APPENDIX 14

Stygofauna Assessment

Mangoola Coal Continued Operations Project

Stygofauna Assessment

Prepared for
Umwelt (Australia) Pty Limited

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Executive summary

Mangoola Coal Mine is an open cut coal mine located approximately 20 kilometres (km) west of Muswellbrook and 10 km north of Denman in the Upper Hunter Valley of NSW. Mangoola has operated the Mangoola Coal Mine in accordance with Project Approval (PA) 06_0014 (as modified) since mining commenced at the site in September 2010. Eco Logical Australia (ELA) has been engaged by Umwelt (Australia) Pty Limited (Umwelt) on behalf of Mangoola Coal Operations Pty Limited (Mangoola) to complete a stygofauna impact assessment for the Mangoola Coal Continued Operations Project (MCCO Project).

Existing bores were selected for stygofauna sampling following a review of groundwater drilling logs, water quality, and hydrogeological information. Bores were given priority if they had characteristics that made them suitable stygofauna habitat - specifically that they were relatively shallow (less than 50 m deep), have suitable water quality and are preferably in porous aquifers. Bores were also selected to give a good spatial coverage across the site and sample all the available aquifer types. Eleven bores were chosen, including two from the Wybong Creek alluvial aquifer and nine from fractured or porous rock aquifers. No bores were available in colluvial aquifers.

Fine-mesh nets were lowered into bores and retrieved to collect samples. None of the samples contained stygofauna, although two soil invertebrate taxa (Oligochaeta and Oribatida) were collected from the rock aquifers. These taxa likely fell into the bores from the upper layers.

No stygofauna were collected during the survey. The rock aquifers are unlikely to be suitable habitat because they lack a significant network of interconnected fractures for stygofauna movement. Colluvium is also generally unsuitable because it is generally dry most of the time. Although no stygofauna were collected from the Wybong alluvium, it is potentially suitable habitat because of its hydrological connection to the Goulburn River, adequate porosity, and acceptable water quality. However, if a stygofauna community is inferred for the Wybong alluvium, then this community would be the same as the Goulburn alluvium community, since this is the source of colonisation.

No drawdown over 1 m is expected in the Wybong Creek alluvium due to mining within the MCCO Additional Project Area. However, cumulative drawdown from the existing Approved Project Area and the proposed MCCO Additional Project Area is expected to result in a maximum of 1 m drawdown in the Wybong Creek alluvium near the confluence with Big Flat Creek (AGE 2019). As only a small section of alluvial aquifer will experience drawdown of over 1 m, there will be no impact on regional stygofauna diversity.

1 Introduction

Eco Logical Australia (ELA) has been engaged by Umwelt Environmental (Australia) Pty Limited (Umwelt) on behalf of Mangoola Coal Operations Pty Limited (Mangoola) to complete a stygofauna impact assessment for the Mangoola Coal Continued Operations Project (MCCO Project). The purpose of the assessment is to form part of an Environmental Impact Statement being prepared by Umwelt to support an application for development consent under Divisions 4.1 and 4.7 of Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) for the MCCO Project.

1.1 Project Overview

Mangoola Coal Mine is an open cut coal mine located approximately 20 kilometres (km) west of Muswellbrook and 10 km north of Denman in the Upper Hunter Valley of NSW (refer Figure 1). Mangoola has operated the Mangoola Coal Mine in accordance with Project Approval (PA) 06_0014 (as modified) since mining commenced at the site in September 2010.

The MCCO Project will allow for the continuation of mining at Mangoola Coal Mine into a new mining area to the immediate north of the existing operations. The MCCO Project will extend the life of the existing operation providing for ongoing employment opportunities for the Mangoola workforce. The MCCO Project Area includes the existing Approved Project Area for Mangoola Coal Mine and the MCCO Additional Project Area as shown on Figure 1.

The MCCO Project generally comprises:

- open cut mining peaking at up to the same rate as that currently approved (13.5 Million tonnes per annum (Mtpa) of run of mine (ROM) coal) using truck and excavator mining methods
- continued operations within the existing Mangoola Coal Mine
- mining operations in a new mining area located north of the existing Mangoola Coal Mine, Wybong Road, south of Ridgelands Road and east of the 500 kV Electricity Transmission Line (ETL)
- construction of a haul road overpass over Big Flat Creek and Wybong Road to provide access from the existing mine to the proposed Additional Mining Area
- establishment of an out-of-pit overburden emplacement area
- distribution of overburden between the proposed Additional Mining Area and the existing mine in order to optimise the final landform design of the integrated operation.
- realignment of a portion of Wybong Post Office Road
- the use of all existing or approved infrastructure and equipment for the Mangoola Coal Mine with some minor additions to the existing mobile equipment fleet
- construction of a water management system to manage sediment laden water runoff, divert clean water catchment, provide flood protection from Big Flat Creek and provide for reticulation of mine water. The water management system will be connected to that of the existing mine
- continued ability to discharge excess water in accordance with the Hunter River Salinity Trading Scheme (HRSTS)
- establishment of a final landform in line with current design standards at Mangoola Coal Mine including use of natural landform design principles consistent with the existing site
- rehabilitation of the proposed Additional Mining Area using the same revegetation techniques as at the existing mine

- a likely construction workforce of approximately 145 persons. No change to the existing approved operational workforce
- Continued use of the mine access for the existing operational mine and access to/from Wybong Road, Wybong Post Office Road and Ridgelands Road to the MCCO Additional Project Area for construction, emergency services, ongoing operational environmental monitoring and property maintenance.

Figure 2 illustrates the key features of the MCCO Project.

1.2 Scope of Work

This stygofauna assessment aims to satisfy the relevant Commonwealth and NSW Government policies and guidelines (summarised in Section 3).

The assessment included a field survey to determine what stygofauna occur in the MCCO Project Area, and an assessment of potential impacts to the stygofauna community from the MCCO Project. As part of the assessment, stygofauna community in aquifers relevant to the MCCO Project were compared with that of the broader Hunter Valley stygofauna community.

The assessment included:

- A gap analysis, review, and assessment of existing data to identify appropriate bores. Where available, bores were selected from hard rock and alluvial aquifers, both in and outside of the direct area of impact. A sampling programme was designed that took into account State and Commonwealth guidelines, and the Hunter Bioregional Assessment guidelines
- Sampling to collect and identify stygofauna in the proposed disturbance area and surrounding areas
- A comparison of the stygofauna in aquifers relevant to the MCCO Project with that of the broader Hunter Valley, and with other similar aquifers in New South Wales (where relevant).
- An assessment of impacts resulting from the MCCO Project
- A report that includes the items above, to the standards required for inclusion in an EIS to meet Commonwealth and NSW environmental planning and assessment requirements.

