Appendix 21

Stygofauna Impact Assessment

Byerwen Coal Pty Ltd

Byerwen Coal Mine Project EIS

Stygofauna Pilot Study

4 March 2013

Limitations and Exclusions

This report has been prepared by GHD for Byerwen Coal Pty Ltd and may only be used and relied on by Byerwen Coal Pty Ltd for the purpose agreed between GHD and Byerwen Coal Pty Ltd as set out in Section 1.5 of this report.

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The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The objective of this study was to conduct a stygofauna Pilot Study 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 1.5. This study was also limited to the quality and extent of information made available to GHD at the time of undertaking the work.

GHD has prepared this report on the basis of information provided by Byerwen Coal Pty Ltd which GHD has not independently verified or checked ("Unverified Information") beyond the agreed scope of work. GHD expressly disclaims responsibility in connection with any Unverified Information, including (but not limited to) errors in, or omissions from, the report, which were caused or contributed to by errors in, or omissions from, the Unverified Information.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points. Investigations undertaken in respect of this report are constrained by the particular site conditions. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

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1. Executive Summary

Byerwen Coal Pty Ltd (the proponent) commissioned Australian Laboratory Services Water Sciences (ALS) now GHD Water Sciences (GHD) to undertake a Stygofauna Pilot Study in order to inform an Environmental Impact Statement (EIS) for the Byerwen Coal Project (the Project) located near Glenden in Central Queensland's Bowen Basin.

ALS conducted the Pilot Study in November/December 2011 at the Project site and prepared a draft report for the proponent in March 2012 (ALS, 2012). In August 2012 GHD was requested by the proponent to finalise the draft report and to supplement the data from the Pilot Study with historic stygofauna survey data obtained from the adjacent Xstrata Newlands Coal Mine (NCP). The intention of extending and expanding the stygofauna dataset available for assessment was to better inform the EIS and negate the need for further stygofauna surveys at Byerwen. The proponent and NCP have a formal agreement to share selected environmental data.

The Project includes an open-cut coal mine located in the Northern Bowen Basin, approximately 20 kilometres west of the mining town of Glenden and 140 kilometres west of the regional centre of Mackay. It should be noted that this Study relates only to the open-cut operations. The proposed mine is located adjacent to and west of the Xstrata Newlands Coal Mine and north of the Xstrata Wollombi and Suttor Creek Coal Mines.

Major construction for the south phase of the Project is due to commence in 2014 with open-cut mining in the southern tenement due to start in 2015. Construction for the north phase of the Project is proposed to commence in 2030 with open-cut mining beginning in 2032.

As part of the Byerwen EIS, an assessment of stygofauna was undertaken in accordance with the Queensland Coordinator General's Terms of Reference (July 2011). A Pilot Study approach was adopted as defined under the WA guidelines (2003 & 2007) which allows for a reduced sampling effort. The aim of the Pilot Study was to determine if stygofauna were present in groundwater associated with the Project, and within the constraints of the Study design, determine the range of taxa present, their conservation significance and sustainable management strategies.

A single sampling event was undertaken at Byerwen during the 2011 pre-wet season between 30th November and 1st December 2011. A total of 8 groundwater bores were sampled within MLA's 10355, 10356, 10357, 70434, 70435 and 70436. Established standard sampling techniques used in Australia and overseas (Hancock and Boulton, 2008; Dumas and Fontanini, 2001) were adopted for this project. In addition to stygofauna samples, *in-situ* groundwater quality samples were also taken and analysed for pH, DO, EC and water temperature.

Analysis of the field samples revealed the presence of stygofauna in one of the eight bores sampled. Site BYGW02 registered the presence of a single specimen of two obligate groundwater species and one terrestrial, possibly edaphobitic (soil dwelling) species. The obligate groundwater fauna was characterised by a single specimen of an Amphipoda and a Copepoda. These species can be found in both the permanent hyporheic as well as the hypogean (true groundwater) ecosystem, which is characterised by relatively low DO, permanent darkness and highly stable water quality (Gilbert et al, 1994). Both groups of subterranean crustaceans 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, particular in the southwest and eastern seaboards.

The eight bores that were sampled on Byerwen were geographically well spread across the existing Byerwen MLA's. The selection of bores covered mostly deeper Rangal and Fort Cooper Coal measures which form the major aquifers within the Byerwen MLA's and which will be impacted by mining. A hydrogeological study undertaken as part of the EIS (RLA 2012) reported no significant alluvial aquifers present on the Project MLA's, so this environment was not sampled as part of the Pilot Study. The aquifers associated with the deeper coal measures were adequately sampled as part of the Pilot Study.

To enhance the spatial and temporal coverage of stygofauna data in order to better inform the EIS, historical stygofauna data from Xstrata NCP which adjoins the Byerwen mining lease, and which is hydrogeologically connected (RLA, 2012), has been incorporated into this study. The inclusion of the NCP data provides a comprehensive dataset for assessment, incorporating a further 67 stygofauna samples collected between 2008 and 2011 to the existing Byerwen dataset of eight stygofauna samples. This provides a very comprehensive and significant dataset from which to assess whether stygofauna represent a relevant environmental factor in consideration of the Byerwen EIS.

The combined Byerwen and NCP stygofauna datasets incorporates 28 sampling sites and 75 samples collected over a 4 year timeframe (2008 to 2011). It is evident from the NCP data, where only two common and widespread stygofaunal taxa have been recovered from one of twenty bores sampled annually for 4 years (Bore SW8896W is located off-lease in the southern region of the NCP survey area), that stygofauna are low in diversity and abundance from this locality. The current Byerwen Pilot Study also failed to identify significant stygofaunal communities (albeit from a single sampling event). Collectively, these data suggest that stygofauna (i.e. stygophiles, stygobites and phreatobites) are poorly represented within the Byerwen and NCP mine lease areas.

In Queensland, to satisfy the TOR for the Byerwen EIS, endemism needs to be disproved at the Family or Order level for stygofauna, in which case the obligate stygofauna collected from both the NCP and Byerwen surveys are not endemic, because the Order/Family they belong to occur in all Australian States (Serov, 2002). Any proposed mining activities associated with the Byerwen Project will not threaten or

put at risk the survival of the amphipod and copepod taxa at the Order/Family level of taxonomic resolution.

Following a review of the combined Byerwen and NCP stygofauna datasets, it can be concluded that stygofauna at the order/family level of taxonomic resolution, do not represent a relevant environmental factor in the assessment of the Byerwen EIS, and no further survey work is recommended.

2. Introduction

Byerwen Coal Pty Ltd (the proponent) commissioned Australian Laboratory Services Water Sciences (ALS) now GHD Water Sciences (GHD) to undertake a Stygofauna Pilot Study (the Study) in order to inform an Environmental Impact Statement (EIS) for the Byerwen Coal Project (the Project) located near Glenden in Central Queensland's Bowen Basin.

Byerwen Coal Pty Ltd is a joint venture between QCoal, which is a Brisbane-based, Queensland-owned and operated coal exploration and mining company, and JFE Steel, which is a subsidiary of the JFE Group of Japan.

ALS conducted a Pilot Study in November/December 2011 at the Project site. A draft report was prepared by ALS for the proponent in March 2012 (ALS, 2012). In August 2012 GHD was requested by the proponent to finalise the report and to supplement the data from the Pilot Study with historic stygofauna survey data obtained from the adjacent Xstrata Newlands Coal Mine (NCP). The intention of extending and expanding the stygofauna dataset available for assessment was to better inform the EIS and to negate the need for further stygofauna surveys at Byerwen. The proponent and NCP have a formal agreement to share selected environmental data.

This report is intended for inclusion as a technical appendix to the Byerwen EIS.

2.1 Background to Byerwen Coal Project

The Project includes an open-cut coal mine located in the Northern Bowen Basin, approximately 20 kilometres west of the mining town of Glenden and 140 kilometres west of the regional centre of Mackay (Figure 1). The proposed mine is located adjacent to and west of the Xstrata Newlands Coal Mine and north of the Xstrata Wollombi and Suttor Creek Coal Mines (Figure 2).

The mine is intended for the extraction of high quality hard coking coal for the export market, primarily to Japan and other Asian countries, with some thermal coal by-product. The project area comprises six mining lease application areas (MLAs), which were lodged on 29 and 30 June 2010, totalling approximately 22,697 hectares. Three of the MLAs (10355 [5411 ha], 10356 [2203 ha] and 10357 [1898 ha]) are administered by the Charters Towers Regional Mining Registrar. The remaining three MLAs (70434 [7731 ha], 70435 [2560 ha] and 70436 [2894 ha]) are administered by the Emerald Regional Mining Registrar. Byerwen Coal holds the two underlying exploration tenements in the project area, namely, Exploration Permit for Coal (EPC) 614 and EPC 739. The project area covers a portion of the two underlying EPC's. The total available coal resource is approximately 690 million tonnes.

Major construction for the south phase of the Project is due to commence in 2014 with open-cut mining in the southern tenement due to start in 2015. Construction for the north phase of the Project is proposed to commence in 2030 with open-cut mining beginning in 2032.

Open-cut mining would be by a combination of a large dragline, excavator, truck and dozer equipment. Mining would occur 24 hours per day, 7 days per week, 52 weeks per year.

Water will be supplied from the existing Burdekin to Moranbah pipeline and will supply the south CHPP via a spur off the existing pipeline running via the southern infrastructure corridor. The water pipeline will then travel north via the central infrastructure corridor to the north CHPP.

2.1.1 South Phase

Infrastructure to be constructed during the south phase of construction (noting that some construction works will continue into the operational years of the project) includes:

- The south CHPP and product coal stockpile area;
- The south MIA including administration facilities, workshops, servicing facilities and fuel storage;
- South ROM coal stockpile and ROM dump station (comprising dump hopper, product conveyor, crushers and surge bin);
- South train loading facility including train loading bin and associated conveyors connected to the coal product stockpile area, rail loop and rail spur;
- ROM coal haul roads and waste rock haul roads and/or conveyor;
- Sewage and waste management facilities for the ongoing use of the operational workforce, including a package sewage treatment plant;
- water supply pipeline and management facilities, including raw water supply, storage and a water treatment plant to treat water to potable quality;
- south co-disposal dam;
- south environmental control pond;
- south mine affected water dams and sediment dams;
- light and heavy vehicle internal roads;
- main gate and security building;
- explosives storage and preparation facilities;
- power lines and substation;
- stream diversions;
- transmission line relocation and new transmission lines;
- bridges and underpasses.

Diesel will be used for all major mobile plant, equipment and vehicles during the construction period. Diesel will be stored in self-bunded tanks.

2.1.2 North Phase

Infrastructure to be constructed during the North construction phase includes:

- the north CHPP and product stockpile area;
- north ROM coal stockpile area and ROM dump station (comprising dump hopper, product conveyor, crushers and surge bin);

- north train loading facility including train loading bin and associated conveyors connected to the product coal stockpile area, rail loop and rail spur;
- ROM coal and waste rock haul roads;
- light and heavy vehicle internal roads;
- the north MIA;
- power lines and substation;
- water supply and management facilities, including raw water supply and storage;
- north mine affected water dams and sediment dams;
- north co-disposal dam;
- north environmental control pond;
- explosives storage and preparation facilities.

