Bennelongia Environmental Consultants

Stygofauna Risk Assessment for Cosmos Mine

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Final Report

Short-Range Endemics I Subterranean Fauna

Waterbirds I Wetlands

Stygofauna Risk Assessment for Cosmos Mine

Bennelongia Pty Ltd
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1. INTRODUCTION

Western Areas Limited (Western Areas) plan to recommence nickel mining operations at Cosmos Mine (the Project) in the northeastern part of the Yilgarn region of Western Australia (Figure 1). This will require abstraction of groundwater to enable access to the ore and disposal of this saline groundwater. Two aspects of this operation may potentially threaten the conservation status of any restricted subterranean fauna species present: the loss of stygofauna habitat as a result of groundwater drawdown; and the possible increase in groundwater salinity associated with leakage of abstracted groundwater from planned dewatering facilities such as waste management ponds.

Complementing the state and federal legislation protecting native biota and ecological communities (Wildlife Conservation Act 1950; Environment Protection and Biodiversity Conservation Act 1999), the assessment of development projects under Part IV of the Western Australian Environmental Protection Act 1986 may consider the impacts of a project on subterranean fauna. The approach adopted to subterranean fauna is described in Environmental Protection Authority Guideline 12 (EPA 2013). In addition, nine subterranean fauna assemblages have been endorsed by the Minister for the Environment as Threatened Ecological Communities (TEC), while the Department of Parks and Wildlife (DPaW) lists more than 80 subterranean fauna assemblages as Priority Ecological Communities (PEC).

This report aims to:

(1) Characterise conservation values of subterranean fauna in the Project area; and
(2) Evaluate risks posed to those conservation values by planned excavations, groundwater abstraction and leakage from groundwater storage and evaporation areas.

2. BACKGROUND

2.1. Regional Setting

The Project is located in the north-eastern part of the Yilgarn Craton of Western Australia. This sub-region has an elevation of 450-550 m AHD and is underlain by Archaean rocks comprising north to north-westerly trending greenstone belts enclosed in regional granite masses intruded by younger granites and felsic rocks (Morgan 1993). A well-developed regional palaeoriver system is represented at the surface by salt lakes chains. Palaeochannels have been progressively in-filled since the Eocene with gravels, clays, lateritic alluvials, calcrete, halite and gypsum deposits (Commander et al. 1992).

The Project itself lies adjacent to Lake Miranda, a terminal salt lake covering about 200 km^2 containing a number of low islands and intersecting playas. The geological profile of the lake consists of surface alluvial and colluvial sediments comprising the lake floor, overlying a layer of dense plastic clay, below which interbedded layers of sand and clay occur. Lake Miranda is part of the Carey palaeoriver system. While groundwater discharge occurs by capillary rise and evaporation through the lakebed during dry conditions, there is seepage to the underlying aquifer during inundation (Coleman 2003).

Groundwater beneath Lake Miranda ranges from 40,000 ppm TDS to 170,000 ppm TDS (URS 2003). Groundwater salinities above 180,000 ppm TDS have been recorded in the palaeoriver north of Lake Miranda (URS 2003). Depth to the water table beneath the lake bed is variable but the water table is mostly 2–4 mbgl (Golder Associates 2000).

Three Priority 1 PECs in calcrete surround Lake Miranda – Lake Miranda West, Lake Miranda East and Yakabindi. These areas are considered to be of conservation significance owing to the likely presence of unique assemblages of subterranean fauna.

2.2. Project description

The Project, formerly operated by Xstrata Nickel Australasia Operations Pty Ltd and subsequently acquired by Western Areas, consists of underground nickel mines and an associated ore processing

