APPENDIX H Subterranean Fauna Reports



Havieron Project:

Subterranean Fauna Survey

Biologic Environmental Survey

Report to Newcrest Mining Limited

September 2020

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Final	M. Lythe	D. Main	L. Whitley (Newcrest)	10/09/2020

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDICES

GLOSSARY

BC Act	*Biodiversity Conservation Act 2016*
BoM	Bureau of Meteorology
DBCA	Department Biodiversity, Conservation and Attractions
EPA	Western Australian Environmental Protection Authority
EP Act	*Environmental Protection Act 1986*
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
mbgl	Metres below ground level
PEC	Priority Ecological Communities
SRE	Short-range endemic
TEC	Threatened Ecological Communities
WAM	Western Australian Museum

EXECUTIVE SUMMARY

The Havieron Project is a farm-in joint venture between Newcrest Mining Limited (Newcrest) and Greatland Gold Ltd. It is located 45 km east of Newcrest's Telfer Gold Mine in the Great Sandy Desert, Western Australia. The Havieron Project is targeting a gold-copper resource and will comprise an underground decline, waste rock landform, workshops, service corridor to the Telfer mine and road/construction bores along this corridor. This report assesses the potential impacts to subterranean fauna from construction of the underground decline to further define the resource. Construction will result in dewatering, excavation, and waste rock landforms, which may potentially have direct and indirect impacts on any subterranean fauna.

Biologic Environmental Survey (Biologic) undertook a desktop assessment and two-season subterranean fauna survey of the Havieron Project and Telfer region in accordance with the EPA guidelines. Four field trips took place between November 2019 and June 2020, sampling 33 holes at the Havieron Project and 41 in the Telfer region. In total, 181 subterranean fauna samples were collected. At the Havieron Project this comprised 60 stygofauna samples and 77 troglofauna samples. Samples were taken from holes of a variety of ages and a few contained drilling muds and/ or hydrocarbons. Subterranean fauna has some inherent limitations and it is difficult to determine whether some samples fully meet EPA guidelines. Sampling occurred both inside and outside the area of impact, and throughout all geologies and habitats present.

The current survey recorded a total of 573 subterranean fauna specimens, of which 15 stygofauna and 167 amphibious animals were recorded at the Havieron Project. Groups collected at the Havieron Project were identified to species level (including any occurring at both the Project and Telfer) and comprised four amphibious taxa (enchytraeid worms) and three stygofauna taxa (a copepod, an amphipod and an ostracod). No troglofauna were recorded.

The Havieron Project predominantly hosts widespread geologies and hydrogeological units that may offer limited habitat to subterranean fauna. The current survey results mostly agreed with this assessment, except for some small or localised areas of alluvials and calcareous cement occurring throughout the region, which may represent more suitable stygofauna habitat.

The Project has a small area of direct and indirect impacts within broad and continuous geologies that do not appear to host a rich community of subterranean fauna. One taxon, Humphreyscandonini sp. indet., is currently only known from the area of impact, however this taxon likely inhabits the unconfined aquifer in an area subject to minimal drawdown. The Project is unlikely to have a negative impact on the subterranean fauna of the region.

1 INTRODUCTION

1.1 Background

The Havieron Project (The Project), a farm-in joint venture between Newcrest Mining Limited (Newcrest) and Greatland Gold Ltd is located 45 km east of Newcrest's Telfer Gold Mine in the Great Sandy Desert, Western Australia (Figure 1.1). The Havieron Project is targeting a gold-copper resource within Proterozoic basement rocks, which are overlain by 410 m of Permian sedimentary cover. The Project will comprise an underground decline, waste rock landform, workshops, service corridor to the Telfer mine, and road/construction bores along this corridor.

To access the top of the resource, an underground decline will be constructed to a depth of approximately 430 m. This report assesses the potential impacts to subterranean fauna from:

- dewatering of the proposed underground decline on groundwater resources (hosted within the Permian sedimentary cover); and
- excavation (of Permian sedimentary rocks) to construct the underground decline.

The Project is geographically isolated and there has been historic sampling for subterranean fauna in the local region (referred to as the Study Area) that has largely occurred at and around the Telfer Gold Mine. Newcrest commissioned Biologic Environmental Survey (Biologic) to undertake a two-season subterranean fauna survey of the Project and vicinity (within the Study Area), in accordance with the EPA guidelines regarding subterranean fauna.

1.2 Objectives

The overarching objective of this assessment was to identify the occurrence of any subterranean fauna assemblages within the Study Area, and their supporting habitats. Specifically, the key objectives of the assessment were to provide:

- a desktop review of all previous subterranean fauna surveys in the vicinity of the Study Area and existing subterranean fauna databases on the local/ sub-regional scale
- results of a two-phase stygofauna and troglofauna survey throughout the Study Area, including detailed identifications of all species collected
- an assessment of the likely local occurrence of stygofauna and troglofauna species relative to key habitat units and proposed impact areas, and a discussion of their conservation status and wider potential distribution with reference to regional taxonomic comparisons
- a detailed risk assessment of key subterranean fauna values (species and habitat) in relation to the potential impacts of the proposed mining development.

1.3 Legislation and guidance

Western Australia's subterranean fauna is considered globally-significant due to an unprecedented richness of species and high levels of short-range endemism (EPA, 2016c). The EPA's environmental objective for subterranean fauna is to "protect subterranean fauna so that biological diversity and ecological integrity are maintained" (EPA, 2016a, p2). In this context, the EPA defines ecological integrity as "the composition, structure, function and processes of ecosystems, and the natural range of variation of these elements" (EPA, 2016a, p2).

Protection for conservation significant subterranean species and/ or Threatened or Priority Ecological Communities (TECs and PECs) is provided under State and Federal legislation, comprising:

- *Environmental Protection Act 1986* (*EP Act 1986*) (WA)
- *Biodiversity Conservation Act 2016* (*BC Act 2016*) (WA)
- *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act 1999*) (Commonwealth).

Most subterranean species and assemblages are not listed under these Acts, due to incomplete taxonomic or ecological knowledge. Consideration of range-restricted subterranean fauna is therefore also important, including species that only occur within restricted habitats, as these have a higher potential of being Short-Range Endemic (SRE) species (Eberhard *et al.*, 2009; Harvey, 2002).

This assessment has been undertaken in consideration of the following EPA guidance statements:

- EPA (2016a) Environmental Factor Guideline: Subterranean Fauna
- EPA (2016c) Technical Guidance: Subterranean Fauna Survey
- EPA (2016b) Technical Guidance: Sampling Methods for Subterranean Fauna.

1.4 Subterranean fauna

Subterranean fauna are animals that live underground. In Western Australia, subterranean fauna are mainly invertebrates such as crustaceans, insects, arachnids, myriapods, worms, and snails, but a small number of vertebrate taxa such as fish and reptiles have also been found (EPA, 2013; Humphreys, 1999). Subterranean fauna are grouped into two major ecological categories:

- stygofauna - aquatic animals that inhabit groundwater in caves, aquifers, and water-saturated interstitial voids
- troglofauna - air-breathing animals that inhabit air-filled caves and smaller voids above the water table.

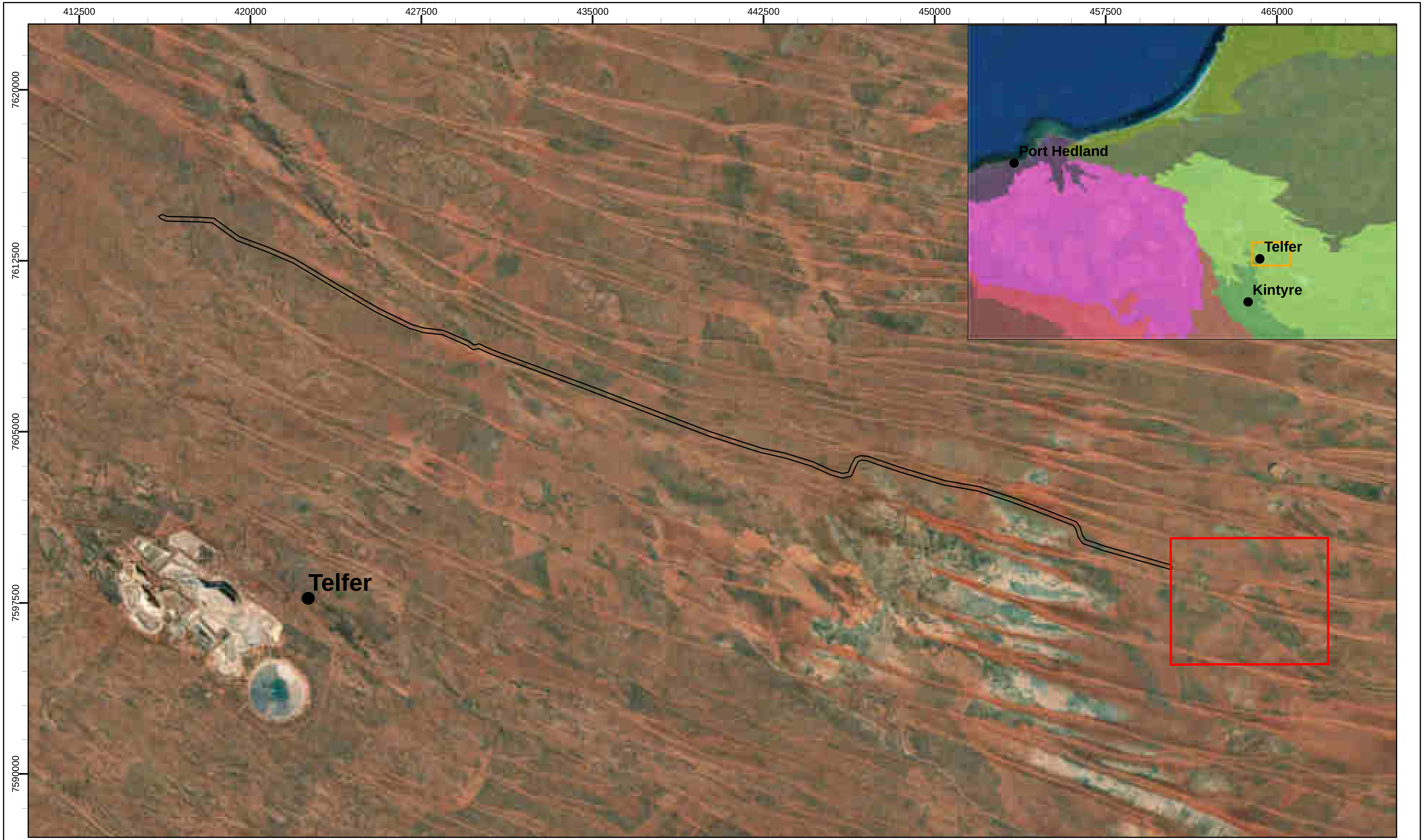
Nevertheless, there are some taxa which cross-over between these categories and are known to occur in groundwater as well as air-filled subterranean habitats (*e.g.* enchytraeid worms), and yet other species that occur within subterranean habitats for only part of their lifecycles (stygoxenes/ stygophiles, and trogloxenes/ troglophiles respectively).

Following EPA (2016c) guidelines, obligate subterranean fauna (known respectively as stygobites and troglobites) are defined as species that live their entire lives underground and are completely dependent upon, or restricted to, subterranean habitats. Such species are considered to have a high likelihood of being limited to very narrow ranges (*i.e.* short-range endemic (SRE) species), and therefore may be at greater risk of impacts from proposed developments (EPA, 2016c). SRE species as described by Harvey

(2002), are species whose natural ranges are limited to <10,000 km^2 (or <100 km x 100 km), whereas Eberhard *et al.* (2009) regarded even this criterion as potentially too vast for range-restricted subterranean fauna, offering an alternative threshold of <1,000 km^2 for subterranean SRE species.

Troglobites and stygobites often display evolutionary adaptations to underground life; these include features such as reduced pigment, reduced or vestigial wings, reduced cuticle thickness, elongation of sensory appendages, and reduced eyes or eyelessness. Additional adaptations to underground life can include changes to physiology, lifecycle, metabolism, feeding and behaviour (Christiansen, 2005; Gibert & Deharveng, 2002).

As the darkness of hypogean environments precludes photosynthesis, subterranean ecosystems are generally dependent upon allochthonous inputs of nutrients and oxygen from the surface (except in cases where chemo-autotrophic bacteria are present) (Hahn, 2009). Energy and nutrients are generally transported into subterranean ecosystems by the infiltration of water, particularly via the roots of groundwater dependent vegetation (Howarth, 1983; Humphreys, 2006; Malard & Hervant, 1999; Poulson & Lavoie, 2000). Thus, the porosity (or otherwise) of the overlying geologies, the distance from the surface, and the presence/absence of caves or fissures that can provide a conduit for water and nutrients are important physical features that influence the suitability of underground habitats for subterranean fauna (Hahn & Fuchs, 2009; Strayer, 1994). Groundwater physicochemistry (including salinity, pH, dissolved oxygen and redox potential) is also an important determinant of habitat suitability for stygofauna (Eberhard *et al.*, 2009; Hahn, 2009; Humphreys, 2008; Watts & Humphreys, 2004).



Legend

- Havieron Project Area
- Service Corridor

IBRA Subregions

- Chichester
- Fitzroy Trough
- Fortescue
- Hamersley
- Mackay
- McLarty
- Pindanland
- Roebourne
- Rudall
- Trainor

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Newcrest Mining Limited

Havieron Project Subterranean Fauna Survey

Fig 1.1: Regional location and IBRA subregions

Coordinate System: GDA 1994 MGA Zone 51
Projection: Transverse Mercator
Datum: GDA 1994

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2 ENVIRONMENT

2.1 Geology

Geology of the Great Sandy Desert is dominated by Phanerozoic sedimentary rock formations which are extensively mantled by reddish aeolian sands, characteristic of a large portion of the Canning Basin (Burbidge & McKenzie, 1983). Red sands dominate the Great Sandy Desert, often occurring as extensive sandplains or longitudinal sand dunes ranging from three to 25 m in height (Burbidge & McKenzie, 1983).

The Study Area is within the Paterson province. This includes the Paleoproterozoic to Mesoproterozoic Rudall Complex, the Neoproterozoic officer and Yeneena Basins, as well as the Phanerozoic Canning and Gunbarrel Basins (Rockwater, 2019).

The surface geology is dominated by Quaternary-aged aeolian sand dunes which is characteristic of the Great Sandy Desert (Figure 2.2). These sand dunes comprise predominantly quartz, minor feldspar and, in some locations, heavy mineral sands, including well rounded zircon and tourmaline. While the interdunal corridors comprise both weathering products (laterite, silcrete, ferricrete, and calcrete) and sediments (aeolian sand, alluvium, and evaporites). Below these dunes lie the Permian aged Sediments of the Kidson Sub-basin (of the Canning Basin) which are likely to belong to the fluvio-glacial Paterson Formation. The Canning Basin sediments overlie the Neoproterozoic Yeneena Basin which hosts the mineralisation for the project (Rockwater, 2019). The typical geological sequence at the Project is shown below in Table 2.2.

The Permian sediments comprise six subunits that include weathered mudstone, tillite, siltstone and sandstone (drill core photos shown below in Table 2.1). The Upper Mudstone (UWM) is dominantly a massive mudstone to clay zone with weathering close to the surface (upper saprolite, lower saprolite and sap-rock subunits). The Upper Tillite (UMT) is a permeable sandstone that comprises a laterally defined conglomerate unit and a broad vertical extent of poorly sorted poly-clastic tillite interbedded with minor thin beds of fine well-rounded sandstone and rare drop stones. The Lower Siltstone has an abundance of fine-grained sediment. The Lower Tillite is dominantly coarse, poorly sorted sandstone. The Proterozoic basement rocks host the mineralisation and are cemented and largely un-fractured. Notable exceptions include the contact with the Permian deposition.

The geologies at the Project are generally flat and become gradually shallower to the west (see cross section in Figure 2.1). The UWM underlies the Quaternary cover unit in the east, but due to the slight dip to the west this unit thins out, leaving Upper Tillite directly under the Quaternary-aged surface sediments (approximately in the Percival Palaeovalley). The basement rocks gradually shallow to the west and outcrop on the western side of the Percival Paleovalley near Telfer.

Table 2.1. Drill core photos of Permian and Permian sediments.

Upper Mudstone	Upper Tillite
	
Lower Siltstone	Lower Tillite
	
Permian Sediments	
	

Table 2.2. Typical Geological Sequence (Rockwater, 2019).

Age	Geological Formation	Unit	Average Thickness (m)	Average Depth to base of formation (m bgl)
Quaternary	Superficial	Undifferentiated COVER (aeolian sand, alluvium, and evaporates)	5-15	5-15
QUATERNARY/PERMIAN UNCONFORMITY				
Permian	Paterson	UWM - Upper Mudstone	95-105	100-110
		UMT - Upper Tillite	60	170
		LCS - Upper Siltstone	85	255
		LST - Middle Sandstone	25	280
		LSL - Lower Siltstone	35	315
		LFT - Lower Tillite	95	410
PERMIAN/PROTEROZOIC UNCONFORMITY				
Proterozoic	Undifferentiated	Undifferentiated Basement	N/D	N/D

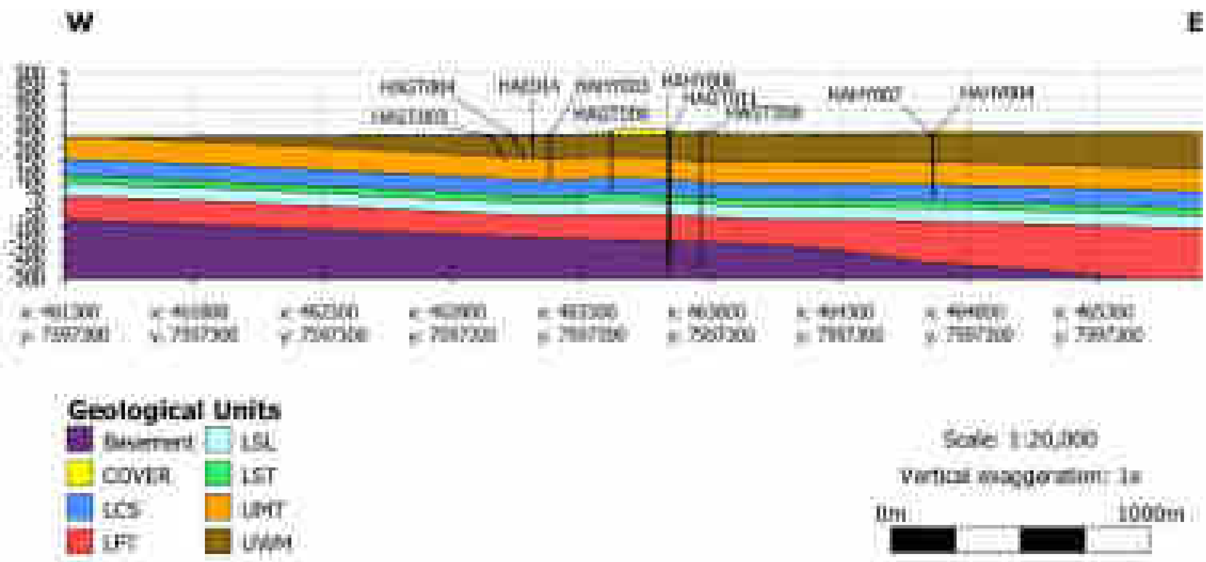


Figure 2.1 Cross-section parallel to the direction of the proposed mine decline.

2.2 Hydrogeology

The Study Area includes sandplains and linear sand dunes rising to 18 m above interdunal corridors. The landforms within the Project are predominantly influenced by Cenozoic erosion and deposition events resulting in a series of westerly to north-westerly trending longitudinal dunes (Ferguson *et al.*, 2005). The most significant valley near the Project is the Percival Palaeovalley (English *et al.*, 2015) and hosts significant calcrete outcrops. The topography trends west towards the palaeovalley, which drains to Lake Dora that is located 34 km southwest of the Project. Lake Dora is the closest substantial surface water feature that lies within the Rudall River National Park and is recognised as a groundwater dependant ecosystem (BoM, 2020).

The water table is generally greater than 10 mbgl at the Project, becoming shallow to the west (up to 5 mbgl). Hydrogeological works by Rockwater (2019) have identified four key aquifer units at the Project, in order from the surface:

1. Unconfined/Perched Aquifer
2. Upper Confined Aquifer
3. Lower Confined Aquifer
4. Proterozoic Aquifer (fractured).

The aquifers are described below with key characteristics summarised in Table 2.3.

2.2.1 Unconfined/ perched aquifer

The unconfined aquifer is small and interpreted to comprise:

- superficial sediments (generally unsaturated at Havieron given their thickness of 5 – 15m and the average water table depth of 14m (Rockwater, 2020))
- part of the upper UWM (upper saprolite, lower saprolite and saprock subunits) where weathered units are underlain by a thick succession of very low-permeability claystone and mudstone of the upper UWM.

It has a low transmissivity (0.37 m²/day) and high salinity of 18,800 to 39,100 mg/L TDS, which is likely due to limited salt flushing and evapoconcentration occurring near playas.

2.2.2 Upper confined aquifer

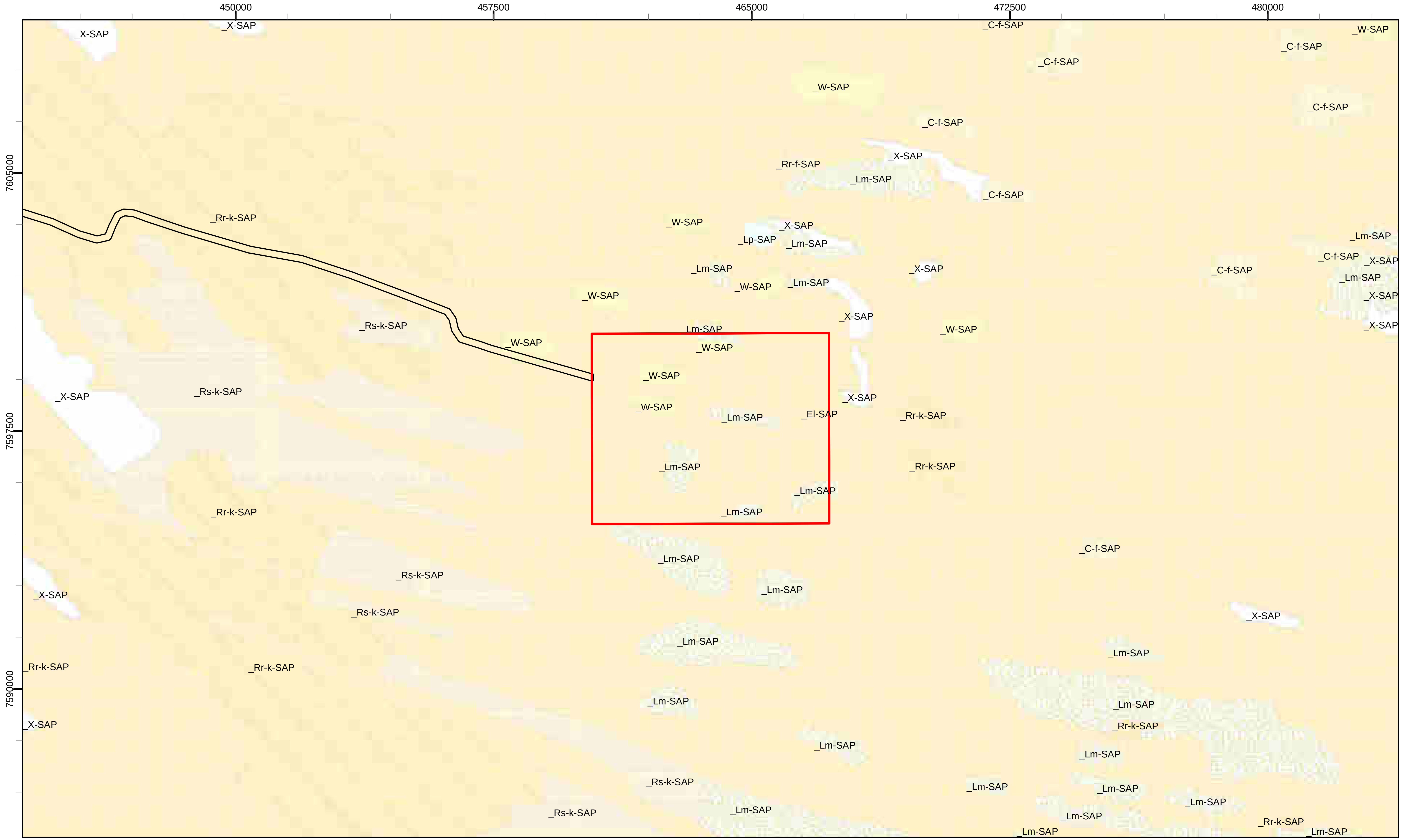
This unit comprises the basal upper silt/sandstone beds of the UWM and entire UMT, with the top of the aquifer located at 15 mbgl in the west to up to 110 mbgl in the east. It is confined by the UWM except where UWM is absent (to the north west and south west of the Project). The average transmissivity is 2.0 m²/day. Groundwater in the Paterson Formation is generally fresh near recharge areas becoming saline with depth and distance down the flow system (Laws (1990). At the Project, low salinities (3,000 to 4,000 mg/L) were observed where the aquifer is shallow and increasing (15,000 to 20,000 mg/L) at greater depth.

2.2.3 Lower confined aquifer

This aquifer comprises two units – the LST and entire LFT, which is typically ~150 mbgl deeper than the Upper Confined Aquifer. It is confined by the low permeability siltstones of the LCS and is underlain by basement Permian rocks. Salinity increases with depth and is recorded at up to 55,000 mg/L.

Table 2.3 Aquifer characteristics

Aquifer	Depth	Hydraulic Transmissivity	Typical Thickness of Aquifer	Salinity (mg/L TDS)
Unconfined/ perched	Within the uppermost 15 m and absent elsewhere	0.37 m²/day	0.0 – 19.2 m (av. 6.2 m)	18,800 to 39,100
Upper confined	Top of aquifer from 15 m in the west to up to 110 m in the east	2.0 m²/day	80 m	Shallow (3,000 to 4,000) At depth (15,000 to 20,000)
Lower Confined	Typically, about 150 m deeper than the Upper Confined Aquifer	0.9 m²/day	95 m	Up to 55,000



Legend

- Havieron Project Area
- Service Corridor
- _C-f-SAP; Colluvial unit, SAP
- _W-SAP; Sheetwash unit, SAP
- _Lm-SAP; Lacustrine unit, SAP
- _Lp-SAP; Lacustrine unit, SAP
- _El-SAP; Eolian unit, SAP
- _Rr-f-SAP; Residual or relict unit, SAP
- _Rr-k-SAP; Residual or relict unit, SAP
- _Rs-k-SAP; Residual or relict unit, SAP
- _X-SAP; Exposed unit, SAP

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Havieron Project Subterranean Fauna Survey

Fig 2.2: Regional surface geology

Coordinate System: GDA 1994 MGA Zone 51
Projection: Transverse Mercator
Datum: GDA 1994

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3 METHODS

3.1 Database search and review of previous reports

Five databases were searched for subterranean fauna records in April 2019 (Table 3.1):

- DBCA's NatureMap database (DBCA, 2020)
- Western Australian Museum (WAM) Arachnida/ Myriapoda database (WAM, 2019a)
- WAM Crustacea database (WAM, 2019b)
- WAM Mollusca database (WAM, 2019c)
- DBCA's Pilbara Stygofauna Survey species list (Halse *et al.*, 2014).

All records were filtered based on collection methods and known stygofauna/ troglofauna taxonomic groups where information on subterranean status was not present in the data.

Table 3.1. Databases searched for subterranean fauna records

Database	Parameters
NatureMap	40 km radius around 21°43'22.1"S 122°38'55.0"E
WAM Arachnida/ Myriapoda WAM Crustacea WAM Mollusca	65 km radius around 21°43'22.1"S 122°38'55.0"E
DBCA's Pilbara Stygofauna Survey	65 km radius around 21°43'22.1"S 122°38'55.0"E

Reports from subterranean fauna surveys within 40 km of the Study Area were reviewed for local and regional context. Reports from Telfer region are listed below:

- Telfer Gold Mine Stygofauna Sampling Report, November 2001 (Biota, 2001)
- Newcrest Telfer Gold Mine Subterranean Fauna Monitoring Program Field Report - November 2004 (Natural Resource Services, 2004)
- Telfer Project – Subterranean Fauna Management Plan (TP-PRO-80-02-0001) (Newcrest, 2004)
- Stygofauna Taxonomy Report for Newcrest Mining Limited (NCM), Telfer Operations - Stygofauna Monitoring (Horwitz & Clarke, 2005)
- Newcrest Mining Limited: Telfer Gold Mine Stygofauna Monitoring, December 2009 (Bennelongia, 2010b)
- Preliminary subterranean fauna sampling, O'Callaghans Deposit, Telfer (Bennelongia, 2010a)
- Telfer Gold Mine. Monitoring program: taxonomic alignment of stygofauna species draft report (Bennelongia, 2010c)
- Stygofauna Monitoring: Telfer Gold Mine, September 2010. Final Report. (Bennelongia, 2011a)
- Telfer Gold Mine: baseline troglofauna survey (Bennelongia, 2011b)
- Stygofauna for the O'Callaghan's Project, Telfer (Bennelongia, 2012a)
- Stygofauna Monitoring: Telfer Gold Mine, September 2011 (Bennelongia, 2012b)
- Telfer Gold Mine: troglofauna monitoring in 2011 (Bennelongia, 2012d)
- Stygofauna Monitoring: Telfer Gold Mine, October 2012 (Bennelongia, 2013a)

- Stygofauna monitoring: Telfer Gold Mine, October 2013 (Bennelongia, 2013b)
- Troglofauna Monitoring: Telfer Gold Mine, October 2013 (Bennelongia, 2014b)
- 10 Years of Stygofauna Monitoring at Telfer Gold Mine (Bennelongia, 2014a)
- Final Report - Subterranean Fauna - 5 Year Review 2009-2013 (Newcrest, 2014)
- Havieron Project Hydrogeological Assessment (Rockwater, 2019).

One additional survey for subterranean fauna have been conducted beyond the 65 km search area and is included due to its relevance and paucity of subterranean fauna sampling within the search area:

- Subterranean fauna Assessment of the Kintyre Uranium Deposit (Bennelongia, 2012c).

3.2 Survey timing

A two-phase survey for subterranean fauna was undertaken in accordance with guidelines for subterranean fauna assessments (EPA, 2016a, 2016b, 2016c). The first phase of sampling was undertaken in November 2019 – February 2020, representing a wet season survey with the second phase undertaken during the dry season months April – June 2020. Each survey phase comprised two field trips as follows:

Phase 1

- Trip 1, 21st to 26th November 2019: trap deployment and scrape / haul / pump sampling; and
- Trip 2, 18th to 21st February 2020: trap retrieval and scrape / haul / pump sampling.

Phase 2

- Trip 3, 30th March to 3rd April 2020: trap deployment and scrape / haul / pump sampling; and
- Trip 4, 14thto 19th June 2020: trap retrieval and scrape / haul / pump sampling.

3.3 Site selection and survey effort

Within the Study Area, site selection for subterranean fauna sampling was limited to accessible, vertical bores (*i.e.* cased, production or monitoring bores) and drill holes (uncased holes). In general, suitable sampling sites are contingent on:

- drill hole construction (uncased required for troglofauna),
- angle (90° required for scraping and net hauling)
- time since drilling (>6 months required for stygofauna, following EPA 2016*b*), and
- whether the holes intercepted groundwater (required for stygofauna).

A total of 74 holes were sampled throughout the Study Area, 33 in Havieron and 41 in the Telfer region, over the course of the two survey phases (Figure 3.1). Stygofauna were sampled for in 63 holes (33 at the Project) and 42 for troglofauna (26 at the Project). Standard sampling methodology was utilised for stygofauna - hauling, dual haul-scraping, and pumps (filtering pump outflow) and troglofauna - scraping, dual haul-scraping, and trapping. Hole and sample details are provided in Appendix A.

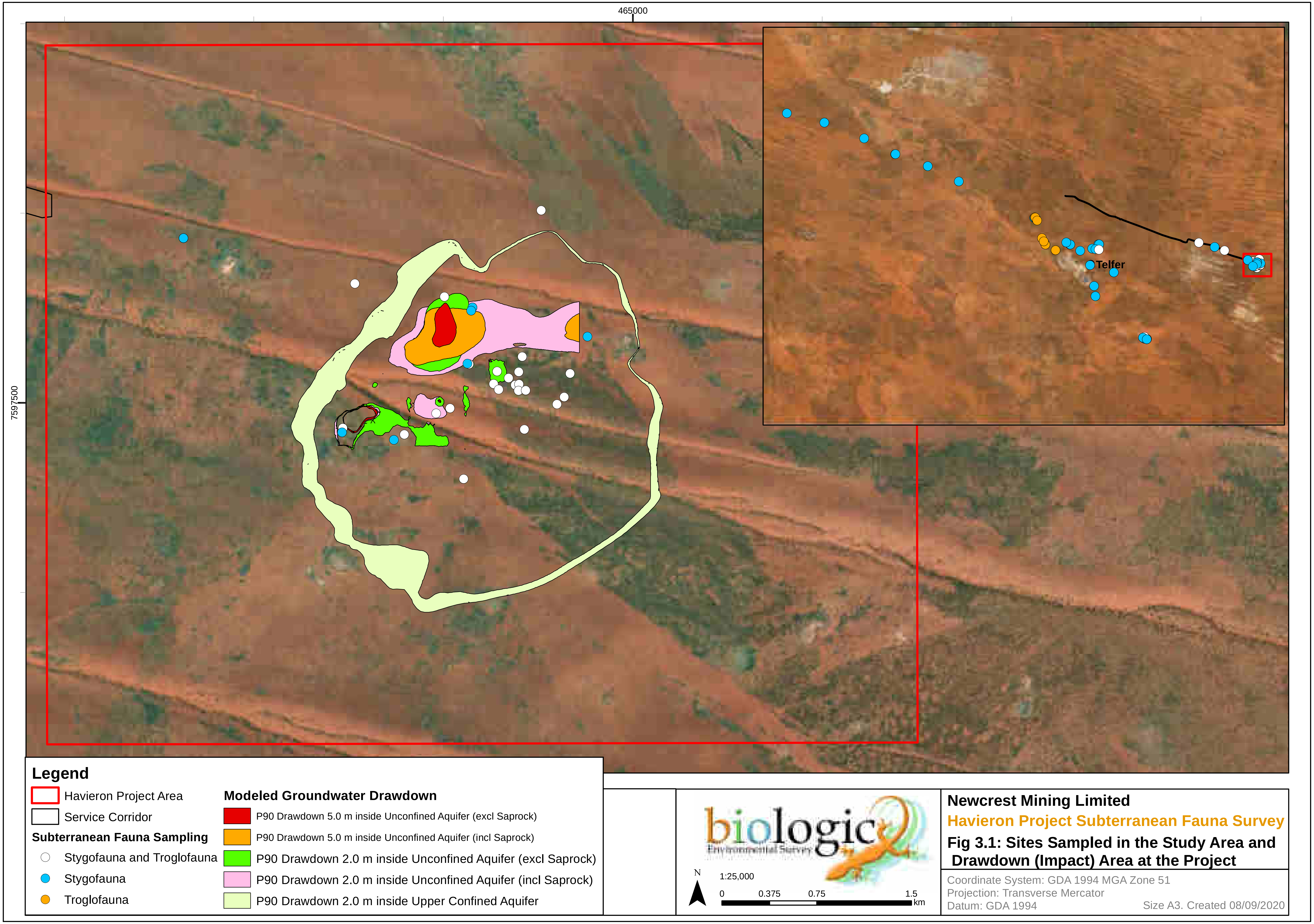
A total of 181 subterranean fauna samples were collected during the survey, of which 93 come from the Project and 88 from Telfer (three troglofauna traps are not included in the tally as they were lost due to hole collapse or hole rehabilitation). The sampling at the Project comprised 60 stygofauna samples (12 hauls, 4 pumps and 44 scrape-hauls) and 77 troglofauna samples (44 scrape-hauls and 33 traps) (Table 3.2; Table 3.3). Samples were taken from holes of a variety of ages and a few contained drilling muds and/or hydrocarbons. Subterranean fauna has some inherent limitations and it is difficult to determine whether some samples fully meet EPA guidelines. See Appendix A for drill hole details and dates. Sampling occurred both inside and outside the area of impact, and throughout all geologies and habitats present.

Table 3.2: Number of subterranean fauna samples collected in the Study Area.

Locality	Trip Number	Haul	Scrape	Scrape-Haul	Pump	Trap Set	Trap Collected
Havieron	1	2		12	1	12	10
	2	2		3	1		
	3	3		18	1	23	23
	4	5		11	1		
Sub-total		**12**		**44**	**4**	**35**	**33**
Telfer	1	18	6	1	1	9	9
	2	2	1	2			
	3	13	2	2	1	15	14
	4	9	4	3			
Sub-total		**42**	**13**	**8**	**2**	**24**	**23**
Total		**54**	**13**	**52**	**6**	**59**	**56**

Table 3.3: Number of subterranean fauna samples collected in the Project.

Method	Target Fauna	Impact	Reference	Total
Haul	Stygofauna	6	6	12
Pump	Stygofauna	4		4
Scrape-Haul	Stygofauna and Troglofauna	36	8	44
Trap	Troglofauna	28	5	33
Total		**74**	**19**	**93**



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Telfer
Legend
Havieron Project Area
Service Corridor
Subterranean Fauna Sampling
Stygofauna and Troglofauna
Stygofauna
Troglofauna
Modeled Groundwater Drawdown
P90 Drawdown 5.0 m inside Unconfined Aquifer (excl Saprock)
P90 Drawdown 5.0 m inside Unconfined Aquifer (incl Saprock)
P90 Drawdown 2.0 m inside Unconfined Aquifer (excl Saprock)
P90 Drawdown 2.0 m inside Unconfined Aquifer (incl Saprock)
P90 Drawdown 2.0 m inside Upper Confined Aquifer
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Newcrest Mining Limited
Havieron Project Subterranean Fauna Survey
Fig 3.1: Sites Sampled in the Study Area and Drawdown (Impact) Area at the Project
Coordinate System: GDA 1994 MGA Zone 51
Projection: Transverse Mercator
Datum: GDA 1994
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3.4 Sampling methods

The sampling methods used were consistent with EAG #12 (EPA, 2016c), Guidance Statement #54A (EPA, 2016b) and the Stygofauna Sampling Protocol developed for the Pilbara Biodiversity Study Subterranean Fauna Survey (Eberhard *et al.*, 2005; Eberhard *et al.*, 2009). The field work was undertaken by Dean Main, Syngeon Rodman, and Courtney Proctor. Laboratory sorting was undertaken by Syngeon Rodman, Mary van Wees, Juliana Pille Arnold, Stephanie Floeckner, Siobhan Paget, Kaylin Geelhoed, Isabelle Johansson, and Morgan Lythe.

3.4.1 Troglofauna trapping

Trapping utilised custom-made cylindrical PVC traps (approximately 50 mm x 300 mm) baited with decaying leaf litter (dead spinifex / acacia sourced from the Pilbara region), which were sterilised with boiling water. Traps were lowered *via* a nylon cord to a suitable depth and left in operation six to eight weeks, before being collected and transported back to the laboratory in Perth.

3.4.2 Troglofauna scraping

Scraping was undertaken at vertical, uncased drill holes using a reinforced 150 µm weighted stygofauna net, with a specialised scraping attachment used above the net to maximise gentle contact with the walls of the hole. The net was lowered and raised through the full length of the hole four times for holes where no water was present, with each haul being emptied into a sample bucket. Where the water table was intercepted, a combined net-haul / scrape sample was taken using the scraping attachment. Each combined net-haul / scrape sample comprised a total of six hauls from the bottom of the hole to the top (including AWT and BWT habitats), with three hauls using a 150 µm mesh and three hauls using a 50 µm mesh. The contents of the sample were elutriated, processed, and stored in 100 % ethanol.

3.4.3 Stygofauna net-hauling

Stygofauna were sampled by standard net-hauling methods, using a plankton net of a diameter to suit each bore or drill hole (in most cases 30 – 80 mm). Each haul sample comprised a total of six hauls from the bottom of the hole to the top, with three hauls using a 150 µm mesh and three hauls using a 50 µm mesh. The base of the net was fitted with a lead weight and a sample receptacle with a base mesh of 50 µm. To stir up sediments, the net was raised and lowered at the bottom of the hole prior to retrieval and hauled at an even pace through the water column to maximise filtration of the water.

The sample from each haul was emptied into a bucket, which was elutriated after the final haul to remove coarse sediments and filtered back through the 50 µm net/ sample receptacle to remove as much water as possible. The sample was transferred to a 50-120 mL preservation vial (depending upon the quantity of sediment) and preserved in 100% ethanol. The ethanol and the samples were kept chilled on ice or in a refrigerator to facilitate cool-temperature DNA fixation.

3.4.4 Pumping (stygofauna)

Two sites were sampled by actively pumping water from bores and running the water from the pump release valve through a stygofauna net three times for approximately 10 minutes total at each site.

3.4.5 Water physicochemistry

Prior to stygofauna sampling, a groundwater sample was collected using a plastic cylindrical bailer (length: 1 m), for the purposes of physicochemical measurements. The bailer was lowered down the hole until reaching groundwater and a water sample was collected at a depth of 2 m below the surface. As such the results were not indicative of water parameters throughout the entire bore (or aquifer) but rather provide a general indication of near surface conditions. Conditions sampled during pumping were measured using a sample collected from the pump outflow, which would have artificially increased the dissolved oxygen readings. Groundwater physicochemical data (including EC, pH, TDS, Redox ORP, and dissolved O_2) was measured using a multi-parameter water meter. Constrictions in piezometer bores, blockages from root material, or excessive depths to groundwater inhibited the collection of physicochemical readings at some sites.

3.4.6 Sorting and taxonomy

Sorting and parataxonomy were undertaken in-house using dissecting microscopes. The personnel involved (Syngeon Rodman, Mary van Wees, Juliana Pille Arnold, Stephanie Floeckner, Siobhan Paget, Kaylin Geelhoed, Isabelle Johansson, Morgan Lythe, Michael Curran, and Giulia Perina) were all suitably trained and experienced in sorting and parataxonomy of subterranean fauna.

Parataxonomy of the specimens utilised published literature and taxonomic keys where available. Each morphospecies from each sample was assigned a separate labelled vial and labelled with a specimen tracking code. Taxonomic groups were examined in as much detail as possible using in-house expertise, before sending a reference collection to specialist taxonomists for detailed taxonomic advice. Species comparisons and alignments were performed using regional specimens collected beyond the Study Area throughout the wider sub-regional area. Dr Giulia Perina provided specialist taxonomic identifications and regional alignments.

Genetic analysis (DNA barcoding using the mitochondrial gene COI) was conducted by Biologic on certain subterranean taxa to validate morphological identifications and provide a basis for species-level identifications and regional comparisons where taxonomic resolution was limited. Refer to Appendix C for further details regarding the methods of DNA extraction, choice of primers, sequencing, and analysis.