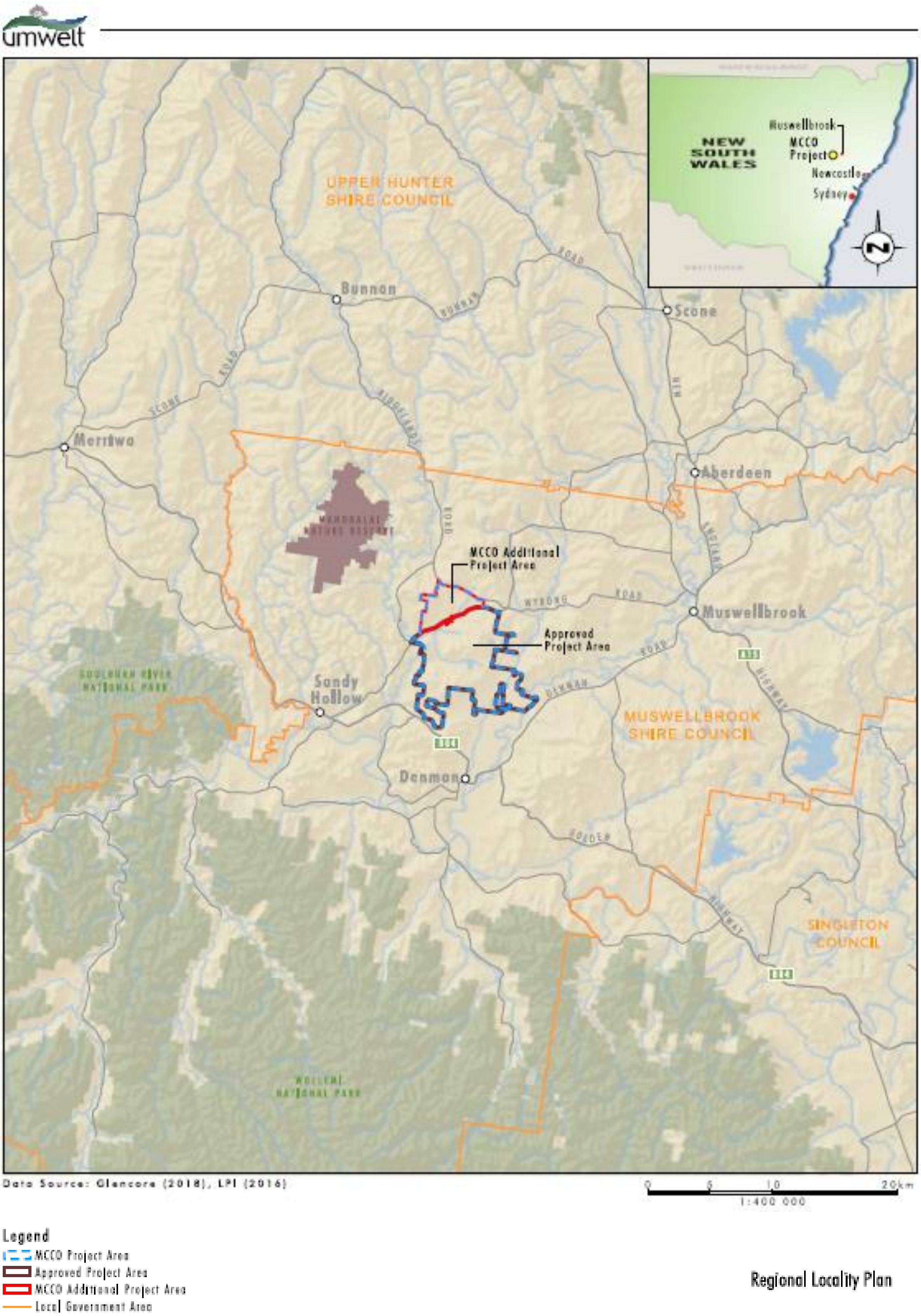

Figure 1. Regional location of the MCCO Project Area and the MCCO Additional Project Area

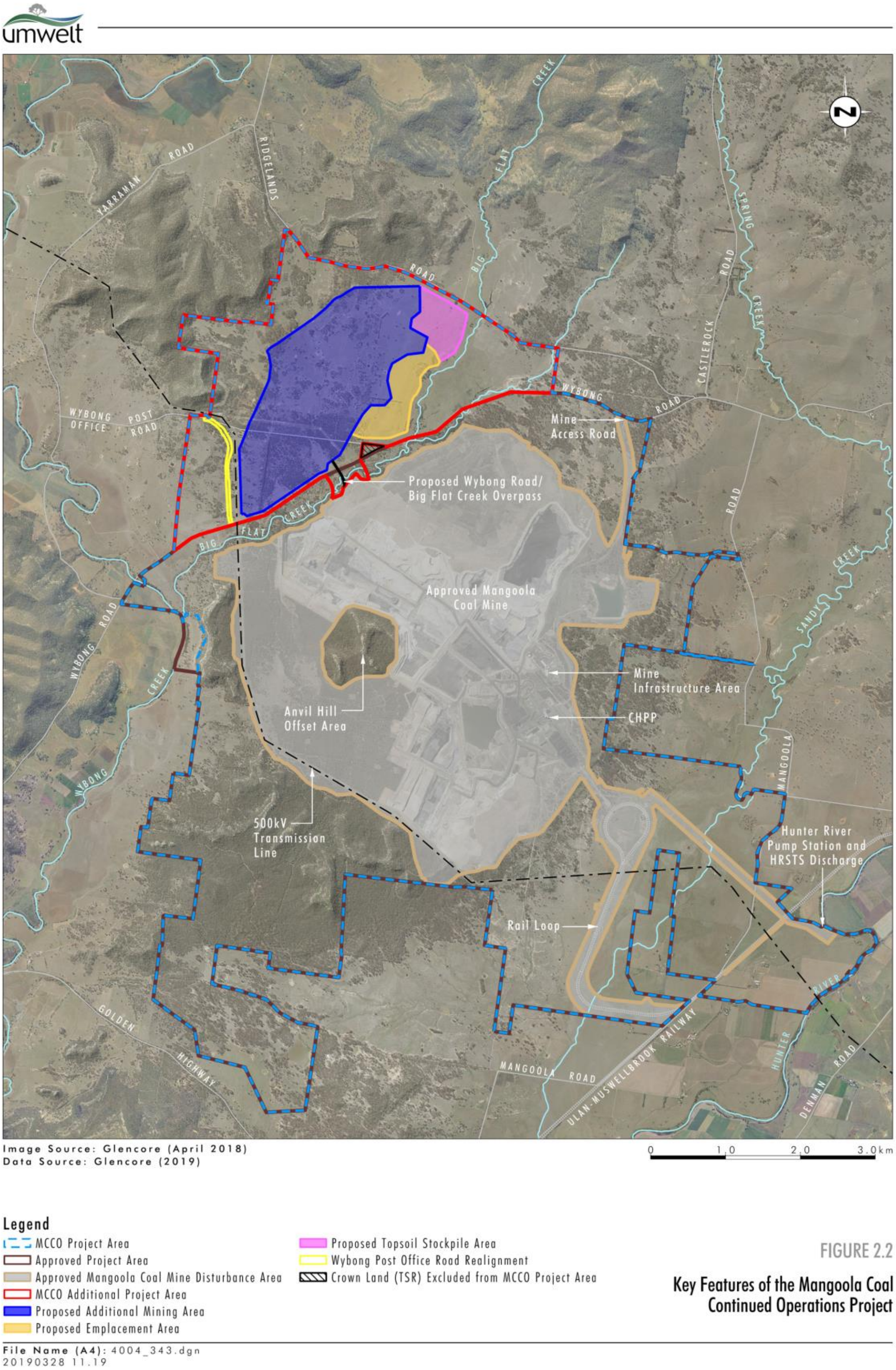

Figure 2: Key features of the MCCO Project Area and the MCCO Additional Project Area

2 Summary of the groundwater environment

2.1 Topography and surface drainage

The topography of the MCCO Project Area consists of lower slopes that give way to undulating hills and rocky outcrops to the north and west. The MCCO Additional Mining Area falls within the catchment of Big Flat Creek, which flows generally in a south west direction between the approved Mangoola Coal Mine and MCCO Additional Project Area (see Figure 2). Several shallow drainage lines lead from the MCCO Additional Project Area into the Big Flat Creek. A series of undulating wooded hills rise in the north, about 200 m above the surrounding land.

2.2 Groundwater

The MCCO Additional Project Area is situated within the Permian Newcastle Coal Measures. These consist of coal seams overlain by medium to coarse-grained sandstone, as well as layers of siltstone and conglomerate. The coal measures and sandstone are considered as porous and fractured rock aquifers.

A thin band of colluvial material runs along either side of Big Flat Creek. This is only a minor aquifer in the MCCO Additional Project Area boundary and is dry most of the time (AGE 2018). It joins the alluvium of Wybong Creek outside of the MCCO Additional Project Area.

Wybong Creek contains a moderately well-developed alluvial aquifer which is approximately 1.5 km west of the MCCO Proposed Additional Mining Area. This aquifer connects with the Goulburn River aquifer approximately 4 km downstream of the MCCO Project, and this joins the Hunter River alluvium after another 7 km.

More details of the groundwater regime relevant to the MCCO Project are provided in AGE (2018).

2.3 Expected impacts from proposed operations

Excavation of the MCCO Additional Mining Area will require the removal of rock aquifers and a small section of colluvial material associated with Big Flat Creek. There will be no excavation of the Wybong Creek alluvium, but water levels in this aquifer may be affected by depressurisation.

No direct drawdown of over 1 m would be caused in the Wybong Creek alluvium by the MCCO Additional Project Area. However, as the Permian strata become depressurised during mining, the volume of water flowing from the Permian strata to the Wybong Creek alluvium becomes less (AGE 2018). This could reach a maximum of 33 ML/year at the end of mining, with most of this being due to the approved Mangoola Coal Mine and only 3 ML/year attributed to the MCCO Proposed Additional Mining Area (AGE 2019). This would result in cumulative drawdown from the existing Approved Project Area and the proposed MCCO Additional Project Area of approximately 1 m in the Wybong Creek alluvium near the confluence with Big Flat Creek (AGE 2018). This drawdown extent is predicted for an area of alluvium approximately 1 km long and 800 m wide near the Big Flat Creek confluence. It is noted that the drawdown primarily occurs as a result of the existing approved mining at Mangoola Coal Mine.

