh, Lambton Meadows and Monklands properties (Table 3-5). As experienced in April 2012, stygofauna diversity and abundance was very low with only two stygofauna taxa recovered which were an oligochaete worm (Enchytraeidae) and an Astigmata water mite (genus/species unknown).

Phreatobites

- Oligochaeta, Enchytraeidae sp. (3412B WAR, 4212C WAR, 3413 WAR and DERM 36821)
- Acarina, Astigmata sp. (3299 WAR, 3401C WAR and DERM 44468)

The Phreatobite fauna is characterised by the freshwater worm family the Enchytraeidae and Astigmata water mites (Table 3-5).

The Enchytraeidae is a small family of aquatic worms that are poorly known from an ecological, geographic and taxonomic perspective. The relatively small size of the specimens (1-5 mm) indicates a moderate connectivity within the river/aquifer environment. Enchytraeid's have been found in freshwater environments in Victoria, NSW and recently in groundwaters in Queensland. They are a group that requires further taxonomic work (Pinder & Brinkhurst, 1994). Subterranean oligochaetes in general are an important component of Australia's groundwater fauna that contain a large number of short range endemic species with large faunas along the continental marginal areas, particularly in the south-west and eastern seaboards.

Although subterranean water mites (such as the Astigmata) are classed as Phreatobites, they have their highest biodiversity within the riverine, hyporheic zones and are often classed as members of the 'permanent hyporheos' or the community that occurs within the deep sand and gravel beds associated with areas of groundwater discharge (Gilbert *et al*, 1994). They have, however, been frequently found in unconsolidated aquifers and coastal sandbed aquifers (Serov, unpublished data). They typically characterize the transition zone between the temporary or shallow hyporheic ecozone and the groundwater hypogean environment. (Boulton & Hancock, 2006; Gilbert *et al*, 1994; Humphreys, 2006; Serov *et al*, 2012). It is, therefore, unusual to find this group within the

Table 3-5: Groundwater fauna collected from Waratah GCP bores sampled in April and September 2012 (ND = Not Determined).

Bore ID	Property	Class	Order	Family	Genus	No.	Habitus	Sampling	
								Method	Date
3815C WAR	Kia Ora	Acarina	Oribatida	ND	ND	1	Edaphobites	50µ net	25/04/12
3815C WAR	Kia Ora	Acarina	Mesostigmata	ND	ND	1	Edaphobites	50µ net	25/04/12
4016C WAR	Kia Ora	Acarina	Mesostigmata	ND	ND	1	Edaphobites	50µ net	25/04/12
3412B WAR	Kia Ora	Annelida	Oligochaeta	Enchytraeidae	ND	290	Phreatobite	50µ net	26/04/12
4212C WAR	Kia Ora	Annelida	Oligochaeta	Enchytraeidae	ND	1	Phreatobite	50µ net	26/04/12
4212C WAR	Kia Ora	Insecta	Diptera	Tipulidae	ND	1	Stygoxene	50µ net	26/04/12
3413 WAR	Kia Ora	Annelida	Oligochaeta	Enchytraeidae	ND	2	Phreatobite	50µ net	26/04/12
DERM 36821	Oakleigh	Annelida	Oligochaeta	Enchytraeidae	ND	17	Phreatobite	50µ net	22/09/12
DERM 36821	Oakleigh	Insecta	Collembola	Entromobryidae	ND	14	Troglobite/ Phreatobite	50µ net	22/09/12
3299 WAR	Lambton Meadows	Acarina	Astigmata	ND	ND	5	Phreatobite	50µ net	25/09/12
3401C WAR	Lambton Meadows	Acarina	Astigmata	ND	ND	2	Phreatobite	50µ net	24/09/12
3401C WAR	Lambton Meadows	Acarina	Hydracarina	ND	ND	2	Stygoxene	50µ net	24/09/12
DERM 44468	Monklands	Acarina	Astigmata	ND	ND	3	Phreatobite	50µ net	22/09/12

Table 3-6: Hyporheic fauna collected from Lagoon and Tallarenha Creeks in April and September 2012 (ND = Not Determined).

Site ID	Locality	Class	Order	Family	Genus	No.	Habitus	Sampling	
								Method	Date
HR2	Tallarenha Creek	Insecta	Diptera	Tipulidae	ND	1	Stygoxene	50µ sieve	26/04/12
HR2	Tallarenha Creek	Insecta	Diptera	Ceratopogonidae	*Bezzia*	41	Stygoxene	50µ sieve	26/04/12
HR2	Tallarenha Creek	Insecta	Diptera	Chironomidae	*Chironominae*	3	Stygoxene	50µ sieve	26/04/12
HR2	Tallarenha Creek	Annelida	Oligochaeta	Phreodrilidae	ND	8	Stygoxene	50µ sieve	26/04/12
HR2	Tallarenha Creek	Insecta	Ephemeroptera	Caenidae	*Tasmanocoenis*	1	Stygoxene	50µ sieve	26/04/12
HR4	Lagoon Creek	Insecta	Diptera	Ceratopogonidae	*Bezzia*	10	Stygoxene	50µ sieve	26/04/12
HR4	Lagoon Creek	Insecta	Ephemeroptera	Caenidae	*Tasmanocoenis*	3	Stygoxene	50µ sieve	26/04/12
HR4	Lagoon Creek	Insecta	Diptera	Chironomidae	*Chironominae*	7	Stygoxene	50µ sieve	26/04/12
HR4	Lagoon Creek	Insecta	Diptera	Tipulidae	ND	4	Stygoxene	50µ sieve	26/04/12
HR4	Lagoon Creek	Insecta	Coleoptera	Hydrophilidae	*Berosus*	1	Stygoxene	50µ sieve	26/04/12
HR4	Lagoon Creek	Insecta	Coleoptera	Hydraenidae	ND	1	Stygoxene	50µ sieve	26/04/12
HR4	Lagoon Creek	Acarina	Mesostigmata	ND	ND	1	Edaphobite	50µ sieve	26/04/12
HR4	Lagoon Creek	Ostracoda	Myodocopida	ND	ND	3	Stygoxene	50µ sieve	26/04/12
HR4	Lagoon Creek	Insecta	Coleoptera	Hydrophilidae	*Berosus*	11	Stygoxene	50µ sieve	23/09/12
HR4	Lagoon Creek	Insecta	Coleoptera	Chrysomelidae	*Cryptocephalus*	4	Stygoxene	50µ sieve	23/09/12
HR4	Lagoon Creek	Insecta	Coleoptera	Ptiliidae	ND	16	Stygoxene	50µ sieve	23/09/12
HR4	Lagoon Creek	Insecta	Hemiptera	ND	ND	4	Stygoxene	50µ sieve	23/09/12
HR4	Lagoon Creek	Crustacea	Copepoda	Cyclopoida	ND	12	Stygoxene	50µ sieve	23/09/12
HR4	Lagoon Creek	Annelida	Oligochaeta	Naididae	ND	2	Phreatobite	50µ sieve	23/09/12