Electricity requirements for the North stage of construction will be supplied by either diesel generators or power lines connecting the electricity transmission grid to the project. Substations will be installed adjacent to the north and south Mining Infrastructure Area (MIA).

2.2 Resource Base and Mine Life

The proponent is seeking 50 year mining leases (two years for construction, 46 years of operation and two years for decommissioning and rehabilitation) for the extraction of the coal resource at a rate of approximately 15 Mtpa Run of Mine (ROM) coal. From commencement, the project will ramp up production to achieve a project average of 15 Mtpa ROM coal.

Exploration has resulted in the delineation of a significant coal resource of approximately 690 Mt ROM coal, within the Project area, located approximately 20 kms west of the township of Glenden. It is proposed that the mine will produce approximately 10 Mtpa of product coal for the export market over the 46 year operational mine life. Production from the project will primarily be high quality coking coal with some thermal coal.

The Project area is situated in the North Bowen Basin. The resource includes coal within both the Moranbah and Rangal Coal Measures. The Moranbah Coal Measures represent the main stratigraphic unit of interest in the Project area, and contains up to seven persistent coal seams. The Moranbah Coal Measures are approximately 290 m thick in the Byerwen Project area and strike north-south, dipping to the east at between 4° and 12°. The principal seams of economic interest are the Goonyella Lower (6-8 m thick), Goonyella Middle (6-10 m), and P Rider (2-4.5 m) seams. The main seam of interest in the Rangal Coal Measures is the Leichhardt seam, a correlative of the Upper Newlands seam which averages 6.5 m thick in the Newlands Mine and 4.5 m thick in the Suttor Creek mining lease (ML 4761) area.

The following three products may be marketed:

- washed coking coal,
- washed thermal coal, and
- crushed raw coal.

Byerwen Coal has additional exploration areas immediately adjacent to the project area and exploration activity will be ongoing during the life of the project. These exploration activities do not form part of the current Byerwen EIS.

2.3 Scope of Work

As part of the Byerwen EIS, an assessment of stygofauna for the Project was undertaken in accordance with the Queensland Coordinator General's Terms of Reference (ToR) (July 2011) as follows:

Description of Environmental Values:

.....'A description to Order or Family taxonomic rank of the presence and nature of stygofauna (fauna living in groundwater systems) occurring in groundwater likely to be affected by the project. Sampling and survey methods should be in accordance with the best practice guideline currently published by the Western Australian Environmental Protection Authority – Guidance for the assessment of environmental factors No.54 (December 2003) and Guidance for the assessment of environmental factors No.54a (August 2007) Technical Appendix to Guidance Statement 54'.....

Potential Impacts and Mitigation Measures:

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

In 2011 a Pilot Study approach was adopted to survey stygofauna for the Byerwen EIS. A Pilot Study approach, as defined under the WA guidelines (2003 & 2007), allows for a reduced sampling effort where it is considered that stygofauna are unlikely to occur (refer Section 1.5). The aim of the Pilot Study was to determine if stygofauna were present in groundwater associated with the Byerwen Coal Project, and within the constraints of the Study design, determine the range of taxa present, their conservation significance and sustainable management strategies.

The Xstrata Newlands Coal Mine is located immediately to the east of the proposed Byerwen Coal Mine and shares a common boundary with the Project site (Figure 2). NCP comprises Newlands Coal (Mining Lease [ML] 4748 and 4771), Suttor Creek and Wollombi (ML 4761), Eastern Creek North (ML 4754), and Eastern Creek South (ML 4755 and ML 10176) open-cut mines, and the Newlands Southern (now closed) and Northern (ML 10316, ML 10317, ML 4774 and ML 10322 – operating) underground mines. NCP has been conducting annual stygofauna surveys at 20 groundwater bores from 2008 to 2011 as part of Environmental Authority (EA) requirements.

The proponent and NCP have recently entered into a formal data sharing agreement for selected environmental data, including stygofauna data. Historical NCP stygofauna data was made available to the proponent for inclusion in this report to provide a more

comprehensive dataset on stygofauna to better inform the Byerwen EIS and to negate the need for additional stygofauna survey work.

2.4 Relevant Legislation

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

The TOR for the Byerwen EIS required stygofauna sampling to be undertaken in accordance with surveys conducted 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 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 inside the expected zone of impact was adopted by ALS.

As previously mentioned, the WA Guidelines allow for a Pilot Study approach where it is considered that the likelihood of finding stygofauna is very low (e.g. poor groundwater quality, unsuitable geology, historic sampling of the local area has not recovered stygofauna, lack of groundwater etc.). Whilst Pilot Studies allow for a reduced sampling effort, there is a requirement in the WA Guidelines that in the event of a Pilot Study finding significant stygofauna, additional survey effort may be required to satisfy the full WA Guideline requirements.

2.4.2 Environment 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.

2.5 GDE's and Stygofauna

GDE is a term occurring more frequently in the scientific literature. GDE's represent a vital and significant component of the natural environment (Agriculture & Resource Management Council of Australia and New Zealand [ARMCANZ], 1996; Australian & New Zealand Environment & Conservation Council [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 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 et al, 1994; Humphreys, 2006; Serov et al, 2012). Scientifically, stygofauna are valuable as they have linkages to species with no or very few surface-dwelling representatives. Examples include Bathynellacea, Thermosbaenacea, and Remipedia (Humphreys, 2008). Stygofauna also represent an important component of the natural environment and add to our knowledge of regional, national and global biodiversity.

2.6 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. This report follows 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 animals that occur in subsurface waters (Ward et al, 2000).

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.

2.7 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 is subject to less fluctuation 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). Stygofauna occur at a variety of depths, with some species being found in surface waters as well as deep aquifers (Halse, 2002). As a general rule, the greater the distance between a groundwater habitat and surface water, the stronger the groundwater affinity of the fauna (Halse, 2002). Generally, stygofauna biodiversity is 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 seam aquifers (although this is changing as further targeted sampling is undertaken in Queensland and NSW). Depending on water quality, surface connectivity, porosity of the sediments, degree of fracturing or extent of cavity development, coal seams can provide suitable habitat for stygofauna.

2.8 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 (NWC, 2011).

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

Several 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, near Maryborough 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, their diversity and abundance have 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, hence, it is not clear if they represent new species (or even new genera) and what their geographic distribution might be.

Six stygofauna taxa have been recorded by GHD (unpublished data) so far from coal seam aquifers in Queensland (excluding the current Byerwen data), which strengthens the fact that coal seam aquifers in Queensland can contain stygofaunal communities. The significance of this data is difficult to estimate as data from other groundwater ecological studies conducted in Queensland are not publicly available. It is not known, therefore, if other studies have also recorded stygofauna from coal seam aquifers in Queensland, and what spatial and temporal trends in diversity and abundance might apply.

The six taxa recorded by GHD from coal seam aquifers are as follows:

- A species of harpacticoid copepod was collected from the Bowen Basin in Central Queensland. This specimen occurred in a shallow coal seam (50m 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 (89m deep with SWL at 38.5 m) in the Galilee Basin. The bore recorded high groundwater quality (EC 1,505 µS/cm; pH 6.28 and DO 2.51 mg/L),

- 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.

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 from 2004 to 2008 surveyed groundwater monitoring bores in agricultural areas and on several mine sites of the upper Hunter Valley (Hancock and Boulton, 2008). 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. These animals are currently undergoing species level identification.

Recent studies in Queensland (Hancock and Boulton, 2008) suggest that stygofauna prefer water with an electrical conductivity (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 an EC of 26,000 µS/cm (GHD unpublished), so it is still quite possible to collect animals in groundwater with an EC in excess of 5,000 µS/cm. Other variables thought to be favourable for stygofauna are a shallow water table ($<$20 m), moderate concentrations of dissolved oxygen ($\geq$1 mg/L) and pH between 6.5 and 7.5 (Hancock and Boulton, 2008), although this range is considered quite narrow (Serov, P. *pers comm*).

3. Project Methodology

3.1 Study Area

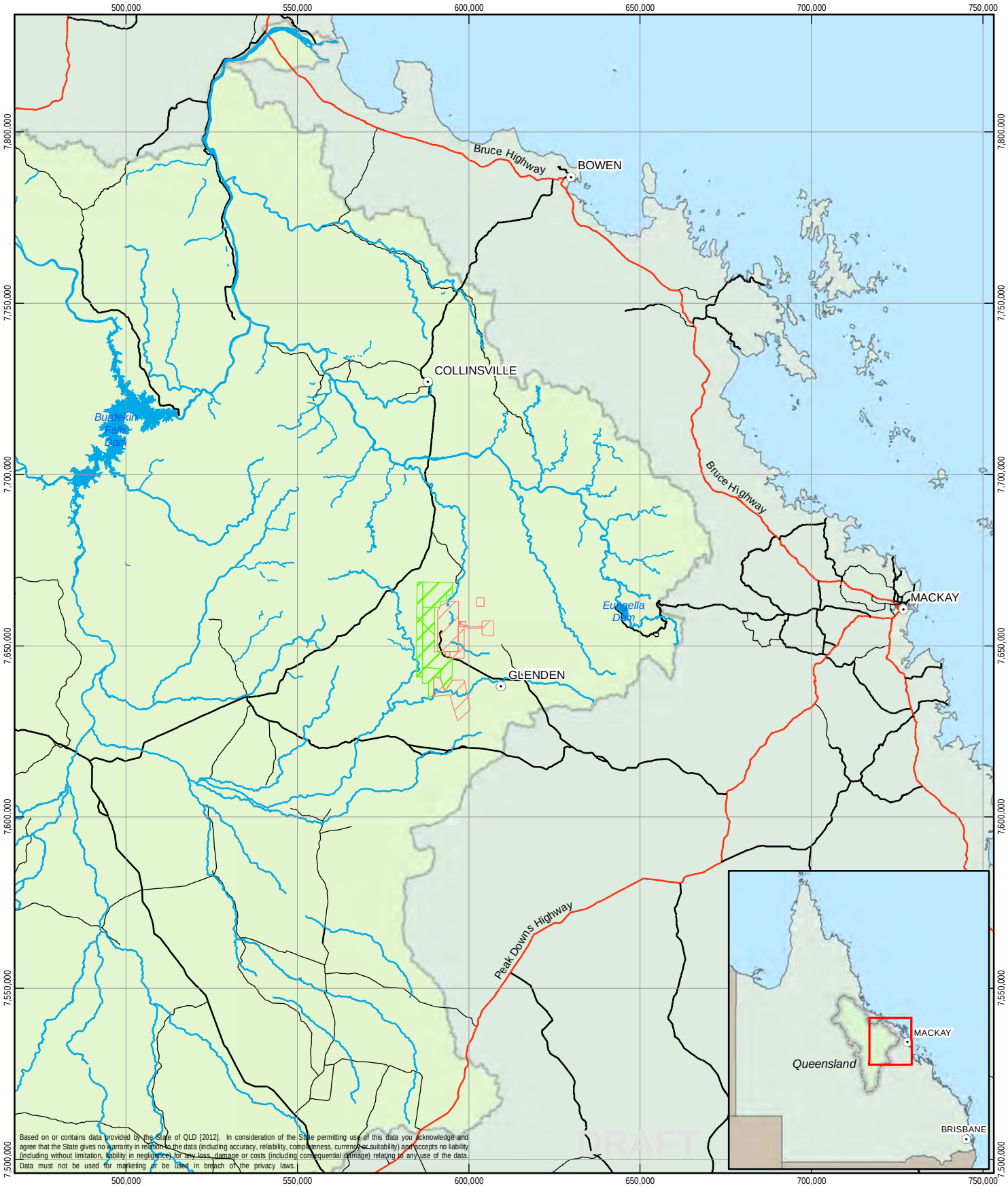
3.1.1 Byerwen Coal Project

The Project area is located in the Northern Bowen Basin, approximately 20 kms west of the mining town of Glenden and 140 kms west of the regional centre of Mackay (Figure 1). The proposed mine is located adjacent to and west of the Xstrata Newlands coal mine and north of the Xstrata Wollombi and Suttor Creek coal mines (Figure 1).