3.4.7 Conservation status and SRE classification

A few subterranean species and assemblages from the Pilbara region are listed under relevant legislation as threatened species, or as Threatened or Priority Ecological Communities in certain locations. Any listed subterranean species or community is regarded as conservation significant although, due to a lack of survey effort and taxonomic certainty for the majority of subterranean fauna in the Pilbara region, there are many potentially range-restricted (SRE) or conservation significant species and communities that do not appear on these lists.

The likelihood of taxa representing SRE species (*i.e.* distribution <10,000 km^2 following Harvey 2002, or <1,000 km^2 following Eberhard *et al.* 2009) was assessed based on the known local species distribution, and regional comparisons where data was available, following advice from the WAM and other relevant taxonomic specialists. The assessment of SRE status was highly dependent on:

1. the degree of taxonomic certainty at the genus and species levels
2. the current state of taxonomic and ecological knowledge for each taxon (including whether a regional genetic context has been investigated)
3. the scale and intensity of the local and regional sampling effort
4. whether or not relevant taxonomic specialists were available to provide advice.

The SRE status categories used in this report follow the WAM's categorisation for SRE invertebrates. This system is based upon the 10,000 km^2 range criterion proposed by Harvey (2002), and uses three broad categories to deal with varying levels of taxonomic certainty that may apply to any given taxon (Table 3.3). Because most subterranean fauna are poorly known taxonomically, and the general limitations to sampling subterranean fauna, the majority of morphospecies invariably fall within one (or several) of the five Potential SRE sub-categories.

Table 3.4: SRE categorisation used by WAM taxonomists

<table>
<tr><th></th><th>Taxonomic Certainty</th><th>Taxonomic Uncertainty</th></tr>
<tr><td>Distribution
<10 000km^2</td><td>Confirmed SRE
• A known distribution of < 10,000km^2.
• The taxonomy is well known.
• The group is well represented in collections and/ or via comprehensive sampling.</td><td rowspan="2">Potential SRE
• Patchy sampling has resulted in incomplete knowledge of geographic distribution.
• Incomplete taxonomic knowledge.
• The group is not well represented in collections.
• Category applies where there are significant knowledge gaps.

SRE Sub-categories may apply:
A) Data Deficient
B) Habitat Indicators
C) Morphology Indicators
D) Molecular Evidence
E) Research & Expertise</td></tr>
<tr><td>Distribution
>10 000km^2</td><td>Widespread (not an SRE)
• A known distribution of > 10,000km^2.
• The taxonomy is well known.
• The group is well represented in collections and/ or via comprehensive sampling.</td></tr>
</table>

The degree of stygomorphy or troglomorphy (observable physical adaptations to subterranean habitats such as eyelessness, depigmentation, elongation of sensory appendages and thinning of the cuticle) assessed to determine each morphospecies' 'subterranean status', *i.e.* whether a taxon was more or less likely to be an obligate subterranean species (stygobite/ troglobite). It is acknowledged that the current EPA guideline for subterranean fauna does not account for non-obligate subterranean fauna, stating, *"…subterranean fauna are defined as fauna which live their entire lives (obligate) below the surface of the earth.... Fauna that use a subterranean environment for only part of the day or season (e.g. soil-dwelling or burrowing species, cave-dwelling bats and birds) are not considered as subterranean fauna for this EAG*" (EPA, 2013).

Nevertheless, there may be fauna with restricted distributions <10,000 km^2 following Harvey (2002), or <1,000 km^2 following Eberhard *et al.* (2009) that are of interest because of their SRE status, regardless of whether they can be definitively regarded as 'obligate' subterranean fauna. For this reason, this report presents an assessment of both the subterranean status and the SRE status of each taxon collected, to the best available knowledge.

In some cases where thorough sampling has been conducted and sufficient habitat information and ecological information is available, the potential occurrence of a taxon at a local scale may be inferred *via* the extent of habitats, particularly where the rest of the assemblages are highly similar, and the habitats appear well-connected. Despite the suggestion within the current EPA (2013) guidelines that related species' ranges may be used as surrogates for poorly-known species' ranges, the level of evidence required to support the identification of an appropriate surrogate is almost prohibitively high for most subterranean fauna, therefore this would only be investigated as a last resort.

3.5 Constraints and limitations

Table 3.5: Survey limitations and constraints

Potential limitation or constraint	Applicability to this survey
Experience of personnel.	No constraint.
Site Selection	No constraint. Availability improved mid survey by drilling of holes specifically designed to target subterranean fauna.
Sampling Techniques	No constraint.
Survey Effort Troglofauna	Minor constraint – some holes contained biodegradable drilling muds/ hydrocarbons
Survey Effort Stygofauna	Minor constraint – some holes contained biodegradable drilling muds/ hydrocarbons or sampling occurred less than 6 months post drilling
Specimen Identification	No constraint, noting that identifications are inherently limited for shells/valves and molecular work was undertaken, providing a very high level of taxonomic resolution.
Level of Survey	No constraint considering small impact area within widespread, well connected geologies.
Sources of information (recent or historic) and availability of contextual information.	All previous surveys relevant to the planning of the survey were available and consulted. Historic, comparative genetic data were not available.

4 RESULTS

4.1 Previous survey and database search results

Reports from subterranean fauna surveys within the vicinity of the Study Area were reviewed for local and regional context. None of the surveys sampled bores or drill holes from within the Study Area. Five of the seven previous surveys were conducted at Telfer Gold Mine, approximately 45 km west of the Study Area, including nearby reference sites. One subterranean fauna survey was conducted at O'Callaghans Deposit just west of Telfer Gold Mine and another at Kintyre Uranium Deposit 83 km south-west of the Study Area.

The earliest subterranean fauna survey was conducted in 2001, sampling 17 water bores within Telfer Borefield and nearby reference sites (Biota, 2001). The six bores yielding stygofauna were located within Proterozoic sediments and tertiary calcrete. In total, eleven stygofauna taxa from six higher level taxonomic groups were recorded, comprising Amphipoda, Copepoda, Gastropoda, Nematoda, Ostracoda, and Polychaeta (this polychaete was possibly the first stygal member of this group recorded in Australia at the time). It should be noted that no lower-level taxonomy was conducted on any of the specimens found in this survey, with only Amphipoda being split into six distinct taxa using electrophoresis. The number of stygofauna taxa may therefore be higher, but this cannot be confirmed.

In 2004, sixteen bores within and nearby the Telfer Gold Mine corridor were sampled for the Subterranean Fauna Monitoring Program (Natural Resource Services, 2004) as outlined in the Telfer Gold Mine – Subterranean Fauna Management Plan (Newcrest, 2004). Stygofauna were recovered from four bores, three of which were reference sites 40 km to the west and 20 km to the east of the central mine corridor. In total, eight taxa (36 individuals) were obtained, comprising four copepod species, three amphipod species, and one oligochaete worm species. Each of the bores in which stygofauna were found intercepted different aquifer geologies, including Wilkie Quartzite, deep weathered siltstones, tertiary calcrete, and Permian Tillite, respectively.

In 2010, Newcrest Mining Ltd. was assessing the feasibility of developing a below-ground mine at O'Callaghans Deposit, situated west of Telfer Gold Mine. As part of this assessment, preliminary subterranean fauna sampling of 20 drill holes was undertaken at O'Callaghans and nearby reference sites (Bennelongia, 2010a). Three bores yielded stygal amphipods belonging to the Paramelitidae family which could not be identified further and may therefore represent more than one species. Only one troglobitic specimen was found, the symphylan *Scutigerella* `sp. B1`. The study concluded that these findings confirm that the geology at O'Callaghans (located in the Punta Punta Formation, consisting of dolomitic limestone) was prospective for troglofauna and stygofauna, but that more sampling would be needed to meet EPA guidelines.

In 2014, Newcrest Mining Ltd. released a review of the 5-year stygofauna monitoring (2009 – 2013) and the four-year troglofauna monitoring (2010 – 2013) conducted at Telfer Gold Mine and surrounds (Newcrest, 2014). Throughout these surveys, a total of 51 bores were sampled (most of them several times). The troglofauna monitoring surveys (Bennelongia, 2014b) revealed nine taxa (25 specimens total) belonging to seven higher level taxonomic groups, including Araneae, Isopoda, Pauropoda, Symphyla, Diplura, Zygentoma, and Hemiptera. Such low specimen numbers from a total of 165 troglofauna samples across four years suggest that the Telfer area is characterised by a depauperate troglofauna community. The stygofauna monitoring surveys (Bennelongia, 2010b, 2011a, 2012b, 2013a, 2013b), on the other hand, revealed rich stygofauna assemblages, detecting 23 distinct taxa (possibly more due to a number of indeterminate taxa) from ten higher level taxonomic groups, comprising Acari, Amphipoda, Copepoda, Gastropoda, Isopoda, Nematoda, Oligochaeta, Ostracoda, Polychaeta, Rotifera, and Syncarida.

Subterranean fauna survey conducted at Kintyre Uranium Deposit (Bennelongia, 2012c), located 83 km south-west of the Study Area was the most distant assessment reviewed. This study sampled a total of 112 bores, collecting 190 samples across three sampling rounds. A total of 23 troglofauna species from twelve higher level taxonomic groups (Araneae, Blattodea, Diplura, Hemiptera, Isopoda, Palpigradi, Pauropoda, Polyxenida, Pseudoscorpiones, Scolopendromorpha, Symphyla, Zygentoma) were found, revealing a moderately rich troglofauna community for the Pilbara region, owing to the presence of good prospective troglofauna habitat such as tertiary detrital sediments, calcrete, and sheared Proterozoic rocks. The surveys also revealed fifteen stygofauna taxa from seven higher level taxonomic groups (Amphipoda, Copepoda, Isopoda, Nematoda, Oligochaeta, Rotifera, and Syncarida), representing a relatively sparse stygofauna community for the Pilbara region.

The database searches (WAM, NatureMap, and PSS) yielded no additional species that had not already been recorded from the survey review. In total, 61 stygofauna and potential stygofauna taxa were recorded within the greater regional area (Table 4.1). Twelve stygofauna taxa were recorded from the Kintyre region and 51 stygofauna taxa were recorded from the Telfer region (Table 4.1). Thirty-one troglofauna and potential troglofauna taxa were recorded from the greater regional area (Table 4.1). Twenty-two troglofauna taxa were recorded from the Kintyre region and nine troglofauna taxa were recorded from the Telfer region (Table 4.1).

Based on current knowledge, none of the stygofauna or troglofauna taxa recorded from the vicinity of the Study Area appear on any threatened species lists, however many of these taxa are potential short-range endemics (Table 4.1).

Table 4.1: Subterranean fauna morphospecies recorded in the databases within 65 km of the Study Area (search parameters as per Table 3.1). Note: based on current taxonomic information indeterminate taxa that appeared highly unlikely to represent a unique species within the search area are not included in this table.

Higher Taxonomy	Lowest Identification	Locale in Search Area	Source	Taxonomic Resolution	Distribution	Subterranean Status	SRE Status
Stygofauna							
Nematoda	Nematoda sp. 12 (PSS)	Telfer	PSS	No taxonomic framework	Unknown	Unknown	Unknown
	Nematoda spp.	Telfer, Kintyre	Cameco, Newcrest	No taxonomic framework	Unknown	Unknown	Unknown
Rotifera							
Bdelloidea	Bdelloidea sp. 3:2	Telfer	Newcrest	No taxonomic framework	Unknown	Unknown	Unknown
Flosculariacea	*Filinia* sp.	Kintyre	Cameco	No taxonomic framework	Unknown	Unknown	Unknown
Mollusca	Hydrobiidae sp. B02	Telfer	Newcrest	Undescribed new species	One aquifer	Stygobite	Potential
Annelida							
Polychaeta	*Namanereis pilbarensis*	Telfer	Newcrest	Described but lacks DNA, includes sp. B01	Pilbara wide	Stygobite	Potential
Aphanoneura							
Aeolosomatidae	*Aeolosoma* sp. 1 (PSS)	Telfer	Newcrest	Complex	Unknown	Unknown	Unknown
Clitellata							
Oligochaeta							
Enchytraeidae	*Enchytraeus* sp. PST1/PSS1	Telfer	Newcrest	Complex	Aquifer to catchment scale	Amphibious	Potential
Phreodrilidae	*Insulodrilus* sp.	Telfer	Newcrest	Indeterminate	Aquifer to catchment scale	Unknown	Unknown
	Phreodrilidae dissimilar ventral chaetae.	Telfer	Newcrest	Complex	Aquifer to catchment scale	Stygobite	Potential
	Phreodrilidae similar ventral chaetae	Telfer	Newcrest	Complex	Aquifer to catchment scale	Stygobite	Potential
Naididae (ex Tubificidae)	Tubificidae stygo type 1 (imm *Ainudrilus* ?WA25/26) (PSS)	Telfer	Newcrest, PSS	Likely new species, found in surface waters	Pilbara wide	Stygoxene	No
	Tubificidae `stygo type 5`	Kintyre	Cameco	Likely new species, found in surface waters	Pilbara wide	Stygoxene	No
Arthropoda							
Crustacea							
Amphipoda							
Bogidiellidae	*Bogidiella* sp. B02	Telfer, Kintyre	Cameco, Newcrest	Likely new species	Unknown	Stygobite	Potential
Melitidae	Melitidae sp.	Telfer	Newcrest	Likely new species	Aquifer to catchment scale	Stygobite	Potential
Paramelitidae	Paramelitidae sp. B06	Telfer	Newcrest	Likely new species	Aquifer to catchment scale	Stygobite	Potential
	Paramelitidae sp. B07	Kintyre	Cameco	Likely new species	Aquifer to catchment scale	Stygobite	Potential
	Paramelitidae sp. B10	Telfer	Newcrest	Likely new species	Aquifer to catchment scale	Stygobite	Potential
	Paramelitidae sp. B11	Telfer	Newcrest	Likely new species	Aquifer to catchment scale	Stygobite	Potential
	Paramelitidae sp. B28	Telfer	Newcrest	Likely new species	Aquifer to catchment scale	Stygobite	Potential

Higher Taxonomy	Lowest Identification	Locale in Search Area	Source	Taxonomic Resolution	Distribution	Subterranean Status	SRE Status
	Paramelitidae sp. B30	Telfer	Newcrest	Likely new species	Aquifer to catchment scale	Stygobite	Potential
	Pilbarus sp.	Telfer	Newcrest, PSS	Likely new species	Aquifer to catchment scale	Stygobite	Potential
Isopoda							
Microcerberidae	Microcerberidae sp.	Telfer	Newcrest, PSS	Likely new species	Aquifer to catchment scale	Stygobite	Potential
	Microcerberidae sp. B04	Kintyre	Cameco	Likely new species	Aquifer to catchment scale	Stygobite	Potential
Olibrinidae	*Adoniscus* sp. B01	Telfer	Newcrest	Likely new species	Aquifer to catchment scale	Stygobite	Potential
Syncarida							
Parabathynellidae	*Atopobathynella* sp. B08	Telfer	Newcrest, WAM	Likely new species, ex Hexabathynella `A`	Aquifer to catchment scale	Stygobite	Potential
	Notobathynella sp. B06	Kintyre	Cameco	Likely new species	Aquifer to catchment scale	Stygobite	Potential
	nr *Billibathynella* (*Brevismobathynella*) sp. B08	Telfer	Newcrest	Likely new species	Aquifer to catchment scale	Stygobite	Potential
Copepoda							
Cyclopoida							
Cyclopidae	*Bryocyclops* sp. 1 (PSS)	Telfer	PSS	Likely new species	Unknown	Stygo-phile/bite	Unknown
	Diacyclops cockingi	Telfer	Newcrest, PSS	Described but lacks DNA	Pilbara wide	Stygophile	Unknown
	Diacyclops einslei	Telfer	Newcrest	Described but lacks DNA	Pilbara wide	Stygophile	Unknown
	Diacyclops humphreysi	Telfer	Newcrest	Described but limited DNA suggests a complex	Pilbara wide	Stygophile	Unknown
	Diacyclops scanloni	Telfer	Newcrest	Described but lacks DNA	Pilbara wide	Stygophile	Unlikely
	Fierscyclops (Fierscyclops) fiersi	Telfer	Newcrest	Described but lacks DNA	Pilbara wide	Stygophile	Unlikely
	Halicyclops kieferi	Telfer	Newcrest, PSS	Described but lacks DNA	Pilbara wide	Stygophile	Unlikely
	Mesocyclops sp.	Telfer	Newcrest	Indeterminate	Unknown	Stygo-phile/bite	Unlikely
	Metacyclops sp.	Telfer	PSS	Indeterminate	Unknown	Stygo-phile/bite	Unlikely
	Microcyclops varicans	Telfer	Newcrest	Described but lacks DNA	Pilbara wide	Stygophile	Unlikely
	Orbuscyclops westaustraliensis	Kintyre	Cameco	Described but lacks DNA	Pilbara wide	Stygophile	Unlikely
	Pilbaracyclops frustratio	Telfer	Newcrest, PSS, WAM	Described but lacks DNA	Pilbara wide	Stygophile	Unlikely
Harpacticoida							
Ameiridae	*Abnitocrella* sp. 1 (TOK)	Telfer	Newcrest	Likely new species	Aquifer to catchment scale	Stygobite	Potential
	Abnitocrella sp. B02 (nr *obesa*)	Telfer	Newcrest	Likely new species	Aquifer to catchment scale	Stygobite	Potential
	Megastygonitocrella sp. B03 (nr *ecowisei*)	Telfer	Newcrest	Likely new species	Aquifer to catchment scale	Stygobite	Potential
	Megastygonitocrella trispinosa	Telfer	Newcrest	Described but lacks DNA	Pilbara wide	Stygophile	Potential
	Nitocrella knotti	Telfer	Newcrest	Described but lacks DNA	Aquifer to catchment scale	Stygobite	Potential
	Nitocrella sp. B04 (nr *obesa*)	Kintyre	Cameco	Likely new species	Aquifer to catchment scale	Stygobite	Potential
	Nitocrella sp. B05	Kintyre	Cameco	Likely new species	Aquifer to catchment scale	Stygobite	Potential
	nr *Gordonitocrella* sp. B01	Telfer	Newcrest	Likely new species	Aquifer to catchment scale	Stygobite	Potential
Parastenocarididae	Parastenocaris sp.	Telfer	Newcrest, WAM	Likely new species	Aquifer to catchment scale	Stygobite	Potential
	Parastenocaris sp. B07	Kintyre	Cameco	Likely new species	Aquifer to catchment scale	Stygobite	Potential

Higher Taxonomy	Lowest Identification	Locale in Search Area	Source	Taxonomic Resolution	Distribution	Subterranean Status	SRE Status
	Parastenocaris sp. B20	Kintyre	Cameco	Likely new species	Aquifer to catchment scale	Stygobite	Potential
Ostracoda							
Candonidae	*Areacandona* `4` (PSS)	Telfer	PSS	Likely new species	Aquifer to catchment scale	Stygobite	Potential
	Areacandona arteria	Telfer	PSS	Described but lacks DNA	Pilbara wide	Stygophile	Potential
	Areacandona cf. *iuno*	Telfer	PSS	Described but lacks DNA	Aquifer to catchment scale	Stygo-phile/bite	Potential
	Leicacandona desserti	Telfer	Newcrest	Described but lacks DNA	One aquifer	Stygobite	Potential
	Leicacandona jula	Telfer	Newcrest, Karanovic & McKay 2010	Described but lacks DNA	One aquifer	Stygobite	Potential
	Leicacandona pinkajartinyi	Telfer	Newcrest, Karanovic & McKay 2010	Described but lacks DNA	One aquifer	Stygobite	Potential
	Leicacandona quasilite	Telfer	Newcrest	Described but lacks DNA	One aquifer	Stygobite	Potential
	Leicacandona yandagoogeae	Telfer	PSS	Described but lacks DNA	One aquifer	Stygobite	Potential
Cyprididae	*Cypretta seurati*	Telfer	Newcrest	Described, found in surface waters	Pilbara wide	Stygoxene	No
Limnocytheridae	*Gomphodella* `BOS354`	Telfer	Newcrest	Likely new species	One aquifer	Stygo-phile/bite	Potential
Troglofauna							
Arthropoda							
Arachnida							
Araneae							
Oonopidae	*Prethopalpus* sp. B20	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
	Prethopalpus sp. B28 (nr *kintyre*)	Telfer	Newcrest	Undescribed new species	One deposit	Troglobite	Potential
Palpigradi	Palpigradi sp. B01	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
Pseudoscorpiones	*Lechytia* sp. B03	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
Crustacea							
Isopoda							
Armadillidae	Armadillidae sp. B10	Telfer	Newcrest	Undescribed new species	One deposit	Troglobite	Potential
	Troglarmadillo sp. B19	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
	Troglarmadillo sp. B33	Telfer	Newcrest	Undescribed new species	One deposit	Troglobite	Potential
Oniscidae	*Hanoniscus* sp. B05	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
Hexapoda							
Diplura	Japygidae sp.	Kintyre	Cameco	Likely new species	One deposit	Troglobite	Potential
	Parajapygidae sp. B13	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
	Projapygidae sp. B03	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
	Projapygidae sp. B07	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
	Projapygidae sp. B15	Telfer	Newcrest	Undescribed new species	One deposit	Troglobite	Potential
Insecta							
Blattodea	*Nocticola* sp.	Kintyre	Cameco	Likely new species	One deposit	Troglobite	Potential
Hemiptera							
Enicocephalidae	*Systelloderes* sp.	Kintyre	Cameco	Undescribed new species	Unknown	Troglo-phile/bite	Unknown

Higher Taxonomy	Lowest Identification	Locale in Search Area	Source	Taxonomic Resolution	Distribution	Subterranean Status	SRE Status
Meenoplidae	Meenoplidae sp.	Telfer	Newcrest	Likely new species	Pilbara wide	Troglo-phile/bite	Potential
Zygentoma							
Nicoletiidae	Atelurinae sp. B16	Telfer	Newcrest	Undescribed new species	One deposit	Troglobite	Potential
	Trinemura sp. B07	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
	Trinemura sp. B12	Telfer	Newcrest	Undescribed new species	One deposit	Troglobite	Potential
Myriapoda							
Chilopoda							
Cryptopidae	*Cryptops* sp. B19	Kintyre	Cameco	Likely new species	One deposit	Troglobite	Potential
	nr *Cryptops* sp. B12	Kintyre	Cameco	Likely new species	One deposit	Troglobite	Potential
	nr *Cryptops* sp. B13	Kintyre	Cameco	Likely new species	One deposit	Troglobite	Potential
Diplopoda							
Polyxenida	*Lophoturus madecassus*	Kintyre	Cameco	Complex, ex Lophoproctidae sp. B01	Pilbara wide	Troglo-phile/bite	Potential
Pauropoda	Pauropodidae sp. B21	Telfer	Newcrest	Undescribed new species	One deposit	Troglobite	Potential
	Pauropodidae sp. B24	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
	Pauropodidae sp. B25	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
	Pauropodidae sp. B26	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
Symphyla							
Scutigerellidae	*Scutigerella* sp. B01	Telfer	Newcrest	Undescribed new species	One deposit	Troglobite	Potential
	Scutigerella sp. B02	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
	Symphyella sp. B06	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
	Symphyella sp. B08	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential

4.2 Current survey results

The current survey recorded a total of 573 subterranean fauna specimens, comprising approximately 27% stygofauna (154 specimens), 69% amphibious (398 specimens) and 4% troglofauna (24 specimens). The samples collected from the Havieron Project Area included 15 stygofauna and 167 amphibious animals. No troglofauna were recorded from the Project Area. The records were collected from 74 bores and holes throughout the Study Area, of which 33 are within the Project.

4.2.1 Amphibious Animals

A total of 395 amphibious animals were collected during the current survey, all of which belong to the Oligochaeta family Enchytraeidae. Of these, 386 were identified as one of five distinct morphospecies supported by molecular analysis (Appendix C). The remaining nine specimens were either immature or in too poor condition for proper identification. Enchytraeids collected in this survey were classed as amphibious because they were collected in samples from both above and below the water table, i.e. troglofauna traps and either hauls or haul-scrapes.

Two morphospecies, Enchytraeidae `sp. Biologic-OLIG026` and Enchytraeidae `sp. 12`, were only collected from regional reference sites. The collections of Enchytraeidae `sp. E12` (see Brown *et al.*, 2015) represent the easternmost records for this morphospecies and it now has a known distribution throughout the central and eastern Pilbara and into the Great Sandy Desert. One other morphospecies, Enchytraeidae `sp. Biologic-OLIG024` was recorded from the Project Area and at regional reference sites at Telfer. Two morphospecies, Enchytraeidae `sp. Biologic-OLIG023` and Enchytraeidae `sp. Biologic-OLIG025`, were only collected from within the Project Area, however neither of these were from sites with significant projected drawdown (Figure 4.1).

4.2.2 Stygofauna

A total of 154 stygofauna specimens were collected during the current survey belonging to nine taxonomic groups: nematodes, tubificid and naidid oligochaetes, ostracods, harpacticoid and cyclopoid copepods, syncarids, amphipods, and isopods (Table 4.1)

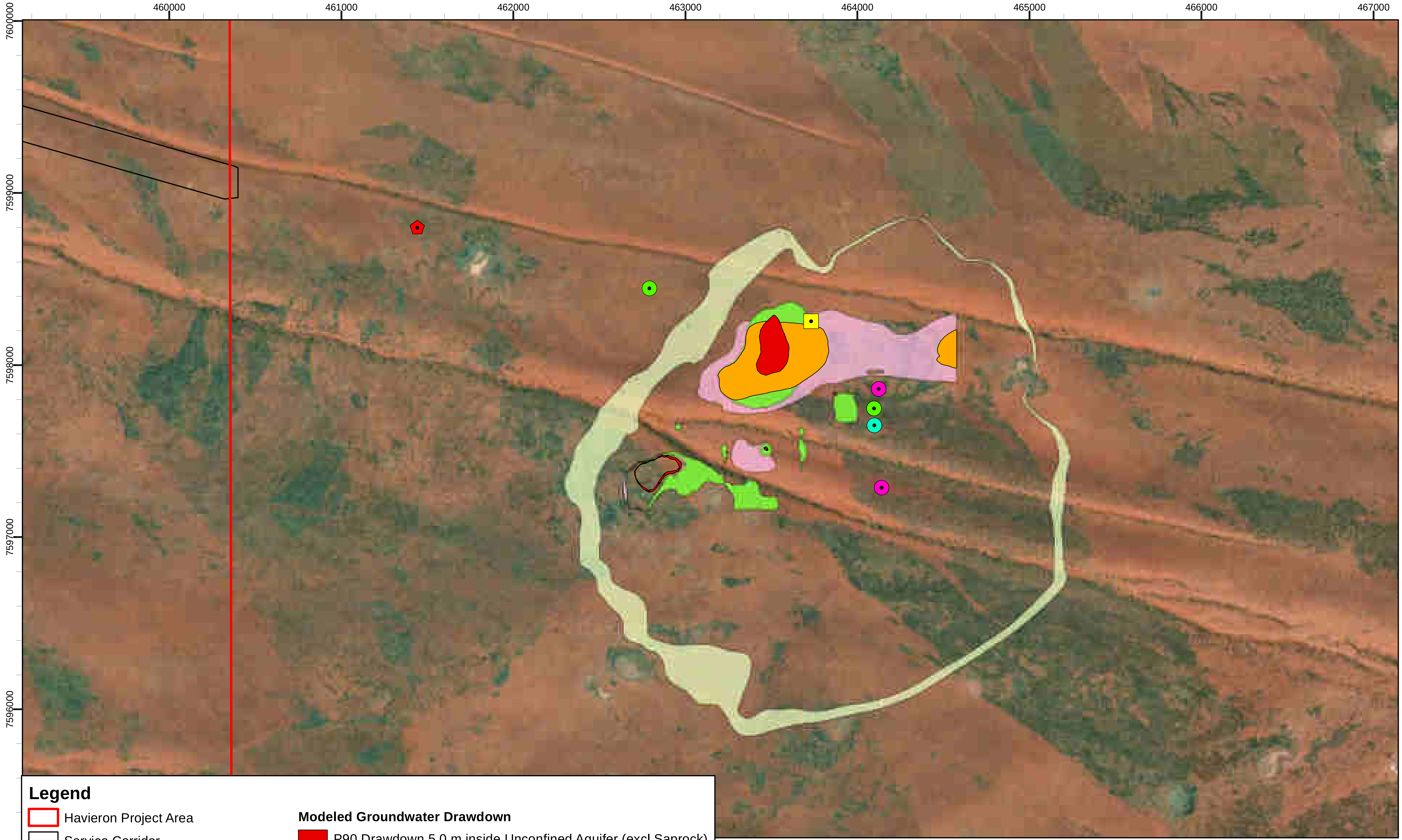
Within the Project Area only two morphospecies was recorded: an amphipod, Paramelitidae `sp. Biologic-AMPH027`, and an ostracod, Humphreyscandonini sp. indet. (Table 4.1, Figure 4.1). Paramelitidae `sp. Biologic-AMPH027` was represented by 11 specimens collected from a single water bore outside of drawdown impacts (Figure 4.1). Humphreyscandonini sp. indet. was represented by two valves (shells) collected in a single sample from within projected drawdown impacts. As only valves were collected and not the entire organism, this specimen could only be identified to tribe. Live, mature animals and extremely intricate dissections of genitalia are needed for accurate identification of ostracods to species level.

See Section 6 for an assessment of potential impacts and risks to subterranean fauna.

Table 4.2:Subterranean results to date, taxonomic and distribution comments, known linear ranges and collection locations

Taxonomy	Havieron (impact)	Havieron (outside impact)	Regional (reference)	Total	Taxonomic resolution	Subterranean status	SRE status	Distribution comments, Known linear range (km)
Stygofauna								
NEMATODA								
Nematoda sp. indet.			**1**	**1**	No taxonomic framework; not assessed in EIAs	Unknown	Unknown	Singleton
OLIGOCHAETA								
Naididae								
Naididae sp. indet.			4	**4**	Indeterminate (family-level)	Stygoxene	Unlikely	Single site
Indeterminate								
Oligochaeta sp. indet.			1	**1**	Indeterminate (subclass-level)	Unknown	Unknown	Singleton
OSTRACODA								
Candonidae								
Humphreyscandonini sp. indet.	2			**2**	Indeterminate (tribe-level)	Stygobite	Potential	Single site
Indeterminate								
Ostacoda sp. indet.			17	**17**	Indeterminate (class-level)	Unknown	Unknown	Known from 5 sites
CYCLOPOIDA								
Cyclopidae								
Fierscyclops (Pilbaracyclops) ?frustatio			1	**1**	Indeterminate (genus-level)	Stygophile	Unlikely	Singleton
Indeterminate								
Cyclopoida sp. indet*			61	**61**	Indeterminate (order-level)	Unknown	Unknown	Known from 3 sites
HARPACTICOIDA								
Harpacticoida sp. indet.			8	**8**	Indeterminate (order-level)	Unknown	Unknown	Known from 4 sites
SYNCARIDA								
Parabathynellidae								
Parabathynellidae sp. indet.			4	**4**	Indeterminate (family-level)	Stygobite	Potential	Single site
AMPHIPODA								
Paramelitidae								
Paramelitidae `sp. Biologic-AMPH025`			10	**10**	Genetically identified (unique lineage)	Stygobite	Potential	Locally restricted (<0.01 km)
Paramelitidae `sp. Biologic-AMPH026`			1	**1**	Genetically identified (unique lineage)	Stygobite	Potential	Singleton
Paramelitidae `sp. Biologic-AMPH027`		11		**11**	Genetically identified (unique lineage)	Stygobite	Potential	Single site
Paramelitidae `sp. Biologic-AMPH028`			4	**4**	Genetically identified (unique lineage)	Stygobite	Potential	Single site
Paramelitidae `sp. Biologic-AMPH029`			15	**15**	Genetically identified (unique lineage)	Stygobite	Potential	Locally restricted (0.4 km)
Paramelitidae `sp. Biologic-AMPH030`			3	**3**	Genetically identified (unique lineage)	Stygobite	Potential	Single site
Paramelitidae `sp. Biologic-AMPH031`			1	**1**	Genetically identified (unique lineage)	Stygobite	Potential	Singleton
Paramelitidae sp. indet.			6	**6**	Indeterminate (family-level)	Stygobite	Potential	Known from 4 sites

ISOPODA								
Microcerberidae								
Microcerberidae sp. indet.			4	**4**		Stygobite	Potential	Known from 2 sites
TOTAL	**2**	**11**	**141**	**154**				
Amphibious								
OLIGOCHAETA								
Enchytraeidae								
Enchytraeidae `sp. Biologic-OLIG023`		142		**142**	Genetically identified (unique lineage)	Amphibious	Potential	Locally restricted (0.58 km)
Enchytraeidae `sp. Biologic-OLIG024`		18	60	**78**	Genetically identified (unique lineage)	Amphibious	No	Regionally widespread (77.2 km)
Enchytraeidae `sp. Biologic-OLIG025`		7		**7**	Genetically identified (unique lineage)	Amphibious	Potential	Locally restricted (1.48 km)
Enchytraeidae `sp. Biologic-OLIG026`			10	**10**	Genetically identified (unique lineage)	Amphibious	Potential	Single site
Enchytraeidae `sp. E12`			149	**149**	Genetically identified (previously detected lineage)	Amphibious	No	Regionally widespread (100+ km[1])
Enchytraeidae sp. indet.			9	**9**	Indeterminate (family-level)	Amphibious	Potential	Single site
TOTAL	**0**	**167**	**228**	**395**				
Troglofauna								
ARACHNIDA								
Palpigradi								
Palpigradi sp. indet.			1	**1**	Indeterminate (order-level)	Troglobite	Potential	Singleton
MYRIAPODA								
Polyxenida								
Polyxenida sp. indet.			8	**8**	Indeterminate (order-level)	Troglophile / Troglobite	Potential	Known from 2 sites
Symphyla								
Symphyla sp. indet.			1	**1**	Indeterminate (class-level)	Troglobite	Potential	Singleton
INSECTA								
Zygentoma								
Atelurinae sp. indet.			12	**12**	Indeterminate (family-level)	Troglobite	Potential	Single site
ISOPODA								
Armadillidae								
Armadillidae sp. indet.			2	**2**	Indeterminate (family-level)	Troglobite	Potential	Known from 2 sites
TOTAL	**0**	**0**	**24**	**24**				



Legend

Havieron Project Area
Service Corridor

Lowest ID_

Enchytraeidae `sp. Biologic-OLIG023`
Enchytraeidae `sp. Biologic-OLIG024`
Enchytraeidae `sp. Biologic-OLIG025`
Humphreyscandonini sp. indet.
Paramelitidae `sp. Biologic-AMPH027`

Modeled Groundwater Drawdown

P90 Drawdown 5.0 m inside Unconfined Aquifer (excl Saprock)
P90 Drawdown 5.0 m inside Unconfined Aquifer (incl Saprock)
P90 Drawdown 2.0 m inside Unconfined Aquifer (excl Saprock)
P90 Drawdown 2.0 m inside Unconfined Aquifer (incl Saprock)
P90 Drawdown 2.0 m inside Upper Confined Aquifer

biologic Environmental Survey

N

1:20,000

0 0.3 0.6 1.2 km

Newcrest Mining Limited
Havieron Project Subterranean Fauna Survey
Fig 4.1: Stygofauna Recorded from within the Project Area

Coordinate System: GDA 1994 MGA Zone 51
Projection: Transverse Mercator
Datum: GDA 1994
Size A3. Created 08/09/2020

5 SUBTERRANEAN HABITAT ASSESSMENT

The habitat assessment for potentially restricted species within the Study Area is based upon available geological and hydrogeological reports, surface geology maps (GSWA, 2020) and three-dimensional geological mapping based on drill-hole logging data in the program Leapfrog® (provided by Rockwater). Groundwater physicochemical measurements taken during the survey were incorporated into the stygofauna habitat assessment where appropriate.

Subterranean fauna habitats are predicated on the occurrence and interconnectedness of subterranean voids, cavities, cracks, porosity, aperture spaces, and caverns, both below and above the water table. The occurrence and distribution of subterranean fauna is influenced or limited by the geology in which they occur. Small and fragmented species ranges, leading to high levels of endemism (EPA, 2003), result from such dispersal limitations. Thus, it is important to identify the type and extent of habitats that are likely to host subterranean fauna.

5.1 Troglofauna habitats (AWT)

Potential AWT habitats for troglofauna (*i.e.* caves, cavities, fractures, vugs, and pore spaces) appear to be very low to absent within the Project. The Study Area lies within the Canning Basin, which was under water during the Jurassic (199.6 – 145.5 Ma) and experienced marine sedimentation (Kellner *et al.*, 2010; Turner *et al.*, 2009). At the Project, the upper 15 m comprises unconsolidated, superficial sediments, which are made of aeolian sand, alluvium and evaporates. The water table lies between 6 and 14 mbgl (metres below ground level).

Troglofauna rely on the presence and continuity of places to live (caves, cavities, fractures, vugs, and pore spaces), high humidity (saturated) and vertical connectivity to supply nutrients and oxygen. The superficial sediments may provide a lot of small pore spaces with high humidity and moderate vertical connectivity; however, they are unconsolidated and highly unlikely to provide continuity across the landscape. The landscape is very flat comprising extensive dunes and together with a shallow water table, may reduce the chances of species persisting during historically wetter times when the water table is elevated.

5.2 Stygofauna habitats

Stygofauna appear in a variety of aquifers, springs, and hyporheos across the world and their existence relies on several current and historical factors. Their persistence depends on vertical connectivity to allow ingress of carbon and nitrogen (Saccò *et al.*, 2019) and lateral connectivity to enable movement. Stygofauna comprise a very diverse range of groups, life histories and adaptations, and although they have been recorded in an expansive range of physiochemical parameters the tolerances are understudied. The first efforts to investigate tolerances are relatively recent and looked at sensitivity of hypogean copepods to agricultural pollutants (Di Lorenzo *et al.*, 2014) and toxicity of arsenic, zinc and chromium to groundwater copepods (Hose *et al.*, 2016). Stygofauna sampling throughout WA has recorded animals from salinities as high as 100,000 mg/L TDS (Outback Ecology, 2012). Stygofauna are known to occur more than 2 km below the surface (Sendra & Reboleira, 2012), although such cave systems are not common in Australia. These very deep communities were found to be generally similar to shallow upper communities, with local ecological and structural factors explaining their distributions (Trontelj *et al.*, 2019).

At the Project, the upper unconfined aquifer appears to represent moderately prospective stygofauna habitat, whereas the two confined aquifers by their nature are unlikely to be prospective, except where they outcrop (away from the Project) and are no longer covered by impermeable layers. The unconsolidated nature of the upper unconfined aquifer is likely to provide reasonable vertical and lateral connectivity and although pore spaces are small, there may be localised patches of calcrete or shallow alluvium that acts as refuges to small communities. The only records of true stygofauna (stygobites) from the Project come from three bores/holes that targeted alluvium/calcrete.

5.3 Groundwater characteristics

Salinity at the Project ranged from fresh to saline (492 to 37,146 mg/L TDS), compared to fresh to brackish around Telfer (120 to 2,874 mg/L TDS). The water at the Project was circum-neutral, ranging from 6.57 to 7.72, compared with a greater range at Telfer (5.94 to 8.77). Similar ORP (redox potential) and oxygen saturation values were recorded at Telfer and the Project, with ORP ranging from -312 to 222 mV and oxygen saturation from 1.7% to 82.4%. Groundwater temperatures ranged from 24.9 to 33.9 degrees. Dissolved oxygen levels varied from 0.13 to 59 ppm. These levels are well within the range suitable for stygofauna.

Redox and DO measurements are typically variable between sites due to individual bore conditions rather than overall aquifer conditions. All bores contained groundwater with sufficient dissolved oxygen for stygofauna to occur (>1 ppm). The redox potential of groundwater is a measure of the system's capacity to oxidise materials through chemical reactions and has important implications for metal mobility, bio-availability and toxicity (Schuring *et al.*, 1999). Stygofauna were only recorded in holes with ORP values greater than -133.7 mV, below salinities of 10,176 mg/L and below dissolved oxygen of 6.7 ppm.

6 RISK ASSESSMENT

Impacts on subterranean fauna may be direct or indirect. Direct impacts cause direct habitat loss and include the removal of habitat, groundwater drawdown, inundation, and water quality changes. Indirect impacts reduce the quality of subterranean habitat and include changes to hydrology, siltation, void collapse, alteration to nutrient balance and contamination (EPA, 2016a). Direct impacts can lead to the extinction of SRE subterranean species, whilst indirect impacts may possibly reduce the population size.

The Project comprises excavation of an underground decline and associated dewatering, both of which may potentially have direct impacts to stygofauna and amphibious fauna, whilst the decline may potentially have a direct impact to troglofauna. The Project includes a waste rock landform that may potentially have an indirect impact on subterranean fauna, through siltation, contamination, or changes to hydrology or nutrient balance.

6.1 Impacts to troglofauna

The decline may potentially have a direct impact to troglofauna, whilst the waste rock landform may potentially have an indirect impact through siltation, contamination, or changes to hydrology or nutrient balance.

6.2 Risks to troglofauna species

Of the 24 troglofauna specimens collected during the current survey, none were recorded from within the Project Area. Most sample sites met EPA guidelines (see Constraints, Section 3.5) and were distributed throughout the Project providing sufficient characterisation of the geologies present. The habitat assessment concluded limited troglofauna habitat is likely to be present at the Project owing to the combination of three factors - low relief, a relatively shallow water table in a geology that lacks structure, continuity and large spaces, and historic marine sedimentation. This habitat assessment is supported by the current survey finding no troglofauna at the Project, when compared with troglofauna records from nearby areas with elevated land features (Telfer, current and historic surveys; Kintyre, historic surveys). The Project appears to be unsuitable for troglofauna species and habitat, though a greatly depauperate community may be present.

Considering the small area of direct and indirect impacts, the lack of troglofauna collected, and lack of suitable troglofauna habitat, the Project is unlikely to pose any risks to troglofauna species.

6.3 Impacts to stygofauna and amphibious species

The Project comprises excavation of an underground decline and associated dewatering, both of which may potentially have direct impacts to stygofauna and amphibious fauna. The waste rock landform may potentially have an indirect impact through siltation, contamination, or changes to hydrology or nutrient balance.

6.4 Risks to stygofauna and amphibious species

It should be noted that some sampling limitations and hole characteristics (See Section 3.5) may have impeded the detection of stygofauna and amphibious fauna within impact areas.

The only records of true stygofauna (stygobites) from the Project came from holes that targeted alluvials and calcareous cement, whereas the large number of amphibious worms collected at the Project and Telfer were collected from various geologies and aquifers. The richness of stygofauna and amphibious species recorded at the Project during the current survey is very low compared to the nearest results at Telfer and Kintyre.

The low richness of stygofauna and amphibious species during the current survey provide strong support that the aquifers in the Project are not prospective for stygofauna, although there appears to be small, localised patches of higher prospect stygofauna habitat present in the Study Area, which are represented by alluvials and calcareous cement, which seem to be associated with claypans in the area. The Claypans may present a unique environment due to the salinity, interactions with significant rainfall events and clayey materials. The Claypan habitat appears associated with the perched aquifer and represents a smaller groundwater system associated with rainfall events. Some interactions with the Upper Confined Aquifer may occur. The amphibious species, on the other hand, appear to be occurring consistently throughout the Study Area, irrespective of geology or aquifer, although likely close to the water table.