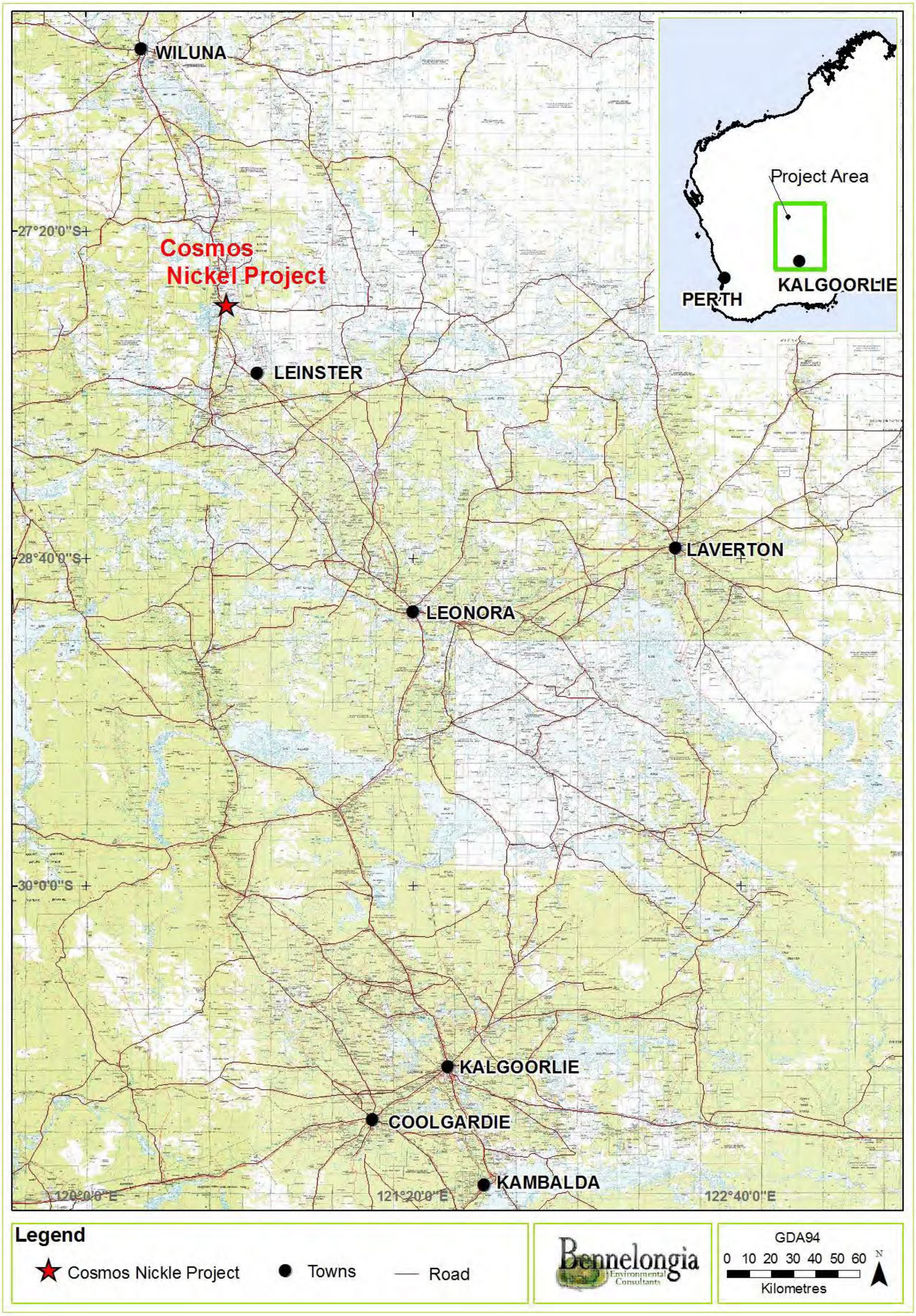

Figure 1. Location of the Cosmos Nickel Project.

