Phase 1 Survey for Subterranean Fauna for the Lake Mackay SOP Project, Western Australia.

Report by Invertebrate Solutions for Agrimin Ltd on behalf of 360 Environmental Pty Ltd

April 2018

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Frontispiece: A stygobiontic bathynellid, *Atopobathynella* sp. 'mackay' from a calcrete aquifer south of Lake Mackay.

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Executive Summary

Agrimin Limited (Agrimin) is developing its Lake Mackay Sulphate of Potash (SOP) Project and requires a number of baseline biological assessments to be carried out. The SOP Project includes 12 tenements covering the majority of Lake Mackay over a total area of 3,500 square kilometres. Lake Mackay is a seasonally inundated salt lake located on the Western Australia (WA) – Northern Territory (NT) border, with most of the lake located within WA.

In May 2017 Invertebrate Solutions was requested by 360 Environmental Pty Ltd (360 Environmental) on behalf of Agrimin to undertake a pilot survey for stygofauna, with eight new species, and two new genera of stygofauna recorded from five sampled bores located within the surficial calcrete aquifer to the south of Lake Mackay.

A subsequent level 2 stygofauna survey was commenced in November 2017 in the various aquifers to the south of Lake Mackay and on Lake Mackay itself. This survey has begun sampling in the surficial calcrete aquifer and the underlying deep alluvial aquifer, located to the south of Lake Mackay, and the perched aquifers associated with the islands in Lake Mackay. A pilot survey for troglofauna within the surficial calcrete deposits also commenced in November 2017, sampling two available uncased bores using both scrape and litter trap sampling techniques. No troglofauna has been recorded at present.

The results of the November 2017 stygofauna sampling has recorded stygofauna in both the surficial calcrete aquifer and the aquifers associated with the islands in Lake Mackay. No stygofauna has been recorded from the deep alluvial aquifer or from the hypersaline water within Lake Mackay situated away from islands.

Currently, the surficial calcrete aquifer shows the greatest diversity, with five classes, six orders, 7 families and 16 species present, whilst the single sampling location within the island aquifer has recorded two additional species. The stygofauna recorded in the Lake Mackay aquifers is significant in that it contains three new species of dytiscid diving beetle (*Paroster* spp.?*),* a new species of parabathynellid (*Atopobathynella* sp. '*mackay'*), and multiple new species of Copepoda, some of which show extremely primitive morphological characters (*Mackaycyclops mouldsi* n. g. & sp. and *Schizopera mackay* n. sp.) and may be important in the evolutionary history of Australian stygofauna.

Fourteen of the 18 species recorded (78%) from both the surficial calcrete and island aquifer are undescribed species and 10 species (56%) are currently only recorded from single bores, although this is invariably due to the lack of suitable sampling locations. These results are not entirely unexpected due to the location of the sampling being many hundreds of kilometres from any other subterranean fauna sampling locations. Currently, most of these new species are known from single bores.

The following recommendations are made with regard to the potential development of the Lake Mackay SOP Project:

- Due to the presence of a stygofaunal community within the surficial calcrete aquifer located within the southern proposed borefield area, a Level 2 survey for stygofauna should be

undertaken with regard to EPA Technical Guidance – subterranean fauna survey (EPA2016a) and EPA Technical Guidance – sampling methods for subterranean fauna (EPA2016b);

- The Level 2 survey for stygofauna will require, at a minimum, 40 samples from each impacted aquifer within the proposed borefield area (EPA2016b);
- Genetic sequencing of the stygobitic Dytiscid beetles and Bathynellids should be undertaken to confirm the current morphological identifications and the distribution of individual species within the Project area. Confirmation of the same species geographically across the project area will enable a more accurate assessment of potential impacts to stygofaunal communities to be determined;
- The deep alluvial aquifer currently presents an environment unfavourable to stygofauna and preliminary sampling of this aquifer has recorded no stygofauna. Additional sampling of this aquifer should be undertaken to obtain sufficient samples to provide a pilot survey level of field sampling before a final assessment regarding the presence or absence of stygofauna within this aquifer can be undertaken;
- A troglofauna pilot survey has commenced in the proposed borefield area and should be continued until the requirements of EPA Guidance (2016a) are met. This would be a minimum of 10 – 15 bores to be sampled. No troglofauna has currently be recorded from the proposed borefield area;
- The stygofauna pilot survey of the island aquifers within Lake Mackay should be continued in all available bores until an assessment of the stygofauna present and the potential for impact to this stygofaunal community can be determined more accurately. This sampling should include all island areas that may be potentially impacted by drawdown associated with trenching; and
- Newly constructed bores should be constructed suitable for stygofauna and/or troglofauna sampling.

1. Introduction

Agrimin Limited (Agrimin) is developing its Lake Mackay Sulphate of Potash (SOP) Project and requires a number of baseline biological assessments to be carried out. The SOP Project includes 12 tenements covering the majority of Lake Mackay over a total area of 3,500 square kilometres. Lake Mackay is a seasonally inundated salt lake located on the Western Australia (WA) – Northern Territory (NT) border, with most of the lake located within WA.

In May 2017, Invertebrate Solutions was requested by 360 Environmental Pty Ltd (360 Environmental) on behalf of Agrimin to undertake a pilot survey for stygofauna, with eight new species, and two new genera of stygofauna recorded from five sampled bores located within the surficial calcrete aquifer to the south of Lake Mackay.

The proposed water supply for the Lake Mackay SOP Project is expected to be sourced from various aquifers within the general area to the south of Lake Mackay. Invertebrate Solutions has subsequently been engaged by 360 Environmental on behalf of Agrimin to undertake a Level 2 survey for subterranean fauna (stygofauna and troglofauna) with regard to EPA Technical Guidance – subterranean fauna survey (EPA2016a) and EPA Technical Guidance – sampling methods for subterranean fauna (EPA2016b).

1.1 Purpose of this Report

360 Environmental has requested Invertebrate Solutions to undertake the following scope of works for the Lake Mackay SOP Project area, Western Australia:

- Undertake a Level 2 field survey for stygofauna in the surficial calcrete aquifer located within the proposed borefield area;
- Undertake a pilot survey for stygofauna in the deep alluvial aquifer within the proposed borefield area;
- Undertake a pilot survey for stygofauna in the Lake Mackay Island aquifers;
- Undertake a pilot survey for stygofauna in the trenches in Lake Mackay;
- Undertake a pilot survey for troglofauna in the proposed borefield area;
- Provide recommendations to minimise potential impacts and any suggested requirements for further work to comply with relevant legislation; and
- Provide a written report containing the above items.

1.2 Project Area

The Project includes 12 tenements covering the majority of Lake Mackay over a total area of 3,500 square kilometres. Lake Mackay is a seasonally inundated salt lake located on the Western Australia (WA) – Northern Territory (NT) border, with most of the lake located within WA and is shown in Figure 1.

Legend

- Project Boundary
- Proposed Infrastructure Boundaries
- Existing Road
- Existing Track
- Proposed Track

Stygofauna Sampling Locations

- Deep Alluvial Aquifer
- Lake Mackay Island
- Lake Mackay trench
- Surficial calcrete

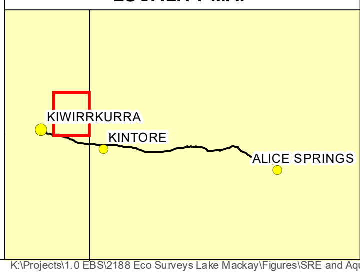
0 5 10 15 20

Kilometers

1:500,000 @ A4

- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS

LOCALITY MAP



- LOCALITY MAP SOURCED FROM LANDGATE 2017
- AERIAL PHOTOGRAPHY SOURCED ESRI 2017
(DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community)

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PROJECT ID	DATE
2188	15/02/2018

HORIZONTAL DATUM AND PROJECTION			
GDA 1994 MGA Zone 52			
CREATED	CHECKED	APPROVED	REVISION
DV	TM	FJ	0

Agrimin Limited
Lake Mackay SOP Project
Phase 1 Survey for Subterranean Fauna for the Lake Mackay SOP Project, Western Australia

Figure 1
Stygofauna Sampling Locations

K:\Projects\1.0 EBS\2188 Eco Surveys Lake Mackay\Figures\SRE and Aquatic Macroinverts\2188 SRE Figure 2 Stygofauna updated 01 Feb 2018.mxd

1.3 Survey Effort and Timing

Invertebrate Solutions completed a pilot survey for stygofauna in the borefield areas in May 2017. A total of five samples were collected from bores within the borefield area (Table 1), however, one sample collected using an *in situ* handpump does not meet the required sampling requirements for a pump sample and is for reference only (refer Section 2.2). Some of the bores (Table 1) that were sampled in the Phase 1 sampling in November 2017 were drilled in September 2017 and so were within the six month settling period (EPA 2016a). These bores will be resampled following the settling period to confirm the results of the current sampling.

Table 1 Bores sampled for Stygofauna in the proposed borefield

Bore ID	Pilot Phase	Phase 1	Aquifer sampled
Camp Bore	X	X	Surficial calcrete
BORE 3*		X	Surficial calcrete
BORE 6*		X	Deep Alluvial Aquifer
Handpump	X		Surficial calcrete
LD02	X	X	Surficial calcrete
LD03	X	X	Surficial calcrete
LM0182		X	Surficial calcrete
LM0183		X	Surficial calcrete
MC13*		X	Lake Mackay Island
MWP2*		X	Deep Alluvial Aquifer
MWP4 SHALLOW*		X	Deep Alluvial Aquifer
MWP6*		X	Deep Alluvial Aquifer
NEW S1*		X	Deep Alluvial Aquifer
Nr LP008	X	X	Surficial calcrete
TRENCH16		X	Lake Mackay trench
TRENCH17		X	Lake Mackay trench

***Newly drilled bore, sampled within the six month settling period.**

The stygofauna sampling effort for each aquifer currently identified within the Project area is shown in Table 2. Currently the most survey effort has been within the surficial calcrete aquifer to the south of Lake Mackay with 12 samples obtained, mainly from historic exploration bores. Two stygofauna samples have been taken from the test trenches in Lake Mackay in order to confirm the absence of stygofauna from these hypersaline environments. No samples have currently been taken in known non-impact areas.