With the loss of influx to the alluvial aquifer, Wybong Creek will receive a lower groundwater contribution to baseflow. The annual contribution of the MCCO Additional Project Area to this lost water is close to 0 ML/year until 2027, when it becomes 1 ML/year (out of a total of 24 ML/ year). This increases to 2 ML/year in 2030, with an additional 26 ML/year from the currently approved mine. However, the total predicted change of 28 ML/year in 2030 is still negligible compared to the mean annual flow in Wybong Creek of 28,287 ML/year (AGE 2019).

3 Relevant Guidelines, Policies and Legislation

The importance of aquifer ecosystems is being increasingly recognised in NSW. The following policies are relevant to the protection and management of aquifer ecosystems in NSW:

- NSW State Groundwater Policy Framework Document, Department of Land and Water Conservation, 1997. http://www.water.nsw.gov.au/Water-Management/Law-and-Policy/Keypolicies/default.aspx
- NSW State Groundwater Dependent Ecosystems Policy, Department of Land and Water Conservation, 2002. http://www.water.nsw.gov.au/Water-Management/Law-and-Policy/Keypolicies/default.aspx
- NSW Groundwater Quality Protection Policy, Department of Land and Water Conservation, 1998. http://www.water.nsw.gov.au/Water-Management/Law-and-Policy/Keypolicies/default.aspx
- NSW Aquifer Interference Policy, NSW Department of Primary Industries, 2012. http://www.water.nsw.gov.au/__data/assets/pdf_file/0004/549175/nsw_aquifer_interference_policy.pdf

3.1 Water Management Act 2000

The Water Management Act 2000 is the key piece of legislation for the management of water in NSW. The Water Management Act 2000 aims to provide for the sustainable and integrated management of the water sources of NSW for the benefit of both present and future generations. The following objects of the Water Management Act 2000 are relevant to the management of groundwater dependent ecosystems (GDEs) to:

- Apply principles of ecologically sustainable development.
- Protect, enhance and restore water sources, their associated ecosystem, ecological processes and biological diversity and their water quality.
- Recognise and foster the significant social and economic benefits to the State that result from the sustainable and efficient use of water, including benefits to the environment.
- Integrate the management of water sources with the management of other aspects of the environment, including the land, its soils, its native vegetation and its native fauna.

The Water Management Act 2000 also provides water management principles and the following general principles are relevant to the management of GDEs:

- Water sources, floodplains and dependent ecosystems (including groundwater and wetlands) should be protected and restored and, where possible, land should not be degraded.
- Habitats, animals and plants that benefit from water or are potentially affected by managed activities should be protected and (in the case of habitats) restored.
- The quality of all water sources should be protected and, wherever possible, enhanced.
- The cumulative impacts of water management licences and approvals and other activities on water sources and their dependent ecosystems, should be considered and minimised.
- The principles of adaptive management should be applied, which should be responsive to monitoring and improvements in understanding of ecological water requirement.

3.2 Risk Assessment guidelines for groundwater dependent ecosystems

The *Risk assessment guidelines for groundwater dependent ecosystems* (Serov et al 2012) has been developed jointly by the NSW Office of Water and the Office of Environment and Heritage (OEH) to:

- Assist agency staff support the requirements of the Water Management Act 2000
- Provide methods to identify and value groundwater dependent ecosystems (GDEs) and assist reporting against the state-wide targets that aim to improve the ability of groundwater systems to support GDEs and designated beneficial uses (as part of the NSW Natural Resources Monitoring, Evaluation and Reporting Strategy 2010–2015).
- Provide a risk assessment framework for GDEs for the National Water Commission Project Coastal Groundwater Quality and Groundwater Dependent Ecosystems (GDE)
- Provides detailed methods for defining, identifying and assessing ecological value and risk through a risk analysis conceptual framework for GDEs, with supporting background information. The conceptual framework allows potential and actual impacts of proposed activities on GDEs to be assessed in accordance with the Water Management Act 2000 and other relevant legislation.

3.3 Assessing Groundwater-Dependent Ecosystems: IESC Information Guidelines Explanatory Note

The purpose of this explanatory note (Doody et al. 2018) is to describe information required, and tools available to assess potential risks to GDEs from coal seam gas and large coal mining operations. The framework lays out a series of six steps for proponents to follow that lead them through the assessment process. These include:

- defining the project area (including the footprint of surface infrastructure and the potential extent of groundwater depressurisation)
- undertaking a desktop study to identify potential GDEs in the project area
- assessing the level of groundwater dependence for each GDE and pathways of cause and effect
- identifying baseline ecological condition for each GDE
- assessing the likelihood, frequency and magnitude of potential impacts to each GDE and determine the risks related to the CSG or LCM operation
- prioritising options to avoid or mitigate impacts to GDEs and establish a monitoring plan to assess effectiveness of mitigation or identify unexpected impacts

4 Stygofauna of the Hunter Valley

4.1 Overview of stygofauna ecology

Stygofauna are generally small aquatic invertebrates that live in groundwater systems. They are typically crustaceans, although there are a few insect taxa and other non-crustacean invertebrates in the communities of the Hunter Valley. Estimates suggest there could be as many as 2680 species in the western half of the Australian continent, although approximately only 12% of these have been described (Guzik et al 2011). It is difficult to estimate the diversity of eastern Australian aquifers, but they may be just as diverse as western aquifers.

Stygofauna have special adaptations to survive in the relatively resource-poor aquifers, where there is no light, space is limited, and food is scarce (Humphreys 2008). Adaptations include blindness, slow metabolism, reduced body size, elongation, and low reproduction rates (Coineau 2000). As there is no photosynthesis below ground, subterranean environments rely on inputs of organic matter from the surface to provide the basis of the food web (Schneider et al. 2011). Alluvial aquifers often have gradients in species diversity associated with distance from recharge areas, where dissolved or fine particulate organic matter enters the aquifer (Datry et al. 2004). Tree roots are also important sources of organic matter for groundwater food webs, and where they intersect the water table can support diverse communities (Hancock and Boulton 2008, Jasinska et al. 1996).

Many ecosystem functions provide essential services to humans, saving both money and resources (Boulton et al. 2008). Despite their small size, the cumulative effect of some key stygofauna processes are likely to cause significant changes to groundwater quality. These processes are evident in alluvial aquifers where water moving though sediment particles is cleaned during transit, in much the same way as water moving through slow sand filters or trickle filters in water and sewage treatment (Hancock et al. 2005). It is likely that through their movement and grazing of sediment-bound microbes, stygofauna also help prevent alluvial aquifer sediments from clogging (Hancock et al. 2005).

Unlike many surface aquatic species, stygofauna have no aerial life stages, and are limited in their ability to disperse. Consequently, movement through aquifers is relatively slow and often restricted to convoluted passages between sediment grains or along fractures in rock. Usually, greater porosity corresponds to higher connectivity between interstitial spaces, meaning that stygofauna can move around in the aquifer with greater ease. Conversely, areas of low porosity can restrict the transfer of genetic material. Aquifers that are hydrologically disconnected from each other often have different stygofaunal compositions, although may share some species if the aquifers were connected in the past or become connected occasionally during periods of high water level. The more frequent the aquifers are connected, the more similar the stygofauna communities will be. However, with prolonged genetic isolation between adjacent aquifers or isolated sections of the same aquifer, species may begin to evolve, resulting eventually in the development of new species (Watts et al. 2007). Aquifers that have been isolated for long periods often contain several unique species of stygofauna with very limited distributions.

As aquifers are relatively stable compared to surface aquatic environments with little or no daily fluctuations in parameters such as temperature, water level, and EC, many stygofauna taxa are sensitive to rapidly changing conditions (Hancock et al. 2005). Activities such as water table draw-down, the removal of aquifer material for mining or quarrying, or rapid changes to water quality can all have detrimental effects to stygofauna communities and possibly cause extinctions (Humphreys 2008).

It is a combination of the features outlined above that have driven concerns for the potential loss of stygofauna biodiversity, particularly in areas subjected to rapid and extensive anthropogenic changes. The key attributes of stygofauna that may place them at risk are:

- The adaptation to relatively stable conditions and vulnerability to rapid or excessive changes in water level, temperature, and salinity;
- Their slow rate of reproduction and slow growth rate;
- The limited ability to disperse through aquifers, and intuitively recolonise following disturbance; and
- The high degree of endemism, with entire species restricted to only small geographic areas.

