



Ministers North Troglafauna Habitat Model and Impact Assessment

Report to BHP WA IRON ORE

8 July 2025



Document Status				
Revision No.	Author	Review / Approved for Issue	Approved for Issue to Name	Date
1	Gladys Condori, Tabitha Rudin, Jenny Abello	Amy Mutton, Shae Callan	Trent Betts	26/05/2025
2	Jenny Abello, Tabitha Rudin	Amy Mutton	Trent Betts	08/07/2025

“IMPORTANT NOTE”

Biologic Environmental Survey Pty Ltd (“Biologic”) has prepared this report for BHP WAIO Pty Ltd (“Client”), in accordance with the Client’s specific instructions and solely for the purposes for which it is required by the Client (“Purpose”). This report and its content are only pertinent to the Purpose and any matters, facts or results contained in this report are not to be used for any purpose other than the Purpose.

The information contained in this report is not financial advice and Biologic is not licenced to provide financial advice. The report does not take into account the investment objectives, financial situation or specific investment needs of the Client and should not form the basis of an investment decision by the Client.

In preparing this report Biologic has assumed the accuracy and completeness of all the information and documents received or obtained from the Client and all information and documents received or obtained as a result of any request or enquiry made to a government department, authority, government register or database. Biologic has not independently verified any such assumptions.

Apart from fair dealing for the purposes of private study, research, criticism, or review as permitted under the Copyright Act, no part of this report, its attachments or appendices may be reproduced by any process, released, or distributed without the written consent of Biologic. All enquiries should be directed to Biologic.

This report is presented without the assumption of a duty of care to any other person (other than the Client) (“Third Party”). The report may not contain sufficient information for the purposes of a Third Party or for other uses and may not be relied on by a Third Party without Biologic’s prior written consent.

Biologic will not be liable to a Third Party for any loss, damage, liability, or claim arising out of or incidental to a Third-Party publishing, using or relying on the facts, content, opinions or subject matter contained in this report.

If a Third Party uses or relies on the facts, content, opinions, or subject matter contained in this report with or without the consent of Biologic, Biologic disclaims all risk, and the Third Party assumes all risk and releases and indemnifies and agrees to keep Biologic indemnified from any Loss, Damage, claim or liability arising directly or indirectly from the use of or reliance on this report.

For the purpose of this document, a reference to “Loss” and “Damage” includes past and prospective economic loss, loss of profits, damage to property, injury to any person (including death) costs and expenses incurred in taking measures to prevent, mitigate or rectify any harm, loss of opportunity, legal costs, compensation, interest and any other direct, indirect, consequential, or financial or other loss.

Executive Summary

BHP Western Australian Iron Ore Pty Ltd (BHP WAIO) are proposing the development of Ministers North (the Proposal), located in the Pilbara region of Western Australia. The Proposal will involve the development of two mining pits above the water table (AWT), with no groundwater drawdown predicted to occur.

Subterranean fauna surveys were conducted between 2009 and 2023 in an area within and surrounding the proposed pits (the Study Area). The surveys detected an assemblage of 48 troglofauna species and species-level taxa, based on morphological and genetic identifications. Of these, 19 taxa were recorded only from the proposed pits and are considered the target taxa for environmental impact assessment (EIA).

Biologic Environmental Survey Pty Ltd (Biologic) was engaged to develop a three-dimensional (3D) subterranean habitat model and undertake impact assessment for each target taxon, based on available sampling data, habitat modelling, and updated genetic comparisons throughout the wider regional area. Troglofauna habitat modelling was based on BHP WAIO's Ministers North geological model compiled from drill hole logging, geophysics data, structural information, weathering profiles, and hydrogeological data, plus publicly available spatial data and geological mapping. The 3D habitat model refined the Ministers North geological model to show the 3D extent, suitability, and connectivity of troglofauna habitats at scales relevant to the impact assessment for the target species.

The Study Area hosts extensive suitable habitats within the Dales Gorge and Joffre Members of the Brockman Iron Formation, and within superficial deposits of detritals and scree. These troglofauna habitats are interlayered and complex, but well-connected throughout the Study Area, with no obvious structural barriers that would prevent troglofauna dispersal between proposed pit areas and habitat remaining intact. The 3D habitat model confidently predicts that suitable geological habitats extend beyond the current drilling, particularly to the east and west of the proposed pits. A large majority of the drill holes available for survey were located within the proposed pit boundaries, with comparatively fewer reference sites available. Consequently, the number of taxa recorded only within pits to date is likely to be influenced by sampling artefacts within the impact areas.

The proposed mining at Ministers North is predicted to result in a localised reduction of suitable troglofauna habitat. Nevertheless, the 3D model showed that suitable troglofauna habitats should remain intact beneath the proposed pit shells in many locations where target taxa were recorded. The habitat modelling also revealed a wider extent of well-connected, suitable habitat outside the proposed pits, primarily within the Dales Gorge and Joffre Members.

The predicted impacts of the Proposal on troglofauna species and habitats are:

- **Low Impact** for 11 of the 19 target troglofauna taxa, due to habitat modelling showing thick and well-connected suitable habitats remaining intact beneath the proposed mining at the known locations of these taxa;
- **Medium Impact** for the remaining 8 target troglofauna taxa, in cases where the proposed mining will remove the local extent of suitable habitat AWT at the known record location(s). In each of these cases however, there is a wider context of well connected, suitable habitats remaining intact AWT following mining. Considering taxonomic and ecological factors of the taxa in question, and the limited availability of drill holes beyond the pits for sampling, it is more likely that the recorded occurrence of these taxa is related to sampling artefacts, rather than being highly restricted to the 3D impact area.

At the overall Study Area scale, an interconnected network of suitable habitat AWT is predicted to continue to support the troglofauna assemblage following the proposed mining. No troglofauna taxon is expected to be lost as a direct impact from the implementation of the Proposal.

Table of Contents

Executive Summary	ii
1 Introduction	1
1.1 Background.....	1
1.2 Scope and objectives.....	1
1.3 Legislative context	2
2 Methods.....	4
2.1 Spatial information and data	5
2.1.1 Project information	5
2.1.2 Geology, topography, hydrology	5
2.1.3 Subterranean fauna data	5
2.2 3D Habitat modelling.....	10
2.2.1 Boundaries.....	10
2.2.2 Stratigraphic modelling	11
2.2.3 Habitat modelling	12
2.2.4 Combined models	15
2.3 Constraints and limitations.....	15
2.3.1 Differences between 2D and 3D assessment	15
2.3.2 Inherent constraints and limitations	16
3 3D habitat assessment	18
3.1 Geological context	18
3.2 Hydrogeology.....	21
3.3 Stratigraphic model	22
3.4 Habitat modelling	24
3.4.1 Troglifauna habitat extent and connectivity.....	29
4 Impact assessment.....	34
4.1 Araneae	37
4.1.1 <i>Anapistula</i> `sp. BAR147`	37
4.1.2 <i>Anapistula</i> `sp. S01`	39
4.1.3 Linyphiidae `sp. BAR148`	41
4.1.4 nr. <i>Encoptarthria</i> `sp. BAR142`	44
4.1.5 <i>Prethopalpus</i> `sp. B32`	46
4.2 Palpigradi.....	49
4.2.1 Palpigradi `sp. BPAL054`	49
4.3 Pseudoscorpiones.....	51
4.3.1 <i>Indohya</i> `sp. BPS560`	51
4.4 Coleoptera	53
4.4.1 Coleoptera `sp. BCO236`	53

4.4.2 Curculionidae Genus 1 `sp. BCO228`	56
4.4.3 <i>Holoparamecus` sp. BCO255`</i>	59
4.4.4 Pselaphinae `sp. S04`	61
4.4.5 Zuphiinae `sp. S01 s.l.`	63
4.5 Hemiptera.....	65
4.5.1 Reduviidae `sp. MN`	65
4.6 Pauropoda.....	67
4.6.1 Pauropodidae `sp. BPU118`	67
4.6.2 Pauropodidae `sp. BPU119`	70
4.6.3 Pauropoda `sp. S04`	72
4.7 Chilopoda.....	74
4.7.1 Cryptopidae `sp. MN`	74
4.8 Symphyla.....	76
4.8.1 <i>Hanseniella` sp. B43`</i>	76
4.8.2 <i>Hanseniella` sp. BSYM129`</i>	79
5 Key Findings.....	81
6 References.....	83
7 Appendices.....	85

Tables

Table 2.1: Habitat suitability framework.....	4
Table 2.2: Target troglofauna taxa.....	7
Table 2.3: Parameters for 3D habitat model in CPG94 Grid.....	10
Table 2.4: List of files with geology and stratigraphy information.....	12
Table 2.5: Combined model outputs.....	15
Table 3.1: Habitat suitability of stratigraphic units within the 3D model.....	26

Figures

Figure 1.1: Study Area and regional context.....	3
Figure 2.1: Target troglofauna taxa restricted to proposed pits.....	9
Figure 3.1: Hamersley Group stratigraphic profile.....	19
Figure 3.2: Surface geology (GSWA 20K).....	20
Figure 3.3: Plan view of the stratigraphic units within the Study Area.....	23
Figure 3.4: Oblique view of the stratigraphic model, showing the Wirriba Anticline and depth extent of the modelling.....	23
Figure 3.5: Cross-section (N-S) through the typical stratigraphic sequence within the Study Area, based on 3D modelling.....	24
Figure 3.6: Plan view of the 3D habitat model, showing the habitat suitability for subterranean fauna within the Study Area.....	28
Figure 3.7: Oblique view of the 3D habitat model, showing the habitat suitability for subterranean fauna within the Study Area.....	28
Figure 3.8: Cross-section (N-S) through the habitat potential within the Study Area, based on 3D modelling.....	29
Figure 3.9: Cross-section (N-S) through the stratigraphy and suitable subterranean habitats within the Study Area, based on 3D modelling.....	31
Figure 3.10: Longitudinal-section (W-E) through the stratigraphy and suitable subterranean habitats within the northern pit, based on 3D modelling.....	32
Figure 3.11: Longitudinal-section (W-E) through the stratigraphy and suitable subterranean habitats within the southern pit, based on 3D modelling.....	33
Figure 4.1: Target taxa and modelled stratigraphic units.....	35
Figure 4.2: Target taxa and modelled suitable AWT habitat.....	36
Figure 4.3: Cross-section showing potential AWT habitats for <i>Anapistula</i> `sp. BAR147` at Ministers North.....	38
Figure 4.4: Cross-section showing potential AWT habitats for <i>Anapistula</i> `sp. S01` at Ministers North.....	40
Figure 4.5: Cross-section showing potential AWT habitats for Linyphiidae `sp. BAR148` at Ministers North.....	43
Figure 4.6: Cross-section showing potential AWT habitats for nr. <i>Encoptarthria</i> `sp. BAR142` at Ministers North.....	45
Figure 4.7: Cross-section showing potential AWT habitats for <i>Prethopalpus</i> `sp. B32` at Ministers North.....	48
Figure 4.8: Cross-section showing potential AWT habitats for Palpigradi `sp. BPAL054` at Ministers North.....	50
Figure 4.9: Cross-section showing potential AWT habitats for <i>Indohya</i> `sp. BPS560` at Ministers North.....	52
Figure 4.10: Cross-section showing potential AWT habitats for Coleoptera `sp. BCO236` at Ministers North.....	55
Figure 4.11: Cross-section showing potential AWT habitats for Curculionidae Genus 1 `sp. BCO228` at Ministers North.....	58

Figure 4.12: Cross-section showing potential AWT habitats for <i>Holoparamacus</i> `sp. BCO255` at Ministers North	60
Figure 4.13: Cross-section showing potential AWT habitats for <i>Pselaphinae</i> `sp. S04` at Ministers North	62
Figure 4.14: Cross-section showing potential AWT habitats for <i>Zuphiinae</i> `sp. S01 s.l.` at Ministers North.....	64
Figure 4.15: Cross-section showing potential AWT habitats for <i>Reduviidae</i> `sp. MN` at Ministers North	66
Figure 4.16: Cross-section showing potential AWT habitats for <i>Pauropodidae</i> `sp. BPU118` at Ministers North.....	69
Figure 4.17: Cross-section showing potential AWT habitats for <i>Pauropodidae</i> `sp. BPU119` at Ministers North	71
Figure 4.18: Cross-section showing potential AWT habitats for <i>Pauropoda</i> `sp. S04` at Ministers North	73
Figure 4.19: Cross-section showing potential AWT habitats for <i>Cryptopidae</i> `sp. MN` at Ministers North.....	75
Figure 4.20: Cross-section showing potential AWT habitats for <i>Hanseniella</i> `sp. B43` at Ministers North.....	78
Figure 4.21: Cross-section showing potential AWT habitats for <i>Hanseniella</i> `sp. BSYM129` at Ministers North	80

Appendices

Appendix A: Ministers North Molecular Memo	85
Appendix B: Lithology codes.....	97
Appendix C: OTV Photo Logging Assessment.....	98
Appendix D: Model Validation	104

1 Introduction

1.1 Background

BHP Western Australian Iron Ore Pty Ltd (BHP WAIO) are proposing the development of Ministers North (the Proposal) in the Pilbara region of Western Australia (WA), approximately 10 km south of the Jugari (Yandi) mining operation (Figure 1.1). The Proposal will involve the development of two open mine pits which are referred to as northern and southern pit for the purposes of this assessment (Figure 1.1), and associated infrastructure. Mining will be conducted above the water table (AWT), with no groundwater drawdown predicted to occur.