The Project is located within the Rosella Creek and Upper Suttor River sub-catchments of the Bowen River catchment and Suttor River catchment respectively. These catchments constitute part of the headwaters of the Burdekin Basin. The Burdekin Catchment is the second largest in Queensland and covers an area of 133,432 km^2. Four key watercourses occur within the study area. Kangaroo Creek drains the northern section of the proposed open cut operations, subsequently flowing into Rosella Creek, which drains into the Bowen River. The southern portion of the Project area is drained by the Suttor River and Suttor Creek. The Suttor River subsequently collects into the Burdekin Falls Dam downstream of its confluence with the Belyando River.

3.1.2 Xstrata Newlands Coal Mine (NCP)

The NCP Mine is located in the headwaters of several small creeks and rivers located in the Bowen-Broken and Suttor River sub-catchments of the Burdekin River drainage basin, 140 km west of Mackay (Figure 1). Three major waterways intersect the NCP Lease including Cerito Creek, Kangaroo Creek, and Suttor Creek. Cerito Creek and Kangaroo Creek are ephemeral tributaries of the Bowen-Broken River catchment. These receive discharges from the Newlands and Eastern Creek South mines. Suttor Creek is an ephemeral tributary of the Suttor River catchment that receives wastewater discharges from Suttor Creek mine. Most of these creeks are classified as temporary or ephemeral and are dry for most of the year, flowing for a short time following episodic rainfall events which typically occur every wet season.



Legend

- Locality
- QCoal ML
- Xstrata ML
- Highway
- Main Road
- Secondary Road
- Watercourses
- Burdekin Catchment
- Dam

1:1,500,000 at A4

0 5 10 20 30 40 50

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

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Stygofauna Pilot Study 2012

Mine lease areas within Burdekin Catchment

Job Number 23-14341
Revision A
Date 08 Oct 2012

Figure 1

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Data source: GA: © Commonwealth of Australia (2007) Watercourses, Populated Places, Roads, Dams; DERM: Drainage Basins, ASGC: State Boundaries (2009); DEEDI: Mining Leases (2012). Created by: KP

3.2 Geology and Hydrogeology Overview

3.2.1 Byerwen Coal Project

The stratigraphy of the Byerwen project area is described in Table 1 (ELP, 2012).

Table 1: Stratigraphy of the Byerwen project area (ELP, 2012).

AGE	GROUP	FORMATION	THICKNESS
Tertiary		Suttor Formation	
Triassic	Rewan Group	Arcadia Formation Sagittarius Formation	230 m 280 m
Late Permian	Blackwater Group	Rangal Coal Measures Fort Cooper Coal Measures Moranbah Coal Measures	60 m 400 m 290 m
Early Permian	Back Creek Group	Exmoor Formation Blenheim Formation Gebbie Formation Tiverton Formation	85 m

The east zone of the Byerwen Coal Project will target coal seams in the Rangal Coal Measures and the south, west and north zones will focus on the seams in the Moranbah Coal Measures (Figure 2).

3.2.2 Xstrata Newlands Coal Mine

NCP mining operations encompass three major mining areas; Suttor, Wollombi and Eastern Creek. Hydrogeological data is only available for the Suttor Creek mining area and is reported in detail in the 'Newlands Coal Mine: Extension into the Wollombi No. 2 Surface Area Environmental Impact Statement'. The information below is summarised from this report.

There are three principal aquifers in the Suttor Creek mining area:

- A deep Quaternary alluvium consisting of quartzlithic sands and clayey sands with some gravel and clay,
- A fractured basalt aquifer, and
- A discrete fractured zone in the Permian sediments that includes coal seams of the Moranbah Coal Measures.

The Tertiary sediments are overlain by approximately 5 to 10 m of Quaternary sands and gravels near Suttor Creek, The shallow alluvial aquifer extends laterally from Suttor Creek for approximately 300 m. Water level in the shallow alluvium reflects rainfall patterns. Beyond this the Tertiary clay, sand, and gravel sediments overly Permian coal measures with the Tertiary sediments containing deep paleochannels to 100 m in some places. To the north of the deposit the sediments are more than 50 m deep with the bottom 20 m comprised of gravels and sands.

A Tertiary basalt aquifer greater than 80 m thick in places occurs in the southern section of the Suttor Ck mine area and comes to within 500 m of the pit boundary. Basalt lies along the sedimentary paleodrainage system and contains groundwater in fractures throughout the rock but more frequently near the base and in the weathered uppermost section.

The Permian strata is made up of sandstones, siltstones, carbonaceous mudstones, tuff beds, and coal seams. Water occurs at the interface between weathered and fresh rock, in fractures of the coal seam, and at the contact zone between sandstone and shale units.

3.2.3 Relationship to the GAB

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. The GAB consists of confined artesian and sub-artesian groundwater and the confined aquifers of the Basin are bounded by the Rewan Group sediments which form the basement of the aquifers, with the Winton Formation acting as the upper confining layer.

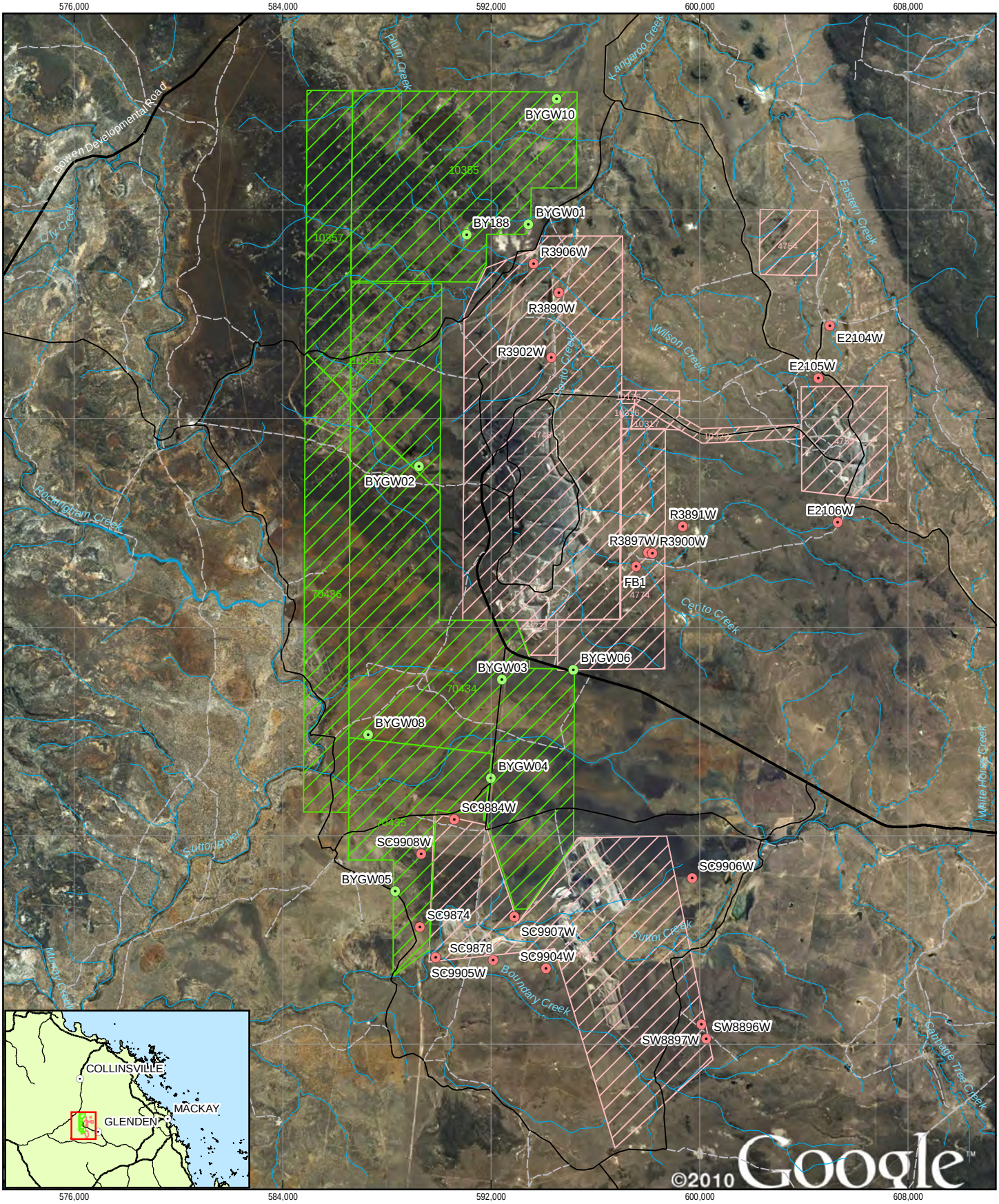
The Byerwen leases have been identified as having entirely different locations, ages and stratigraphy to the GAB, so there is no established association or potential impact from the Project on the GAB (Rob Lait, *pers comm*).

3.3 Study Design

3.3.1 Byerwen Coal Project

Stygofauna sampling was conducted by ALS in accordance with WA Guidelines (2003 & 2007) as specified by the Queensland Coordinator General in the ToR for this project. Established standard sampling techniques used in Australia and overseas (Hancock and Boulton, 2008; Dumas and Fontanini, 2001) were adopted and all field equipment was of high quality, well maintained, fully calibrated and operated to manufacturer's specifications. The stygofauna sampling program was conducted by professionally qualified and experienced ALS aquatic ecologists (refer Section 3.5 of this report).

In accordance with WA Guidelines (2003 & 2007) for Pilot Studies a single sampling event was undertaken during the 2011 pre-wet season between 30th November and 1st December 2011. A total of 8 groundwater bores were sampled within MLA's 10355, 10356, 10357, 70434, 70435 and 70436 (Figure 2).



LEGEND

- QCoal Byerwen bore locations
- QCoal ML
- Xstrata Newlands bore locations
- Xstrata ML
- Creeks / Rivers
- Major Road
- Minor Road
- Track

1:200,000 at A4

0 1 2 4 6 8

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

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Stygofauna Pilot Study 2012

Job Number 23-14341
Revision C
Date 04 Mar 2013

Bore locations

Figure 2

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Data source: © Commonwealth of Australia (2007): Roads, Watercourselines, Populated places; ASGC: State boundary (2009); DEEDI: Mining Lease boundaries (2012); GHD: Bore locations (2011); Google Earth Imagery: extracted 8/10/12.
Created by: KP

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

- Order/Family taxonomic resolution was applied as defined in the TOR for the Byerwen Coal Project EIS,
- Six hauls (where possible) were undertaken using a 50 micron mesh net of 50 mm diameter.