Table 2 Sample effort for aquifers in the Lake Mackay SOP Project

Aquifer sampled	Pilot Phase	Phase 1	Total
Surficial calcrete	4	7	11
Deep Alluvial Aquifer	0	5	5
Lake Mackay Island	0	1	1
Lake Mackay trench	0	2	2
Reference samples (non-impact areas)	0	0	0

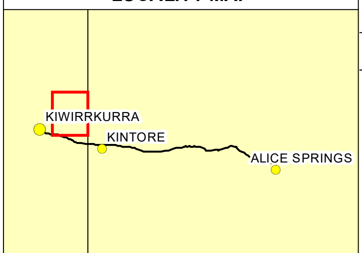
0 5 10 15 20
Kilometers
1:500,000 @ A4

- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS

Legend

- Project Boundary
- Proposed Infrastructure Boundaries
- Existing Road
- Existing Track
- Proposed Track
- Troglofauna Sampling Locations

LOCALITY MAP



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Lake Mackay SOP Project
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Figure 2
Troglofauna Sampling Locations

K:\Projects\1.0 EBS\2188 Eco Surveys Lake Mackay\Figures\SRE and Aquatic Macroinverts\2188 SRE Figure 2 Troglofauna Sampling Locations.mxd

The pilot survey of troglofauna commenced in November 2017 and has included two scrape samples and the placement of six litter traps in the two bores suitable for troglofauna sampling (Table 3). The litter traps will be retrieved during subsequent field surveys. Additional uncased bores suitable for troglofauna sampling are anticipated to be constructed in the future.

Table 3 Bores sampled for troglofauna in the proposed borefield

Bore ID	Easting	Northing	Scraped	Litter Trap	Date Sampled
BORE 3	466729	7488333	X	3	17/11/2017
BORE 5 (MWP8)	440076	7485415	X	3	19/11/2017

A map showing the locations of the bores sampled for troglofauna and stygofauna is shown in Figure 2.

1.4 Introduction to Subterranean Fauna

Subterranean fauna are comprised of stygofauna (aquatic subterranean dependent species) and troglofauna (air breathing subterranean dependent species) which are known to be relatively diverse on a worldwide scale in Western Australia. Stygofauna and troglofauna are known to occur widely in the Pilbara, Yilgarn and Ngalia basins. Many species of subterranean fauna have highly restricted ranges due to habitat connectivity issues and evolutionary history.

The high degrees of local endemism and lack of habitat connectivity makes subterranean fauna susceptible to high levels of impact from sometimes localised projects, with species' extinction a real possibility if they are not adequately considered during project planning phases.

An extensive amount of jargon is associated with subterranean fauna and multiple forms of classification have been used historically. The most commonly accepted and used terms divide troglofauna into categories that describe a particular species' degree of dependence upon the subterranean environment. Due to the reliance upon ecological information to determine if a species is a troglobite, the concept of troglomorphy (Christiansen 1962) - specific morphological adaptations to the subterranean environment - is used to define obligate subterranean species. The term troglomorphy, initially confined to morphology, has since been used to describe both morphological or behavioural adaptations (Howarth 1973). This combination provides a practical system, easily applied in the field and with a minimum of detailed ecological study required. The level of subterranean dependency for different ecological groupings is described below:

- Troglobiont: animals that are obligate subterranean species and mostly show morphological adaptation to subterranean habitats (troglomorphisms) including depigmentation, loss or reduction of eyes, elongation of appendages, absent or reduced wings and extra sensory hairs;
- Troglophiles: animals that can complete their entire lifecycle within a cave but possess no specific adaptations to the cave environment. These species are capable of living outside caves in suitably dark and moist epigean habitats; and

- Trogloxenes: animals that use the subterranean environment but require surface environments to complete part of their lifecycle (generally either feeding or breeding). Common trogloxenes are cave dwelling bats, cave swiftlets and cave crickets that leave subterranean habitats to feed.

The aforementioned terms refer to stygofauna when the prefix is altered to stygo (Humphreys 2000).

Species which inhabit the deep soil habitat (Edaphophiles) often exhibit convergent morphological adaptations to those animals found exclusively within caves, such as reduced or absent eyes, body flattening, loss of pigmentation, etc. Soil dwelling species commonly do not show highly restricted distributions as they are less easily isolated in evolutionary timeframes, thus only true troglobitic animals are the focus of surveys for subterranean fauna. Taxa discussed in this study were assessed on their combination of loss/reduction of eyes, reduction in pigmentation and wing development, and elongation of appendages to assess if a taxa was an edaphophile or truly reliant upon the subterranean habitat (Troglobiont).

1.5 Conservation Legislation and Guidance Statements

Subterranean fauna are protected under state legislation via the Wildlife Conservation (WC) Act (1950), the Environmental Protection Act (1986) and federally under the Environment Protection and Biodiversity Conservation (EPBC) Act (1999). The assessment of subterranean fauna for environmental impact assessment (EIA) is undertaken in Western Australia with regard to the Technical Guidance – Subterranean Fauna Survey (EPA2016a), Technical Guidance – Sampling Methods for Subterranean Fauna (EPA2016b) and the Environmental Factor Guideline – Subterranean Fauna (EPA 2016c).

At the State level, the WC Act provides a list of species that have special protection as species listed under the Wildlife Conservation (Specially Protected Fauna) Notice 2018 (DBCA 2018). This notice is updated periodically by the Department of Biodiversity, Conservation and Attractions (DBCA) (formerly the Department of Parks and Wildlife (DPaW) and the current list (January 2018) includes numerous subterranean species mainly from the Cape Range and Pilbara regions. Included in the list are crustaceans, arachnids and myriapods that are considered to be “rare or likely to become extinct, as critically endangered fauna, or are declared to be fauna that is in need of special protection” (DPaW 2015). In addition to the specially protected fauna, DBCA also maintains a list of Priority fauna that are considered to be of conservation significance but do not meet the criteria for formal listing under the WC Act as Scheduled species. The Priority fauna list is irregularly updated by DBCA and, although it offers no formal legislative protection, these species are generally considered in the EIA process.

There is no current ability for the state government of Western Australia to formally list Threatened or Priority Ecological Communities (TECs/PECs), however, a list of such communities is maintained by DBCA and overseen by the Minister for the Environment. Several subterranean ecological communities are recognised as Threatened including the Bundera Cenote Anchialine community on Cape Range, Cameron’s Cave near the townsite of Exmouth on Cape Range, stygal root mat communities in both the Yanchep and Margaret River regions and stygobionts in the Ethel Gorge aquifer in the Pilbara. Communities that are not considered by DBCA to be threatened but may be vulnerable to future impacts are classed as PECs and include numerous calcrete aquifers in the Yilgarn region where each calcrete has been shown to contain an endemic stygal community.

The WC Act is expected to be imminently replaced by the new Biodiversity Conservation Act that has yet to be enacted into law. This new act has been passed by the lower house of the State parliament and will be capable of protecting both species and ecological communities under legislation.

The federal EPBC Act protects both species and ecological communities. The most relevant listings for subterranean fauna include the Bundera Cenote on the western side of the Cape Range which contains a unique anchialine ecosystem including the stygal Cape Range Remipede *Kumonga exleyi* that is listed as Vulnerable. The Cape Range gudgeon *Milyeringa veritas* and the Cape Range blind eel *Ophisternon candidum* are also listed as Vulnerable species from subterranean habitats on the Cape Range.

1.6 Survey Staff Qualifications

Field sampling for invertebrates was undertaken by experienced ecologists and comprised of:

- Dr Timothy Moulds BSc (Hons) Geol., PhD. Invert. Ecol.
- Gerry Bradley BSc (Hons) Zool. (Agrimin Sustainability Manager).

Invertebrate extraction and sorting was completed by Dr Timothy Moulds.

Survey work was undertaken under the collection licences issued by the Department of Biodiversity, Conservation and Attractions:

- 08-001304-1; Licensee Dr Tim Moulds; Valid from 9/11/2017.

The pilot survey sampling for stygofauna was undertaken between 12th – 18th May 2017 and Phase 1 sampling was undertaken between 12th – 20th November 2017.

1.7 Report Limitations and Exclusions

This study was limited to the written scope provided to the client by Invertebrate Solutions (8th August 2016) and in Section 1.1. This study was limited to the extent of information made available to Invertebrate Solutions at the time of undertaking the work. Information not made available to this study, or which subsequently becomes available, may alter the conclusions made herein. Assessment of potential impacts to subterranean fauna was based on proposed infrastructure plans provided by Agrimin Ltd.

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. Invertebrate Solutions 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 opinions, conclusions and any recommendations in this report are based on assumptions made by Invertebrate Solutions described in this report (this section and throughout this report). Invertebrate Solutions disclaims liability arising from any of the assumptions being incorrect.

Invertebrate Solutions has prepared this report on the basis of information provided by 360 Environmental for Agrimin Ltd and others (including Government authorities), which Invertebrate Solutions has not independently verified or checked beyond the agreed scope of work. Invertebrate Solutions does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

Site conditions may change after the date of this report. Invertebrate Solutions does not accept responsibility arising from, or in connection with, any change to the site conditions. Invertebrate Solutions is also not responsible for updating this report if the site conditions change.

Species were identified to the lowest practical taxonomic level, taking into consideration that the taxonomic framework of many invertebrate groups is incomplete and often in need of substantial revision to enable accurate identification. Insufficient information exists for many invertebrate species due to specimens being juvenile, the wrong sex to allow identification, damaged, or inadequate taxonomic frameworks, precluding identification.

Field surveys for subterranean fauna require multiple seasonal surveys to fully record all species that may be present in an area and additional surveys at different times of the year may record additional species.