BHP WAIO commissioned Biologic Environmental Survey Pty Ltd (Biologic) to develop three-dimensional (3D) habitat modelling at Ministers North to inform an impact assessment of the direct impacts of the Proposal (proposed pits) on the target troglofauna species and habitats. Subterranean fauna surveys and a desktop review undertaken by Bennelongia (2024) detected a troglofauna assemblage comprising approximately 48 taxa from the Ministers North Study Area (the Study Area) (Figure 1.1).

Based on survey work undertaken to date, BHP WAIO identified 16 troglofauna taxa potentially restricted to the proposed pit areas as target taxa for EIA. As part of the impact assessment, Biologic conducted a review of molecular data from the Study Area to investigate regional genetic matches and detect wider species ranges where possible (Appendix A). A refined list of 19 target troglofauna taxa and updated linear ranges were subsequently assessed in relation to the final proposed impact areas and 3D habitat modelling results throughout the Study Area. The results of this assessment will be used to inform future environmental approvals for the Proposal.

1.2 Scope and objectives

The aim of the habitat modelling and impact was to evaluate the suitability, extent, and connectivity of troglofauna habitats within the Study Area to inform the assessment of direct impacts to the target troglofauna species. The molecular data review provided updated taxonomic alignments of target species with regional genetic sequence data and informed a reassessment of the number and diversity of target troglofauna taxa and their linear ranges. Subsequently, the 3D habitat modelling aimed to determine:

- The most likely geological habitat that each target taxa was collected from at the known record location(s) for each taxon, particularly in relation to weathered, fractured, vuggy, or porous geological strata (which provide the most likely suitable habitat);
- The modelled extent and connectivity of suitable habitat AWT throughout the Study Area, particularly in relation to areas outside the potential direct impacts (i.e. the proposed pits); and

- The presence and extent of any geological structures, units, or features that may limit troglofauna occurrence or dispersal (i.e. dykes, fresh rock, water table, clay, shale or other lithologies lacking suitable void spaces).

The impact assessment used the updated species information and habitat information to determine the likely magnitude of direct impacts to each target troglofauna species from the implementation of the Proposal.

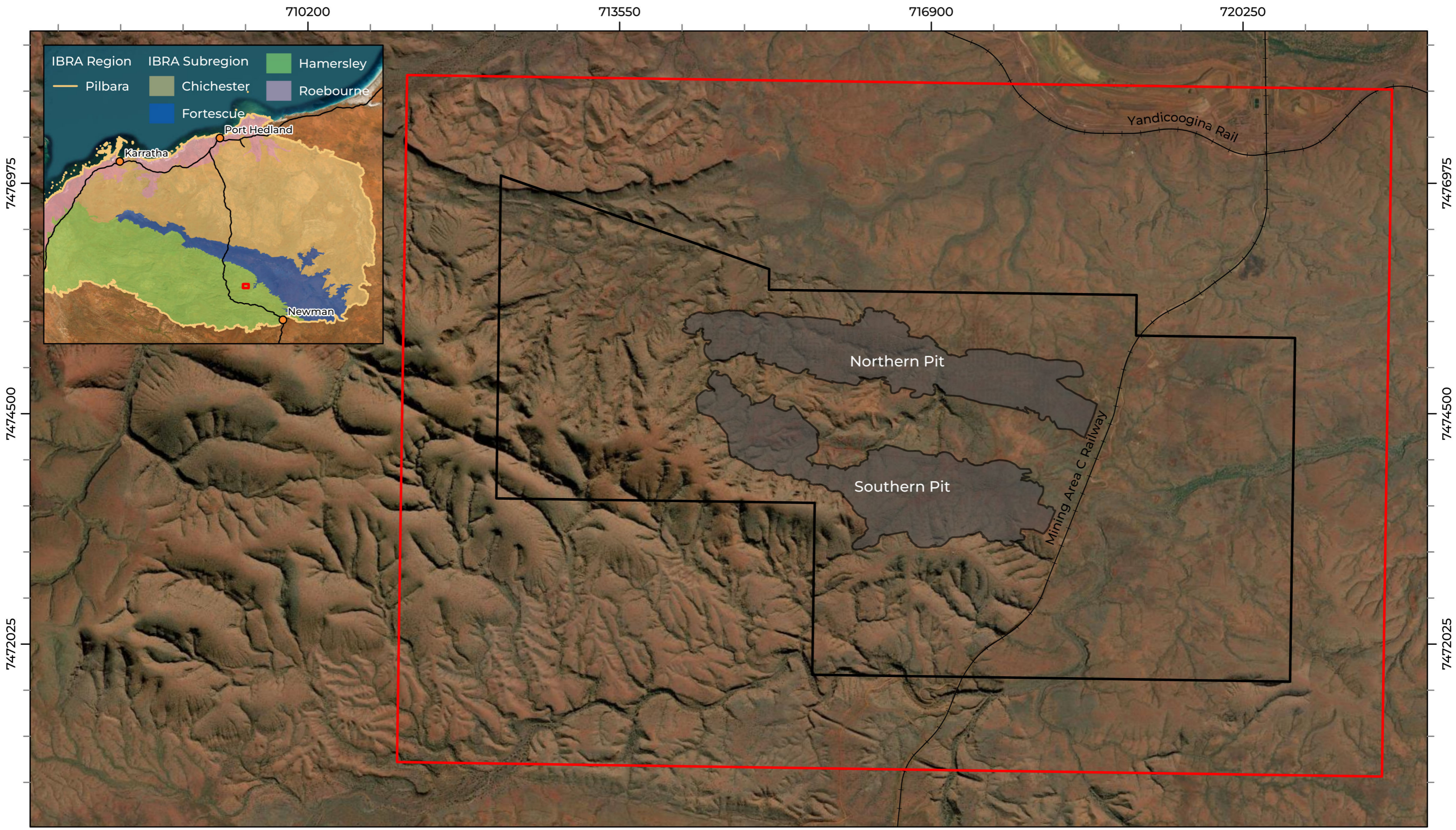
1.3 Legislative context

This assessment was carried out in acknowledgement of the following guidelines and recommendations developed by the relevant state and federal regulatory bodies:

- EPA (2023) Statement of Environmental Principles, Factors, Objectives and Aims of EIA;
- EPA (2016) Environmental Factor Guideline: Subterranean Fauna; and
- EPA (2021) Technical Guidance – Subterranean Fauna Surveys for Environmental Impact Assessment.


At the time of writing there was no formal regulatory guideline for subterranean fauna habitat modelling in WA. The Technical Guidance for Subterranean Fauna Surveys (EPA, 2021) includes 3D modelling as an approach that may be used to inform habitat suitability assessment and demonstrate adequate consideration of habitat connectivity. Methodology for modelling, apart from a mention of Leapfrog (referring to Leapfrog® Geo software), is not included in the guidance but it is noted that modelling methods are to be detailed in reporting where it has been used for assessments.

Biologic has developed a 3D modelling approach that aims to provide a rigorous and realistic characterisation of the extent, connectivity, and suitability of subterranean habitats. This can facilitate quantification of potential impacts to subterranean fauna habitat above water table (AWT) and below water table (BWT) and supports a more confident assessment of the extent and connectivity of habitats remaining intact following proposed impact scenarios. 3D modelling can assist in identifying specific environmental outcomes for a proposal, addressing the requirements of EPA guidance in considering and meeting the principles and objectives of the *Environmental Protection Act 1986* (EP Act), and informing the environmental approvals process.



LEGEND

- Study Area
- Tenement M 266SA
- Rail
- Proposed Pit



Biologic

Scale 1:38,000

0.5 0 0.5 1 Km

Coordinate System: GDA 1994 MGA Zone 50 Transverse Mercator Created: 27/06/2025



BHP WAIO
Ministers North
Subterranean Fauna
Habitat Assessment

Figure 1.1: Study Area and regional context

2 Methods

This assessment comprises a desktop investigation based on spatial information, data, and modelling provided by BHP WAIO, and publicly available sources. No new field data was collected. Habitat modelling was undertaken by integrating two-dimensional (2D) spatial data into 3D modelling software to demonstrate the extent of suitable habitats for troglofauna. 3D modelling provides a rich visual platform for demonstrating realistic models and conceptualisations of the extent and connectivity of subterranean fauna habitats.

Characterising suitable habitat is contingent upon the occurrence of sufficient underground void spaces. Subterranean void spaces are related to rock type and the degree of weathering or fracturing within the local geological context. Suitable habitat for troglofauna can occur AWT within a variety of fractured and weathered rocks (including banded iron formations, limestone, and dolomite); in secondarily weathered regolith deposits (e.g. calcrete, pisolitic hardcap, and channel iron deposits); and in coarse textured detritals (i.e. gravels, pebbles, and scree).

Assessment of potential habitat suitability for troglofauna was based on the physical characteristics of the rock or regolith by applying the habitat suitability framework shown below in Table 2.1, and as evidenced by the data and information sources described in Section 2.1 and 2.2.

Table 2.1: Habitat suitability framework

Habitat Suitability Category	Description
High	Observed cavities; obvious and well-defined interconnected voids, vugs, and microcavities; open fractures, particularly those affected by water penetration. Evident signs of secondary weathering and hydrated weathering of rock.
Medium	Partially weathered rock, calcareous detritals, or pisolite with less well-developed cavities; smaller, less obvious fractures, voids, and vugs; singular or poorly developed voids and fractures; gravels and gravelly detritals; cavity fill; fault contacts.
Low	Fresh rock lacking cavities, fractures, vugs, or minor evidence of weathering; fresh rock with fractures derived during drilling (no signs of weathering or water penetration); fresh clay, silt, and fine textured detritals; fresh or crumbly shale and black shale.
Uncertain	Intervals that cannot be confidently placed in previous categories due to data limitations.

2.1 Spatial information and data

2.1.1 Project information

BHP WAIO provided spatial information regarding the proposed pits at Ministers North within the Study Area. The Central Project Grid (CPG94) was used to reference all project's boundaries and features.

2.1.2 Geology, topography, hydrology

The habitat assessment used publicly available 2D spatial data comprising topography and surface hydrology, as well as groundwater contours and local 20K geological data provided by BHP WAIO.

Evaluation and categorisation of 2D geological mapping is the first step in subterranean fauna habitat assessment (EPA, 2021) to understand the geological units occurring in the Study Area and immediate surrounds. Although the information available for 2D habitat assessment can be broad scaled and limited spatially (especially vertically below surface), it provides a necessary context for more detailed interpretations of habitat suitability.

Other Geographical Information System (GIS) spatial data that was used included hydrogeological data (in the form of water level contours), linear structural mapping, and subterranean fauna sampling results. This information contributed to the 3D modelling as discussed further below.

2.1.3 Subterranean fauna data

Subterranean fauna data (sampling site data and subterranean fauna occurrence records) from studies undertaken between 2009 and 2023 (Bennelongia, 2018, 2024; Subterranean Ecology, 2010) was provided by BHP WAIO from their internal databases. The data reflected current records from sampling within the Study Area and immediate surrounds as of April 2025.

In the context of the current assessment and for clarification of terminology used: "taxon" (singular)/taxa (plural) is used in reference to troglofauna at any level of taxonomic hierarchy (i.e. family, genus, species); "OTU" refers to a genetically defined taxon (at any taxonomic level) identified to the lowest taxonomic level possible from the DNA sequences available at the time of analysis; "species" refers to a taxon that had been identified to the lowest taxonomic level of 'species' (in some cases may be used only when referring to formally name species); and "morphospecies" is a morphologically defined taxon (at any taxonomic level).

A consolidation of historic data and taxonomic alignment of species-level Operational Taxonomic Units (OTUs) was undertaken by Bennelongia (2018, 2024). Further consolidation of historic data was beyond the scope of the current assessment, but a molecular study (Appendix A) was conducted which reviewed troglofauna molecular genetic information (DNA sequences) from Ministers North. This review aimed to determine if troglofauna species/OTUs

that were possibly restricted to direct impact areas should be attributed a wider distribution, due to a DNA sequence match with another species/OTU.