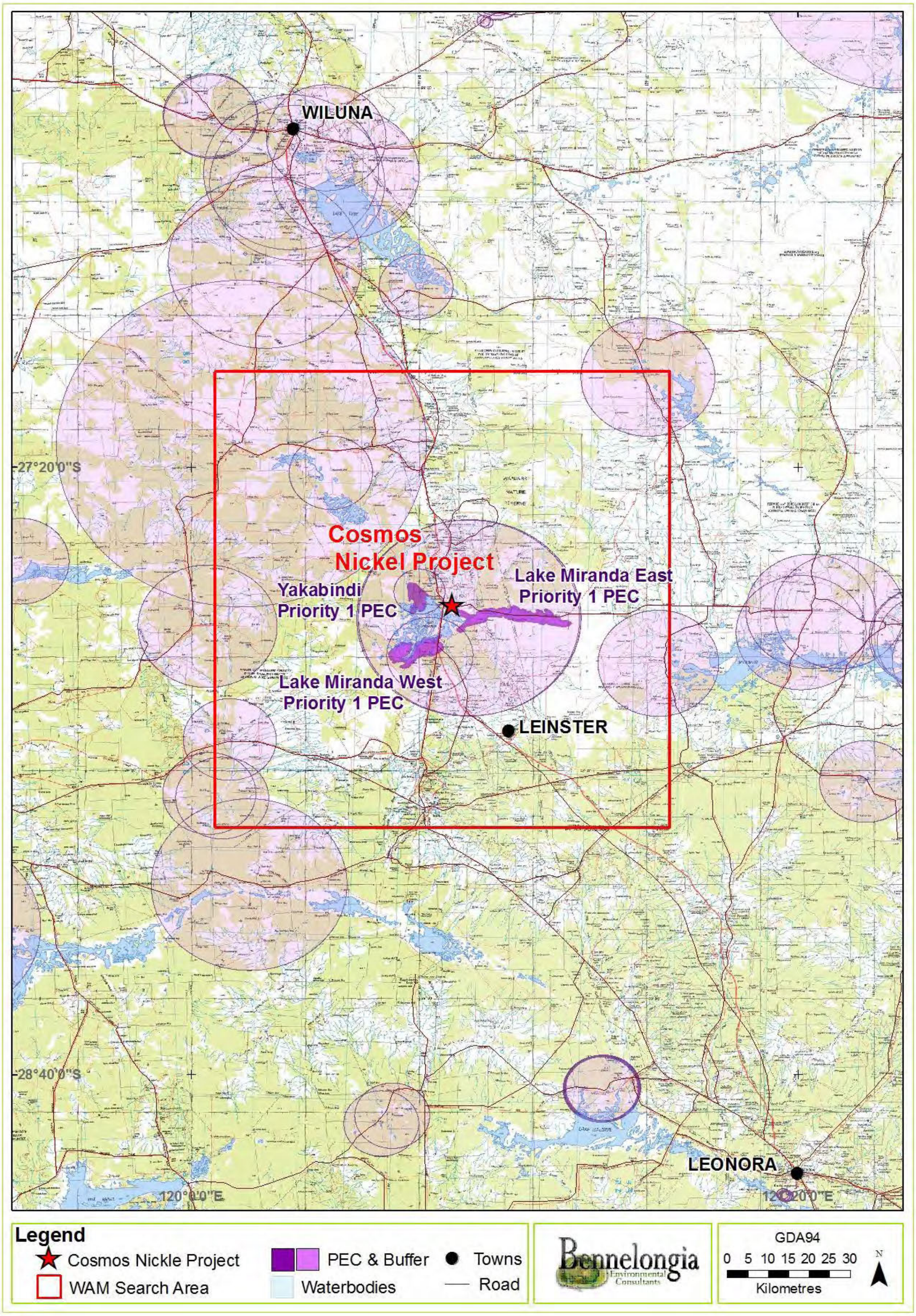

Figure 2. WAM search area boundaries and calcrete Priority Ecological communities in the vicinity of the Project.

facility. Mining will occur via underground declines to a depth of more than 1000 mbgl and dewatering of surrounding aquifers to a depth of approximately 1100 m will be required.

Within its setting of Yilgarn geology, the Project area lies in ultramafics. The nickel to be mined occurs in komatiite. Pre-mining groundwater levels were 15–20 mbgl.

2.3. Dewatering Strategy

Groundwater salinity in Project area is hypersaline, with monitoring in 2012 returning salinity readings in the Cosmos pit of 110–160 mS/cm (Xstrata 2013) (approximately 70,000–100,000 ppm TDS). Groundwater occurs in several aquifers around the Cosmos pit that are likely to be highly compartmentalised and may have limited hydraulic connectivity with one another (Xstrata 2013), which may mitigate the effect of abstraction between aquifers and limit the spatial extent of drawdown. The aquifers lie (1) within vugs and cavities in ultramafic cap rock, (2) in the transition zone between fresh and weathered rocks, (3) adjacent to the contact of footwall felsic volcanic and ultramafic units, (4) adjacent to the contact between the ultramafic unit and felsic porphyry, and (5) along the margins of the intrusive mafic unit within the footwall sequence (Xstrata 2013).

The dewatering strategy currently proposed entails disposal of excess mine groundwater via evaporation in a series of storages (Figure 3) comprising:

- **WMP1–5:** series of five ponds east of the Cosmos pit constructed in the late-1990s. The ponds are linked by a common wall and trend north-south from WMP1 to WMP5, with the gradient running from WMP1 to WMP5. The ponds are lined along external embankments to remove lateral seepage and surface breakout, however pond floors are unsealed to allow vertical seepage to underlying hypersaline groundwater.
- **WMP6–7:** two ponds located north of the TSF and WMP1–5. The ponds share a common wall to manage the natural gradient (WMP6 is up-gradient of WMP7). The embankments fitted with a synthetic liner to limit lateral seepage.
- **WMP8:** a potential new pond to be located north of WMP6–7, with which it will share a common wall. There will be a synthetic liner on the embankment to limit lateral seepage.
- **Orleans Pit:** 2.7 km south of Cosmos pit. Previously used to manage discharge from Prospero pit.
- **Waste Dump Dam:** located on the western side of WMP2–3. Fully lined but the liner is in need of refurbishment prior to proposed operations.