2. Methods

Invertebrate Solutions undertook the following tasks for the pilot survey of the Lake Mackay Project area:

- Desktop subterranean fauna assessment;
- Stygofauna Phase 1 field survey of the surficial calcrete aquifer within the proposed borefield;
- Stygofauna pilot survey of the deep alluvial aquifer within the proposed borefield;
- Stygofauna pilot survey of the Island aquifers;
- Stygofauna pilot survey of the trenches in Lake Mackay;
- Troglofauna pilot survey of the proposed borefield.

The survey program was undertaken with regard to the Technical Guidance – Subterranean Fauna Survey (EPA2016a), Technical Guidance – Sampling Methods for Subterranean Fauna (EPA2016b) and the Environmental Factor Guideline – Subterranean Fauna (EPA 2016c).

2.1 Subterranean Fauna Desktop Methodology

The likelihood of stygofauna and troglofauna species occurring in the Study Area was assessed using a combination of regional information, geological, hydrogeological and database searches including:

- Analysis of published and unpublished reports concerning subterranean fauna from the region;
- Available geological maps;
- Geological, geotechnical and hydrogeological information available for the Study area;
- Records of fauna held by the Western Australian Museum.

Based on the analysis of all available information, the study area was assigned a level of likelihood to support subterranean fauna of either ‘Low’, ‘Moderate’, ‘High’, or ‘Definite’.

2.2 Stygofauna Sampling Methods

Stygofauna was sampled using modified plankton nets in accordance with the Environmental Protection Authority (EPA) Technical Guidance – Subterranean Fauna Survey (EPA2016a) and EPA Technical Guidance – Sampling Methods for Subterranean Fauna (EPA2016b). Bores were sampled for stygofauna using a plankton net of suitable diameter (32 mm to 90 mm) to match the bore/well. The net (either 125 µm or 50 µm mesh), with a weighted vial attached, was lowered into the bore and then hauled up through the water column.

The net was dropped to the base of the bore then agitated up and down (±1 m) several times to disturb the bottom sediment and any stygofauna contained within. Six hauls of the entire water column were undertaken at each bore. Depths to the water table and the bottom of bores were calculated using the number of rotations of the fishing reel. Three hauls were undertaken with both the 125 µm and the 50 µm mesh nets. Each net haul sample was transferred to a labelled polycarbonate container and preserved in 100% alcohol. Samples with large quantities of sediment were elutriated prior to preservation. To minimise the possibility of stygofauna cross contamination, the nets were treated with a decontamination solution and thoroughly rinsed in water and air-dried.

Sampling of the handpump site was undertaken by pumping water through a 50 µm mesh net into bucket of known volume. Approximately 165 L of water was pumped from the bore through the stygofauna net prior to the well going temporarily dry. This volume is well below the recommended volume of 300 L or three times the bore volume (EPA 2016b) and so this sample should not be regarded as an indication that stygofauna is absent from this bore.

2.3 Troglofauna sampling methods

2.3.1 Litter traps

Troglofauna was sampled using litter traps suspended in drill holes following EPA Technical Guidance – sampling methods for subterranean fauna (EPA2016b).

The traps comprise 50 mm diameter PVC pipe cut to a length of 140 mm. Leaf litter comprising mainly of spinifex (*Triodia* sp.) was soaked in water and irradiated for 10 minutes in a microwave set on high power, to kill any terrestrial invertebrates present. The sterilised litter was packed inside the traps with one end of the tube covered with 10 mm mesh. The packed traps were sealed in garbage bags to retain moisture and sterile conditions prior to deployment.

The traps were suspended in the holes using venetian blind cord. Where possible, the traps were aligned at depths corresponding to recorded cavities in drill logs. Traps were left in place for 16 weeks to allow colonisation by subterranean fauna. When traps are recovered the condition (moist or dry) of the hole environment and the litter in each trap is recorded. The traps from each drill hole were sealed in zip lock bags for transport to the laboratory.

2.3.2 Scraping

In addition to placing troglofauna litter traps in the bores the innovative scraping technique was used at each bore. This involved scraping a modified stygofauna haul net up the sides of unlined bores to scrape off any troglofauna that is present. This was repeated at least three times at each hole and the sample stored in an ethanol filled vial for sorting in the laboratory. This technique allows a more rapid determination if troglofauna are present within an area compared with the use of litter traps, although litter traps are required in order to meet EPA Technical Guidance – subterranean fauna survey (EPA2016a) and Technical Guidance – sampling methods for subterranean fauna (EPA2016b).

2.4 Water Quality

Water samples were collected in conjunction with stygofauna sampling and analysed *in situ* using a Hanna HI 9811-5 water quality meter. Water samples were collected from the upper 1 - 2 m of the water column prior to stygofauna sampling using a bailer. Four parameters (Temperature, Total

Dissolved Solids, Electrical conductivity and pH) were recorded from each bore where a stygofauna sample was collected.

2.3.1 Temperature

The temperature of ground water in arid Australia is generally fairly constant throughout the year and reflects the average surface temperature of the area. Ground water temperature was measured in degrees Celsius (°C). Stygofauna have been recorded from a variety of temperatures in the Ngalia Basin, and in the Yilgarn and Pilbara cratons, and currently no direct correlation has been detected between temperature and either presence, diversity or abundance of stygofauna.

2.3.2 Total Dissolved Solids

Total dissolved solids (TDS) was measured in milligrams per litre (mg/L) and provides a measure of all organic and inorganic substances such as calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates dissolved in groundwater. The measurement provides a general indication of the quality of the water with lower values (less than 500 mg/L) associated with high quality drinking water while seawater is approximately 35,000 mg/L. Stygofauna have been detected in a wide variety of water qualities from completely fresh to groundwater that is equivalent to seawater. Species response to TDS cannot be generalised and will be species specific (Leijs 2009).

2.3.3 Electrical Conductivity

Electrical conductivity was measured in milli Siemens per centimetre (mS/cm) and provides an indication of salinity. Stygofauna have been detected in a wide variety of salinities from completely fresh to groundwater that is equivalent to seawater. Species response to salinity cannot be generalised and will be species specific (Leijs 2009).

2.3.4 pH

The concentration of hydrogen ions ($H+$) is shown as a logarithmic scale where a low value indicates a high concentration and higher values indicate a more basic solution. The neutral value of 7 is more likely to support stygofauna, however, communities of stygofauna have previously been found to occur in a wide variety of pH values.

2.5 Sorting and Curation

Sorting for all samples occurred in the Invertebrate Solutions laboratory using an Amscope 45x dissecting microscope and was undertaken by Dr Timothy Moulds. Each taxon was identified to the lowest practical taxonomic rank using published keys and descriptions, and the numbers of each taxon recorded. Each identified taxon was kept in a separate labelled vial and assigned a specimen tracking code. Specimen and site collection data were recorded in an Excel spreadsheet. At the conclusion of the study, all specimens will be lodged at the Western Australian Museum.

2.6 Taxonomy and Nomenclature

Identification of collected invertebrate material was undertaken by Dr Timothy Moulds. The level of specimen identification achievable is dependent on the level of taxonomic knowledge and expertise available. The majority of the taxonomic expertise relating to subterranean taxa resides with the staff of the Western Australian Museum, while some groups are also worked on by researchers within other government departments and academic institutions. Taxonomic treatments are available for some invertebrate groups, but not all. The EPA expects that invertebrates collected for identification will be identified to the lowest taxonomic level possible. Ideally, this is to the species level, but there will be limits due to the nature of specimens and the availability of taxonomic keys.

Taxonomic groups known to contain troglobitic or stygobitic representatives were examined in more detail to determine if the specimens collected in this study are subterranean or non-subterranean forms. Obligate subterranean forms were distinguished by the possession of troglomorphic characters such as depigmentation, reduction or loss of eyes, elongation of appendages and sensory structures. Troglobitic/stygobitic status was assigned after comparison with the morphology of other close relatives in the group, and current knowledge on their distribution and ecology where known. Identifications of copepods and ostracods were undertaken by Drs Tomislav Karanovic and Ivana Karanovic, respectively. Identification of bathynellid specimens was undertaken by Dr Kym Abrams.

3. Desktop Assessment

3.1 Subterranean Fauna in Central Australia

There has been limited sampling for subterranean fauna in central Australia with stygofauna recorded from calcretes in the Ngalia basin north of the MacDonnell Ranges near Alice Springs in the Northern Territory (Balke *et al*. 2004; Taiti and Humphreys 2001; Watts and Humphreys 2006, Leys and Watts 2008, Humphreys 2008). The stygofauna recorded has included multiple species of Dytiscid diving beetles, similar to the fauna recorded in the Yilgarn calcretes, along with a diverse assemblage of stygobiont oniscoid isopods from the genus *Haloniscus,* and Bathynellids from the genus *Atopobathynella* (Cho *et al*. 2006). There has been some sampling of calcretes beyond the Ngalia basin near Nolans Bore approximately 135 km to the north of Alice Springs associated with a rare earth element project (GHD 2010), however, no stygofauna were recorded from this area. Calcrete aquifers have been shown throughout arid and semi-arid Australia to be highly likely to contain stygofauna, hence, if this habitat is likely to be impacted upon during Project development activities (i.e. dewatering or borefield operation) there is a high risk of significant impacts being caused to local stygofauna communities.

There are no records of any subterranean fauna studies being previously undertaken in the vicinity of Lake Mackay and no subterranean specimens are held in the records of the Western Australian Museum (WAM 2017a, 2017b).

3.2 Troglofauna Desktop Assessment

No previous records of troglofauna are present in the databases of the Western Australian Museum (WAM 2017a, 2017b). Suitable habitat for troglofauna is highly likely to occur in the calcrete areas (Figure 3) to the south of Lake Mackay (Bureau of Mineral Resources 1976). The upper unsaturated portions of the calcrete provide suitable conditions for troglofauna in the extensive interconnected void networks found in calcrete outcrops (Plate 1).

3.3 Stygofauna Desktop Assessment

No previous records of stygofauna are present in the databases of the Western Australian Museum (WAM 2017a, 2017b).