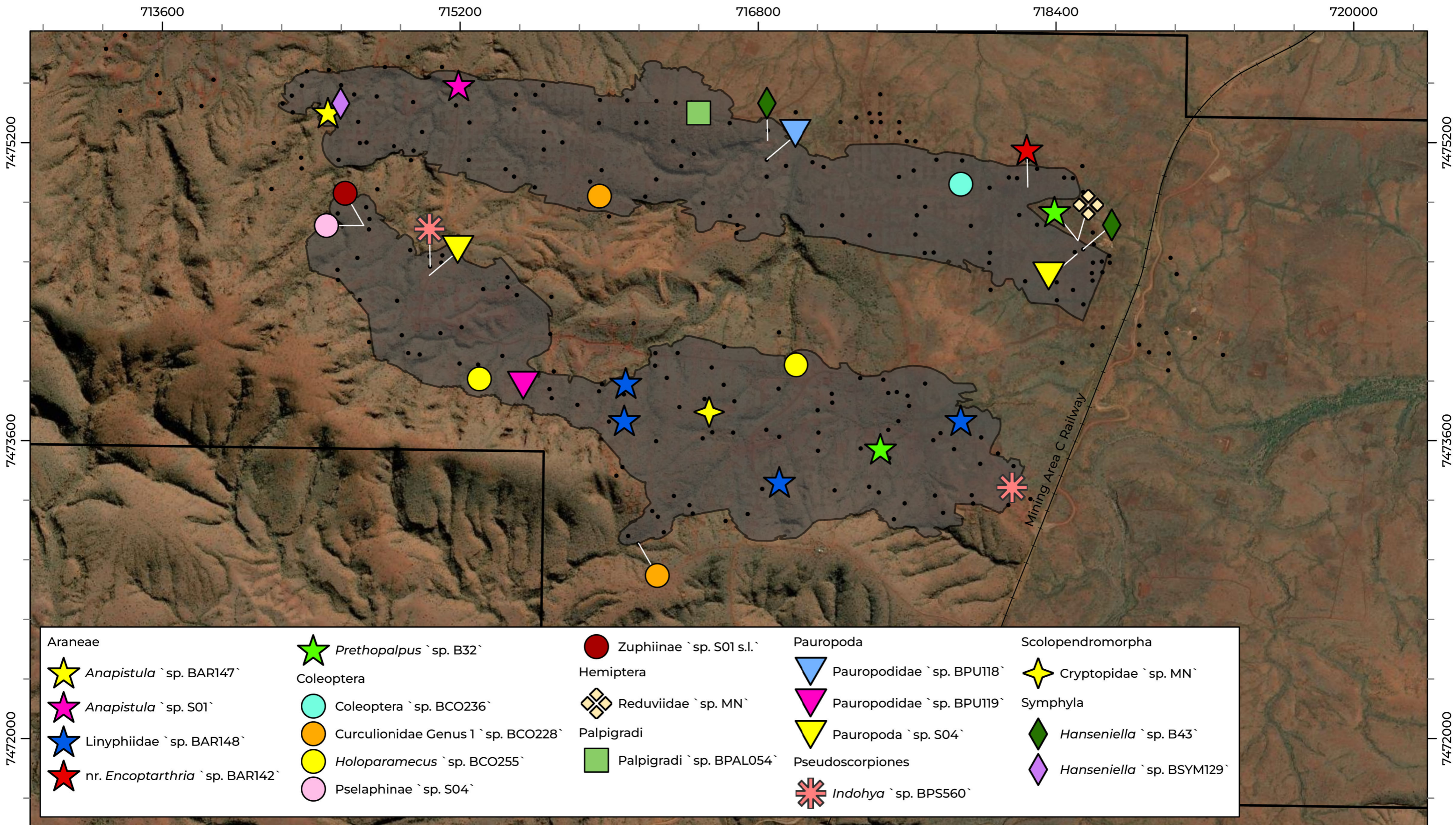
BHP WAIO provided DNA sequence data generated by Bennelongia and Subterranean Ecology from the Study Area, which could be compared against Biologic's DNA sequence database and GenBank (using BLAST Basic Local Alignment Search Tool) to potentially extend the known distribution of OTUs. A total of 123 DNA sequences from 88 specimens were provided which belonged to 28 species/OTUs (Appendix A). Comparisons with GenBank and Biologic's genetic databases revealed successful matches for 18 OTUs previously recorded from the wider region. These genetic matches significantly increased the linear ranges of all 18 OTU's, with nine taxa matching sequences recorded more than 10 km beyond the Study Area.

Following the data consolidation and molecular work, the distribution of all troglofauna taxa occurring within the Study Area was reassessed in relation to the outline of the updated proposed pits. Nineteen troglofauna taxa currently only known from inside the proposed pits were identified as target taxa and were the focus of the current habitat and impact assessment (Table 2.2, Figure 2.1). This revised list of target taxa differs from the one produced by Bennelongia (2024) due to updates in the pit design and revised taxonomy and distribution following Biologic's molecular work.

Table 2.2: Target troglofauna taxa

Lowest identification	No. of specimens	Collection location	Linear range	Location in pit		Survey		
				Northern Pit	Southern Pit	Subt. Ecol. 2010	Bennel. 2018	Bennel. 2024
ARACHNIDA								
Araneae								
<i>Anapistula</i> `sp. BAR147`	4	MN0885R	Single site	✓				✓
<i>Anapistula</i> `sp. S01`	2	EXR0969	Single site	✓		✓		
Linyphiidae `sp. BAR148`	12	MN0866DTM, MN1690R, MN2382R, MN2388R	2 km		✓			✓
nr. <i>Encoptarthria</i> `sp. BAR142`	1	MN1404RE	Single site	✓				✓
<i>Prethopalpus</i> `sp. B32`	2	EXR0509, EXR0597	1.5 km	✓	✓	✓		
Palpigradi								
Palpigradi `sp. BPAL054`	1	MN1125R	Single site	✓				✓
Pseudoscorpiones								
<i>Indohya</i> `sp. BPS560`	2	MN2323R, MN2614R	3.3 km		✓			✓
INSECTA								
Coleoptera								
Coleoptera `sp. BCO236`	1	EXR0765	Single site	✓				✓
Curculionidae Genus 1 `sp. BCO228`	2	MN1056R, MN2397R	2 km	✓	✓			✓
<i>Holoparamecus</i> `sp. BCO255`	11	MN2346R, MN2520R	1.7 km		✓			✓
Pselaphinae `sp. S04`	3	EXR1150	Single site		✓	✓		
Zuphiinae `sp. S01 s.l.`	1	EXR1150	Single site		✓	✓		

Lowest identification	No. of specimens	Collection location	Linear range	Location in pit		Survey		
				Northern Pit	Southern Pit	Subt. Ecol. 2010	Bennel. 2018	Bennel. 2024
Hemiptera								
Reduviidae `sp. MN`	1	EXR0597	Single site	✓		✓		
PAUROPODA								
Pauropodidae `sp. BPU118`	1	MN1179R	Single site	✓				✓
Pauropodidae `sp. BPU119`	1	MN2364R	Single site		✓			✓
Pauropoda `sp. S04`	2	EXR0975, MN2	3.5 km	✓	✓	✓		
CHILOPODA								
Scolopendromorpha								
Cryptopidae `sp. MN`	1	MN0013R	Single site		✓	✓		
SYMPYLA								
<i>Hanseniella</i> `sp. B43`	2	MN0708R, MN1178R	1.8 km	✓				✓
<i>Hanseniella</i> `sp. BSYM129`	1	MN0890R	Single site	✓				✓



LEGEND

- Study Area
- Proposed Pit
- Tenement M 266SA
- Troglofauna Sampling Site (Bennelongia, 2024)
- Rail

Biologic

Scale 1:19,000

0.2 0 0.2 0.4 0.6 Km

Coordinate System: GDA 1994 MGA Zone 50 Transverse Mercator Created: 27/06/2025



BHP WAIO
Ministers North
Subterranean Fauna
Habitat Assessment

Figure 2.1: Target troglofauna taxa restricted to proposed pits

2.2 3D Habitat modelling

Assessing and modelling subterranean habitats in 3D facilitates a more realistic representation of suitable habitats within the modelled boundaries. Rather than approximating simple, planar (2D) areas of occupancy for subterranean fauna, 3D modelling can more accurately show the depth, thickness, and continuity of suitable habitat throughout the Study Area and can incorporate the complexity of weathering, geological structure, and morphology that is often inadequately represented in 2D.

3D habitat modelling was undertaken using Leapfrog® Geo software (Leapfrog), based on the Ministers North geological model provided by BHP WAIO. The BHP WAIO model was updated with additional geological mapping files, drill hole logging (i.e. down-hole lithological data), geophysics data, structural information, weathering profiles, and hydrogeological data.

The 3D habitat model was refined from the updated geological model using the information sources and parameters discussed below to specifically investigate suitability, extent, and connectivity of habitats for troglofauna.

2.2.1 Boundaries

Spatial boundaries are required in 3D modelling to determine the limit of extrapolation of geological and hydrogeological trends away from data points (e.g. data from drilling and other surface or down-hole measurements). Subterranean fauna habitats were modelled using lateral and vertical boundaries that represented the Study Area (external boundary of modelling), the land-surface (topography), water table (aquifer), pit shells (proposed pits), and fault structures, as described in further detail below.

2.2.1.1 Study Area

The Study Area (Figure 1.1) is defined by a boundary box between the data points shown in Table 2.3.

Table 2.3: Parameters for 3D habitat model in CPG94 Grid

Data point	Easting	Northing
North-west	58700	178200
South-east	69300	170800

2.2.1.2 Topography

Topographic information was provided by BHP WAIO as a Leapfrog surface mesh within the geological model and formed the vertical boundary of the habitat modelling (i.e. separating the geology from the air). This surface has a resolution of 10 meters.

2.2.1.3 Water level and system basement

Water level data provided by BHP WAIO as Leapfrog surface meshes, was used to model the aquifer within the Study Area and surrounds at pre-impact water levels. These meshes were validated against the bore hole water level measurements (point data file *March 2024 WLS.csv*) provided by BHP WAIO. The pre-impact water level was used as a vertical boundary, marking the maximum depth from surface for AWT troglofauna habitat, otherwise known as the system basement.

Under the current Proposal, no groundwater drawdown (GWDD) is anticipated and hence no impacts to AWT or BWT habitats from GWDD are expected to occur.

2.2.1.4 Pit shells

Proposed pit shells for the northern and southern pit were provided by BHP WAIO as Vulcan triangulations (.00t) and shapefiles, which were converted to CPG94 grid format. Two versions of the pit designs were provided during the study, one from January and an updated version in April. A maximum pit design was selected for the final assessment, which necessitated merging and clipping the southern pit boundaries. The pit meshes were then extracted from the topography to show the remaining habitat post-disturbance.

2.2.1.5 Structures

Regional geological interpretations identified one significant fault, the Keystone fault, occurring in the Study Area (Figure 3.2). The Keystone fault is sub-vertical and shows a vertical displacement rather than horizontal displacement. The Keystone fault forms a lateral boundary that defines the 'fault blocks' within the Leapfrog model. Small dykes were identified in the region, but they were not considered significant and thus not included in the model.

2.2.2 Stratigraphic modelling

A geological/stratigraphic model was created by merging the compiled up-to-date drill hole logging data with contact meshes from the initial BHP WAIO model.

2.2.2.1 Drill hole logging data

All drill holes within the Study Area were logged for lithology (rock type) and weathering characteristics by BHP WAIO for each drilled depth interval. The resulting drill hole logging data is the foundation of the geology modelling and provides the basis for interpretations of stratigraphic trends, structure, and weathering.

Geology and stratigraphic (STRAT) data were compiled from drill hole files listed in Table 2.4. The 3D model was developed using drill logging data from 2,033 drill holes and almost 169,000 metres of drilled rock samples throughout the Study Area.

Table 2.4: List of files with geology and stratigraphy information

File Name	Information Type
20240430MN_borehole_export_Geology.csv	Geology
Export2_Geology.csv	Geology
ALLHoles_Geology.csv	Geology
MN_Geology.csv	Geology
20240430MN_Hydro_borehole_export_Geology.csv	Geology
HydroHoles_Geology.csv	Geology
20240430MN_borehole_export_Strat.csv	Stratigraphy
ALLHoles_Strat.csv	Stratigraphy
MN_Strat.csv	Stratigraphy
20240430MN_Hydro_borehole_export_Strat.csv	Stratigraphy
HydroHoles_Strat.csv	Stratigraphy

2.2.3 Habitat modelling

Using the updated geology model as a basis, the habitat model built upon each of the stratigraphic units to show habitat suitability by applying the framework presented in Table 2.1 to classify all the available data and create a 'refined' model in Leapfrog.

2.2.3.1 Habitat suitability classification

Interpretations of drill hole logging, Optical Televiewer (OTV) imagery, and downhole geophysical data were used to categorise the stratigraphic units for potential habitat suitability, including a review of the weathering over the Study Area.

Collated data was reviewed for suitable troglofauna habitat attributes, including subterranean voids, the degree of weathering and fracturing, and geophysical attributes such as downhole gamma (American Petroleum Institute units or API) and calliper measurements.

Visual inspection and interpretations of habitat suitability were based on the framework presented in Table 2.1.

Drill hole logging

Within the available data, geology has been recorded with up to three major lithologies and three minor lithologies (designated as MAJ1, MAJ2, MAJ3, MIN1, MIN2, and MIN3). From these, only the first two major lithologies (MAJ1, MAJ2) were selected to serve as the basis of the habitat classification (Appendix B) as they contained the most data compared to the other fields.