Neither of these modifications reduced the efficacy of the sampling program.

3.3.2 Xstrata Newlands Coal Mine

NCP sampling methods conformed with WA EPA Guidance Statements No. 54 and 54a (2003 & 2007). Stygofauna sampling conducted by GHD for NCP from 2008 to 2012 used the same sampling methods and sampling equipment adopted for the Byerwen Coal Project (GHD 2008, 2009, 2010, 2011 and 2012). As a consequence, stygofauna data collected for NCP are directly comparable with stygofauna data collected for the Byerwen Project.

3.3.3 Location of Sampling Bores and Bore Characteristics

Byerwen Coal Project

A total of 12 groundwater bores were initially selected for stygofauna sampling. Of the 12 bores selected only eight bores could be sampled by ALS (Figure 2). Bore BYGW04 was blocked at around 70m so was not sampled for either stygofauna or *in-situ* water quality. ALS sampled bore BY188 as an alternative to BYGW04. Due to a severe wet weather event during the sampling program QCoal instructed ALS not to sample bores BYGW07(a), BYGW07(b), BY073 and BYGW09 for safety reasons. Information on bore characteristics and bore history is provided in Table 2. The eight groundwater bores were located within EPC 614 and EPC 739 (Figure 2).

Xstrata Newlands Coal Mine

A total of 20 NCP groundwater bores were sampled annually by GHD for stygofauna in December 2008, September 2009, July 2010, September 2011 and June 2012 (GHD 2008, 2009, 2010, 2011 and 2012). Information on NCP bore characteristics and sampling frequency for four consecutive sampling events conducted between 2008 and 2011 is provided in Table 3. The 20 NCP groundwater bores were located both on-lease (7 bores) and off-lease (13 bores) (Figure 2). The total number of bores sampled for the life of the NCP project to date is 87 (note: stygofauna sampling was conducted by GHD in June 2012, however, at the time of writing this report these samples have yet to be analysed so these data are not included in this report).

3.3.4 Selection of Groundwater Bores for Stygofauna Sampling

The basic criteria for selection of groundwater bores for stygofauna sampling for both the Byerwen and NCP projects 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 the proposed mine lease 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 (if present);
- 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 with a salinity less than 5,000 µS/cm EC (and preferably less than 1,500 µS/cm), a dissolved oxygen concentration $\geq$1 mg/L and pH within the range 6.5 to 7.5 (where possible).

Table 2: Byerwen groundwater bore characteristics. These bores were sampled for stygofauna by ALS in November/December 2011. Bore BYGW04 was collapsed at ~70m and could not be sampled. (ND = No Data) (SWL measured as metres below top of casing) (Depth of Hole measured as metres below ground level).

Bore ID	Location	Easting	Northing	Depth of Hole (m)	SWL (m)	Bore Diam. (mm)	Purpose of Bore	Cased Depth (m)	Perforated Interval (m)	Hydrostratigraphic Unit
BYGW01	on-lease	593438	7663430	59.5	10.57	100	Monitoring	59.5	47.5 – 59.5	Rangal Coal Measures
BYGW02	on-lease	589229	7654175	59.5	33.47	100	Monitoring	59.5	47.5 – 53.5	Fort Cooper Coal Measures
BYGW03	on-lease	592422	7645985	67.0	34.19	100	Monitoring	62.0	56 – 62	Fort Cooper Coal Measures
BYGW04	on-lease	591997	7642215	119.0	ND	100	Monitoring	113.0	95 – 107	Fort Cooper Coal Measures
BYGW05	on-lease	588323	7637881	105.0	80.69	100	Monitoring	105.0	81 – 93 & 99 – 105	Exmoor Formation
BYGW06	on-lease	595167	7646339	120.0	55.95	100	Monitoring	115.0	103 – 115	Rangal Coal Measures
BYGW08	on-lease	587279	7643867	66.0	42.70	100	Monitoring	65.5	56.5 – 65.5	Basalt
BYGW010	on-lease	594512	7668243	52.0	27.08	100	Monitoring	52.0	40 – 52	Rangal Coal Measures
BY188	on-lease	591055	7663050	56.0	21.03	125	Monitoring	50.0	ND	'unknown'

3.4 Sampling and Processing Methodology

3.4.1 Stygofauna Sampling

Stygofauna sampling was undertaken by ALS using a 50 mm diameter phreatobiological net (ALS net design conformed to WA Guidelines 2003 & 2007 requirements). 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. 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 (or as

Table 3: NCP groundwater bores sampled annually for stygofauna by GHD on five occasions from 2008 to 2012. (note: NCP 2012 data not presented in this report) (ND = No Data) (SWL measured as metres below top of casing) (Depth of Hole measured as metres below ground level).

Bore ID	Location	Easting	Northing	Depth of Drilled Hole (m)	SWL (m)	Bore Diameter (mm)	Purpose of Bore	Date Drilled
SC9874	off-lease	589269	7636480	154	27.94	100	Monitoring	Nov 2007
SC9878	off-lease	592085	7635211	52	20.47	100	Monitoring	Nov 2007
SC9884W	off-lease	590585	7640615	84	42.65	150	Monitoring	Sept 2008
SC9904W	off-lease	594116	7634918	66	22.12	150	Monitoring	Sept 2008
SC9905W	off-lease	589874	7635333	66	9.46	150	Monitoring	Oct 2008
SC9906W	off-lease	599718	7638361	66	29.86	150	Monitoring	Oct 2008
SC9908W	off-lease	589313	7639292	102	47.71	150	Monitoring	Nov 2007
E2105W	off-lease	604558	7657555	56	20.15	150	Monitoring	Mar 2009
E2104W	off-lease	605001	7659551	68	5.09	150	Monitoring	Mar 2009
E2106W	off-lease	605311	7652019	64	8.11	150	Monitoring	Mar 2009
R3891W	off-lease	599358	7651856	126	16.97	150	Monitoring	Jan 2009
SW8897W	off-lease	600079	7632760	96	16.17	150	Monitoring	Mar 2009
SW8896W	off-lease	600265	7632217	42	12.91	150	Monitoring	Mar 2009
SC9907W	on-lease	592885	7636869	66	65.5	150	Monitoring	Nov 2008
R3890W	on-lease	594602	7660831	78	21.24	150	Monitoring	Jan 2009
R3897W	on-lease	598028	7650854	72	18.34	150	Monitoring	Jan 2009
R3900W	on-lease	598192	7650821	57	17.77	150	Monitoring	Jan 2009
R3902W	on-lease	594317	7658358	50	13.38	150	Monitoring	Jan 2009
R3906W	on-lease	593645	7661920	42	2.15	150	Monitoring	Mar 2009
Farming Bore at Cerito Creek Dam	on-lease	597571	7650318	40	4.08	150	Windmill	ND

many hauls that could be completed), the entire sieve contents were transferred into a labelled sample jar and preserved in 100% AR Grade ethanol (i.e. to enable future DNA analysis of individual specimens if required). A small amount of Rose Bengal, which stains animal tissue pink, was added to each sample to aid sample processing.

3.4.2 Laboratory Processing

Stygofauna samples were processed by ALS at their Brisbane Laboratory. Sample jars were drained of ethanol and washed gently into channelled sorting trays to create a thin layer of sediment spread across the bottom of the tray. Samples were then sorted under a Leica MZ9 stereomicroscope with plan achromatic 10x objective lenses and a zoom capability of between 6.3 x and 60 x. All aquatic animals were removed, identified to Order/Family level (or lower taxonomic rank if possible) in accordance with DEHP TOR for the Byerwen EIS, and placed in labelled, polyethylene containers filled with 100% AR Grade ethanol for long-term storage.

3.4.3 Groundwater Quality Sampling

Groundwater samples were collected by ALS using a hand operated bailer lowered to approximately 3 m below the water surface prior to stygofauna sampling. Water was measured for temperature (°C), pH, electrical conductivity (µs/cm), and dissolved oxygen (mg/L and % saturation) using a YSI 556 multi-parameter water quality meter in order to provide a general estimate of standing groundwater quality. It is noted 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 WQ Sampling – Guidance on Sampling of Groundwater).

Groundwater sampling preceded biological sampling to ensure the groundwater contained within the bore was undisturbed. The YSI field meter was calibrated prior to its use in the laboratory, 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 by ALS from each groundwater bore on depth to water table (using a Solinst electronic dip probe), depth to end of hole, 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 ALS recording sheets.

3.5 ALS/GHD Project Personnel

The November/December 2011 field sampling program was conducted by Garry Bennison (BSc. Hons.) and Kim Piercy (BSc. Hons.) from ALS Water Sciences. Both staff are professional aquatic ecologists and experienced in stygofauna sample collection and analysis. Garry Bennison is a Principal Consultant with in excess of 30 years of experience as an aquatic ecologist. Kim Piercy is a Senior Scientist and has in excess of 12 years of experience as an aquatic ecologist.

Laboratory processing of samples, including stygofauna taxonomy, was undertaken by ALS Senior Taxonomist Gavin Williams (Advanced Diploma of Aquatic Resource Management) with taxonomic QA/QC conducted by Dr Peter Serov (BSc.Hons. PhD) of the NSW DPI Office of Water. The written reports for this project (March 2012 and October 2012) were prepared by Garry Bennison (ALS and GHD Water Sciences).

4. Results

4.1 Groundwater Bore Selection

The eight bores that were sampled on Byerwen were geographically well spread across the existing Byerwen MLA's. The selection of bores covered mostly deeper Rangal and Fort Cooper Coal measures which form the major aquifers within the Byerwen MLA's and which will be impacted by mining. A hydrogeological study undertaken as part of the EIS (RLA 2012)(Appendix A) reported no significant alluvial aquifers present on the Project MLA's, so this environment was not sampled as part of the Pilot Study. The aquifers associated with the deeper coal measures were adequately sampled as part of the Pilot Study.

The age of seven of the groundwater bores sampled for stygofauna ranged between two and three months old (no data is available for bore BY188) (Table 4). As indicated in Section 2.3.4 of this report 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. This is because it can take 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 and for stygofauna to fully populate the bore environment (assuming they are present in the aquifer).

4.2 Groundwater Quality

The water table was generally deep across the Byerwen study area and ranged from 10.57 m at site BYGW01 (Rangal Coal Measures) to 80.69 m at site BYGW05 (Exmoor Formation) (Table 4). Stygofauna in QLD have been found to prefer shallow water tables, generally less than 20 m (Hancock and Boulton, 2008). The quality of standing water within the bores sampled for stygofauna is discussed below.

Groundwater temperatures were generally high and averaged 27.12^{o}C across all eight bores, with a minimum of 24.19^{o}C at BYGW06 and a maximum of 28.46^{o}C at BYGW05 (Table 4).