Stygofauna are known from the Ngalia basin to the south east of Lake Mackay with significant diversity present including bathynellids, isopods, copepods, ostracods and subterranean dytiscid diving beetles. The calcrete outcrops identified in the Webb 1:250,000 geological map (Bureau of Mineral Resources 1976) provide suitable habitat for stygofauna. The islands on Lake Mackay may also have some calcrete deposits or horizons within halite and gypsum units (Figure 3, Plate 2). The extent of these calcrete horizons is unknown although, if of a suitable size, they may provide habitat for stygofauna if saturated, however, the salinity of any such groundwater would be anticipated to be very high and thus may reduce the likelihood of any stygofauna being present. It should be noted that high salinity does not necessarily preclude the presence of stygofauna (Leijs 2009).

Plate 1 Exposure of calcrete within a quarry on the southern side of Lake Mackay showing micro and meso caverns that provide suitable habitat for stygofauna (when saturated) and troglofauna.

Plate 2 Exposure of calcrete on an island of Lake Mackay that may provide suitable habitat for stygofauna (when saturated) and troglofauna.

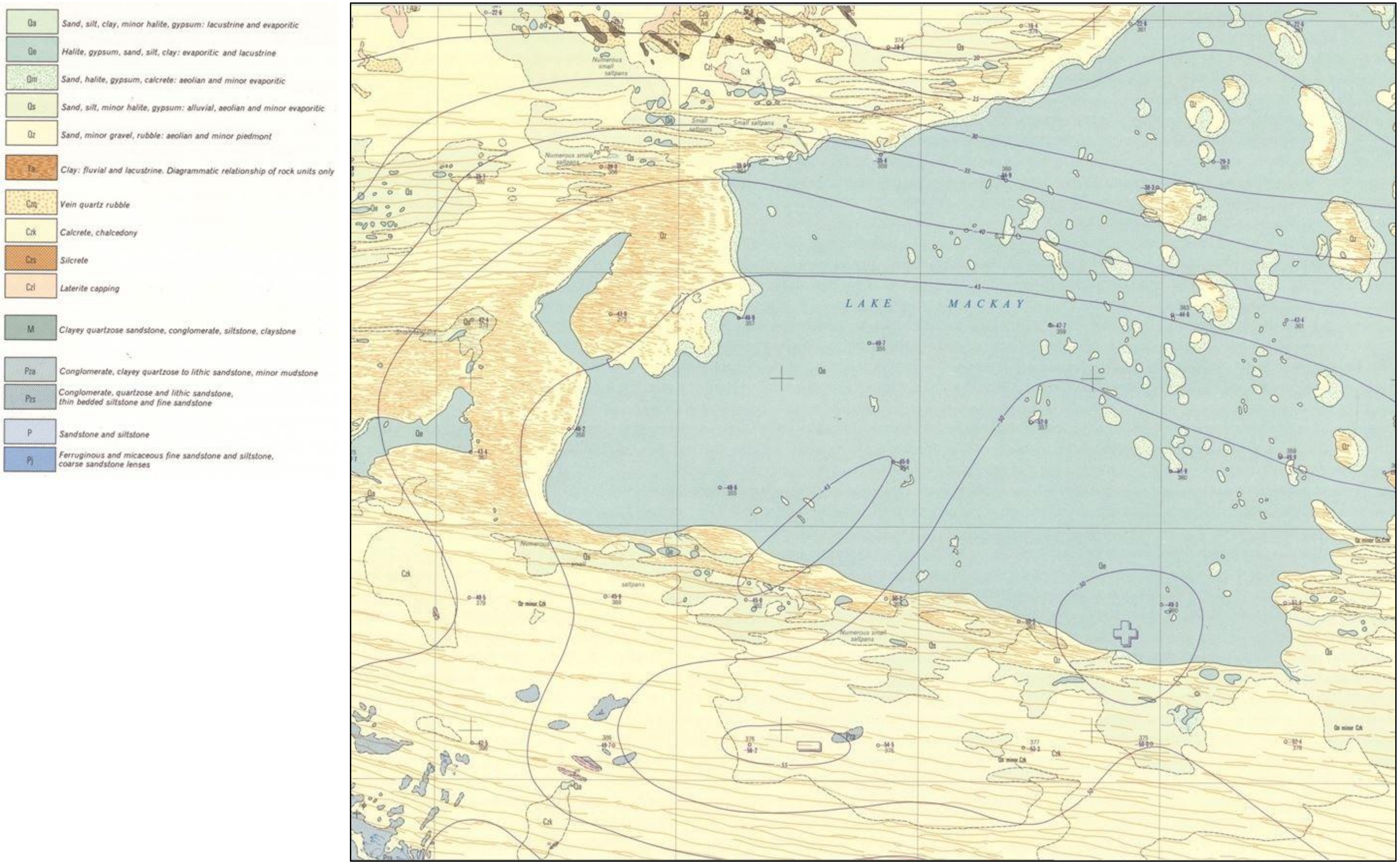

Figure 3 Extract from 1:250,000 Geological Map of Lake Mackay (Webb SF5210, Bureau of Mineral Resources WA 1976) showing extensive calcrete (Czk) present on the southern side of the lake. It is likely that the individual calcrete surface expressions on the southern side of the lake form a continuous outcrop with intermittent surface cover by sand dunes.

4. Stygofauna Survey Results

4.1 Pilot Survey – Surficial Calcrete Aquifer

The stygofauna pilot survey of the surficial calcrete aquifer in May 2017 recorded 10 species and 121 individuals of stygofauna from two of the five bores sampled within the proposed borefield area (Table 4, Table 5, Appendix 3). The samples included three classes, six orders, seven families and nine genera. The greatest diversity was among the copepods with two orders, three families, five genera and six species recorded, including two new genera and five new species (Karanovic and Karanovic 2017).

Abundance data for each bore is shown in Appendix 3.

4.2 Pilot Survey – Deep Alluvial Aquifer

The preliminary stygofauna survey of the deep alluvial aquifer has currently recorded no stygofauna. It should be noted that additional samples are required in order to satisfy the minimum requirements for a pilot survey (EPA 2016b). The bores sampled within the deep alluvial aquifer during Phase 1 were drilled in September 2017 and so were within the six month settling period (EPA 2016a). These bores will be resampled following the settling period to confirm the results of the current sampling.

4.3 Pilot Survey – Lake Mackay Trenches

Two of the test trenches (Trench 16 and 17) constructed by Agrimin were sampled for stygofauna. No stygofauna was obtained from either trench.

4.4 Pilot Survey – Lake Mackay Islands

The preliminary stygofauna survey of the Lake Mackay island aquifers is currently based on a single sample from bore MC013. This sample recorded two species from two orders of Copepoda. One of the species *Fierscyclops fiersi* (De Laurentiis *et al*., 2001) is a widespread stygophilic species whilst the other, *Schizopera bradleyi* is an undescribed species and currently only known from this location.

4.5 Phase 1 – Surficial Calcrete Aquifer

The Phase 1 sampling of the surficial calcrete aquifer in November 2017 recorded 16 species and 222 individuals of stygofauna from two of the five bores sampled within the proposed borefield area (Table 4, Table 5, Appendix 3). The samples included three classes, four orders, five families and nine genera. The greatest diversity was among the copepods with two orders, three families, seven genera and 12 species recorded, including two previously unrecorded genera for the Project and four species new to science, not previously recorded form the Project area (Karanovic 2018).

Abundance data for each bore is shown in Appendix 3.

Table 4 Stygofauna recorded from the Lake Mackay SOP Project area by survey phase

Higher Order	Genus and species	Pilot Survey	Phase 1	Notes
Annelida: Oligochaeta	*Phreodrilidae?* sp.	X		Damaged specimen
Crustacea: Bathynellacea: Parabathynellidae	*Atopobathynella* sp. *'mackay'* n. sp.	X	X	New species, likely endemic
Crustacea: Ostracoda: Podocopida: Candonidae	*Abcandonopsis mackay* n. sp.	X		New species, likely endemic
Crustacea: Copepoda: Harpacticoida: Ameiridae	*Mackaynitocrella mouldsi* n. gen., n. sp.	X	X	New genus and species, likely endemic
	Parapsuedoleptomesochra mackay n. sp.	X	X	New species, likely endemic
	Nitokra lacustric pacifica Yeatman, 1983		X	Widespread in Oceania
Crustacea: Copepoda: Harpacticoida: Miraciidae	*Schizopera bradleyi* n. sp.		X	New species, likely endemic
	Schizopera mackay n. sp.	X	X	New species, likely endemic
	Schizopera medifurca n. sp.		X	New species, likely endemic
	Schizopera paracooperi n. sp.		X	New species, likely endemic
Crustacea: Copepoda: Cyclopoida: Cyclopidae	*Fierscyclops fiersi* (De Laurentiis *et al*., 2001)		X	Widespread, stygophilic species
	Halicyclops cf. kieferi	X	X	Widespread in the Yilgarn but likely cryptic species complex
	Halicyclops mackay n. sp.	X	X	New species, likely endemic
	Mackaycyclops bradleyi n. g. & sp.		X	New species, likely endemic
	Mackaycyclops mouldsi n. gen., n. sp.	X	X	New genus and species, likely endemic
Insecta: Coleoptera: Dytiscidae	*Paroster* sp. *'mackay large'* n. sp.	X	X	New species, likely endemic
	Paroster sp. *'mackay medium* n. sp.		X	New species, likely endemic
	Paroster? sp. *'mackay small'* n. sp.		X	New species, likely endemic