Additional options to dispose of excess mine water that are being investigated include storage in four existing pits on third-party tenements and re-injection into groundwater aquifers. The impacts of these options are not considered here.

The annual volumes of groundwater abstracted from around Cosmos in 2011 and 2012 (when the mine was in care and maintenance and the groundwater level was rebounding) were 91.96 ML and 86.00 ML. In 2012 the Cosmos pit was used as a storage and transfer dam rather than an in-pit sump. These volumes of groundwater were produced by nine pumps operating continuously (Xstrata 2012, 2013).

The estimated volume of dewatering required to recommence mining as of 2016 is 1.6 GL, which is more than an order of magnitude greater than pumped in 2011 and 2012 but is comparable to historical annual dewatering volumes by Xstrata of 1.4–1.7 GL in 2009–2011 (Xstrata 2011, 2012). The long-term pumping rate necessary for continued operations is 25–50 L s^{-1} (approximately 1.2 GL annually) (B. Williams, pers. comm.). The extent of the drawdown cone associated with this dewatering has not yet been modelled but Xstrata (2011, 2012) reported that when the watertable was >100 mbgl near the mine there was negligible drawdown in monitoring bores 3.2 km away at the neighbouring Prospero pit.

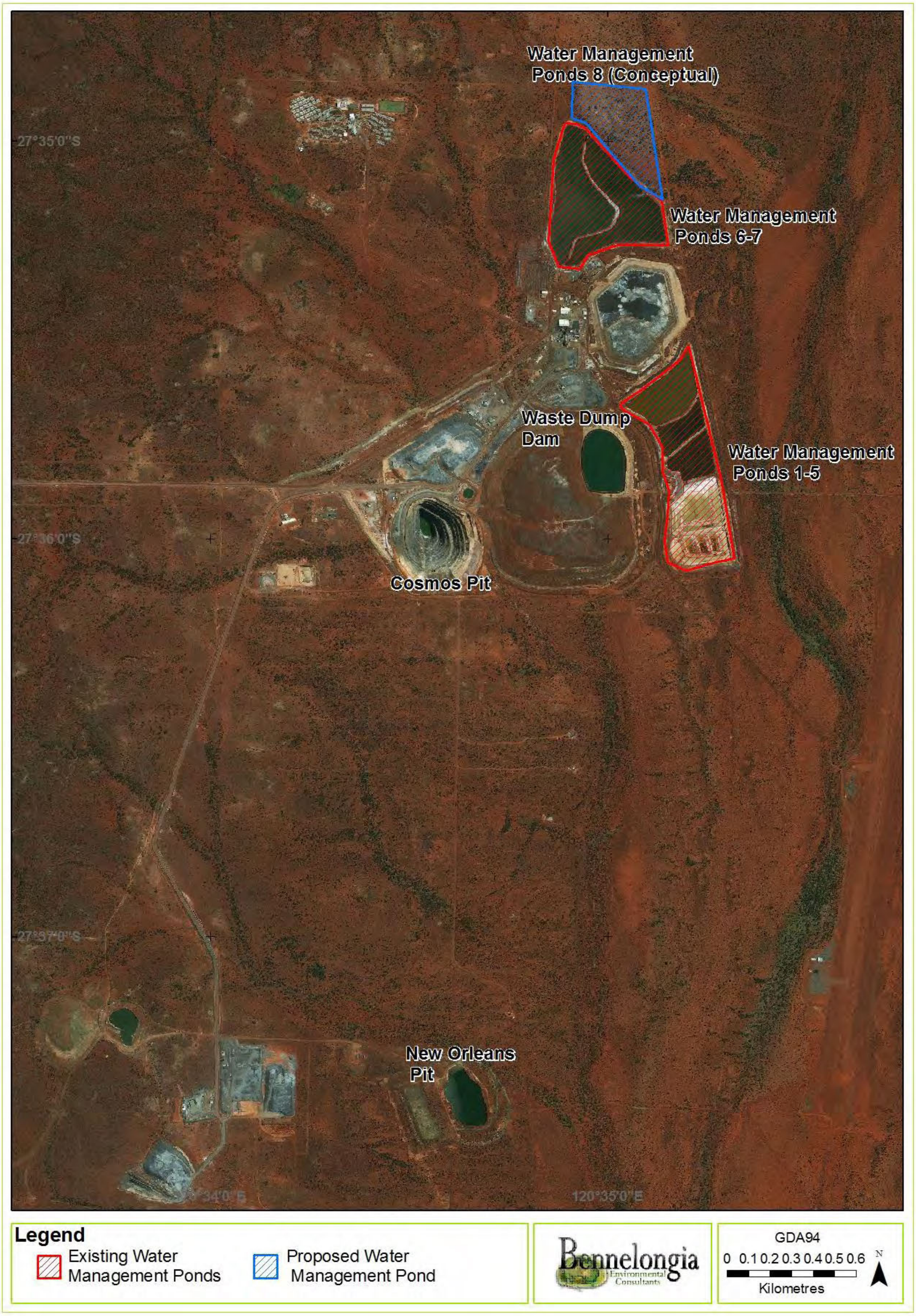

Figure 3. Infrastructure and layout of proposed groundwater disposal facilities at the Project.

3. SUBTERRANEAN FAUNA IN THE YILGARN

3.1.1. Troglofauna

Troglofauna are air-breathing animals that inhabit underground spaces such as interstices, vughs and caves, and their presence, abundance and diversity is strongly dependent on the extent of suitable transmissive geology. Significant troglofauna communities have been documented in Yilgarn, mainly in calcretes, with less diverse assemblages having been documented in BIF and alluvium. Consolidated geologies such as ultramafic rock tend not to be prospective troglofauna habiat.

Direct habitat loss is the main mine-related threat to troglofauna. Given the small extent of the proposed excavation zone at the Project, it is considered unlikely that operations will remove a significant amount of troglofauna habitat. Moreover, it is considered unlikely that significant troglofauna communities would exist within the impact zone where ultramafic geologies dominate. Therefore, the Project is considered to pose a low risk to the conservation values of troglofauna, which are not subject to further consideration here.

3.1.2. Stygofauna

Stygofauna – subterranean animals that inhabit groundwater – are important components of biodiversity in Australia and the Yilgarn is considered a globally significant area for such creatures (Guzik et al. 2011). Typical stygofaunal groups include beetles, amphipods, copepods, ostracods, syncarids and earthworms. Aquifers in calcretes along palaeodrainage channels frequently host diverse stygofaunal assemblages (e.g. Humphreys 2001; Cooper et al. 2002, 2007), including a high incidence of species that are restricted to individual aquifers (Watts and Humphreys 2006; Karanovic et al. 2014; Jadvikar et al. 2015). Species with highly localised ranges are highly susceptible to anthropogenic threats, such as habitat removal by mining (Ponder & Colgan 2002).