Under current groundwater drawdown modelling scenarios, only one taxon appears to be at risk of direct drawdown impact: the ostracod Humphreyscandonini sp. indet. The distributions of stygobitic ostracods in Western Australia range from widespread to highly range-restricted (Reeves *et al.*, 2007). While the identification of Humphreyscandonini sp. indet. is tentative, the family Candonidae is known to contain Confirmed SREs as well as widespread species. This taxon was found from a borehole targeting the patches of alluvials and calcareous cements. While this borehole did extend through both the Upper Unconfined and Upper Confined Aquifers, bore logs strongly suggest the specimen comes from the upper unconfined aquifer, where the geology is highly porous and not under pressure. The Upper Unconfined Aquifer is extensive throughout the Project Area and beyond. Additionally, nearby bore logs indicate approximately 16.5 m of saturated saprolite and saprock at this location. The saprock is modelled to experience 2 - 5 m of drawdown, which will reduce the overall saturated thickness to approximately 11.5 – 14.5 m. This level of impact is likely to be lessened by annual recharge, as the hole is located very close to a claypan, which is a low point in the landscape and likely a greater area of recharge.

Based on current taxonomic and ecological information, modelling of groundwater drawdown and the likely extent of suitable habitats for stygofauna fauna beyond these impacts, Humphreyscandonini sp. indet. was assessed as ‘low risk’ (Table 6.1). All stygofauna/ amphibious fauna risk levels are contingent upon the extent of groundwater drawdown as modelled. Any new information or modelling that changes the spatial extent or magnitude of drawdown, the duration of drawdown, or the duration of subsequent recovery of aquifer habitats following the end of project may result in changes to the potential risks to stygofauna and amphibious taxa.

Table 6.1: Stygofauna risk assessment based on current taxonomic and habitat factors, and distribution relative to impacts

Potentially restricted taxon	Taxonomic factors	Distribution factors	Habitat factors	Risk level	Confidence in risk assessment
Ostracoda					
Humphreyscandonini sp. indet.	Potential Stygobite. Represented by two valves (dead shells). Indeterminate tribe-level taxon identification (Ivana Karanovic), likely unique species.	Known from a single site within modelled groundwater drawdown. Family includes stygophiles with catchment distributions and stygobites only known from single aquifers. Potential SRE (C- Morphology Indicators, E- Research and Expertise). Family includes both widespread and restricted species.	Modelled drawdown at location of record from 2 – 5 m within the Upper Unconfined Aquifer. Modelled drawdown within the Upper Confined Aquifer is 2 m. Habitat (alluvials and calcareous concrete) occurs patchily within the Quaternary cover that forms part of the extensive Upper Unconfined Aquifer. Some interactions between the Upper Unconfined and Upper Confined Aquifers may occur.	**LOW**	**LOW** Due to uncertainty of identification, extent of habitat, limited impact (2 – 5 m) and record from a single site.

7 KEY FINDINGS

The key findings are based on the sampling results of the current survey, available habitat information and current knowledge of the impacts to subterranean fauna:

- There are currently no troglofauna taxa known from the Project Area.
- Geology within the Project Area does not appear to be suitable for troglofauna.
- One stygofauna taxon, Humphreyscandonini sp. indet., is known only from within modelled groundwater drawdown of 2 – 5 m.
- Based on current taxonomic and ecological information, modelling of groundwater drawdown and the likely extent of suitable habitats for stygofauna fauna beyond impacts, the risk to Humphreyscandonini sp. indet. is considered Low.
- Impact to the available stygofauna habitat of the Upper Confined Aquifer, which extends throughout and beyond the Project Area, is likely to be minimal.
- The overall impact to the wider extent of subterranean fauna habitat, and any assemblages occurring therein, is considered negligible.

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9 APPENDICES

Appendix A: Drill and bore holes sampled during the current survey

Hole Name	Latitude	Longitude	Drill Date	Broad Locality	Fine Locality	Site Type
411-BO-117	-21.66467	122.13341	27/05/05	Telfer	Passmore	Reference
BTB5	-21.8862473	122.3759652	Unknown	Telfer	Big Tree	Reference
BTC206001	-21.8896513	122.3851531	Unknown	Telfer	Big Tree	Reference
HAC0301	-21.72578424	122.6557641	10/05/03	Havieron		Impact
HAC9101	-21.72433568	122.6525514	26/08/91	Havieron		Impact
HAC9502	-21.72235922	122.6531041	01/10/95	Havieron		Impact
HAD001	-21.72428227	122.6528487	22/06/19	Havieron		Impact
HAD002	-21.72343188	122.6511956	22/06/19	Havieron		Impact
HAD003	-21.72388803	122.6521318	22/06/19	Havieron		Impact
HAD004	-21.72339361	122.6528467	22/06/19	Havieron		Impact
HAD005	-21.7242942	122.6509157	22/06/19	Havieron		Impact
HAD006	-21.72470424	122.6528248	22/06/19	Havieron		Impact
HAD008	-21.72472012	122.6533363	22/06/19	Havieron		Impact
HAD009A	-21.72520844	122.6562334	22/06/19	Havieron		Impact
HAD010A	-21.72471102	122.6513225	09/06/19	Havieron		Impact
HAD027	-21.72288022	122.6490118	17/09/19	Havieron		Impact
HAD030	-21.72634941	122.6464783	25/09/19	Havieron		Impact
HAE001	-21.72755741	122.6532572	22/03/20	Havieron		Impact
HAE002	-21.68421483	122.5472892	26/03/20	Havieron		Reference
HAE003	-21.69295239	122.5714711	25/03/20	Havieron		Reference
HAE004	-21.71705945	122.6402291	24/03/20	Havieron		Reference
HAE005	-21.71803869	122.6471031	23/03/20	Havieron		Impact
HAE006	-21.71188451	122.6546223	24/03/20	Havieron		Reference
HAE007	-21.72353655	122.6567953	23/03/20	Havieron		Impact
HAE008	-21.72600068	122.6475414	22/03/20	Havieron		Impact
HAE009	-21.67505996	122.5112941	??/03/20	Havieron		Reference
HAE010	-21.72743466	122.6393908	01/04/20	Havieron		Impact
HAE011	-21.72790923	122.6440575	01/04/20	Havieron		Impact
HAE012	-21.73108323	122.6485882	31/03/20	Havieron		Impact
HAE014	-21.72823596	122.6433176	10/04/20	Havieron		Impact
HAHY002	-21.72767245	122.6391829	11/04/20	Havieron		Impact
HAHY007	-21.72093784	122.6582853	17/05/20	Havieron		Impact
HAVUNK02	-21.8873701	122.3796527	Unknown	Telfer	Big Tree	Reference
HAVUNK03	-21.69197262	122.1660277	Unknown	Telfer		Reference
HAVUNK03_2	-21.886917	122.3793304	Unknown	Telfer	Big Tree	Reference
HAVUNK04	-21.67906196	122.2008553	Unknown	Telfer		Reference
HAVWB01	-21.71880564	122.6493049	Unknown	Havieron		Impact
HAVWB02	-21.7190348	122.6492181	Unknown	Havieron		Impact
HAVWB03	-21.7138192	122.6271789	22/09/19	Havieron		Reference
HAVWB04	-21.7228138	122.6490065	29/09/19	Havieron		Impact
HB106	-21.6884548	122.2537054	??/??/88	Telfer	Wilkie Glen	Reference
HB10B	-21.61938784	122.114753	17/03/84	Telfer	Thompsons	Reference
HB144	-21.69270219	122.2252264	Unknown	Telfer		Reference
HB157	-21.7250731	122.2490239	02/07/93	Telfer	Staggers	Reference
HB164	-21.67876958	122.2689355	09/11/93	Telfer	Wilkie Glen	Reference
HB165	-21.67883439	122.2704724	10/11/93	Telfer	Wilkie Glen	Reference
HB225	-21.67927613	122.2011041	01/02/02	Telfer		Reference
HB227	-21.67455999	122.1915715	05/02/02	Telfer		Reference
HB23A	-21.7411884	122.3057203	15/02/93	Telfer	Staggers	Reference
HB243	-21.77179681	122.2587267	27/02/02	Telfer	Staggers	Reference
HB281	-21.67937997	122.1419646	28/03/08	Telfer		Reference
HB326	-21.7941169	122.2615609	01/08/08	Telfer	Prices Fault	Reference
HB400	-21.53877467	121.9340038	10/08/02	Telfer		Reference
HB401	-21.50436285	121.8595696	Unknown	Telfer		Reference
HB402	-21.50430042	121.8596585	26/07/99	Telfer		Reference
HB406	-21.477845	121.7814067	29/09/91	Telfer		Reference
HB407	-21.44265585	121.7073823	05/10/91	Telfer		Reference
HB445	-21.8886664	122.3798653	01/08/91	Telfer	Big Tree	Reference
HB446	-21.8901671	122.3849207	11/08/91	Telfer	Big Tree	Reference
HB447	-21.88464291	122.3794966	13/08/91	Telfer	Big Tree	Reference
HB448	-21.8862437	122.3759739	17/08/91	Telfer	Big Tree	Reference
HB449	-21.8901966	122.3849189	28/08/91	Telfer	Big Tree	Reference
HB67	-21.6892676	122.2619372	17/08/93	Telfer	Wilkie Glen	Reference
HB71	-21.690824	122.2697215	30/09/83	Telfer	Wilkie Glen	Reference
Telfer 73/1	-21.40756755	121.6112586	Unknown	Telfer		Reference
Telfer 84/2	-21.38624244	121.5215411	Unknown	Telfer		Reference

Hole Name	Latitude	Longitude	Drill Date	Broad Locality	Fine Locality	Site Type
TelfUnkT3001	-21.6764433	122.1403883	Unknown	Telfer	Passmore	Reference
TelfUnkT3002	-21.67938024	122.1418494	Unknown	Telfer		Reference
TelfUnkT3003	-21.6721054	122.1379849	Unknown	Telfer		Reference
TelfWindmill	-21.4777417	121.7820067	Unknown	Telfer		Reference
TMR0001	-21.61869209	122.1158671	Unknown	Telfer		Reference
TMR0002	-21.62223048	122.118996	Unknown	Telfer		Reference
TMUNK001	-21.61910151	122.1175142	Unknown	Telfer		Reference
TR103	-21.62561879	122.1216991	Unknown	Telfer		Reference

Appendix B: Sampling effort during the current survey

Borehole	Method	Trip	Sampling Date	Trap Collected
411-BO-117	Scrape	1	22/11/2019	
411-BO-117	Trap	1	22/11/2019	19/02/2020
411-BO-117	Trap	3	2/04/2020	16/06/2020
BTB5	Haul	1	22/11/2019	
BTB5	Haul	3	2/04/2020	
BTB5	Haul	4	16/06/2020	
BTC206001	Scrape	1	22/11/2019	
BTC206001	Trap	1	22/11/2019	20/02/2020
BTC206001	Scrape	3	2/04/2020	
BTC206001	Trap	3	2/04/2020	16/06/2020
HAC0301	Scrape-Haul	1	25/11/2019	
HAC9101	Scrape-Haul	1	24/11/2019	
HAC9101	Trap	1	24/11/2019	19/02/2020
HAC9101	Scrape-Haul	3	31/03/2020	
HAC9101	Trap	3	31/03/2020	15/06/2020
HAC9502	Scrape-Haul	1	25/11/2019	
HAC9502	Trap	1	25/11/2019	19/02/2020
HAC9502	Scrape-Haul	2	19/02/2020	
HAC9502	Scrape-Haul	3	31/03/2020	
HAC9502	Trap	3	31/03/2020	15/06/2020
HAD001	Scrape-Haul	1	24/11/2019	
HAD001	Trap	1	24/11/2019	19/02/2020
HAD001	Scrape-Haul	3	31/03/2020	
HAD001	Trap	3	31/03/2020	15/06/2020
HAD002	Scrape-Haul	1	24/11/2019	
HAD002	Trap	1	24/11/2019	19/02/2020
HAD002	Trap	3	31/03/2020	15/06/2020
HAD003	Scrape-Haul	1	24/11/2019	
HAD003	Trap	1	24/11/2019	19/02/2020
HAD003	Scrape-Haul	3	31/03/2020	
HAD003	Trap	3	31/03/2020	15/06/2020
HAD004	Scrape-Haul	1	23/11/2019	
HAD004	Trap	1	23/11/2019	19/02/2020
HAD004	Scrape-Haul	3	30/03/2020	
HAD004	Trap	3	30/03/2020	15/06/2020
HAD005	Scrape-Haul	1	24/11/2019	
HAD005	Trap	1	24/11/2019	19/02/2020
HAD005	Scrape-Haul	3	1/04/2020	
HAD005	Trap	3	1/04/2020	15/06/2020
HAD006	Scrape-Haul	1	24/11/2019	
HAD006	Trap	1	24/11/2019	19/02/2020
HAD006	Scrape-Haul	3	1/04/2020	
HAD006	Trap	3	1/04/2020	15/06/2020
HAD008	Scrape-Haul	1	24/11/2019	
HAD008	Trap	1	24/11/2019	19/02/2020
HAD008	Scrape-Haul	3	1/04/2020	

Borehole	Method	Trip	Sampling Date	Trap Collected
HAD008	Trap	3	1/04/2020	15/06/2020
HAD009A	Scrape-Haul	1	23/11/2019	
HAD009A	Trap	1	23/11/2019	19/02/2020
HAD009A	Scrape-Haul	3	1/04/2020	
HAD009A	Trap	3	1/04/2020	15/06/2020
HAD010A	Scrape-Haul	1	24/11/2019	
HAD027	Scrape-Haul	2	19/02/2020	
HAD027	Scrape-Haul	3	31/03/2020	
HAD027	Trap	3	31/03/2020	15/06/2020
HAD030	Scrape-Haul	2	19/02/2020	
HAE001	Scrape-Haul	3	30/03/2020	
HAE001	Trap	3	30/03/2020	15/06/2020
HAE001	Scrape-Haul	4	15/06/2020	
HAE002	Haul	3	31/03/2020	
HAE002	Trap	3	31/03/2020	15/06/2020
HAE002	Haul	4	15/06/2020	
HAE003	Scrape-Haul	3	31/03/2020	
HAE003	Trap	3	31/03/2020	15/06/2020
HAE003	Scrape-Haul	4	15/06/2020	
HAE004	Scrape-Haul	3	31/03/2020	
HAE004	Trap	3	31/03/2020	15/06/2020
HAE004	Scrape-Haul	4	15/06/2020	
HAE005	Scrape-Haul	3	31/03/2020	
HAE005	Trap	3	31/03/2020	15/06/2020
HAE005	Scrape-Haul	4	15/06/2020	
HAE006	Scrape-Haul	3	31/03/2020	
HAE006	Trap	3	31/03/2020	15/06/2020
HAE006	Scrape-Haul	4	15/06/2020	
HAE007	Scrape-Haul	3	30/03/2020	
HAE007	Trap	3	30/03/2020	15/06/2020
HAE007	Scrape-Haul	4	15/06/2020	
HAE008	Scrape-Haul	3	30/03/2020	
HAE008	Trap	3	30/03/2020	15/06/2020
HAE008	Scrape-Haul	4	15/06/2020	
HAE009	Scrape-Haul	3	31/03/2020	
HAE009	Trap	3	31/03/2020	15/06/2020
HAE009	Scrape-Haul	4	15/06/2020	
HAE010	Trap	3	3/04/2020	15/06/2020
HAE010	Scrape-Haul	4	15/06/2020	
HAE011	Trap	3	3/04/2020	15/06/2020
HAE011	Scrape-Haul	4	15/06/2020	
HAE012	Trap	3	3/04/2020	15/06/2020
HAE012	Scrape-Haul	4	15/06/2020	
HAE014	Haul	4	16/06/2020	
HAHY002	Haul	4	16/06/2020	
HAHY007	Pump	4	15/06/2020	

Borehole	Method	Trip	Sampling Date	Trap Collected
HAVUNK02	Trap	1	22/11/2019	20/02/2020
HAVUNK02	Scrape-Haul	2	20/02/2020	
HAVUNK02	Trap	3	2/04/2020	16/06/2020
HAVUNK02	Scrape-Haul	4	16/06/2020	
HAVUNK03	Scrape	1	23/11/2019	
HAVUNK03	Trap	1	23/11/2019	20/02/2020
HAVUNK03	Trap	3	3/04/2020	17/06/2020
HAVUNK03	Scrape	4	17/06/2020	
HAVUNK03_2	Trap	1	22/11/2019	19/02/2020
HAVUNK03_2	Scrape	2	20/02/2020	
HAVUNK03_2	Trap	3	2/04/2020	16/06/2020
HAVUNK04	Scrape	1	23/11/2019	
HAVUNK04	Trap	1	23/11/2019	20/02/2020
HAVUNK04	Trap	3	3/04/2020	17/06/2020
HAVUNK04	Scrape	4	17/06/2020	
HAVWB01	Haul	1	25/11/2019	
HAVWB01	Haul	2	19/02/2020	
HAVWB01	Haul	3	31/03/2020	
HAVWB01	Haul	4	16/06/2020	
HAVWB02	Pump	2	19/02/2020	
HAVWB02	Pump	3	31/03/2020	
HAVWB03	Haul	1	24/11/2019	
HAVWB03	Haul	2	19/02/2020	
HAVWB03	Haul	3	31/03/2020	
HAVWB03	Haul	4	16/06/2020	
HAVWB04	Pump	1	25/11/2019	
HB106	Haul	1	22/11/2019	
HB106	Haul	3	1/04/2020	
HB10B	Haul	2	20/02/2020	
HB10B	Haul	3	2/04/2020	
HB144	Haul	4	17/06/2020	
HB157	Haul	1	22/11/2019	
HB157	Haul	3	1/04/2020	
HB164	Haul	1	22/11/2019	
HB164	Haul	4	17/06/2020	
HB165	Haul	1	22/11/2019	
HB165	Haul	3	1/04/2020	
HB165	Haul	4	17/06/2020	
HB225	Haul	1	23/11/2019	
HB225	Haul	4	17/06/2020	
HB227	Haul	1	23/11/2019	
HB227	Haul	4	17/06/2020	
HB23A	Haul	1	22/11/2019	
HB23A	Haul	3	1/04/2020	
HB243	Haul	3	2/04/2020	

Borehole	Method	Trip	Sampling Date	Trap Collected
HB281	Haul	4	17/06/2020	
HB326	Haul	1	22/11/2019	
HB326	Haul	3	2/04/2020	
HB400	Haul	1	21/11/2019	
HB400	Haul	3	2/04/2020	
HB401	Haul	1	21/11/2019	
HB402	Haul	1	21/11/2019	
HB406	Haul	3	2/04/2020	
HB407	Pump	1	21/11/2019	
HB445	Haul	1	22/11/2019	
HB445	Haul	3	2/04/2020	
HB445	Haul	4	16/06/2020	
HB446	Haul	1	22/11/2019	
HB446	Haul	2	20/02/2020	
HB446	Haul	3	2/04/2020	
HB447	Scrape-Haul	2	20/02/2020	
HB447	Scrape-Haul	3	2/04/2020	
HB447	Trap	3	2/04/2020	16/06/2020
HB447	Scrape-Haul	4	16/06/2020	
HB448	Haul	1	22/11/2019	
HB449	Haul	1	22/11/2019	
HB449	Haul	4	16/06/2020	
HB67	Haul	3	1/04/2020	
HB71	Scrape-Haul	3	1/04/2020	
HB71	Trap	3	1/04/2020	16/06/2020
Telfer 73/1	Haul	1	21/11/2019	
Telfer 84/2	Haul	1	21/11/2019	
TelfUnkT3001	Trap	3	2/04/2020	17/06/2020
TelfUnkT3002	Trap	3	2/04/2020	17/06/2020
TelfUnkT3002	Scrape	4	17/06/2020	
TelfUnkT3003	Trap	3	3/04/2020	17/06/2020
TelfUnkT3003	Scrape	4	17/06/2020	
TelfWindmill	Pump	3	2/04/2020	
TMR0001	Scrape	1	21/11/2019	
TMR0001	Trap	1	21/11/2019	20/02/2020
TMR0002	Scrape-Haul	1	22/11/2019	
TMR0002	Trap	1	22/11/2019	20/02/2020
TMR0002	Trap	3	2/04/2020	16/06/2020
TMR0002	Scrape-Haul	4	16/06/2020	
TMUNK001	Scrape	1	22/11/2019	
TMUNK001	Trap	1	22/11/2019	20/02/2020
TMUNK001	Scrape	3	2/04/2020	
TMUNK001	Trap	3	2/04/2020	16/06/2020
TR103	Trap	3	2/04/2020	16/06/2020

Appendix C: Molecular Report



Havieron Project –
Pilot Subterranean Fauna Survey
Molecular Systematics Analysis

Biologic Environmental Survey

Report to Newcrest Mining Limited

August 2020

DOCUMENT STATUS				
Version No.	**Authors**	**Review / Approved for Issue**	**Approved for Issue to**	
			Name	**Date**
1	Joel Huey, Stephanie Floeckner	Nihara Gunawardene	Michael Curran	21/08/2020

GLOSSARY

12S	Mitochondrially encoded 12S ribosomal RNA, a component of the small subunit of the mitochondrial ribosome, which is useful in phylogenetic studies
Bootstrap	Value between 0 and 100 that indicates the robustness of the node in a phylogenetic tree
COI	Cytochrome Oxidase subunit 1, a mitochondrial gene commonly used in phylogenetic studies and used as a DNA barcode to identify species
GenBank	Annotated open access sequence database of all publicly available nucleotide sequences and their protein translations
OTU	Operational taxonomic unit – species-equivalent taxonomic unit based on COI or 12S cluster similarity

1 INTRODUCTION

Newcrest Mining Limited commissioned Biologic Environmental Survey (Biologic) to undertake a molecular systematics analysis (DNA barcoding) of 28 specimens collected from the Havieron Project Area (the Study Area).

1.1 Aims and objectives

The aims and objectives of the molecular systematics analysis were to:

- Undertake DNA sequencing of 28 subterranean fauna specimens to obtain barcoding sequences of the mitochondrial gene Cytochrome Oxidase I (COI; Hebert *et al.*, 2003b). These specimens were comprised of 19 oligochaetes and 9 amphipods;
- Investigate the interspecific and intraspecific relationships between sequences of each higher taxonomic group (*i.e.* use the results of the DNA analysis to indicate how many different species/ OTUs are likely to occur within each group based on published species-thresholds); and
- Investigate the relationships between sequences from the Study Area and relevant previous sequences from the wider Pilbara region, using available DNA databases (*i.e.* compare the results of the current analysis with accessible DNA databases to assess whether any of the species/ OTUs from the Study Area have been collected previously or more widely beyond the Study Area).

This document reports the methods and results of the molecular systematics analysis. All sequence data will be uploaded to GenBank (https://www.ncbi.nlm.nih.gov/genbank/) as per Biologic Molecular Systematics standard procedure.

2 METHODS

2.1 Sub-sample preparation

Specimens were selected for sequencing from survey work undertaken by Biologic. Specimens of oligochaetes and amphipods were to represent geographic and morphological variation across the Study Area. A total of 28 specimens collected from the Study Area by Biologic were selected for molecular systematics analysis (Table 2.1). Adequate redundancy in specimen selection was incorporated to account for any potential sequence generation failure. Specimens in good condition were chosen to increase their DNA extraction potential. Specimen selection was undertaken by Michael Curran.

Whole animals were selected for DNA extraction, where multiple specimens of a putative morpho-type had been collected from a site. Where only a single specimen was available, tissue preparation was undertaken by removing a leg of amphipods, or bisecting the oligochaete specimen, thus retaining taxonomically informative body parts. Tissue was dried briefly to remove ethanol and placed in ATL buffer. Greatest care was taken to decontaminate all tools and equipment between samples, using bleach and repeated rinsing in deionised water. Table 2.1 provides details of the taxonomic orders chosen for molecular analysis. Further taxonomic clarification for each specimen included in the analysis can be found in Appendix A.

Table 2.1: Taxonomic groups from the Study Area included in the analysis, with a summary of PCR and sequencing success.

Class/Subclass	Order	Family	Number of samples	PCR success	Sequence success	% sequence success
Oligochaeta	Haplotaxida	Enchytraeidae	19	19	19	100%
Malacostraca	Amphipoda	Paramelitidae	9	9	9	100%
TOTAL			**28**	**28**	**28**	**100%**

2.2 DNA extraction, amplification and sequencing

DNA extraction and sequencing methods followed Cullen and Harvey (2017, 2018), as follows:

Subsampled tissue/specimen was placed directly into ATL buffer for extraction using the *QIAGEN DN-easy* Blood and Tissue extraction kit, and DNA extraction followed the manufacturer's protocols. DNA extractions were amplified by Polymerase Chain Reaction (PCR) using Folmer PCR primers (LCO1490, HCO2198; Folmer et al., 1994) to assess the variability of COI.

The resulting PCR product was cleaned up and sequenced by the Australian Genomic Research Facility (AGRF) Perth node. Molecular laboratory workflows were managed using GENEIOUS Prime (Kearse *et al.*, 2012) with the Biocode plugin (http://www.mooreabiocode.org). Raw sequence data were edited and assemrbled in GENEIOUS, and final consensus sequences were then available for downstream analysis.

2.3 Specimen selection for comparative analysis

DNA comparisons were typically conducted at the order level (Table 2.1). Comparative sequences were from GenBank (a publicly available DNA sequence database) and Biologic's unpublished DNA sequence libraries (3,135 sequences), using two separate methods.

- BLAST (Basic Local Alignment Search Tool): a method for rapidly searching a DNA sequence library to identify similar sequences. Sequences were searched using the "blastn" function, which returns similar matches.
- Taxonomic Curation: BLAST occasionally fails to identify sequences that could be considered useful for comparison, such as species that might be genetically distant, but are required to be included in the analysis for comparison. Taxonomically relevant specimens were identified using the available taxonomic classifications and identifications in those databases.

The final phylogenies and distance matrices in this report were pruned back to an easily visualised dataset, comprised of those sequences that can be provided to the Client, with any matches to sequences that cannot be provided to the Client discussed in the relevant sections.

2.4 Analysis and interpretation of sequence alignments/divergence

For each taxonomic group, the selected sequences were aligned using the MAFFT (Multiple Alignment using Fast Fourier Transform) algorithm (Katoh *et al.*, 2002). Trees were constructed on resulting alignments using the RaxML plugin in GENEIOUS (Stamatakis, 2014), with 1,000 bootstrap replicates, and the GTR+G substitution model.

To delimit taxonomic units using molecular data, we applied a genetic distance-based threshold method, combined with our morphological identifications. Fauna-specific genetic distance thresholds for delimiting species and OTUs were used wherever possible, based on published literature and available previous reports. Where these thresholds were not available, the assessment used average divergence thresholds for related groups or higher taxa developed by broad-level studies (*e.g.* Hebert *et al.*, 2003a).

In general, ≤8% COI divergence is seen as appropriate to determine OTUs (Hebert et al., 2003a), however, higher or lower divergences are sometimes justified depending on the organism studied. Unless otherwise stated, we considered sequences that exhibited COI divergences ≤8% to belong to the same OTU.

2.5 Constraints and Limitations

The analysis was constrained by the breadth of data available to undertake comparisons, the accessibility of pre-existing regional sequences, and the success rate of genetic sequencing, which can be affected by specimen collection, preservation, storage methods and contamination. Best practises were followed during specimen collection, preservation, and storage, prior to specimens arriving at Biologic's laboratories. All care was taken to ensure that the risks of laboratory contamination, data handling issues, and specimen management issues were minimised within Biologic's laboratories throughout the subsampling, processing and genetic analysis.

The databases used for regional comparisons included GenBank and Biologic's Sequence Library. While these sequence databases, in combination, comprise a large portion of the subterranean fauna genetic work undertaken in Western Australia, it is acknowledged that there may be many other relevant sequences from third party project areas nearby or elsewhere in the region that were not available for comparison at the time of the study. GenBank is dynamic database, and the addition of new sequences and altered taxonomic classifications could not be included into this report if they occurred after the 14th of August 2020.

DNA barcoding using the mitochondrial gene COI, while useful for explaining genetic differences between closely related or moderately related species, is limited in its ability to resolve deeper phylogenetic relationships among taxa at higher taxonomic levels (*e.g.* genus, family, order). In the current study, phylogenetic relationships among species/OTUs at >25% COI divergence are treated with caution. If further resolution of deeper phylogeny is important for project goals, this could be investigated using a multiple gene approach.

3 RESULTS AND DISCUSSION

A total of 28 specimens were processed for sequencing by Biologic. Sequences were successfully derived for all of these specimens (100% of specimens). Of these 28 sequences, all produced a high-quality sequence of the target organism. Therefore, 28 high quality sequences were available for analysis (100% of sequences). The orders of the sequences are tabulated in Table 2.1.

In total, 12 OTUs have been designated to specimens from the Study Area, 11 of these being unique to this survey (Table 3.1). The results of each taxonomic group's analysis are described in the subsequent sections.

Table 3.1: Summary of species and OTUs recovered from 28 samples successfully sequenced in this study, organised by taxon.

Species/OTU	Number of specimens from Study Area	Unique to Study Area?	Linear Distance
Oligochaeta	**19**		
Enchytraeidae `sp. E12`	5	No	>>100 km
Enchytraeidae `sp. Biologic-OLIG023`	4	Yes	0.58 km
Enchytraeidae `sp. Biologic-OLIG024`	5	Yes	77.20 km
Enchytraeidae `sp. Biologic-OLIG025`	4	Yes	1.48 km
Enchytraeidae `sp. Biologic-OLIG026`	1	Yes	-
Amphipoda	**9**		
Paramelitidae `sp. Biologic-AMPH025`	2	Yes	<0.01 km
Paramelitidae `sp. Biologic-AMPH026`	1	Yes	-
Paramelitidae `sp. Biologic-AMPH027`	1	Yes	-
Paramelitidae `sp. Biologic-AMPH028`	1	Yes	-
Paramelitidae `sp. Biologic-AMPH029`	2	Yes	0.4 km
Paramelitidae `sp. Biologic-AMPH030`	1	Yes	-
Paramelitidae `sp. Biologic-AMPH026`	1	Yes	-

3.1 Oligochaeta

The 19 sequenced oligochaete specimens fell into five OTUs (Fig 3.1.1, Table 3.1), which were all ≥9.27% divergent from all other specimens in the analysis (Table 3.1.1).

Five specimens matched a previously sequenced OTU, Enchytraeidae `sp. E12` (Fig. 3.1.1), which has been sampled in the upper Fortescue catchment of the Pilbara region (Brown *et al.*, 2015). This OTU therefore has a large geographic distribution (Table 3.1) and exhibited <4% intraspecific genetic divergence (Table 3.1.1).

Three OTUs were comprised of multiple specimens from multiple sites. Enchytraeidae `sp. Biologic-OLIG023` and Enchytraeidae `sp. Biologic-OLIG025` had small geographic ranges (<2 km, Table .1), but showed moderate intraspecific genetic divergence (7.14% and 5.78%, respectively, Table 3.1.1). Enchytraeidae `sp. Biologic-OLIG024` had a much larger geographic range (77 km, Table 3.1), and displayed moderate intraspecific genetic variation (≤7.3%, Table 3.1.1). A single specimen formed a singleton lineage, Enchytraeidae `sp. Biologic-OLIG026`, which was >18% divergent from all other specimens in the analysis (Table 3.1.1).

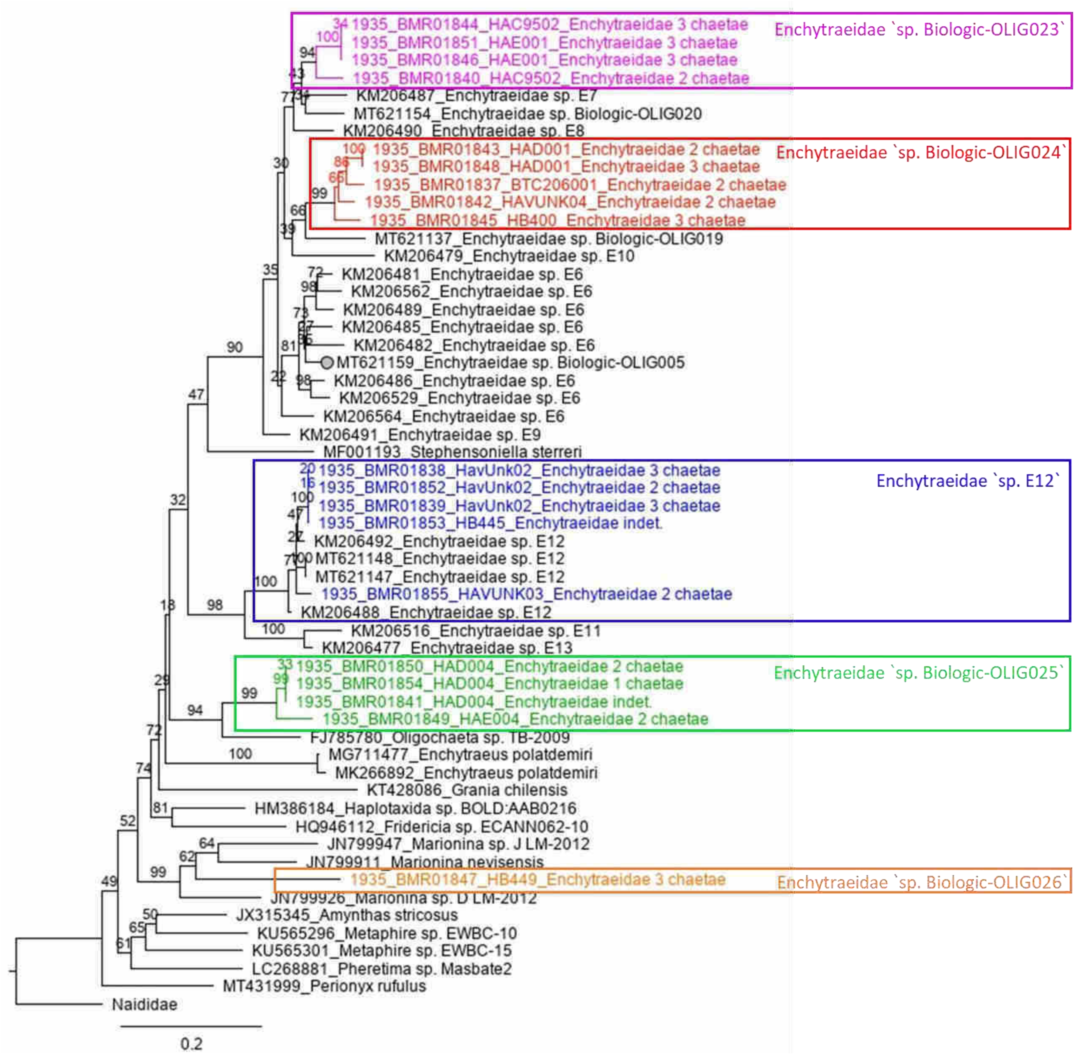

Figure 3.1.1: Maximum Likelihood phylogeny, with bootstrap values.

Table 3.1.1: Pairwise distances for the dataset included in Fig 3.1.1. Colours of OTUs match those in Fig 3.1.1.