Groundwater pH varied greatly between bores which may be a reflection of bore age or the fact that standing bore water was measured as opposed to true aquifer water. pH values averaged 9.4 across all eight bores (Table 4) with a minimum of 6.34 at BYGW03 and a maximum of 12.07 at BTGW08. Stygofauna have been shown in QLD to prefer pH in the range of 6.5 to 7.5 (Hancock and Boulton, 2008).

Electrical Conductivity (EC) was generally low across all eight groundwater bores with six of the eight bores sampled recording an EC value less than 5,000 µS/cm which is the preferred range quoted for stygofauna (Table 4) (Hancock and Boulton, 2008). EC values ranged from a high of 17,058 µScm^{-1} at BYGW05 to a low of 1,477 µScm^{-1} at BYGW010.

Dissolved Oxygen (DO) concentrations were low to medium for groundwater with an average of 1.63 mg/L across all eight bores (Table 4). These figures 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. Dissolved oxygen concentrations ranged from a low of 0.92 mg/L at site BYGW03 to a high of 2.75 mg/L at site BYGW08.

Table 4: Groundwater quality data for eight bores sampled for stygofauna at Byerwen in November/December 2011. Groundwater samples were collected by a hand operated bailer prior to any biological sampling occurring (refer section 3.4.3). Bore BYGW04 was blocked at around 70 m and could not be sampled for water quality or stygofauna. (ND – No Data) (EC = Electrical Conductivity) (SWL measured as metres below top of casing) (Depth of Hole measured as metres below ground level).

Bore ID	Depth of Drilled Hole (m)	Date Drilled	SWL (m)	pH	EC (µS/cm)	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% satn)	Date Sampled
BYGW01	59.5	17/9/11	10.57	8.33	1,697	26.78	1.39	17.8	30/11/11
BYGW02	59.5	8/9/11	33.47	6.82	9,975	28.42	1.92	25.7	30/11/11
BYGW03	67.0	8/9/11	34.19	6.34	2,302	26.74	0.92	12.2	30/11/11
BYGW04	119.0	6/9/11	ND	ND	ND	ND	ND	ND	30/11/11
BYGW05	105.0	16/9/11	80.69	10.39	17,058	28.46	1.04	14.3	29/11/11
BYGW06	120.0	14/9/11	55.95	11.77	3,026	24.19	2.01	24.2	01/12/11
BYGW08	66.0	11/9/11	42.70	12.07	4,458	28.35	2.75	36.2	30/11/11
BYGW010	52.0	18/9/11	27.08	11.70	1,477	26.96	1.03	13.1	30/11/11
BY188	56.0	ND	21.03	7.97	1,532	27.02	1.98	24.8	30/11/11
MEAN			**38.21**	**9.40**	**5,191**	**27.12**	**1.63**	**21.04**	
RANGE			**10.57 to 80.69**	**6.34 to 12.07**	**1,477 to 17,058**	**24.19 to 28.46**	**1.03 to 2.75**	**13.1 To 36.2**	

Groundwater quality samples were also collected in October 2011 for all bores shown in Table 4 above with the exception of BYGW04 and BY188 (ELP, 2012). Data available for pH and EC show similar figures to those obtained by ALS. Groundwater level data also collected in October 2011 (ELP, 2012) indicates a lower water table across all sites than what was observed by ALS in November/December 2011.

4.3 Stygofauna

4.3.1 Byerwen Coal Project

A total of eight groundwater bores were sampled for stygofauna within Byerwen MLA's 10355, 10356, 10357, 70434, 70435 and 70436 between the 29th November and 1st December 2011. Sample quality varied, as shown in Table 5.

Table 5: Summary of the quality of stygofauna samples collected in Nov/Dec 2011. Four to six hauls, with each haul reaching the bottom of the bore were required for a sample to be classified as 'good'.

Bore ID	Number of Net Hauls	Quality of Sample
BYGW01	6	Good sample with all net hauls off the bottom of the bore.
BYGW02	6	Good sample with all net hauls off the bottom of the bore.
BYGW03	4	Average sample. Net snagging at ~56 m so unable to reach bottom of bore.
BYGW04	0	**No Sample**. Net snagging at ~70 m so unable to collect WQ or stygofauna sample.
BYGW05	2	Poor sample. Net and sieve clogging with fine colloidal clays so only 2 hauls able to be collected and neither from the bottom of the bore.
BYGW06	4	Average sample. Net snagging at ~65 m for hauls 3 & 4. First 2 hauls reached the bottom of the bore.
BYGW08	4	Average sample. Net and sieve clogging with fine colloidal clays. Only 3 hauls reached the bottom of the bore.
BYGW010	6	Good sample with all net hauls off the bottom of the bore.
BY188	6	Good sample with all net hauls off the bottom of the bore.

Analysis of the field samples revealed the presence of stygofauna in one of the eight bores sampled (Table 6). Site BYGW02 (Figure 2) registered the presence of a single specimen of 2 obligate groundwater species and one terrestrial, possibly edaphobitic (soil dwelling) species. The relatively small size (<1 mm) of the species present and small number of specimens of each species suggests a low to moderate hydraulic conductivity within the aquifer.

Stygobites / Stygophiles

- **Amphipoda**, sp.
- **Copepoda**, Cyclopoida sp.

The obligate groundwater fauna was characterised by a single specimen of an Amphipoda and a Copepoda. The Amphipod was a very young larva with some damage and therefore could not be identified further than Class. These species can be found in both the permanent hyporheic as well as the hypogean (true groundwater) ecosystem, which is characterised by relatively low DO, permanent darkness and highly stable water quality (Gilbert, 1994).

Table 6: List of Subterranean Fauna collected from Byerwen MLA's 10355, 10356, 10357, 70434, 70435 and 70436 in November/December 2011. Shaded rows show true stygofauna (# The Amphipod specimen was immature and damaged so could not be identified beyond Order level) (* Refer Section 2.7 for a definition of terms).

Bore ID	Order	Family	Species	No. Animals	Habitus*	Collection Method	Collection Date
BYGW01	–	–	–	0	–	50µ Net	30/11/11
BYGW02	Amphipoda	Not Determined #	*sp.*	1	Stygobite	50µ Net	30/11/11
BYGW02	Copepoda	Cyclopoida	*sp.*	1	Stygophile	50µ Net	30/11/11
BYGW02	Psocoptera	Trogiomorpha	*sp.*	1	Edaphobite	50µ Net	30/11/11
BYGW03	–	–	–	0	–	50µ Net	30/11/11
BYGW04	–	–	–	0	–	50µ Net	30/11/11
BYGW05	–	–	–	0	–	50µ Net	29/11/11
BYGW06	–	–	–	0	–	50µ Net	01/12/11
BYGW08	–	–	–	0	–	50µ Net	30/11/11
BYGW010	–	–	–	0	–	50µ Net	30/11/11
BY188	–	–	–	0	–	50µ Net	30/11/11

Both groups of subterranean crustaceans 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, particular in the southwest and eastern seaboards. They can also occur in other specialised habitats such as caves, alluvials and the hyporheic zone of sand and gravel bed river systems which receive their water principally from groundwater. The Amphipoda are predominantly detrital feeders consuming sediment, alga and diatoms, whereas the Copepoda are predatory on zooplankton and phytoplankton.

Although subterranean, these two groups have their highest biodiversity within the riverine, hyporheic zones and are 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, 1994). They typically characterize the transition zone between the permanent shallow hyporheic ecozone and the groundwater hypogean environment (Gilbert, 1994).

Edaphobite

- **Psocoptera**, Trogiomorpha sp.

The third species belongs to the insect group Psocoptera or Book Lice/Bark Lice. They are typically detrital or fungal feeders associated with the ground litter layer and tree bark. Their presence in the sample is most likely coincidental either by falling in or occupying the vegetation adjacent to the bore or living within the bore above the water table, as they have a preference for humid environments.

Details of the occurrence of this animal have been provided in this report as they were collected as part of the Pilot Study for the Byerwen EIS, however, as they are not aquatic and groundwater dependent they have no specific relevance to this study other than scientific interest, and will not be considered further in this report.

4.3.2 Xstrata Newlands Coal Mine

A total of 20 groundwater bores were sampled for stygofauna by GHD within and adjoining the NCP mine Lease in September 2011 (GHD, 2011). High quality samples were collected from all 20 groundwater bores. A standard six net hauls were collected from each groundwater bore with the exception of bores SC9878 and SW8897W where only 4 net hauls were collected.

Three sites (SW8896W, SC9907W and SC9874) registered the presence of aquatic fauna in September 2011 from 20 sites sampled, however, only one groundwater bore recorded stygofauna (SW8896W) (Table 7). Site SW8896W recorded 2 obligate groundwater species as follows:

- **Syncarida**, Family Parabathynellidae, and
- **Oligochaeta**, Family Naididae.

The same 20 groundwater bores were sampled by GHD in December 2008, September 2009, July 2010 and June 2012, however, no stygofauna were recovered from the 2008, 2009 and 2010 sampling events. In summary, 67 samples have been collected from four annual sampling events conducted between 2008 and 2011 with the recovery of stygofauna (two taxa only) from one bore on one occasion in 2011. Groundwater samples collected in July 2012 have yet to be processed so data is not currently available for inclusion in this report (GHD, 2012).

Bore SW8896W was located off-lease in the southern region of the NCP survey area (Figure 2). The relatively small size (i.e. 2-3 mm) and diameter of the species present and the relatively large number of specimens of each species (i.e. 53 Notobathynellids and 11 oligochaetes) suggests a moderate connectivity within the aquifer.

Stygobites

- **Syncarida**, *Notobathynella sp.*
- **Oligochaeta**, Naididae sp.

The obligate groundwater fauna is characterised by Syncarida (Crustacea) and Oligochaeta (Worms). Both are common taxa and can be found in permanent hyporheic as well as hypogean (true groundwater) ecosystems. These environments are characterised by relatively low DO, permanent darkness, and stable high water quality

Table 7: List of Groundwater Fauna collected from 20 NCP groundwater bores sampled in September 2011. Shaded rows show groundwater dependent fauna (* Refer Section 2.7 for a definition of terms).

Bore ID	Order	Family	Genus	No. Animals	Habitus*	Collection Method	Collection Date
SC9874	Coleoptera	Not determined	Not determined	1	Stygoxene	50µ Net	13/9/11
SC9878	-	-	-	0	-	50µ Net	13/9/11
SC9884W	-	-	-	0	-	50µ Net	14/9/11
SC9904W	-	-	-	0	-	50µ Net	13/9/11
SC9905W	-	-	-	0	-	50µ Net	13/9/11
SC9906W	-	-	-	0	-	50µ Net	15/9/11
SC9908W	-	-	-	0	-	50µ Net	13/9/11
E2105W	-	-	-	0	-	50µ Net	16/9/11
E2104W	-	-	-	0	-	50µ Net	16/9/11
E2106W	-	-	-	0	-	50µ Net	16/9/11
R3891W	-	-	-	0	-	50µ Net	17/9/11
SW8897W	-	-	-	0	-	50µ Net	15/9/11
SW8896W	Oligochaeta	Naididae	Not determined	11	Stygobite	50µ Net	15/9/11
SW8896W	Syncarida	Parabathynellidae	*c.f.Notobathynella*	53	Stygobite	50µ Net	15/9/11
SC9907W	Hempitera	Amphidoidea	Not determined	2	Stygoxene	50µ Net	13/9/11
R3890W	-	-	-	0	-	50µ Net	19/9/11
R3897W	-	-	-	0	-	50µ Net	17/9/11
R3900W	-	-	-	0	-	50µ Net	17/9/11
R3902W	-	-	-	0	-	50µ Net	17/9/11
R3906W	-	-	-	0	-	50µ Net	14/9/11
Farming Bore at Cerito Ck. Dam	-	-	-	0	-	50µ Net	17/9/11

(Gilbert, 1994). Both groups of subterranean species are important components of Australia's groundwater fauna. They contain a large number of short range endemic species with a large biodiversity along the continental marginal areas, particular in the southwest and eastern seaboards.