4. PREVIOUS ASSESSMENT

A risk assessment for subterranean fauna was completed for the Project by Bennelongia (2011) when operations were controlled by Xstrata. The assessment examined the potential impact of groundwater abstracted during mine dewatering being discharged into Lake Miranda.

The assessment consisted of:

- Characterisation of prospective stygofauna habitat at the Project;
- Summary of recorded subterranean fauna within the vicinity; and
- Evaluation of potential impacts to subterranean fauna resulting from discharge of hypersaline groundwater into Lake Miranda.

The assessment identified two stygofauna habitats in the Project area:

- Habitat 1, consisting of calcrete aquifers with high stygofauna conservation values (Miranda West, Miranda East and Yakabindi Priority 1 PECs) at the margins of Lake Miranda; and
- Habitat 2, consisting of any sections of the aquifer below Lake Miranda with salinities <60,000 mg/L TDS.

The assessment forecast two possible outcomes in Habitat 1 resulting from dewatering and discharge according to the degree of connectivity between the area of saline discharge and the PECs. The low risk scenario was considered more likely (Table 1).

The assessment forecast low to moderate risk to stygofauna in Habitat 2. It was considered unlikely that areas of aquifer under Lake Miranda with salinities of 40,000-60,000 mg/L^{-1} had many stygofauna and so the increase in aquifer salinity associated with discharge of Project area groundwater into the lake would not have great impact on stygofaunal conservation values.

Table 1. Potential impacts on stygofauna in calcrete aquifer PECs near Lake Miranda forecast in previous risk assessment.

Habitat	Outcome	Risk	Description	Assumptions
Habitat 1 (calcrete aquifers)	**1**	Extreme	Salinisation of calcrete aquifers due to hypersaline discharge	Hydrological connectivity between Lake Miranda and calcretes; location of discharge point allows connectivity
	2	Low	No significant salinising effect of discharge on calcrete aquifers	Poor connectivity between Lake Miranda and calcretes; discharge point appropriately located

Two recommendations were made:

- Examine in more detail the extent of hydrological connection between the PECs and the groundwater discharge site within Lake Miranda (i.e. distinction between Scenarios 1 and 2 for Habitat 1, with further quantification of Scenario 2 if applicable).
- Acquire more information about the extent of Habitat 2 under Lake Miranda and the salinity characteristics of Habitat 2 (which has implications for the prospectivity of this area for stygofauna).