COI Pairwise Distances (%)	BMR01837	BMR01843	BMR01848	BMR01842	BMR01845	BMR01840	BMR01844	BMR01846	BMR01851	KM206487	MT621154	KM206490	KM206481	KM206489	KM206562	KM206485	MT621159	KM206486	KM206529	KM206482	KM206564	KM206491	MT621137	KM206479	BMR01838	BMR01839	BMR01852	BMR01853	KM206492	MT621147	MT621148	KM206488	BMR01855	KM206477	KM206516	HM386184	BMR01841	BMR01850	BMR01854	BMR01849	FJ785780	LC268881	JX315345	KU565296	KU565301	MF001193	HQ946112	MG711477	MK266892	MT431999	BMR01847	JN799911	JN799947	JN799926	KT428086	Naididae
1935_BMR01837_BTC206001_Enchytraeidae 2 chaetae		4.56	4.56	5.47	7.30	12.31	13.22	13.22	13.22	13.37	12.46	13.53	12.77	13.22	14.29	13.83	12.92	12.92	13.37	14.29	10.79	12.92	12.31	14.15	17.93	17.93	17.93	17.93	17.48	17.33	17.33	17.02	17.93	16.57	17.78	17.48	18.69	18.69	18.69	19.00	18.14	21.13	19.76	22.34	20.21	17.02	18.24	19.30	19.45	19.48	20.52	20.40	20.70	20.09	20.97	23.40
1935_BMR01843_HAD001_Enchytraeidae 2 chaetae	4.56		0.00	5.62	6.23	12.31	12.77	12.77	12.77	13.83	12.46	13.83	13.68	13.83	13.98	14.44	13.53	12.61	13.68	14.74	10.79	12.77	11.70	12.38	17.63	17.63	17.63	17.63	17.17	17.33	17.33	16.72	17.02	16.72	17.78	17.78	17.33	17.33	17.33	18.24	18.46	20.67	19.61	21.73	20.67	17.02	17.78	19.45	19.30	19.48	20.06	21.46	20.70	20.24	19.61	23.25
1935_BMR01848_HAD001_Enchytraeidae 3 chaetae	4.56	0.00		5.62	6.23	12.31	12.77	12.77	12.77	13.83	12.46	13.83	13.68	13.83	13.98	14.44	13.53	12.61	13.68	14.74	10.79	12.77	11.70	12.38	17.63	17.63	17.63	17.63	17.17	17.33	17.33	16.72	17.02	16.72	17.78	17.78	17.33	17.33	17.33	18.24	18.46	20.67	19.61	21.73	20.67	17.02	17.78	19.45	19.30	19.48	20.06	21.46	20.70	20.24	19.61	23.25
1935_BMR01842_HAVUNK04_Enchytraeidae 2 chaetae	5.47	5.62	5.62		6.23	11.09	12.31	12.31	12.31	13.37	12.46	12.31	13.37	12.92	13.37	13.22	12.77	11.70	12.77	13.83	10.49	12.16	11.40	13.02	17.78	17.78	17.78	17.78	17.48	17.33	17.33	17.33	17.63	16.57	17.93	17.17	18.09	18.09	18.09	18.69	18.78	20.97	19.61	21.28	20.06	17.48	18.54	19.00	20.06	18.71	20.21	20.70	20.09	19.64	19.76	22.80
1935_BMR01845_HB400_Enchytraeidae 3 chaetae	7.30	6.23	6.23	6.23		12.01	12.31	12.31	12.31	12.61	12.31	12.61	13.68	13.07	13.83	13.07	13.37	12.16	13.53	14.89	10.33	13.22	12.31	12.86	17.78	17.78	17.78	17.78	17.33	17.17	17.17	16.72	17.48	17.17	18.39	16.87	17.93	17.93	17.93	18.69	18.78	20.67	19.45	21.43	19.30	17.63	18.24	19.61	20.06	19.33	20.52	21.46	20.70	19.64	20.37	23.10
1935_BMR01840_HAC9502_Enchytraeidae 2 chaetae	12.31	12.31	12.31	11.09	12.01		7.14	7.14	7.14	10.18	9.42	10.03	10.64	11.25	10.64	11.55	11.25	10.49	10.18	11.09	10.33	10.79	12.92	13.51	17.33	17.33	17.33	17.33	17.48	17.02	17.02	17.33	17.02	18.54	18.54	17.78	18.69	18.69	18.69	19.00	18.78	21.13	19.30	20.97	21.43	17.63	19.15	20.37	20.82	19.94	22.34	20.70	20.24	21.01	19.91	22.19
1935_BMR01844_HAC9502_Enchytraeidae 3 chaetae	13.22	12.77	12.77	12.31	12.31	7.14		0.00	0.00	9.27	9.73	10.03	11.70	11.40	11.70	11.55	10.94	10.64	10.03	11.70	11.09	9.88	12.92	13.67	18.09	18.09	18.09	18.09	18.09	17.78	17.78	17.63	18.54	18.69	19.61	18.09	19.30	19.30	19.30	20.37	18.62	21.28	20.82	22.80	21.28	17.48	20.67	20.52	20.82	20.25	21.43	20.85	20.70	21.61	19.15	23.10
1935_BMR01846_HAE001_Enchytraeidae 3 chaetae	13.22	12.77	12.77	12.31	12.31	7.14	0.00		0.00	9.27	9.73	10.03	11.70	11.40	11.70	11.55	10.94	10.64	10.03	11.70	11.09	9.88	12.92	13.67	18.09	18.09	18.09	18.09	18.09	17.78	17.78	17.63	18.54	18.69	19.61	18.09	19.30	19.30	19.30	20.37	18.62	21.28	20.82	22.80	21.28	17.48	20.67	20.52	20.82	20.25	21.43	20.85	20.70	21.61	19.15	23.10
1935_BMR01851_HAE001_Enchytraeidae 3 chaetae	13.22	12.77	12.77	12.31	12.31	7.14	0.00	0.00		9.27	9.73	10.03	11.70	11.40	11.70	11.55	10.94	10.64	10.03	11.70	11.09	9.88	12.92	13.67	18.09	18.09	18.09	18.09	18.09	17.78	17.78	17.63	18.54	18.69	19.61	18.09	19.30	19.30	19.30	20.37	18.62	21.28	20.82	22.80	21.28	17.48	20.67	20.52	20.82	20.25	21.43	20.85	20.70	21.61	19.15	23.10
KM206487_Enchytraeidae sp. E7	13.37	13.83	13.83	13.37	12.61	10.18	9.27	9.27	9.27		9.42	9.69	12.52	12.52	12.07	12.22	12.46	11.18	11.48	12.22	10.88	10.58	12.92	15.22	18.69	18.69	18.69	18.69	18.03	18.24	18.24	17.74	19.00	18.48	18.48	18.09	19.15	19.15	19.15	20.21	18.62	20.67	19.52	21.67	21.52	18.54	21.13	20.37	20.67	21.12	22.49	21.92	20.24	22.37	20.67	22.50
MT621154_Enchytraeidae sp. Biologic-OLIG020	12.46	12.46	12.46	12.46	12.31	9.42	9.73	9.73	9.73	9.42		9.57	11.85	12.61	11.55	12.31	11.85	11.25	11.85	12.16	8.82	10.64	12.31	13.51	15.96	15.96	15.96	15.96	15.65	15.50	15.50	15.50	16.11	16.87	18.24	17.17	18.09	18.09	18.09	18.69	18.14	19.61	19.91	20.67	21.73	16.87	18.24	20.21	20.82	19.48	22.04	20.55	21.01	21.61	18.85	22.04
KM206490_Enchytraeidae sp. E8	13.53	13.83	13.83	12.31	12.61	10.03	10.03	10.03	10.03	9.69	9.57		11.62	11.77	12.07	10.58	11.40	10.43	11.92	11.77	10.13	10.58	13.37	13.94	17.17	17.17	17.17	17.17	16.69	17.17	17.17	16.99	17.63	17.29	18.18	16.41	19.30	19.30	19.30	19.61	20.39	19.61	19.67	20.61	18.94	16.87	20.21	20.06	20.52	20.21	20.37	20.85	19.94	21.46	19.30	21.91
KM206481_Enchytraeidae sp. E6	12.77	13.68	13.68	13.37	13.68	10.64	11.70	11.70	11.70	12.52	11.85	11.62		4.92	5.51	7.45	6.84	7.30	7.15	8.64	9.69	9.84	13.22	14.74	16.26	16.26	16.26	16.26	16.24	16.26	16.26	16.39	17.02	16.69	18.33	17.33	18.85	18.85	18.85	19.91	18.94	20.82	19.52	20.76	19.70	18.24	18.39	20.06	20.67	20.06	20.82	18.87	19.64	19.48	19.61	21.76
KM206489_Enchytraeidae sp. E6	13.22	13.83	13.83	12.92	13.07	11.25	11.40	11.40	11.40	12.52	12.61	11.77	4.92		5.81	6.71	6.69	7.15	7.30	8.35	9.84	10.28	13.22	14.26	16.72	16.72	16.72	16.72	17.14	17.17	17.17	16.84	17.93	16.54	17.44	17.33	18.85	18.85	18.85	19.76	18.78	20.82	18.63	19.85	20.00	18.24	18.85	19.45	20.52	20.21	20.21	19.48	19.18	19.94	19.76	21.76
KM206562_Enchytraeidae sp. E6	14.29	13.98	13.98	13.37	13.83	10.64	11.70	11.70	11.70	12.07	11.55	12.07	5.51	5.81		7.30	7.45	7.75	8.35	9.39	9.99	10.13	13.07	14.10	16.11	16.11	16.11	16.11	16.39	15.81	15.81	16.54	17.02	16.84	17.88	17.93	19.30	19.30	19.30	20.21	18.30	21.73	19.37	19.70	20.30	16.87	18.54	17.93	17.93	20.21	21.28	19.94	19.33	19.48	19.45	21.16
KM206485_Enchytraeidae sp. E6	13.83	14.44	14.44	13.22	13.07	11.55	11.55	11.55	11.55	12.22	12.31	10.58	7.45	6.71	7.30		6.08	7.30	7.75	8.05	10.43	10.28	13.53	14.58	16.57	16.57	16.57	16.57	16.54	16.57	16.57	15.80	17.48	17.29	17.59	17.33	18.69	18.69	18.69	19.91	16.85	20.97	18.63	20.91	19.09	17.33	18.54	19.61	20.21	20.51	19.91	19.33	19.18	19.64	19.45	21.91
MT621159_Enchytraeidae sp. Biologic-OLIG005	12.92	13.53	13.53	12.77	13.37	11.25	10.94	10.94	10.94	12.46	11.85	11.40	6.84	6.69	7.45	6.08		6.84	6.54	7.30	8.82	9.88	13.22	13.34	15.20	15.20	15.20	15.20	15.35	15.05	15.05	15.20	16.11	17.17	18.39	16.72	17.93	17.93	17.93	19.15	18.14	20.37	18.69	20.82	19.00	17.33	19.15	19.15	19.76	20.40	19.91	18.57	20.09	19.18	19.15	22.19
KM206486_Enchytraeidae sp. E6	12.92	12.61	12.61	11.70	12.16	10.49	10.64	10.64	10.64	11.18	11.25	10.43	7.30	7.15	7.75	7.30	6.84		4.47	8.50	8.50	9.99	11.70	12.66	15.81	15.81	15.81	15.81	15.65	15.81	15.81	15.20	16.87	15.65	17.29	16.11	19.00	19.00	19.00	20.21	19.10	20.21	19.23	19.85	19.70	18.24	19.00	19.30	20.06	19.16	20.06	19.79	19.79	20.09	19.15	22.36
KM206529_Enchytraeidae sp. E6	13.37	13.68	13.68	12.77	13.53	10.18	10.03	10.03	10.03	11.48	11.85	11.92	7.15	7.30	8.35	7.75	6.54	4.47		8.35	8.79	9.54	12.31	12.50	16.57	16.57	16.57	16.57	17.29	16.57	16.57	17.14	17.17	17.59	17.74	16.11	18.39	18.39	18.39	19.45	18.30	20.21	19.08	20.76	20.15	17.48	19.45	19.91	20.21	20.97	20.82	20.09	19.48	19.64	19.76	21.31
KM206482_Enchytraeidae sp. E6	14.29	14.74	14.74	13.83	14.89	11.09	11.70	11.70	11.70	12.22	12.16	11.77	8.64	8.35	9.39	8.05	7.30	8.50	8.35		10.88	9.99	13.07	14.26	16.41	16.41	16.41	16.41	16.69	16.26	16.26	15.95	17.63	16.39	17.14	16.26	17.48	17.48	17.48	18.39	19.10	20.52	19.52	20.46	19.39	17.48	18.54	19.76	20.37	21.57	20.82	19.79	18.42	19.64	20.21	21.91
KM206564_Enchytraeidae sp. E6	10.79	10.79	10.79	10.49	10.33	10.33	11.09	11.09	11.09	10.88	8.82	10.13	9.69	9.84	9.99	10.43	8.82	8.50	8.79	10.88		9.39	11.55	11.70	15.50	15.50	15.50	15.50	15.35	14.74	14.74	14.61	15.35	15.95	17.88	17.02	17.78	17.78	17.78	19.30	18.46	20.06	19.82	20.61	19.24	17.63	18.24	20.06	20.67	19.46	19.91	20.55	19.64	19.79	18.54	21.16
KM206491_Enchytraeidae sp. E9	12.92	12.77	12.77	12.16	13.22	10.79	9.88	9.88	9.88	10.58	10.64	10.58	9.84	10.28	10.13	10.28	9.88	9.99	9.54	9.99	9.39		13.53	12.98	15.20	15.20	15.20	15.20	15.20	15.05	15.05	14.90	15.81	16.99	18.33	16.26	18.39	18.39	18.39	19.91	18.46	19.15	19.82	20.30	20.15	15.81	17.78	19.61	20.37	18.85	20.21	18.42	18.42	19.94	18.69	21.61
MT621137_Enchytraeidae sp. Biologic-OLIG019	12.31	11.70	11.70	11.40	12.31	12.92	12.92	12.92	12.92	12.92	12.31	13.37	13.22	13.22	13.07	13.53	13.22	11.70	12.31	13.07	11.55	13.53		15.43	16.87	16.87	16.87	16.87	17.02	17.02	17.02	17.17	17.48	16.41	19.15	17.02	17.78	17.78	17.78	18.85	19.26	20.97	17.78	21.43	20.21	18.24	19.61	18.54	19.30	20.86	21.13	20.40	21.92	21.46	19.76	22.34
KM206479_Enchytraeidae sp. E10	14.15	12.38	12.38	13.02	12.86	13.51	13.67	13.67	13.67	15.22	13.51	13.94	14.74	14.26	14.10	14.58	13.34	12.66	12.50	14.26	11.70	12.98	15.43		17.36	17.36	17.36	17.36	17.79	17.52	17.52	16.83	18.33	19.55	20.19	19.13	18.65	18.65	18.65	18.65	20.78	19.78	19.39	19.87	20.99	18.81	19.45	19.45	19.94	20.09	22.19	21.78	20.17	21.14	18.81	22.28
1935_BMR01838_HavUnk02_Enchytraeidae 3 chaetae	17.93	17.63	17.63	17.78	17.78	17.33	18.09	18.09	18.09	18.69	15.96	17.17	16.26	16.72	16.11	16.57	15.20	15.81	16.57	16.41	15.50	15.20	16.87	17.36		0.00	0.00	0.00	2.58	3.04	3.04	3.19	3.95	13.22	14.59	15.81	18.69	18.69	18.69	19.61	17.18	20.06	19.15	21.28	20.21	17.93	18.69	17.02	17.78	19.33	22.19	19.18	20.85	18.72	20.52	19.76
1935_BMR01839_HavUnk02_Enchytraeidae 3 chaetae	17.93	17.63	17.63	17.78	17.78	17.33	18.09	18.09	18.09	18.69	15.96	17.17	16.26	16.72	16.11	16.57	15.20	15.81	16.57	16.41	15.50	15.20	16.87	17.36	0.00		0.00	0.00	2.58	3.04	3.04	3.19	3.95	13.22	14.59	15.81	18.69	18.69	18.69	19.61	17.18	20.06	19.15	21.28	20.21	17.93	18.69	17.02	17.78	19.33	22.19	19.18	20.85	18.72	20.52	19.76
1935_BMR01852_HavUnk02_Enchytraeidae 2 chaetae	17.93	17.63	17.63	17.78	17.78	17.33	18.09	18.09	18.09	18.69	15.96	17.17	16.26	16.72	16.11	16.57	15.20	15.81	16.57	16.41	15.50	15.20	16.87	17.36	0.00	0.00		0.00	2.58	3.04	3.04	3.19	3.95	13.22	14.59	15.81	18.69	18.69	18.69	19.61	17.18	20.06	19.15	21.28	20.21	17.93	18.69	17.02	17.78	19.33	22.19	19.18	20.85	18.72	20.52	19.76
1935_BMR01853_HB445_Enchytraeidae indet.	17.93	17.63	17.63	17.78	17.78	17.33	18.09	18.09	18.09	18.69	15.96	17.17	16.26	16.72	16.11	16.57	15.20	15.81	16.57	16.41	15.50	15.20	16.87	17.36	0.00	0.00	0.00		2.58	3.04	3.04	3.19	3.95	13.22	14.59	15.81	18.69	18.69	18.69	19.61	17.18	20.06	19.15	21.28	20.21	17.93	18.69	17.02	17.78	19.33	22.19	19.18	20.85	18.72	20.52	19.76
KM206492_Enchytraeidae sp. E12	17.48	17.17	17.17	17.48	17.33	17.48	18.09	18.09	18.09	18.03	15.65	16.69	16.24	17.14	16.39	16.54	15.35	15.65	17.29	16.69	15.35	15.20	17.02	17.79	2.58	2.58	2.58	2.58		2.43	2.43	2.53	3.50	12.97	14.90	15.96	19.00	19.00	19.00	20.06	17.50	19.45	19.23	20.61	20.30	17.78	19.45	17.02	17.78	18.55	21.73	19.48	21.77	18.72	20.37	19.08
MT621147_Enchytraeidae sp. E12	17.33	17.33	17.33	17.33	17.17	17.02	17.78	17.78	17.78	18.24	15.50	17.17	16.26	17.17	15.81	16.57	15.05	15.81	16.57	16.26	14.74	15.05	17.02	17.52	3.04	3.04	3.04	3.04	2.43		0.00	3.04	3.50	13.53	15.50	16.26	19.15	19.15	19.15	20.21	17.66	19.15	19.30	21.43	20.37	18.54	19.30	17.33	17.78	19.33	21.73	19.33	21.16	18.72	20.67	19.91
MT621148_Enchytraeidae sp. E12	17.33	17.33	17.33	17.33	17.17	17.02	17.78	17.78	17.78	18.24	15.50	17.17	16.26	17.17	15.81	16.57	15.05	15.81	16.57	16.26	14.74	15.05	17.02	17.52	3.04	3.04	3.04	3.04	2.43	0.00		3.04	3.50	13.53	15.50	16.26	19.15	19.15	19.15	20.21	17.66	19.15	19.30	21.43	20.37	18.54	19.30	17.33	17.78	19.33	21.73	19.33	21.16	18.72	20.67	19.91
KM206488_Enchytraeidae sp. E12	17.02	16.72	16.72	17.33	16.72	17.33	17.63	17.63	17.63	17.74	15.50	16.99	16.39	16.84	16.54	15.80	15.20	15.20	17.14	15.95	14.61	14.90	17.17	16.83	3.19	3.19	3.19	3.19	2.53	3.04	3.04		3.50	12.37	14.46	15.50	18.39	18.39	18.39	19.30	17.50	19.30	18.63	20.46	19.70	17.17	18.69	16.41	17.02	17.80	20.82	19.33	21.31	18.72	20.21	19.67
1935_BMR01855_HAVUNK03_Enchytraeidae 2 chaetae	17.93	17.02	17.02	17.63	17.48	17.02	18.54	18.54	18.54	19.00	16.11	17.63	17.02	17.93	17.02	17.48	16.11	16.87	17.17	17.63	15.35	15.81	17.48	18.33	3.95	3.95	3.95	3.95	3.50	3.50	3.50	3.50		14.13	15.05	15.96	19.00	19.00	19.00	20.21	17.18	20.06	19.45	21.28	20.67	17.63	18.69	17.63	18.09	19.33	21.43	20.24	21.31	18.11	20.21	19.00
KM206477_Enchytraeidae sp. E13	16.57	16.72	16.72	16.57	17.17	18.54	18.69	18.69	18.69	18.48	16.87	17.29	16.69	16.54	16.84	17.29	17.17	15.65	17.59	16.39	15.95	16.99	16.41	19.55	13.22	13.22	13.22	13.22	12.97	13.53	13.53	12.37	14.13		5.96	17.17	18.24	18.24	18.24	19.61	18.46	20.97	18.33	20.00	19.85	17.17	18.54	19.00	19.30	18.10	20.97	20.09	20.70	19.64	20.52	20.57
KM206516_Enchytraeidae sp. E11	17.78	17.78	17.78	17.93	18.39	18.54	19.61	19.61	19.61	18.48	18.24	18.18	18.33	17.44	17.88	17.59	18.39	17.29	17.74	17.14	17.88	18.33	19.15	20.19	14.59	14.59	14.59	14.59	14.90	15.50	15.50	14.46	15.05	5.96		17.93	18.54	18.54	18.54	19.45	18.78	20.52	20.12	20.61	20.91	18.85	18.24	20.06	19.45	20.81	22.34	21.92	20.55	21.01	22.04	21.31
HM386184_Haplotaxida sp. BOLD:AAB0216	17.48	17.78	17.78	17.17	16.87	17.78	18.09	18.09	18.09	18.09	17.17	16.41	17.33	17.33	17.93	17.33	16.72	16.11	16.11	16.26	17.02	16.26	17.02	19.13	15.81	15.81	15.81	15.81	15.96	16.26	16.26	15.50	15.96	17.17	17.93		18.39	18.39	18.39	19.45	17.98	18.09	16.87	20.37	17.17	16.57	16.57	19.30	19.61	19.17	20.06	19.33	19.48	18.42	21.73	18.54
1935_BMR01841_HAD004_Enchytraeidae indet.	18.69	17.33	17.33	18.09	17.93	18.69	19.30	19.30	19.30	19.15	18.09	19.30	18.85	18.85	19.30	18.69	17.93	19.00	18.39	17.48	17.78	18.39	17.78	18.65	18.69	18.69	18.69	18.69	19.00	19.15	19.15	18.39	19.00	18.24	18.54	18.39		0.00	0.00	5.78	13.97	16.41	17.33	17.17	19.00	17.17	17.02	18.69	19.30	19.79	22.80	19.94	19.79	19.48	20.67	20.82
1935_BMR01850_HAD004_Enchytraeidae 2 chaetae	18.69	17.33	17.33	18.09	17.93	18.69	19.30	19.30	19.30	19.15	18.09	19.30	18.85	18.85	19.30	18.69	17.93	19.00	18.39	17.48	17.78	18.39	17.78	18.65	18.69	18.69	18.69	18.69	19.00	19.15	19.15	18.39	19.00	18.24	18.54	18.39	0.00		0.00	5.78	13.97	16.41	17.33	17.17	19.00	17.17	17.02	18.69	19.30	19.79	22.80	19.94	19.79	19.48	20.67	20.82
1935_BMR01854_HAD004_Enchytraeidae 1 chaetae	18.69	17.33	17.33	18.09	17.93	18.69	19.30	19.30	19.30	19.15	18.09	19.30	18.85	18.85	19.30	18.69	17.93	19.00	18.39	17.48	17.78	18.39	17.78	18.65	18.69	18.69	18.69	18.69	19.00	19.15	19.15	18.39	19.00	18.24	18.54	18.39	0.00	0.00		5.78	13.97	16.41	17.33	17.17	19.00	17.17	17.02	18.69	19.30	19.79	22.80	19.94	19.79	19.48	20.67	20.82
1935_BMR01849_HAE004_Enchytraeidae 2 chaetae	19.00	18.24	18.24	18.69	18.69	19.00	20.37	20.37	20.37	20.21	18.69	19.61	19.91	19.76	20.21	19.91	19.15	20.21	19.45	18.39	19.30	19.91	18.85	18.65	19.61	19.61	19.61	19.61	20.06	20.21	20.21	19.30	20.21	19.61	19.45	19.45	5.78	5.78	5.78		15.25	17.78	18.39	17.78	19.76	18.39	18.24	18.09	18.54	20.55	24.47	21.01	21.31	19.79	20.67	21.28
FJ785780_Oligochaeta sp. TB-2009	18.14	18.46	18.46	18.78	18.78	18.78	18.62	18.62	18.62	18.62	18.14	20.39	18.94	18.78	18.30	16.85	18.14	19.10	18.30	19.10	18.46	18.46	19.26	20.78	17.18	17.18	17.18	17.18	17.50	17.66	17.66	17.50	17.18	18.46	18.78	17.98	13.97	13.97	13.97	15.25		19.90	18.46	19.42	19.26	16.21	17.34	19.26	19.74	19.26	23.44	19.90	19.42	19.74	20.71	19.58
LC268881_Pheretima sp. Masbate2	21.13	20.67	20.67	20.97	20.67	21.13	21.28	21.28	21.28	20.67	19.61	19.61	20.82	20.82	21.73	20.97	20.37	20.21	20.21	20.52	20.06	19.15	20.97	19.78	20.06	20.06	20.06	20.06	19.45	19.15	19.15	19.30	20.06	20.97	20.52	18.09	16.41	16.41	16.41	17.78	19.90		16.41	17.17	17.17	20.37	20.21	21.88	22.95	18.56	20.06	20.40	18.27	20.55	20.97	20.06
JX315345_Amynthas stricosus	19.76	19.61	19.61	19.61	19.45	19.30	20.82	20.82	20.82	19.52	19.91	19.67	19.52	18.63	19.37	18.63	18.69	19.23	19.08	19.52	19.82	19.82	17.78	19.39	19.15	19.15	19.15	19.15	19.23	19.30	19.30	18.63	19.45	18.33	20.12	16.87	17.33	17.33	17.33	18.39	18.46	16.41		13.64	14.85	17.63	18.69	19.45	19.76	16.37	21.13	19.48	19.33	17.96	20.97	19.79
KU565296_Metaphire sp. EWBC-10	22.34	21.73	21.73	21.28	21.43	20.97	22.80	22.80	22.80	21.67	20.67	20.61	20.76	19.85	19.70	20.91	20.82	19.85	20.76	20.46	20.61	20.30	21.43	19.87	21.28	21.28	21.28	21.28	20.61	21.43	21.43	20.46	21.28	20.00	20.61	20.37	17.17	17.17	17.17	17.78	19.42	17.17	13.64		17.42	19.00	19.00	20.82	21.28	17.64	23.40	20.70	18.72	18.27	20.06	20.46
KU565301_Metaphire sp. EWBC-15	20.21	20.67	20.67	20.06	19.30	21.43	21.28	21.28	21.28	21.52	21.73	18.94	19.70	20.00	20.30	19.09	19.00	19.70	20.15	19.39	19.24	20.15	20.21	20.99	20.21	20.21	20.21	20.21	20.30	20.37	20.37	19.70	20.67	19.85	20.91	17.17	19.00	19.00	19.00	19.76	19.26	17.17	14.85	17.42		19.61	19.15	19.76	20.21	18.56	18.85	18.11	19.03	19.48	21.58	21.82
MF001193_Stephensoniella sterreri	17.02	17.02	17.02	17.48	17.63	17.63	17.48	17.48	17.48	18.54	16.87	16.87	18.24	18.24	16.87	17.33	17.33	18.24	17.48	17.48	17.63	15.81	18.24	18.81	17.93	17.93	17.93	17.93	17.78	18.54	18.54	17.17	17.63	17.17	18.85	16.57	17.17	17.17	17.17	18.39	16.21	20.37	17.63	19.00	19.61		16.41	18.54	19.30	20.25	22.64	17.81	19.03	19.33	19.91	19.45
HQ946112_Fridericia sp. ECANN062-10	18.24	17.78	17.78	18.54	18.24	19.15	20.67	20.67	20.67	21.13	18.24	20.21	18.39	18.85	18.54	18.54	19.15	19.00	19.45	18.54	18.24	17.78	19.61	19.45	18.69	18.69	18.69	18.69	19.45	19.30	19.30	18.69	18.69	18.54	18.24	16.57	17.02	17.02	17.02	18.24	17.34	20.21	18.69	19.00	19.15	16.41		20.52	20.67	19.63	20.67	19.33	19.79	19.03	20.21	21.43
MG711477_Enchytraeus polatdemiri	19.30	19.45	19.45	19.00	19.61	20.37	20.52	20.52	20.52	20.37	20.21	20.06	20.06	19.45	17.93	19.61	19.15	19.30	19.91	19.76	20.06	19.61	18.54	19.45	17.02	17.02	17.02	17.02	17.02	17.33	17.33	16.41	17.63	19.00	20.06	19.30	18.69	18.69	18.69	18.09	19.26	21.88	19.45	20.82	19.76	18.54	20.52		1.52	20.40	21.73	21.16	21.31	18.42	20.37	23.10
MK266892_Enchytraeus polatdemiri	19.45	19.30	19.30	20.06	20.06	20.82	20.82	20.82	20.82	20.67	20.82	20.52	20.67	20.52	17.93	20.21	19.76	20.06	20.21	20.37	20.67	20.37	19.30	19.94	17.78	17.78	17.78	17.78	17.78	17.78	17.78	17.02	18.09	19.30	19.45	19.61	19.30	19.30	19.30	18.54	19.74	22.95	19.76	21.28	20.21	19.30	20.67	1.52		20.71	21.73	21.46	21.61	18.72	20.67	23.40
MT431999_Perionyx rufulus	19.48	19.48	19.48	18.71	19.33	19.94	20.25	20.25	20.25	21.12	19.48	20.21	20.06	20.21	20.21	20.51	20.40	19.16	20.97	21.57	19.46	18.85	20.86	20.09	19.33	19.33	19.33	19.33	18.55	19.33	19.33	17.80	19.33	18.10	20.81	19.17	19.79	19.79	19.79	20.55	19.26	18.56	16.37	17.64	18.56	20.25	19.63	20.40	20.71		19.94	19.17	21.32	19.33	18.87	19.76
1935_BMR01847_HB449_Enchytraeidae 3 chaetae	20.52	20.06	20.06	20.21	20.52	22.34	21.43	21.43	21.43	22.49	22.04	20.37	20.82	20.21	21.28	19.91	19.91	20.06	20.82	20.82	19.91	20.21	21.13	22.19	22.19	22.19	22.19	22.19	21.73	21.73	21.73	20.82	21.43	20.97	22.34	20.06	22.80	22.80	22.80	24.47	23.44	20.06	21.13	23.40	18.85	22.64	20.67	21.73	21.73	19.94		18.27	19.48	18.72	19.91	25.53
JN799911_Marionina nevisensis	20.40	21.46	21.46	20.70	21.46	20.70	20.85	20.85	20.85	21.92	20.55	20.85	18.87	19.48	19.94	19.33	18.57	19.79	20.09	19.79	20.55	18.42	20.40	21.78	19.18	19.18	19.18	19.18	19.48	19.33	19.33	19.33	20.24	20.09	21.92	19.33	19.94	19.94	19.94	21.01	19.90	20.40	19.48	20.70	18.11	17.81	19.33	21.16	21.46	19.17	18.27		15.83	16.44	22.68	23.14
JN799947_Marionina sp. J LM-2012	20.70	20.70	20.70	20.09	20.70	20.24	20.70	20.70	20.70	20.24	21.01	19.94	19.64	19.18	19.33	19.18	20.09	19.79	19.48	18.42	19.64	18.42	21.92	20.17	20.85	20.85	20.85	20.85	21.77	21.16	21.16	21.31	21.31	20.70	20.55	19.48	19.79	19.79	19.79	21.31	19.42	18.27	19.33	18.72	19.03	19.03	19.79	21.31	21.61	21.32	19.48	15.83		17.20	20.85	21.46
JN799926_Marionina sp. D LM-2012	20.09	20.24	20.24	19.64	19.64	21.01	21.61	21.61	21.61	22.37	21.61	21.46	19.48	19.94	19.48	19.64	19.18	20.09	19.64	19.64	19.79	19.94	21.46	21.14	18.72	18.72	18.72	18.72	18.72	18.72	18.72	18.72	18.11	19.64	21.01	18.42	19.48	19.48	19.48	19.79	19.74	20.55	17.96	18.27	19.48	19.33	19.03	18.42	18.72	19.33	18.72	16.44	17.20		20.09	21.31
KT428086_Grania chilensis	20.97	19.61	19.61	19.76	20.37	19.91	19.15	19.15	19.15	20.67	18.85	19.30	19.61	19.76	19.45	19.45	19.15	19.15	19.76	20.21	18.54	18.69	19.76	18.81	20.52	20.52	20.52	20.52	20.37	20.67	20.67	20.21	20.21	20.52	22.04	21.73	20.67	20.67	20.67	20.67	20.71	20.97	20.97	20.06	21.58	19.91	20.21	20.37	20.67	18.87	19.91	22.68	20.85	20.09		22.19
Naididae	23.40	23.25	23.25	22.80	23.10	22.19	23.10	23.10	23.10	22.50	22.04	21.91	21.76	21.76	21.16	21.91	22.19	22.36	21.31	21.91	21.16	21.61	22.34	22.28	19.76	19.76	19.76	19.76	19.08	19.91	19.91	19.67	19.00	20.57	21.31	18.54	20.82	20.82	20.82	21.28	19.58	20.06	19.79	20.46	21.82	19.45	21.43	23.10	23.40	19.76	25.53	23.14	21.46	21.31	22.19	

3.2 Amphipoda

The nine amphipod sequences represented seven OTUs, all unique to the Study Area (Fig. 3.2.1, Table 3.1). All these OTUs showed interspecific genetic distances over 12% within the Study Area (Table 3.2.1). Only two OTUs had more than one specimen, and in both cases, they were sampled from two sites, less than 400 m apart (Table 3.1), with no genetic variation within the OTUs.

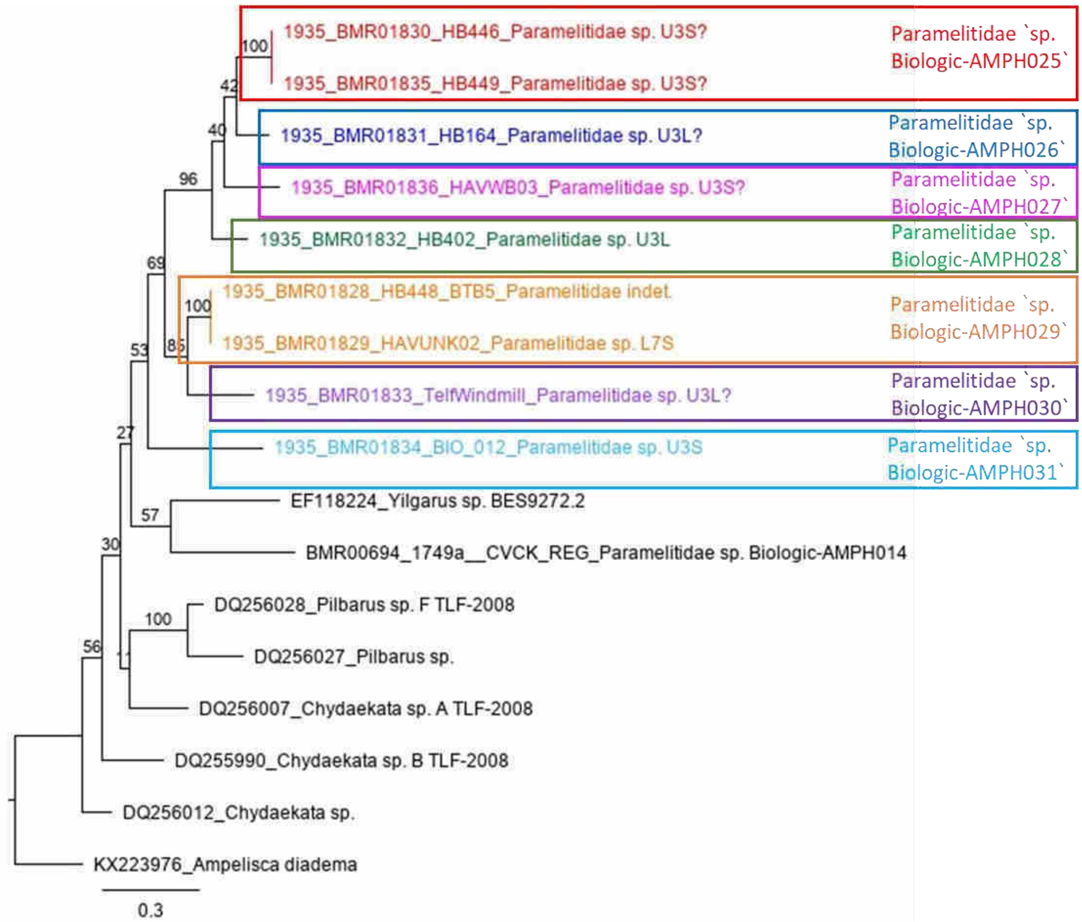

Figure 3.2.1: Maximum Likelihood phylogeny, with bootstrap values.

Table 3.2.1: Pairwise distances for the dataset included in Fig 3.2.1. Colours of OTUs match those in Fig 3.2.1.

COI Pairwise Distances (%)	BMR01828	BMR01829	BMR01833	BMR01830	BMR01835	BMR01831	BMR01832	BMR01836	DQ255990	DQ256007	DQ256012	DQ256027	DQ256028	KX223976	BMR01834	EF118224	BMR00694
1935_BMR01828_HB448_BTB5_Paramelitidae indet.		0.00	14.13	17.93	17.93	17.63	16.87	19.45	17.02	16.26	17.37	18.81	19.61	23.56	21.13	19.90	21.81
1935_BMR01829_HAVUNK02_Paramelitidae sp. L7S	0.00		14.13	17.93	17.93	17.63	16.87	19.45	17.02	16.26	17.37	18.81	19.61	23.56	21.13	19.90	21.81
1935_BMR01833_TelfWindmill_Paramelitidae sp. U3L?	14.13	14.13		20.06	20.06	20.67	19.15	21.13	20.67	21.28	21.75	22.88	21.73	28.12	21.88	22.99	25.35
1935_BMR01830_HB446_Paramelitidae sp. U3S?	17.93	17.93	20.06		0.00	12.31	13.98	14.59	20.06	20.37	20.50	20.53	20.52	25.68	19.45	22.99	22.58
1935_BMR01835_HB449_Paramelitidae sp. U3S?	17.93	17.93	20.06	0.00		12.31	13.98	14.59	20.06	20.37	20.50	20.53	20.52	25.68	19.45	22.99	22.58
1935_BMR01831_HB164_Paramelitidae sp. U3L?	17.63	17.63	20.67	12.31	12.31		14.13	13.98	20.21	20.67	18.62	19.91	20.82	23.40	21.73	22.13	23.96
1935_BMR01832_HB402_Paramelitidae sp. U3L	16.87	16.87	19.15	13.98	13.98	14.13		15.96	22.95	20.67	18.62	22.10	21.88	23.10	22.34	22.47	25.35
1935_BMR01836_HAVWB03_Paramelitidae sp. U3S?	19.45	19.45	21.13	14.59	14.59	13.98	15.96		20.06	22.80	20.34	21.16	20.67	23.25	21.28	24.70	23.35
DQ255990_Chydaekata sp. B TLF-2008	17.02	17.02	20.67	20.06	20.06	20.21	22.95	20.06		17.93	15.96	19.75	17.63	22.49	19.76	20.07	22.73
DQ256007_Chydaekata sp. A TLF-2008	16.26	16.26	21.28	20.37	20.37	20.67	20.67	22.80	17.93		14.87	17.71	17.02	21.88	22.19	19.38	21.20
DQ256012_Chydaekata sp.	17.37	17.37	21.75	20.50	20.50	18.62	18.62	20.34	15.96	14.87		19.84	19.25	17.84	20.81	21.44	21.80
DQ256027_Pilbarus sp.	18.81	18.81	22.88	20.53	20.53	19.91	22.10	21.16	19.75	17.71	19.84		12.07	21.63	23.82	22.13	23.04
DQ256028_Pilbarus sp. F TLF-2008	19.61	19.61	21.73	20.52	20.52	20.82	21.88	20.67	17.63	17.02	19.25	12.07		21.28	20.67	20.76	22.43
KX223976_Ampelisca diadema	23.56	23.56	28.12	25.68	25.68	23.40	23.10	23.25	22.49	21.88	17.84	21.63	21.28		25.53	24.36	25.81
1935_BMR01834_BIO_012_Paramelitidae sp. U3S	21.13	21.13	21.88	19.45	19.45	21.73	22.34	21.28	19.76	22.19	20.81	23.82	20.67	25.53		24.53	22.58
EF118224_Yilgarus sp. BES9272.2	19.90	19.90	22.99	22.99	22.99	22.13	22.47	24.70	20.07	19.38	21.44	22.13	20.76	24.36	24.53		21.27
BMR00694_1749a__CVCK_REG_Paramelitidae sp. Biologic-AMPH014	21.81	21.81	25.35	22.58	22.58	23.96	25.35	23.35	22.73	21.20	21.80	23.04	22.43	25.81	22.58	21.27	

4 SUMMARY

Using well-established DNA extraction and sequencing methods, this molecular systematics analysis designated 12 distinct species/ OTUs to 28 high quality sequences from the Study Area. All OTUs, the areas in which they were found, and the specimen numbers per OTU are shown in Appendix A. The following are the key findings at the species/ OTU level:

- Oligochaeta (COI): five OTUs, four unique lineages, one matching a external sequences,
- Amphipoda (COI): seven OTUs, all unique lineages.

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Appendix 1: All Operational Taxonomic Units (OTUs) found in the Study Area.

BMR	Unique ID code	Site	Latitude	Longitude	Family	Lowest ID Legacy	OTU Name	Reaction State
Oligochaeta								
BMR01837	7361	BTC206001	-21.88965	122.38515	Enchytraeidae	Enchytraeidae 2 chaetae	Enchytraeidae `sp. Biologic-OLIG024`	PASS
BMR01838	6362	HavUnk02	-21.88737	122.37965	Enchytraeidae	Enchytraeidae 3 chaetae	Enchytraeidae `sp. E12`	PASS
BMR01839	6373	HavUnk02	-21.88737	122.37965	Enchytraeidae	Enchytraeidae 3 chaetae	Enchytraeidae `sp. E12`	PASS
BMR01840	6418	HAC9502	-21.72233	122.65311	Enchytraeidae	Enchytraeidae 2 chaetae	Enchytraeidae `sp. Biologic-OLIG023`	PASS
BMR01841	6438	HAD004	-21.72342	122.65285	Enchytraeidae	Enchytraeidae indet.	Enchytraeidae `sp. Biologic-OLIG025`	PASS
BMR01842	6511	HAVUNK04	-21.67906	122.20086	Enchytraeidae	Enchytraeidae 2 chaetae	Enchytraeidae `sp. Biologic-OLIG024`	PASS
BMR01843	6684	HAD001	-21.72430	122.65286	Enchytraeidae	Enchytraeidae 2 chaetae	Enchytraeidae `sp. Biologic-OLIG024`	PASS
BMR01844	7085	HAC9502	-21.72233	122.65311	Enchytraeidae	Enchytraeidae 3 chaetae	Enchytraeidae `sp. Biologic-OLIG023`	PASS
BMR01845	7183	HB400	-21.53877	121.93400	Enchytraeidae	Enchytraeidae 3 chaetae	Enchytraeidae `sp. Biologic-OLIG024`	PASS
BMR01846	7275	HAE001	-21.72754	122.65326	Enchytraeidae	Enchytraeidae 3 chaetae	Enchytraeidae `sp. Biologic-OLIG023`	PASS
BMR01847	7390	HB449	-21.89020	122.38492	Enchytraeidae	Enchytraeidae 3 chaetae	Enchytraeidae `sp. Biologic-OLIG026`	PASS
BMR01848	7854	HAD001	-21.72430	122.65286	Enchytraeidae	Enchytraeidae 3 chaetae	Enchytraeidae `sp. Biologic-OLIG024`	PASS
BMR01849	7950	HAE004	-21.71708	122.64032	Enchytraeidae	Enchytraeidae 2 chaetae	Enchytraeidae `sp. Biologic-OLIG025`	PASS
BMR01850	8478	HAD004	-21.72342	122.65285	Enchytraeidae	Enchytraeidae 2 chaetae	Enchytraeidae `sp. Biologic-OLIG025`	PASS
BMR01851	8550	HAE001	-21.72754	122.65326	Enchytraeidae	Enchytraeidae 3 chaetae	Enchytraeidae `sp. Biologic-OLIG023`	PASS
BMR01852	8557	HavUnk02	-21.88737	122.37965	Enchytraeidae	Enchytraeidae 2 chaetae	Enchytraeidae `sp. E12`	PASS
BMR01853	8570	HB445	-21.88867	122.37987	Enchytraeidae	Enchytraeidae indet.	Enchytraeidae `sp. E12`	PASS
BMR01854	8574	HAD004	-21.72342	122.65285	Enchytraeidae	Enchytraeidae 1 chaetae	Enchytraeidae `sp. Biologic-OLIG025`	PASS
BMR01855	8583	HAVUNK03	-21.69197	122.16603	Enchytraeidae	Enchytraeidae 2 chaetae	Enchytraeidae `sp. E12`	PASS
Amphipoda								
BMR01828	7893	BTB5	-21.88625	122.37597	Paramelitidae	Paramelitidae indet.	Paramelitidae `sp. Biologic-AMPH029`	PASS
BMR01829	6094	HavUnk02	-21.88737	122.37965	Paramelitidae	Paramelitidae sp. L7S	Paramelitidae `sp. Biologic-AMPH029`	PASS
BMR01830	6115	HB446	-21.89017	122.38492	Paramelitidae	Paramelitidae sp. U3S?	Paramelitidae `sp. Biologic-AMPH025`	PASS
BMR01831	6186	HB164	-21.67877	122.26894	Paramelitidae	Paramelitidae sp. U3L?	Paramelitidae `sp. Biologic-AMPH026`	PASS
BMR01832	6762	HB402	-21.50430	121.85966	Paramelitidae	Paramelitidae sp. U3L	Paramelitidae `sp. Biologic-AMPH028`	PASS
BMR01833	7886	TelfWindmill	-21.47774	121.78201	Paramelitidae	Paramelitidae sp. U3L?	Paramelitidae `sp. Biologic-AMPH030`	PASS
BMR01834	8544	HAE009	-21.67508	122.51007	Paramelitidae	Paramelitidae sp. U3S	Paramelitidae `sp. Biologic-AMPH031`	PASS
BMR01835	8561	HB449	-21.89020	122.38492	Paramelitidae	Paramelitidae sp. U3S?	Paramelitidae `sp. Biologic-AMPH025`	PASS
BMR01836	8568	HAVWB03	-21.71380	122.62719	Paramelitidae	Paramelitidae sp. U3S?	Paramelitidae `sp. Biologic-AMPH027`	PASS



Havieron Project Stage 2:

Stygofauna Survey and Risk Assessment

Biologic Environmental Survey

Report to Newcrest Mining Limited

July 2022

Document Status				
Revision No.	Author	Review / Approved for Issue	Approved for Issue to	
			Name	Date
1	T. Wild, S. Rodman, V. Steptoe, M. Curran, M. Lythe, J Abello	M. Curran		
2	T. Wild, A. Mittra, J. Abello, M. Curran	M. Curran	Louise Whitley	27/05/2022
3	T. Wild, A. Mittra, J. Abello, M. Curran	M. Curran	Louise Whitley	28/07/2022

EXECUTIVE SUMMARY

The Havieron Project (Project) is a farm-in joint venture between Newcrest Mining Limited (Newcrest) and Greatland Gold Ltd. The Project is located approximately 45 km east of Newcrest's Telfer Gold Mine and has the potential to deliver a high-grade underground gold deposit. The first stage (Stage 1) of the Project has environmental approval for development and Newcrest is seeking information to inform environmental approvals for Stage 2 of the Project.

Biologic Environmental Survey (Biologic) undertook a single-phase subterranean fauna survey of the Project Area in 2021 to provide additional information on stygofauna presence and extent of distribution, which include the areas of proposed dewatering and the Service Corridor. This second survey (third phase) focussed on stygofauna as it was determined through the initial survey and habitat analysis (geological and hydrogeological information) that the Project Area did not support troglofauna.

The single-phase stygofauna survey was undertaken in May 2021 with a total of 325 subterranean fauna specimens collected, comprising approximately 97% stygofauna (314 specimens), 3% amphibious taxa (11 specimens). From these, a total of seven stygofauna taxa and eight amphibious taxa were recorded. To date (Stage 1 and Stage 2 stygofauna surveys), 508 specimens belonging to eight stygal (329 specimens) and nine amphibious (178 specimens) taxa have been recorded within the Project Area. Groups recorded included amphipods, isopods, cyclopoids, harpacticoids, ostracods, oligochaetes and amphibious enchytraeid oligochaetes. This is considered a moderately diverse stygofauna community compared to the nearby Telfer Mine (23 taxa) which is considered to have a rich stygofauna assemblage.

Of the 17 stygofauna taxa recorded within the Project Area, four were identified as potentially restricted within impact areas (groundwater drawdown); Paramelitidae `sp. Biologic-AMPH027, Microcerberidae `sp. Biologic-ISOP034`, *Mesocyclops* `sp. Biologic-CYCL021` and Humphreyscandonini `sp. indet.`. Although the identification of Humphreyscandonini `sp. indet.` is tentative, it was included in the assessment as the family Candonidae is known to contain both Confirmed SREs and Widespread species. Three of these taxa are only known from a single site within the impact areas of the Project Area; Microcerberidae `sp. Biologic-ISOP034`, *Mesocyclops* `sp. Biologic-CYCL021` and Humphreyscandonini sp. indet.

Analysis of available geological and hydrogeological information (detailed information limited to a small number of holes) indicated that suitable stygofauna habitat was most likely to occur within the upper unconfined aquifer or perched water system. There is evidence to suggest that stygofauna may also occur below the unconfined aquifer within sections of the Upper Mudstone (UWM) or Upper Tillite (UMT) sandstone lithological units where there is sufficient permeability, fracturing and suitable water conditions. However, within the Project Area the upper mudstone is considered to be an aquitard, with limited potential habitat for stygofauna. The Upper Tillite sandstone has much more prospective characteristics for stygofauna habitat however as neither unit will experience a change in the surficial water table during groundwater extraction they are not considered further in this assessment. Therefore, the potential impacts of groundwater drawdown on stygofauna were assessed under the conditions within the upper unconfined aquifer only.

At the time of report preparation, the level of geological and hydrogeological information was not sufficient to inform a 3D habitat model for the entire Project Area. Therefore, the impacts to stygofauna habitat values were assessed at the bore locations where potentially restricted stygofauna have been recorded (HAVWB01 and HAVWB02) and geological and hydrogeological information was available from nearby (200 m distance) bores. This impact assessment is therefore deemed preliminary as the risk rankings may require re-assessment when additional information (additional targeted stygofauna sampling and geological and hydrogeological studies) is available. Nevertheless, the currently proposed impacts of groundwater drawdown to the potential stygofauna habitat are considered low (1-2 m).