The combination of the STRAT, lithology (MAJ1, MAJ2), and weathering was used for a preliminary classification, based on previous knowledge of similar deposits. For example, rocks containing cavities were logged as High habitat potential, while rocks with clay were classified

as Low habitat potential. Some units remained labelled as Uncertain due to limited information for these intervals (e.g., lithology was not recorded, or weathering could not be defined).

Downhole OTV Televiewer images

Photos and imagery are often reviewed to assist and confirm classification of the habitat suitability according to visible fractures or openings.

OTV and Acoustic Televiewers (ATV) instruments are specialised tools that capture the inside of a drill or borehole, detailing the rock features including fractures, bedding orientations, and potential porosity, resulting in a 3D image capture of the rock formations as they are in the ground (Dempers *et al.*, 2019).

Available OTV logging imagery was visually examined to confirm physical habitat suitability at key depth intervals within the rock. 105 drill holes were selected for OTV analysis, chosen to provide spatial coverage of the Study Area and key stratigraphic intercepts from the model.

Additional OTV photo logging was reviewed for intervals that remained classified as 'Uncertain' after the preliminary classification.

Weathering

The detailed weathering database was limited in extent and coverage (only available for 48 drill holes, equivalent to 6,391.9 metres). Therefore, Biologic extracted weathering information from the available logging description stored in the comment of the available data tables.

The following terms were extracted to flag intervals without lithology information: Broken, Cavity, Crumbly, Gravel, Clay, CID, Fracture, Vuggy, Vugs, Porous, Pisolite, Weathered, and Siliceous.

Additionally, weathering zones were defined by BHP WAIO into the 3D models based on drill hole logging data, via coding the drilled intervals from the surface downwards, as follows:

- 0 – Detritals;
- 1 – Transitional – Weathered/oxidised rock sitting above the base of complete oxidation (BOCO); and
- 2 – Hardcap – indurated and weathered duricrust.

Within BHP WAIO's coding system, '0' was used to refer to fresh rock below the BOCO as well as detritals. To avoid confusion, replacements were made to the previously existing numeric codes to categorical codes for modelling purposes:

- The code "0" has been redefined as "Detritals"
- The code "1" has been redefined as "Transitional"
- The code "2" has been redefined as "Hardcap"
- The code "0," intervals separated from Detritals, has been redefined as "Fresh Rock"

Geophysics

Geophysical information can provide a specific insight into subsurface conditions. Within the provided data, downhole gamma (API) data was used to help classify habitat suitability. These data comprised 1,964 drill holes (155,407.3 metres), of which 588 holes (9,938.1 metres) were used for the interpretation of stratigraphic units with limited logging data.

For this interpretation, a threshold of 13.1 cm in calliper records was applied to differentiate between medium and low potential habitat. Furthermore, gamma readings exceeding 150 API units were used as a criterion to downgrade intervals to low potential habitat.

The second step in the review involved the analysis of geophysical measurements (gamma (API) and calliper) for units D1 and RU (Appendix B) to categorise their intervals as Medium or Low habitat potential based on selected thresholds.

2.2.3.2 Habitat Classification

Once the logging was completed, the classification was reviewed based on the majority rule (i.e. the class with the highest metre usage was assigned to the unit). A unit was classified into a specific class if more than 60% of its logged metres belonged to that class.

Some units did not meet this criterion, however they accounted for less than 1.4% of the database. Each stratigraphic unit was reviewed and, in most cases, the highest percentage classification was maintained.

The final classification was based on the logging combined with the geophysical analysis prioritised over the preliminary classification. The final classification was then coded in the drill hole database and uploaded to Leapfrog for 3D modelling.

2.2.3.3 Habitat Model Creation

The habitat model was developed using the Refined Geological Model tool available in Leapfrog Geo. This tool allows for further modelling within the stratigraphic geological model and the integration of habitat classification drillhole data.

Habitat volumes were constructed using the 'vein'-function in Leapfrog Geo which uses an upper (hangingwall) and lower (footwall) surface to create a thickness (or volume) called a vein. This method enables smaller intersections within a stratigraphic unit to be created which are then 'pinched out' or terminated a little beyond the data. In the habitat model, this allows the suitability categories to be modelled within a stratigraphic unit without extrapolating too far. Drillhole data provided the habitat suitability classification, while stratigraphic trends contributed to the orientation and dip of the habitat within each stratigraphic unit. The result is a model that represents habitat classification based on the available geological information, as well as the form of the stratigraphy.

2.2.4 Combined models

After the habitat model was created, Leapfrog's 'combine models' function was used to identify areas of habitat occurring inside and outside of boundaries relevant to the impact assessment, namely the layers derived from the aquifer and the pit shells (refer section 2.2.1).

Importantly for subterranean fauna habitat modelling for impact assessment, the 'combined modelling' function allows the grouping of the most likely AWT habitat within various habitats, within the impact areas vs the same habitat occurring outside of impact areas.

Table 2.5: Combined model outputs

	Habitat model	Proposed pits	Water scenarios	Scenarios/ components	Output description
Habitat extent AWT	✓		✓	Potential habitat zones and basement water level	Troglofauna habitat extent (AWT)
Proposed impact	✓	✓		Potential habitat zones and proposed pit designs	Habitat extent within and outside of proposed pit
Combined impact model	✓	✓	✓	Potential habitat zones, water level and proposed pit designs	Troglofauna habitat extent (AWT) within and outside of the proposed pits

2.3 Constraints and limitations

2.3.1 Differences between 2D and 3D assessment

The most significant difference between 2D assessment and 3D modelling is the granularity of the data resolution. 2D assessment is generally based on regional data sets which tend to be much less detailed and will not always align with the finer scaled, local data used in 3D models. 2D habitat assessment from surface mapping typically underrepresents the complexity of 3D trends (such as faults, folds, interlayering, and variable weathering) below the surface.

Surficial differences in mapping of regolith vs basement geology or bedrock can provide the potential for contradictory interpretations. In a 2D assessment, units mapped as 'regolith' (such as "Residual duricrust") would be equivalent to 'hardcap' classification across several bedrock lithologies, although these classifications may have different weathering implications.

While 2D geological information was integrated where appropriate (e.g. broad trends and context beyond the model boundaries), the 3D modelling was given precedence within the Study Area as it provides a much more rigorous interpretation of subterranean habitat based on richer and more fine-scaled data.

2.3.2 Inherent constraints and limitations

The modelling and habitat assessment is limited to the extent and density of information available at the time of assessment. The spatial layout of drill holes is the limit of granularity/density of data within the model. It is not possible to precisely model the extent and connectivity of individual subterranean voids, caves, or fractures that may provide habitat. Localised variability is likely to occur within every modelled stratigraphic unit, which could affect the likelihood of suitable habitat occurring, or being connected, at scales beyond the ability to model. Nevertheless, the use of down hole data (e.g. OTV, geophysics) to evaluate porosity provides a representative basis for interpretation of the likely presence and abundance of cavities, voids, fractures, and weathered/porous rock zones within and between stratigraphic units.

The 3D models primarily focus on the occurrence and frequency of subterranean voids within rock, because without this fundamental factor (i.e. where rock is fresh/unaltered, or where compact fine sediments and clays occur), there is no physical space available for subterranean fauna to inhabit. There are other habitat quality factors that may influence the relative suitability of some areas of habitat over others that are beyond the scope of the current modelling. Habitat quality data AWT (such as temperature, humidity, or air quality monitoring) is not routinely collected during sampling, and there was no such data available for this assessment.

The modelling is created to provide the best available representation of the extent and connectivity of potentially suitable habitat for subterranean fauna throughout the Study Area based on the best available data. Nevertheless, the model cannot precisely predict the occurrence or distribution of any particular species over another. Other potentially important variables beyond the scope of modelling that could affect habitat preferences and species distributions may include (but are not limited to):

- AWT habitat quality within subterranean voids (such as temperature, humidity, or air quality);
- geochemical characteristics of the rock (e.g. pyritic shales, acid forming material);
- infiltration rates and variability in surface inputs (e.g. water nutrients and oxygen);
- biological interactions with surface (e.g. vegetation roots);
- behavioural and ecological influences, such as vagility, dispersal mechanisms, competition for resources, trophic interactions; and
- complex evolutionary histories (e.g. differential colonisation patterns or dispersal patterns over time).

The scope of the impact assessment is limited to the consideration of direct impacts (i.e., excavation of habitat within the proposed pits) to troglofauna species and habitat values. Any potential indirect or cumulative impacts to troglofauna species and habitat values, and any

potential impacts direct or indirect to stygofauna values were not included in the scope of this assessment.

Subterranean fauna surveys have well-documented sampling limitations and artefacts (Halse & Pearson, 2014), and regional/historical records may be subject to the limitations of knowledge available at the time of survey. Prior to the current technical guidance (EPA 2021), sampling effort was often more limited than the current three-phase standard, and the use of DNA to confirm species level identifications was rarer. As a result, some of the taxonomy and linear ranges of historically recorded troglofauna taxa within the Study Area cannot be fully resolved. Further potential limitations surrounding the subterranean fauna data utilised in this assessment may include (but are not limited to):

- most drill holes available for sampling at the time of survey were located within the proposed pit areas, and comparatively fewer sampling sites were available outside the pits. As a result, the current understanding of troglofauna diversity and the linear ranges of the species detected are likely to be affected by sampling biases within impact areas;
- 3D habitat modelling was not available at the time of the survey work to help target the sampling within suitable troglofauna habitats occurring beyond the proposed pits ; and
- the ability to align and consolidate historic species records was limited by the amount of genetic sequencing undertaken by previous surveys. It is possible that there is some unresolved synonymy between historic records (Subterranean Ecology 2010) and recent records from the Study Area (Bennelongia, 2024), or other regional collections that are unable to be compared due to a lack of genetic data.

The assessment was limited to the information provided by the client and publicly available data at the time of writing. The current results and conclusions may be subject to change with future work including (but not limited to);

- Changes to species information, such as further taxonomic revisions, genetic sequence data, new specimen collections (within the Study Area or regionally), or updated ecological information regarding the target taxa;
- Updated habitat information, beyond that provided by client and publicly available at the time of writing (e.g. further drilling, regional habitat modelling, potential future updates to geological or hydrogeological information);
- Updated impact information, including potential future changes to mine plans and 3D pit shapes at Ministers North; and
- Any potential additional impact assessment for subterranean fauna (including indirect or cumulative impacts, or below water table impacts to stygofauna).

3 3D habitat assessment

3.1 Geological context

In the Pilbara region, many different lithologies (and detrital formations) have been found to provide suitable voids, cavities, fractures, and pore spaces for subterranean fauna; including (but not limited to):

- Weathered and fractured Banded Iron Formation (BIF) (e.g. Brockman Iron Formations);
- Weathered hardcap and duricrust (typically occurring atop BIF);
- Weathered and karstic limestone, calcrete, and dolomite;
- Porous and karstic calcrete deposits; and
- Unconsolidated and partly consolidated detritals (colluvium, alluvium, particularly coarse sediment textures such as gravel, talus, scree).

The geological setting of the Study Area and surrounds is dominated by a typical Hamersley Group stratigraphic sequence (Figure 3.1), featuring superficial detritals, the Weeli Wolli Formation, Brockman Iron Formation (comprising Yandicoogina Shale Member, Joffre Member, Dales Gorge Member, and Whaleback Shale Member), Mount McRae Shale, and Mount Sylvia Formation. These geological units have been folded at the location of the Study Area, forming the Wirriba Anticline. The Mount Sylvia Formation represents the oldest geological unit in the fold that has been drilled; however, it is interpreted that the Wittenoom Formation occurs at depth below the Mount Sylvia. The Weeli Wolli Formation represents the youngest geological unit of the Wirriba Anticline and outcrops at surface in the northern part of the Study Area and to the south of the Study Area (Figure 3.2).

The proposed pits are hosted by the Brockman Iron Formation which consists of alternating sequences of BIF, shale, and chert. The Brockman Iron Formation is subdivided into four Members, comprising (from top to bottom) the Yandicoogina Shale Member, Joffre Member, Whaleback Shale Member, and Dales Gorge Member (Figure 3.1). Preferential erosion of the elevated stratigraphic units near the centre of the fold have exposed the Mount McRae Shale in the area between the proposed northern and southern pit (Figure 3.2) and the Dales Gorge Member at the location of both pits.

The potential for subterranean fauna habitat within the Hamersley Group geologies has been well established regionally, particularly in relation to the Brockman Iron Formation (as one of the hosts of the major economic mineral resources in the region, these formations have been the target of considerably greater research than other geologies), as well as certain detrital and regolith units (e.g. alluvium, colluvium, laterite, and pisolite, and calcrete). Other Hamersley formations such as Weeli Wolli and Mount McRae Shale, have received considerably less sampling attention. Nevertheless, these rock types are known to be less permeable in most

settings throughout the Hamersley subregion, and subject to different weathering processes. Therefore, they tend to be less likely to host suitable void spaces for subterranean fauna.