deeper phreatic zone (Waratah bores 3299 and 3401C both recorded a SWL of between 29 and 32 m). The Astigmata specimens were alive and in good condition when collected and were, therefore, living within the habitat from which they were collected. It is an indication that this aquifer is, or has been, connected to surface water sources as a discharge source where the discharge can be either point source springs or diffuse discharge through a moderate to course grained substrate such as sand or gravels (Gilbert *et al*, 1994). Astigmata water mites were also recovered in September 2012 from a DERM bore (44468) with a SWL of only 10.5 m, so it would seem likely that there is a strong vertical hydraulic connection between the shallower (10 m) and deeper aquifers (30 m).

Troglobite/Phreatobite

- Collembola, Entromobryidae sp. (DERM 35821)

The Collembolan family Entromobryidae is an interesting find from a subterranean habitat as this group is typically associated with leaf litter, soil, bark and on vegetation (Greenslade, 1991), and normally has eyes. The specimens collected from DERM bore 36821 are blind and unpigmented indicating a hypogean existence. The large number of specimens and their intact condition indicates a significant population within the aquifer. It is unclear whether the species is aquatic or Troglobitic (ie. terrestrial fauna occurring within open unsaturated voids above the water column).

Other Groundwater Fauna

- Acarina: Oribatida sp.(3815C WAR)
- Acarina: Mesostigmata sp.(3815C WAR; 4016C WAR)
- Diptera, Tipulidae sp. (4212C WAR)
- Acarina, Hydracarina sp. (3401C WAR)

Two species of terrestrial soil dwelling (Edaphobitic) mites (Orbatida and Mesostigmata) were recovered in April 2012. All specimens were in a state of decay indicating they were not living in the bore when collected. Although Orbatid mites have been recorded living in wet environments, including hyporheic/groundwater environments where they have been associated with mesostigmatid mites and Enchytraeidae worms (Williams, 1993), their occurrence in Waratah GCP bores is considered incidental/accidental and of no specific relevance to this report.

The presence of a single specimen of an aquatic Tipulid larvae (stygoxene) is also considered incidental and of no specific relevance to this report. Tipulids are normally associated with river pool and wetland environments and it is most likely the specimen would have entered the groundwater bore by accident.

The two specimens of Hydracarina were also deceased when collected and in a highly decayed state. Although the Hydracarina are often collected from hyporheic and groundwater environments, they are typically an epigean order, and given the condition of these specimens, they should be considered as accidentals in this sample. Their presence is of no relevance to the current study.

3.4.2 Hyporheic Fauna

- Acarina, Mesostigmata sp.(HR4)
- Oligochaeta, Phreodrilidae sp.(HR2)
- Oligochaeta, Naididae sp. (HR4)
- Copepoda, Cyclopoida sp.(HR4)
- Coleoptera, Chrysomelidae, *Cryptocephalus* sp.(HR4)

- Coleoptera, Hydraenidae sp.(HR4)
- Coleoptera, Hydrophilidae, *Berosus* sp.(HR4)
- Coleoptera, Ptiliidae sp.(HR4)
- Diptera, Ceratopogonidae, *Bezzia* sp.(HR2 and HR4)
- Diptera, Chironomidae, *Chironominae* sp.(HR2 and HR4)
- Diptera, Tipulidae sp.(HR2 and HR4)
- Ephemeroptera, Caenidae, *Tasmanocoenis* sp.(HR2 and HR4)
- Hemiptera, sp.(HR4)
- Ostracoda, Myodocopida, sp.(HR4)

A diverse and abundant hyporheic community was recovered from two sites (HR2 and HR4) on Lagoon (HR2) and Tallarenha (HR4) Creeks in April and September 2012 (Table 3-6). The majority of fauna present are termed stygoxenes (i.e. animals that have no affinities with groundwater systems but may passively infiltrate caves and alluvial sediments) which normally inhabit slow flowing or still surface waters, and can retreat into the hyporheos as a refugial environment when an ephemeral creek (such as Lagoon/Tallarenha Creeks) dries up. Overall, the hyporheic fauna collected contain a relatively consistent assemblage of common surface water macroinvertebrate species that are associated with slow moving or still surface water bodies with soft, silty sediments and a high organic (allocthonous) content of the substrate. They are also typical taxa associated with shallow hyporheic zones.