Under these information limitations, 4 stygofauna taxa (Paramelitidae `sp. Biologic-AMPH027`, *Mesocyclops* `sp. Biologic-CYCL021`, Microcerberidae `sp. Biologic-ISOP034` and Humphreyscandonini sp. indet.), were considered to be at **Low** risk from the groundwater drawdown associated with the Project within the upper unconfined aquifer. It is also considered likely that their distribution extends beyond Project impacts as suitable continuous habitat is expected to remain outside of and below the proposed extent of groundwater drawdown.

TABLE OF CONTENTS

TABLES

FIGURES

PLATES

APPENDICES

GLOSSARY

3D	Three dimensional (related to habitat modelling)
AWT	Above the watertable
BC Act	*Biodiversity Conservation Act 2016*
BoM	Bureau of Meteorology
BWT	Below the watertable
DBCA	Department Biodiversity, Conservation and Attractions
EPA	Western Australian Environmental Protection Authority
EP Act	*Environmental Protection Act 1986*
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
LFT	Lower Tillite
mbgl	Metres below ground level
OTU	Operation taxonomic unit
PEC	Priority Ecological Communities
PSS	Pilbara Stygofauna Survey (Halse *et al.*, 2014).
SRE	Short-range endemic
TEC	Threatened Ecological Communities
UMW	Upper Mudstone
UMT	Upper Tillite
WAM	Western Australian Museum

1 INTRODUCTION

1.1 Background

The Havieron Project (Project) is a farm-in joint venture between Newcrest Mining Limited (Newcrest) and Greatland Gold Ltd. The Project is located approximately 45 km east of Newcrest's Telfer Gold Mine in the Great Sandy Desert, Western Australia (Figure 1-1). The Project is targeting a gold-copper (Au-Cu) resource and will comprise an underground decline, waste rock landform, workshops, service corridor to the Telfer mine and road/construction bores along this corridor.

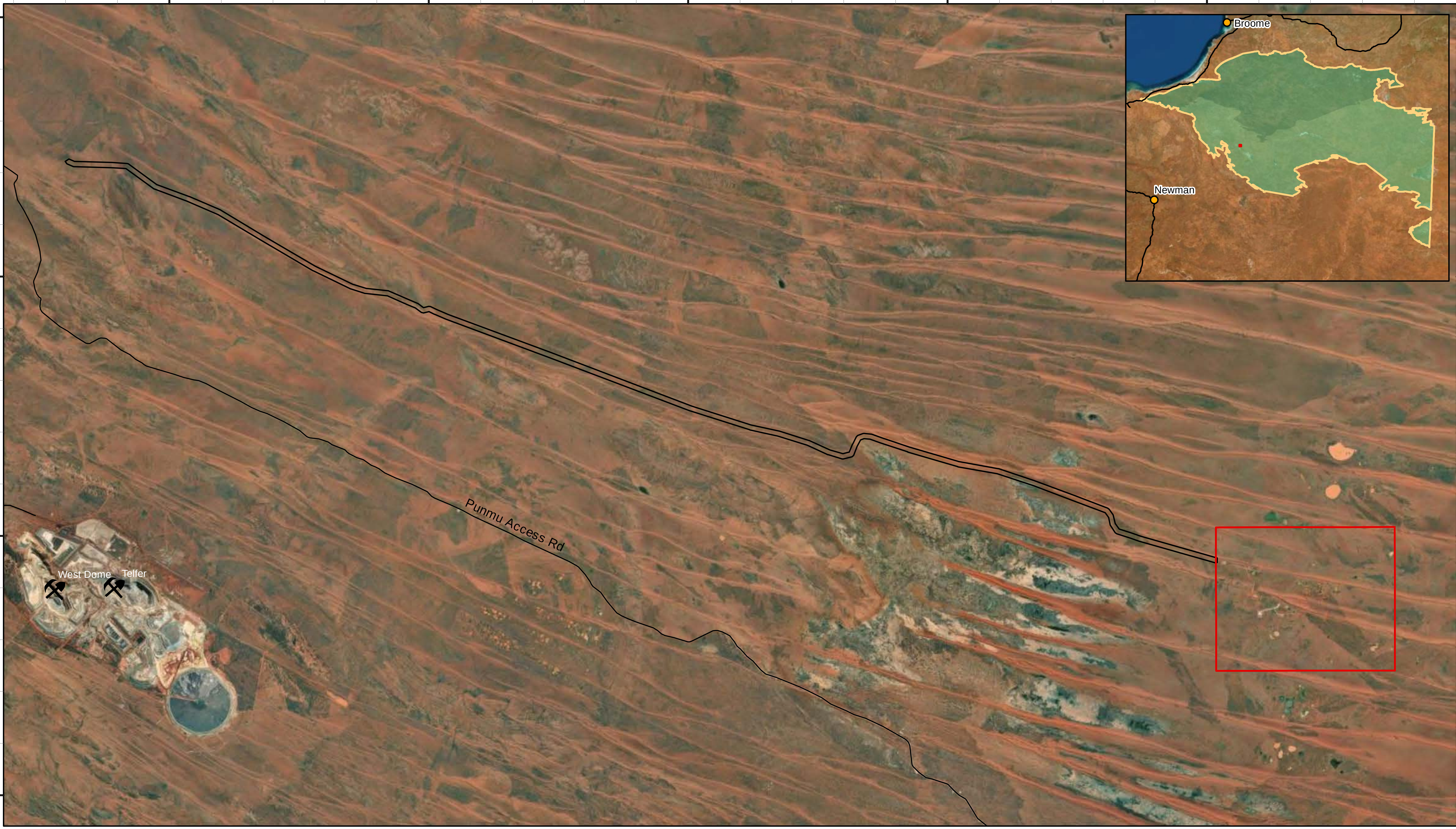
The Havieron deposit will be mined using sub-level open stoping (SLOS). The mineralised zone will be accessed by a decline which extends through the Permian strata, to the top of the mineralised zone which commences 20 m below the top of the Proterozoic basement rocks. The Project commenced in December 2020, with Exploration and Stage 1 activities approved. Stage 1 comprises a boxcut and decline development to 400 m below ground level, a service road and supporting infrastructure. Stage 2 of the mine is planned to commence in early 2023. This will include the development of a decline to the base of the mine 4,075 m RL (about 1,185 m depth) over a 70 month period whilst simultaneously developing mine access drives and extracting ore (Rockwater, 2021). Both Stage 1 and Stage 2 involve groundwater extraction to allow mining below the watertable (2 GL per year).

Biologic Environmental Survey (Biologic) undertook a desktop assessment and two-season subterranean fauna survey of the Project Area in 2019/2020 to inform the Stage 2 environmental approvals (Biologic, 2020). Newcrest is now seeking further information regarding risks to stygofauna to inform environmental approvals for Stage 2 of the Project.

1.2 Objectives

The objective of the current study was to undertake a single phase stygofauna survey and risk assessment to provide a greater understanding of the stygofauna community present within the Project Area to further inform environmental approvals for Stage 2 of the Havieron Project (Figure 1-1). More specifically the aims of this survey were to provide:

- a desktop review of all previous stygofauna surveys in the vicinity of the Project Area and of existing subterranean fauna databases on the local/ sub-regional scale;
- results of the additional single-phase stygofauna survey within the Project Area in the context of the original two-phase stygofauna survey previously undertaken (Biologic, 2020), including detailed identifications of all species collected;
- outcomes of the 3D habitat modelling using available hydrogeological and geological data to inform availability of suitable stygofauna habitat within the Project Area; and
- further information in which to conduct an assessment of potential risk of the proposed groundwater extraction on stygofauna values within the Project Area (including cumulative impacts of Stage 1 and Stage 2).



Legend

- Havieron Project Area
- Service Corridor
- Operating Mine
- Local Road

IBRA Region

- Great Sandy Desert

IBRA Subregion

- Mackay
- McLarty

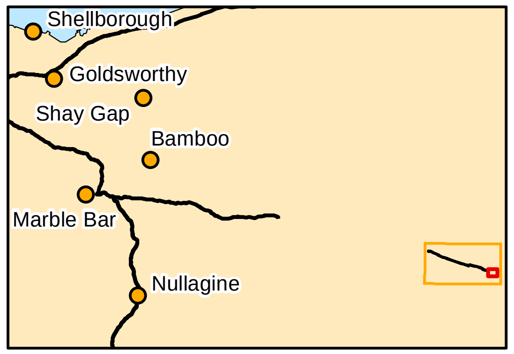
N

biologic Environmental Survey

Scale: 1:140,000

0 2 4 6 8 Km

Coordinate System: GDA2020 MGA Zone 51
Projection: Transverse Mercator
Datum: GDA2020 Created 10/03/2022



NEWCREST MINING LIMITED

Havieron Project Stage 2: Subterranean Fauna Survey

Figure 1.1: Project Area and regional location

1.3 Legislation and Guidance

Western Australia's subterranean fauna is considered globally significant due to an unprecedented richness of species and high levels of short-range endemism (EPA, 2016c). The EPA's environmental objective for subterranean fauna is to "protect subterranean fauna so that biological diversity and ecological integrity are maintained" (EPA, 2016a, p2). In this context, the EPA defines ecological integrity as "the composition, structure, function and processes of ecosystems, and the natural range of variation of these elements" (EPA, 2016a, p2).

Protection for conservation significant subterranean fauna species and/ or Threatened or Priority Ecological Communities (TECs and PECs) is provided under State and Federal legislation, comprising:

- *Environmental Protection Act 1986* (*EP Act 1986*) (WA);
- *Biodiversity Conservation Act 2016* (*BC Act 2016*) (WA); and
- *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act 1999*) (Commonwealth).

Most subterranean fauna species and assemblages are not listed under these Acts, due to incomplete taxonomic or ecological knowledge. Consideration of range-restricted subterranean fauna is therefore also important, including species that only occur within restricted habitats, as these have a higher potential of being Short-Range Endemic (SRE) species (Harvey, 2002; Eberhard *et al.*, 2009).

This assessment has been undertaken in consideration of the following EPA guidance statements:

- EPA (2016c) Technical Guidance: Subterranean Fauna Survey;
- EPA (2016a) Environmental Factor Guideline: Subterranean Fauna;
- EPA (2016b) Technical Guidance: Sampling Methods for Subterranean Fauna; and
- EPA (2021) Technical Guidance: Subterranean Fauna Surveys for Environmental Impact Assessment

1.4 Subterranean fauna

Subterranean fauna are animals that live underground. In Western Australia, subterranean fauna are mainly invertebrates such as crustaceans, insects, arachnids, myriapods, worms, and snails, but a small number of vertebrate taxa such as fish and reptiles have also been found (Humphreys, 1999). Subterranean fauna are grouped into two major ecological categories:

- stygofauna – aquatic animals that inhabit groundwater in caves, aquifers, and water-saturated interstitial voids; and
- troglofauna – air-breathing animals that inhabit air-filled caves and smaller voids above the water table.

Nevertheless, there are some taxa which cross-over between these categories and are known to occur in groundwater as well as air-filled subterranean habitats (*e.g.* enchytraeid worms), and yet other species that occur within subterranean habitats for only part of their lifecycles (stygoxenes/ stygophiles, and trogloxenes/ troglophiles respectively).

Following EPA (2016a) guidelines, obligate subterranean fauna (known respectively as stygobites and troglobites) are defined as species that live their entire lives underground and are completely dependent upon, or restricted to, subterranean habitats. Such species are considered to have a high likelihood of being limited to very narrow ranges (*i.e.* short-range endemic (SRE) species), and therefore may be at greater risk of impacts from proposed developments (EPA, 2016a). SRE species as described by Harvey (2002), are species whose natural ranges are limited to <10,000 km^2 (or <100 × 100 km), whereas Eberhard *et al.* (2009) regarded even this criterion as potentially too vast for range-restricted subterranean fauna, offering an alternative threshold of <1,000 km^2 (or approx. 31 × 31 km) for subterranean SRE species.

Troglobites and stygobites often display evolutionary adaptations to underground life; these include features such as reduced pigment, reduced or vestigial wings, reduced cuticle thickness, elongation of sensory appendages, and reduced eyes or eyelessness. Additional adaptations to underground life can include changes to physiology, lifecycle, metabolism, feeding and behaviour (Gibert & Deharveng, 2002; Christiansen, 2005)

As the darkness of hypogean environments precludes photosynthesis, subterranean ecosystems are generally dependent upon allochthonous inputs of nutrients and oxygen from the surface (except in cases where chemo-autotrophic bacteria are present) (Hahn, 2009). Energy and nutrients are generally transported into subterranean ecosystems by the infiltration of water, particularly *via* the roots of groundwater dependent vegetation (Howarth, 1983; Malard & Hervant, 1999; Poulson & Lavoie, 2000; Humphreys, 2006). Thus, the porosity (or otherwise) of the overlying geologies, the distance from the surface, and the presence/absence of caves or fissures that can provide a conduit for water and nutrients are important physical features that influence the suitability of underground habitats for subterranean fauna (Strayer, 1994; Hahn & Fuchs, 2009). Groundwater physicochemistry (including salinity, pH, dissolved oxygen and redox potential) is also an important determinant of habitat suitability for stygofauna (Watts & Humphreys, 2004; Humphreys, 2008; Eberhard *et al.*, 2009; Hahn, 2009).

2 EXISTING ENVIRONMENT

The Project Area is located within the Mackay subregion of the Great Sandy Desert bioregion (GSD2) within the Pilbara region of Western Australia (Figure 1-1), as defined by the Interim Biogeographic Regionalisation of Australia (IBRA) (Thackway & Cresswell, 1995; Cowan, 2001). The bioregion is characterised by mainly tree steppe grading to shrub steppe in south; comprising open hummock grassland of *Triodia pungens* and *Triodia schinzii* with scattered trees of *Owenia reticulata* and bloodwood (*Corymbia* spp.), and shrubs of Acacia spp., *Grevillea wickhamii* and *G. refracta*, on Quaternary red longitudinal sand dune fields overlying Phanerozic sediments of the Canning and Armadeus Basins (Kendrick, 2001). The landforms are predominantly influenced by Cenozoic erosion and deposition events resulting in a series of westerly to north-westerly trending longitudinal dunes (Ferguson *et al.*, 2005).

Topography trends west towards the Percival palaeovalley, which drains to Lake Dora, a major salt lake and wetland of national significance in the Great Sandy Desert (DBCA, 2021). Lake Dora is the closest (34km southwest) substantial surface water feature that lies within the Rudall River National Park and is recognised as a groundwater dependant ecosystem (BoM, 2021).

2.1 Geology

The Project Area sits within the broader Paterson Province which covers over 30 000 km^2 of north central Western Australia and includes multi-deformed and metamorphosed rocks of the Paleo- to Mesoproterozoic Rudall Complex, Neoproterozoic Officer and Yeneena Basins, as well as Phanerozoic Canning Basin (Rockwater, 2019). Locally, the metamorphosed sedimentary sequences of the Neoproterozoic Yeneena Basin hosts the Au-Cu mineralisation that is the focus of the Project (Rockwater, 2019). The mineralisation is understood to be hosted in the eastern limb of a fault propagated anticlinal fold. The bedded sediments were brecciated by this deformation, cemented and then replaced by sulphide minerals, followed by a dolerite intrusion (Biologic, 2020; Rockwater, 2021). The Lamil Group from within the Yeneena Basin sequence was intruded by granites during the earlier Miles Orogeny 650 Ma (Rockwater, 2019). Unconformably overlying the Yeneena Basin sediments in this region are the Canning Basin sediments, comprising a series of Permian aged fluvio-glacial units ranging from weathered mudstone, tillite, siltstone and sandstone (drill core photos shown below in Plate 2-1) and are better known as the Paterson Formation.

At surface, the geology is dominated by red Quaternary-aged aeolian sand dunes, characteristic of the Great Sandy Desert, and often occurring as extensive sandplains or longitudinal sand dunes ranging from three to 25 m in height (Burbidge & McKenzie, 1983). These sand dunes comprise predominantly quartz, minor feldspar and, in some locations, heavy mineral sands, including well rounded zircon and tourmaline. The interdunal corridors comprise both weathering products (laterite, silcrete, ferricrete, and calcrete) and sediments (aeolian sand, alluvium, and evaporites) (Rockwater, 2019).

A typical geological sequence at the Project is shown below in Table 2-1 and details the units of the Paterson Formation as defined within the Project Area.

The Upper Mudstone (UWM) is dominantly a massive mudstone to clay zone with weathering close to the surface (upper saprolite, lower saprolite and sap-rock subunits). The Upper Tillite (UMT) is a permeable sandstone that comprises a conglomerate unit and a broad- poorly sorted poly-clastic tillite, interbedded with minor thin beds of fine well-rounded sandstone and rare drop stones. The Lower Siltstone (LSL) has an abundance of fine-grained sediment. The Lower Tillite (LFT) is dominantly coarse, poorly sorted sandstone.

Most lithologies are flat lying and dip gradually to the east (see cross section in Figure 2-1). Within the Project Area, the UWM underlies the Quaternary cover until it thins out in the west, leaving Upper Tillite (UMT) closer to the surface (approximately in the Percival Palaeovalley). The Proterozoic basement rocks gradually shallow to the west and outcrop on the western side of the Percival Paleovalley near Telfer.

Table 2-1: Typical Geological Sequence (adapted from (Rockwater, 2019).

Age	Geological Formation	Unit	Average Thickness (m)	Average Depth to Base of Formation (mbgl)	Aquifer
Quaternary	Superficial	Undifferentiated COVER (aeolian sand, alluvium, and evaporates)	5-15	5-15	Predominantly unsaturated. Where saturated included in the Unconfined/ Perched
QUATERNARY/PERMIAN UNCONFORMITY					
Permian	Paterson	UWM - Upper Mudstone	95-105	100-110	Aquitard
		UMT - Upper Tillite	60	170	Upper Confined
		LCS - Upper Siltstone	85	255	Aquitard
		LST - Middle Sandstone	25	280	Minor Aquifer
		LSL - Lower Siltstone	35	315	Aquitard
		LFT - Lower Tillite	95	410	Lower confined
PERMIAN/PROTEROZOIC UNCONFORMITY					
Proterozoic	Yeneena Basin	Undifferentiated Basement and mineralised orebody	N/D	N/D	Proterozoic

Upper Mudstone

Upper Tillite

Lower Siltsone

Lower Tillite

Permian Sediments

Plate 2-1: Drill core photos of Permian and Proterozoic sediments.

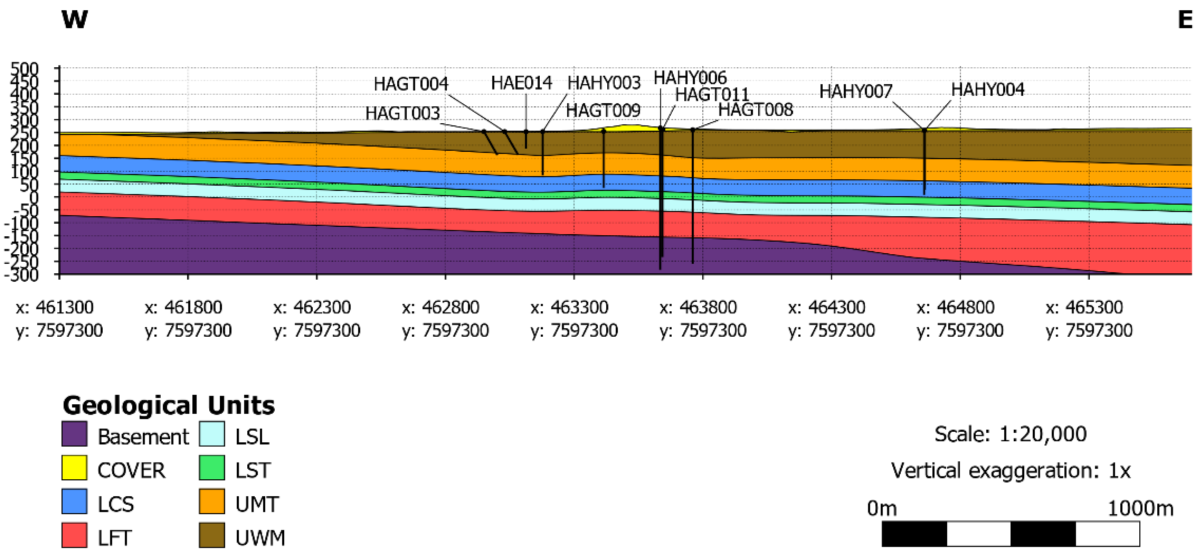


Figure 2-1: Cross-section parallel to the direction of the proposed mine decline.

2.2 Hydrogeology

Watercourses in this region are largely ephemeral, retaining surface water following large deluges of rainfall and drain into several playa lakes located in inter-dunal swales close to the Havieron deposit (Rockwater, 2019; Van Etten, 2020). The Rudall River system flows from upland ranges (e.g Miles Ridge) across the desert into Eva Broadhurst Lake and then Lake Dora. Rudall River is the only example of an arid zone river, with wetlands and waterholes along its course, including Curran Curran Waterhole and Coondegoon Pool (Kendrick, 2001; DBCA, 2021). It is likely that Lake Dora and the playa lakes have a high potential for groundwater interaction (Rockwater, 2021). The most significant feature near the Project is the Percival Palaeovalley (English *et al.*, 2015) a non-glaciogenic palaeovalley presumed to be Cenozoic in age. In places, these river valleys have been incised down to the Permian sediments. hosts significant calcrete outcrops.((Rockwater, 2021). The valley seems to correlate well with mapped massive calcrete outcrops.

2.2.1 Groundwater systems

Hydrogeological studies by Rockwater (2019) have identified four key aquifer units at the Project, in order from the surface:

1. Unconfined/Perched Aquifer;
2. Upper Confined Aquifer;
3. Lower Confined Aquifer; and
4. Proterozoic Aquifer (fractured).

The aquifers are described below with key characteristics summarised in Table 2-2. Due to the depths of these aquifers, only the Unconfined/Perched Aquifer and the Upper Confined Aquifer are considered potential subterranean fauna BWT habitats.

Table 2-2: Aquifer characteristics.

Aquifer	Depth	Hydraulic Transmissivity	Typical Thickness of Aquifer	Salinity (mg/L TDS)
Unconfined/ perched	Within the uppermost 15 m and absent elsewhere	0.37 m²/day	0.0 – 19.2 m (av. 6.2 m)	18,800 to 39,100
Upper confined	Top of aquifer from 15 m in the west to up to 110 m in the east	2.0 m²/day	80 m	Shallow (3,000 to 4,000) At depth (15,000 to 20,000)
Lower Confined	Typically, about 150 m deeper than the Upper Confined Aquifer	0.9 m²/day	95 m	Up to 55,000

Unconfined/ perched aquifer

The Unconfined/Perched Aquifer is predominantly made up of weathered Permian material and is relatively thin (<10 m thickness); in the east the saprolite overlies fresh mudstone of low permeability and it is hydraulically disconnected from the underlying Upper Confined Aquifer, in the west the mudstone is thin or absent and there is hydraulic connection between the two units. The undifferentiated

Quaternary cover is generally unsaturated but is included in this aquifer where the sequence is saturated (Rockwater, 2021).

The unconfined aquifer is small and interpreted to comprise:

- Quaternary sediments (generally unsaturated at Havieron given their thickness of 5 - 15 m and the average water table depth of 14 m (Rockwater, 2020);
- part of the upper UWM (upper saprolite, lower saprolite and saprock subunits) where weathered units are underlain by a thick succession of very low-permeability claystone and mudstone of the upper UWM.

It has a low transmissivity (0.37 m²/day) and high salinity of 18,800 to 39,100 mg/L TDS, which is likely due to limited salt flushing and evapoconcentration occurring near playas.

Upper confined aquifer

This unit comprises the basal upper silt /sandstone beds of the UWM and entire UMT, with the top of the aquifer located at 15 mbgl in the west to up to 110 mbgl in the east. It is confined by the UWM except where UWM is absent (to the northwest and southwest of the Project Area). The average transmissivity is 2.0 m²/day. Groundwater in the Paterson Formation is generally fresh near recharge areas becoming saline with depth and distance down the flow system (Laws, 1990 from (Rockwater, 2019)). At the Project, low salinities (3,000 to 4,000 mg/L) were observed where the aquifer is shallow and increasing (15,000 to 20,000 mg/L) at greater depth.

Lower confined aquifer

The lower aquifer is also made up of glacial tillite with a mud matrix to sand matrix. It is separated from the upper aquifer by a thick succession of siltstone. The aquifer is brackish to saline and has a different potentiometric surface from the Upper Confined Aquifer.

This aquifer comprises the entire Lower Tillite, which is typically ~150 m deeper than the Upper Confined Aquifer. It is confined by the low permeability siltstones of the LCS and is underlain by basement Permian rocks. Salinity increases with depth and is recorded at up to 55,000 mg/L.

Proterozic Aquifer

The Proterozoic aquifer is comprised of bedded sediments of the Proterozoic Yeneena Basin. The Proterozoic formation has negligible primary porosity and groundwater is only hosted in the weathered contact with the overlying Permian strata or in fractures, which are most notable in the dolerite dyke (Rockwater, 2021).

3 METHODS

3.1 Database search and review of previous reports

Eight databases were searched for records of stygofauna within 65 km of the Project Area as detailed in Biologic, 2021 (Table 3-1).

All records were filtered based on collection methods and known stygofauna/ troglofauna taxonomic groups where information on subterranean status was not present in the data.

Table 3-1. Databases searched for subterranean fauna records

Database	Parameters
NatureMap	40 km radius around 21°43'22.1"S 122°38'55.0"E
WAM Arachnida/ Myriapoda WAM Crustacea WAM Mollusca	65 km radius around 21°43'22.1"S 122°38'55.0"E
DBCA's Pilbara Stygofauna Survey	65 km radius around 21°43'22.1"S 122°38'55.0"E

Reports from subterranean fauna surveys within 40 km of the Study Area were reviewed for local and regional context. Reports from Telfer region are listed in Biologic, 2021.

3.2 Field Survey

A single-phase stygofauna survey was undertaken within the Havieron Project Area and Service Corridor from the 3rd to the 7th of May 2021 by Senior Zoologist Syngeon Rodman and Zoologist Isabelle Johansson. Martu Traditional Ecological Advisors Gilbert Williams, Mark French, and Patrick Jadai accompanied and assisted the Biologic team throughout the survey. The survey was conducted under fauna collection licence BA27000177-2 issued to Morgan Lythe (Appendix D). The methods used followed relevant guidelines for subterranean fauna assessments (EPA, 2016c, b, a).

A total of 25 samples from 25 bores were collected from the Project Area comprising 24 samples collected by net hauling and one pumping sample (Figure 3-1, Table 4.1). This survey followed subterranean fauna sampling previously undertaken for Stage 1 of the Project in 2019–2020 (Biologic, 2020) and the results of both surveys, in terms of sampling effort (Table 4.1), the animals collected and their known distributions, are combined and reported here.

The number and location of sampling holes was based on:

- The suitability of bores in terms of interception of groundwater, construction (i.e. cased and slotted below the water table or uncased) and accessibility.
- Ensuring a thorough spatial distribution of samples throughout the Project Area, including adequate sampling coverage both within and outside the extent of predicted groundwater drawdown impacts.
- The extent of prospective geological and hydrogeological habitat units sampled by each bore.

Table 3-2: Subterranean fauna sample effort within Project Area including regional reference sampling.

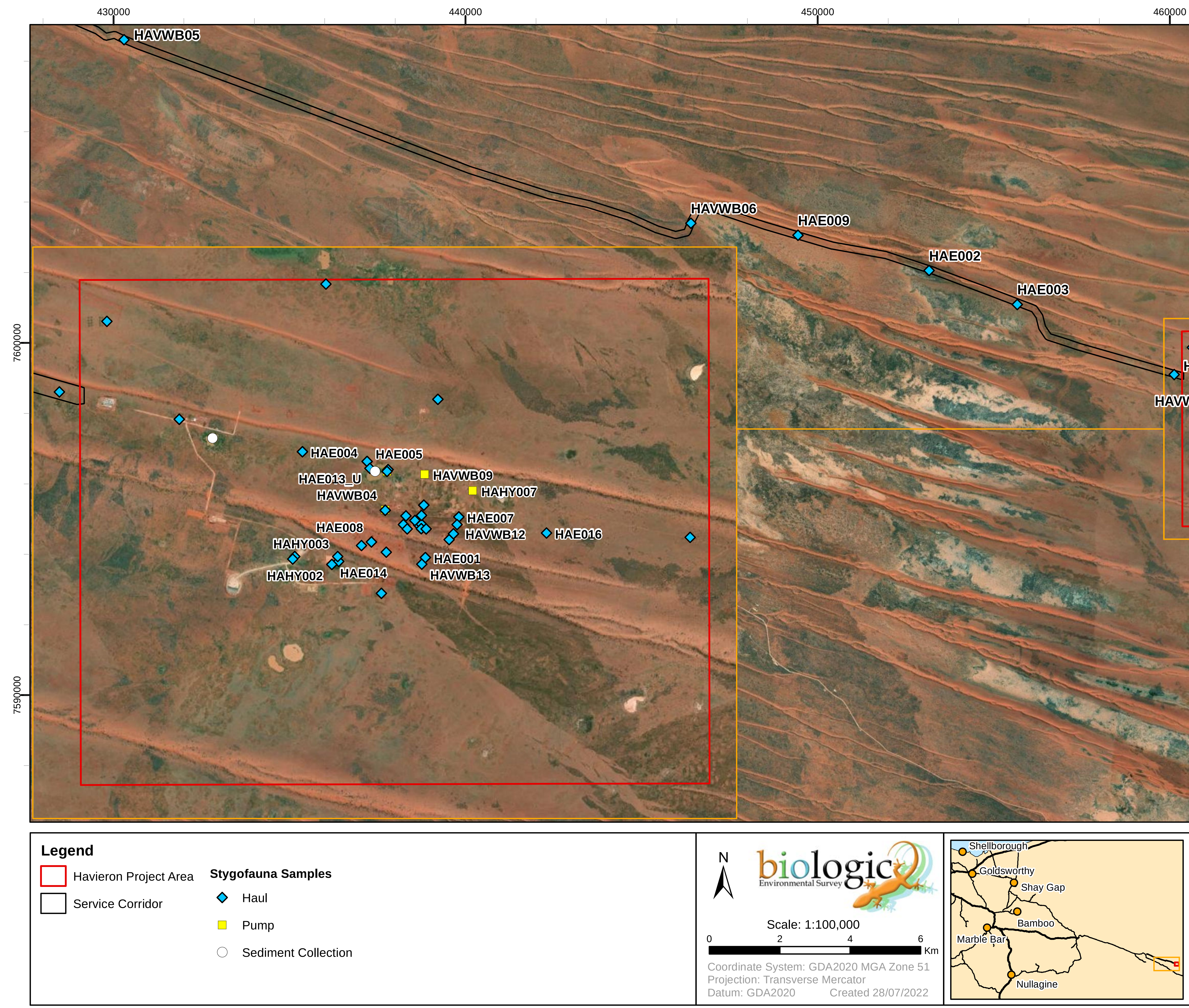
Project Stage	Survey Phase	Stygofauna Samples		Total
		Haul	Pump	
Stage 1	Phase 1	2	0	**2**
	Phase 2	54	4	**58**
Stage 2	Phase 3	24	1	**25**

3.2.1 Water chemistry

Prior to stygofauna sampling groundwater physicochemical parameters (EC, pH, TDS, oxidative-reductive potential and dissolved oxygen) were measured using a YSI multi-parameter water quality meter from a groundwater sample collected using a plastic bailer from close to the top of the watertable. These measurements are not necessarily indicative of water quality throughout the entire bore (or aquifer) but rather provide a general indication of near-surface conditions. Dissolved oxygen levels measured from bores sampled by pumping are likely to be artificially elevated due to the water sample collection method. Constrictions in piezometer bores, blockages by roots or excessive depths to groundwater inhibited water quality assessments at some sites.

3.2.2 Stygofauna sampling

Stygofauna were sampled in each bore (or well) by net hauling using conical, weighted plankton nets. Each haul sample consisted of six net hauls (three with 150 µm mesh and three with 50 µm mesh) along the entire length of the bore. The base of each net was fitted with a sinker and a sample receptacle with a mesh base (50 µm) to allow filtration. The net was vigorously bounced at the bottom of the hole to agitate sediments and collect benthic animals and then retrieved at a moderate pace to collect animals from the water column. The diameter of sampling nets was chosen to maximise the collection of stygofauna based on the diameter of each hole, while also considering the need to reduce equipment damage and loss via snagging (for example, 100 mm holes were usually sampled using 90 mm diameter nets). Bores that could not be sampled via hauling due to headworks or other infrastructure were instead sampled by running actively pumped bore water through a stygofauna net three times for a total of approximately 10 minutes at each site. The contents of the net and receptacle were flushed into a bucket with potable water after each haul or pump. After the final haul or pump was collected and emptied in the bucket the composite sample was elutriated to remove coarse and inorganic sediments and filtered through a 50 µm mesh net to reduce water content to improve preservation. The sample was transferred to a 120 mL polycarbonate vial and preserved in 100% ethanol. Samples containing relatively large amounts of sediment were split between two or more vials to optimise preservation. The ethanol and samples were kept on ice to promote cool-temperature DNA fixation.



NEWCREST MINING LIMITED

Havieron Project Stage 2: Subterranean Fauna Survey

Figure 3.1: Stygofauna sample sites - all surveys

3.2.3 Sorting and taxonomy

Sorting and parataxonomy were undertaken in-house using dissecting microscopes. The personnel involved (Mary van Wees, Juliana Pille Arnold, Stephanie Floeckner, Siobhan Paget, Isabelle Johansson, Courtney Wilkins, and Giulia Perina) were all suitably trained and experienced in sorting and parataxonomy of subterranean fauna. Parataxonomy was guided by published literature and taxonomic keys where available. Each morphospecies from each sample was assigned a separate labelled vial and labelled with a specimen tracking code. Taxonomic groups were examined in as much detail as possible using in-house expertise, before sending a reference collection to specialist taxonomists for detailed taxonomic advice. Species comparisons and alignments were performed using regional specimens collected beyond the Project Area throughout the wider sub-regional area. Dr Giulia Perina provided specialist taxonomic identifications and regional alignments.

3.2.4 Sediment rehydration trial

To determine whether any species collected from groundwater via bore sampling also occur in surface habitats and could therefore be inferred to be stygophiles[1] or stygoxenes[2] (Boulton, 2001) likely to have relatively widespread distributions, sediment samples were collected from three claypans within the Project Area (Figure 3-1) by Zac Zhang of Newcrest and rehydrated under laboratory conditions by Biologic to promote hatching and maturation of resting stage fauna. Approximately 2 kg of surficial (top 3-5 cm) sediment were collected in calico bags from five locations in the claypans and transported to the Biologic laboratory. The sediment samples were rehydrated in separate glass aquaria by flooding with dechlorinated tap water, aerated using a pond pump, provided diluted liquid fertiliser to enhance productivity, heated to simulate field conditions and maintained under a 12-hour light/12-hour dark cycle. Each sample was examined every 24 to 48 hours for emergent fauna for a total of 28 days after rehydration. After this time, all emergent fauna were harvested by filtering the water through a 53 µm net. Emergent fauna were identified to class level (or lower) and abundance recorded on a $\log_{10}$ scale. Microcrustacean taxa, specifically ostracods, were identified to family level and compared with specimens of Humphreyscandonini sp. indet recorded during Stage 1 sampling. Specimens were sorted and preliminarily identified by Zoologists Isabelle Johansson, Siobhan Paget and Courtney Wilkins. Taxonomic identification and specimen comparisons were undertaken by taxonomists Dr Giulia Perina and Alex Riemer.

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[1] Species using the groundwater habitat seasonally or during early life history stages.

[2] Species that appear rarely and apparently at random in groundwater habitats, there by accident or seeking refuge during spates or drought; not specialised for groundwater habitat.

3.2.5 DNA analysis

Genetic analysis (DNA barcoding using the mitochondrial gene COI) was conducted by Biologic on certain subterranean taxa to validate morphological identifications and provide a basis for species-level identifications and regional comparisons where taxonomic resolution was limited. DNA analyses and regional comparisons were limited to the material collected during the survey and genetic sequences that were publicly available at the time of the analysis. Appendix C further details the methods of DNA extraction, choice of primers, sequencing and analysis.

3.2.6 Ecological, SRE and conservation statuses

The likely stygal ecology (degree of dependence on subterranean habitats), geographic range and conservation status of each stygofauna taxon recorded in the Project Area were assessed with consideration of:

- The degree of stygomorphy (observable physical adaptations to subterranean habitats such as eyelessness, depigmentation, elongation of sensory appendages and thinning of the cuticle) and by inference whether a taxon was likely to be an obligate subterranean species (stygobite).
- The extent of its known geographic distribution based on sampling data (i.e. collection locations) relative to the nominal range criteria for short-range endemic (SRE) species of less than 10,000 km^2 (Harvey, 2002) or less than 1,000 km^2 (Eberhard *et al.*, 2009). The potential of each taxon to be an SRE species was further informed by a range of other factors in line with the categories applied by the WAM (Table 3-3).
- The inferred extent of suitable habitat, if known.
- Listings for Priority and Threatened species and ecological communities as per State and Federal legislation. While all listed subterranean species and communities are regarded as conservation significant, most species and communities are not listed, despite most being highly likely have limited geographic distributions and thus inferred conservation significance, due to insufficient survey data and taxonomic knowledge.

Table 3-3: SRE categories of the WAM adapted from Harvey (2002) and applied in the current assessment.

<table>
<tr><th></th><th>Taxonomic Certainty</th><th>Taxonomic Uncertainty</th></tr>
<tr><td>Distribution <10 000km^2</td><td>Confirmed SRE
• A known distribution of < 10,000km^2.
• The taxonomy is well known.
• The group is well represented in collections and/ or via comprehensive sampling.</td><td rowspan="2">Potential SRE
• Patchy sampling has resulted in incomplete knowledge of geographic distribution.
• Incomplete taxonomic knowledge.
• The group is not well represented in collections.
• Category applies where there are significant knowledge gaps.
SRE Sub-categories may apply:
A) Data Deficient
B) Habitat Indicators
C) Morphology Indicators
D) Molecular Evidence
E) Research & Expertise</td></tr>
<tr><td>Distribution >10 000km^2</td><td>Widespread (not an SRE)
• A known distribution of > 10,000km^2.
• The taxonomy is well known.
• The group is well represented in collections and/ or via comprehensive sampling.</td></tr>
</table>

3.3 Subterranean Habitat

The occurrence and distribution of subterranean fauna is influenced or limited by the geology in which they occur. Important features that can influence the suitability of habitats for subterranean fauna include the geomorphology and porosity of the target geological habitat and overlying strata, the depth from the surface of the target layer/s, and the presence of cavities or tree roots that can provide conduits for water and nutrients (Strayer, 1994). Subterranean fauna habitats are predicated on the occurrence and interconnectedness of subterranean voids, cavities, cracks, porosity, aperture spaces, and caverns, both below and above the water table. Small and fragmented species ranges, leading to high levels of endemism (EPA, 2003), result from such dispersal limitations. Thus, it is important to identify the type and extent of habitats that are likely to host subterranean fauna.

3.3.1 Subterranean Habitat Modelling

Subterranean habitat assessment within the Project Area was based upon available geological and hydrogeological reports, surface geology maps (GSWA, 2020) and three-dimensional (3D) geological and hydrogeological modelling based on drill-hole logging data in the program Leapfrog® (provided by Rockwater).

A review of the potential habitat extent and quality was first evaluated using traditional two-dimension data (i.e. maps) and secondly attempted from within the 3D Leapfrog model which included validating all available drilling data and applying new information to the model as well as updating geological interpretations of the major stratigraphies. New geotechnical information for rock quality or fragmentation was also reviewed, along with logged oxidation states all conducted to better characterise the subterranean habitat within the Project Area.

Rockwater created a 3D geological model within Leapfrog based on drill-hole logging data (representing geological codes, geospatial data, angle/ trace of drilling, and depth information) by intrinsically connecting data points of the same geological types/ formations in 3D space. Geological zones were then modelled to form upper and lower surfaces or meshes of geological layers, including erosional layers, depositional layers, intrusives, and faults/ disconformities. The extent and shapes of the geological units and their interactions within the model were then used by geologists and hydrogeologists to create a hydrological model as reported in H3 report (Rockwater, 2021).

Biologic used the geological model provided by Rockwater (Figure 3-2)to update the model from a habitat model perspective. Drill log data from 437 reverse circulation and diamond core drill holes throughout the Project Area was validated and compiled into a relational database using Microsoft Excel® then exported to in csv format for use in Leapfrog Geo. The drilling data was filtered to 200m depth as this was expected to be a reasonable maximum depth for potential subterranean fauna and only 269 holes contained further lithological descriptions. The drill log data was coded with potential

habitat suitability based on key stratigraphic units (rock types) and geomorphology characteristics or weathering as shown in
Table **3-4**.

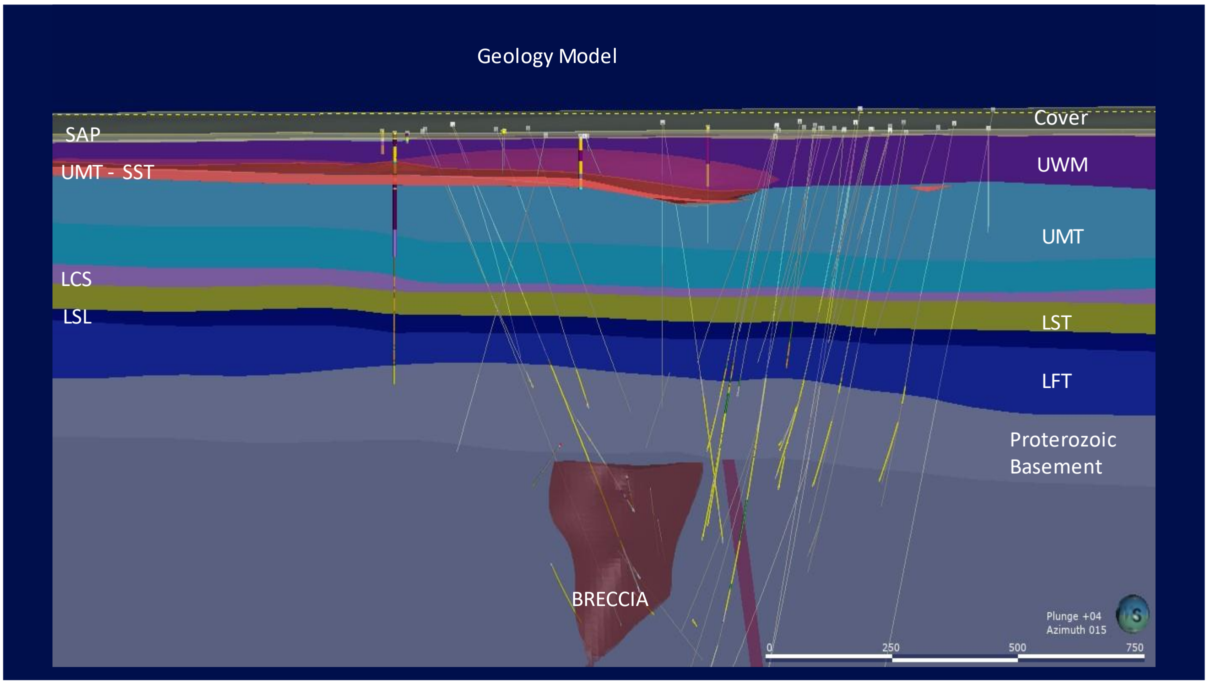


Figure 3-2: Havieron Leapfrog 3D Geological Model (based on Rockwater interpretation), showing a cross-section with drilling

Table 3-4: Leapfrog Model coding of rock type by habitat suitability potential

Habitat Code	Rocktype	Character	Weathering
High	SST, CON,SAN, LC, CL,	“Calc”, “Ft”,	TOx
Medium		“Pisolitic", "Gyp",	“Frac”, “Pox”
Low	SSL, CLY, SHL, MST		“Fresh”

All relevant information such as the groundwater table, topographical surface, extent of proposed underground development, extent of groundwater drawdown and point data to label bores/ holes, in addition to the location of potential restricted subterranean fauna species was then added to enhance the model’s capacity for visual habitat assessment/ impact assessment.