Table 5 Stygofauna recorded from the Lake Mackay SOP Project area by aquifer

Higher Order	Genus and species	Surficial Calcrete Aquifer				Island Aquifer
		Camp Bore	Nr LP008	MWP08	Bore 3	MC013
Annelida: Oligochaeta	*Phreodrilidae?* sp.		X			
Crustacea: Bathynellacea: Parabathynellidae	*Atopobathynella* sp. *'mackay'* n. sp.		X			
Crustacea: Ostracoda: Podocopida: Candonidae	*Abcandonopsis mackay* n. sp.		X			
Crustacea: Copepoda: Harpacticoida: Ameiridae	*Mackaynitocrella mouldsi* n. gen., n. sp.	X	X			
	Parapsuedoleptomesochra mackay n. sp.	X			X	
	Nitokra lacustric pacifica Yeatman, 1983			X		
Crustacea: Copepoda: Harpacticoida: Miraciidae	*Schizopera bradleyi* n. sp.					X
	Schizopera mackay n. sp.		X			
	Schizopera medifurca n. sp.	X				
	Schizopera paracooperi n. sp.	X				
Crustacea: Copepoda: Cyclopoida: Cyclopidae	*Fierscyclops fiersi* (De Laurentiis *et al*., 2001)					X
	Halicyclops cf. kieferi	X				
	Halicyclops mackay n. sp.	X				
	Mackaycyclops bradleyi n. g. & sp.			X		
	Mackaycyclops mouldsi n. gen., n. sp.	X	X	X		
Insecta: Coleoptera: Dytiscidae	*Paroster* sp. *'mackay large'* n. sp.	X	X			
	Paroster sp. *'mackay medium* n. sp.		X			
	Paroster? sp. *'mackay small'* n. sp.		X			

4.6 Water Quality

Water quality parameters were collected from each bore sampled for stygofauna using a Hanna HI 9811-5 water quality meter. Samples were analysed in the field to provide a measure of temperature, total dissolved solids (TDS), electrical conductivity (EC) and pH. Results for the pilot and Phase 1 surveys are shown in Table 6 and for Phase 1 in Table 7.

Water quality was found to be near fresh to brackish in most shallow bores accessing calcrete aquifers, the deep alluvial aquifer was substantially more saline, with stygofauna recorded only from the bores slotted or accessing the surficial calcrete aquifer or the island aquifer.

Table 6 Water quality in Borefield bores sampled for stygofauna in May 2017

Bore ID	Temperature ˚C	pH	TDS mg/L	EC µS/cm	Depth to Water (m)	Water Depth (m)	Total Depth (m)
Camp Bore	29.3	6.7	320	660	5	33	38
LD02	27.7	8.2	>1310	>2500	9	32	41
LD03	29.5	8.7	>1310	>2500	7	30	37
Nr LP008	29.5	8.6	3710	7460	2	20	22
Handpump	28.8	8.1	100	210	-	-	-

Table 7 Water quality in Borefield bores sampled for stygofauna in November 2017

Bore ID	Temperature ˚C	pH	TDS mg/L (ppm)	EC µS/cm	Depth to Water (m)	Water Depth (m)	Total Depth (m)
Camp Bore	31.6	6.6	30	80	5	33	38
BORE 3	29.5	7.3	>1310	>2500	5	5	10
BORE 6	30.0	6.8	>1310	>2500	5	82	87
LD02	29.3	7.3	>1310	>2500	9	32	41
LD03	30.6	8.3	>1310	>2500	7	30	37
LM0182	30.4	6.5	70	150	4	93	97
LM0183	31.8	6.9	>1310	>2500	6	73	79
MC13	33.6	6.6	30	80.79*	3	7	10
MWP2	30.7	7.7	7,289*	>2500	1	41	42
MWP4 SHALLOW	28.6	8.6	>1310	>2500	3	39	42
MWP6	28.6	7.4	15,999*	>2500	3	97	100
NEW S1	28.9	7.5	>1310	>2500	5	92	97
Nr LP008	30.8	7.9	2980	6030	2	20	22
TRENCH16	29.4	6.9	~200,000*	>2500	-	6	-
TRENCH17	27.8	6.9	~200,000*	>2500	-	6	-

* Lab analysis results obtained by Agrimin ltd.

5. Troglofauna Survey Results

The two scrape samples obtained in November 2017 contained no fauna exhibiting obligate subterranean characteristics. The litter traps remain *in situ* and the results of these will be reported once the traps have been retrieved and any specimens identified. This is anticipated to occur in late March or April 2018.

6. Discussion

The results of the pilot and Phase 1 survey have revealed a diverse stygofauna community within the surficial calcrete aquifer to the south of Lake Mackay. The extent and distribution of this habitat is shown in Plate 3 with the calcrete units representing habitat with a high likelihood of containing stygofauna whilst the underlying palaeochannel aquifers also potentially support stygofauna communities, especially when salinity levels are low.

Preliminary sampling for stygofauna within the underlying deep alluvial aquifer has currently not recorded any stygofauna, however, these bores have been sampled prior to the full six month bore settling period and additional sampling will be required in these bores to exclude the presence of stygofauna. The deep alluvial aquifer is substantially more saline than the surficial calcrete aquifer, with laboratory analysis of water samples by Agrimin showing TDS levels between 7,000 – 58,000 with an average of 33,000 TDS which is close to sea water salinity (refer Appendix 4).

The islands within Lake Mackay also host aquifers, although the extent, depth and connectivity of these aquifers is unknown. Although initially suggested by Ecologia (2016) that stygofauna would be absent, or consist only of widespread stygophilic species, a single sample from bore MC013 has found a possibly endemic species of *Shizopera* copepod. These island aquifers should continue to be sampled until a proper understanding of their connectivity, diversity and level of endemicity can be established.

5.1 Stygofauna Assessment

A pilot survey for stygofauna within the proposed Project borefield recorded 10 species of stygofauna. At least eight of these species are new to science and likely endemic to the individual calcrete situated to the south of Lake Mackay (Figure 3) due to the repeated pattern of endemism found in the Yilgarn and Ngalia basin calcretes (Leys *et al*. 2003, Watts and Humphreys 2006, 2009, Watts and Leys 2005).

The presence of stygofauna within the calcrete to the south of Lake Mackay from the sampling of 5 bores would indicate that a stygofaunal community is present, although its complete diversity and distribution is currently unknown beyond the two bores where stygofauna was identified (Camp Bore and Nr LP008, refer). A discussion of the individual species recorded is below.

5.1.1. Annelida: Oligochaeta: Pheodrilidae? sp.

A single specimen of Pheodrilid oligochaete was recorded from bore Nr LP008. The specimen was damaged and so unable to be identified further than family level. Additional collecting from this bore in the future may enable further identification.

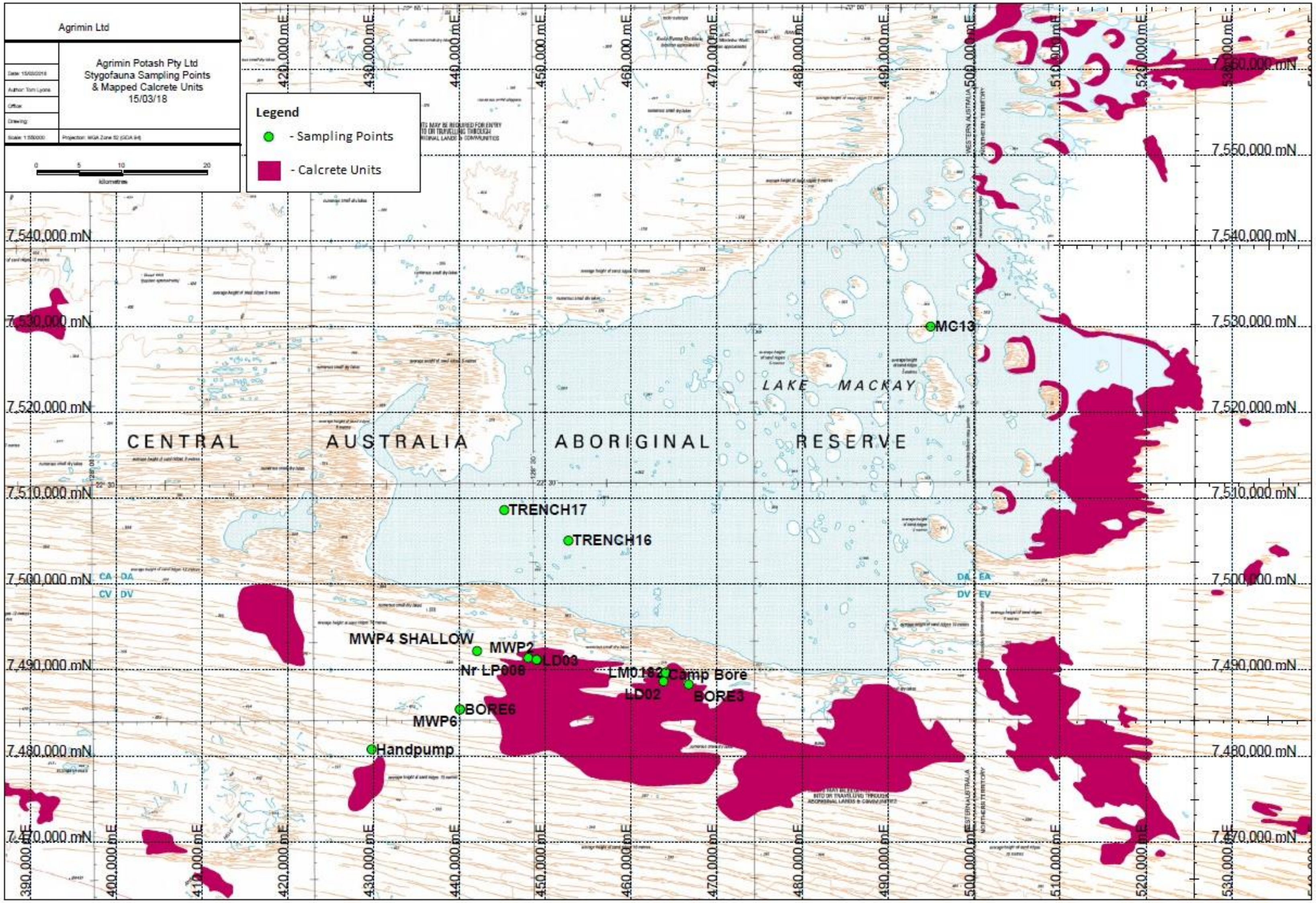

Plate 3 Stygofauna habitat map with surface expression of calcrete shown in purple. Additional stygofauna habitat potentially occurs in underlying palaeochannels.