The beetle and bugs are regarded as stygoxenes with an epigean [terrestrial] lifestyle. That is, the presence of the beetles is most likely incidental. The specimens have no morphological modifications that are normally associated with a subterranean transition zone existence between the unsaturated or vadose zone and the water table, such as loss of eyes or colour. The Chrysomelidae and the Ptiliidae are arboreal terrestrial families, often collected from foliage. The Hydrophilidae is predominantly an aquatic family including both the adults and larvae with a preference for still water environments. This would suggest that Lagoon Creek has a groundwater baseflow component to its normal flow patterns and is connected to a very shallow aquifer system.

Hyporheic Stygobites

- Oligochaeta, Naididae sp. (HR4)
- Oligochaeta, Phreodrilidae sp. (HR2)
- Copepoda, Cyclopoida sp. (HR4)

The hyporheic fauna of Tallarenha Creek also included three stygobitic taxa which are obligate groundwater fauna. The stygobitic fauna included the Oligochaete families Naididae and Phreodrilidae and the Cyclopoid Copepods.

Cyclopoid Copepods are normally associated with fine to course sandy substrates of still water environments of rivers, wetlands, the hyporheic zone and shallow groundwaters. Although they are a ubiquitous component of these habitats, their small size means that they are often overlooked and undercounted. Cyclpoid Copepods are potentially very useful bioindicators, particular of baseflow fed streams or alluvial aquifers or flow through wetlands, as they are sensitive to changes in the environment such as flow, land use, pollution and changes in the water table (Tomlinson & Boulton, 2008).

The Oligochaete Family Phreodrilidae was recorded at HR2 in April 2012. This species is possibly associated with groundwater environments. The Family consists of five genera in Australia with a particularly rich diversity of species. The endemicity of species is high and they have a predominantly southern hemisphere and southern Australian distribution, with the highest diversity being found in Tasmania and eastern Victoria (Pinder and Brinkhurst, 1994). They have a preference for cool, freshwater environments and are soft sediment dwellers. This group of oligochaetes is increasingly becoming a vital component of groundwater ecosystems in southern Australia and now Queensland as our knowledge of their ecology, taxonomy and environmental requirements improves (P. Serov, pers comm.). They are increasingly being recognised as a taxa associated with ecosystems of high water quality.

The Oligochate Family, Naididae has approximately 23 genera and 59 species currently described, although very little is known from Queensland (Pinder & Brinkhurst, 1994). In general the microdrile oligochaetes occur in both running and still waters including oligotrophic lakes and streams, typically in environments with higher levels of organic carbon sourced through direct connection with the surface (Pinder & Brinkhurst, 1994). The Naididae are found in or on the substratum. Species without gills may occur in small burrows. Aquatic worms ingest large amounts of the substratum, feeding on organic material (diatoms, algae, plant matter) and bacteria in silt and mud, however, some species of Naididae may be carnivorous, while others are parasitic (Pinder & Brinkhurst, 1994). This group of oligochaetes is a vital component of groundwater ecosystems in Queensland and occurs frequently within ecosystems with high water quality. They exhibit high diversity and possibly high endemicity.

The Australian Naidid fauna consists mostly of cosmopolitan species, although there are indications of greater endemicity than is currently recognised. Increasingly, new Naidid species are being collected from seasonal habitats on granite outcrops and from refugial habitats (caves, groundwater and permanent river pools) in drier regions (P. Serov, pers comm). A complete picture of Oligochaeta distribution will require a great deal more research (Pinder 2001).

3.4.3 Groundwater Quality

Preliminary observations in Queensland (Hancock and Boulton, 2008) suggest that the highest stygofauna diversity and abundance occurs in groundwater with EC less than 5,000 µS/cm. Other variables thought to be favourable for stygofauna are a shallow water table (<20 m), moderate concentrations of dissolved oxygen (1-5 mg/L), and pH between 6.5 and 7.5, although this range is considered quite narrow (P.Serov, pers comm).

The seven Waratah GCP groundwater bores that recorded the presence of stygofauna (Phreatobites) in April and September 2012 recorded water chemistries generally consistent with the observed preferences for stygofauna in Queensland reported by Hancock and Boulton (2008). SWL's were recorded in the low to medium range and varied between 10.5 m and 34.63 m. Electrical conductivity (as a measure of salinity) varied between 702 µS/cm and 6,749 µS/cm and pH ranged between 6.24 and 7.93.

4. Discussion

4.1 Groundwater Fauna

4.1.1 Stygofauna

A total of 45 groundwater bores and 8 hyporheic sites were sampled for stygofauna in April and September 2012 within Waratah Coal MLA 70454 using standard sampling methods described in WA Guidelines 54 and 54a (2003 & 2007). Seven groundwater bores and two hyporheic sampling sites recorded the presence of five subsurface species which can be classed as stygofauna, including obligate groundwater species associated with the hypogean and permanent hyporheic environments. The remaining 38 groundwater bores and six hyporheic sites did not record the presence of stygofauna (stygobites/phreatobites). These results were obtained following a comprehensive seasonal sampling program conducted across an extensive area.

The stygofauna that were recovered included three species of oligocaete worms, one species of Cyclopoid Copepod and one species of Astigmata water mite. These taxa are common groundwater fauna at the Order/Family level of taxonomic resolution. From the data available the overall diversity of stygofauna is considered to be low, and collectively the taxa recorded do not constitute a significant stygofaunal community.

One of the requirements when sampling for stygofauna as defined under the WA Guidelines (2003 & 2007) is the need to sample all hydrogeological units present within the mine lease area, including a focus on shallower alluvial aquifers, if present. Alluvial aquifers adjacent to large permanent rivers often have suitable conditions for stygofauna, and can contain diverse stygofaunal communities (Danielopol and Marmonier, 1992; Hancock and Boulton, 2008). Stygofauna biodiversity is also higher in areas of recharge where the water table is close (<20 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.