The Parabathynellidae are one of the major faunal components within Queensland's groundwater ecosystems. They have an ancient lineage dating back to Pangaea, and are often the largest faunal group within western and north-western regions of Australia. Parabathynellidae, as with other Syncarida, are predominantly detrital feeders consuming sediment, algae and diatoms although many will consume animal tissue (they can also be cannibalistic). The species collected belongs to the genus *Notobathynella*, however, as this genus has only been described (so far) from NSW, Victoria, Tasmania and New Zealand, it may belong to a new but related genus. Undescribed species have also been collected in WA and north-west Queensland.

The Oligochaete Family, Naididae, is a common and widespread aquatic family of freshwater worms, which currently contains approximately 23 genera and 59 species. The Family is usually associated with high water quality environments.

The Naididae typically inhabit and swim in the water column just above the substratum, whereas other aquatic oligochaetes that do not burrow, crawl along the substratum. The feeding habit of most aquatic oligochates is to ingest detritus and sediments, however, some species of Naididae may be carnivorous, while others are parasitic (Pinder & Brinkhurst, 1994).

The Australian naidid fauna consists mostly of cosmopolitan species, although there are indications of greater endemicity than 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 oligochaete distribution will require a great deal more research (Pinder, 2001).

Although primarily stygobites (i.e. belonging to the deep groundwater ecotone), these two groups (Syncarida and Oligochaeta) can also be found within the riverine hyporheic zones in areas of groundwater discharge where the discharge can be either point source springs or diffuse discharge through a moderate to course grained substrate such as sand or gravel (Gilbert, 1994).

Stygoxenes

- **Hemiptera**, Aphid sp.
- **Coleoptera**, sp.

Two NCP sites (SC9907W and SC9874) recorded two species of stygoxenes. These are species that are not adapted to living within the groundwater environment and usually occur in this environment by accident. The recoded taxa were Aphids (SC9907W) and a terrestrial beetle (SC9874). Both species demonstrated signs of decomposition

indicating they were not alive when collected. Their presence in the sample is most likely coincidental, either by falling in, or occupying the vegetation adjacent to the bore. Bore SC9874 was also uncapped so it is possible the coleopteran was washed into the bore following recent flooding. The occurrence of these animals is of no direct relevance or significance to this study.

5. Discussion

5.1 Byerwen Pilot Study

A total of 8 groundwater bores were sampled for stygofauna in November/December 2011 within Byerwen EPC 614 and 739 using standard sampling methods described in WA Guidelines 54 and 54a (2003 & 2007). One groundwater bore (BYGW02) recorded the presence of two subsurface species (Amphipoda and Copepoda) which can be classed as stygofauna and obligate groundwater species which are associated with the hypogean and permanent hyporheic environments. A soil-dwelling species (Psocoptera) was also recovered from this bore.

Of particular interest was the fact that bore BYGW02 intersected the Fort Cooper Coal Seam with a drilled depth of 59.5 mbgl. The recovery of stygofauna from this bore is notable as it extends the body of knowledge on stygofauna in the northern Bowen Basin as well as providing further evidence that stygofauna can exist in coal seam aquifers. In addition, it demonstrates that relatively young bores (i.e. less than 6 months old) can be successfully sampled for stygofauna (BYGW02 was less than 3 months old when sampled). It is also notable that bore BYGW02 recorded an EC concentration of 9,975 µS/cm, which is well above the EC preference for stygofauna suggested by Hancock and Boulton (2008) of $\leq$5,000 µS/cm (and preferably $\leq$1,500 µS/cm). Dissolved oxygen (1.92 mg/L) and pH (6.82) concentrations for BYGW02 were, however, both within the preferred range for stygofauna (Hancock and Boulton, 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 seven Byerwen groundwater bores does not necessarily indicate 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.

The need for replicated seasonal sampling was recently demonstrated by GHD at the adjoining Xstrata Newlands Coal Mine where sampling failed to record the presence of stygofauna from three annual surveys conducted in 2008, 2009 and 2010. In 2011, the same 20 groundwater bores were sampled and stygofauna were recovered in high abundance from a non-alluvial aquifer.

Byerwen bore BYGW02 and NCP bore SW8896W both contained obligate groundwater species. BYGW02 contained a single specimen of an amphipod and a copepod. Bore SW8896W also contained two stygobitic taxa, namely an oligochaete and a syncarid,

however, these animals were recorded in large numbers (53 syncarids and 11 oligochaetes). Bores BYGW02 and SW8896W are approximately 20 kms apart with bore SW8896W lying to the south-east of BYGW02 (Figure 2). The total drilled depth of these two bores is similar (59.5 mbgl for BYGW02 and 42 mbgl for SW8896W) and a recent investigation by RLA (2012 – Refer Appendix A for full report) suggests these bores intersect the same aquifer. If this is correct, the aquifer exists within a coal seam of the Fort Cooper Coal Measures. It would be expected then, given adequate hydraulic connectivity and conductivity within the aquifer, that the four distinct stygobitic taxa recovered from these two bores would be distributed throughout the aquifer and would exist across both the Byerwen and NCP mining lease areas. It is highly likely, therefore, that stygofauna diversity and abundance within the Byerwen mining lease would be higher than what was observed from the current Pilot Study. Equally, stygofauna biodiversity is likely to be higher in NCP aquifers than what has currently been observed.

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. A hydrogeological study undertaken as part of the EIS (RLA 2012) reported no significant alluvial aquifers present on the Byerwen MLA's, so this environment was not sampled as part of the Pilot Study. The RLA study (2012) also identified the Rangal and Fort Cooper Coal measures as the major aquifers within the Byerwen MLA's and the only aquifers likely to be impacted by mining operations. These coal seam aquifers were adequately sampled as part of the Pilot Study.

A study design using a Pilot Study approach (WA Guidelines 2003 & 2007) was adopted for this project which allowed for a reduced sampling effort in order to determine if stygofauna were present within the Project study area (MLA's 10355, 10356, 10357, 70434, 70435 and 70436). A single sampling event conducted at 8 groundwater bores across a large mining lease area of approximately 22,697 ha may not be considered as a significant sampling effort, even though the eight bores were geographically well spread across the mining lease. To improve the spatial and temporal coverage of stygofauna data in order to better inform the EIS, historical stygofauna data from Xstrata NCP which adjoins the Byerwen mining lease (Figure 2), and which is hydrogeologically connected (RLA, 2012), has been incorporated into this study. The inclusion of the NCP data provides a comprehensive dataset for assessment, incorporating a further 67 stygofauna samples collected between 2008 and 2011 to the existing Byerwen dataset of eight stygofauna samples.

It must also be noted that the stygofauna collected from the Byerwen mining lease were true obligate groundwater species recovered from the Fort Cooper Coal Measures

which will be intercepted during mining activities. Activities of this kind that result in a reduction in groundwater level and/or impacts on groundwater quality can have a detrimental impact on groundwater dependent fauna.

5.2 Suitability and Relevance of Including Xstrata NCP Stygofauna Data in the Byerwen EIS

As mentioned above, historic stygofauna monitoring data from the adjoining Xstrata Newlands Coal Mine was incorporated into the current Study. In order for the NCP data to be relevant to the Byerwen project it must first be determined that the key aquifers associated with the Byerwen mine lease also occur within the NCP mining lease, and that there is sufficient hydraulic connectivity and hydraulic conductivity within these aquifers to allow for the movement of stygofauna within the groundwater. Under this scenario, where stygofauna occur, they are likely to be distributed within the entire aquifer, which means across both Byerwen and NCP mining leases and potentially beyond, depending on the extent of the aquifer. Any impacts from mining on groundwater fauna that may occur within the Byerwen mining lease may not be felt by stygofaunal communities in the NCP mining lease area, and vice versa (notwithstanding cumulative impacts). This would substantially reduce the risk of loss of species and potential species extinctions from proposed mining operations at both Byerwen and NCP.

In September 2012, a technical assessment of the suitability of including Xstrata NCP stygofauna data in the Byerwen Coal Project EIS was undertaken by RLA, (2012). The assessment considered the locations and depths of NCP bores in relation to the stratigraphy of the region. Groundwater occurrence and flow is controlled by both the formations in which the aquifers occur and the geological structure of the region. RLA (2012) determined that the regional strike of the formations within the study area was north-west to south-east. The tests used for assessing the suitability of including the NCP stygofauna data in the Byerwen EIS were as follows:

- Whether the Xstrata stygofauna monitoring bores are along the regional strike trend so as to be representative of groundwater in that formation, and
- Whether the depths of the Xstrata stygofauna monitoring bores are similar to the depths of the Byerwen stygofauna monitoring bores.

The test matrix used by RLA for the assessment of suitability of the NCP stygofauna monitoring bores is shown in Table 8. RLA concluded from their assessment that there are sufficient NCP stygofauna monitoring bores in the appropriate locations and at the correct depths to be directly applicable to each of the Byerwen stygofauna monitoring bores, and for the NCP data to be suitable for inclusion in the Byerwen stygofauna Pilot Study. In essence, the two adjoining mining leases (Byerwen and NCP) share the same hydrogeology, with common aquifers hydraulically connected with sufficient conductivity to ensure the movement of stygofauna within the aquifers.

The relevance of this determination by RLA is that it is scientifically defensible to include the NCP stygofauna dataset in the Byerwen Pilot Study in order to better inform the EIS. The dataset for assessment now includes both the current Byerwen dataset (i.e.

8 bores sampled in 2011) as well as the 67 bores sampled annually for NCP between 2008 and 2011. This provides a very comprehensive and significant dataset from which to assess whether stygofauna represent a relevant environmental factor in consideration of the EIS.

Table 8: Test Matrix for suitability assessment (RLA, 2012) (ND = No Data).

Bore ID	Total Depth of Byerwen Bore (mbgl)	NCP Stygofauna Monitoring Bores along Strike	Total Depth of NCP Bore (mbgl)	Suitability for Translation to Byerwen EIS
BYGW01	59.5	R3890W R3902W R3906W Cerito Farm Bore	78 50 43 40	Yes
BYGW02	59.5	SC9905W SW8897W SW8896W	66 96 42	Yes
BYGW03	67.0	SC9906W	66	Yes
BYGW04	119.0	SW8897W SW8896W	96 42	Yes
BYGW05	105.0	SC9874	154	Yes
BYGW06	120.0	SC9908W	102	Yes
BYGW08	66.0	SC9907W	66	Yes
BYGW010	52.0	E2105W	56	Yes
BYGW188	ND	ND	ND	ND

5.3 Interpretation of Joint Byerwen and NCP Stygofauna Datasets

Knowledge of stygofauna in the Bowen Basin (and indeed QLD generally) is limited at present, based on the fact that very few surveys have been conducted in this extensive region of Queensland, and that data that have been generated from individual studies are not shared. The current Byerwen and NCP studies, therefore, add substantially to this limited body of knowledge.