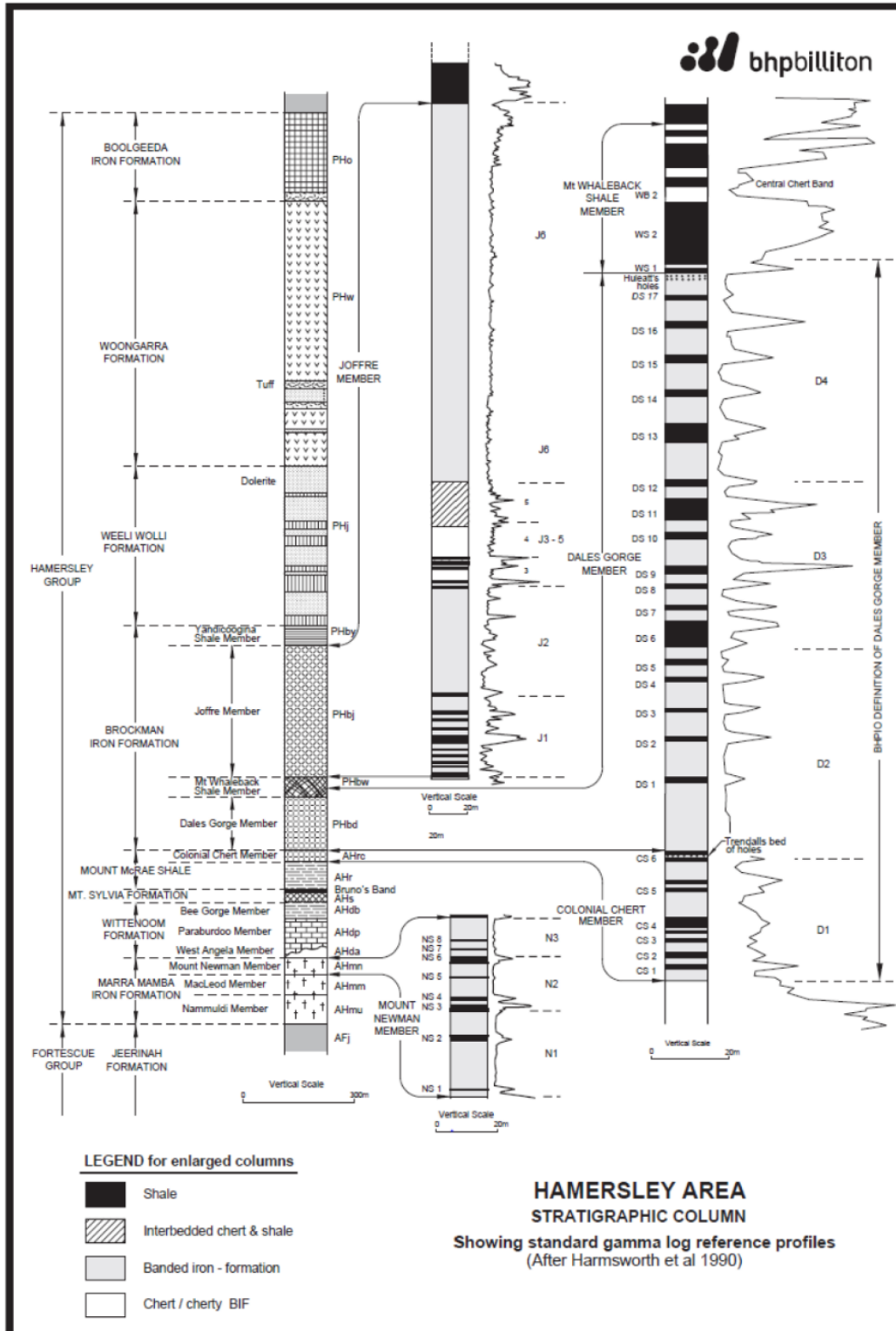


Figure 3.1: Hamersley Group stratigraphic profile. Image provided by BHP WAIO (Perring & Hronsky, 2019)

698400

705600

712800

720000

727200

- Surface Geology (1:20K)**
- AHdb - Wittenoom - Bee Gorge Member
 - AHr - Mt McRae Shale
 - AHs - Mt Sylvia Formation
 - CID - Robe - Oolitic channel iron deposit
 - Cza - Alluvium (consolidated)
 - Czb - Silcrete (indurated)
 - Czcg - Indurated colluvium (Canga)
 - Czci - Indurated Czc / Czcb
 - Czc - Colluvium & alluvium
 - Czl - Ferricrete (laterite)
 - Czm - Oakover - Micritic lacustrine limestone
 - Czpi - Consolidated ferruginous pisolites
 - H1 - Martite (microplaty haematite)
 - H2 - Martite goethitic supergene ore (ochereous)
 - PHbd - Brockman - Dales Gorge (BIF & Shale)
 - PHbj - Brockman - Joffre (BIF with chert & shale)
 - PHbw - Brockman - Mt Whaleback Shale
 - PHby - Brockman - Yandicoogina Shale
 - PHj - Weeli Wollie - BIF
 - Pd - Dolerite dykes
 - Pds - Weeli Wollie - Dolerite sills
 - Phj - Weeli Wollie - Dolerite 1-4
 - Phjb - Shaly BIF 1; Phjd - Shaly BIF 2
 - Phje - Cherty BIF Band
 - Phjg - BIF Marker 1; Phji - BIF Marker 2
 - Qa - Alluvium (drainage channels)
 - Qc - Talus & colluvium; Qct - Colluvium - TP talus
 - Td - Duricrust - Limonitic mesa capping
 - To - Oakover - Fluvial calcareous sediments
 - Tp - Robe Pisolite - Goethite pisolite with fossil wood fragments

7481200

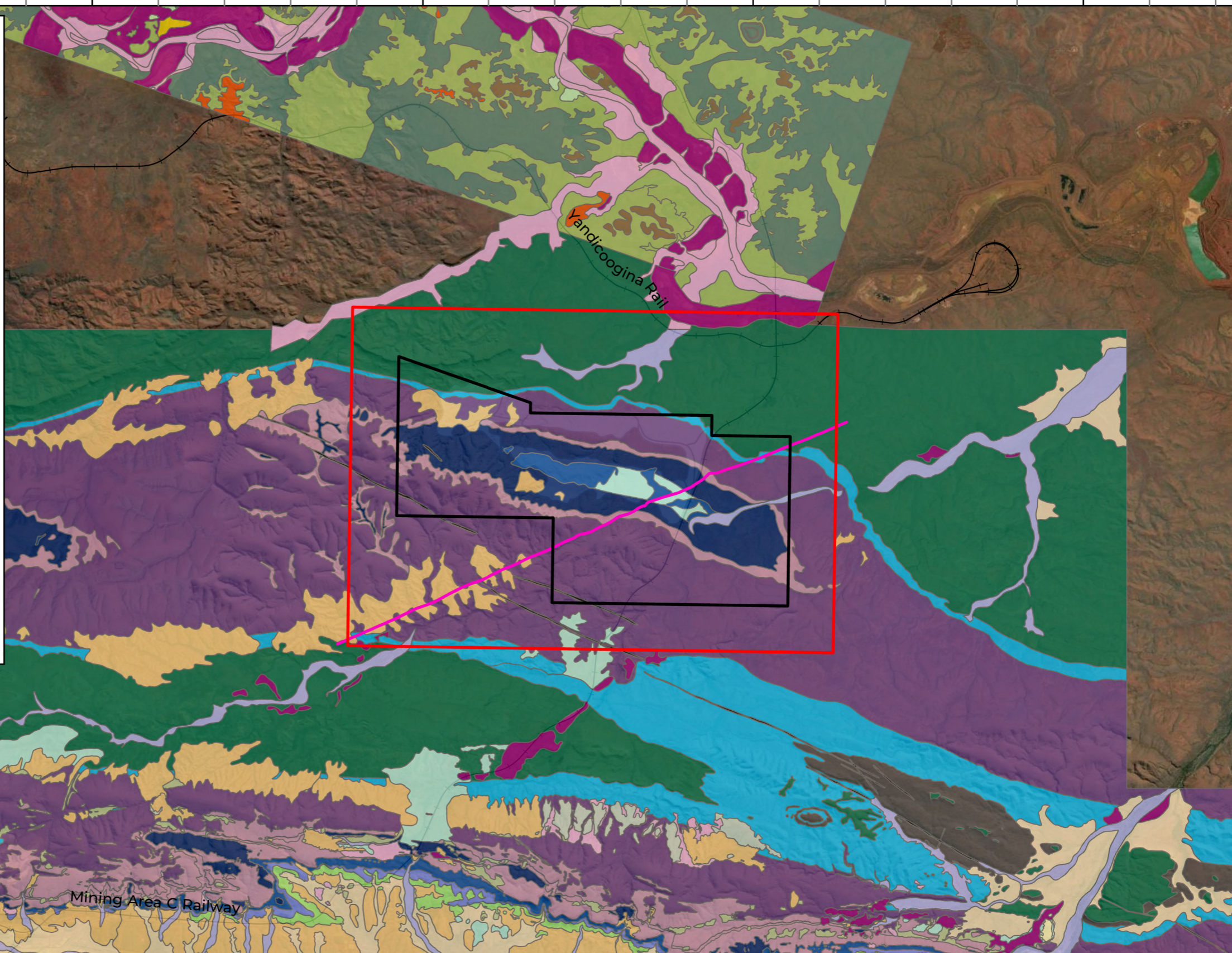
7475300

7469400

7481200

7475300

7469400



LEGEND

- Study Area
- Tenement M 266SA
- Proposed Pit
- Proposed Infrastructure
- Rail
- Keystone Fault

Biologic

Scale 1:92,000

Coordinate System: GDA 1994 MGA Zone 50
Transverse Mercator Created: 27/06/2025



BHP WAIO
Ministers North
Subterranean Fauna
Habitat Assessment

Figure 3.2: Surface geology
(GSA 20K)

3.2 Hydrogeology

The regional groundwater level in the Ministers North aquifer is at approximately 561 metres Relative Level (mRL) or on average 80 m below surface on the top of the range. Works undertaken at Ministers North have shown that water levels are relatively flat across the Study Area, between 561.4 metres Australian Height Datum (mAHD) and 561.6 mAHD and without obvious gradient direction (RPS, 2022). Groundwater levels have fluctuated since measurements began in 2002. However, since 2018 there has been a consistent decline (around 0.6 m/yr) (BHP, 2024). Although groundwater levels rise temporarily following rainfall events, these seasonal increases do not reverse the long-term downward trend (BHP, 2024).

The Ministers North aquifer is considered a hard rock aquifer located within the Dales Gorge Member of the Brockman Iron Formation. The Mount McRae Shale Member divides the Ministers North aquifer, creating a preferential flow path forming along the strike of the orebodies and influenced by the lower permeability units adjacent to the Dales Gorge Member (i.e. Mount McRae Shale and Weeli Wolli formations) (BHP, 2024).

The Keystone fault (Figure 3.2) does not appear to form a barrier to groundwater flow and may contribute to higher bore water yields due to increased fracturing observed within its vicinity (BHP, 2023).

3.3 Stratigraphic model

3D stratigraphic modelling of the Study Area covered the area of proposed pits and surrounding areas beyond. Figure 3.3 and Figure 3.4 provide a plan and oblique view of the stratigraphic model, showing the 3D extent of all rock types present within the model area, while Figure 3.5 provides an example 2D cross-section through the stratigraphy, oriented in the north-south direction.

The Wirriba Anticline is the main feature of the Study Area and shows uplifted stratigraphic units near the centre that have been preferentially eroded to a deeper stratigraphic unit, revealing the older units (Mount McRae Shale and Mount Sylvia Formation) at the centre of the fold (Figure 3.5). The younger geological units (Joffre and Dales Gorge Members of the Brockman Iron Formation) are located along the flanks of the anticline.

The typical sequence of the stratigraphic units of the Wirriba Anticline within the Study Area is as follows (refer Figure 3.3, Figure 3.4, Figure 3.5):

- Surface Scree (SZ – dark green);
- Tertiary Detritals 3 (TD3 – olive green);
- Tertiary Detritals 2 (TD2 – beige);
- Weeli Wollie Formation (HJ – light green);
- Yandicoogina Shale Member (Y – dark blue);
- Joffre Member J6 (J6 – pink);
- Joffre Member J5 (J5 – violet);
- Joffre Member J4 (J4 – plum);
- Joffre Member J3 (J3 – light pink);
- Joffre Member J2 (J2 – lavender);
- Joffre Member J1 (J1 – light lavender);
- Whaleback Shale (W – forest green);
- Dales Gorge Member D4 (D4 – red);
- Dales Gorge Member D3 (D3 – orange);
- Dales Gorge Member D2 (D2 – light orange);
- Dales Gorge Member D1 (D1 – lime green);
- Mount McRae Shale Upper Unit (RU – blue);
- Mount McRae Shale Nodule Zone (RN – periwinkle);
- Mount McRae Shale Chert (RC – dark navy);
- Mount McRae Shale Lower Unit (RL – light blue);
- Mount Sylvia Formation Undifferentiated Turbites (TRB – yellow);
- Mount Sylvia Formation AHs (S – brown); and
- Wittenoom Formation (O - pink).