5.1.2. Crustacea: Bathynellacea: Parabathynellidae:

Atopobathynella? sp. *'mackay'* n. sp.

Bathynellids are small, groundwater crustaceans that have a worldwide distribution in freshwater environments. There are over 35 genera and 120 species of parabathynellids described worldwide (Cho 2005). The genus *Atopobathynella* was first erected in 1973 and is now one of 10 genera of Parabathynellids in Australia. The genus contains nine described specimens, three from surface waters in Victoria and Tasmania, with the remainder being stygobitic from subterranean waters in Western Australia (Cho, Humphreys and Lee 2006). The specimen recorded from bore Nr LP008 shows morphological differences in the structures of the uropod and pleotelson to other described species of *Atopobathynella*, and so is regarded as a new species (Plate 4). This species has been recorded in both the Pilot and Phase 1 surveys but only from a single location. Genetic sequencing of the Bathynellids is recommended as it will confirm the current morphological identifications and also enable a more accurate assessment of potential impacts to stygofaunal communities to be determined.

Plate 4 Lateral view of Parabathynellidae: *Atopobathynella* sp. '*mackay'* from bore Nr LP008. Scale approximately 1mm.

5.1.3. Crustacea: Ostracoda: Podocopida: Candonidae

Abcandonopsis mackay n. sp.

Ostracods are aquatic micro-crustaceans distributed worldwide in virtually every imaginable aquatic habitat, both fresh and saline. This trapezoid species is similar to some congeners from the Murchison region (Karanovic I. 2004) and exhibits a smooth shell surface, pronounced asymmetry in valve shape and size. Details of soft part morphology were not checked, as only one specimen was available, but it is clearly distinct from other congeners in shell shape and ornamentation (Karanovic and Karanovic 2017).

5.1.4. Crustacea: Copepoda: Cyclopoida:

Fierscyclops fiersi (De Laurentiis* et al., *2001)

This is a widely distributed species in the Murchison region and probably a stygophile rather than a stygobiont (Karanovic 2004).

***Halicyclops cf. kieferi* Karanovic, 2004**

This species is large (refer Plate 5) and is clearly distinct from its small-sized congener. It was first described by Karanovic T. (2004) from several bores in the Murchison region and has been commonly recorded in multiple locations since, often with another smaller congener in the same bore. There are parallels in niche partitioning by size class, similar to that of diving beetles in the Yilgarn region (Watts and Humphreys 2006). To be sure that these specimens from Lake Mackay are indeed *H. kieferi*, comparative morphology and possible DNA would have to be studied in detail. Other molecular work on this genus (from other regions of WA) suggest that, in most cases, we are dealing with cryptic species in separate large calcretes (Karanovic and Karanovic 2017).

***Halicyclops mackay* n. sp.**

This species is small (refer Plate 5) and very similar to *H. eberhardi* De Laurentiis, Pesce & Humphreys, 2001, which was also redescribed from several bores in the Murchison region by Karanovic T. (2004). This new species differs mostly by longer (more slender) caudal rami and larger lateral wings on the genital double somite (Karanovic and Karanovic 2017).

Plate 5 Dorsal view of two adult females of *Halicyclops mackay* n. sp. on the left and two adult females of *Halicyclops cf. kieferi* Karanovic, 2004 on the right. Note the pronounced size differentiation. Image by T. Karanovic. Scale bar approximately 350 µm.

Mackaycyclops bradleyi n. g. & sp.

This species differs from *Mackaycyclops mouldsi* n. sp. mostly in size (it is much smaller, refer Plate 5). It also has a proportionately longer female genital double somite. Other characters, that are unique to this new genus, include the segmentation and armature of the swimming legs, and the absence of outer principal seta on caudal rami (also long dorsal seta). This is another case of two closely related species living together in the same habitat and differing mostly in size (as it is common with *Halicyclops* species and also with diving beetles in this region), resulting probably from niche partitioning.

Mackaycyclops mouldsi n. g. & sp.

This cyclopoid is extremely primitive and unlike modern species. It has a unique segmentation of the swimming legs (2/2, 2/2, 3/2, 3/3) and completely reduced outer principal seta on the caudal rami. Other characters include: antennule 11-segmented; antenna without exopod; fifth leg 2-segmented, inner apical element in between genera *Diacyclops* and *Thermocyclops* in size, but a seta is present instead of a spine; genital somite with pronounced lateral corners (as in *Acanthocyclops vernalis*). This species represents an important discovery for Australian copepoda (Karanovic and Karanovic 2017).

Plate 6 Photograph of two adult females of *Mackaycyclops bradleyi* n. sp. on the right and two adult females of *Mackaycyclops mouldsi* n. sp. on the left. Notice the pronounced size differentiation. Insert: one female *of M. bradleyi* enlarged.

5.1.5. Crustacea: Copepoda: Harpacticoida:

Mackaynitocrella mouldsi n. g. & sp.

This new genus of ameirid harpacticoid is somewhat similar to the genus *Nitocrella* (which has several unusual representatives in Australia), but with important differences in the armature of the swimming legs (Exp3P1 and Exp3P2 with 3 outer elements). The most important morphological characters are the P1-P4 armature formula (exp/enp) 0.1.023/1.0.3, 0.1.123/1.2, 0.1.122/1.3, 0.1.222/1.3; Enp1P1 reaching midlength of Exp3P1; ExpA2 with 3 setae; Fu short; female fifth leg similar to *Nitocrella trajani* but with longer setae; no additional rows of spinules on anal somite; male fifth leg with 4 setae on exopod and only 1 on endopodal lobe.

Nitokra lacustric pacifica Yeatman, 1983

This is a widely distributed species and certainly not a stygobiont; its morphological characters (Plate 7) are the same as those reported in Karanovic (2004). It was reported from crab holes in Western Samoa, Tonga, and Fiji (Yeatman 1983), temporary brackish pools in Papua New Guinea (Fiers 1986), and numerous bores in the Murchison regions of Western Australia (Karanovic 2004 and unpublished data).

Plate 7 Adult female and male of *Nitokra lacustris pacifica* Yeatman, 1983.

Parapsuedoleptomesochra mackay n. sp.

Several species of this genus have already been described from the Murchison region (Karanovic T. 2004) and several more have been discovered but remain unpublished. This one differs from them all in a unique armature formula of EnpP2-P4. It is relatively similar to *P. rouchi*, but, in addition to different armature formula, it has only one row of spinules on the anal somite (Karanovic and Karanovic 2017).

Schizopera bradleyi n. sp.

This harpacticoid is a very slender species, with caudal rami about as long as anal somite and cylindrical in the anterior half but conical in the posterior half. This species exhibits a unique morphological character where the anterior lateral seta on the caudal rami has been transformed into a laterally reaching robust claw, unseen in any of the other 100 species described in this genus (Karanovic & McRae 2013).

Schizopera paracooperi n. sp.

This is a very small species, cylindrical but not very slender, with very short cylindrical caudal rami similar to the shape of this structure in the majority of marine members of this genus. This species is similar in its appearance to *S. cooperi* described from the Pilbara region (Karanovic & MacRae 2013), and to several species identified from the vicinity of Lake Way in Western Australia (T. Karanovic, unpublished).

Schizopera mackay n. sp.

This harpacticoid is another extremely primitive species from the Lake Mackay area. The genus is very common in arid Western Australia, with most diversity in the Murchison region (Karanovic T. 2004; Karanovic and Cooper 2012) but a few species also in the Pilbara (Karanovic 2006; Karanovic & McRae 2013). This new species differs from them all in having extremely long caudal rami (maybe twice as long as in *S. jundeei*) and the outer principal seta are reduced to a minute hair (smaller than inner principal seta). It is unusual to find a character reduced in the same way in two completely unrelated copepods in the same habitat (refer to *Mackaycyclops mouldsi*), and this could plausibly be some kind of convergent adaptation for this specific habitat (Karanovic and Karanovic 2017), although it is very unusual morphologically.

Schizopera mediafurca n. sp.

This is a large species for the genus (about twice as long as the syntopic *S. paracooperi*), with very long caudal rami, although their elongation is resulting from elongation of the posterior portion, meaning therefore, that the dorsal and anterior lateral seta are inserted almost at mid-length. This is a very unusual feature on this genus. Unfortunately, only one male was collected, so the female characters are unknown.

5.1.6. Insecta: Coleoptera

Dytiscidae: *Paroster* spp.

Sampling within the surficial calcrete aquifer has recorded at least three species of stygobiontic diving beetles from the genus *Paroster* in two separate bores (Nr LP008 and Camp Bore). The diving beetle genus *Paroster* currently contains 43 species known to occur in Australia, with the majority being stygobiont species from calcrete aquifers in Western Australia (Leys *et al*. 2003, Watts and Humphreys 2006, 2009, Watts and Leys 2005). Every stygobiont species of *Paroster* known are endemic to individual calcrete aquifers in the Ngalia Basin and Yilgarn Craton (Watts and Humphreys 2006, 2009, Humphreys 2008). Every calcrete also shows an amazing repeated morphological adaptation where the diving beetles differentiate into three size classes (small, medium and large) sympatrically within the same aquifer. Due to the often extreme morphological conservatism in the characters used to identify dystiscid diving beetles genetic barcoding is required in order to comprehensively determine individual species delimitation.

All three species currently known from bores Nr LP008 and Camp Bore are considered endemic (Plate 8).

Plate 8 Dorsal view of Dytiscidae: *Paroster* sp. '*mackay large'* from bore Nr LP008. Scale approximately 1mm.

5.2 Troglofauna Assessment

The desktop assessment has identified suitable habitat in the form of unsaturated calcrete. Troglofauna, if present, may be impacted by borefield development through drawdown reducing available habitat with a saturated humidity upon which troglofauna rely.