5. LIKELIHOOD OF STYGOFAUNA AT THE PROJECT

5.1. Subregional occurrence of stygofauna

Records of stygofauna in a search area of 10,000 km² defined by 27.17–28.08°S, 120.02–121.02°E were retrieved from Western Australian Museum (WAM) databases, previous assessments and scientific literature (Table 2). The known or probable distribution of each species was also determined.

At least 58 species have been recorded in the search area. Further survey and better taxonomic resolution would increase the number of species known from the area. Major groups recorded include crustaceans (amphipods, syncarids, copepods, isopods, ostracods), beetles, oligochaetes, flatworms and nematodes.

One TEC and six Priority 1 PECs occur in calcretes within the search area (Figure 1) and all records of stygofauna in the search area come from these communities. There is no information on the extent of stygofauna occurrence outside the calcretes hosting these PECs. It is thought that only low numbers of stygofauna occur outside palaeoriver channels and occurrence within palaeorivers is largely dependent on groundwater salinity.

5.2. Stygofauna in the Project area

Limited sampling has collected 10 species of stygofauna from the immediate vicinity of the Project, with three, six and one species have been recorded from the Lake Miranda West, Lake Miranda East and Yakabindi PECs, respectively. These include amphipods, copepods, ostracods, *Haloniscus* isopods and dytiscid beetles (Table 2). Despite low sampling effort and low yields compared with other Yilgarn calcretes such as Yeelirrie (Bennelongia 2015), the PECs occurring within the vicinity of the Project have the potential to harbour significant stygofauna communities.

Whether stygofauna occur in the alluvial aquifers underlying Lake Miranda itself (especially in the less saline Habitat 2) is currently unknown because of the lack of sampling. Occurrence will be affected by physical structure of the aquifers as well as by groundwater quality, especially salinity. Provided there are adequately coarse substrates and groundwater salinities that allow the persistence of at least halophilic taxa, it may reasonably be expected that stygofauna would occur in Habitat 2. Stygal harpacticoid copepods, *Haloniscus* isopods, nematodes and oligochaetes have been recorded in hypersaline aquifers at Lake Maitland, farther north in the Carey palaeochannel, in salinities of approximately 38,000–96,000 mg/L TDS (Outback Ecology 2007). Salinity tolerances of individual species are likely to reflect adaptation to ambient salinity levels over evolutionary time (Kefford et al. 2015) and even stygofauna that occur in naturally saline conditions may not be robust to large post-discharge changes in salinity.

No investigations have been completed regarding the occurrence of subterranean fauna in the Cosmos pit area, but ultramafic geologies rarely contain the fissures and vugs necessary to support significant stygofauna communities. Furthermore, with a salinity of 70,000–100,000 ppm TDS it is unlikely any stygofauna species do occur there, although records by Outback Ecology (2007) show that

Table 2. Recorded stygofauna in a search area encompassing the Project defined by 27.17–28.08°S, 120.02–121.02°E.
Taxa shaded in grey were not included in estimates of number of species to avoid artificial inflation. '*' denotes species recorded from calcretes bordering Lake Miranda.