Concerns over the impact of mining and other large development projects, and concerns for State responsibility to maintain biodiversity, prompted the Western Australian and Queensland Governments to require stygofauna sampling as part of Environmental Impact Assessments (WA EPA 2003, 2007). In New South Wales, the Department of Primary Industries (DPI) developed the *Risk assessment guidelines for groundwater dependent ecosystems* (Serov et al. 2012). This document lays out the methods to identify and determine the value of groundwater dependent ecosystems (GDEs), and also provides a risk assessment framework. Under the NSW GDE Guidelines, the aquifer ecosystems that accommodate stygofauna, are classified as either Karst and Cave Ecosystems or Subsurface Phreatic Aquifer Ecosystems (Serov et al. 2012).

4.2 Background - Factors influencing biological distribution in aquifers

As with all fauna, stygofauna require favourable conditions to inhabit an aquifer, but with the large number of species occurring in aquifers, there is a broad range of variability in ecological requirements. Not all aquifers are naturally suitable for stygofauna and those that are suitable, may become unsuitable as a result of human activities or natural changes. The biological distribution of stygofauna in groundwater is influenced by historical, geological, hydrological, physico-chemical, and biological properties (Strayer 1994, Hancock et al 2005). There is still a lot being learned about stygofauna ecology, particularly in the eastern states where there have been relatively few surveys when compared to Western Australia. Nevertheless, it is possible to briefly summarise what is already known about the aquifer conditions that are likely to influence the distribution of stygofauna.

4.2.1 Aquifer type

Stygofauna have been collected from many aquifer types, including fractured basalt, fractured sandstone aquifers, and pesolithic aquifers, but are most common in karstic and alluvial aquifers. Critical aquifer characteristics are the hydraulic conductivity, depth to water table, and porosity.

Generally, stygofauna occur more frequently in alluvial aquifers and karst than in other geological formations (Hancock et al 2005, Humphreys 2008). Alluvial aquifers occur beneath floodplains, which often provide the following conditions favourable to stygofauna:

- Water table is shallow, so there is recharge of infiltrating rainwater and organic matter, and the water table is accessible to floodplain tree roots
- There is often some degree of hydrological connectivity with surface rivers. This is particularly influential in regulated rivers where artificial flow releases from upstream dams may provide

aquifer recharge of organic matter and oxygen in periods where natural surface flow would be absent

- Compared to deeper aquifers, water in alluvial aquifers is young, has a rapid flux, and can have a lower salinity.

4.2.2 Hydraulic conductivity

Hydraulic conductivity indicates how rapidly water flows through an aquifer. This is important to stygofauna communities because the flux of water through an aquifer often influences how rapidly organic matter and oxygen concentrations can be replenished.

4.2.3 Depth of water table

Depth to water table influences the amount of organic matter and oxygen that are available to aquifer foodwebs. With increasing depth below the land surface, the concentration of organic matter dissolved in infiltrating rainwater diminishes as it is absorbed in transit by soil bacteria and plant roots. Shallow water tables of less than 15 m have been found to favour high diversity in alluvial aquifers in the Hunter Valley and other parts of eastern Australia (Hancock and Boulton 2008).

Another source of organic matter to aquifer invertebrates is the presence of phreatophytic roots (Jasinska et al. 1996). Root density is likely to be higher in shallower aquifers, and the resultant availability of organic matter provides food to diverse stygofauna communities (Hancock and Boulton 2008).

4.2.4 Connectivity to recharge areas

A large proportion of the organic matter that fuels aquifer food webs has its origin at the surface and enters groundwater in particulate or dissolved forms. Therefore, sections of aquifers that are nearer to recharge areas are likely to have higher diversity and abundance than those that are further away since the transfer of organic matter and oxygen is greater at these sites (Datry et al. 2004).

4.2.5 A space for living

Stygofauna can only live in aquifers with enough space for them to move around in. Space is present in the solute cavities in karst, between pesolithic sediments in calcrete, and fractures in sandstone and basalt. In unconsolidated sedimentary aquifers, the size of pore space between particles often correlates to the size of the animals present, with larger species occurring in aquifers of coarser material (Strayer 1994).

Also important when considering the space available for living is the connectivity between pores, cavities, and fractures. These act as migration pathways to allow fauna to move around in the aquifer and are likely to be important in recolonising following disturbance.

4.2.6 Evolutionary history

Most stygofauna evolved from ancestors that once lived in surface freshwater or marine environments. As a result, it is possible that they have retained some of the traits and environmental tolerances of their ancestry. As an example, in coastal areas where ancestral stygofauna species may have come from a marine origin, contemporary taxa may be tolerant of high salinity (Hancock and Steward 2004, Humphreys 2008). Conversely, taxa with a freshwater ancestry may prefer lower salinities (Hancock and Boulton 2008).

4.2.7 Food availability

Stygofauna have adapted to the resource-starved conditions in aquifers and can tolerate low concentrations of organic matter (Strayer 1994, Hahn 2006). Food is available to stygofauna as particulate organic matter, groundwater bacteria, or as roots of phreatic trees. In its dissolved or fine particulate form, organic matter enters aquifers with recharging water. Dissolved organic matter is taken up by groundwater bacteria, which are then imbibed by smaller stygofauna. Most stygofauna are opportunistic omnivores.

4.2.8 Water regime

Local or regional climate and river-flow regimes can influence aquifer recharge, and so affect the organic matter flux in the aquifer. Periods of high, steady rainfall can increase hydrological connectivity between the land surface and the aquifer and can reduce depth to water table. Exchange between rivers, the hyporheic zone, and aquifers can be an important source of nutrients to stygofauna communities (Dole-Olivier et al 1994), so flow fluctuations that enhance hyporheic exchange can subsequently enrich stygofauna communities in deeper parts of the aquifer.

4.2.9 Salinity

Stygofauna in inland aquifers are generally restricted to fresh or partly brackish water. Hancock and Boulton (2008) suggest that most taxa collected from alluvial aquifers in NSW and Queensland prefer Electrical Conductivity (EC) less than 5000 µS/cm. In surveys of coastal areas and near salt lakes in Western Australia, stygofauna were collected from aquifers with salinities at or exceeding sea water (50,000 µS/cm, Watts and Humphreys 2004). No stygofauna in NSW are known from aquifers where EC is this high, but there have been recent collections from an aquifer in the Condomine basin, Qld, where EC was between 36,000 and 56,000 µS/cm (Andrea Prior *pers comm.* Glanville et al 2016).

4.2.10 Dissolved oxygen

Stygofauna are able to tolerate very low concentrations of dissolved oxygen. Hahn (2006) observed a strong decrease in concentrations below 1.0 mg/L, but found some fauna in concentrations down to 0.5 mg/L. Some taxa are able to survive with virtually no oxygen for temporary periods for up to 6 months (Henry and Danielopol 1999, Malard and Hervant 1999). Aquifers can be heterogeneous environments, so may contain patches of water with sufficient oxygen concentration to be suitable for stygofauna. As dissolved oxygen is measured from water pumped from bores, it can be difficult to identify where these patches occur.

4.3 Previous stygofauna surveys

4.3.1 Hunter River Hyporheic Survey

Stygofauna research in the Hunter Valley began in 2000, with a four year survey investigating the impacts of river flow variation on groundwater adjacent to the Hunter River (Hancock 2004, 2006). During this survey, samples were collected from beneath the bed sediments and lateral bars of nine sites along the Hunter River, Goulburn River, and Wollombi Brook (Figure 3).

Hyporheic zones are the areas of river bed where groundwater and surface water mix, and often contain surface water, hyporheic, and groundwater taxa (Marmonier et al. 1993, Marmonier and Creuzé des Châtelliers 1991). The results from the survey validated such diversity in the invertebrate community, with groundwater representatives from Microturbellaria (flatworms), Oligochaeta (aquatic worms), and Ostracoda, Cyclopoida, and Harpacticoida (microcrustacea) recorded at all sites (Table 1). At the time of the survey, stygofauna taxonomy for microcrustaceans was poorly developed for eastern Australia, therefore it was not possible to identify specimens to species level; however, groundwater affinity was inferred by the presence of troglomorphic characteristics (e.g. blindness, elongation and depigmentation; Coineau 2000, Danielopol et al. 1994). This was later confirmed in consultation with international experts (Pierre Marmonier, Tom Karanovic, Ivana Karanovic *pers comm.*).

Two genera of Bathynellacea (an order of crustacean) were collected from the hyporheic zone. *Bathynella* sp. was collected from Hunter River sites at Bowmans Bridge, Dights Crossing, and Aberdeen, and from the Goulburn River at Sandy Hollow. *Notobathynella* sp. occurred at Denman, Dights Crossing, and Aberdeen. The largest stygofaunal taxon collected was a single species (Peter Serov *pers comm.*) of the undescribed Anaspidacean family, Family A. Specimens were collected at all Hunter River sites except Dights Crossing.