A regional habitat suitability model was attempted to show the High, Medium and Low potential habitats in 3D space. Due to the limitations in drilling information especially in the locations of stygofauna occurrence, the model failed to project any habitat through the necessary areas. Habitat was instead reviewed using section views within the model with detailed evaluation of the geological profile of nearby bore holes.

3.4 Constraints and limitations

The results and conclusions of the survey and risk assessment are limited to the available information at the time of document preparation. Subterranean fauna taxonomy, ecology, and habitat assessment (particularly 3D assessment) are evolving disciplines; however, much remains uncertain, providing some challenges for the interpretation of results and impact assessment.

Specific limitations relating to the current survey and assessment include:

- Sampling –
    - The availability, location, and construction (whether bores were cased, slotted and intercepted suitable aquifers) of water bores were limiting factors in some areas, particularly outside of the nominal impact area, where relatively few bores were available for sampling. The overall sampling effort does not meet the EPA guidelines for the assessment of stygofauna values (EPA, 2021). Sampling was only conducted on Newcrest tenements and was concentrated in the Project impact area and a few bores in the service corridor. Further regional sampling has not been undertaken, which limits the knowledge of assemblage composition and species ranges beyond the Project/impact area. The constraint of limited regional sampling is somewhat mitigated by the small extent of predicted groundwater impacts and by the widespread, largely uniform geologies.
    - The construction of a number of bores (prefixed HAD and HAC) were not suitable for subterranean fauna sampling owing to age (<2.5 months) or blank casing from the surface to significant depth.
    - Determining impact and reference samples – the final extent of the proposed groundwater drawdown was not confirmed at the time of sampling. Therefore, the spatial distribution of stygofauna samples was driven by bore availability and the balance of impact vs. reference sampling was unknown.
    - Genetic analysis – regional comparisons of sequences were limited to the few that were available from sampling at Telfer. This limited the power of genetic comparisons to extend the known ranges of species recorded in the Project Area.
- 3D modelling –
    - The 3D modelling was based on geological extrapolation of drilling data over the entire Project Area and grouped into large stratigraphic units. This level of extrapolation risks oversimplifying local variations in the geology and environment. The available data was variable in depth, distribution and content.
    - Potential impact areas had a higher concentration of drill holes and bores while non-impact areas within the Project Area had a poorer distribution of bores making it difficult to validate the stratigraphic conceptualisations. Some extraordinarily deep holes targeting mineralisation, however they did not provide information at the shallower depths (important for subterranean fauna habitat assessment) as there was significant coreloss

or they simply were not logged. This affected the habitat suitability modelling which was targeting the upper 200 m of lithologies.

- The 3D habitat modelling was limited to the area within and immediately surrounding the locations of bores and drill holes, and any extrapolations beyond the immediate vicinity of the drilled area was not possible as drill holes were missing geological information. Potentially suitable habitat may occur beyond the extent of modelling, however these areas are unable to be modelled to the same level of detail.
- The baseline groundwater levels used in the hydrological modelling were based on averages from regional bores and exploration holes from data collected prior to impact works commencing. In areas where drilling and subsequent water investigations were dense, this produced fairly reliable contours of average depths to water, while in other areas where information was sparser, the modelled water levels lacked accuracy and validation to ongoing monitoring.

4 RESULTS

4.1 Desktop assessment

A total of 21 reports from subterranean fauna surveys within or in the vicinity of the Project Area were identified and reviewed for local and regional context (Appendix E). Based on the database searches and survey reports a total of seven stygofauna and potential stygofauna taxa were recorded within the Project Area and 66 stygofauna and potential stygofauna taxa were recorded within the greater regional area (within approximately 65 km; Appendix E). None of these taxa are listed as Threatened or Priority species, however many are Potential SREs (Appendix E).

There is one Environmentally Sensitive Area located approximately 35 km to the south of the Project Area, the Nationally Important Wetland Lake Dora (Rudall River) System (DWER, 2021). There are no Threatened Ecological Communities or Priority Ecological Communities recorded in the vicinity of the Project Area (DAWE, 2020).

4.1.1 Summary of historical regional surveys

There have been numerous stygofauna surveys in the surrounds of the Project, especially in and around the Telfer Gold Mine, with targeted stygofauna sampling first undertaken in 2001 (Biota, 2001). The region has a rich stygofauna assemblage, comprising at least 23 distinct taxa (likely more due to a number of indeterminate taxa and nominal use of genetics) from ten higher level taxonomic groups, comprising Acari, Amphipoda, Copepoda, Gastropoda, Isopoda, Nematoda, Oligochaeta, Ostracoda, Polychaeta, Rotifera and Syncarida (Bennelongia, 2010, 2011, 2012a, 2013a, b) (Appendix E). Geologies from which stygofauna have been recorded in the Telfer region include Proterozoic sediments, Tertiary calcrete, Wilkie Quartzite, deep weathered siltstones and Permian Tillite.

More recently, stygofauna survey has been conducted in the Telfer region in 2019 to 2020 as part of regional effort for Stage 1 of the proposed Havieron Project. Not including specimens collected from the Project Area, which is east of the Telfer Gold Mine area, a total of 375 stygofauna fauna specimens were recorded (including 228 specimens from amphibious taxa; Biologic, 2020) including paramelitid amphipods, cyclopoid and harpacticoid copepods, ostracods, parabathynellid syncarids, microcerberid isopods and oligochaetes. Finally, a subterranean fauna survey at Kintyre Uranium Deposit collected specimens from fifteen stygofauna taxa including amphipods, copepods, isopods, syncarids and oligochaetes (Bennelongia, 2012b).

4.2 Survey Results

4.2.1 Survey effort within the Project Area

There has been one subterranean fauna survey undertaken within the Project Area for Stage 1 of the Project and comprised a two-phase subterranean fauna survey in 2019–2020 (Biologic, 2020). This study focused on the Project Area and reference sampling around the Telfer Gold Mine. Up to and including the current survey, 85 stygofauna samples (hauling and pump outflow sampling) and 73 troglofauna samples (trapping and scraping, which sometimes collect stygofauna as bycatch) have been collected in the Project Area (Figure 3-1, Table 4.1, Appendix A). Samples have been collected from holes of a variety of ages and throughout all geologies and habitats in the Project Area in which drilling had been undertaken.

Table 4.1: Subterranean fauna sampling effort within the Project Area to date.

			Stygofauna Samples		Troglofauna Samples		
Survey	**Phase**	**Trip**	**Haul**	**Pump**	**Scrape**	**Trap**	**Total**
Stage 1 Biologic, 2020	1	1	2	0	2	2	**6**
	2	2	22	2	17	12	**53**
	2	3	16	1	11	19	**47**
	2	4	16	1	6	0	**23**
Stage 2 Current survey	3	5	24	1	4	0	**29**
Total			**80**	**5**	**40**	**33**	**158**

Following phases 1 and 2 some samples have been identified as unlikely to be suitable for stygofauna sampling due to hole age (no stygofauna collected prior to 2.5 months) or construction (holes prefixed HAD/HAC cased to below the upper confined aquifer). The adjusted sample effort is presented below where samples have been removed where there was high confidence in the assessment of adequacy (Table 4.2).

Table 4.2: Subterranean fauna sampling effort within the Project Area to date with invalid samples removed.

		Stygofauna Samples		Troglofauna Samples		
Survey	**Phase**	**Haul**	**Pump**	**Scrape**	**Trap**	**Total**
Stage 1 Biologic, 2020	1	2	0	1	0	**3**
	2	15	2	5	0	**22**
Stage 2 Current survey	3	24	1	4	0	**29**
Total		**41**	**3**	**10**	**0**	**54**

4.2.2 Current survey

The current Stage 2 survey recorded 325 subterranean fauna specimens in the Project Area comprising approximately 314 specimens belonging to stygal taxa and 11 specimens belonging to amphibious taxa (Table 4-3, Appendix B). A total of 15 stygofauna taxa (seven) and amphibious taxa (eight) were recorded in the Project Area during the current survey. Groups that were recorded included amphipods, isopods, cyclopoids, harpacticoids, ostracods and amphibious enchytraeid oligochaetes (Table 4-3).

4.2.3 Stygofauna recorded from the Project Area to date

To date, including survey for both Stage 1 and Stage 2 of the Project, 507 specimens belonging to eight stygal (329 specimens) and nine amphibious (178 specimens) taxa have been recorded across 13 sites in the Project Area. Most specimens have been assigned to morphospecies (Table 4-3; Figure 4-1) while a small number of amphipod and oligochaete specimens could not be identified beyond higher order classifications (Table 4-4). The distribution and ecology of each stygal and amphibious species that is known only from the Project Area are outlined below and shown in Figure 4-1 & Figure 4-2.

Amphipods

Two species of amphipod, Paramelitidae `sp. Biologic-AMPH027` and P. `sp. Biologic-AMPH031` were recorded within the Project Area (Table 4-3, Figure 4-1) and were separated based on molecular sequencing. An additional 11 indeterminate amphipod specimens (Amphipoda sp.) were also recorded at a bore in which both other amphipod morphospecies were also collected (HAE009; Table 4-3). These indeterminate specimens were not sequenced and are considered highly likely to belong to either of the two recorded paramelitid species. Species of paramelitid amphipod are stygobites (obligate stygofauna) and the family includes both relatively widespread species and SREs (Finston *et al.*, 2011). The bores in which these species were recorded within the Project Area occur within higher prospective habitat comprising alluvials and calcareous cement (Biologic, 2020).

Cyclopoid copepods

The most abundant stygofauna taxon recorded within the Project Area were cyclopoid copepods (210 specimens) with 208 specimens of *Fierscyclops* `sp. Biologic-CYCL022` having been recorded from site HAE009 (Table 4-3, Figure 4-1). This OTU was formerly referred to as *Fierscyclops* cf. *fiersi* in the preliminary survey report, prior to molecular analysis (Biologic, 2021). Two specimens of *Mesocyclops* `sp. Biologic-CYCL021` were observed at site HAVWB02 (Table 4-3, Figure 4-1). This OTU was formerly identified as *Mesocyclops notius* (based on morphology) and Cyclopoida sp., prior to molecular analysis (Biologic, 2021). This taxon is likely to be a stygoxene, known to occur in surface waters including lakes, dams, and reservoirs (Ueda & Reid, 2003). Both taxa are considered Potential SRE.

Harpacticoid copepods

Seven specimens of harpacticoid copepods were collected at one site (HAW003) within the Project Area, comprising two specimens of *Parapseudoleptomesochra* cf. *tureei* and five specimens of *Schizopera* `sp. Biologic-HARP013` (Table 4-3, Figure 4-1). Both genera contain many SRE species and hence both taxa are likely SRE. The single specimen of *Parapseudoleptomesochra* cf. *tureei* failed to sequence.

Microcerberid isopods

Two specimens of Microcerberidae `sp. Biologic-ISOP034` were recorded at site HAVWB03 (Table 4-3, Figure 4-1). This taxon is a stygobite (true stygofauna), recorded from the same site as Paramelitidae `sp. Biologic-AMPH027`. This bore site is located within a localised patch of higher prospective stygofauna habitat. Microcerberids are adapted to subterranean and interstitial (inhabiting saturated aquatic sediments) habitats and might be able to disperse during flood events (Coineau & Albuquerque, 2001; Bishop *et al.*, 2020). Very little work has been done on this group in Australia, and from international research, this group is known to be locally restricted (Coineau & Albuquerque, 2001). As such this taxon is a potential SRE.

Ostracods

Two ostracod specimens recorded from one site (HAVWB01) were identified as Humphreyscandonini sp. indet. (Table 4-3, Figure 4-1). The distributions of stygobitic ostracods in Western Australia range from widespread to highly range-restricted (Reeves *et al.*, 2007). While the identification of Humphreyscandonini sp. indet. is tentative, the family Candonidae is known to contain both Confirmed SREs and Widespread species. Humphreyscandonini sp. indet should be treated as a Potential SRE for the purposes of assessment until further collections are made and can be aligned with the specimens from the Project Area. Humphreyscandonini sp. indet was not recorded on sediment rehydration trials and it is considered highly likely that the specimens collected from bores belong to a stygobitic species.

4.2.4 Amphibious fauna recorded from the Project Area to date

Oligochaete worms

A total of 178 specimens belonging to nine oligochaete OTUs were collected across nine sites within the Project Area across both stages (Table 4-3, Figure 4-2). These include Enchytraeidae `sp. Biologic-OLIG023`, E. `sp. Biologic-OLIG024`, E. `sp. Biologic-OLIG025, E. `sp. Biologic-OLIG060`, E. `sp. Biologic-OLIG061`, E. `sp. Biologic-OLIG062`, E. `sp. Biologic-OLIG063`, E. `sp. Biologic-OLIG064` and E. `sp. Biologic-OLIG065`. Of these OTUs, Enchytraeidae `sp. Biologic-OLIG023` was the most abundant recorded within the Project Area, with 145 specimens observed over both stages. Taxa in this family are highly likely to have distributions of catchment-scale to basin-scale, or greater. They appear to tolerate extremes in temperature, salinity and depth and are generalists, principally living off plant residues (Didden, 1991; Ponge, 1991). Enchytraeids are frequently collected in samples from both above and below the water table, i.e. troglofauna traps and either hauls or haul-scrapes (Biologic, 2020). As there is no taxonomic framework for this family in Australia, identification past family level is not possible (Pinder pers. comm. 2020). There is mounting evidence that enchytraeids should not be considered SREs. Therefore, any 'new' species are very likely to be artefacts of a significant lack of knowledge, both in terms of taxonomy and collection records.

4.3 Sediment rehydration trials

The sediment rehydration trial was successful in simulating flood conditions with over 10 distinct emergent taxa were recorded, largely represented by crustacean groups Diplostraca (water fleas and clam shrimp) and Ostracoda (seed shrimp). Ostracoda was the primary interest for the trials and taxonomic identifications were only undertaken for this group. Four ostracod genera were recorded (*Bennelongia*, *Cypretta*, *Ilyodromus* and *Stenocypris*) as well as two taxa that could not be identified to genus due to specimen condition or maturity of the specimens. The trials did not record the target taxon Humphreyscandonini sp. (collected during the baseline subterranean fauna survey in a single bore in the Project Area; Table 4-3), nor were any species belonging to the same family as Humphreyscandonini sp. (Candonidae). The valve (exterior shell) morphology of Humphreyscandonini was distinctly different to the ostracod taxa recorded during the trial (Plate **4-1**).

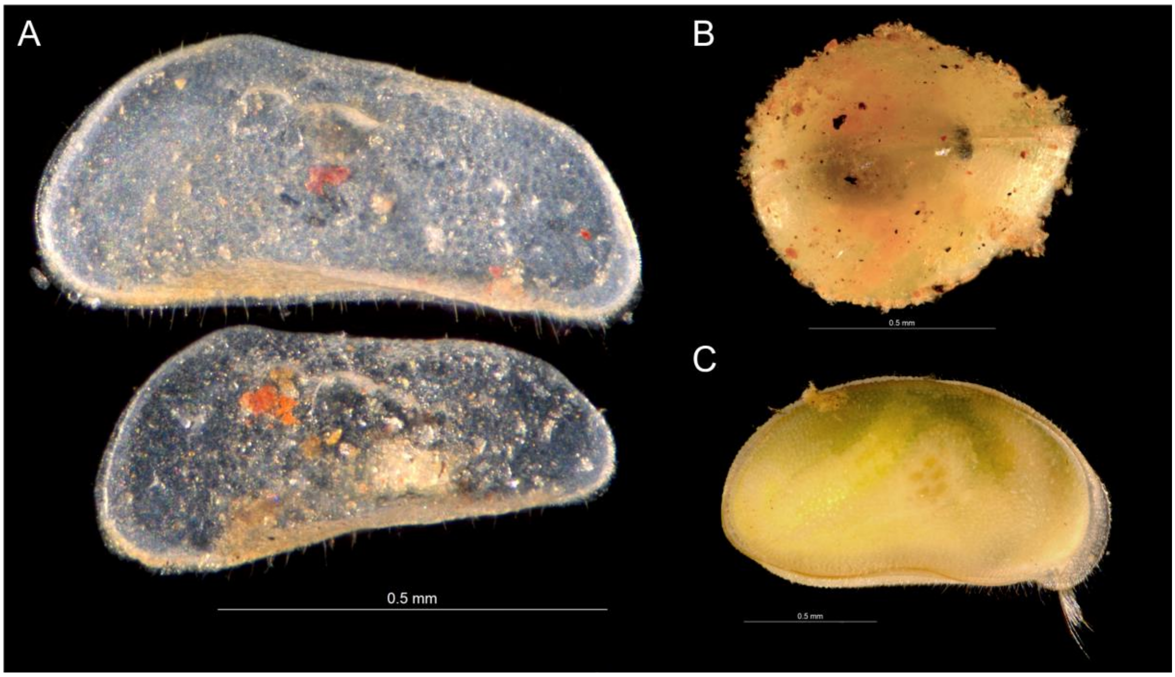


Plate 4-1: Valve morphology of A) Humphreyscandonini sp. indet - baseline survey; B) *Cypretta* sp. – sediment rehydration trial; and C) *Bennelongia* sp. – sediment rehydration trial.

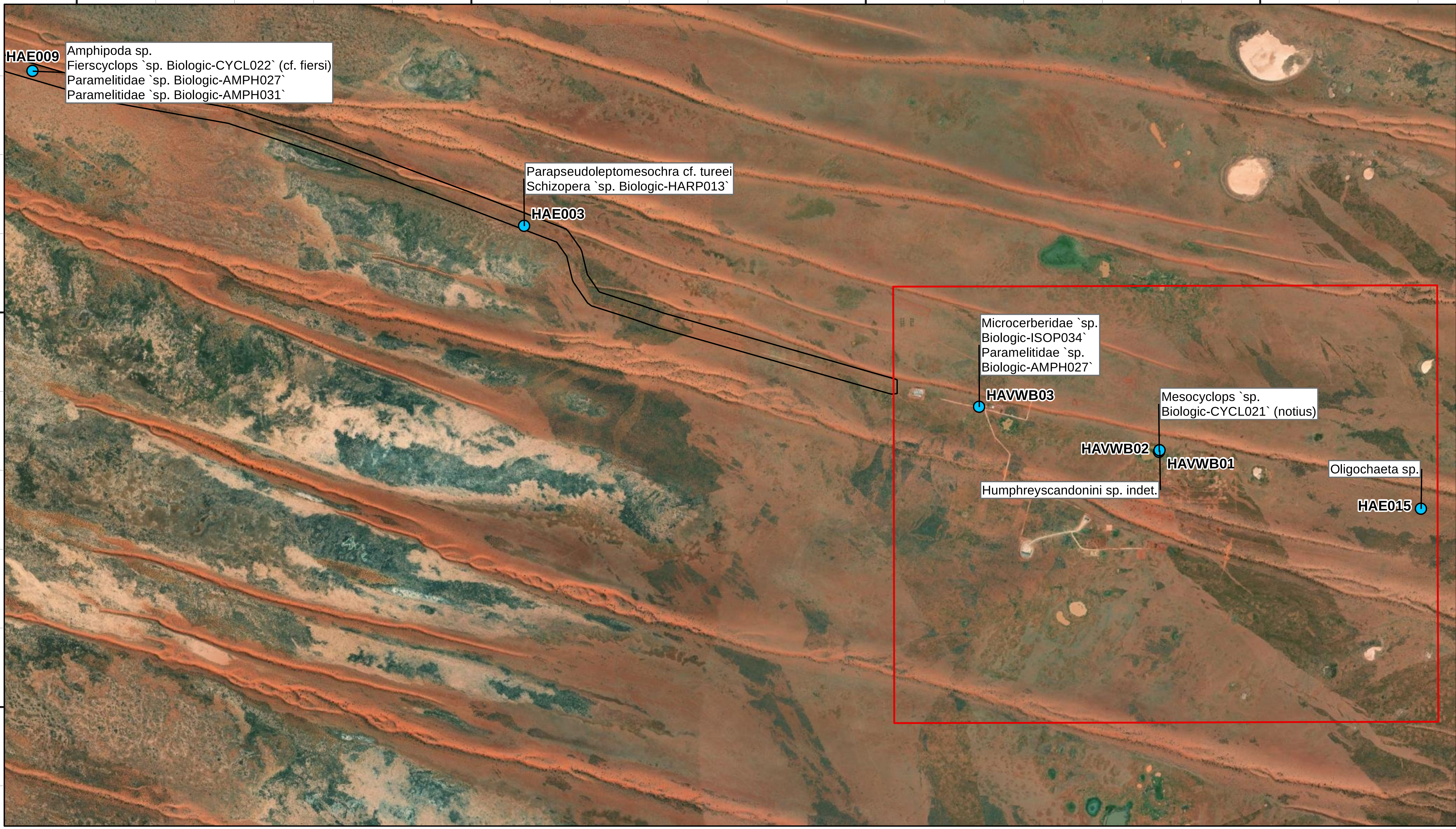
Table 4-3: Stygofauna and amphibious fauna recorded within the Project Area to date.

Taxon	Taxonomic Method	No. of specimens	Survey	Sites Recorded	Linear range (km)	Subterranean & SRE Status	Taxonomic/Habitat/Distribution comments
STYGOFAUNA							
Amphipoda							
Paramelitidae							
Paramelitidae `sp. Biologic-AMPH027`	Morphological & Molecular	18	Stage 1 Stage 2	HAE009, HAVWB03	12.7	Stygobite, likely SRE	Habitat (alluvials and calcareous concrete).
Paramelitidae `sp. Biologic-AMPH031`	Morphological & Molecular	3	Stage 1 Stage 2	HAE009	Single site	Stygobite, likely SRE	Habitat (alluvials and calcareous concrete).
Isopoda							
Microcerberidae							
Microcerberidae `sp. Biologic-ISOP034`	Morphological & Molecular	2	Stage 2	HAVWB03	Single site	Stygobite, potential SRE	Habitat (alluvials and calcareous concrete). Cryptic group with uncertain distribution trends.
Cyclopoida							
Cyclopidae							
Fierscyclops `sp. Biologic-CYCL022`	Morphological & Molecular	208	Stage 1 Stage 2	HAE009	Single site	Stygobite/phile, potential SRE	High uncertainty regarding taxonomy. Negligible genetic work undertaken. Family can comprise SREs.
Mesocyclops `sp. Biologic-CYCL021`	Morphological & Molecular	2	Stage 2	HAVWB02	Single site	Stygobite/phile, potential SRE	
Harpacticoida							
Ameiridae							
Parapseudoleptomesochra cf. *tureei*	Morphological	2	Stage 2	HAE003	Single site	Stygobite, likely SRE	This family comprises many SREs, limited to moderate genetic work available. Specimen failed sequencing
Miraciidae							
Schizopera `sp. Biologic-HARP013`	Morphological & Molecular	5	Stage 2	HAE003	Single site	Stygobite, likely SRE	This family comprises many SREs, limited to moderate genetic work available.
Ostracoda							
Candonidae							
Humphreyscandonini sp. indet.	Morphological	2	Stage 1	HAVWB01	Single site	Stygobite/phile, potential SRE	Habitat (alluvials and calcareous concrete) occurs patchily within the Quaternary cover that forms part of the extensive Upper Unconfined Aquifer. Represented by two valves (dead shells). Indeterminate tribe-level taxon identification (Ivana Karanovic), likely unique species.

Taxon	Taxonomic Method	No. of specimens	Survey	Sites Recorded	Linear range (km)	Subterranean & SRE Status	Taxonomic/Habitat/Distribution comments
AMPHIBIOUS FAUNA							
Oligochaeta							
Enchytraeidae							
Enchytraeidae `sp. Biologic-OLIG023`	Molecular	145	Stage 1 Stage 2	HAE001, HAE015, HAC9502	2.94	Amphibious, unlikely SRE	Present throughout aquatic and subterranean habitats, catchment, or basin scale distribution
Enchytraeidae `sp. Biologic-OLIG024`	Molecular	19	Stage 1 Stage 2	HAD001, HAE009, BTC206001, HAVUNK04, HB400	77.2		
Enchytraeidae `sp. Biologic-OLIG025`	Molecular	7	Stage 1	HAD004, HAE004	1.48		
Enchytraeidae `sp. Biologic-OLIG060`	Molecular	1	Stage 2	HAE015	Single site		
Enchytraeidae `sp. Biologic-OLIG061`	Molecular	1	Stage 2	HAE017	Single site		
Enchytraeidae `sp. Biologic-OLIG062`	Molecular	1	Stage 2	HAE016	Single site		
Enchytraeidae `sp. Biologic-OLIG063`	Molecular	2	Stage 2	HAE016	Single site		
Enchytraeidae `sp. Biologic-OLIG064`	Molecular	1	Stage 2	HAE017	Single site		
Enchytraeidae `sp. Biologic-OLIG065`	Molecular	1	Stage 2	HAE017	Single site		

Table 4-4: Stygofauna (higher order classifications) recorded within the Project Area to date.

Taxon	#	Survey	Sites Recorded	Subterranean & SRE Status	Taxonomic/Habitat/Distribution comments
Amphipoda sp.	11	Stage 2	HAE009	Stygobite, likely SRE	Habitat (alluvials and calcareous concrete).
Oligochaeta sp.	76	Stage 2	HAE015	Unknown	



Legend

- Stygofauna records
- Havieron Project Area
- Service Corridor

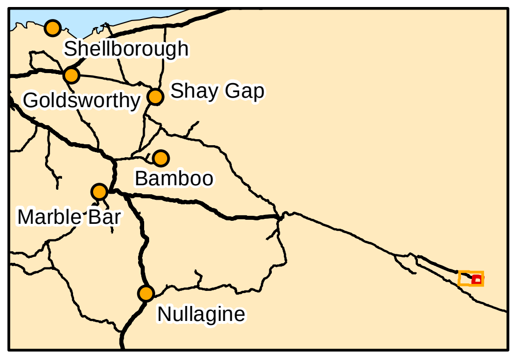
N

biologic Environmental Survey

Scale: 1:46,000

0 1 2 Km

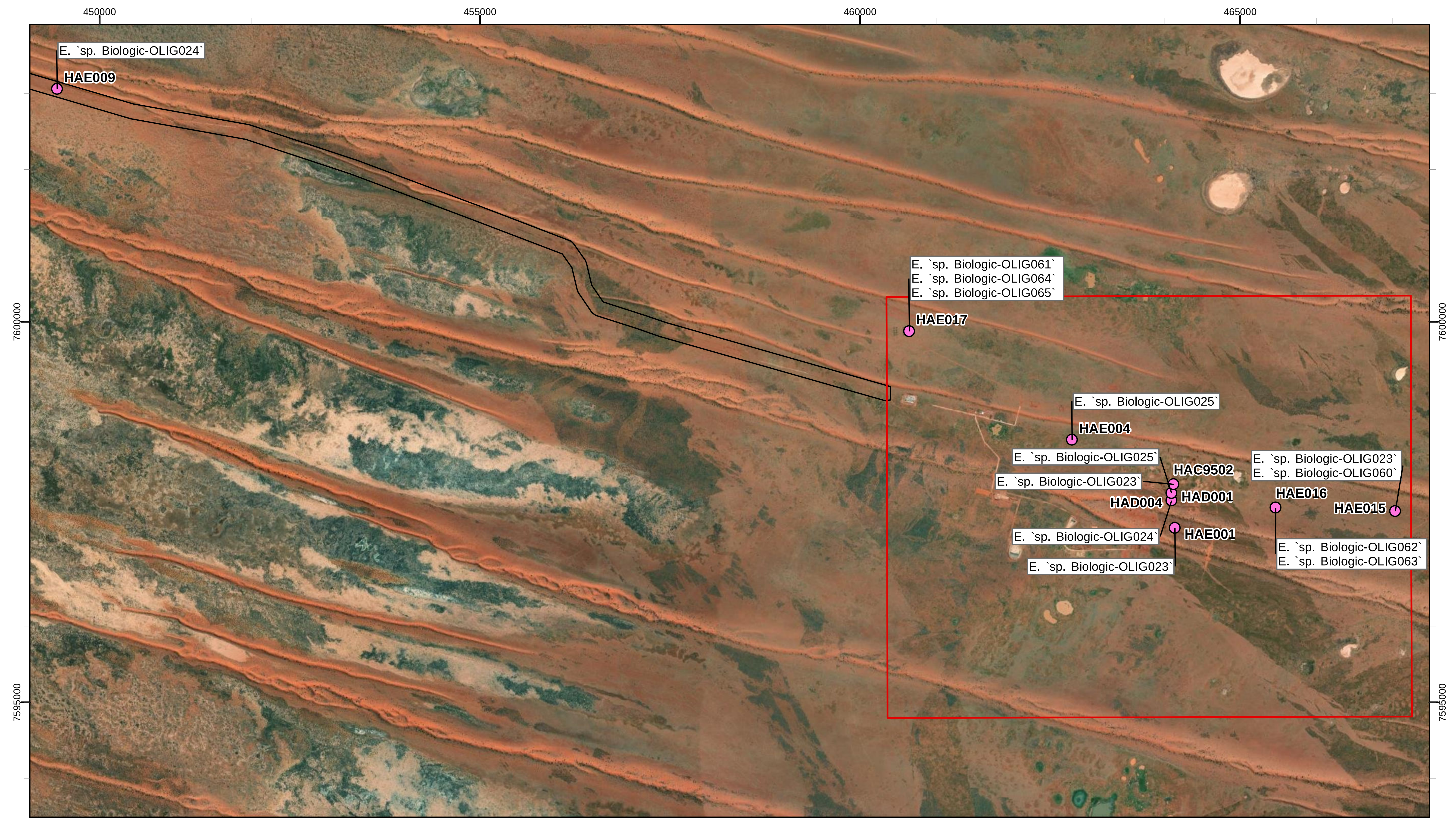
Coordinate System: GDA2020 MGA Zone 51
Projection: Transverse Mercator
Datum: GDA2020 Created 28/07/2022



NEWCREST MINING LIMITED

Havieron Project Stage 2: Subterranean Fauna Survey

Figure 4.1: Stygofauna recorded from the Project Area to date (except Oligochaeta)



Legend

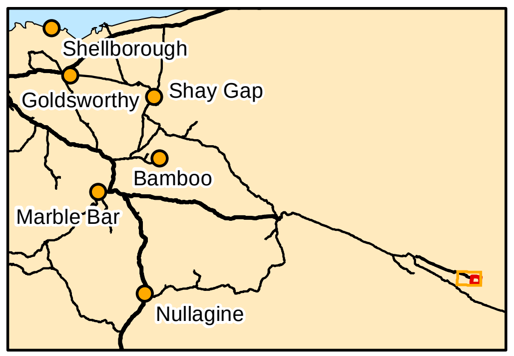
- Enchytraeid Oligochaetes
- Havieron Project
- Service Corridor

N

Scale: 1:46,000

0 1 2 Km

Coordinate System: GDA2020 MGA Zone 51
Projection: Transverse Mercator
Datum: GDA2020 Created 28/07/2022



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Havieron Project Stage 2: Subterranean Fauna Survey

Figure 4.2: Amphibious fauna recorded from the Project Area to date

5 SUBTERRANEAN HABITAT ASSESSMENT

5.1 3D Habitat Modelling

Assessment of the extent, thickness, and connectivity of local geological habitats above and below water table was undertaken by using a three-dimensional hydrogeological model based on drill-hole logging data and regional GSWA mapping in the program Leapfrog® Geo V6.

The 3D habitat modelling using Leapfrog® Geo v6 complements and in some cases supersedes (where sufficient information is available for modelling purposes) preliminary habitat assessments by providing a stronger basis for interpolation of geological/ hydrogeological habitat occurrence between drill holes, and a reasonable basis for extrapolation of the wider extent of habitable layers beyond the drilling area.

The assessment of habitat suitability was based on the following criteria relating to geological and geomorphological characteristics that are known to provide habitat for subterranean fauna:

- Permeability and/or secondary weathering (including supergene/ hydrated mineralization and oxidation);
- Presence or likelihood of subterranean voids, cavities, cracks, fractures;
- Geological/ stratigraphic unit known to support subterranean fauna based on regional knowledge/ previous experience in similar geological settings; and
- Depth from surface and depth to water table (important considerations affecting extent of habitat for troglofauna and stygofauna).

5.1.1 Troglofauna habitats (AWT)

Potential AWT habitats for troglofauna appear to be very thin to absent within the Project where the upper 15 m comprises unconsolidated sediments, made up of aeolian sand, alluvium and evaporates. Troglofauna rely on the presence and continuity of places to live (caves, cavities, fractures, vugs, and pore spaces), high humidity (saturated) and vertical connectivity to supply nutrients and oxygen. The sediments may provide a lot of tiny pore spaces with high humidity and moderate vertical connectivity; however, as the superficial water table lies between 6 and 14 mbgl (metres below ground level), the potential troglofauna habitat would be thin and potentially patchy dependant on seasonal water level variations.

5.1.2 Stygofauna habitats (BWT)

Stygofauna appear in a variety of aquifers, springs, and hyporheos across the world and their existence relies on several current and historical factors. Their persistence depends on vertical connectivity to allow ingress of carbon and nitrogen (Saccò *et al.*, 2019) and lateral connectivity to enable movement.

Conceptually, at the Havieron Project, stygofauna habitat is most likely to occur within the unconfined or perched water system. However, sections of the Upper Mudstone (UWM) or Upper Tillite sandstone (UMT-SST) geological units where there is sufficient porosity, fracturing and suitable water conditions may provide suitable subterranean habitat.

The unconsolidated nature of the upper unconfined aquifer is likely to provide reasonable lateral connectivity and although pore spaces are small, there may be localised patches of calcrete or shallow alluvium which may act as refuges to small stygofauna communities. The vertical extent of this habitat is limited to within 6-14 mbgl, providing approximately 8 metres depth of potential habitat. Where the aquifer sits within modelled saprolitic rocks, the porosity or fractured nature of the lithology is less easy to assess with available data. If the saprolite is shown (through further geological/ hydrogeological and sampling information) to have the potential to host subterranean fauna, this will extend the potential saturated habitats for stygofauna beyond 14 mbgl.

Initial modelling of the upper confined aquifer within the hydrological model, identified the Upper Mudstone (UWM) as a thick (60 m) aquitard separating the upper unconfined aquifer from the confined aquifer (Figure 5-1, Figure 5-2). Review of the drill logging (as well as additional sampling of bores) indicates this upper mudstone has significant variability within it, from mudstone to siltstone, to sandstone and can be inclusive of tillites and conglomerates (Figure 5-2). Unfortunately, sampled bores with potentially restricted stygofauna within the impact area (HAVWB01 and HAVWB02), do not have sufficient geological information to determine the composition of the Upper Mudstone. However geological and hydrogeological information available in nearby bores (HAHY005, HAVWB008, HAVWB09) indicates that the Upper Mudstone may provide suitable stygofauna habitat below the modelled massive mudstones at 28m in HAHY005 and 40m in HAVWB08, where there is sufficient fracturing, evidence of oxidation and porosity.

Below the upper mudstone, the upper confined aquifer units of UMT has the potential to host stygofauna within the upper sandstone unit. However, within the tillites the geological logging indicates they are well cemented and well sorted implying little porosity or available space for stygofauna to inhabit.

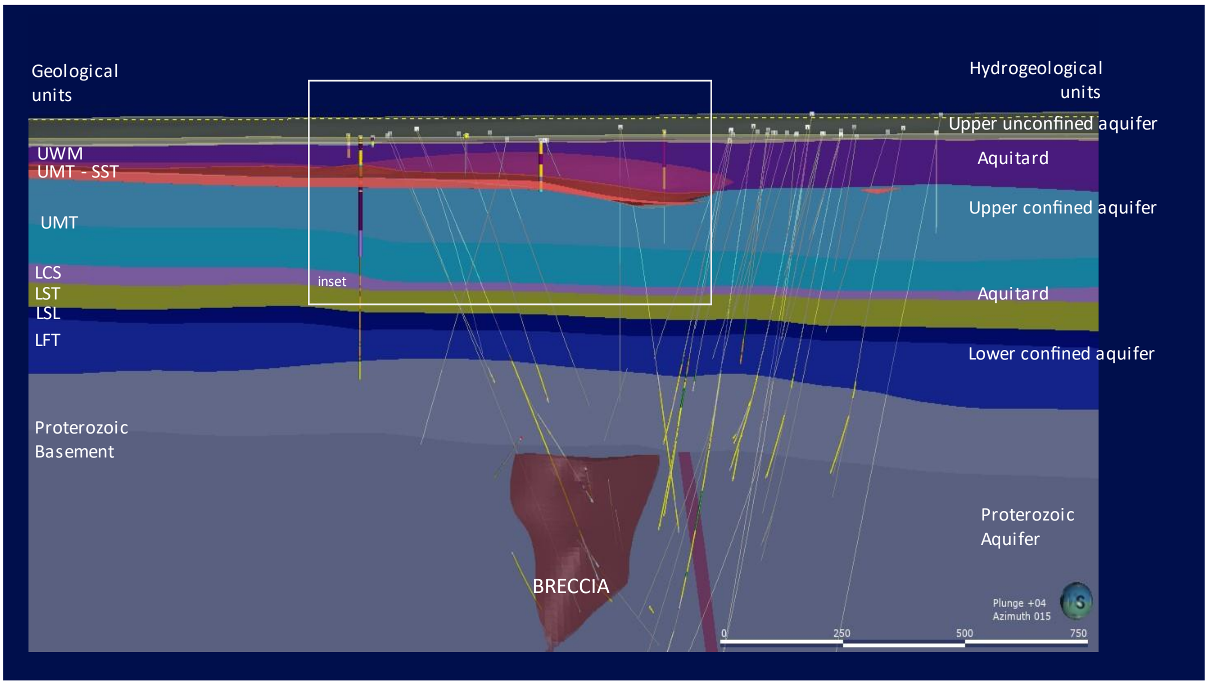


Figure 5-1: Hydrological model identifying the upper mudstone as the aquitard separating the upper unconfined aquifer from the confined aquifer.

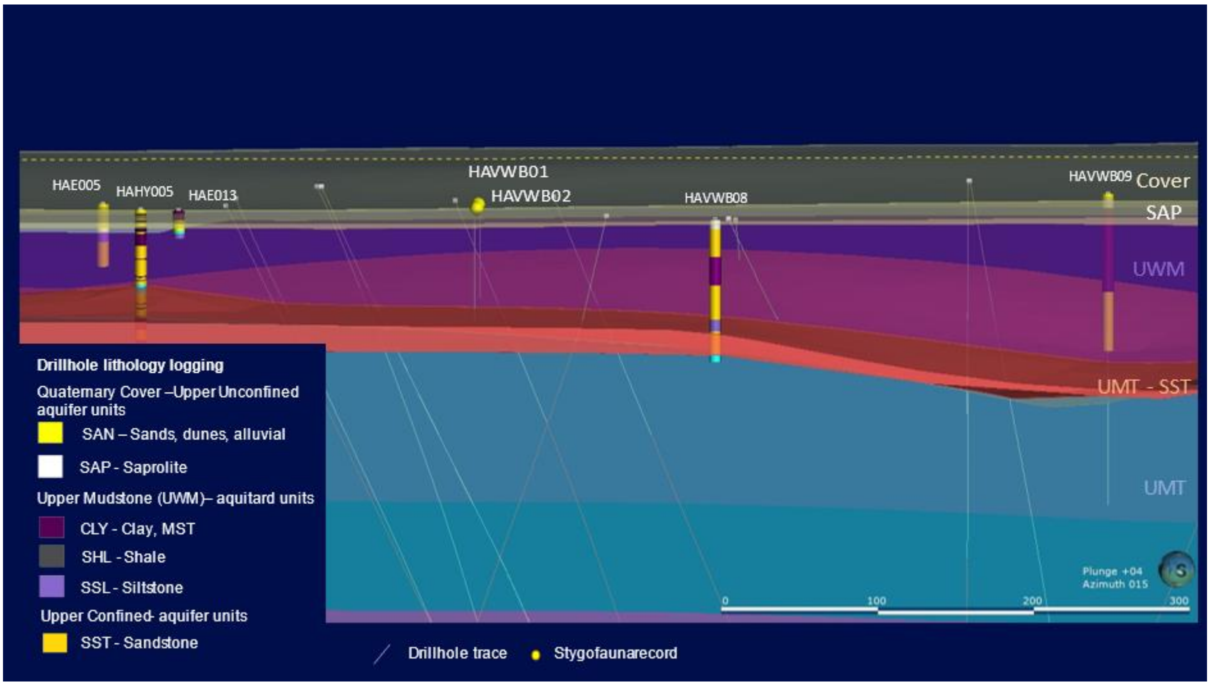


Figure 5-2 inset to Figure 5.1 showing the lithological variability within the logging of the upper mudstone. Drill hole collars close to stygofauna records in HAVWB01 and HAVWB02.

6 RISK ASSESSMENT

6.1 Framework for assessing risks/ impacts

The assessment of impacts to stygofauna fauna is based on the results of all sampling to date, available habitat information (based on geology and drill core logs), 3D modelling and current knowledge of the impacts to stygofauna from the proposed developments associated with the Project (see Table 6-1 for Decision framework for assessment). The impact assessment solely focuses on potentially restricted stygofauna taxa. Widespread or putatively widespread taxa and known stygophiles/ xenes were excluded from the assessment. This impact assessment is deemed preliminary as the level of geological, hydrogeological and stygofauna sampling information was not sufficient throughout the Project Area to provide a high level of certainty regarding assigning risk rankings to stygofauna throughout the Project Area.

Implementation of the Project will potentially result in the following direct impacts to stygofauna:

1. removal of suitable habitat *via* mining/ excavation and groundwater drawdown; and
2. loss of stygofauna individuals.