Mineralisation is present on both limbs of the anticline (where the proposed pits are located), predominantly occurring within the upper units of the Dales Gorge Member and, to a lesser extent, the Joffre Member of the Brockman Iron Formation.

The Keystone fault is a significant geological feature that trends northeast through the Study Area, displacing the geological sequence downward on the southern side of the fault relative to its northern side (Figure 3.5).

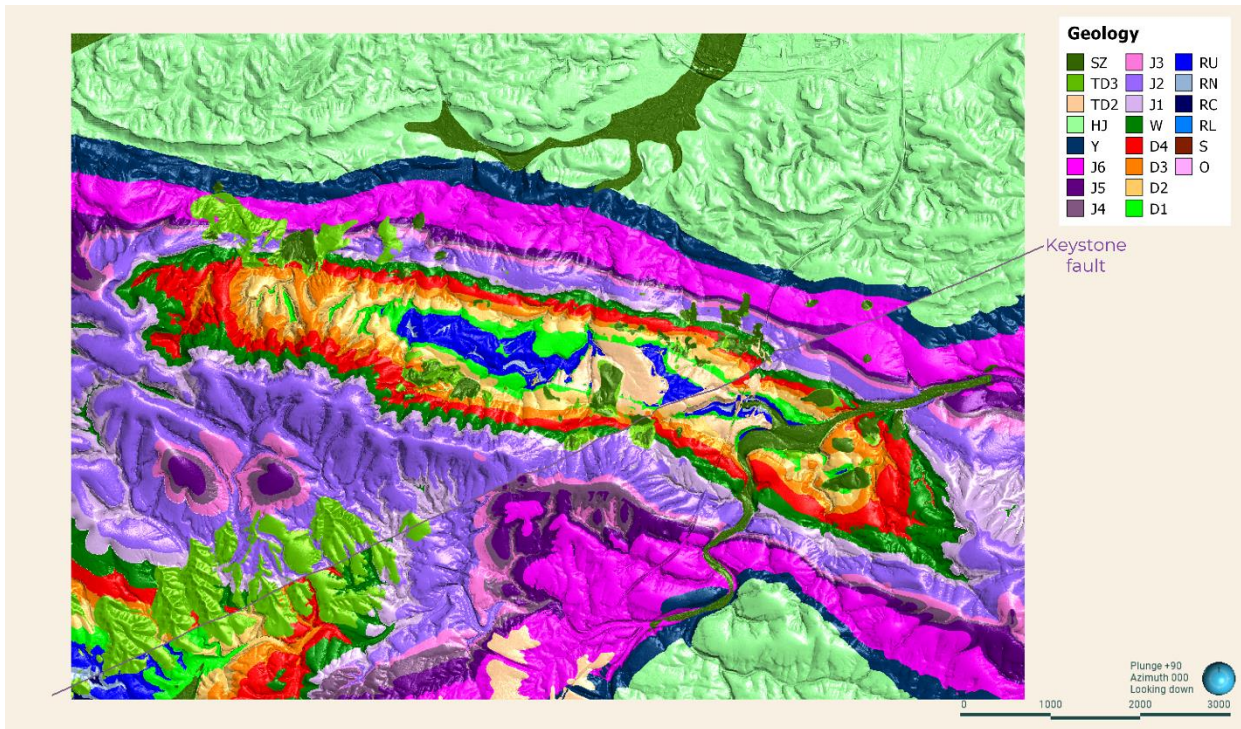


Figure 3.3: Plan view of the stratigraphic units within the Study Area

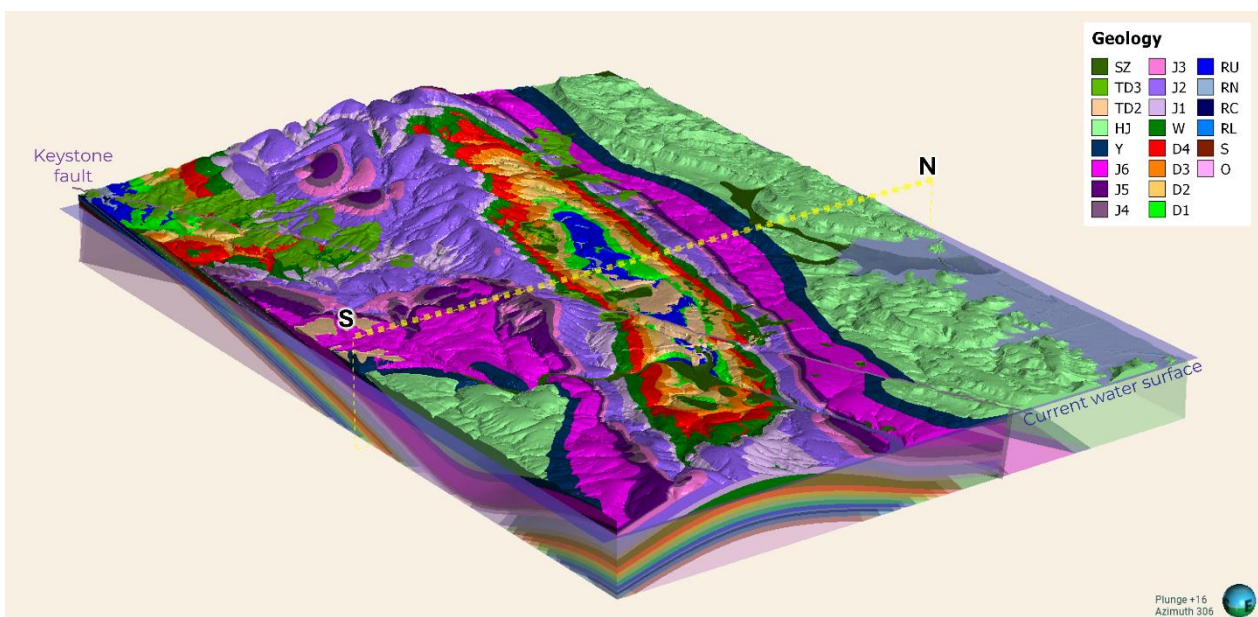


Figure 3.4: Oblique view of the stratigraphic model, showing the Wirriba Anticline and depth extent of the modelling

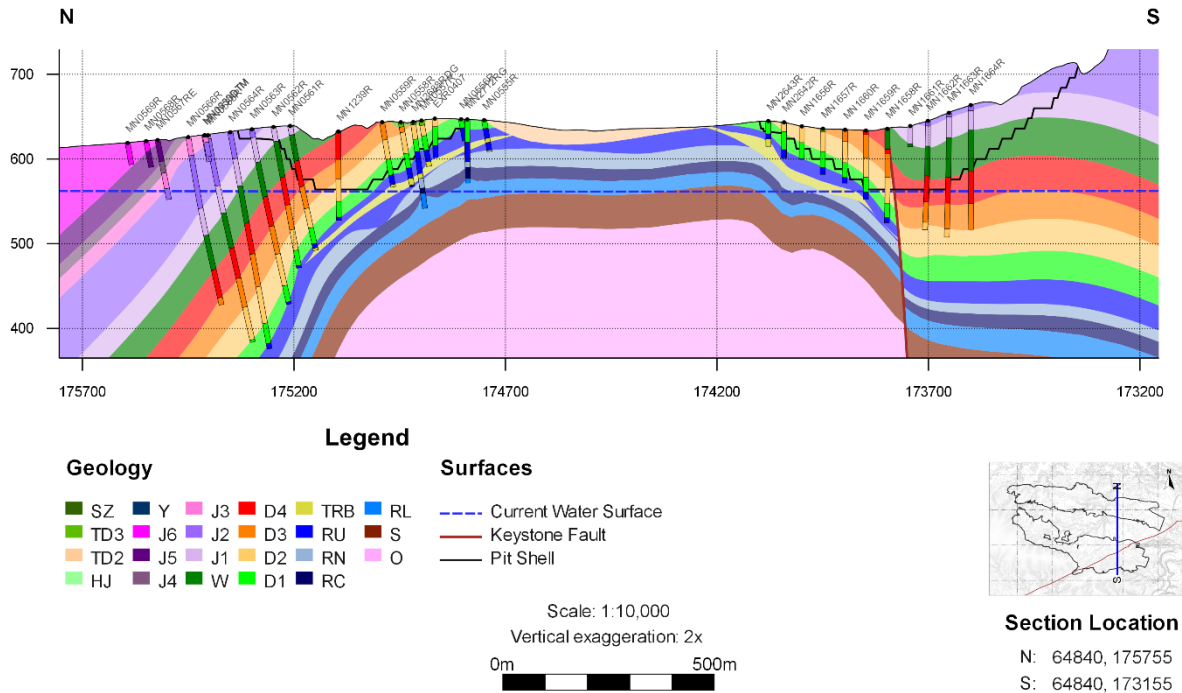


Figure 3.5: Cross-section (N-S) through the typical stratigraphic sequence within the Study Area, based on 3D modelling.

3.4 Habitat modelling

Four habitat suitability categories (High, Medium, Low, and Uncertain; Table 2.1) were applied to the stratigraphic model as described in Section 2.2.2. The results were cross-referenced against the subterranean fauna sampling data where available. Full results of the habitat assessment are provided in Table 3.1.

Of the members and units modelled, the Joffre and Dales Gorge Members presented the most consistently suitable potential habitats for troglofauna; however, there was a degree of variability in weathering throughout most members and units logged (Table 3.1, Appendix C).

Localised variability in the occurrence and prevalence of subterranean voids is typical for weathered/fractured rock habitats. No caves or macro-cavities were logged or recorded within the available imagery, therefore the primary habitat for troglofauna is likely to comprise cracks and fractures, meso- and micro-cavities, vugs, and interstitial spaces between coarse gravels. These types of habitats are inherently variable throughout the vertical profile, even within a zone, as the lower sections of rock are subject to comparatively less weathering, and smaller cavities are subject to fill with clays and fine sediments at depth.

Aside from localised variability, the evaluation of OTV imagery (Appendix C) showed a minimum of medium suitability habitat (Table 3.1) within the following stratigraphic units:

- Tertiary detritals and surface scree
 - SZ
 - TD3
 - TD2
- Weeli Wolli Formation
 - HJ
- Joffre Member units
 - J2
 - J4
 - J6
- Dales Gorge Member units
 - D1
 - D2
 - D4

Table 3.1: Habitat suitability of stratigraphic units within the 3D model

Stratigraphic unit	Map Code/s	Description	Habitat potential	Subterranean fauna habitat suitability assessment	Colour band
DETRITALS & CID					
Quaternary Detritals	SZ	Surface Scree	High	Habitat suitability of these deposits is typically highly variable based on texture (clay, silt, sand, gravel). 90% of the assessed drillhole (DH) metres at Ministers North were Medium or High Suitability.	
Tertiary detritals	TD3	Tertiary Detritals 3 (includes former AZ, BZ, CZ, FZ, GZ, HMZ, LLZ, LZ)	High	Void spaces expected to occur frequently throughout these Tertiary Detritals (e.g. secondary weathering, vugs, fractures, porosity). Typically forms highly suitable subterranean fauna habitat. 92% of the assessed DH metres at Ministers North were Medium or High Suitability.	
	TD2	Tertiary Detritals 2 (CID Equivalent)	Medium	Void spaces expected to occur frequently throughout these Tertiary Detritals (e.g. secondary weathering, vugs, fractures, porosity). Typically forms highly suitable subterranean fauna habitat. 77% of the assessed DH metres at Ministers North were Medium or High Suitability.	
Geology					
Weeli Wolli Iron Formation	HJ	Weeli Wolli Iron Formation – Undifferentiated	Medium	Poorly sampled regionally. Habitat suitability varies widely at Ministers North depending on degree of weathering and fracturing. 54% of the assessed DH metres at Ministers North were Medium Suitability.	
Brockman Iron Formation	Y	Yandicoogina Shale Member - Undifferentiated	Low	Insufficient void spaces, mostly shale, chert and fine textured material. 65% of the assessed DH metres at Ministers North were Low Suitability.	
	J6	Joffre Member (PHbj), J6 - BIF rich	Medium	Habitat suitability varies depending on degree of weathering and fracturing. 67% of the assessed DH metres at Ministers North were Medium or High Suitability.	
	J5	Joffre Member, J5 - Shaly	Low	Habitat suitability is generally low due to insufficient void spaces in the shales. 66% of the assessed DH metres at Ministers North were Low Suitability.	
	J4	Joffre Member, J4 - BIF-rich	Medium	Habitat suitability varies depending on degree of weathering and fracturing. 76% of the assessed DH metres at Ministers North were Medium or High Suitability.	
	J3	Joffre Member, J3 - Shaly	Low	Habitat suitability is generally low due to insufficient void spaces in the shales. 54% of the assessed DH metres at Ministers North were Low Suitability.	
	J2	Joffre Member, J2 - BIF-rich	Medium	Habitat suitability varies depending on degree of weathering and fracturing. 77% of the assessed DH metres at Ministers North were Medium or High Suitability.	