One species of the isopod *Heterias* sp. 1 was also collected at five sites along the Hunter River. The amphipod family, Paramaletidae, occurred at six hyporheic sites. It is often difficult to distinguish between amphipod species based solely on morphological characters (Finston et al. 2004) and until recently, molecular techniques were not sufficiently available to allow identification to species level. As a result, there is uncertainty about the number of species present in the Hunter hyporheic specimens.

A complete inventory of the species identified in the survey is shown in Table 1.

Table 1: Stygofauna identified in the Hunter River Hyporheic Survey

Location	Alluvial Aquifer Sampled	Oligochaeta	Microturbellaria	*Bathynella* sp.	*Notobathynella* sp.	Anaspid Family A sp. 1	Paramelitidae sp.	*Heterias* sp. 1	Ostracoda	Cyclopoida	Harpacticoida
Bowman Bridge	Hunter River	✓	✓	✓		✓	✓	✓	✓	✓	✓
Jerrys Plains	Hunter River	✓	✓			✓			✓	✓	✓
Moses Crossing	Hunter River	✓	✓			✓	✓	✓	✓	✓	✓
Denman	Hunter River	✓	✓		✓	✓	✓	✓	✓	✓	✓
Dights Crossing	Hunter River	✓	✓	✓	✓		✓	✓	✓	✓	
Warkworth	Wollombi Brook	✓	✓						✓	✓	✓
Sandy Hollow	Goulburn River	✓	✓	✓					✓	✓	✓
Aberdeen	Hunter River	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Maison Dieu	Hunter River	✓	✓			✓	✓		✓	✓	✓

4.3.2 Hunter Valley Alluvial Aquifer Survey

The confirmation that stygofauna was present throughout much of the Hunter Valley led to further sampling between 2004 and 2008 of bores in the Hunter River, Pages River, Dart Brook, and Kingdon Ponds alluvial aquifers (Hancock and Boulton 2008, 2009; Watts *et al.* 2007). Samples were collected from 40 groundwater monitoring bores operated by mining companies and the NSW Office of Water

(Figure 3). The results of the sampling program, increased the number of known stygofauna taxa in the Hunter Valley to at least 26 groups with this number likely to rise as more of the collected taxa are formally described (Ana Camacho, Tom Karanovic, Ivana Karanovic *pers comm.*). To date, copepods and ostracods from Denman, Muswellbrook, Pages River, Dart Brook (north), and Kingdon Ponds samples have been identified to a species level.

Dart Brook, Pages River, and Kingdon Ponds alluvial aquifers each had similar diversity to the Hunter River alluvial aquifer at Denman. The Hunter River alluvial aquifer near Denman and the Pages River alluvial aquifer had 20 stygofauna taxa. The northern Dart Brook bores had 21 taxa, while Kingdon Ponds had 18 taxa and the Hunter River alluvial aquifer near Muswellbrook had only eight taxa.

A list of the species identified in the survey is shown in Table 2.

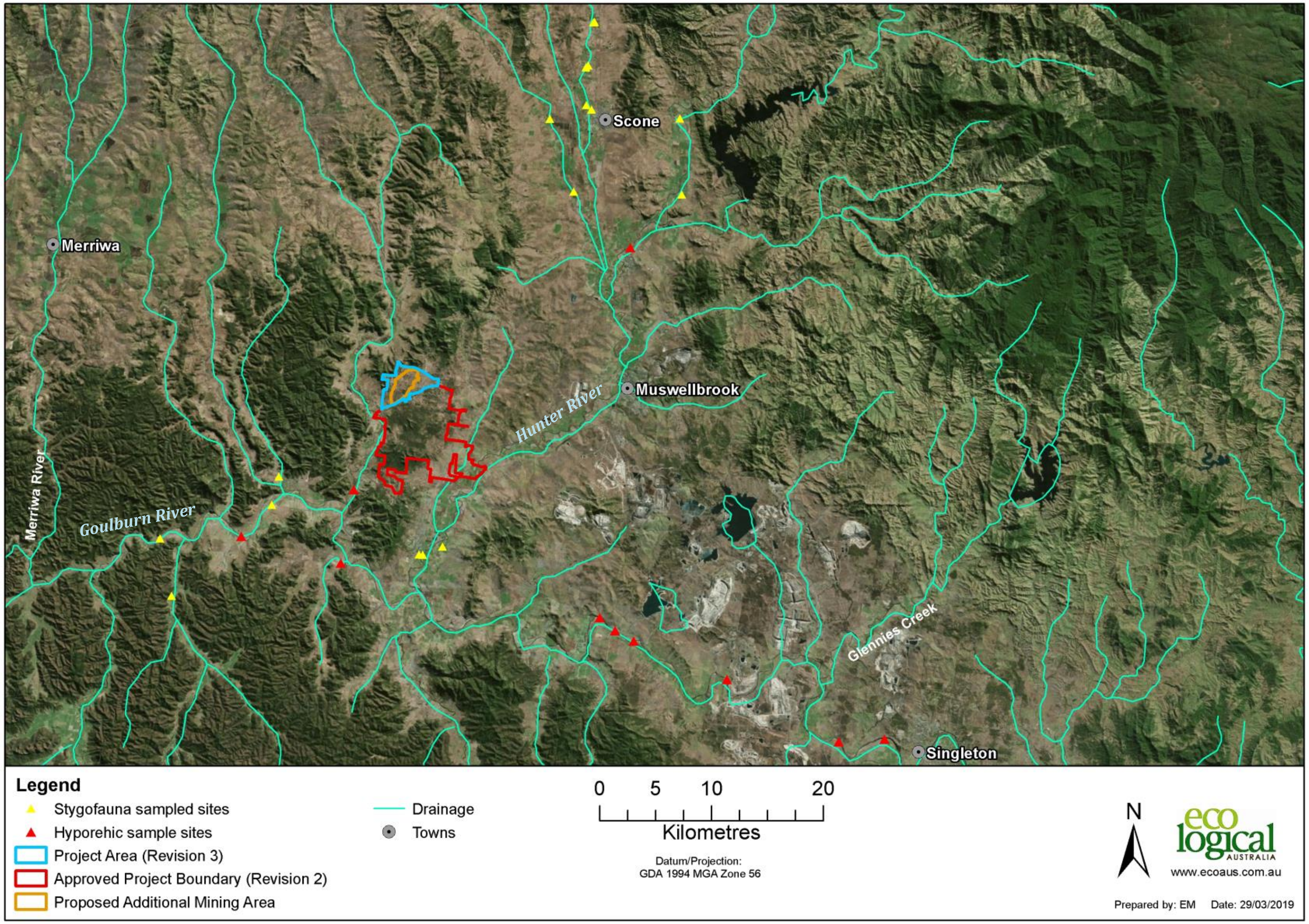

Figure 3: Location of sites sampled in the Hunter River Hyporheic Survey (Hancock 2004, 2006) and the Hunter Valley Alluvial Aquifer Survey (Hancock and Boulton 2008, 2009).

Table 2: Stygofauna identified in the Hunter Valley Alluvial Aquifer Survey (Hancock 2004, 2006)

Location	Alluvial aquifer	Oligochaeta	Microturbellaria	*Bathynella* sp.	*Notobathynella* sp.	Anaspid Family A sp. 1	Paramelitidae sp.	*Heterias* sp. 1	Ostracoda	Cyclopoida	Harpacticoida	*Eucyclops* cf. *ruttneri*	*Diacyclops cryonastes*	*Diacyclops* sp. 1	*Metacyclops* sp. 1	*Haplocyclops* sp. 1	*Elaphoidella* sp. 1	*Australocamptus* sp. 1	*Hancockcamptus* sp. 1	*Huntercamptus* sp. 1	*Huntercamptus* sp. 2	*Huntervallia* sp. 1	Aturidae sp 1	Elmidae sp 1	*Carabhydrus stephanieae*	*Limnobodesis* sp nov	*Hydrobiidae* sp nov
Denman	Hunter	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓		✓	✓	✓		✓	✓		✓
Muswellbrook	Hunter	✓	✓				✓		✓	✓		✓	✓	✓													
Dart Brook south	Dart Brook	✓	✓				✓		✓	✓	✓																
Goulburn	Goulburn River	✓		✓	✓					✓	✓																
Pages	Pages	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓			✓	✓		✓		✓	✓	✓	✓	✓	
Dart Brook north	Dart Brook	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		✓	✓	✓	✓	✓	✓	✓	
Kingdon Ponds	Kingdon Ponds	✓		✓	✓	✓	✓			✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓			✓	✓		

Of the stygofauna identified to species level in the survey, only four (*Notobathynella* sp. nov. 3, Anaspid Family A sp. 1, *Dyacyclops cryonastes*, and possibly *Eucyclops* cf *ruttneri*) out of 19 are known to occur at sites beyond the Hunter Valley. With the exception of a previously undescribed species of Hydrobiidae snail, all taxa collected from the Hunter River aquifer occurred in at least one of the tributary aquifers. Similarly, most species in Dart Brook, Pages River and Kingdon Ponds bores were shared with at least one other aquifer. This suggests that approximately 80% of the species recorded are endemic to the region with many species typically occurring in more than one alluvial aquifer. Only four species are endemic to single aquifers: *Metacyclops* sp. 1, *Haplocyclops* sp. 1, *Hancockcamptus* sp. 1, and *Hydrobiidae* sp. nov.