The combined Byerwen and NCP stygofauna datasets provides a comprehensive set of data incorporating 28 sampling sites and 75 samples collected over a 4 year timeframe (2008 to 2011). It is evident from the NCP data, where only two stygofaunal taxa have been recovered from one of twenty bores sampled annually for 4 years, that stygofauna are low in diversity and abundance from this locality. The current Byerwen Pilot Study also failed to identify significant stygofaunal communities (albeit from a single sampling event). Collectively, these data suggest that stygofauna (i.e. stygophiles, stygobites and phreatobites) are poorly represented within both Byerwen and NCP mining lease areas.

5.4 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 Project) that have the potential to cause some degree of change in natural water regimes (surface and groundwater). These activities include some, or all, of the following (SKM, 2010):

- Below water table mining;
- Water supply development (e.g. groundwater, dewatering, surface water);
- 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, potential 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 the only true 'obligate' groundwater dependent fauna) will depend largely on the scale of the Byerwen operation, mining methods, and process water requirements. Effects would also be influenced by climatic conditions and geological settings.

5.5 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 (Brereton and Moran, 2008). 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 (SKM, 2010).

For the Project, 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 Byerwen 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 including hyporheic fauna).

It is not clear at this stage if mining proposals exist on nearby or adjoining land to MLA's 10355, 10356, 10357, 70434, 70435 and 70436 other than the Xstrata Newlands Coal Mine which lies immediately to the east of Byerwen. RLA (2012) has shown that Byerwen and NCP share common aquifers so a potentially high risk exists for significant drawdown of these groundwater resources depending on the location and extent of mining operations across both sites.

5.6 Implications for the Byerwen EIS

The stygobite/stygophile taxa collected from bore BYGW02 in November/December 2011 have been identified as belonging to the Orders Amphipoda and Copepoda (Family Cyclopoida). Order/Family level taxonomic analysis was undertaken by ALS as this is the level of taxonomic resolution specified by the Queensland Coordinator General in the TOR for the Byerwen EIS.

In Queensland, to satisfy the Coordinator General's Terms of Reference for an EIS, endemism needs to be disproved at the Family or Order level for stygofauna, in which case the Amphipod and Copepod collected from BYGW02 are not endemic, because the Order/Family they belong to (i.e. Amphipoda and Cyclopoida) occur in all Australian

States (Serov, 2002). Any proposed mining activities associated with the Byerwen Project will not threaten or put at risk the survival of the amphipod and copepod taxa at the Order/Family level of taxonomic resolution. Based on these results, no mitigation measures are required.

6. Conclusions

The following major conclusions can be drawn from the Byerwen Pilot Study:

- The Pilot Study, conducted in accordance with WA Guidelines 54 and 54a (2003 & 2007), achieved its primary objective of identifying the presence of stygofauna in groundwater associated with the Byerwen Project.

- Two adjoining mining leases (Byerwen and NCP) share the same hydrogeology, with common aquifers hydraulically connected with sufficient conductivity to allow the movement of stygofauna within the aquifers (RLA, 2012). The Byerwen and NCP stygofauna datasets were, therefore, combined to generate a comprehensive stygofauna dataset encompassing 28 sampling sites and 75 individual samples collected over a 4 year timeframe (2008 to 2011) in order to better inform the EIS.

- Only two stygofaunal taxa were recovered from one of 20 NCP bores sampled annually for four years. It is evident from the NCP data that stygofauna are low in diversity and abundance from this locality. The current Byerwen Pilot Study also failed to identify significant stygofaunal communities (albeit from eight sites and a single sampling event). Collectively, these data suggest that stygofauna (i.e. stygophiles, stygobites and phreatobites) are poorly represented within the Byerwen and NCP mine lease areas.

- In Queensland, to satisfy the TOR for the Byerwen EIS, endemism needs to be disproved at the Family or Order level for stygofauna, in which case the obligate stygofauna collected from both the NCP and Byerwen surveys are not endemic, because the Order/Family they belong to occur in all Australian States (Serov, 2002). Any proposed mining activities associated with the Byerwen Project will not threaten or put at risk the survival of the amphipod and copepod taxa at the Order/Family level of taxonomic resolution.

- 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. A hydrogeological study undertaken as part of the EIS (RLA 2012) reported no significant alluvial aquifers present on the Byerwen MLA's, so this environment was not sampled as part of the Pilot Study. The RLA study (2012) also identified the Rangal and Fort Cooper Coal measures as the major aquifers within the Byerwen MLA's and the only aquifers likely to be impacted by mining operations. These coal seam aquifers were adequately sampled as part of the Pilot Study.

- Following a review of the combined Byerwen and NCP stygofauna datasets, it can be concluded that stygofauna at the order/family level of taxonomic resolution, do not represent a relevant environmental factor in the assessment of the Byerwen EIS, and no further survey work is recommended.

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8. Glossary

- **Alluvial**

Alluvial deposits are sediments composed of gravel, sand, silt or clay deposited in river channels or on floodplains. Alluvial aquifers are generally shallower than sedimentary and fractured rock aquifers and water levels often fluctuate due to varying recharge and pumping rates. Due to their shallow and unconfined nature, alluvial aquifers are susceptible to contamination and pollution.

- **ANZECC**

Austalia and New Zealand Environment and Conservation Council.

- **Aquifer**

A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield economic quantities of water to wells and springs.

- **ARMCANZ**

Agriculture and Resource Management Council of Australia and New Zealand.

- **Confined Aquifer**

An aquifer that lies below a low permeability material. The piezometric surface in confined aquifers is above the base of the confining material e.g. artesian aquifers.

- **Cosmopolitan Species**

Species with very large distribution in many, or all, parts of the world and ecosystems.

- **DEHP**

Queensland Department of Environment, Heritage and Planning.

- **Drawdown**

The distance between the static water level and the surface of the cone of depression.

- **EA**

Environmental Authority.

- **Ecosystem**

A functional unit consisting of all the living organisms (plants, animals and microbes) in a given area, and all the non-living physical and chemical factors of their environment, linked together through nutrient cycling and energy flow.

- **Ecotone**

A transitional zone between two communities containing the characteristic species of each.

- **Ecozone**

A broad geographic area in which there are distinctive climate patterns, ocean conditions, types of landscapes and species of plants and animals.

- **Edaphobites**

Deep soil dwelling (or endogean) species that frequently display troglomorphisms and may sometimes occur in caves.

- **Endemic**

Pertaining to organisms in a specific geographical region or ecological habitat; organisms native to a region and not introduced.

- **EPBC Act**

Environment Protection and Biodiversity Conservation Act.

- **EPC**

Exploration Permit for Coal.

- **Extinct**

A taxon is extinct when there is no reasonable doubt that the last living individual has died.

- **Facultative GDE**

A GDE that is not entirely dependent on groundwater but may rely on groundwater on a seasonal basis or only during extended drought periods. At other times water requirements may be met by soil or surface water.

- **Groundwater Dependent Ecosystem or GDE**

Is a broad overarching term encompassing all ecosystems that use groundwater either permanently or occasionally to survive. In this context the term covers a vast majority of terrestrial and aquatic ecosystems.

- **Hydraulic Conductivity**

A coefficient pf proportionality describing the rate ate which water can move through a permeable medium. Horizontal hydraulic conductivity (Kh) refers to the coefficient of proportionality in the horizontal direction, whereas vertical hydraulic conductivity (Kv) refers to the coefficient of proportionality in the vertical direction.

- **Hydrogeologic**

Those factors that deal with subsurface waters and related geologic aspects of surface waters.

- **Hypogean**

Located under the earth's surface; underground.

- **Hyporheic Zone**

The ecotonal zone below and within the porous sand and gravel substrate of a river bed. This ecotonal zone often connects the surface running water system to that of the deep subterranean.

- **Hyporheos**

The assemblage of organisms which inhabit the hyporheic zone.

- **Karst**

Terrain with special landforms and drainage characteristics on account of greater solubility of certain rocks in natural waters than is common.

- **mbgl**

metres below ground level.

- **mbtoc**

metres below top of casing.

- **MIA**

Mining Infrastructure Area.

- **ML**

Mining Lease.

- **MLA**

Mining Lease Application.

- **Mt**

Million Tons.

- **Mtpa**

Million Tons per Annum.

- **NCP**

Xstrata Newlands Coal Project.

- **NWC**

National Water Commission.

- **Obligate GDE**

A GDE that is entirely dependent on groundwater. Typically most karst, wetland and hypogean/aquifer GDE's, all baseflow and some terrestrial GDE's will be obligate.

- **Permeability**

The property or capacity of a porous rock, sediment or soil for transmitting a fluid. It is a measure of the relative ease of fluid flow under unequal pressure.

- **Phreatic Water**

Water below the level at which all voids in the rock are completely filled with water.

- **Phreatic Zone**

Zone where voids in the rock are completely filled with water. Also refers to deep groundwater.

- **Phreatobite**

Stygobites that are restricted to the deep groundwater substrata of alluvial aquifers (phreatic waters). All species within this classification have specialised morphological and physiological adaptations.

- **Piezometer**

A narrow tube, pipe or borehole for measuring the moisture in a soil or water level in an aquifer.

- **Recharge Area**

An area that allows water to enter the aquifer. The area is particularly vulnerable to any pollutants that could be in the water.

- **ROM**

Run of Mine.

- **Saturated Zone**

The zone in which the voids in the rock or soil are filled with water. Sometimes referred to as the phreatic zone.

- **Stygobite**

Organisms that are specialised subterranean forms, obligatory hypogea. Some are ubiquitous, widely distributed in all types of groundwater systems (both karst and alluvia).

- **Stygofauna**

An all encompassing term for all animals that occur in subsurface waters.

- **Stygophile**

Having greater affinities with the groundwater environment than stygoxenes because they appear to actively exploit resources in the groundwater system and/or actively seek protection from nfavourable situations in the surface environment resulting from biotic or stochastic processes. Stygophiles can be divided into (1) occasional or temporary hyporheos, and (2) permanent hyporheos. The occasional or temporary hyporheos include individuals of the same species that could either spend their lives in the surface environment or spend a part of their lives in the surface environment and a part in groundwater. The permanent hyporheos is present during all life stages in either groundwater or in benthic habitats and possess specialist adaptations for living

in this environment.

- **Stygoxenes**

Organisms that have no affinities with groundwater systems but occur accidentally in caves and alluvial sediments. Some planktonic groups and a variety of benthic crustacean and insect species may passively infiltrate alluvial sediments.

- **ToR**

Terms of Reference (of an EIS).

- **Unconfined Aquifer**

A water table aquifer or an aquifer that does not have an impermeable bed between the water table and the lands surface e.g. Alluvial and Coastal Sand Bed aquifers.