Perhaps two of the 45 groundwater bores sampled as part of this study (DERM 12030077 and 44468) intersected an alluvial aquifer, so this important aquifer environment for stygofauna was most likely under-represented in the sampling design. At the time of writing this report, hydrogeological modelling for the Waratah GCP site was not finalised, therefore, it is not clear from the current Study if all the hydrogeological units present on Waratah MLA 70454 have been adequately sampled for stygofauna.

In Australia, stygofauna are known from alluvial, limestone karst, fractured rock, and calcrete aquifers (Hancock *et al* 2005; Humphreys 2008). To be suitable for stygofauna, aquifers must have sufficient porosity or fractionation (connectivity) for adequate living space, and have a sufficient flux of organic matter (DOC) and dissolved oxygen (Humphreys 2008). The absence of stygofauna from the remaining 38 groundwater bores does not necessarily mean that stygofauna are not present in these aquifers, rather, it may be due to unsuitable conditions such as:

- Local geology (e.g. low porosity, low hydraulic conductivity etc.),
- Inadequate range of bores selected for sampling (e.g. absence of alluvial aquifers in sampling regime),
- Poor groundwater quality (e.g. presence of toxicants or high salinity etc.),
- Recent bore disturbance (e.g. regular purging or pumping etc.), and/or

- A low abundance of animals coupled with a heterogeneous distribution highlighting the basic need for replicated sampling covering different seasons and seasonal events.

4.1.2 Hyporheic Fauna

As mentioned earlier, the hyporheic fauna collected from one site on Lagoon Creek and one site on Tallarenha Creek in April and September 2012 contained a relatively consistent assemblage of common surface water macroinvertebrate species that are associated with slow moving or still surface water bodies with soft, silty sediments and a high organic (allocthonous) content of the substrate. They are also typical taxa associated with shallow hyporheic zones and can retreat into the hyporheos as a refugial environment when an ephemeral creek dries up. The hyporheic fauna could not be considered unique in any way and are taxa commonly found in local permanent and ephemeral waterways (e.g. Alpha Creek) and would be found at other locations on Lagoon and Tallarenha Creeks outside the mine impact zone. It is highly unlikely , therefore, that proposed mining operations would in any way put at risk the survival of the hyporheic fauna recorded from Lagoon and Tallarenha Creeks.

Attempts were made to collect hyporheic fauna from Beta, Malcolm and Saltbush Creeks using Karaman-Chappuis pits (Malard *et al*, 2001). Three pits were excavated into the dry sand bed of each creek at points considered likely to be near water (e.g. outside of bends, areas of damp sand, depressions in sand bed etc.). At the locations chosen for sampling on these creeks, a confining layer of clay was encountered at depths between 20 cm and 30 cm. There was no standing water in the pits that were dug indicating that the local water table had receded beneath the clay layer and the hyporheic zone was absent. As a result, no hyporheic samples were collected from these locations.

4.2 Other Stygofauna Studies

Our knowledge of stygofauna in the Galilee Basin is very limited at present based on the fact that very few surveys have been conducted in this extensive region of Queensland and relevant data that has been collected is not shared. The current Waratah GCP study adds substantially to this body of knowledge.

GHD has recently conducted stygofauna studies in the Galilee Basin for AMCI Pty Ltd and Adani (Carmichael Coal Pty Ltd) and has also worked with AARC in identifying stygofauna for Hancock Prospecting Pty Ltd's Alpha Coal Project. These studies have all concluded that stygofauna are generally in low diversity and abundance and the surveys have failed to identify significant stygofaunal communities. In all cases the stygofauna taxa collected have been similar to the taxa recovered from the Waratah GCP project. Collectively these studies tend to suggest that stygofauna (i.e. stygophiles, stygobites, phreatobites) may be poorly represented in the Alpha region and perhaps also more widely in the Galilee Basin. The studies mentioned above have all concluded that stygofauna do not constitute a relevant environmental factor in consideration of the project EIS's.

4.3 Stygofauna Ecological Requirements

There are three critical factors that make stygofauna communities in aquifers vulnerable to the impacts of human activity:

- ***Stable water quality/physicochemical parameters***. Many groundwater species have evolved under strict constraints on environmental physicochemical parameters and, therefore, need stable conditions. Stygofauna are able to tolerate natural fluctuations in water parameters such as water level, electrical conductivity, and temperature, and this has been demonstrated experimentally (Tomlinson, M. unpublished data) for stygofaunal amphipods, copepods, and syncarids. However, changes outside the natural range of water quality, water chemistry and levels such as rapid drawdown or changes to water chemistry such as a pollution plume is likely to have significant impacts on the community composition, biodiversity and overall sustainability of the community.

- ***Surface connectivity***. Groundwater communities require links to the surface environment to provide organic matter (DOC) and oxygen. If that linkage is broken or disrupted, the stygofauna community in the area affected could decline over time.
- ***Subterranean connectivity***. The third critical factor that makes stygofauna vulnerable to human activity is their high degree of endemicity (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 through the aquifer matrix, however, as aquifers are not homogenous in porosity and change over geological time, natural hydrological barriers within the matrix can restrict their movement. Over time, these natural barriers encourage genetic isolation and ultimately, speciation. Barriers, however, can also be created rapidly by changes in water levels or water chemistry/quality such as an area of lower porosity or sections of poor water quality. If any area is impacted by a disturbance that results in a loss of biodiversity, these new barriers to dispersal may prevent recolonisation of the habitat.