4.3.3 Other surveys

Other opportunistic sampling for stygofauna has been conducted by Dr Grant Hose (University of Technology, Sydney) from some of the bores sampled in the 2004 to 2008 Hunter Valley Alluvial Aquifer Survey. No further taxa were found during these surveys.

Eco Logical Australia has conducted stygofauna surveys for several Hunter Valley mines, including Bengalla (ELA 2013a), Liddell (ELA 2013b), and the Bylong project (ELA 2014). All taxa collected during these surveys (Table 3) were previously known from the alluvial aquifers of the Hunter River or its tributaries, except for two. The exceptions were *Chilibathynella peelensis*, previously known only from near Tamworth, and an unknown species of Anaspidacea that occurred in two bores at Bylong.

Table 3: Stygofauna from three mines in the Hunter Valley

Order	Family	Genus/ species	Bengalla	Liddell	Bylong
Anaspidacea	Psammaspididae			✓	✓
	Family A	Anaspidacea sp.			✓
Bathynellacea	Parabathynellidae	*Notobathynella* sp.	✓	✓	✓
	Parabathynellidae	*Chilibathynella peelensis*			✓
	Bathynellidae	*Bathynella* sp.	✓	✓	✓
Isopoda	Janiridae	*Heterias* sp.		✓	
Amphipoda	Paramelitidae	*Chillagoe* sp.	✓	✓	✓
Cyclopoida	Cyclopidae		✓	✓	✓
	Harpacticoida				✓
Ostrocoda			✓	✓	
Coleoptera	Dytiscidae	*Carabhydrus stephanieae*		✓	
Coleoptera	Elmidae	*Austrolimnius* sp.		✓	
Oligochaeta			✓		

4.4 Likelihood of stygofauna occurring in the study area

The Hunter River alluvial aquifer has a diverse stygofauna community, however is located over 8.5 km from the MCCO Additional Project Area. There is also a relatively diverse stygofauna community associated with alluvial deposits of the Goulburn River, which was sampled at Sandy Hollow, over 9 km from the MCCO Additional Project Area.

The alluvium of Wybong Creek consists of medium sand and gravel, which is similar to that of the Goulburn River. As there is a strong hydrological connection between the aquifers of Wybong Creek and Goulburn River, it is possible that there is also a shared stygofaunal community. If there are stygofauna in the Wybong Creek alluvium, then it is likely that the species present also occur in the Goulburn River aquifer and will consist of small crustacean taxa such as *Bathynella* spp., *Notobathynella* spp., and harpacticoids.

Where sedimentary deposits are thin, or where the aquifer dries frequently or for prolonged periods, stygofauna will be unlikely. For this reason, it is unlikely that stygofauna occur in the colluvial sediments along Big Flat Creek, which are poorly developed and not likely to hold permanent water.

Although stygofauna are unlikely to occur in the underlying Permian aquifer due to increasing depth below ground, low hydraulic conductivity and generally high salinity, there may be areas where EC is less than 5000 μS/cm and weathering is likely to have increased the space available for stygofauna. As the Permian aquifers will be the main aquifers impacted by the MCCO Project, samples were collected to confirm if stygofauna occur there.

5 Methods

5.1 Study sites

The Western Australian EPA (2003, 2007) specifies that bores selected for stygofauna sampling should be at least three months old before the first sampling. This resting period allows stygofauna to colonise the immediate vicinity of the bore following the disturbance created during construction and subsequent development.

Following a review of previous groundwater assessments, drilling programmes, and recent groundwater monitoring data, a list of bores was generated for sampling. Generally, bores were chosen which:

- Gave a range of spatial and depth coverage across each aquifer type present;
- Were most likely, of the bores available in each aquifer, to contain stygofauna;
- Had casings that were vertical, at least 50 mm in diameter, and were screened at appropriate depths;
- Had water quality (if data were available) that was favourable to stygofauna; and
- Had shallow water tables (where this information was available)

These criteria aimed to maximise chances of collecting as many stygofauna taxa as possible.

There were 11 bores selected for sampling (Table 4, Figure 4). This included two bores in the Wybong Creek alluvium and nine in the fractured and porous rock aquifer. To maximise the chance of finding fauna in rock aquifers, only bores shallower than 40 m were sampled. No bores were sampled in the colluvium, as none could be found with a screened interval that was both below the water table and in the colluvium. BFC01A and GW047877 passed through the colluvium. These were both sampled but had their screened intervals below the base of the colluvium, at 14-17 m and 21-30 m respectively.

5.2 Field sampling and laboratory identification

Field sampling occurred on 3 and 4 October 2017 and was carried out by ELA Aquatic Ecologists Dr Peter Hancock and Tim Henderson.

Bore water quality was sampled for physio-chemical parameters at each site. A one litre bailer was used to haul up to six litres of water which were stored in buckets until sampling was complete. On the third haul, water quality was measured using a YSI-556 meter and the temperature, dissolved oxygen (DO), electrical conductivity (EC) and pH were recorded. The meter was calibrated prior to fieldwork and DO was calibrated at the start of each survey day.

Bores were sampled using a weighted net with 50 μm-mesh. The net was lowered to the bottom of each bore, then raised and dropped over approximately 50 cm three to five times to dislodge resting fauna. It was then slowly retrieved to the surface. Slow retrieval is necessary to avoid a bow-wave pushing fauna from the net entrance. Once the net was at the surface, it was rinsed into a 50 μm-mesh sieve and then lowered once more to the bottom of the bore. This process was repeated until the contents of six net hauls, where possible, were retrieved. Sieve contents were washed into a sample jar containing ethanol and labelled.

Samples were transported to the laboratory and sorted under a Leica MZ8 dissecting microscope. Any species observed were then identified as far as possible using available taxonomic keys.

Table 4: Bore location and depth to water level

Site	Geology	Aquifer type	Water level (mbgl)	Zone	Easting	Northing
BFC01A	Weathered conglomerate, clay, coarse sediment	Rock	17.93	56 H	280757	6427278
GW047877	Rock	Rock	5.26	56 H	282442	6428565
GW202249	Unknown	Rock	7.01	56 H	281192	6428206
MN1006	Siltstone and coal	Rock	5.68	56 H	283065	6429028
MP12-B	Conglomerate	Rock	15.25	56 H	280614	6425589
MP14-A	Interburden, conglomerate	Rock	13.39	56 H	280630	6425113
MP1-B	Conglomerate	Rock	15.70	56 H	284885	6426057
NGW01B	Conglomerate and alluvial gravel	Wybong Creek Alluvium	13.90	56 H	278075	6427065
NGW01C	Conglomerate and alluvial granite	Wybong Creek Alluvium	13.85	56 H	278075	6427065
NGW02B	Weathered and fresh conglomerate	Rock	6.31	56 H	280975	6429920
NGW03A	Weathered conglomerate	Rock	17.66	56 H	285380	6428687