Stratigraphic unit	Map Code/s	Description	Habitat potential	Subterranean fauna habitat suitability assessment	Colour band
	J1	Joffre Member, J1 – Shaly	Low	Habitat suitability is generally low due to insufficient void spaces in the shales. 71% of the assessed DH metres at Ministers North were Low Suitability.	
	W	Whaleback Shale – Undifferentiated	Low	Insufficient void spaces within chert, shales, clay and fine textured material. 90% of the assessed DH metres at Ministers North were Low Suitability.	
	D4	Dales Gorge Member, D4 - BIF-rich	Medium- High	Void spaces expected to occur frequently (e.g. frequent well-developed vugs, fractures, BIF-enriched zone). Potential areas where less vuggy. 84% of the assessed DH metres at Ministers North were Medium or High Suitability.	
	D3	Dales Gorge Member, D3 – shaly	Low	Habitat suitability of this unit at Ministers North is mostly low due to insufficient void spaces in the shales. 72% of the assessed DH metres at Ministers North were Low Suitability.	
	D2	Dales Gorge Member, D2 - BIF-rich	Medium- High	Void spaces expected to occur frequently (e.g. frequent well-developed vugs, fractures, BIF-enriched zone). Potential areas where less vuggy. 85% of the assessed DH metres at Ministers North were Medium or High Suitability.	
	D1	Includes Colonial Chert Member (AHrc) unit of the Dales Gorge Member	Medium	Habitat suitability varies widely at Ministers North depending on degree of weathering and fracturing. 67% of the assessed DH metres at Ministers North were Medium or High Suitability.	
Mount McRae Shale	RU	Upper unit	Low	Mainly clays and fine textured material, mostly insufficient void spaces. 74% of the assessed DH metres at Ministers North were Low Suitability.	
	RN	Nodule Zone	Low	Mainly clays and fine textured material, mostly insufficient void spaces. 68% of the assessed DH metres at Ministers North were Low Suitability.	
	RC	Chert	Low	Mainly clays and fine textured material, mostly insufficient void spaces. 95% of the assessed DH metres at Ministers North were Low Suitability.	
	RL	Lower unit	Low	Mainly pyritic/black shales, impervious, occurs in fresh rock with mostly insufficient void spaces. 85% of the assessed DH metres at Ministers North were Low Suitability.	
Mount Sylvia Formation	TRB	Undifferentiated Turbidites	Low	Occurs in fresh rock without void spaces. 95% of the assessed DH metres at Ministers North were Low Suitability.	
	S	Mount Sylvia Formation (AHs)	Low	Occurs in fresh rock without void spaces. 100% of the assessed DH metres at Ministers North were Low Suitability.	
Wittenoom Formation	O	Undifferentiated Wittenoom	Uncertain	Habitat suitability varies widely depending on degree of weathering. No drilling data available for assessment	

Figure 3.6 and Figure 3.7 provide a plan and oblique view of the 3D habitat model, showing the 3D extent of subterranean habitats within the model area, while Figure 3.8 provides an example 2D cross-section through the 3D habitat model, oriented in the north-south direction.

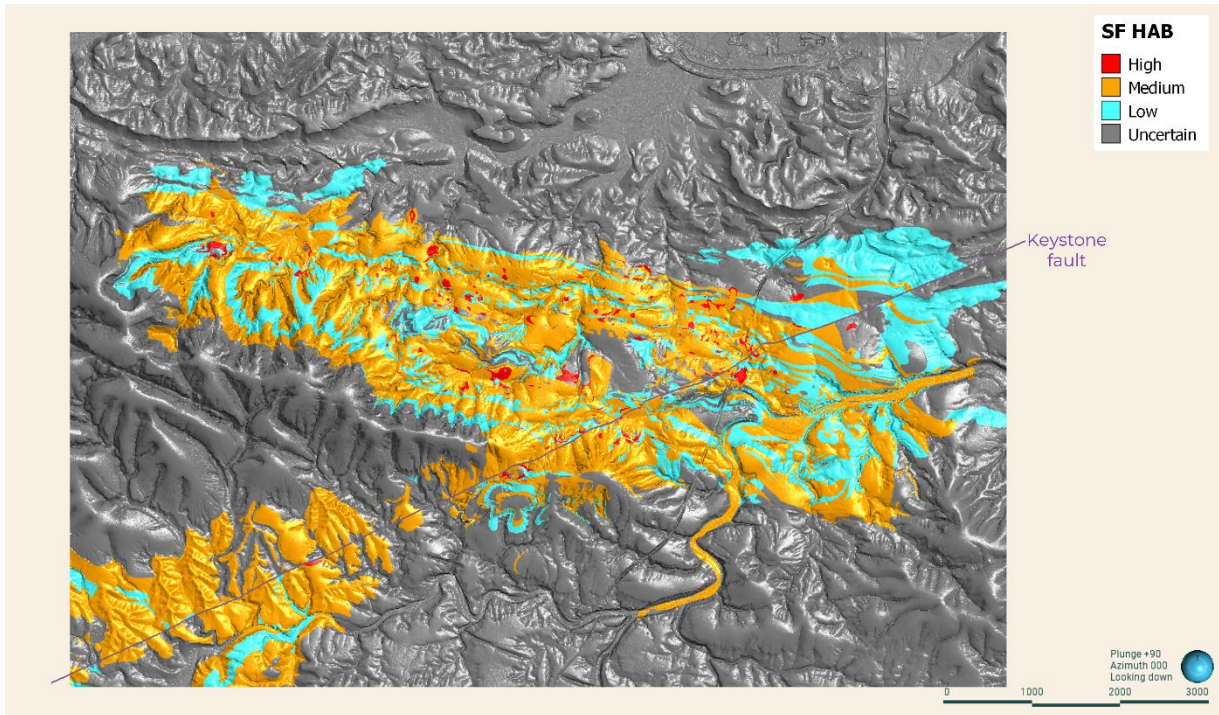


Figure 3.6: Plan view of the 3D habitat model, showing the habitat suitability for subterranean fauna within the Study Area

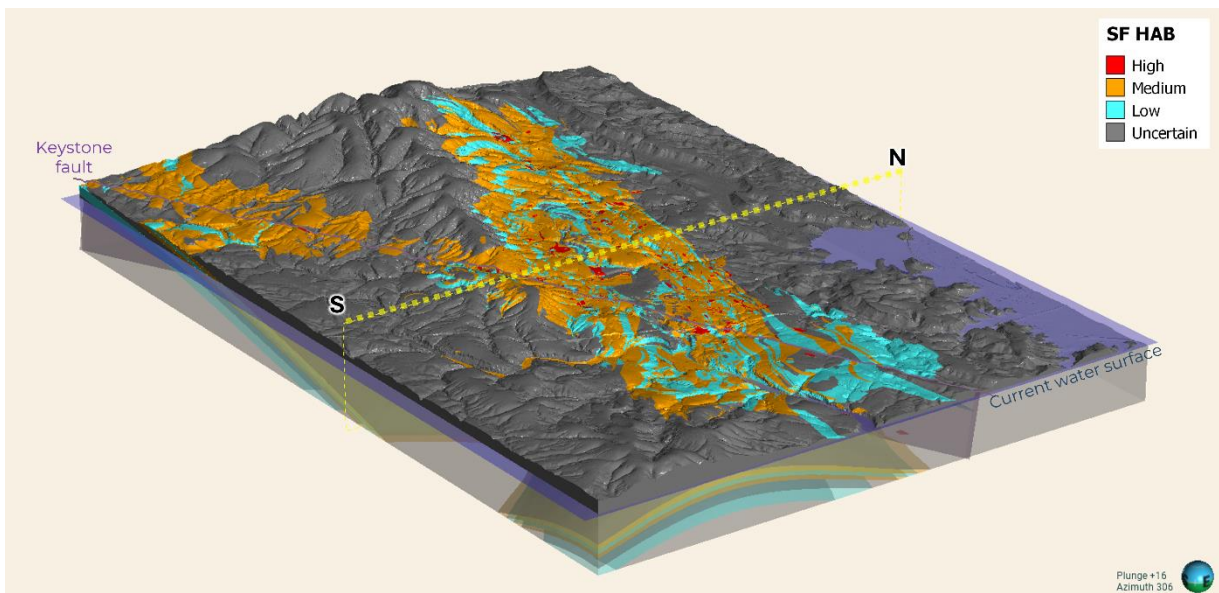


Figure 3.7: Oblique view of the 3D habitat model, showing the habitat suitability for subterranean fauna within the Study Area

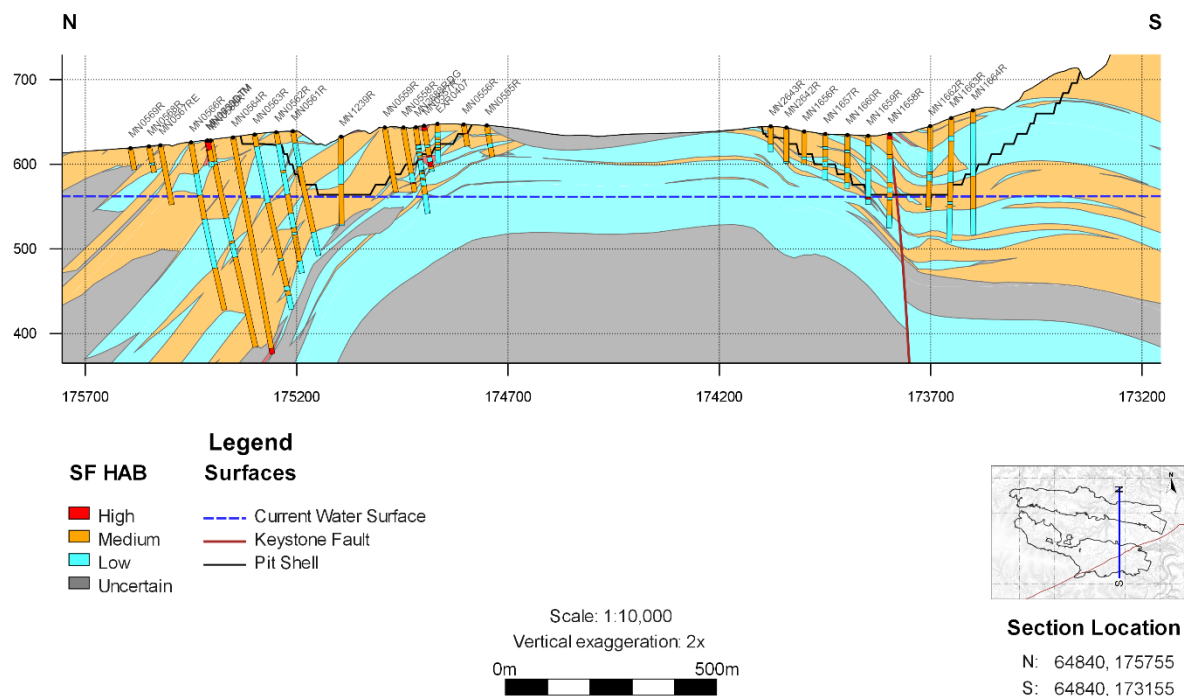


Figure 3.8: Cross-section (N-S) through the habitat potential within the Study Area, based on 3D modelling

3.4.1 Troglifauna habitat extent and connectivity

3D modelling showed that suitable habitats for subterranean fauna occur extensively throughout the Study Area, hosted within several members and units of the Brockman Iron Formation and superficial deposits of tertiary detritals and scree (Figure 3.9, Figure 3.10, Figure 3.11). The data used for habitat modelling is unable to directly map the extent and connectivity of individual fractures and cavities within the rock; however, contiguous strands of potentially suitable rock within a consistent weathering profile (or zone) provide a reasonable estimation of the potential for interconnected fractures and cavities to occur.

Extensive and thick troglifauna habitats have been modelled on either side of the anticline at the location of the proposed pits (Figure 3.9). Here, the BIF-rich units of the Dales Gorge Member (D4, D2, and D1) provide extensive suitable habitats for troglifauna within and underneath the pit shell. These habitats extend beyond the area of the proposed pits in an east-west direction (Figure 3.10, Figure 3.11) and continue towards the north and south of the Study Area (Figure 3.9). Further medium suitability AWT habitats occur within the BIF-rich units of the Joffre Member (J2, J4 and J6) located further away from the centre of the anticline (Figure 3.9).

Because the shaly and BIF-rich units of the Dales Gorge and Joffre Members alternate sequentially along the anticline (weathered and fractured units suitable for troglifauna are sandwiched between non-porous units unsuitable for troglifauna), there is a corresponding

alternating sequence of medium and low suitability AWT habitat within the flanks of the anticline (Figure 3.9). Consequently, habitat connectivity through the flanks of the anticline towards the north and south of the proposed pits may be lower compared to the well-connected habitats trending in an east-to-west direction underneath and beyond the proposed pits. Nevertheless, analysis of OTV data confirmed some weathering and fracturing within the shaly units of the Dales Gorge and Joffre Members, providing some habitat connectivity through these otherwise low suitability habitat units in a north-south direction (Figure 3.9, Appendix C).