Many species of stygofauna are restricted to small geographical areas. This is particularly the case in non-alluvial aquifers such as some of the limestone karsts of NSW (Eberhard & Spate, 1995: Thurgate *et al*, 2001), and 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 and community. 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.

4.4 Factors that Threaten 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 to be degraded or lost with the potential for significant impact on groundwater communities.

Mining operations incorporate a range of generic water affecting activities in their operations (not all of which may be applicable to the Waratah GCP) that have the potential to cause some degree of change in natural water regimes (surface and groundwater), including some or all of the following (SKM, 2010):

- Below water table mining;
- Water supply development (e.g. groundwater, dewatering, surface water);
- Desalination for potable supply (with subsequent brine disposal);
- Dust suppression;
- Seepage;
- Tailings disposal;
- Rock storages;
- 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 (e.g. stygofauna) may be as follows:

- Changes to water quantity (groundwater levels, pressures and fluxes);
- Changes to water quality (concentrations of salts and other toxic 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, and subsequently on groundwater dependent ecosystems (and stygofauna and hyporheic fauna in particular as these animals are true obligate groundwater dependent fauna) will depend largely on the scale of the Waratah GCP operation, mining method, and process water requirements, as well as the climatic and geological setting.

4.4.1 Implications of Threatening Processes

Water Resources:

Water resources might be influenced by mining activities in two important ways, namely:

- aquifer storage depletion (e.g. groundwater pumping to dewater, evaporative discharge or extracting water for use in mining operations), and
- aquifer storage enhancement (e.g. as a result of seepage from mine facilities such as water ponds and tailings storages).

Through aquifer storage depletion (water table decline) the natural water regime may be influenced by the Waratah GCP mining operation with subsequent detrimental impacts on stygofauna. This has become a particular issue for mining proponents over the last decade, principally because of their perceived biodiversity significance and the fact that little is known of their environmental water requirements. It needs to be recognised that groundwater drawdown can also occur outside the Waratah GCP mining operation. Knowledge of the spatial and temporal extent of the proposed drawdown zone and the specific aquifers impacted will be necessary to fully assess any impacts on the stygofaunal community. Future expansion of the Waratah GCP operation should also be considered.

Impacts from aquifer storage enhancement have been reduced by the proposed use of dry paste treatment of tailings and the storage of tailings and rejects in fully engineered clay-lined storage cells (Waratah GCP SEIS, 2012). Waratah has proposed that the use of these cells, along with the pre-processing of the tailings, will enable water savings and greatly reduce any leaching of contaminants into the water table.

Lithology & Soils:

Geology and soil type will influence recharge (and seepage) potential as well as catchment yields. Some rock types can provide suitable capping material for tailings and rock storages and have a beneficial impact on stygofauna by protecting impacts on groundwater quality. Other rock types, however, can present hazards such as Acid Mine Drainage that may cause long-term impacts to surface water drainages if not managed properly. Significant changes to groundwater quality will impact detrimentally on stygofauna.

The Waratah GCP MLA is underlain with Tertiary Clays which are ‘effectively impervious’ (Waratah GCP SEIS, 2012). This impervious clay layer can reduce and possibly stop seepage from surface areas into deeper aquifers, though it cannot be known if this clay layer is continuous throughout the entire MLA, and additional safeguards such as those proposed for tailing storage facilities will be needed to prevent possible impacts to groundwater (and stygofauna) from leachate from mining by-products. While tailings and rejects can be toxic and a threat to stygofauna if not contained, testing to date by Waratah has found that the tailings and rejects are benign, and that effective encasement in the clay cells will prevent both oxidation and seepage and prevent impacts on groundwater quality and stygofaunal communities (Waratah GCP SEIS, 2012).

Mine Process:

The proposed Waratah GCP mine will generate waste material through processing operations although coal mining does not have large treatment requirements for the beneficiation process when compared with some other commodity groups (e.g. precious metals). The waste stream from the mine process can have varying levels of contaminants (both native and added through beneficiation). The safe storage of these wastes during mine operations and post-closure will be an important consideration in protecting groundwater quality and managing potential impacts on stygofauna.

The proposed storage of mine rejects and tailings by Waratah will involve a process of storing dry paste tailings in an impervious clay layer which should effectively provide a safe storage of mining wastes and reduce the short and long-term risk of groundwater contamination.

Mining Method:

The Waratah GCP mining operation will involve excavation below the water table with identified impacts on groundwater resources such as:

- Reduction in groundwater levels and surface water flows through mine dewatering,
- Degradation of groundwater quality through spoil and tailing disposal and operation of processing plants and machinery and general waste landfill, and
- Linkage of aquifers and leakage from surface water courses resulting from longwall mining.

The effect of these impacts manifests itself as groundwater drawdown around the mine pits and changes to groundwater quality which may extend for large distances depending on mine life, target depth of dewatering and aquifer hydraulic parameters (permeability and storage). For the Waratah GCP it will be important to assess the location and distribution of the stygofauna recovered against the aquifers from which they originated and the forecasted drawdown zone (zone of impact) over the life of the mine. A rapid decline in the water table would be detrimental to stygofauna however laboratory research has shown that stygofauna can cope with a small and slow decline in aquifer storage. Evaporative losses of water and concentration of salts in the Waratah Coal mine pit is also a consideration post mine closure.

Another consideration is the impact to overlying bedrock strata as a result of longwall mining operations (particularly relevant to coal mining). In particular, the impact on the rock strata following the decommissioning of longwall mines by the destruction of the mine’s support pillars which can cause the mine to collapse into itself. This can cause minor to major cracking of the substrate. The impact of this can include the drainage of surface waters into fractures/cracks following streambed cracking and the drainage of groundwater out of aquifers through the cracks leading to possible:

- Drying of overlying aquifers,
- Drying of entire river systems (and recharge capabilities),
- Contamination of underlying aquifers and outflow streams, and
- The impact of this process could have rapid and irreversible effects on sub-surface aquatic fauna.