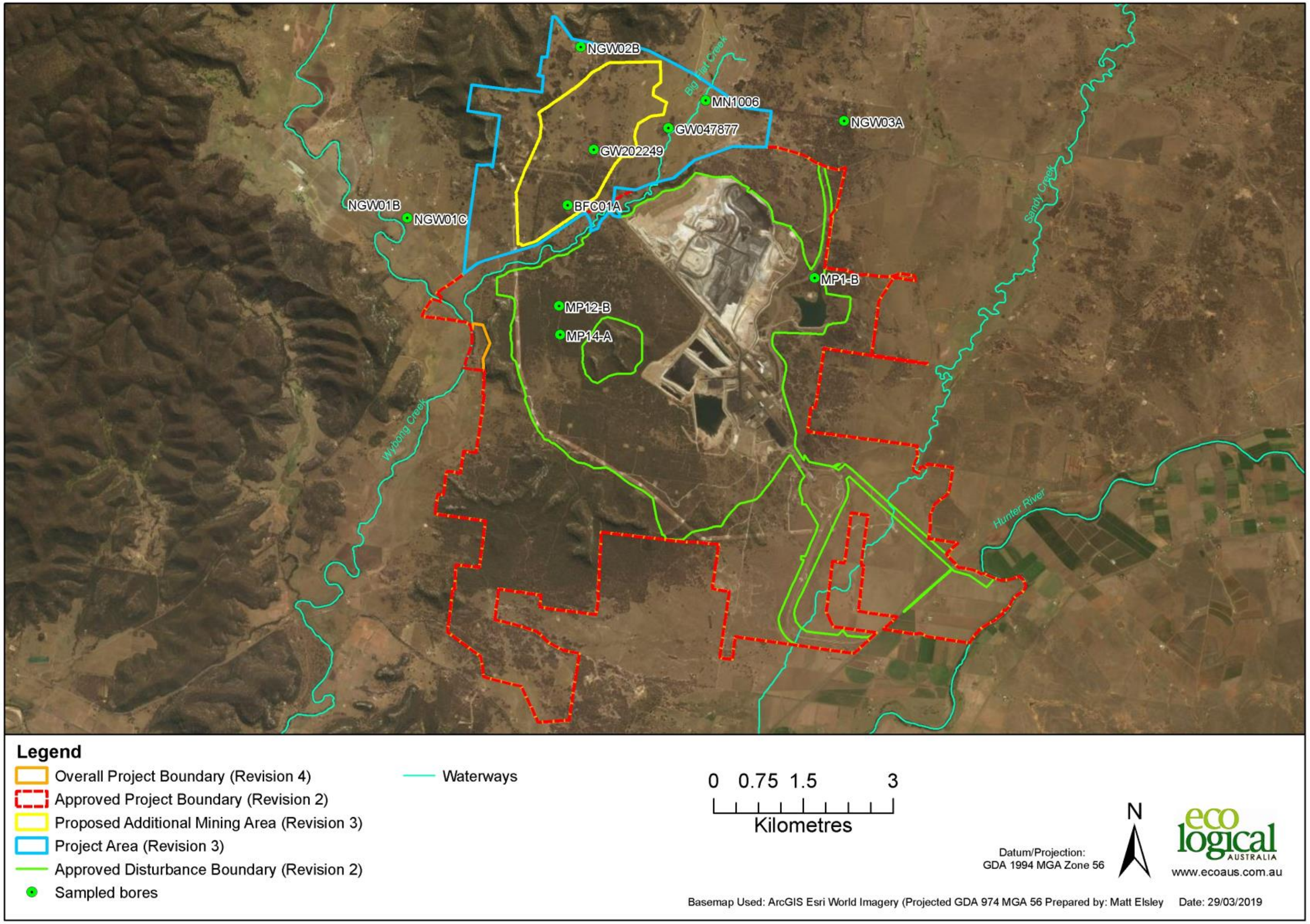

Figure 4: Location of bores sampled for the MCCO Project

5.3 Risk assessment process

Risk Assessment Guidelines for Groundwater Dependent Ecosystems (Serov et al. 2012) outlines the processes for risk assessment of GDEs. The steps involved in the assessment process (specific to aquifer ecosystems) are:

- Identify and classify the ecosystems,
- Assess the level of dependence on groundwater
- Identify high ecological value components of the aquifer
- Determine the ecological value of the aquifer
- Determine the impact of the activity on the aquifer community
- Determine risk magnitude to the aquifer community
- Apply the GDE Risk Matrix
- Apply management actions, including mitigation measures.

The GDE Risk Matrix (Table 5) is a method of outlining appropriate management responses for an environmental value under a particular activity.

The matrix consists of a vertical axis that plots ecological value, and a horizontal axis that plots the level of risk of an activity. The ranking of both ecological values and risk is divided into a three-category system of "High, Medium, and Low" values.

The Risk Matrix management action table (Table 6) identifies both the level of management action required and the time frame in which this action needs to be implemented (Action Priority). The management action is aligned with ecological value and does not vary with changes in risk (i.e. the rules for the management of high ecological value ecosystems or aquifers are the same whether the risk is high or low). However, the timing of the management action is aligned and determined by the level of risk.

Stygofauna are a critical, and often defining, component of aquifer ecosystems. Aquifer ecosystems are the only GDE type considered during this assessment.

Table 5: GDE Risk Matrix (Serov et al. 2012)

Category 1: High Ecological Value (HEV) Sensitive Environmental Area (SEA)	**A**	**B**	**C**
Category 2: Moderate Ecological Value (MEV) Sensitive Environmental Area (SEA)	**D**	**E**	**F**
Category 3: Low Ecological Value (LEV)	**G**	**H**	**I**
	Category 1: Low Risk	**Category 2:** Moderate Risk	**Category 3:** High Risk

Table 6: Risk Matrix management actions (Serov et al. 2012)

Risk Matrix Box	Descriptor	Management action		
		Short term	Mid-term	Long term
A	High value/Low risk	Protection measures for aquifer and GDEs.	Continue protection measures for aquifers and GDEs.	Adaptive management. Continue monitoring.
		Baseline Risk monitoring.	Periodic monitoring and assessment.	
B	High value/Moderate Risk	Protection measures for aquifer and GDEs.	Protection measures for aquifer and GDEs.	Adaptive management. Continue monitoring.
		Baseline Risk monitoring. Mitigation action.	Monitoring and periodic assessment of mitigation.	
C	High Value/High Risk	Protection measures for aquifer and GDEs.	Protection measures for aquifer and GDEs.	Adaptive management. Continue monitoring.
		Baseline Risk monitoring. Mitigation.	Monitoring and annual assessment of mitigation	
D	Moderate Value/Low Risk	Protection of hotspots.	Protection of hotspots.	Adaptive management. Continue monitoring.
		Baseline Risk monitoring.	Baseline Risk monitoring.	
E	Moderate Value/Moderate Risk	Protection of hotspots.	Protection of hotspots.	Adaptive management. Continue monitoring.
		Baseline risk monitoring.	Monitoring and periodic assessment of mitigation.	
		Mitigation action.		
F	Moderate Value/High Risk	Protection of hotspots.	Protection of hotspots.	Adaptive management. Continue monitoring.
		Baseline risk monitoring. Mitigation action.	Monitoring and annual assessment of mitigation.	
G	Low value/Low risk	Protect hotspots (if any).	Protect hotspots (if any).	Adaptive management. Continue monitoring.
		Baseline risk monitoring.	Baseline risk monitoring.	

Risk Matrix Box	Descriptor	Management action		
		Short term	Mid-term	Long term
H	Low Value/Moderate Risk	Protect hotspots (if any).	Protect hotspots (if any).	Adaptive management. Continue monitoring.
		Baseline risk monitoring. Mitigation action.	Monitoring and periodic assessment of mitigation.	
I	Low Value/High Risk	Protect hotspots (if any).	Protect hotspots (if any).	Adaptive management. Continue monitoring.
		Baseline risk monitoring. Mitigation Action.	Monitoring and annual assessment of mitigation	

6 Results

6.1 Water Chemistry

Bore water was sampled at a total of 11 sites.

Water temperature ranged from 20.6°C to 23.6°C with an average of 22.3 ± 0.9°C (Table 7). Electrical conductivity (EC) was lowest at MP14-A (833 µS/cm), highest at site BFC01A (13340 µS/cm) and averaged 5591.5 ± 3301.8 µS/cm across all sites (Table 7). The pH remained consistent, ranging between 6.3 and 7.3, with only MP1-B having a higher pH of 8.1 (Table 7). Dissolved oxygen concentration ranged from 0.3 mg/L at NGW02B to 5.4 mg/L at GW202249 (Table 7).