Higher Classification	Lowest Classification	No. of Records	Comments on Distribution
Platyhelminthes	Turbellaria sp.	1	Identification incomplete; possibly restricted to Yeelirrie[11]
Nematoda	Nematoda sp.	5	Identification incomplete; possibly restricted to Yeelirrie[11]
Annelida			
Aeolosomatidae	*Aeolosoma* sp. S1	2	Yeelirrie[11]
Enchytraeidae	Enchytraeidae sp.	19	Yeelirrie[11]
	Enchytraeidae sp. B04	1	Yeelirrie[11]
	Enchytraeidae sp. Y1	2	Yeelirrie[11]
	Enchytraeidae sp. Y4	1	Yeelirrie[11]
	Enchytraeidae sp. Y5	1	Yeelirrie[11]
	Enchytraeidae sp. Y7	1	Yeelirrie[11]
Phreodrilidae	Phreodrilidae sp.	1	Yeelirrie[11]
	Phreodrilidae sp. B07	1	Yeelirrie[11]
	Phreodrilidae sp. S08	1	Yeelirrie[11]
Tubificidae	Tubificidae sp.	1	Yeelirrie[11]
Crustacea			
Amphipoda	Amphipoda sp. *	-	May represent multiple species[10]
Chiltoniidae	nr *Phreatochiltonia* sp. S1	24	Gascoyne[1]
Syncarida	Bathynellacea sp.	-	Likely restricted to Albion Downs Calcrete[10]
Parabathynellidae	*Atopobathynella* \`line k\`	1	Yeelirrie[11]
	Atopobathynella hinzeae	16	Depot Springs, linear range 7 km[4]
	Atopobathynella sp.	1	Not identified to species
	Atopobathynella sp. OES8	1	Species undescribed; likely restricted to Mt Keith area
	Atopobathynella sp. S04	1	Yeelirrie[11]
	Kimberleybathynella sp. B05	3	Yeelirrie[11]
Bathynellidae	Bathynellidae sp. S02	1	Yeelirrie[11]
	Bathynellidae sp. S04	3	Yeelirrie[11]
Copepoda			
Cyclopoida	Copepoda sp. *	8	Not identified to species but may represent additional taxa.
Cyclopidae	*Dussartcyclops* \`dostoyevskyi\`	2	
	Fierscyclops fiersi	1	Swan Coastal Plain, Gascoyne[3,5]

Higher Classification	Lowest Classification	No. of Records	Comments on Distribution
	Goniocyclops uniartculatus	3	Depot Springs, linear range 14 km[3]
	Halicyclops ambiguus	3	Uramurah Lake Calcrete[3]
	Halicyclops cf. *eberhardi* sp.	6	Uncertain but see *H. eberhardi*
	Halicyclops cf. *eberhardi* sp. B01 (C)	2	Uncertain but see *H. eberhardi*
	Halicyclops cf. *eberhardi* sp. B02 (A)	3	Uncertain but see *H. eberhardi*
	Halicyclops eberhardi	1	Widely distributed in Yilgarn[3]
	Halicyclops kieferi	1	Probably widespread in arid WA[3]
	Mesocyclops brooksi *	2	WA, QLD[5]
	Metacyclops laurentiisae	4	Murchison, Gascoyne[5]
	Metacyclops pilanus	1	Murchison[3]
Harpacticoida Ameiridae	?*Parapseudoleptomesochra* sp. B03	1	Yeelirrie[11]
	Nitokra esbe	4	Yeelirrie[6]
	Nitokra sp. group `yeelirrie`	4	Uncertain but see *N. yeelirrie*
	Nitokra yeelirrie	2	Yeelirrie[6]
Canthocamptidae	*Australocamptus hamondi*	5	Depot Springs, linear range 15 km[3]
Ectinosomatidae	*Pseudectinosoma* `pentedicos` sp. A	1	Yeelirrie [11]
	Pseudectinosoma `pentedicos` sp. B	3	Yeelirrie [11]
	Pseudectinosoma sp. B01	1	Yeelirrie [11]
Miraciidae	*Schizopera* `line N`	1	Yeelirrie [11]
	Schizopera akation	9	Yeeliriie[7]
	Schizopera analspinulosa	11	Yeeliriie[7]
	Schizopera analspinulosa linel	5	Yeelirrie [11]
	Schizopera depotspringsi	8	Depot Springs, linear range 15 km[3]
	Schizopera kronosi	3	Yeelirrie[7]
	Schizopera leptafurca	7	Yeelirrie[7]
	Schizopera sp.	1	Not identified to species
	Schizopera sp. B16	1	Yeelirrie [11]
	Schizopera sp. B17	1	Yeelirrie [11]
	Schizopera sp. group akation	5	Uncertain but see *S. akation*
	Schizopera sp. group analspinulosa	1	Uncertain but see *S. analspinulosa*
Parastenocarididae	*Kinnecaris esbe*	4	Yeelirrie[8]
	Kinnecaris lined	8	Yeelirrie[8]
	Kinnecaris linel	11	Yeelirrie[8]
	Kinnecaris solitaria	3	Depot Springs, linear range 14 km[3]
	Kinnecaris nr. *solitaria*	3	Probably *K. solitaria*
	Kinnecaris sp.	2	Not identified to species
	Kinnecaris uranusi	5	Yeelirrie[8]
Isopoda Oniscidae	*Haloniscus* sp. *	-	Likely restricted to individual calcretes[10]
Paraplatyarthridae	*Paraplatyarthrus pallidus* sp. nov.	9	Miranda East Calcrete[1]
Philosciidae	Philosciidae sp. S01	2	Yeelirrie[10]
Ostracoda	Ostracoda sp. *	-	May represent multiple species[10]
Candonidae	*Candonopsis westraliensis*	5	Depot Springs, linear range 15 km[2]
Cyprididae	*Riocypris hinzae*	4	Depot Springs[9]
Insecta **Coleoptera** Dytiscidae	*Limbodessus mirandaae* *	5	Miranda West Calcrete[5]
	Limbodessus phoebeae *	4	Miranda East Calcrete[5]
	Limbodessus sp. 1	1	Yeelirrie[11]
	Limbodessus yandalensis	4	Yandal Calcrete[5]