Mine Maturity:

The proposed Waratah GCP mine is currently a greenfield mining operation that will take place within a variety of groundwater regimes, most of which will have been impacted to some degree by agricultural activities. Establishing a baseline prior to the commencement of operations is important in order for the Waratah GCP to gauge the effects of its operations on existing groundwater conditions through the construction, operational and rehabilitation phases. Full compliance with WA guidelines (2003 & 2007) and the adoption of two sampling events across two seasons covering 53 different sampling points (for stygofauna and hyporheic fauna) using best practice sampling procedures has ensured that the Waratah GCP has established a significant baseline. Ongoing monitoring of stygofaunal communities through the life of the mine is highly recommended to provide an indication of changes (if any) to groundwater condition and health.

4.5 Cumulative Effects

In relation to mining, cumulative effects can arise from:

- The compounding effects of a single mining or processing operation;
- Interference effects between multiple mining and processing operations; and
- Interaction between mining and non-mining activities.

Cumulative effects may result from a number of activities interacting with the environment. The nature and scale of these effects can vary substantially, depending on factors such as the type of activity performed, the proximity of activities to each other and the characteristics of the surrounding natural, social and economic environments (SKM, 2010). They may also be caused by the synergistic and antagonistic effects of different individual activities, as well as the temporal or spatial characteristics of the activities. Importantly, cumulative effects are not necessarily additive to the issue (SKM, 2010).

For the Waratah GCP quantification of the direct cumulative effects of mining on the regions groundwater systems will need to be considered, particularly the potential for mine water affecting activities to impact on:

- Groundwater quantity (i.e. alteration to groundwater levels and fluxes),
- Groundwater quality (i.e. alteration to regional salinity levels and concentrations of other important toxicants);
- Groundwater – surface water interaction (i.e. reduction to levels of interaction between groundwater and surface systems e.g. reduced baseflow to streams, reduced recharge of aquifers and a reduced water table depth); and
- Physical disruption to aquifers (i.e. will the proposed Waratah Coal mine contribute to the permanent disruption of a groundwater system).

All of the above cumulative effects impact on groundwater quantity and quality and ultimately on obligate groundwater dependent fauna (stygofauna).

Potential cumulative impacts of adjoining mines (e.g. AMCI South Galilee Coal Project and Hancock Prospecting Alpha Coal Project) on local groundwater resources could have far reaching impacts on groundwater dependent ecosystems, and certainly be more significant than a single mine operation (albeit a very large one) on its own.

4.6 Implications for the Waratah GCP EIS

The stygofauna collected from the seven groundwater bores on Waratah GCP MLA 70454 in April and September 2012 have been identified as a cyclopoid copepod, an Astigmata water mite and specimens from three Oligochaete Families (Enchytraeidae, Naididae and Phreodrilidae).

Order/Family level taxonomic analysis was undertaken by GHD on stygofauna recovered as part of this project as this is the level of taxonomic resolution specified in the Waratah GCP EIS TOR. If further taxonomic investigations were conducted on these taxa (both morphological and genetic) the animals may prove to be new species or possibly even new genera.

In Queensland, to satisfy the DEHP Terms of Reference for an EIS, endemism needs to be disproved at the Family or Order level for stygofauna, in which case the copepod, water mite and oligochaetes are not endemic, because the Order/Family they belong to occur in all Australian States (Serov, 2002). Any proposed mining activities associated with the Waratah GCP will not threaten or put at risk the survival of the taxa at the Order/Family level of taxonomic resolution.

The WA Guidelines (2003 & 2007) require proponents to identify stygofauna to species level (where possible) in order to be able to show that species will not be threatened by development. This requirement in WA provides a stronger basis for protecting biodiversity and may become the future requirement in Queensland.

4.7 Recommended Management Approach

- Identify the obligate stygofauna to species (i.e. those listed as stygobites and phreatobites) to determine levels of endemicity of the stygofauna community within the aquifers as this community is the most disturbance sensitive environmental indicator for changes in aquifer conditions. Despite there being no immediate benefit to Waratah Coal in analysing the DNA of the Acarina, Copepod and Oligochaeta taxa there may in fact be longer term benefits. Having this DNA sequence in a database will allow future comparisons with stygofauna from other local, regional, state and national collections, thereby improving the understanding of the conservation significance, evolution and distribution of the species (Finston *et al*, 2004). Of equal importance for the Waratah GCP in the future is that if DEHP (as expected) tighten their regulations with regards to the protection of groundwater dependent ecosystems in Queensland, and conform more closely to the WA Guidelines (2003 & 2007), the ability to link the stygofauna (by molecular DNA) with other animals from other collections and regions may assist the Waratah GCP in being able to eliminate the risk of potentially causing the extinction of a species.
- Consider conducting further stygofauna sampling once the hydrogeological report is released for the Waratah GCP to ensure all aquifers within MLA 70454 have been adequately sampled.
- Build on the existing baseline by conducting annual stygofauna surveys during mine construction, operation and closure phases in order to monitor and measure groundwater health and condition over the life of the mine.

5. Conclusions

A comprehensive survey of stygofauna and hyporheic fauna was undertaken on Waratah MLA 70454 to inform the development of the Waratah GCP SEIS. Stygofauna and hyporheic fauna studies were conducted in April (post-wet) and September (pre-wet) 2012. In total, 45 groundwater bores were sampled for stygofauna using standard sampling methods defined in WA Guidance Statements 54 and 54a (2003 & 2007) and eight sites located on five waterways were surveyed specifically for hyporheic fauna.