9. Appendix A

TECHNICAL NOTE
'Suitability of Xstrata Bores for Assessment of Stygofauna'
Byerwen Coal Project

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20th September 2012

TECHNICAL NOTE

SUITABILITY OF XSTRATA BORES FOR ASSESSMENT OF STYGOFAUNA

BYERWEN COAL PROJECT

TABLE OF CONTENTS

1.0 INTRODUCTION

Byerwen Coal Pty Ltd (Byerwen) requested Rob Lait and Associates Pty Ltd (RLA) was requested to assess the suitability of bores used for the assessment of stygofauna in groundwater by Xstrata Ltd (Xstrata), on properties and mining leases to the east and south on the Byerwen leases.

2.0 XSTRATA STYGOFAUNA ASSESSMENT BORES

Mr Garry Bennison of GHD has assessed stygofauna in groundwater ,on behalf of Xstrata, in a number of bores to the east and south of the Byerwen leases for a number of years. The locations and details of the bores used by GHD for this purpose were provided by GHD and are shown in Table 1.

TABLE 1: LOCATIONS AND DETAILS OF EXISTING STYGOFAUNA BORES

Bore ID	*Location*	*Easting MGA94*	*Northing MGA94*	*Depth of Hole (m)*	*SWL (m)*	*Bore Diameter (mm)*	*Purpose of Bore*	*Bore Installation Date*
SC9874	off-lease	589269	7636480	154	27.94	100	Monitoring	Nov 2007
SC9878	off-lease	592085	7635211	52	20.47	100	Monitoring	Nov 2007
SC9884W	off-lease	590585	7640615	84	42.65	150	Monitoring	Sept 2008
SC9904W	off-lease	594116	7634918	66	22.12	150	Monitoring	Sept 2008
SC9905W	off-lease	589874	7635333	66	9.46	150	Monitoring	Oct 2008
SC9906W	off-lease	599718	7638361	66	29.86	150	Monitoring	Oct 2008
SC9908W	off-lease	589313	7639292	102	47.71	150	Monitoring	Nov 2007
E2105W	off-lease	604558	7657555	56	20.15	150	Monitoring	March 2009
E2104W	off-lease	605001	7659551	68	5.09	150	Monitoring	March 2009
E2106W	off-lease	605311	7652019	64	8.11	150	Monitoring	March 2009
R3891W	off-lease	599358	7651856	126	16.97	150	Monitoring	Jan 2009
SW8897W	off-lease	600079	7632760	96	16.17	150	Monitoring	March 2009
SW8896W	off-lease	600265	7632217	42	12.91	150	Monitoring	March 2009
SC9907W	on-lease	592885	7636869	66	65.5	150	Monitoring	Nov 2008
R3890W	on-lease	594602	7660831	78	21.24	150	Monitoring	Jan 2009
R3897W	on-lease	598028	7650854	72	18.34	150	Monitoring	Jan 2009
R3900W	on-lease	598192	7650821	57	17.77	150	Monitoring	Jan 2009
R3902W	on-lease	594317	7658358	50	13.38	150	Monitoring	Jan 2009
R3906W	on-lease	593645	7661920	42	2.15	150	Monitoring	March 2009
Farming Bore at Cerito Creek Dam	on-lease	597571	7650318	40	4.08	150	Windmill	unknown

3.0 SUITABILITY ASSESSMENT

The assessment of the suitability of the Xstrata stygofauna bores to the Byerwen leases was undertaken by considering the locations and depths of those bores in relation to the stratigraphy of the area.

Groundwater occurrence and flow is controlled by both the formations in which the aquifers occur, and the geological structure of the area. The regional strike of the formations in the area under consideration is north west – south east.

Figure 1 shows the published geological mapping of the area (after Malone, 1969[1]). It also shows the locations of the dedicated Byerwen groundwater monitoring bores (shown with red symbols), and the locations of the Xstrata stygofauna assessment bores (shown with yellow symbols). The regional strike trend of the stratigraphy is indicated on Figure 1.

The tests used for assessing the suitability of the Xstrata stygofauna assessment bores for the Byerwen project were:

- Are the Xstrata stygofauna assessment bores along the regional strike trend so as to be representative of groundwater in that formation? and

- Are the depths of the Xstrata stygofauna assessment bores similar to the depths of the Byerwen groundwater monitoring bores?

Provided that the Xstrata stygofauna assessment bores fulfilled the requirements of these tests they were considered to be directly applicable to the evaluation of stygofauna in groundwater on the Byerwen leases.

[1] *Malone, E.J., (1969), Mount Coolon, Queensland 1:250 000 Geological Series Sheet and Explanatory Notes.*

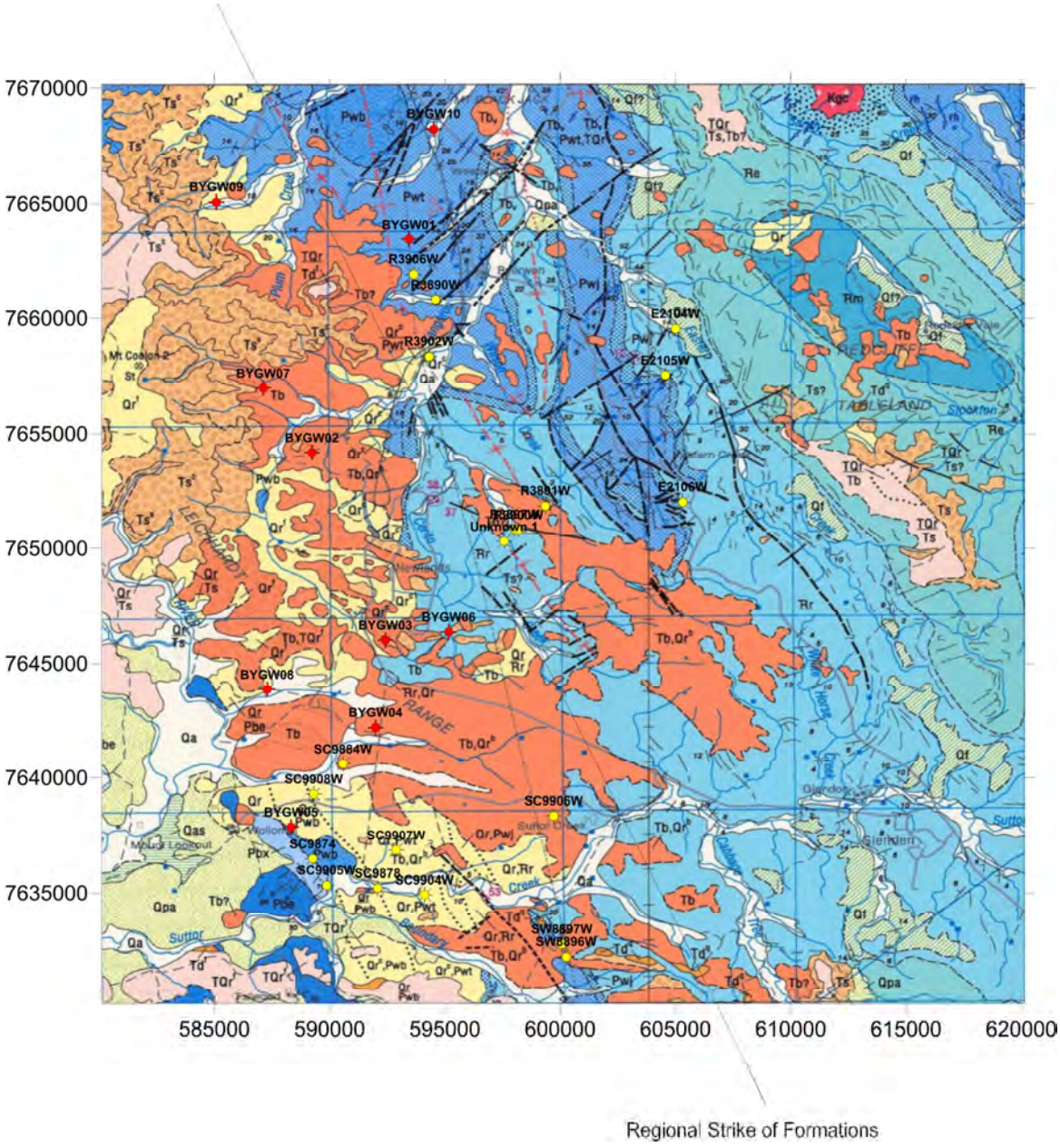

Figure 1: Published Geological Map of Assessment Area
(Byerwen groundwater monitoring bores shown with red symbols,
Xstrata stygofauna assessment bores shown with yellow symbols)

Table 2 shows the test matrix used for the assessment of suitability of the the Xstrata stygofauna assessment bores

TABLE 2: TEST MATRIX - SUITABILITY ASSESSMENT OF XSTRATA STYGOFAUNA BORES FOR TRANSLATION TO BYERWEN PROJECT

Bore_ID	***Total depth (TD) (m)***	***Xstrata Stygofana Bores along strike***	***TD of Xstrata Stygofana Bores (m)***	***Suitability for Translation to Byerwen Project***
BYGW01	59.5	R3890W R3902W R3906W Cerito Farm bore	78 50 43 40	Yes
BYGW02	59.5	SC9905W SW8897W SW8896W	66 96 42	Yes
BYGW03	67.0	SC9906W	66	Yes
BYGW04	119.0	SW8897W SW8896W	96 42	Yes
BYGW05	105.0	SC9874	154	Yes
BYGW06	120.0	SC9908W	102	Yes
BYGW07A	68.5	SC9905W SW8897W SW8896W	66 96 42	Yes
BYGW07B	52.0	SC9905W SW8897W SW8896W	66 96 42	Yes
BYGW08	66.0	SC9907W	66	Yes
BYGW09	97.0	SC9905W SW8897W SW8896W	66 96 42	Yes
BYGW10	52.0	E2105W	56	Yes

Table 2 shows that there are sufficient Xstrata stygofauna monitoring bores, in the appropriate locations and of the correct depths, to be directly applicable to each of the Byerwen dedicated groundwater monitoring bores, and therefore to enable valid assessment of stygofauna in groundwater for the Byerwen project.

4.0 CONCLUSION

It is concluded from this review that there are sufficient Xstrata stygofauna monitoring bores, in the appropriate locations and of the correct depths, to enable valid assessment of stygofauna in groundwater for the Byerwen project.

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Document Status

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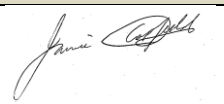
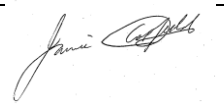
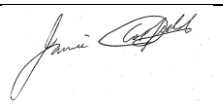
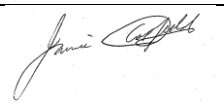
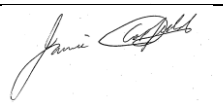
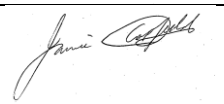
1	G.Bennison	N.Chandrasena		J.Corfield		17/10/12
2	G.Bennison	N.Chandrasena		J.Corfield		05/11/12
3	G.Bennison	J.Corfield		J.Corfield		19/12/12
4	G.Bennison	J.Corfield		J.Corfield		04/03/2013

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