No troglofauna has been recorded from the two available scrape samples collected in November 2017. The litter traps remain *in situ* and will be retrieved in March or April 2018.

5.3 Potential Impacts to Subterranean Fauna

The potential impacts of resource development including, developing a borefield in the region to the south of Lake Mackay, trenching of the lake bed to collect potash rich brine, and general construction activities on subterranean fauna may be categorised as being either direct or indirect impacts.

Direct impacts are the obvious and unavoidable destruction or degradation of habitat that occurs in excavating voids such as for trenching and adjacent terrain, including associated aquifer dewatering. The development of a borefield to the south of Lake Mackay has the potential to drawdown the regional watertable to varying amounts, although generally greater drawdown will occur in the vicinity of production bores. The hydrogeological nature of the area to the south of Lake Mackay is currently being investigated by Agrimin, but there are currently two identified aquifers; the surficial calcrete aquifer at the surface (up to ~10m depth) and the deep alluvial aquifer beneath this (Hydrominex Geoscience 2016). It is currently unknown if there is a hydrological connection between these two aquifers or if they are separated by an aquitard layer. The identified stygofaunal community is currently only recorded from the surficial calcrete aquifer and abstraction from the deep alluvial aquifer will directly affect stygofauna if there is a connection, even in part between these two aquifers.

The trenching system to abstract potash-rich brine from Lake Mackay will generally be at least five kilometres from lake islands, however, there are several locations where passing close to islands is unavoidable (Knight Piesold 2018). The larger islands occupy approximately 214 km^2, of which approximately 1.2% of the island surface is within the zone of influence of the trench drawdown area (Knight Piesold 2018). The fresh to brackish aquifers that underlay the lake islands support in at least one instance unique stygofauna (Bore MC013) and further investigation is required to determine what impacts may occur to the affected islands and their biota.

Indirect impacts are generally gradational, and more difficult to predict and manage because they may occur at moderate to large distances from the Project footprint. These impacts may be expressed some time after Project development has begun. Some examples include changes to hydrology, nutrient and microclimate regimes, contamination, reduced habitat area, water quality, and population viability. The zone of influence for indirect impacts may be considerably larger than the immediate area of the trenches or disturbance area. Potential indirect impacts of excavation include:

- Alteration of surface hydrology that affects groundwater recharge regimes, sedimentation, and water quality (e.g. under and adjacent to remediation areas, roads and infrastructure);
- Changes to subterranean microclimate in the zone of influence of groundwater abstraction from bores for construction or operational water requirements (causing drying of habitat);
- Dewatering that removes support and leads to physical damage to karstic geology types from the slumping of strata in calcrete aquifers (Humphreys 1999);
- Surface and groundwater contamination from plant equipment and infrastructure (e.g. chemical pollutants, hydrocarbons or waste water of lower quality);
- Salinisation of groundwater systems caused by changes to surface and subsurface hydrology;
- Reduction in organic inputs beneath areas cleared of vegetation and sealed surfaces;

- Vibration disturbance from construction and operational activities; and
- Risk of species extinction from reduction and/or fragmentation in habitat.

7. Conclusions and Recommendations

The desktop assessment for subterranean fauna identified suitable habitat in the form of a large continuous calcrete unit on the southern side of Lake Mackay. There is also the potential for subterranean fauna to occur in the smaller calcrete outcrops located on the islands within Lake Mackay. This habitat was confirmed as present by the preliminary sampling in the augered bore MC013, however, the extent of this habitat is unknown without additional subsurface information (such as from drilling, augering or test pits).

The pilot survey for subterranean fauna at the Lake Mackay SOP Project was undertaken in May 2017. Five stygofauna samples were obtained from the surficial calcrete aquifer to the south of Lake Mackay. Stygofauna was identified in two of the five samples (Camp Bore and Nr LP008) with 10 species present.

A subsequent level 2 stygofauna survey was commenced in November 2017 in the various aquifers to the south of Lake Mackay and on Lake Mackay itself. This survey has begun sampling in the surficial calcrete aquifer and the underlying deep alluvial aquifer, located to the south of Lake Mackay, and the perched aquifers associated with the islands in Lake Mackay. A pilot survey for troglofauna within the surficial calcrete deposits also commenced in November 2017, sampling two available uncased bores using both scrape and litter trap sampling techniques. No troglofauna has been recorded at present.

The results of the November 2017 stygofauna sampling has recorded stygofauna in both the surficial calcrete aquifer and the aquifers associated with the islands in Lake Mackay. No stygofauna has been recorded from the deep alluvial aquifer or from the hypersaline water within Lake Mackay situated away from islands.

Currently, the surficial calcrete aquifer shows the greatest diversity, with five classes, six orders, 7 families and 16 species present, whilst the single sampling location within the island aquifer has recorded two additional species. The stygofauna recorded in the Lake Mackay aquifers is significant in that it contains three new species of dytiscid diving beetle (*Paroster* spp.?*),* a new species of parabathynellid (*Atopobathynella* sp. '*mackay'*), and multiple new species of Copepoda, some of which show extremely primitive morphological characters (*Mackaycyclops mouldsi* n. g. & sp. and *Schizopera mackay* n. sp.) and may be important in the evolutionary history of Australian stygofauna. The diversity of copepoda stygofauna in the Lake Mackay region is potentially very high. Currently, from a pilot survey and phase 1 sampling rounds, there are four very different species of *Schizopera,* and some of them are even syntopic (Karanovic 2018). This is a much higher diversity than is commonly encountered in this genus, with only Yeelirrie exhibiting a similar diversity. (Karanovic & Cooper 2012).

Genetic sequencing of the stygobitic Dytiscid beetles and Bathynellids will confirm the current morphological identifications and the distribution of individual species within the Project area. Confirmation of the same species geographically across the Project area will enable a more accurate assessment of potential impacts to stygofaunal communities to be determined.

Fourteen of the 18 species recorded (78%) from both the surficial calcrete and island aquifers are undescribed species and 10 species (56%) are currently only recorded from single bores, although this is invariably due to the lack of suitable sampling locations. These results are not entirely unexpected due to the location of the sampling being many hundreds of kilometres from any other subterranean fauna sampling locations. Currently, most of these new species are known from single bores.

6.1 Recommendations

The following recommendations are made with regard to the potential development of the Lake Mackay SOP Project:

- Due to the presence of a stygofaunal community within the surficial calcrete aquifer located within the southern proposed borefield area, a Level 2 survey for stygofauna should be undertaken with regard to EPA Technical Guidance – subterranean fauna survey (EPA2016a) and EPA Technical Guidance – sampling methods for subterranean fauna (EPA2016b);
- The Level 2 survey for stygofauna will require, at a minimum, 40 samples from each impacted aquifer within the proposed borefield area (EPA2016b);
- Genetic sequencing of the stygobitic Dytiscid beetles and Bathynellids should be undertaken to confirm the current morphological identifications and the distribution of individual species within the Project area. Confirmation of the same species geographically across the Project area will enable a more accurate assessment of potential impacts to stygofaunal communities to be determined;
- The deep alluvial aquifer currently presents an environment unfavourable to stygofauna and preliminary sampling of this aquifer has recorded no stygofauna. Additional sampling of this aquifer should be undertaken to obtain sufficient samples to provide a pilot survey level of field sampling before a final assessment regarding the presence or absence of stygofauna within this aquifer can be undertaken;
- A troglofauna pilot survey has commenced in the proposed borefield area and should be continued until the requirements of EPA Guidance (2016a) are met. This would be a minimum of 10 – 15 bores to be sampled. No troglofauna has currently be recorded from the proposed borefield area;
- The stygofauna pilot survey of the island aquifers within Lake Mackay should be continued in all available bores until an assessment of the stygofauna present and the potential for impact to this stygofaunal community can be determined more accurately. This sampling should include all island areas that may be potentially impacted by drawdown associated with trenching; and
- Newly constructed bores should be constructed to be suitable for stygofauna and/or troglofauna sampling.

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Appendix 1

Location of Bores sampled for Stygofauna (May and November 2017)

Bore ID	Easting	Northing	Pilot survey sample date	Phase 1 sample date
Camp Bore	463762	7489435	12/05/2017	14/11/2017
BORE3	466729	7488333		17/11/2017
BORE6	440099	7485405		20/11/2017
Handpump	429786	7480760	18/05/2017	-
LD02	463802	7488674	18/05/2017	13/11/2017
LD03	449111	7491138	18/05/2017	13/11/2017
LM0182	464058	7489688		17/11/2017
LM0183	464050	7489687		14/11/2017
Nr LP008	448025	7491415	18/05/2017	12/11/2017
MC13	494917	7530028		15/11/2017
MWP2	449028	7491199		13/11/2017
MWP4 SHALLOW	442075	7492213		16/11/2017
MWP6	440085	7485416		16/11/2017
NEW S1	449014	7491206		13/11/2017
TRENCH16	452712	7505086		16/11/2017
TRENCH17	445232	7508636		16/11/2017

Appendix 2

Department of Parks and Wildlife Conservation Codes (November 2015)

CONSERVATION CODES

For Western Australian Flora and Fauna

Specially protected fauna or flora are species* which have been adequately searched for and are deemed to be, in the wild, either rare, at risk of extinction, or otherwise in need of special protection, and have been gazetted as such.

Categories of specially protected fauna and flora are:

T Threatened species

Published as Specially Protected under the *Wildlife Conservation Act 1950,* and listed under Schedules 1 to 4 of the Wildlife Conservation (Specially Protected Fauna) Notice for Threatened Fauna and Wildlife Conservation (Rare Flora) Notice for Threatened Flora (which may also be referred to as Declared Rare Flora).

Threatened fauna is that subset of 'Specially Protected Fauna' declared to be 'likely to become extinct' pursuant to section 14(4) of the Wildlife Conservation Act.

Threatened flora is flora that has been declared to be 'likely to become extinct or is rare, or otherwise in need of special protection', pursuant to section 23F(2) of the Wildlife Conservation Act.