Direct impacts to stygofauna occur from the removal of BWT habitat within the mining area and the reduction of groundwater habitat within the drawdown cone of depression. Direct impacts to subterranean species (*i.e.* loss of individuals) are inferred to occur where a species' known distribution range and/ or known extent of habitat is entirely within the direct impact zone of the groundwater drawdown areas. Species known to occur, or highly likely to occur (based on available evidence), beyond these impact zones are at a lower risk of impact from the Proposed Development. The Project comprises excavation of an underground decline and associated dewatering, both of which may potentially have direct impacts to stygofauna and amphibious fauna

The Project includes a waste rock landform that may potentially have an indirect impact on stygofauna, through siltation, contamination, or changes to hydrology or nutrient balance. Other indirect impacts to subterranean habitats could potentially include shock and vibration from blasting (likely limited to a very short distance from the proposed mining areas) and habitat desiccation above and within the groundwater drawdown zone. Such indirect impacts are typically gradational, are harder to quantify than the direct impacts, and have very little experimental data to draw conclusions regarding impacts and are therefore not considered herein.

Table 6-1: Decision framework for subterranean fauna impact assessment factors

	Distribution factors	Ecological factors	Habitat factors
Definition	The recorded distribution of the taxon and the ability to infer its wider occurrence relative to impacts	Ecological characteristics that influence potential wider occurrence of the taxon relative to impact areas	The extent and connectivity of suitable habitats and their influence on the potential wider occurrence of a taxon
Degree of potential Impact	• Singleton/ recorded at a single site within direct impact area • Recorded at few sites in a localised spatial area within direct impact area	• Potential/ confirmed SRE taxon • Obligate subterranean fauna • Dispersal-limited taxon • Species or higher taxon is known to have highly restricted ranges	• Remaining suitable habitat beyond direct impact area is limited in extent, and/ or highly fragmented, and/ or highly affected by indirect impacts
Moderating factors to reduce impact	• Recorded outside of direct impact areas • Recorded from widespread areas, many sites	• Non-obligate subterranean fauna • Known vagile/ highly vagile taxon • Related species tend to be locally or regionally widespread	• Remaining suitable habitat is extensive, and well-connected beyond impact areas • Recorded from multiple different habitat units

Groundwater drawdown zones of impact have been identified based on the extent of modelled groundwater drawdown, within the upper unconfined aquifer, in relation to the generalised amount of remaining habitat (as defined in section 5.1.2). Modelling indicates that prior to groundwater extraction there is approximately 8 m of saturated (suitable) habitat within the upper unconfined aquifer (see section 5.1.2). This extent of suitable habitat was then used as a basis for assigning the risk classifications outlined in Table 6-2.

Table 6-2: Groundwater drawdown zones of impact to stygofauna and habitats

Habitat impacted by Groundwater drawdown	Risk classification	Justification
0-12.5%	Low	Groundwater drawdown unlikely to impact primary habitat
12.5-25%	Medium	Groundwater drawdown impacts primary habitat in the unconfined aquifer, but the majority remains saturated
25-50%	High	Groundwater drawdown impacts primary habitat in the unconfined aquifer, with up to half of the thickness of habitat remaining saturated
>50%	Significant	Significant impact to or complete removal of suitable BWT habitat

Considering distribution, ecological and habitat factors presented in Table 6-1, and the extent of groundwater drawdown impact presented in Table 6-2, each stygofauna species/ taxon was allocated an overall risk ranking of High, Medium, Low as follows:

- **High** – Impacts to the taxon are unavoidable or are not sufficiently managed/ mitigated under the current Proposal. Proposed impacts are likely to affect the long-term viability or survival of the species/ taxon. Under the current Proposal, it is unlikely that the EPA objectives will be met in relation to the known values.
- **Medium** – Impacts to the taxon are likely to occur but are manageable under the current Proposal. Impacts can be managed/ mitigated to improve the likely long-term viability or survival of the species/ taxon. With appropriate management/ mitigation measures, it is likely that the EPA objectives can be met in relation to known values.

- **Low** – Impacts to the taxon are unlikely to occur or have sufficient mitigating factors under the current Proposal. The long-term viability or survival of the species/ taxon is not likely to be impacted. The EPA objectives are met in relation to known values, under the current Proposal.

6.2 Sampling adequacy

The sampling undertaken for stygofauna in the Project Area to date totalled 85 samples from 58 sites within the Newcrest tenement areas (Project Area and service corridor) over three phases (

Table 6-3). The 58 sample sites comprised 50 from the direct impact areas and 8 from outside impacts. The location and number of sampling sites was based on the availability of suitable drill holes (sampling was only conducted on Newcrest tenements), which were concentrated within the Project Area (impact areas). The spatial spread of sample sites throughout the Project Area was broad enough to provide a reasonable assessment of species distributions within the direct impact areas however it was very limited beyond the impact areas. It should be noted that information regarding the extent of the direct impacts of groundwater drawdown was not available at the time of sampling. Additionally, some holes (prefixed HAD, HAC) included in the sampling program are now understood to be blank-cased to significant depth (14 holes, 48 samples), and others were sampled less than 2.5 months post drilling (17 holes, 29 samples), and are therefore unsuitable for stygofauna sampling. As a result, the current level of stygofauna sampling does not meet the sampling requirements of the EPA technical guidance for environmental impact assessment (EPA, 2021).

Table 6-3: Stygofauna sampling undertaken within the Project Area inside and outside groundwater drawdown impact areas*

Collection type	Survey	Inside Impacts	Outside Impacts	Total
Number of stygofauna samples collected	Stage 1	54	6	60
	Stage 2	20	5	25
Total		**74**	**11**	**85**
Number of sites sampled for stygofauna	Stage 1	30	3	33
	Stage 2	20	5	25
Total		**50**	**8**	**58**

* Sample numbers include holes which have since been deemed unsuitable for stygofauna sampling due to hole age (<2.5 months) or construction (prefixed HAD, HAC).

6.3 Preliminary assessment of impacts to stygofauna habitat values

The level of geological and hydrogeological information was not sufficient at the time of report preparation to inform a 3D habitat model for the entire Project Area. The impacts to stygofauna habitat values were therefore assessed using the available geological and hydrogeological information at the bore locations where potentially restricted stygofauna have been recorded (HAVWB01 and HAVWB02) and was available from nearby bores (as noted in section 5.1.2). Therefore, this is considered a preliminary impact assessment.

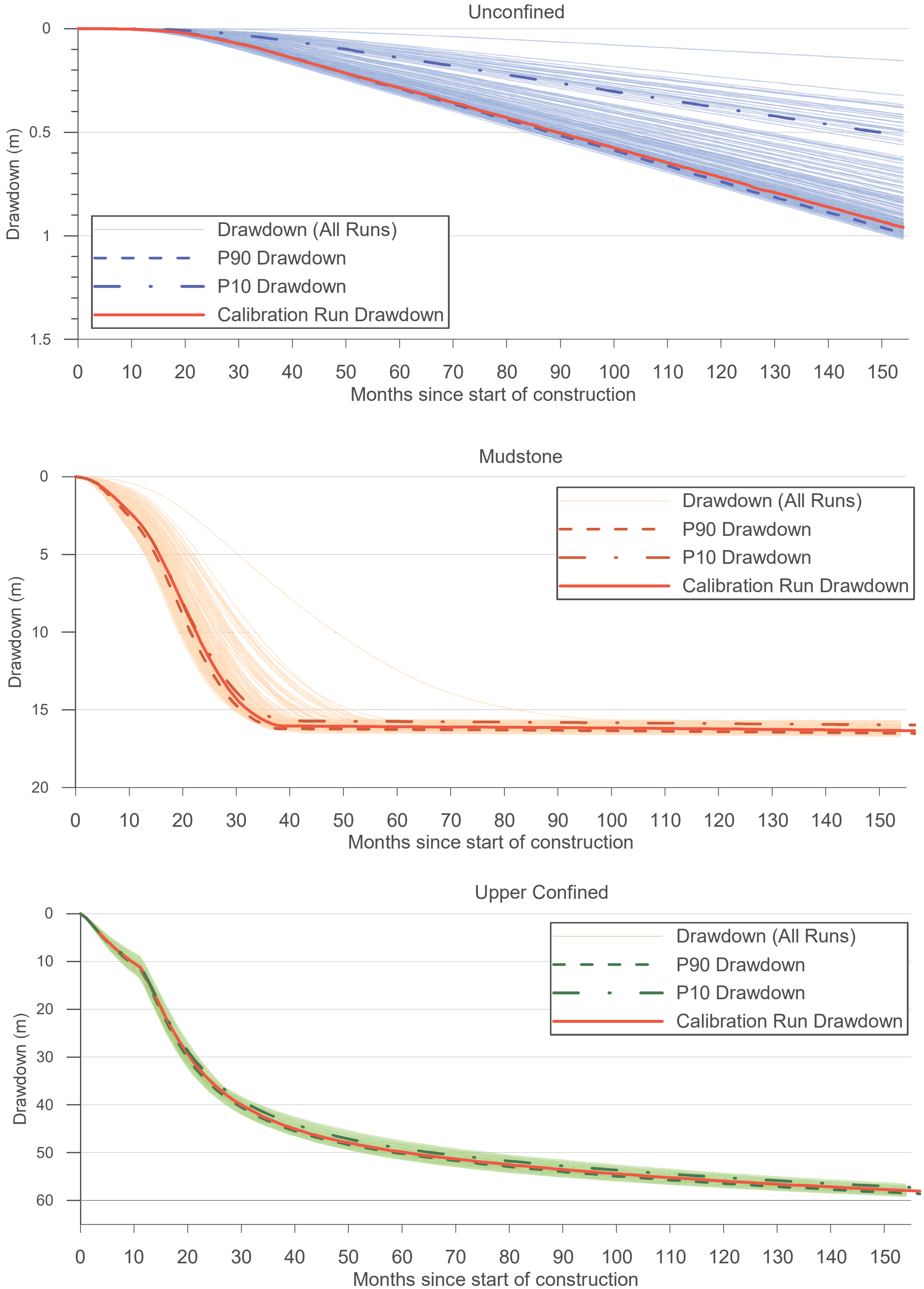
From the available information, there is some evidence to suggest that the upper unconfined aquifer may be linked to the upper confined aquifer as interaction has been reported between the two aquifers during groundwater extraction (Rockwater, 2021). However, this interaction appears minimal. Groundwater drawdown modelling at HAVWB01 has shown impacts to three units, the upper unconfined aquifer, the mudstone unit and the upper confined aquifer (Rockwater H3 Report - Rockwater, 2021) (Figure 6-1). The upper unconfined aquifer is predominantly separated from the upper confined aquifer by the mudstone and therefore drawdown proposed from the upper confined aquifer will not result in a significant change to the surficial water table (at 6 m) within the upper unconfined aquifer. Drawdown in the upper mudstone and the upper confined aquifers is considered as changes of the potentiometric surface only, which will not impact the upper unconfined aquifer.

Therefore, for the purpose of the preliminary assessment, the risk of groundwater extraction on stygofauna taxa within the Project Area is considered only within the upper unconfined aquifer where suitable habitat is known to be present and changes in groundwater are predicted. The potential suitable habitat (saturated habitat) within the upper unconfined aquifer is estimated to be 8 m thick, with the surficial water table at 6 mbgl and the mudstone commencing at a depth of approximately 14 mbgl (see Figure 6-2 for diagrammatic representation of suitable habitat). Given the relatively shallow (8 m) stygofauna habitat, drawdown greater than 4 m is considered a significant risk to resident stygofauna with 50 percent of suitable habitat removed.

At bores HAVWB01 and HAVWB02, the extent of groundwater drawdown in the upper unconfined aquifer is up to 1 m. Within the location of these bores this level of groundwater drawdown is considered a Low risk to stygofauna habitat, as it is unlikely to impact primary habitat (

Table 6-2). Groundwater drawdown at HAVWB03 is predicted to be up to 2 m which is considered a Medium risk to stygofauna habitat with 25% of suitable habitat impacted.

Figure 18



6-3/Grapher/21-05/Figure 18.grf

Client: Newcrest Australia
Project : H3 Level of Assessment
Date : December 2021
Dwg. No: 6-3/21/5-18

MODEL PREDICTED DRAWDOWN
AT MONITORING BORE HAVWB01

Rockwater

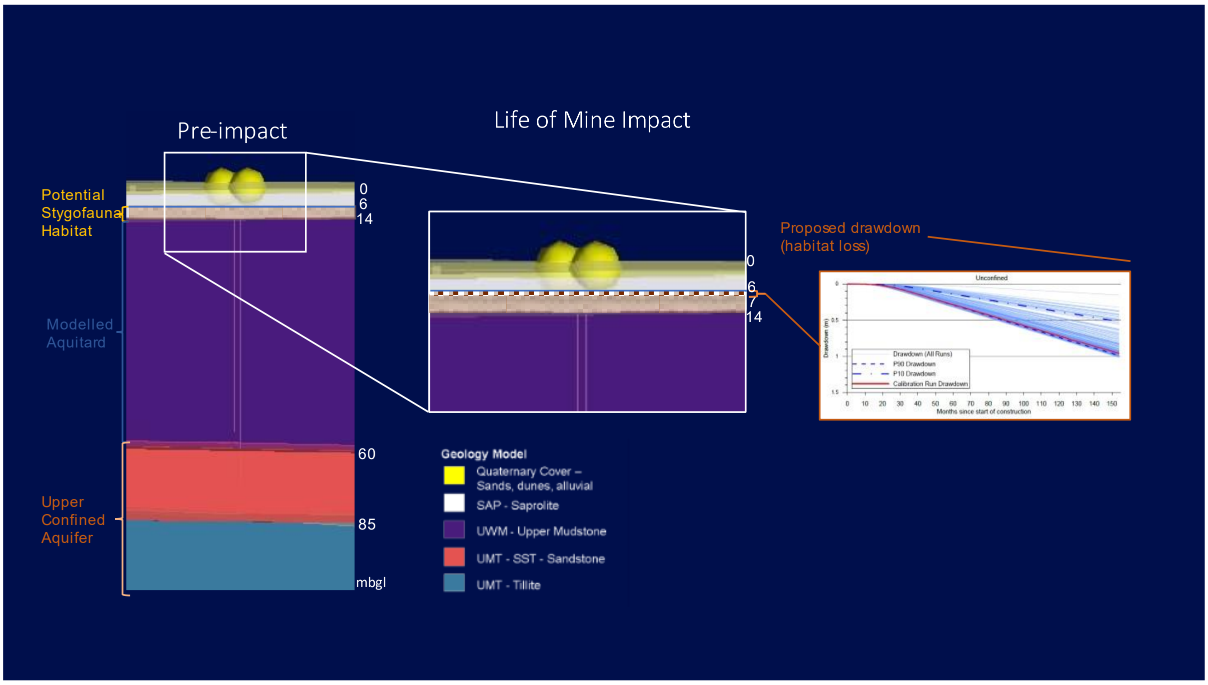


Figure 6-2: Schematic cross-section of the hydrogeological model at HAVWB01 and HAVWB02 showing the pre-impact modelled geology and potential habitat versus the impact of the modelled groundwater drawdown at life of mine.

6.4 Preliminary assessment of impacts to stygofauna species values

Of the 17 stygofauna and amphibious fauna taxa recorded in the Project Area (Table 4-3), 13 were not included in the risk assessment as they either occurred outside of the predicted extent of the groundwater drawdown (4 taxa) or they were known to represent regionally widespread species (9 Enchytraeid taxa) (Table 4-3).

Four (4) taxa have been recorded within the groundwater drawdown impact area for the Havieron Project and are the focus of this preliminary impact assessment. These potentially restricted stygofauna taxa were included in the assessment as their current known distribution is only within the Project Area and often (3 out of 4 taxa), only within the impact areas. Although the identification of one of these taxa, Humphreyscandonini sp. indet., is tentative, it was included in the assessment as the family Candonidae is known to contain numerous Confirmed SREs. The distribution of these taxa relative to the predicted groundwater drawdown impacts within the upper unconfined aquifer and the preliminary level of risk from the proposed development are shown in Figure 6-3 and Table 6-4.

Based on current information regarding each of the species and their known distribution, groundwater drawdown in the upper unconfined aquifer is not likely to have a **High** or **Medium** impact on any of the potentially restricted stygofauna taxa known to occur within the Project Area (Table 6-4).

At the end of mine life, 4 stygofauna taxa (Paramelitidae `sp. Biologic-AMPH027`, *Mesocyclops* `sp. Biologic-CYCL021`, Microcerberidae `sp. Biologic-ISOP034` and Humphreyscandonini sp. indet.), were classified as being at **Low** risk from the Projects dewatering program (Table 6-4). If the assumptions around the functioning of the upper unconfined, mudstone aquitard and upper confined aquifers during extraction are correct (see section 5), the proposed extent of groundwater drawdown at the locations at which these taxa were recorded is **Low** to **Medium** (up to 1 m at HAVWB01 and HAVWB02; and ~ 2 m at HAVWB03) in relation to the extent of suitable habitat (approximately 8 m) remaining. Additionally, Paramelitidae `sp. Biologic-AMPH027` was recorded at two locations within the Project Area (HAE009 and HAVWB03), one of which is outside of the proposed groundwater drawdown area.

Microcerberidae `sp. Biologic-ISOP034`, was recorded at site HAVWB03 (~ 2m groundwater drawdown), the same site as Paramelitidae `sp. Biologic-AMPH027` (Table 6-4, Figure 6-3). Microcerberids are adapted to subterranean and interstitial (inhabiting saturated aquatic sediments) habitats and might be able to disperse during flood events (Coineau & Albuquerque, 2001; Bishop *et al.*, 2020). Very little work has been done on this group in Australia, and from international research, this group is known to be locally restricted (Coineau & Albuquerque, 2001). The extent of groundwater drawdown at this location is considered **Medium** risk (Table 6-2), however under the guidance outlined in Table 6-1 the extent of suitable continuous habitat surrounding this record moderates the risk to **Low**.

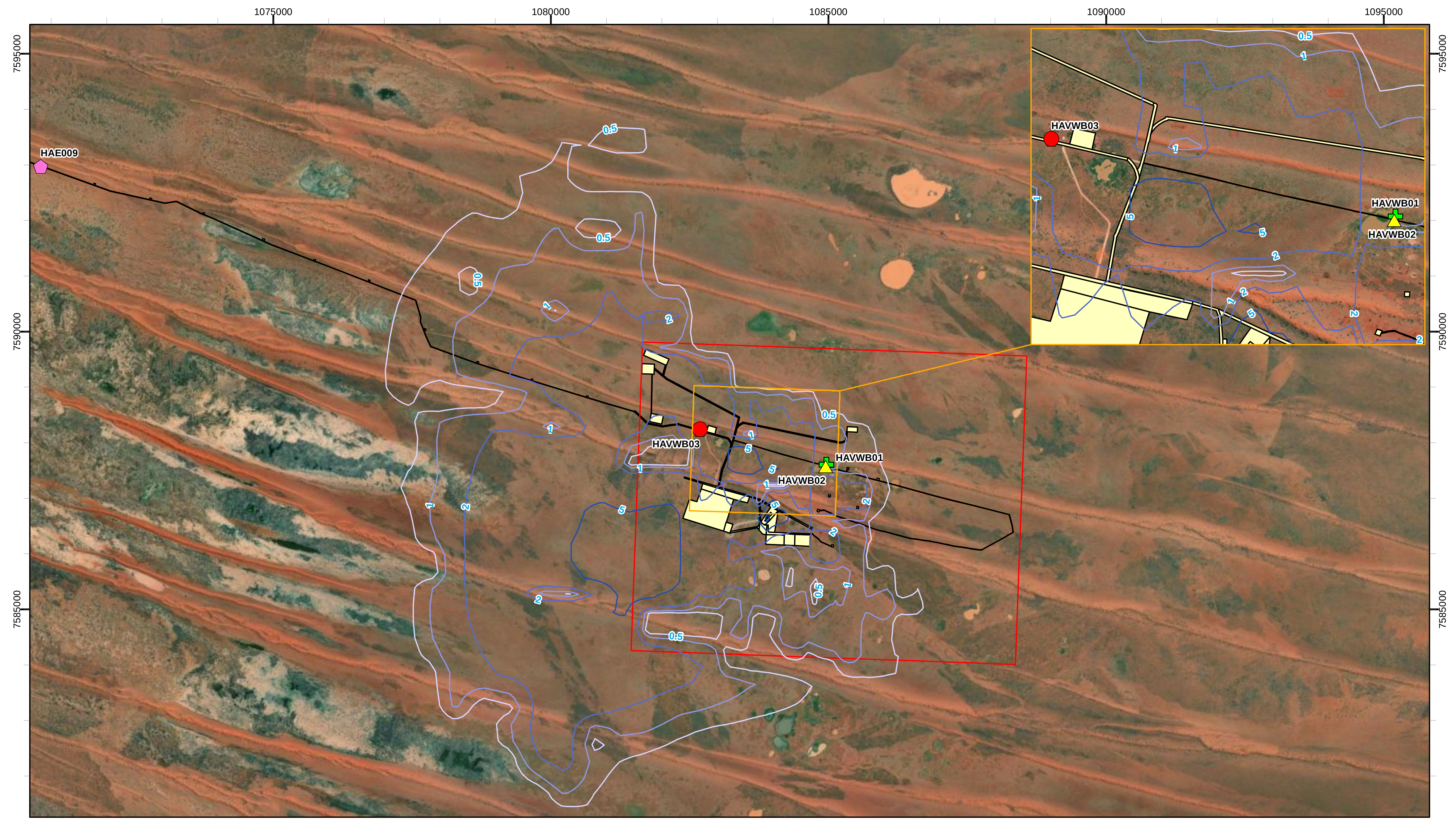
Two specimens of the cyclopoid copepod *Mesocyclops* `sp. Biologic-CYCL021` were recorded at site HAVWB02 (Table 6-4, Figure 6-3, less than 100 m from a claypan) which is predicted to experience a groundwater drawdown on 1 m. This group is known to occur in surface waters including lakes, dams, and reservoirs (Ueda & Reid, 2003) and therefore may persist in the surface water claypans within the Project Area.

The ostracod, Humphreyscandonini sp. indet. was recorded at HAVWB01 (Table 6-4, Figure 6-3). The distributions of stygobitic ostracods in Western Australia range from widespread to highly range-restricted (Reeves *et al.*, 2007). As the identification of this taxon is tentative and only two specimens were recorded in the Stage 1 sampling, it has been included in the current assessment as a **Low** risk.

The degree to which stygofauna communities can tolerate and adapt to changes in groundwater levels and the extent of change (due to dewatering) from the natural fluctuations in groundwater levels within the upper unconfined aquifer is currently unknown. If potential impacts resulting from the Project are found to be greater than predicted, further stygofauna sampling and geological and hydrogeological information will assist in determining the extent of suitable habitat beyond (and beneath) the impacts of groundwater drawdown within the Project Area as well as adding to the general knowledge of the natural groundwater conditions. Genetic analysis of stygofauna specimens collected from within and surrounding the Project Area would enable comparison of taxa in the broader region (Telfer, Kintyre, Lake Disappointment). Investigations into the location of the taxa within the geological profile would also provide further clarification of the potential impact of the Project on resident stygofauna communities. This additional information would support a more robust impact assessment.

Table 6-4: Stygofauna risk assessment based on current taxonomic factors, habitat factors and distribution relative to impacts

Taxonomy	Occurrence in Project Area	Subterranean and SRE status	Linear range	Distribution	Risk rating
Amphipoda					
Paramelitidae					
Paramelitidae `sp. Biologic-AMPH027`	HAE009 HAVWB03	Stygobite Potential SRE	12.7 km.	Locally widespread, inside (GWDD ~2 m) and outside impacts. Potentially suitable habitat remaining throughout the Project Area and beyond within the taxons known range. Taxon likely to occur beyond currently recorded location – further survey required to confirm.	**Low**
Isopoda					
Microcerberidae					
Microcerberidae `sp. Biologic-ISOP034`	HAVWB03	Stygobite Potential SRE	-	Single site. Inside impacts (GWDD ~2 m). Potentially suitable habitat remaining within the Project Area and beyond. Taxon likely to occur beyond currently recorded location - further survey required to confirm.	**Low**
Cyclopoida					
Cyclopidae					
Mesocyclops `sp. Biologic-CYCL021`	HAVWB02	Stygobite/phile Potential SRE	-	Single site. Inside impacts (GWDD ~1 m). Potentially suitable habitat remaining within the Project Area and beyond. Taxon likely to occur beyond currently recorded location further survey required to confirm.	**Low**
Ostracoda					
Candonidae					
Humphreyscandonini `sp. indet.`	HAVWB01	Stygobite/phile Potential SRE	-	Single site. Inside impacts (GWDD ~ 1 m). Potentially suitable habitat remaining throughout the Project Area and beyond. Taxon likely to occur beyond currently recorded location - further survey required to confirm.	**Low**



Legend

Stygofauna

- Humphreyscandonini sp. indet.
- Mesocyclops `sp. Biologic-CYCL021`
- Microcerberidae `sp. Biologic-ISOP034`
- Paramelitidae `sp. Biologic-AMPH027`

Drawdown

DDnL2Y12m10

- 0.5
- 1
- 2
- 5
- 10

- Mining Area
- Proposed Mine Layout

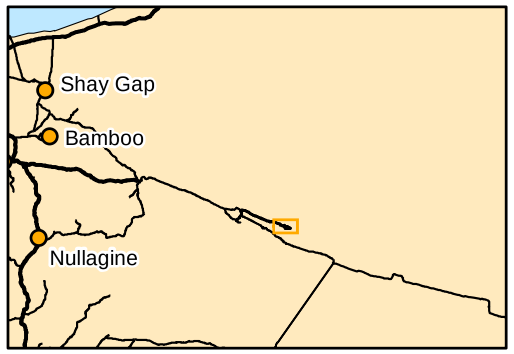
N

biologic Environmental Survey

Scale: 1:63,000

0 1 2 3 Km

Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020 Created 19/05/2022



NEWCREST MINING LIMITED

Havieron Project
Stage 2

Figure 6.3: Potentially restricted stygofauna species within the Project Area in relation to groundwater drawdown within the upper unconfined aquifer

6.5 Cumulative Impact Assessment

Cumulative impacts have been defined as the combination of direct impacts (i.e. groundwater drawdown) from the existing Stage 1 operations and the proposed direct impacts associated with Stage 2. The spatial scale of the cumulative impact assessment is defined as the Project Area and immediate adjacent areas, as these areas are likely to comprise the same or similar connected stygofauna habitats and similar fauna assemblages. The cumulative impacts does not include operations outside this immediate area (such as the current Telfer Gold Mine and borefield operations, 10 km away) as these operations occupy different geological and hydrogeological settings which are known to support different subterranean fauna assemblages (Biologic, 2020).

The change in the spatial extent and depth of the groundwater drawdown within the upper unconfined aquifer is significant between that predicted for Stage 1 and Stage 2 (Biologic, 2020). This may, in part, be due to an increase in knowledge of the aquifers gained through construction of the decline as well as knowledge gained from additional drilling within the Project Area for Stage 2. The extent of groundwater drawdown predicted for Stage 2 has reduced the percentage of the upper unconfined aquifer that will be impacted. For example, at bore location HAVWB01, predicted groundwater drawdown has reduced from approximately 5 m (as predicted for Stage 1) to 1 m predicted for Stage 2. Considering the vertical extent of suitable stygofauna habitat at this location is limited to between 6-14 mbgl, (approximately 8 metres of potential habitat) this is a significant change in percentage of habitat impacted. It should be noted that the impact of groundwater drawdown within the confined aquifer was not assessed in the previous report (Biologic, 2020).

Knowledge of the stygofauna present at the Project Area has increased from Stage 1 to Stage 2 due to the additional stygofauna survey (Phase 3, section 4.2). Three new species (Paramelitidae `sp. Biologic-AMPH027`, *Mesocyclops* `sp. Biologic-CYCL021` and Microcerberidae `sp. Biologic-ISOP034`) in addition to Humphreyscandonini sp. indet. were identified within the Project Area, predominantly within the areas of impact. Prior to undertaking the current survey and habitat assessment, the risk to Humphreyscandonini sp. indet. was considered **Low** (Biologic, 2020) (Stage 1). In the current assessment, the preliminary risk to Humphreyscandonini sp. indet, was still considered **Low**.

7 KEY FINDINGS

The key findings are based on the sampling results to date, available habitat information (including geological and hydrogeological modelling) and current knowledge of the impacts to subterranean fauna:

- A total of 17 stygofauna (8) and amphibious (9) fauna taxa have been recorded in the Project Area across three phases of sampling.
- Current geological and hydrogeological information from within and surrounding the Project Area indicates that the upper unconfined aquifer provides suitable BWT habitat able to support stygofauna values. The geological setting is regular and consistent within and beyond the Project Area and stygofauna habitat very likely to be well-connected or laterally continuous in the local area.
- The upper mudstone aquifer is not likely to provide suitable habitat (saturated habitat) for stygofauna, rather an aquitard.
- The level of geological and hydrogeological information was not sufficient at the time of report to inform a 3D habitat model for the entire Project Area. The impacts to stygofauna habitat values were assessed in detail at the bore locations where potentially restricted stygofauna have been recorded (HAVWB01 and HAVWB02) and geological and hydrogeological information from nearby bores (HAVWB008, HAHY005 and HAHY024).
- Potential suitable habitat (saturated habitat) for stygofauna within the upper unconfined aquifer is estimated to be 8 m thick. The potential habitat within the upper unconfined aquifer is relatively thin, however the currently proposed groundwater drawdown (at life of mine) is overall expected to be low (up to 2 m).
- At the end of mine life, 4 stygofauna taxa (Paramelitidae `sp. Biologic-AMPH027`, *Mesocyclops* `sp. Biologic-CYCL021`, Microcerberidae `sp. Biologic-ISOP034` and Humphreyscandonini sp. indet.), were classified as being at **Low** risk from the Projects dewatering program. It is considered likely that their distribution extends beyond Project impacts as suitable continuous habitat is expected to remain outside of and below the proposed extent of groundwater drawdown.
- Although there is a change in the spatial extent and depth of the groundwater drawdown within the upper unconfined aquifer predicted for Stage 1 compared to Stage 2 (due to increased knowledge of the systems) the cumulative risk to Humphreyscandonini sp. indet, is still considered **Low**.

In conclusion, the results of this preliminary impact assessment indicate that impacts to these four restricted stygofauna species as a result of Project operations are likely to be **Low**. Additional survey and further geological and hydrogeological investigations will improve knowledge of the subterranean fauna communities within the Project Area and will therefore allow a more robust risk assessment to be undertaken, if required.

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Appendix A: Subterranean fauna sample effort within the Project Area to date

Site name	Sample/set date	Haul	Pump	Scrape	Trap	Latitude	Longitude	Trip	Drill Date
HAC0301	25/11/2019	x		x		-21.7258	122.6558	2	10/05/2003
HAC9101	24/11/2019	x		x	x	-21.7243	122.6526	2	26/08/1991
HAC9101	31/03/2020	x		x	x	-21.7243	122.6526	3	26/08/1991
HAC9502	25/11/2019	x		x	x	-21.7224	122.6531	2	1/10/1995
HAC9502	19/02/2020	x		x		-21.7224	122.6531	2	1/10/1995
HAC9502	31/03/2020	x		x	x	-21.7224	122.6531	3	1/10/1995
HAD001	24/11/2019	x		x	x	-21.7243	122.6528	2	22/06/2019
HAD001	31/03/2020	x		x	x	-21.7243	122.6528	3	22/06/2019
HAD002	24/11/2019	x		x	x	-21.7234	122.6512	2	22/06/2019
HAD002	31/03/2020				x	-21.7234	122.6512	3	22/06/2019
HAD003	24/11/2019	x		x	x	-21.7239	122.6521	2	22/06/2019
HAD003	31/03/2020	x		x	x	-21.7239	122.6521	3	22/06/2019
HAD004	23/11/2019	x		x	x	-21.7234	122.6528	1	22/06/2019
HAD004	30/03/2020	x		x	x	-21.7234	122.6528	2	22/06/2019
HAD005	24/11/2019	x		x	x	-21.7243	122.6509	2	22/06/2019
HAD005	1/04/2020	x		x	x	-21.7243	122.6509	3	22/06/2019
HAD006	24/11/2019	x		x	x	-21.7247	122.6528	2	22/06/2019
HAD006	1/04/2020	x		x	x	-21.7247	122.6528	3	22/06/2019
HAD008	24/11/2019	x		x	x	-21.7247	122.6533	2	22/06/2019
HAD008	1/04/2020	x		x	x	-21.7247	122.6533	3	22/06/2019
HAD009A	23/11/2019	x		x	x	-21.7252	122.6562	1	22/06/2019
HAD009A	1/04/2020	x		x	x	-21.7252	122.6562	3	22/06/2019
HAD010A	24/11/2019	x		x		-21.7247	122.6513	2	9/06/2019
HAD027	24/11/2019	x		x		-21.7229	122.649	2	17/09/2019
HAD027	19/02/2020	x		x		-21.7229	122.649	2	17/09/2019
HAD027	31/03/2020	x		x	x	-21.7229	122.649	3	17/09/2019
HAD030	19/02/2020	x		x		-21.7263	122.6465	2	25/09/2019
HAE001	30/03/2020	x		x	x	-21.7276	122.6533	2	22/03/2020
HAE001	15/06/2020	x		x		-21.7276	122.6533	4	22/03/2020
HAE001	4/05/2021	x		x		-21.7276	122.6533	5	22/03/2020
HAE002	31/03/2020	x			x	-21.6842	122.5473	3	26/03/2020
HAE002	15/06/2020	x				-21.6842	122.5473	4	26/03/2020
HAE003	31/03/2020	x			x	-21.693	122.5715	3	25/03/2020
HAE003	15/06/2020	x				-21.693	122.5715	4	25/03/2020
HAE003	4/05/2021	x				-21.693	122.5715	5	25/03/2020
HAE004	31/03/2020	x		x	x	-21.7171	122.6402	3	24/03/2020
HAE004	15/06/2020	x		x		-21.7171	122.6402	4	24/03/2020
HAE004	4/05/2021	x		x		-21.7171	122.6402	5	24/03/2020
HAE005	31/03/2020	x		x	x	-21.718	122.6471	3	23/03/2020
HAE005	15/06/2020	x		x		-21.718	122.6471	4	23/03/2020
HAE005	4/05/2021	x		x		-21.718	122.6471	5	23/03/2020
HAE006	31/03/2020	x		x	x	-21.7119	122.6546	3	24/03/2020
HAE006	15/06/2020	x		x		-21.7119	122.6546	4	24/03/2020
HAE006	4/05/2021	x		x		-21.7119	122.6546	5	24/03/2020
HAE007	30/03/2020	x			x	-21.7235	122.6568	2	23/03/2020
HAE007	15/06/2020	x				-21.7235	122.6568	4	23/03/2020
HAE007	4/05/2021	x				-21.7235	122.6568	5	23/03/2020
HAE008	30/03/2020	x		x	x	-21.726	122.6475	2	22/03/2020
HAE008	15/06/2020	x		x		-21.726	122.6475	4	22/03/2020
HAE009	31/03/2020	x			x	-21.6751	122.5113	3	27/03/2020
HAE009	15/06/2020	x				-21.6751	122.5113	4	27/03/2020
HAE009	4/05/2021	x				-21.6751	122.5113	5	27/03/2020
HAE010	3/04/2020				x	-21.7274	122.6394	3	1/04/2020
HAE010	15/06/2020	x		x		-21.7274	122.6394	4	1/04/2020
HAE011	3/04/2020				x	-21.7279	122.6441	3	1/04/2020
HAE011	15/06/2020	x				-21.7279	122.6441	4	1/04/2020
HAE011	6/05/2021	x				-21.7279	122.6441	5	1/04/2020
HAE012	3/04/2020				x	-21.7311	122.6486	3	31/03/2020
HAE012	15/06/2020	x				-21.7311	122.6486	4	31/03/2020
HAE012	4/05/2021	x				-21.7311	122.6486	5	31/03/2020
HAE013_U	4/05/2021	x				-21.7187	122.6474	5	10/04/2020
HAE014	16/06/2020	x				-21.7282	122.6433	4	10/04/2020
HAE014	4/05/2021	x				-21.7282	122.6433	5	10/04/2020
HAE015	4/05/2021	x				-21.7256	122.6813	5	8/12/2020
HAE016	4/05/2021	x				-21.7252	122.6661	5	13/12/2020
HAE017	4/05/2021	x				-21.7041	122.6195	5	12/12/2020
HAE018	4/05/2021	x				-21.7004	122.6428	5	12/12/2020

Site name	Sample/set date	Haul	Pump	Scrape	Trap	Latitude	Longitude	Trip	Drill Date
HAE020	4/05/2021	x				-21.7111	122.6145	5	12/12/2020
HAHY002	16/06/2020	x				-21.7277	122.6392	4	11/04/2020
HAHY003	4/05/2021	x				-21.7274	122.6439	5	8/04/2020
HAHY007	15/06/2020		x			-21.7209	122.6583	4	17/05/2020
HAVWB01	25/11/2019	x				-21.7188	122.6493	2	3/08/1991
HAVWB01	19/02/2020	x				-21.7188	122.6493	2	3/08/1991
HAVWB01	31/03/2020	x				-21.7188	122.6493	3	3/08/1991
HAVWB01	16/06/2020	x				-21.7188	122.6493	4	3/08/1991
HAVWB02	19/02/2020		x			-21.719	122.6492	2	3/11/2018
HAVWB02	31/03/2020		x			-21.719	122.6492	3	3/11/2018
HAVWB02	4/05/2021	x				-21.719	122.6492	5	3/11/2018
HAVWB03	24/11/2019	x				-21.7138	122.6272	2	22/09/2019
HAVWB03	19/02/2020	x				-21.7138	122.6272	2	22/09/2019
HAVWB03	31/03/2020	x				-21.7138	122.6272	3	22/09/2019
HAVWB03	16/06/2020	x				-21.7138	122.6272	4	22/09/2019
HAVWB03	4/05/2021	x				-21.7138	122.6272	5	22/09/2019
HAVWB04	25/11/2019		x			-21.7228	122.649	2	29/09/2019
HAVWB05	4/05/2021	x				-21.6243	122.3265	5	12/12/2020
HAVWB06	4/05/2021	x				-21.6719	122.482	5	11/12/2020
HAVWB09	5/05/2021		x			-21.7193	122.6532	5	3/12/2020
HAVWB11	5/05/2021	x				-21.727	122.6491	5	24/11/2020
HAVWB12	5/05/2021	x				-21.7243	122.6566	5	29/11/2020
HAVWB13	4/05/2021	x				-21.7282	122.6529	5	20/11/2020

Appendix B: Subterranean fauna species within the Project Area to date

Site name	Sample/set date	Sample type	BES	Final Identification	Subt. Status	No. Spec.	BMR	WAM REG. NO.
HAC9502	25/11/2019	Trap	6418	Enchytraeidae `sp. Biologic-OLIG023`	Amph	95	1840	
HAC9502	19/02/2020	HS	7085	Enchytraeidae `sp. Biologic-OLIG023`	Amph	1	1844	
HAD001	24/11/2019	Trap	6684	Enchytraeidae `sp. Biologic-OLIG024`	Amph	5	1843	
HAD001	31/03/2020	HS	7854	Enchytraeidae `sp. Biologic-OLIG024`	Amph	13	1848	
HAD004	23/11/2019	Trap	6438	Enchytraeidae `sp. Biologic-OLIG025`	Amph	1	1841	
HAD004	30/03/2020	HS	8574	Enchytraeidae `sp. Biologic-OLIG025`	Amph	1	1854	
HAD004	30/03/2020	Trap	8478	Enchytraeidae `sp. Biologic-OLIG025`	Amph	4	1850	
HAD006	1/04/2020	Trap	7248	Pauropoda sp.	Trog	1		
HAE001	30/03/2020	Trap	7275	Enchytraeidae `sp. Biologic-OLIG023`	Amph	5	1846	
HAE001	15/06/2020	HS	8550	Enchytraeidae `sp. Biologic-OLIG023`	Amph	41	1851	
HAE003	4/05/2021	Haul	12596	Parapseudoleptomesochra cf. tureei	Stygo	2		
HAE003	4/05/2021	Haul	10545a	Schizopera `sp. Biologic-HARP013`	Stygo	2		
HAE003	4/05/2021	Haul	10545b	Schizopera `sp. Biologic-HARP013`	Stygo	1	3751	
HAE003	4/05/2021	Haul	10545c	Schizopera `sp. Biologic-HARP013`	Stygo	1	3752	
HAE003	4/05/2021	Haul	10545d	Schizopera `sp. Biologic-HARP013`	Stygo	1	3778	
HAE004	15/06/2020	HS	7950	Enchytraeidae `sp. Biologic-OLIG025`	Amph	1	1849	
HAE009	15/06/2020	Haul	8544	Paramelitidae `sp. Biologic-AMPH031`	Stygo	1	1834	
HAE009	15/06/2020	Haul	8558	Fierscyclops `sp. Biologic-CYCL022` (cf. fiersi)	Stygo	1	3746	
HAE009	4/05/2021	Haul	10975	Enchytraeidae `sp. Biologic-OLIG024`	Amph	1	2967	
HAE009	4/05/2021	Haul	11099	Paramelitidae `sp. Biologic-AMPH027`	Stygo	1	3740	
HAE009	4/05/2021	Haul	9543	Paramelitidae `sp. Biologic-AMPH031`	Stygo	1	3738	
HAE009	4/05/2021	Haul	11043	Paramelitidae `sp. Biologic-AMPH031`	Stygo	1	3739	
HAE009	4/05/2021	Haul	10894	Amphipoda sp.	Stygo	11		
HAE009	4/05/2021	Haul	10859a	Fierscyclops `sp. Biologic-CYCL022` (cf. fiersi)	Stygo	99		
HAE009	4/05/2021	Haul	10859b	Fierscyclops `sp. Biologic-CYCL022` (cf. fiersi)	Stygo	1	3747	
HAE009	4/05/2021	Haul	10859c	Fierscyclops `sp. Biologic-CYCL022` (cf. fiersi)	Stygo	1	3748	
HAE009	4/05/2021	Haul	10859d	Fierscyclops `sp. Biologic-CYCL022` (cf. fiersi)	Stygo	1	3749	
HAE009	4/05/2021	Haul	10859e	Fierscyclops `sp. Biologic-CYCL022` (cf. fiersi)	Stygo	1	3750	
HAE015	4/05/2021	Haul	11496	Enchytraeidae `sp. Biologic-OLIG023`	Amph	1	2971	
HAE015	4/05/2021	Haul	11521	Enchytraeidae `sp. Biologic-OLIG023`	Amph	1	2968	
HAE015	4/05/2021	Haul	11720	Enchytraeidae `sp. Biologic-OLIG023`	Amph	1	2970	
HAE015	4/05/2021	Haul	10598	Oligochaeta sp.	Stygo	76		
HAE015	4/05/2021	Haul	10058	Pauropoda `sp. Biologic-PAUR045`	Trog	1	2940	
HAE015	4/05/2021	Haul	11667	Enchytraeidae `sp. Biologic-OLIG060`	Amph	1	2969	
HAE016	4/05/2021	Haul	11549	Enchytraeidae `sp. Biologic-OLIG062`	Amph	1	2972	
HAE016	4/05/2021	Haul	9993	Enchytraeidae `sp. Biologic-OLIG063`	Amph	1	2974	
HAE016	4/05/2021	Haul	11774	Enchytraeidae `sp. Biologic-OLIG063`	Amph	1	2973	
HAE017	4/05/2021	Haul	11497	Enchytraeidae `sp. Biologic-OLIG061`	Amph	1	2976	
HAE017	4/05/2021	Haul	11706	Enchytraeidae `sp. Biologic-OLIG064`	Amph	1	2975	
HAE017	4/05/2021	Haul	10560	Enchytraeidae `sp. Biologic-OLIG065`	Amph	1	2977	
HAVWB01	19/02/2020	Haul	5269	Humphreyscandonini sp. indet.	Stygo	2		
HAVWB02	4/05/2021	Haul	10739b	Mesocyclops `sp. Biologic-CYCL021` (notius)	Stygo	1	3779	
HAVWB02	4/05/2021	Haul	10739a	Mesocyclops `sp. Biologic-CYCL021` (notius)	Stygo	1		
HAVWB03	19/02/2020	Haul	5512	Paramelitidae `sp. Biologic-AMPH027`	Stygo	1		
HAVWB03	31/03/2020	Haul	7858	Paramelitidae `sp. Biologic-AMPH027`	Stygo	5		
HAVWB03	16/06/2020	Haul	8568	Paramelitidae `sp. Biologic-AMPH027`	Stygo	5	1836	
HAVWB03	4/05/2021	Haul	11510	Paramelitidae `sp. Biologic-AMPH027`	Stygo	1	3741	
HAVWB03	4/05/2021	Haul	11756	Paramelitidae `sp. Biologic-AMPH027`	Stygo	1	3742	
HAVWB03	4/05/2021	Haul	11764	Paramelitidae `sp. Biologic-AMPH027`	Stygo	1	3743	
HAVWB03	4/05/2021	Haul	13022	Microcerberidae `sp. Biologic-ISOP034`	Stygo	1	2937	
HAVWB03	4/05/2021	Haul	11379	Microcerberidae `sp. Biologic-ISOP034`	Stygo	1		
HAVWB03	4/05/2021	Haul	12971	Paramelitidae `sp. Biologic-AMPH027`	Stygo	3		

Abbreviations: HS, Haul/Scrape; Amph, Amphibious; Stygo, Stygofauna; BES, Biologic Environmental Specimen identifier; BMR, Biologic Molecular Registration identifier.