The key conclusions from this study can be summarised as follows:

- Seven groundwater bores and two hyporheic sampling sites recorded the presence of five subsurface species which can be classified as stygofauna, including obligate groundwater species associated with the hypogean and permanent hyporheic environments. The remaining 38 groundwater bores and six hyporheic sites did not record the presence of stygofauna (stygobites/phreatobites).
- The stygofauna that were recovered included three species of oligocaete worms, one species of Cyclopoid Copepod and one species of Astigmata water mite. These taxa are common groundwater fauna at the Order/Family level of taxonomic resolution. From the data available, the overall diversity of stygofauna is considered to be low, and collectively the taxa recorded do not constitute a significant stygofaunal community.
- At the time of writing this report, hydrogeological modelling for the Waratah GCP site was not finalised, therefore, it is not clear from the current Study if all the hydrogeological units present on Waratah MLA 70454 (particularly alluvial aquifers) have been adequately sampled for stygofauna.
- Our knowledge of stygofauna in the Galilee Basin is very limited at present based on the fact that very few surveys have been conducted in this extensive region of Queensland and relevant data that has been collected by a range of organisations is not shared. Recent stygofauna studies conducted by GHD in the Galilee Basin for AMCI Pty Ltd, Adani (Carmichael Coal Pty Ltd) and Hancock Prospecting Pty Ltd have all concluded that stygofauna are generally in low diversity and abundance and the surveys have failed to identify significant stygofaunal communities. In all cases the stygofauna taxa collected have been similar to the taxa recovered from the Waratah GCP. Collectively, these studies tend to suggest that stygofauna (i.e. stygophiles, stygobites, phreatobites) may be poorly represented in the Alpha region, and perhaps even more widely in the Galilee Basin. The studies mentioned above have all concluded that stygofauna do not constitute a relevant environmental factor in consideration of the project EIS's.
- Hyporheic fauna were collected from one site on Lagoon Creek and one site on Tallarenha Creek in April and September 2012. The fauna consisted of common surface water macroinvertebrate species that are normally associated with slow moving or still (lentic) surface water bodies with soft, silty sediments and a substrate containing a high organic (allocthonous) content. The fauna are also typical taxa associated with shallow hyporheic zones and can retreat into the hyporheos as a refugial environment when an ephemeral creek dries up. The hyporheic fauna could not be considered unique in any way and are taxa commonly found in local permanent and ephemeral waterways (e.g. Alpha Creek) and would be found at other locations on Lagoon and Tallarenha Creeks outside the mine impact zone. It is highly unlikely, therefore, that proposed mining operations would in any way put at risk the survival of the hyporheic fauna recorded from Lagoon and Tallarenha Creeks. A true hyporheic zone was not present at the remaining 6 sites sampled for hyporheic fauna in April and September 2012.

- In Queensland, to satisfy the DEHP Terms of Reference for an EIS, stygofauna endemism needs to be disproved at the Family or Order level for stygofauna, in which case the copepod, water mite and oligochaetes recovered from the current study are not endemic because the Order/Family they belong to occur in all Australian States (Serov, 2012). Any proposed mining activities associated with the Waratah GCP will not threaten or put at risk the survival of the taxa at the Order/Family level of taxonomic resolution.
- In consideration of the data included in this technical report it can be concluded that a significant stygofaunal community does not exist within the aquifers sampled on Waratah GCP MLA 70454, and that stygofauna at the Order/Family level of taxonomic resolution do not represent a relevant environmental factor in consideration of the Waratah GCP EIS.

6. References

AMEC 2010. Water Balance Report for Six New Coal Mines. Waratah Coal Pty Ltd.

ARMCANZ 1996. *Allocation and Use of Groundwater. A National Framework for Improved Groundwater Management in Australia*. Policy Position Paper for Advice to States and Territories Task-Force on COAG Water Reform Sustainable Land Water Resource Management Committee. Occasional Paper No.2, December 1996.

ANZECC 1996. *National Principles for the Provision of Water for Ecosystems*. Sustainable Land and Water Resources Management Committee on Water Resources. Occasional Paper SWR No.3, July 1996.

Boulton, A.J., 1993. Stream ecology and surface-hyporheic hydrologic exchange: Implications, techniques and limitations. *Australian Journal of Marine & Freshwater Research*. 44: 553-564.

Boulton, A.J., Findlay, S., Marmonier, P., Stanley, E.H. and Valett, H.M. 1998. The functional significance of the hyporheic zone in streams and rivers. *Annual reviews in Ecology and Systematics* 29: 59-81.

Boulton, A.J., 2001. Twixt two worlds: taxonomic and functional biodiversity at the surface water/groundwater interface. *Records of the Western Australian Museum* 64: 1–13.

Boulton, A.J., & M.S. Harvey, 2003. Effects of a simulated spate on water mites in the hyporheic zone of an Australian subtropical river. In *An Acarological Tribute to David R. Cook—From Yankee Springs to Wheeny Creek*, ed. I.M. Smith, pp. 57–73. Indira Publishing House, W. Bloomfield.

Boulton, A.J., W.F. Humphreys & S.M. Eberhard, 2003. Imperilled subsurface water in Australia: Biodiversity, threatening processes and conservation. *Aquatic Ecosystem Health & Management* 6: 41–54.

Boulton, A.J., & Hancock, P.J. (2006) ' Rivers as groundwater dependent ecosystems: a review of degrees of dependency, riverine process and management implications'. Australian Journal of Botany, V54: 133-144.

Bradshaw, B. & Bradshaw, J. 2010. Galilee Basin data Gap Analysis. CO2 Geological Storage Solutions Pty Ltd.