The assessment of the conservation status of these species is based on their national extent and ranked according to their level of threat using IUCN Red List categories and criteria as detailed below.

CR Critically endangered species

Threatened species considered to be facing an extremely high risk of extinction in the wild. Published as Specially Protected under the *Wildlife Conservation Act 1950,* in Schedule 1 of the Wildlife Conservation (Specially Protected Fauna) Notice for Threatened Fauna and Wildlife Conservation (Rare Flora) Notice for Threatened Flora.

EN Endangered species

Threatened species considered to be facing a very high risk of extinction in the wild. Published as Specially Protected under the *Wildlife Conservation Act 1950,* in Schedule 2 of the Wildlife Conservation (Specially Protected Fauna) Notice for Threatened Fauna and Wildlife Conservation (Rare Flora) Notice for Threatened Flora.

VU Vulnerable species

Threatened species considered to be facing a high risk of extinction in the wild. Published as Specially Protected under the *Wildlife Conservation Act 1950,* in Schedule 3 of the Wildlife Conservation (Specially Protected Fauna) Notice for Threatened Fauna and Wildlife Conservation (Rare Flora) Notice for Threatened Flora.

EX Presumed extinct species

Species which have been adequately searched for and there is no reasonable doubt that the last individual has died. Published as Specially Protected under the *Wildlife Conservation Act 1950,* in Schedule 4 of the Wildlife Conservation (Specially Protected Fauna) Notice for Presumed Extinct Fauna and Wildlife Conservation (Rare Flora) Notice for Presumed Extinct Flora.

IA Migratory birds protected under an international agreement

Birds that are subject to an agreement between the government of Australia and the governments of Japan (JAMBA), China (CAMBA) and The Republic of Korea (ROKAMBA), and the Bonn Convention, relating to the protection of migratory birds. Published as Specially Protected under the *Wildlife Conservation Act 1950,* in Schedule 5 of the Wildlife Conservation (Specially Protected Fauna) Notice.

CD Conservation dependent fauna

Fauna of special conservation need being species dependent on ongoing conservation intervention to prevent it becoming eligible for listing as threatened. Published as Specially Protected under the *Wildlife Conservation Act 1950,* in Schedule 6 of the Wildlife Conservation (Specially Protected Fauna) Notice.

OS Other specially protected fauna

Fauna otherwise in need of special protection to ensure their conservation. Published as Specially Protected under the *Wildlife Conservation Act 1950,* in Schedule 7 of the Wildlife Conservation (Specially Protected Fauna) Notice.

P Priority species

Possibly threatened species that do not meet survey criteria, or are otherwise data deficient, are added to the Priority Fauna or Priority Flora Lists under Priorities 1, 2 or 3. These three categories are ranked in order of priority for survey and evaluation of conservation status so that consideration can be given to their declaration as threatened flora or fauna.

Species that are adequately known, are rare but not threatened, or meet criteria for near threatened, or that have been recently removed from the threatened species or other specially protected fauna lists for other than taxonomic reasons, are placed in Priority 4. These species require regular monitoring.

Assessment of Priority codes is based on the Western Australian distribution of the species, unless the distribution in WA is part of a contiguous population extending into adjacent States, as defined by the known spread of locations.

1 Priority 1: Poorly-known species

Species that are known from one or a few locations (generally five or less) which are potentially at risk. All occurrences are either: very small; or on lands not managed for conservation, e.g. agricultural or pastoral lands, urban areas, road and rail reserves, gravel reserves and active mineral leases; or otherwise under threat of habitat destruction or degradation. Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under immediate threat from known threatening processes. Such species are in urgent need of further survey.

2 Priority 2: Poorly-known species

Species that are known from one or a few locations (generally five or less), some of which are on lands managed primarily for nature conservation, e.g. national parks, conservation parks, nature reserves and other lands with secure tenure being managed for conservation. Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under threat from known threatening processes. Such species are in urgent need of further survey.

3 Priority 3: Poorly-known species

Species that are known from several locations, and the species does not appear to be under imminent threat, or from few but widespread locations with either large population size or significant remaining areas of apparently suitable habitat, much of it not under imminent threat. Species may be included if they are comparatively well known from several locations but do not meet adequacy of survey requirements and known threatening processes exist that could affect them. Such species are in need of further survey.

4 Priority 4: Rare, Near Threatened and other species in need of monitoring

(a) Rare. Species that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently threatened or in need of special protection, but could be if present circumstances change. These species are usually represented on conservation lands.
(b) Near Threatened. Species that are considered to have been adequately surveyed and that are close to qualifying for Vulnerable, but are not listed as Conservation Dependent.
(c) Species that have been removed from the list of threatened species during the past five years for reasons other than taxonomy.

*Species includes all taxa (plural of taxon - a classificatory group of any taxonomic rank, e.g. a family, genus, species or any infraspecific category i.e. subspecies or variety, or a distinct population).

Appendix 3

Species and abundance data by collection phase (Pilot and Phase 1)

Higher Order	Genus and species	Pilot Survey		Phase 1				
		Surficial Calcrete		Surficial Calcrete				Island
		Nr LP008	Camp bore	Nr LP008	Camp bore	Bore 3	MWP8	MC013
Annelida: Oligochaeta	*Phreodrilidae?* sp.	**1**						
Crustacea: Bathynellacea: Parabathynellidae	*Atopobathynella* sp. *'mackay'* n. sp.	**30**		**45**				
Crustacea: Ostracoda: Podocopida: Candonidae	*Abcandonopsis mackay* n. sp.	**1 male**						
Crustacea: Copepoda: Harpacticoida: Ameiridae	*Mackaynitocrella mouldsi* n. gen., n. sp.	**3 females**		**16**				
	Parapsuedoleptomesochra mackay n. sp.		**1 male, 2 females**			**4**		
	Nitokra lacustric pacifica Yeatman, 1983						**4**	
Crustacea: Copepoda: Harpacticoida: Miraciidae	*Schizopera bradleyi* n. sp.							**21**
	Schizopera mackay n. sp.	**9 females, 1 juv.**		**22**				
	Schizopera medifurca n. sp.				**1**			
	Schizopera paracooperi n. sp.				**2**			
Crustacea: Copepoda: Cyclopoida: Cyclopidae	*Fierscyclops fiersi* (De Laurentiis *et al*., 2001)							**28**
	Halicyclops cf. kieferi		**3 males, 8 females**		**58**			
	Halicyclops mackay n. sp.		**3 males, 3 females, 1 juv**		**6**			
	Mackaycyclops bradleyi n. g. & sp.						**5**	
	Mackaycyclops mouldsi n. gen., n. sp.	**44 male, 9 female, 9 Juv**	**2 females**	**7**	**30**		**1**	
Insecta: Coleoptera: Dytiscidae	*Paroster* sp. *'mackay large'* n. sp.	**1**		**3**	**1**			
	Paroster sp. *'mackay medium* n. sp.			**3**				
	Paroster? sp. *'mackay small'* n. sp.			**4**				

Appendix 4

Drilling and laboratory water quality data for bores constructed in September 2017 in the Deep Alluvial Aquifer.

Bore ID	Type	Location	Easting	Northing	Casing Depth	Casing Diameter (mm)	Blank casing	Slotted Casing	Airlift (L/s)	Lab TDS
MWP1	MB	Drill Pad 1	466737	7488337	36	50	0-12 & 33-36	12 - 33	2	14,896
MWP2	MB	Drill Pad 3	449026	7491202	42	50	0-24 & 36-42	24-36	2	7,289
MWP3	PB	Drill Pad 3	449026	7491202	102	150	0-48, 54-84 & 96-102	48-54 & 84-96	sand inflow	97,766
MWP4_S	MB	Drill Pad 4	442075	749221	42	50	0-24, 36-42	24-36		?
MWP4_D	MB	Drill Pad 4			96	50	0-66, 90-96	66-90	2	58,000
MWP5	MB	Drill Pad 1			108	50	0-60, 105-108	60-105	2	46,518
MWP6	MB	Drill Pad 5	440098	74855422	100	50	0-40, 97-100	40-97	2	15,599
MWP7 (BORE6)	PB	Drill Pad 5			96	150	0-60, 90-96	60-90	3.6 - 5.5	21,400
MWP8	Stygo Hole	Drill Pad 5			2	150	drilled to 15m	open hole	NA	NA
MWP9	MB	Drill Pad 6	428274	7481083	72	50	0-23, 69-72	23-69	1	2,780

www.invertebratesolutions.com

25 June 2018
Dr Tim Moulds
Director Invertebrate Solutions
PO Box 14
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Troglofauna litter trap samples from Lake Mackay

Attention: Gerry Bradley
Sustainability Manager
Agrimin Ltd

Dear Gerry

This letter is an update to the existing report Phase 1 Survey for Subterranean Fauna for the Lake Mackay SOP Project, Western Australia, April 2018. Unpublished report to Agrimin Ltd, on behalf of 360 Environmental Pty Ltd. Invertebrate Solutions Report Number 2017ISJ07_F03_20180410.

Six troglofauna litter traps were set in two bores within the area immediately to the south of Lake Mackay in November 2017 and these traps were retrieved in June 2018. Two traps were irretrievable (one from each bore). The remaining four troglofauna litter traps were transported to Perth and potential troglofauna specimens were extracted in tullgren funnels in the Invertebrate Solutions laboratory between 21-25th June 2018 until the litter was completely dry. The samples were the sorted using an Amscope 45x dissecting microscope and was undertaken by Dr Timothy Moulds.

No specimens exhibiting troglomorphisms were identified from the samples with only limited abundance of surface forms present.

The two sampling locations Bore 3 and Bore 5 (MWP8) represent the initial sampling of a pilot survey for troglofauna and an additional eight to 13 troglofauna litter samples will be required to meet the EPA Technical Guidance – Subterranean Fauna Survey (EPA2016a), Technical Guidance – Sampling Methods for Subterranean Fauna (EPA2016b) and the Environmental Factor Guideline – Subterranean Fauna (EPA 2016c).

Invertebrate Solutions

Sincerely

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