Appendix C: Molecular results

Table B-1: Molecular analysis of stygofauna and amphibious fauna recorded within the Project Area.

Site name	Morph_ID	PCR	Final_ID	GenBank Accession No.
HAC9502	Enchytraeidae sp.	PASS	Enchytraeidae `sp. Biologic-OLIG023`	
HAC9502	Enchytraeidae sp.	PASS	Enchytraeidae `sp. Biologic-OLIG023`	
HAE001	Enchytraeidae sp.	PASS	Enchytraeidae `sp. Biologic-OLIG023`	
HAE001	Enchytraeidae sp.	PASS	Enchytraeidae `sp. Biologic-OLIG023`	
HAE015	Enchytraeidae sp.	PASS	Enchytraeidae `sp. Biologic-OLIG023`	
HAE015	Enchytraeidae sp.	PASS	Enchytraeidae `sp. Biologic-OLIG023`	
HAE015	Enchytraeidae sp.	PASS	Enchytraeidae `sp. Biologic-OLIG023`	
HB400	Enchytraeidae sp.	PASS	Enchytraeidae `sp. Biologic-OLIG024`	
HAVUNK04	Enchytraeidae sp.	PASS	Enchytraeidae `sp. Biologic-OLIG024`	
BTC206001	Enchytraeidae sp.	PASS	Enchytraeidae `sp. Biologic-OLIG024`	
HAE009	Enchytraeidae sp.	PASS	Enchytraeidae `sp. Biologic-OLIG024`	
HAD001	Enchytraeidae sp.	PASS	Enchytraeidae `sp. Biologic-OLIG024`	
HAD001	Enchytraeidae sp.	PASS	Enchytraeidae `sp. Biologic-OLIG024`	
HAE004	Enchytraeidae sp.	PASS	Enchytraeidae `sp. Biologic-OLIG025`	
HAD004	Enchytraeidae sp.	PASS	Enchytraeidae `sp. Biologic-OLIG025`	
HAD004	Enchytraeidae sp.	PASS	Enchytraeidae `sp. Biologic-OLIG025`	
HAD004	Enchytraeidae sp.	PASS	Enchytraeidae `sp. Biologic-OLIG025`	
HB449	Enchytraeidae sp.	PASS	Enchytraeidae `sp. Biologic-OLIG026`	
HAE015	Enchytraeidae sp.	PASS	Enchytraeidae `sp. Biologic-OLIG060`	
HAE017	Enchytraeidae sp.	PASS	Enchytraeidae `sp. Biologic-OLIG061`	
HAE016	Enchytraeidae sp.	PASS	Enchytraeidae `sp. Biologic-OLIG062`	
HAE016	Enchytraeidae sp.	PASS	Enchytraeidae `sp. Biologic-OLIG063`	
HAE016	Enchytraeidae sp.	PASS	Enchytraeidae `sp. Biologic-OLIG063`	
HAE017	Enchytraeidae sp.	PASS	Enchytraeidae `sp. Biologic-OLIG064`	
HAE017	Enchytraeidae sp.	PASS	Enchytraeidae `sp. Biologic-OLIG065`	
HAVUNK03	Enchytraeidae sp.	PASS	Enchytraeidae `sp. E12`	
HAVUNK02	Enchytraeidae sp.	PASS	Enchytraeidae `sp. E12`	
HAVUNK02	Enchytraeidae sp.	PASS	Enchytraeidae `sp. E12`	
HAVUNK02	Enchytraeidae sp.	PASS	Enchytraeidae `sp. E12`	
HB445	Enchytraeidae sp.	PASS	Enchytraeidae `sp. E12`	
HB449	Paramelitidae sp. U3S?	PASS	Paramelitidae `sp. Biologic-AMPH025`	
HB446	Paramelitidae sp. U3S?	PASS	Paramelitidae `sp. Biologic-AMPH025`	
HB164	Paramelitidae sp. U3L?	PASS	Paramelitidae `sp. Biologic-AMPH026`	
HAE009	Paramelitidae sp. U3S	PASS	Paramelitidae `sp. Biologic-AMPH027`	
HAVWB03	Paramelitidae sp. U3S?	PASS	Paramelitidae `sp. Biologic-AMPH027`	
HAVWB03	Paramelitidae sp. U3S	PASS	Paramelitidae `sp. Biologic-AMPH027`	
HAVWB03	Paramelitidae sp. U3S	PASS	Paramelitidae `sp. Biologic-AMPH027`	
HAVWB03	Paramelitidae sp. U3S	PASS	Paramelitidae `sp. Biologic-AMPH027`	
HB402	Paramelitidae sp. U3L	PASS	Paramelitidae `sp. Biologic-AMPH028`	
BTB5	Paramelitidae indet. (juv)	PASS	Paramelitidae `sp. Biologic-AMPH029`	
HAVUNK02	Paramelitidae sp. L7S	PASS	Paramelitidae `sp. Biologic-AMPH029`	
TelfWindmill	Paramelitidae sp. U3L?	PASS	Paramelitidae `sp. Biologic-AMPH030`	
HAE009	Paramelitidae sp. U3S	PASS	Paramelitidae `sp. Biologic-AMPH031`	
HAE009	Paramelitidae sp. U3S	PASS	Paramelitidae `sp. Biologic-AMPH031`	
HAE009	Paramelitidae sp. U3S	PASS	Paramelitidae `sp. Biologic-AMPH031`	
HB446	Microcerberidae sp.	PASS	Microcerberidae `sp. Biologic-ISOP033`	
HB446	Microcerberidae sp.	PASS	Microcerberidae `sp. Biologic-ISOP033`	
HAVWB03	Microcerberidae sp.	PASS	Microcerberidae `sp. Biologic-ISOP034`	
HB449	Microcerberidae sp.	FAIL; bad seq	Microcerberidae sp.	
HAE009	Fierscyclops cf fiersi	PASS	Fierscyclops `sp. Biologic-CYCL022` (cf. fiersi)	
HAE009	Fierscyclops cf fiersi	PASS	Fierscyclops `sp. Biologic-CYCL022` (cf. fiersi)	
HAE009	Fierscyclops cf fiersi	PASS	Fierscyclops `sp. Biologic-CYCL022` (cf. fiersi)	
HAE009	Fierscyclops cf fiersi	PASS	Fierscyclops `sp. Biologic-CYCL022` (cf. fiersi)	
HAE009	Fierscyclops cf fiersi	FAIL; bad seq	Fierscyclops `sp. Biologic-CYCL022` (cf. fiersi)	
HAVWB02	Mesocyclops notius	PASS	Mesocyclops `sp. Biologic-CYCL021` (notius)	
HB106	Pilbaracyclops nr frustatio	FAIL; contamination	Pilbaracyclops nr frustratio	
HB401	Megastygonitocrella sp.	PASS	Megastygonitocrella `sp. Biologic-HARP011`	
HB401	Megastygonitocrella sp.	PASS	Megastygonitocrella `sp. Biologic-HARP012`	
HB401	Megastygonitocrella sp.	PASS	Megastygonitocrella `sp. Biologic-HARP012`	
HB406	Harpacticoida sp.	PASS	Nitocrella `sp. Biologic-HARP010`	
TelfWindmill	Harpacticoida sp.	PASS	Nitocrella `sp. Biologic-HARP010`	
HAE003	Schizopera sp.	PASS	Schizopera `sp. Biologic-HARP013`	
HAE003	Schizopera sp.	PASS	Schizopera `sp. Biologic-HARP013`	
HAE003	Schizopera sp.	PASS	Schizopera `sp. Biologic-HARP013`	
HAE015	Pauropoda sp.	PASS	Pauropoda `sp. Biologic-PAUR045`	

Figure B-1: COI genetic tree - Amphipoda.

Figure B-2: COI genetic tree – Copepoda.

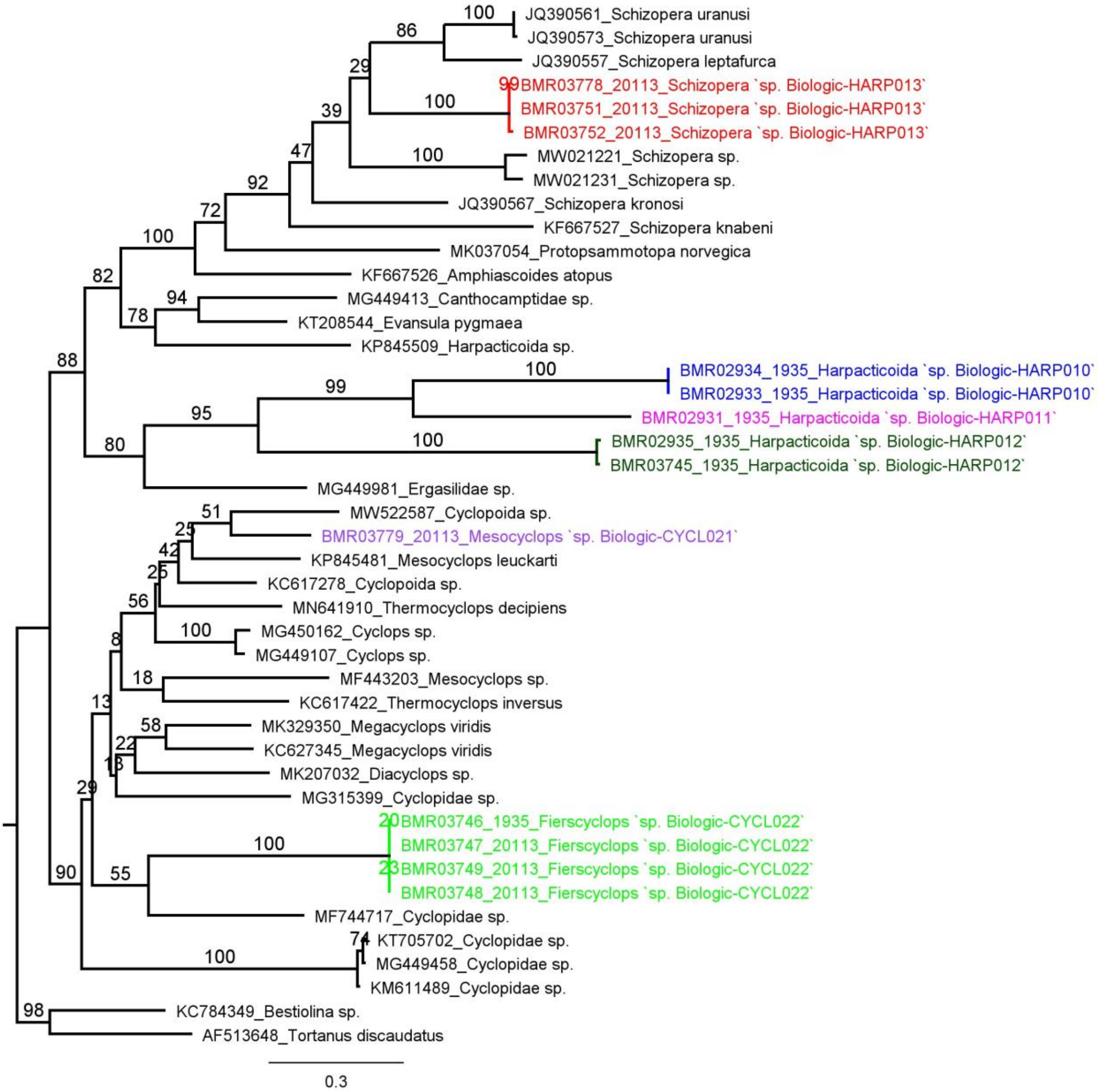


Figure B-3: COI genetic tree – Isopoda.

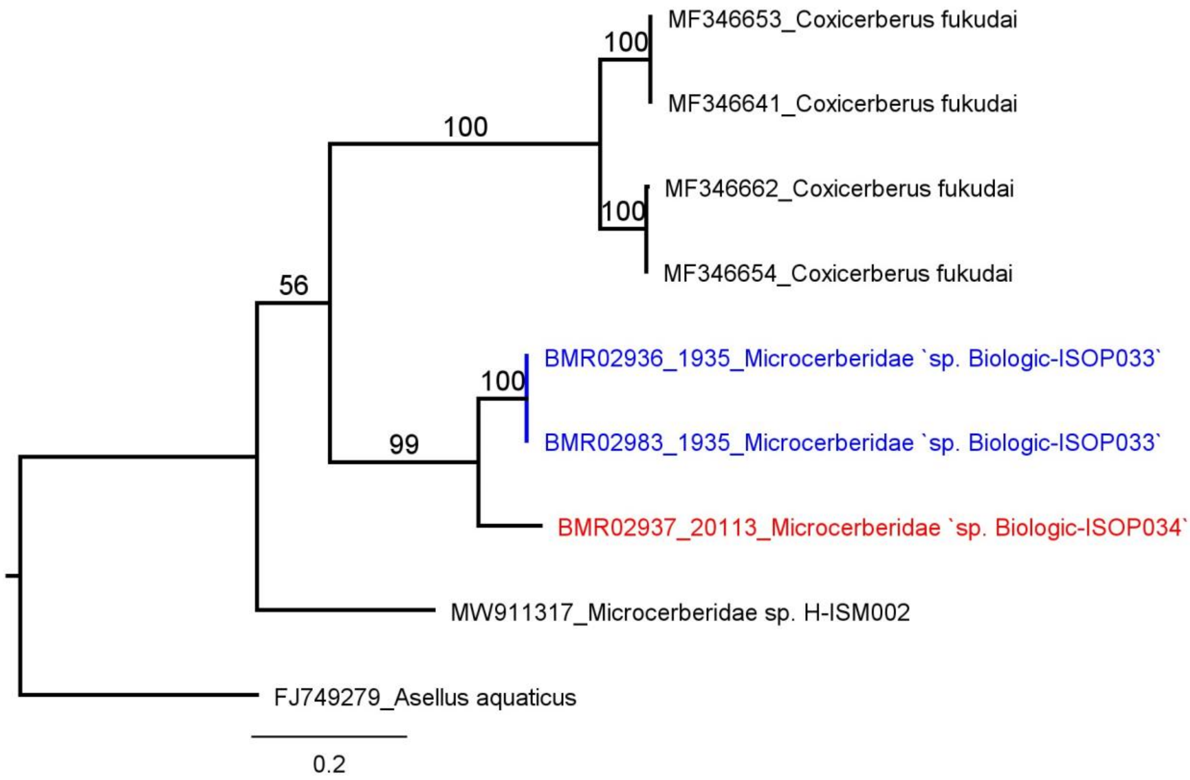


Figure B-4: COI genetic tree – Pauropoda.

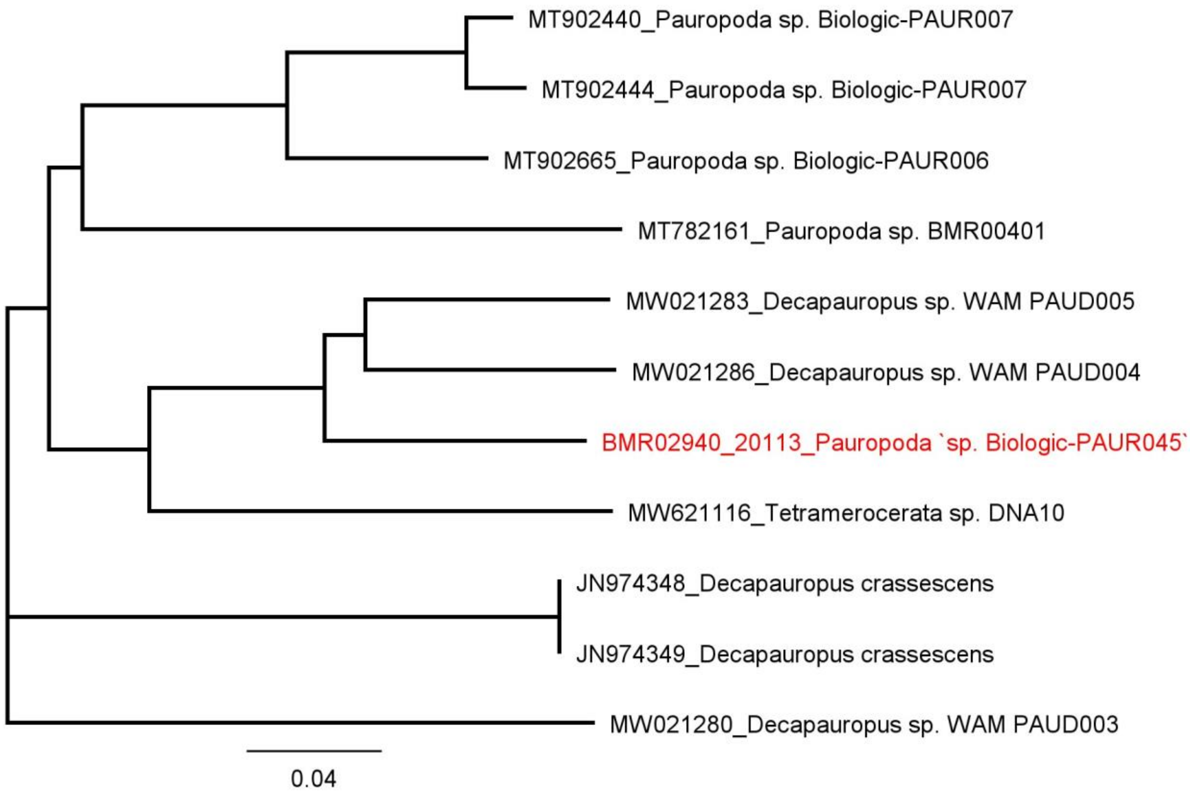
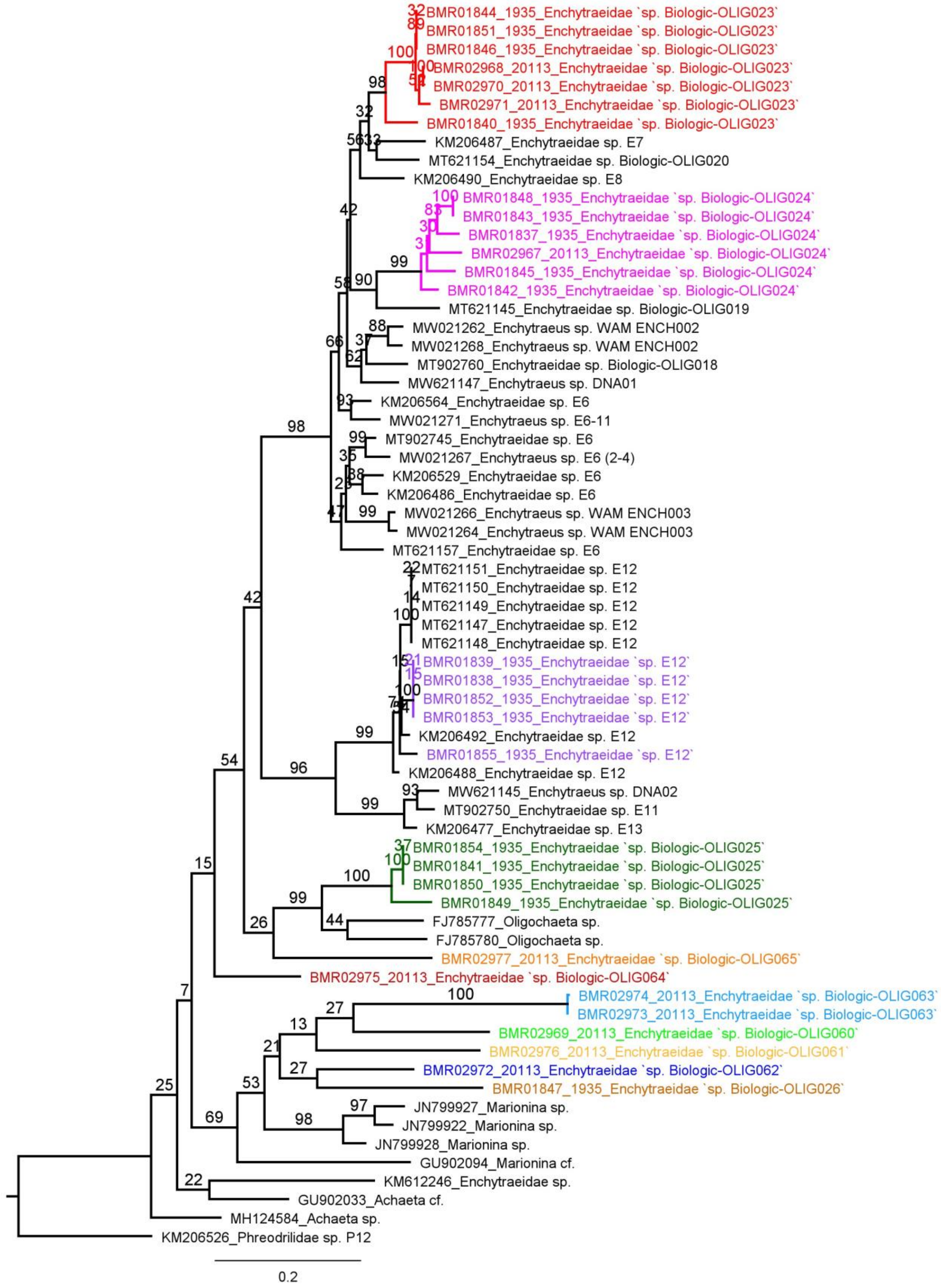


Figure B-5: COI genetic tree – Enchytraeidae.



Appendix D: Fauna licence

DEPARTMENT OF PARKS AND WILDLIFE

Department of Parks and Wildlife

Enquiries: 17 DICK PERRY AVE, KENSINGTON, WESTERN AUSTRALIA
Telephone: 08 9219 9000
Facsimile: 08 9219 8242
Web Site: https://wildlifelicensing.dpaw.wa.gov.au
Correspondance: **Locked Bag 30**
Bentley Delivery Centre WA 6983

PAGE 1

NO. 08-003860-2

Wildlife Conservation Act 1950

REGULATION 17

Fauna taking (scientific or other purposes) licence (Fauna taking (scientific or other purposes) licence)

The undermentioned person may take fauna for research or other scientific purposes and where authorised, keep it in captivity, subject to the following and attached conditions, which may be added to, suspended or otherwise varied as considered fit.

Director General

Conditions

1 The licensee must comply with the provisions of the Wildlife Conservation Act 1950, Wildlife Conservation Regulations 1970 and any Notices in force under this legislation.

2 The licensee shall take fauna only in the manner stated on the endorsed Regulation 17 licence application form and endorsed related correspondence.

3 Unless specifically authorised in the conditions of this Licence or otherwise in writing by the Director General, species of fauna declared as likely to become extinct, rare or otherwise in need of special protection shall not be taken.

4 Any by-catch of fauna, which is declared to be rare, likely to become extinct, or otherwise in need of special protection shall be released immediately at the point of capture. Where such fauna taken under this licence is injured or deceased, the licensee shall contact the Department's Wildlife Licensing Section for advice on disposal. Records must be kept of any such fauna so captured and details are to be included in the report required under further condition below.

5 Any interaction involving Gazetted Threatened Fauna that may be harmful to the fauna and/or invasive may require approval from the Commonwealth Department of the Environment ph 02 6274 1111. Interaction with such species is controlled by the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 and Environment Protection and Biodiversity Conservation Regulations 2000 as well as the Wildlife Conservation Act 1950 and Wildlife Conservation Regulations 1970.

6 No fauna shall be taken in areas where it would impinge on pre-existing scientific research programs.

7 Except in the case of approved lethal traps, the licensee shall ensure that measures are taken in the capture and handling of fauna to prevent injury or mortality resulting from that capture or handling. Where traps or other mechanical means or devices are used to capture fauna these shall be deployed so as to prevent exposure of trapped animals to ants and debilitating weather conditions and inspected at regular intervals throughout each day of their use. At the conclusion of research all markers used, and signs and structures erected by the licensee shall be removed and the environment returned to its original condition.

8 Not more than ten specimens of any one protected species of fauna shall be taken and removed from any location less than 20km apart. Where exceptional circumstances make it necessary to take a larger number of specimens from a particular location in order to obtain adequate statistical data, the collector must proceed with circumspection and justify their actions to the Director General in advance.

9 The licensee shall not release any fauna or their progeny in any area where it does not naturally occur, nor hand such fauna over to any other person or authority unless approved by the Director General, nor dispose of the remains of such fauna in any manner likely to confuse the natural or present day distribution of the species.

10 Bioprospecting involving the removal of sample aquatic and terrestrial organisms for chemical extraction and bioactivity screening shall not be conducted without specific written approval by the Director General.

11 No fauna is to be taken from any CALM land, as defined in the Conservation and Land Management Regulations 2002, without prior written approval of the Director General. No fauna is to be taken from any public land without the prior written approval of the Government Authority managing that land.

12 The licensee must not enter upon any private property or pastoral lease for the purposes of this licence, nor take any fauna from any private land or pastoral lease without the prior consent in writing of the owner or occupier. Similarly, in the case of Aboriginal lands, the licensee must not enter upon or take fauna from such lands without the written approval of the Department of Aboriginal Affairs and/or the relevant native title holders or applicants.

13 Copies of this licence and any written approval or consent required by conditions of this licence must be carried by the licensee and any person/s authorised under the licence at all times when conducting activities relevant to the licence

DEPARTMENT OF PARKS AND WILDLIFE

Department of Parks and Wildlife

Enquiries: 17 DICK PERRY AVE, KENSINGTON, WESTERN AUSTRALIA
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Web Site: https://wildlifelicensing.dpaw.wa.gov.au
Correspondance: **Locked Bag 30**
Bentley Delivery Centre WA 6983

and must be presented to an authorised officer of the Department upon request.

14 All holotypes and syntypes and a half share of paratypes of species or subspecies permitted to be permanently taken under this licence shall be donated to the Western Australian Museum. Duplicates (one pair in each case) of any species collected, which represents a significant extension of geographic range shall upon request be donated to the Western Australian Museum.

15 To prevent any unnecessary collecting in this State, all specimens and material taken and retained under the authority of this license shall, upon request, be loaned to the Western Australian Museum. Any unused portion or portions of any specimen collected under the authority of this license shall be offered to the Western Australian Museum for inclusion in its collection or made available to other scientific workers if so required.

16 Within one month of the expiration of this licence, the holder shall submit an electronic return into the department's Wildlife Licensing System, detailing the locality, site, geocode, date and number of each species of fauna captured, sighted or vouchered during the currency of the licence. A copy of any paper, report or thesis resulting from the research shall upon completion be lodged with the Director General.

Purpose

Issued as BA27000177-2

Authorised Person

Surname	Given name(s)
Main	Dean
Callan	Shae
Durrant	Brad
Rodman	Syngeon
Rudin	Fabian
Runham	Phil

Date of Issue	19/04/2021
Valid From	19/04/2021
Date of Expiry	19/04/2021

Licensee:	Mr Morgan James Lythe
Address	24-26 Wickham Street East Perth WA 6004 Australia

Issued by a Wildlife Licensing Officer of the Department of Parks and Wildlife under delegation from the Minister for Environment pursuant to section 133(1) of the Conservation and Land Management Act 1984.

Appendix E: Previously recorded regional subterranean fauna

Higher Taxonomy	Lowest Identification	Location	Source	Taxonomic Resolution	Distribution	Subterranean Status	SRE Status
Stygofauna							
NEMATODA							
	Nematoda sp. 12 (PSS)	Telfer, Kintyre	Cameco, Newcrest	No taxonomic framework	Unknown	Unknown	Unknown
ROTIFERA							
	Bdelloidea sp. 3:2	Telfer	Newcrest	No taxonomic framework	Unknown	Unknown	Unknown
Trochosphaeridae	*Filinia* sp.	Kintyre	Cameco	No taxonomic framework	Unknown	Unknown	Unknown
GASTROPODA							
Hydrobiidae	Hydrobiidae sp. B02	Telfer	Newcrest	Undescribed new species	One aquifer	Stygobite	Potential
POLYCHAETA							
Aeolosomatidae	*Aeolosoma* sp. 1 (PSS)	Telfer	Newcrest	Complex	Unknown	Unknown	Unknown
Nereididae	*Namanereis pilbarensis*	Telfer	Newcrest	Described species but lacks DNA, includes sp. B01	Pilbara wide	Stygobite	Potential
OLIGOCHAETA							
Enchytraeidae	*Enchytraeus* sp. PST1/PSS1	Telfer	Newcrest	Complex, not a valid species	Aquifer to catchment scale	Amphibious	Potential
	Enchytraeidae `sp. Biologic-OLIG023`	Havieron	Newcrest	Molecular but lacks taxonomic framework	Aquifer to catchment scale	Amphibious	Unlikely
	Enchytraeidae `sp. Biologic-OLIG024`	Havieron	Newcrest	Molecular but lacks taxonomic framework	Aquifer to catchment scale	Amphibious	Unlikely
	Enchytraeidae `sp. Biologic-OLIG025`	Havieron	Newcrest	Molecular but lacks taxonomic framework	Aquifer to catchment scale	Amphibious	Unlikely
Phreodrilidae	*Insulodrilus* sp.	Telfer	Newcrest	Indeterminate	Aquifer to catchment scale	Unknown	Unknown
	Phreodrilidae dissimilar ventral chaetae.	Telfer	Newcrest	Complex	Aquifer to catchment scale	Stygobite	Potential
	Phreodrilidae similar ventral chaetae	Telfer	Newcrest	Complex	Aquifer to catchment scale	Stygobite	Potential
Naididae	Naididae `stygo type 1` (imm *Ainudrilus* ?WA25/26) (PSS)	Telfer	Newcrest, PSS	Likely new species, found in surface waters	Pilbara wide	Stygoxene	No
	Tubificidae `stygo type 5`	Kintyre	Cameco	Likely new species, found in surface waters	Pilbara wide	Stygoxene	No
AMPHIPODA							
Bogidiellidae	*Bogidiella* sp. B02	Telfer, Kintyre	Cameco, Newcrest	Likely new species	Unknown	Stygobite	Potential
	Bogidiellidae sp. 1	Telfer	PSS	Possibly synonymy with B02	Unknown	Stygobite	Unlikely
Melitidae	Melitidae sp.	Telfer	Newcrest	Likely new species	Aquifer to catchment scale	Stygobite	Potential
Paramelitidae	Paramelitidae sp. B06	Telfer	Newcrest, WAM, NatureMap	Likely new species, no DNA, synonymy possible at Telfer	Aquifer to catchment scale	Stygobite	Potential
	Paramelitidae sp. B07	Kintyre	Cameco		Aquifer to catchment scale	Stygobite	Potential
	Paramelitidae sp. B10	Telfer	Newcrest		Aquifer to catchment scale	Stygobite	Potential
	Paramelitidae sp. B11	Telfer	Newcrest, WAM		Aquifer to catchment scale	Stygobite	Potential
	Paramelitidae sp. B28	Telfer	Newcrest		Aquifer to catchment scale	Stygobite	Potential
	Paramelitidae sp. B30	Telfer	Newcrest		Aquifer to catchment scale	Stygobite	Potential
	Paramelitidae sp. 6		NatureMap	Taxonomy out-of-date	Pilbara wide	Stygobite	Unlikely
	Paramelitidae `sp. Biologic-AMPH027`	Havieron	Newcrest	Morphological and molecular. Limited regional sequences available	Havieron	Stygobite	Potential
	Paramelitidae `sp. Biologic-AMPH031`	Havieron	Newcrest	Morphological and molecular. Limited regional sequences available	Havieron	Stygobite	Potential
	Pilbarus millsi		PSS	Taxonomy out-of-date	Pilbara wide	Stygobite	Unlikely
	Pilbarus sp.	Telfer	Newcrest, PSS, NatureMap	Likely new species, but synonymy likely	Aquifer to catchment scale	Stygobite	Potential
ISOPODA							
Microcerberidae	Microcerberidae sp.	Telfer	Newcrest, PSS	Likely new species	Aquifer to catchment scale	Stygobite	Potential
	Microcerberidae sp. B04	Kintyre	Cameco	Likely new species	Aquifer to catchment scale	Stygobite	Potential
Olibrinidae	*Adoniscus* sp. B01	Telfer	Newcrest	Likely new species	Aquifer to catchment scale	Stygobite	Potential
BATHYNELLACEA							
Parabathynellidae	*Atopobathynella* sp. B08	Telfer	Newcrest, WAM	Likely new species, ex Hexabathynella `A`	Aquifer to catchment scale	Stygobite	Potential
	Hexabathynella sp. A		NatureMap, PSS	Likely new species, but synonymy likely	Aquifer to catchment scale	Stygobite	Potential
	Notobathynella sp. B06	Kintyre	Cameco	Likely new species	Aquifer to catchment scale	Stygobite	Potential
	nr *Billibathynella* (*Brevismobathynella*) sp. B08	Telfer	Newcrest	Likely new species	Aquifer to catchment scale	Stygobite	Potential
CYCLOPOIDA							
Cyclopidae	*Bryocyclops* sp. 1 (PSS)	Telfer	PSS	Likely new species	Unknown	Stygo-phile/bite	Unknown
	Diacyclops cockingi	Telfer	Newcrest, PSS	Described but lacks DNA	Pilbara wide	Stygophile	Unknown
	Diacyclops einslei	Telfer	Newcrest	Described but lacks DNA	Pilbara wide	Stygophile	Unknown
	Diacyclops humphreysi	Telfer	Newcrest	Described but limited DNA suggests a complex	Pilbara wide	Stygophile	Unknown
	Diacyclops scanloni	Telfer	Newcrest	Described but lacks DNA	Pilbara wide	Stygophile	Unlikely
	Fierscyclops `sp. Biologic-CYCL022` (cf. *fiersi*)	Havieron	Newcrest	Morphological and molecular. Limited regional sequences available	Havieron	Stygobite/phile	Potential
	Fierscyclops (Fierscyclops) fiersi	Telfer	Newcrest	Described but lacks DNA	Pilbara wide	Stygophile	Unlikely
	Halicyclops kieferi	Telfer	Newcrest, PSS	Described but lacks DNA	Pilbara wide	Stygophile	Unlikely

Higher Taxonomy	Lowest Identification	Location	Source	Taxonomic Resolution	Distribution	Subterranean Status	SRE Status
	Mesocyclops sp.	Telfer	Newcrest	Indeterminate	Unknown	Stygo-phile/bite	Unlikely
	Metacyclops sp.	Telfer	PSS, NatureMap	Indeterminate	Unknown	Stygo-phile/bite	Unlikely
	Microcyclops varicans	Telfer	Newcrest	Described but lacks DNA	Pilbara wide	Stygophile	Unlikely
	Orbuscyclops westaustraliensis	Kintyre	Cameco	Described but lacks DNA	Pilbara wide	Stygophile	Unlikely
	Pilbaracyclops frustratio	Telfer	Newcrest, PSS, WAM, NatureMap	Described but lacks DNA	Pilbara wide	Stygophile	Unlikely
HARPACTICOIDA							
Ameiridae	*Abnitocrella* sp. 1 (TOK)	Telfer	Newcrest	Likely new species	Aquifer to catchment scale	Stygobite	Potential
	Abnitocrella sp. B02 (nr *obesa*)	Telfer	Newcrest	Likely new species	Aquifer to catchment scale	Stygobite	Potential
	Megastygonitocrella sp. B03 (nr *ecowisei*)	Telfer	Newcrest	Likely new species	Aquifer to catchment scale	Stygobite	Potential
	Megastygonitocrella trispinosa	Telfer	Newcrest	Described but lacks DNA	Pilbara wide	Stygophile	Potential
	Nitocrella knotti	Telfer	Newcrest	Described but lacks DNA	Aquifer to catchment scale	Stygobite	Potential
	Nitocrella sp. B04 (nr *obesa*)	Kintyre	Cameco	Likely new species	Aquifer to catchment scale	Stygobite	Potential
	Nitocrella sp. B05	Kintyre	Cameco	Likely new species	Aquifer to catchment scale	Stygobite	Potential
	nr *Gordonitocrella* sp. B01	Telfer	Newcrest	Likely new species	Aquifer to catchment scale	Stygobite	Potential
Parastenocarididae	*Parastenocaris* sp.	Telfer	Newcrest, WAM	Likely new species	Aquifer to catchment scale	Stygobite	Potential
	Parastenocaris sp. B07	Kintyre	Cameco	Likely new species	Aquifer to catchment scale	Stygobite	Potential
	Parastenocaris sp. B20	Kintyre	Cameco	Likely new species	Aquifer to catchment scale	Stygobite	Potential
OSTRACODA							
Candonidae	*Areacandona* `4` (PSS)	Telfer	PSS	Likely new species	Aquifer to catchment scale	Stygobite	Potential
	Areacandona arteria	Telfer	PSS	Described but lacks DNA	Pilbara wide	Stygophile	Potential
	Areacandona cf. *iuno*	Telfer	PSS	Described but lacks DNA	Aquifer to catchment scale	Stygo-phile/bite	Potential
	Humphreyscandonini sp. indet.	Havieron	Newcrest	Tentative ID as based on two empty valves but likely new species	Unknown	Stygobite	Potential
	Leicacandona desserti	Telfer	Newcrest	Described but lacks DNA	One aquifer	Stygobite	Potential
	Leicacandona jula	Telfer	Newcrest, Karanovic & McKay 2010	Described but lacks DNA	One aquifer	Stygobite	Potential
	Leicacandona pinkajartinyi	Telfer	Newcrest, Karanovic & McKay 2010	Described but lacks DNA	One aquifer	Stygobite	Potential
	Leicacandona quasilite	Telfer	Newcrest	Described but lacks DNA	One aquifer	Stygobite	Potential
	Leicacandona yandagoogeae	Telfer	PSS	Described but lacks DNA	One aquifer	Stygobite	Potential
Cyprididae	*Cypretta seurati*	Telfer	Newcrest	Described, found in surface waters	Pilbara wide	Stygoxene	Widespread
Limnocytheridae	*Gomphodella* `BOS354`	Telfer	Newcrest	Likely new species	One aquifer	Stygo-phile/bite	Potential
TROGLOFAUNA							
ARANEAE							
Oonopidae	*Prethopalpus* sp. B20	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
	Prethopalpus sp. B28 (nr *kintyre*)	Telfer	Newcrest	Undescribed new species	One deposit	Troglobite	Potential
PALPIGRADI							
	Palpigradi sp. B01	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
PSEUDOSCORPIONES							
	Lechytia sp. B03	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
ISOPODA							
Armadillidae	Armadillidae sp. B10	Telfer	Newcrest	Undescribed new species	One deposit	Troglobite	Potential
	Troglarmadillo sp. B19	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
	Troglarmadillo sp. B33	Telfer	Newcrest	Undescribed new species	One deposit	Troglobite	Potential
Oniscidae	*Hanoniscus* sp. B05	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
DIPLURA							
Japygidae	Japygidae sp.	Kintyre	Cameco	Likely new species	One deposit	Troglobite	Potential
Parajapygidae	Parajapygidae sp. B13	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
Projapygidae	Projapygidae sp. B03	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
	Projapygidae sp. B07	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
	Projapygidae sp. B15	Telfer	Newcrest	Undescribed new species	One deposit	Troglobite	Potential
BLATTODEA							
Blattodea	*Nocticola* sp.	Kintyre	Cameco	Likely new species	One deposit	Troglobite	Potential
HEMIPTERA							
Enicocephalidae	*Systelloderes* sp.	Kintyre	Cameco	Undescribed new species	Unknown	Troglo-phile/bite	Unknown
Meenoplidae	Meenoplidae sp.	Telfer	Newcrest	Likely new species	Pilbara wide	Troglo-phile/bite	Potential
ZYGENTOMA							
Nicoletiidae	Atelurinae sp. B16	Telfer	Newcrest	Undescribed new species	One deposit	Troglobite	Potential
	Trinemura sp. B07	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
	Trinemura sp. B12	Telfer	Newcrest	Undescribed new species	One deposit	Troglobite	Potential

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SCOLOPENDROMORPHA							
Cryptopidae	*Cryptops* sp. B19	Kintyre	Cameco	Likely new species	One deposit	Troglobite	Potential
	nr *Cryptops* sp. B12	Kintyre	Cameco	Likely new species	One deposit	Troglobite	Potential
	nr *Cryptops* sp. B13	Kintyre	Cameco	Likely new species	One deposit	Troglobite	Potential
POLYXENIDA							
Lophoproctidae	*Lophoturus madecassus*	Kintyre	Cameco	Complex, ex Lophoproctidae sp. B01	Pilbara wide	Troglo-phile/bite	Widespread
PAUROPODA							
Pauropodidae	Pauropodidae sp. B21	Telfer	Newcrest	Undescribed new species	One deposit	Troglobite	Potential
	Pauropodidae sp. B24	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
	Pauropodidae sp. B25	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
	Pauropodidae sp. B26	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
SYMPHYLA							
Scutigerellidae	*Scutigerella* sp. B01	Telfer	Newcrest	Undescribed new species	One deposit	Troglobite	Potential
	Scutigerella sp. B02	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
	Symphylella sp. B06	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential
	Symphylella sp. B08	Kintyre	Cameco	Undescribed new species	One deposit	Troglobite	Potential