Brunke, M. & Gonser, T. 1997. The ecological significance of exchange processes between rivers and groundwater. *Freshwater Biology*. 37: 1-33.

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

Danielopol, D.L., Griebler, C., Gunatilaka, A and Notenboom, J. 2003. Present state and future prospects for groundwater ecosystems Environmental Conservation 30 (2): 104–130.

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.

Dillon, P.Kumar, A., Kookana, R., Leijs, R., Reed, D., Parsons, S. and Ingleton, G. 2009. *Managed Aquifer Recharge – Risks to Groundwater Dependent Ecosystems – A Review*. Water for a Healthy Country Flagship Report. Land and Water Australia.

Dumas P. & Fontanini G. (2001) Sampling fauna in aquifers: a comparison of net-sampling and pumping. Archiv für Hydrobiologie 150, 661-676

E3 Consulting Australia. 2010. Waratah Coal EIS – China First Groundwater Assessment. September 2010. Queensland, Australia.

Eberhard S.M. & Spate, A.P. 1995. Cave invertebrate survey: Toward an atlas of NSW Cave fauna. A report under NSW Heritage Assistance program NEP94765. NSW National Parks and Wildlife Service, Queanbeyan.

Environment Protection and Biodiversity Conservation Act (EPBC Act) 1999. Australian Government. Department of Sustainability, Environment, Water, Population and Communities.

Finston, T.L., Bradbury, J.H., Johnson M.S. and Knott B. 2004. When morphology and molecular markers conflict: a case history of subterranean amphipods from the Pilbara, Western Australia. Animal Biodiversity and Conservation 27, 83-94

Gibert, J., Danielopol, D., & Stanford, J.A. (Eds), 1994, Groundwater Ecology, Academic Press.

Greenslade, P. J. 1991. Chapter 11. Collembola. The Insects of Australia. Second edition. CSIRO Publishing.

Ham, B.W. 1982. Collinsville Ground Water Study. Collinsville Coal Company Pty Ltd. Library, Catalogue No. CCP-WTR-GRW-004.

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.

Harvey, M.S. 2002. Short range endemism among the Australian fauna: some examples from non-marine environments. *Invertebrate Systematics*. 16, 555-570.

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. 2006. Aquifers: the ultimate groundwater-dependent ecosystems. Australian Journal of Botany, 2006, 54, 115–132

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

Malard, F., Dole-Olivier, M.-J., Mathieu, J., Stoch, F., Boutin, C., Brancelj, A., Camacho, A.I., Fiers, F., Galasi, D., Gibert, J., Lefebure, T., Martin, P., Sket, B., and Valdecasas, A.G. 2001. Sampling Manual for the Assessment of Regional Groundwater Biodiversity. PASCALIS Project.

Marmonier P., Vervier P., Gibert J. & Dole-Olivier M.-J. (1993) Biodiversity in ground waters. Trends in Ecology and Evolution 8, 392-395.

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

Parsons, S. 2009. Appendix 5. Effects on groundwater dependent vegetation of groundwater level changes induced by managed aquifer recharge in (eds) Dillion, P. et al. *Managed Aquifer Recharge – Risks to Groundwater Dependent Ecosystems – A Review*. Water for a Healthy Country Flagship Report. Land and Water Australia.

Pinder, A. 2001. Notes on the diversity and distribution of Australian Naididae and Phreodrilidae (Oligochaeta: Annelida). Hydrobiologia. 463: 49-64.

Pinder, A.M. & Brinkhurst, R.O. (1994) *A preliminary guide to the identification of microdile oligochaetes of Australian freshwaters.* Identification Guide No. **1**, Cooperative Research Centre for Freshwater Ecology: Albury.

Queensland Government Coordinator General 2009. Terms of Reference for an EIS for the Galilee Coal Project (northern export facility). August 2009.

Serov, P., Kuginis, L., Byrne, G.T., Williams, J.P. 2012. Risk Assessment Guidelines for Groundwater Dependent Ecosystems in NSW. National Water Commission and NSW Office of Water.

Sket, B. (2010) Can we agree on an ecological classification of subterranean animals ? *Journal of Natural History*, 42, 1549-1563.

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.

Thurgate, M.E., Gough, J.S., Clarke, A.K., Serov, P. and Spate, A. 2001. Stygofauna diversity and distribution in Eastern Australia cave and karst areas. Records of the Western Australian Museum, Supplement No. 64: 49-62.

Tomlinson, M. and Boulton, A. 2008. Subsurface Groundwater Dependent Ecosystems, A Review of their biodiversity, ecolological processes and ecosystem services, *Waterline,* Occasional Paper No.8.

Trajano E. (2001) Ecology of subterranean fishes: an overview. *Environmental Biology of Fishes* 62, 133-160

Ward, J.V., Malard, F., Stanford, J.A., Gonser, T., Wilkens, H., Culver, D.C. and Humphreys, W.F. 2000. Interstitial aquatic fauna of shallow unconsolidated sediments, particularly hyporheic biotopes. Pp: 41-58. *Ecosystems of the World*. Vol. 30. Subterranean Ecosystems. Elsevier. Amsterdam.

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.

Waratah Galilee Coal Project 2012. Supplementary Environmental Impact Statement. *In preparation*.

Williams, D.D. 1993. Changes in Freshwater Meiofauna Communities along the Groundwater-Hyporheic Water Ecotone. *Transactions of the American Microscopial Society*. V112, No.3: 181-194.

Williams, D.D. & Hynes, H.B.N. 1974. The occurrence of benthos deep in the substratum of a stream. *Freshwater Biology*. 4: 233-256.

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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
1	Mark Dahm	Garry Bennison		Jamie Corfield		03/12/12
2	Mark Dahm	Garry Bennison		Kim Piercy		04/12/12

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