[1]WAM database; [2]Karanovic and Marmonier 2002; [3]Karanovic 2004; [4]Cho et al. 2006; [5]Watts and Humphreys 2006; [6]Karanovic et al. 2014; [7]Karanovic and Cooper 2012; [8]Karanovic and Cooper 2011; [9]Karanovic 2008; [10]Bennelongia 2011; [11]Bennelongia 2015.

some halophilic species can tolerate hypersaline conditions. Given the salinity and probably lack of hydraulic connectivity between aquifers, it is unlikely that the immediate Project area provides prospective stygofauna habitat. More generally, very few stygofauna species have been collected in the Yilgarn from aquifers in lithologies other than calcrete, alluvium and colluvium. Stygofauna records from the search area are from the above three lithologies and nearly all from within palaeochannels.

6. CURRENT RISK ASSESSMENT

6.1. Groundwater abstraction

Previous records demonstrate that stygofauna occur in calcretes near Lake Miranda and some of these areas have been listed as PECs. The nearest part of a PEC to the Project is approximately 6 km. Although no modelling has been done, it is suggested that there will be no reduction of the watertable within the PECs or under Lake Miranda due to the compartmentalised nature of aquifers. Therefore, no loss of stygofauna habitat as a result of Project operations is expected (B. Williams, pers. comm.) No drawdown was observed in monitoring bores 3 km from the pit during previous pumping periods.

While the drawdown in the Project area is likely to remove all of the aquifer close to the mine (which will extend to a depth of approximately 1100 m), it is considered unlikely that stygofauna are present in this area because of unfavourable geology and a salinity that is probably too high for stygofauna species. Salinity levels of 110,000–140,000 mg/L were recorded in the Project area during monitoring in September 2012.

Accordingly, the risk to stygofauna conservation values from groundwater abstraction is considered to be low.

6.2. Disposal of Excess Mine Water

The risk to stygofauna from leakage of hypersaline water from the waste storage ponds evaporating excess mine water is also considered to be low. Rather than flowing towards the PECs or Lake Miranda, any leakage from waste management ponds is likely to be captured by the drawdown associated with mine dewatering.

7. CONCLUSIONS

This report characterised the conservation values of subterranean fauna at the Project and surrounding areas and evaluated the risks posed by proposed excavations, groundwater abstraction and dewatering strategies. In relation to the initial aims, the following conclusions are drawn:

Conservation values of subterranean fauna

There are PECs in calcretes around Lake Miranda that were listed on the basis of having potentially high stygofauna conservation values, as is typical of calcrete bodies in the Yilgarn. Less saline parts of aquifers underlying Lake Miranda itself may potentially support stygofauna, although the salinities that these species would be exposed to are towards the upper limit of stygofauna tolerances. The immediate Project area is unlikely to contain a significant stygofauna community because of high salinity and lack of suitable physical habitat.

Significant troglofauna communities are also unlikely to occur in the Project area because of the lack of suitable geology. Furthermore, the proposed excavation area is sufficiently small to be present a very low risk to the persistence of even the most restricted troglofauna species. Thus, operation of the Project is unlikely to affect troglofauna conservation values.

Risks of abstraction and disposal

Given that stygofauna are unlikely to occur in the Project area or its close vicinity, the substantial groundwater drawdown that will occur in this area is unlikely to affect stygofauna conservation values.

In relation to the conservation values of the PECs, it is considered unlikely that groundwater drawdown will extend the 6 km or more that would be required to reduce the stygofauna habitat available within nearby PECs. Although the likely extent of drawdown has not been modelled, previous monitoring results demonstrate that dewatering in the pit area has no effect on groundwater levels 3 km away.

Evaporation of excess groundwater via storage ponds is unlikely to impact on stygofauna through leakage of hypersaline groundwater from the ponds. Any leakage is likely to be captured within the area of groundwater drawdown, where groundwater is hypersaline and stygofauna conservation values are low.

Accordingly, operation of the Project is considered unlikely to affect stygofauna conservation values.

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