Table 7: Groundwater physico-chemistry at Mangoola bores sampled for stygofauna

Site	Sample Date	Depth to water (mbgl)	Water Temperature (°C)	pH	Conductivity (µS/cm)	Dissolved Oxygen (% saturation)	Dissolved Oxygen (mg/L)
BFCO1A	4/10/2017	17.93	22.9	6.6	13340	37.5	3.1
GW047877	3/10/2017	5.26	23.6	6.6	5393	23.7	2
GW202249	4/10/2017	7.01	22.7	7	2187	63.5	5.4
MN1006	3/10/2017	5.68	23.1	6.6	3500	26.7	2.3
MP12-B	4/10/2017	15.25	21.9	6.3	7652	23	2
MP14-A	4/10/2017	13.39	20.6	7.3	833	30.1	2.7
MP1-B	3/10/2017	15.70	20.9	8.1	6068	21.3	1.9
NGW01B	4/10/2017	13.90	22.6	6.5	4525	26.9	2.3
NGW01C	4/10/2017	13.85	23.2	6.6	7403	31.2	2.6
NGW02B	3/10/2017	6.31	22.1	6.7	4505	3.9	0.3
NGW03A	3/10/2017	17.66	22.1	6.2	6101	19.9	1.7

6.2 Stygofauna

No stygofauna taxa were recorded from the field sampling and analysis completed for the MCCO Project.

Two non-stygofauna taxa were collected from four bores: Oligochaeta (worms) were collected from GW202249 and GW047877, while Oribatida (soil mites) were collected from NGW01B and MP12B (Table 8). Oribatids are members of the soil invertebrate community and are likely to have either fallen into the bore from the surface or entered through a crack or join in the bore casing. They are not dependent on groundwater.

The taxonomy and ecology of aquatic oligochaetes is almost completely unknown in NSW beyond family level, so it is impossible to conclusively distinguish among soil, groundwater, and aquatic species (Pinder

2010). Oligochaeta are sometimes encountered in alluvial aquifers, but they are more likely to be members of the soil community than they are to be stygofauna. Because of this, and uncertainties associated with taxonomy, oligochaetes are sometimes excluded from consideration as stygofauna (Halse and Pearson, 2014). The two oligochaetes collected at Mangoola are likely to be soil invertebrates because if they were living in the groundwater, the sample would also have contained other stygofauna taxa, or there would have been greater numbers of oligochaetes collected.

Table 8. Invertebrates collected from bores at Mangoola

Bore	Oligochaeta	Oribatida
GW202249	1	
NGW01C		
BFC01A		
NGW01B		3
MP12B		6
MP14A		
NGW02B		
NW03A		
MN1006		
MP1B		
GW047877	1	

7 Risk assessment

The following sections assess the potential for these impacts to occur within the MCCO Additional Project Area, based on the processes outlined in *Risk Assessment Guidelines for Groundwater Dependent Ecosystems* (Serov et al. 2012).

7.1 Identify and classify the ecosystems

No stygofauna were collected during sampling of the Wybong Creek alluvial aquifer or fractured rock aquifers within the MCCO Additional Project Area. Although no stygofauna were found in the Wybong Creek aquifer, this is still potential stygofauna habitat given the connection to the Goulburn River alluvium. The Wybong Creek alluvium has a moderate chance of being an Aquifer Ecosystem.

Fractured rock aquifers may contain stygofauna if they are close to an aquifer with stygofauna and there is a network of sufficiently interconnected fractures by which they can colonise. The community would only extend into the rock aquifer as far as an uninterrupted network of fracture passages allow. It is unlikely that such a network of fractures would exist to allow stygofauna to colonise rock aquifers in the MCCO Additional Project Area.

There were no suitable bores for sampling colluvial aquifers, but these are very unlikely to contain stygofauna because they are dry most of the time (AGE 2019). While colluvial aquifers may occasionally have stygofauna, this is generally only where they are close to large alluvial or karstic aquifers where stygofauna are able to colonise during wet periods. This situation does not occur in the MCCO Additional Project Area apart from, possibly where Big Flat Creek enters Wybong Creek alluvium. The lower reaches of the colluvium may occasionally be connected to the larger Wybong Creek alluvium, and so have fauna migrate into it. However, faunal residence time would last only as long as water remains in the colluvium.

7.2 Assess the level of dependence on groundwater

Both oligochaetes and oribatids were collected from rock aquifers. These are widespread members of the soil invertebrate community and will have fallen into the bores they were collected from. Neither of these taxa are dependent on groundwater.

While no stygofauna were collected from the two bores sampled in the Wybong alluvium, there may be stygofauna in this aquifer that originated from the Goulburn River alluvium. If there are stygofauna present in the aquifer, they will be entirely dependent on groundwater. Stygofauna would be more diverse and abundant closer to the main channel of the river where alluvial sediments are thicker.

7.3 Identify high ecological value components of the aquifer

The rock and colluvial aquifers within the MCCO Additional Project Area do not constitute likely stygofauna habitat. No stygofauna were collected during sampling, and none are likely because the aquifers are unsuitable.

The Wybong Creek alluvium may have a moderate ecological value if it contains stygofauna, but the ecological value will decrease as the aquifer thins towards its margin. This is because thin sections of the aquifer dry more frequently than thick sections. In the area near to the MCCO Additional Project Area, the aquifer would be thin and of low ecological value.

7.4 Determine the impact of the activity on the aquifer community

Minimal drawdown is expected in the Wybong Creek alluvium due to the MCCO Additional Project Area. However, cumulative drawdown from the existing Approved Project Area and the proposed MCCO Additional Project Area is expected to result in a maximum of 1 m drawdown in the Wybong Creek alluvium near the confluence with Big Flat Creek (AGE 2019). This drawdown is due to the existing approved mine with no incremental drawdown of over 1 m predicted on the Wybong Creek alluvium due to the MCCO Project. As only a small section of aquifer will experience over 1 m drawdown, and the extent of this drawdown is minor, there will be minimal impact on regional stygofauna diversity due to the cumulative MCCO Project, and negligible impact predicted due to the MCCO Additional Project Area+

7.5 Determine risk magnitude to the aquifer community

While no stygofauna were recorded in the Wybong Creek alluvium during sampling for the MCCO Project, it's possible that the Wybong Creek alluvium has a stygofauna community that is an extension of the Goulburn and Hunter River aquifer community. There are unlikely to be any endemic taxa living in the Wybong Creek aquifer, particularly in the small area modelled for drawdown due to the existing approved mining operations, so the magnitude of risk is low. No additional drawdown of the Wybong Creek alluvium is predicted as a result of the MCCO Project.

For the rock and colluvial aquifers there is no risk from the development to stygofauna communities.

7.6 Apply the GDE Risk Matrix

Under the GDE risk assessment guidelines, the MCCO Project poses a Category 1 (low) threat to a Category 3 (low environmental value) aquifer community. The resultant interaction of these two categories in the GDE Risk Matrix is G. Management actions for a Category G interaction are summarised below.

7.7 Apply management actions, including mitigation measures

Recommended management actions in the GDE Assessment Guidelines for Category G interactions are to protect hotspots, implement mitigation measures, and monitor risk. There were no hotspots of stygofauna diversity identified during the survey, but there are potential hotspots further downstream in the Goulburn River Alluvium. No drawdown is expected in the Wybong Creek alluvium due to the MCCO Additional Project Area. However, cumulative drawdown from the existing Approved Project Area and the proposed MCCO Additional Project Area is expected to result in a maximum of 1 m drawdown in the Wybong Creek alluvium near the confluence with Big Flat Creek (AGE 2018). There is not likely to be any impact to the Goulburn River alluvium, and this potential hotspot requires no additional protection.

As no stygofauna occurred in the aquifers sampled, ongoing monitoring of bores for stygofauna would not be necessary. Routine water monitoring of the Wybong alluvium forms part of the groundwater management program. This would assist in protecting the Wybong alluvium, which is a potential habitat for stygofauna, and would be a precaution against unexpected impacts to the aquifer ecosystems of the Goulburn River alluvium.

8 Conclusion

Eleven bores were sampled, but none of the bores contained stygofauna taxa. Two widespread soil invertebrate taxa were collected from four bores. Neither of these are dependent on groundwater.

Of the aquifers near the MCCO Additional Project Area, only the Wybong Creek alluvium has potential to be stygofauna habitat. Although no taxa were collected from the two bores sampled in this aquifer, it has a strong hydrological connection to the Goulburn River alluvium. This suggests that there could be some stygofauna that have migrated into the Wybong Creek aquifer. If this is the case, then the fauna are likely to be concentrated around the centre of the aquifer where water levels are more stable and there is a greater connection to the Goulbourn River. The thinner sediments on the margin of the aquifer, where a minor drawdown is likely to occur due to the existing approved mining operations, have low ecological value. There is no additional drawdown predicted as a result of the MCCO Project. As a result, the proposed impacts from operations during development of the MCCO Project will not pose a significant threat to any stygofauna communities and no subsequent monitoring for stygofauna is required.

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