At the centre of the anticline in the area between the two pits, the Dales Gorge Member of the Brockman Iron Formation has been partially eroded, and only the D2 and D1 units remain (Figure 3.9). Both units provide a comparatively thin (up to 30 m) layer of medium suitability habitat in that area and, together with superficial AWT habitats within the detritals, support habitat connectivity across the two pits. The occurrence of multiple taxa with otherwise small distributions across the pit further supports the existence of habitat connectivity between the northern and southern pit (Bennelongia, 2018, 2024).

At the centre of the anticline, the Mount McRae Shale unit is exposed to the surface (Figure 3.9). This unit is typically considered low permeability and does not represent suitable troglofauna habitat, though localised weathering and fracturing have also provided some smaller pockets of medium suitability habitat within this unit on a localised scale.

Superficial deposits of scree and tertiary detritals provide further medium to highly suitable troglofauna habitats near the surface. However, these deposits are relatively thin and patchy within the Study Area and do not represent a major habitat resource for troglofauna (Figure 3.9).

3D modelling shows continuity of medium suitability habitats across the Keystone fault, suggesting that this structure does not impact habitat connectivity in a significant way (Figure 3.8). This is further supported by the occurrence of multiple taxa across the fault (Bennelongia, 2018, 2024).

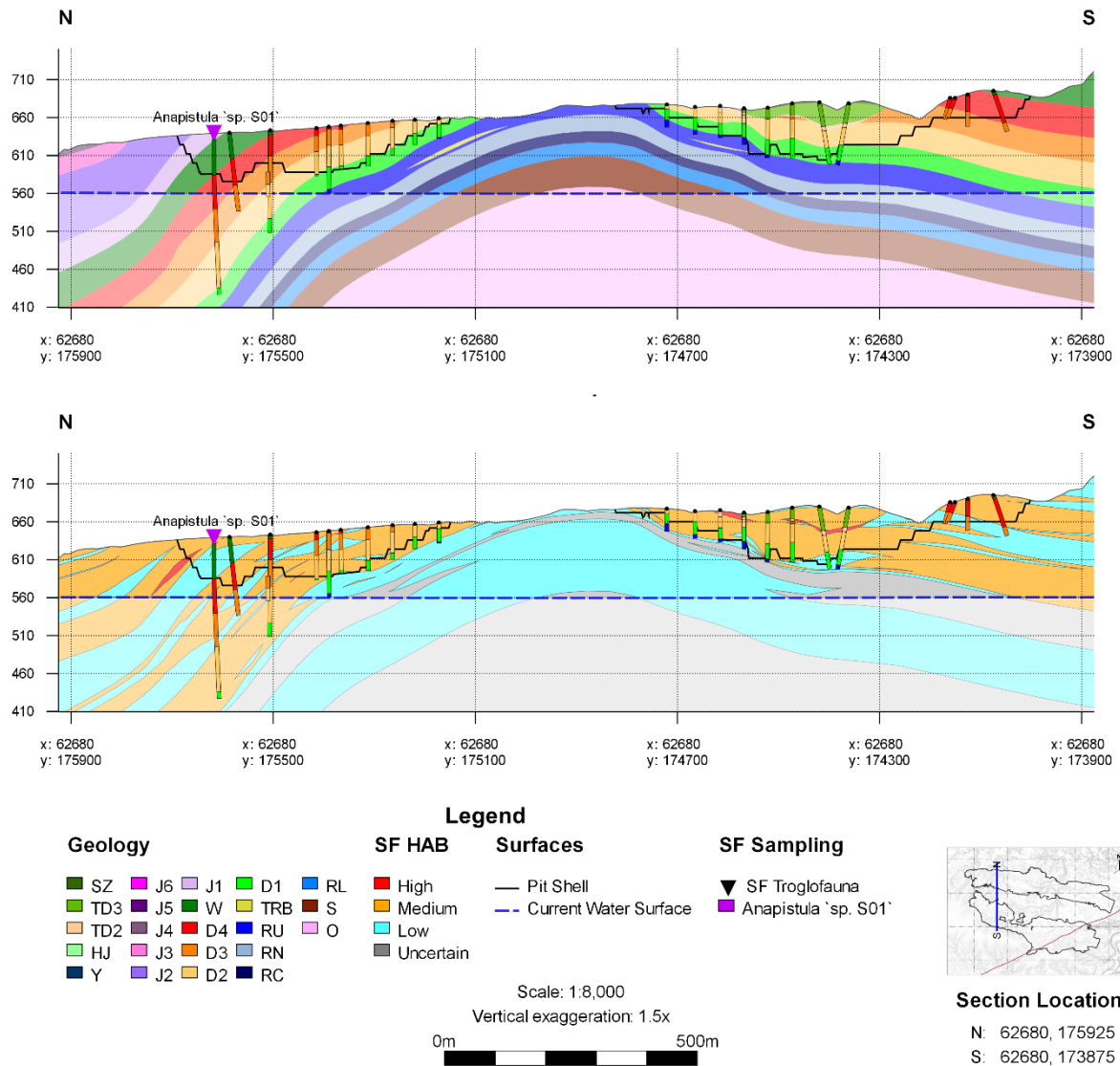


Figure 3.9: Cross-section (N-S) through the stratigraphy and suitable subterranean habitats within the Study Area, based on 3D modelling

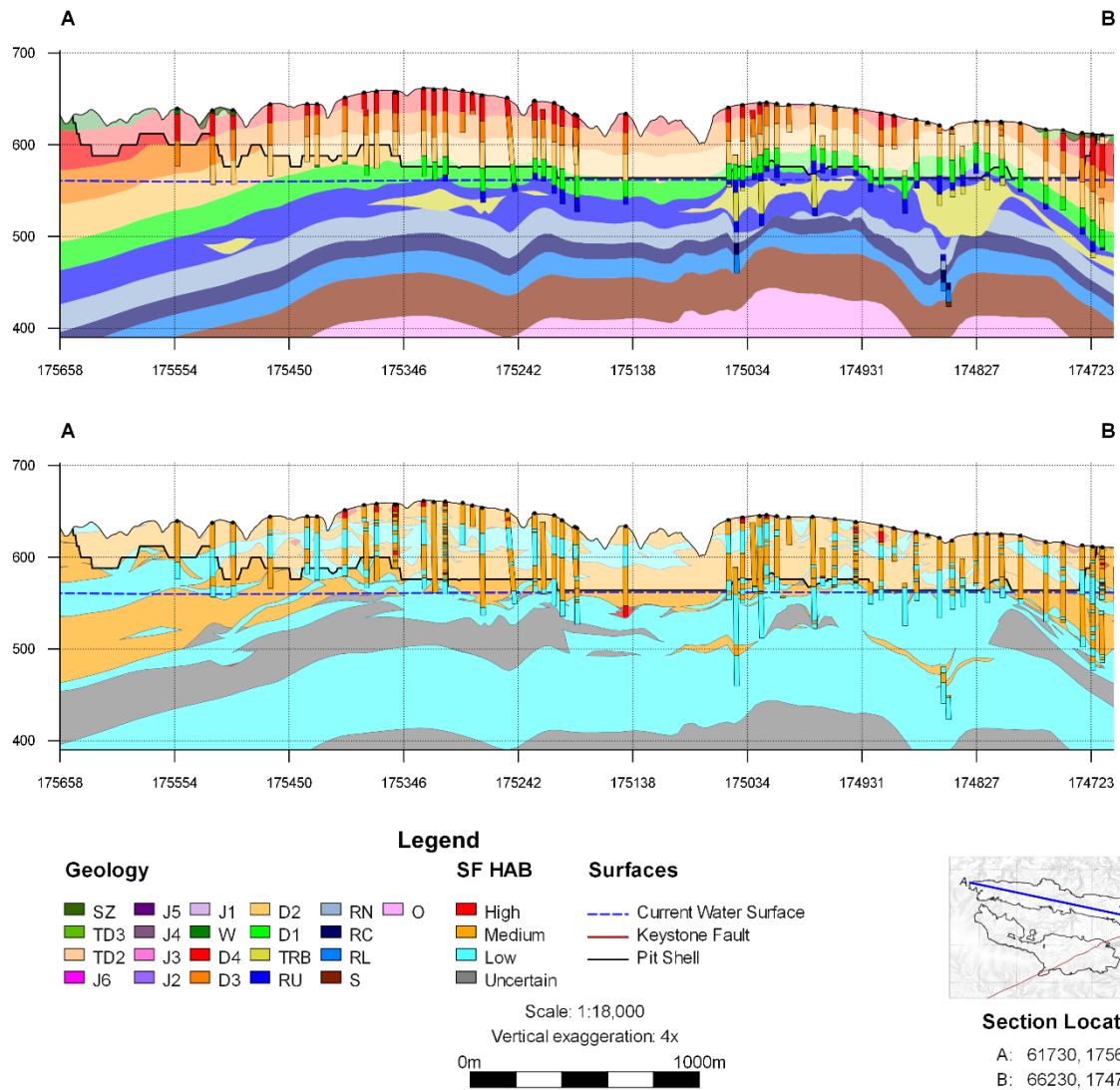


Figure 3.10: Longitudinal-section (W-E) through the stratigraphy and suitable subterranean habitats within the northern pit, based on 3D modelling

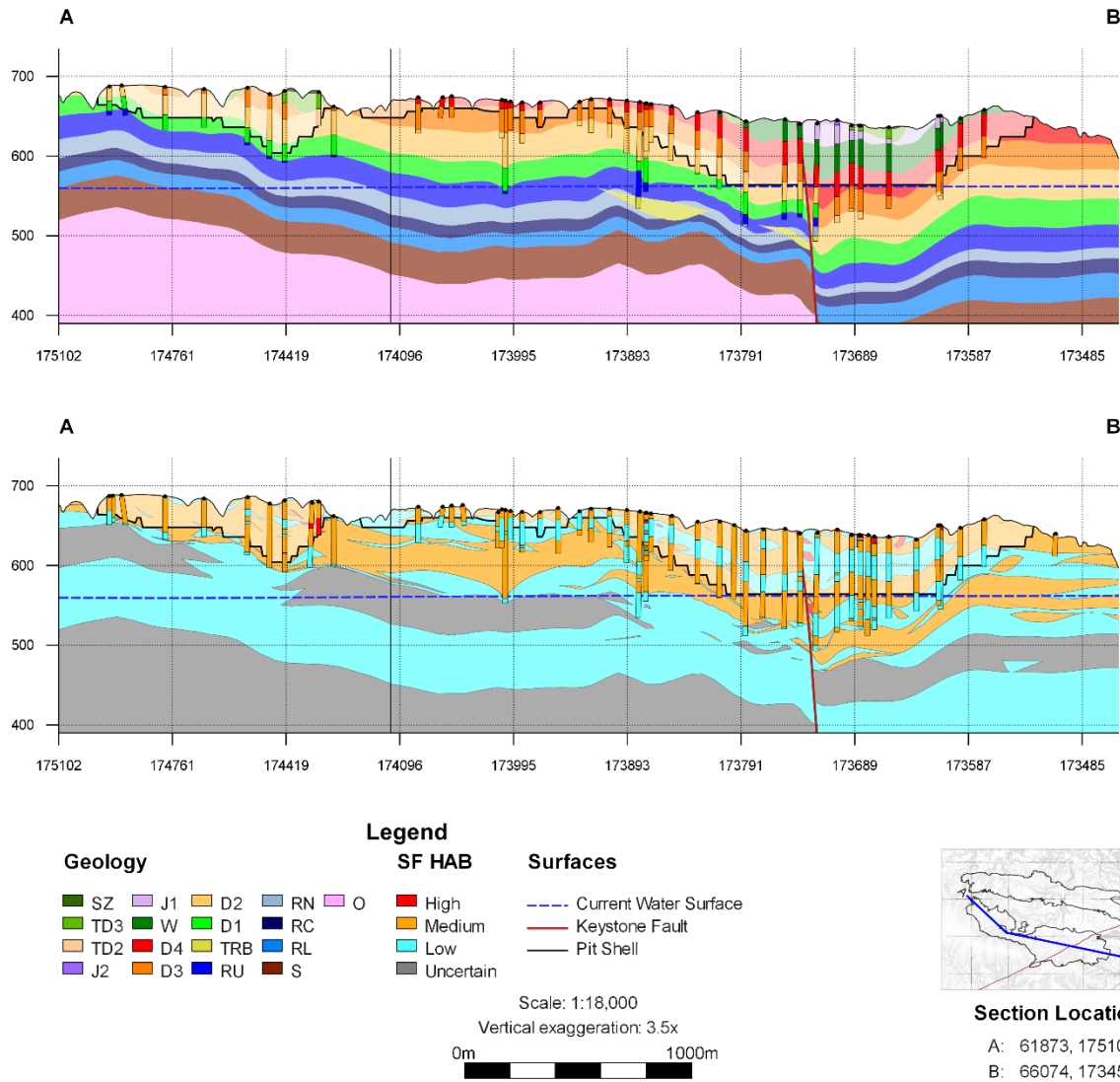
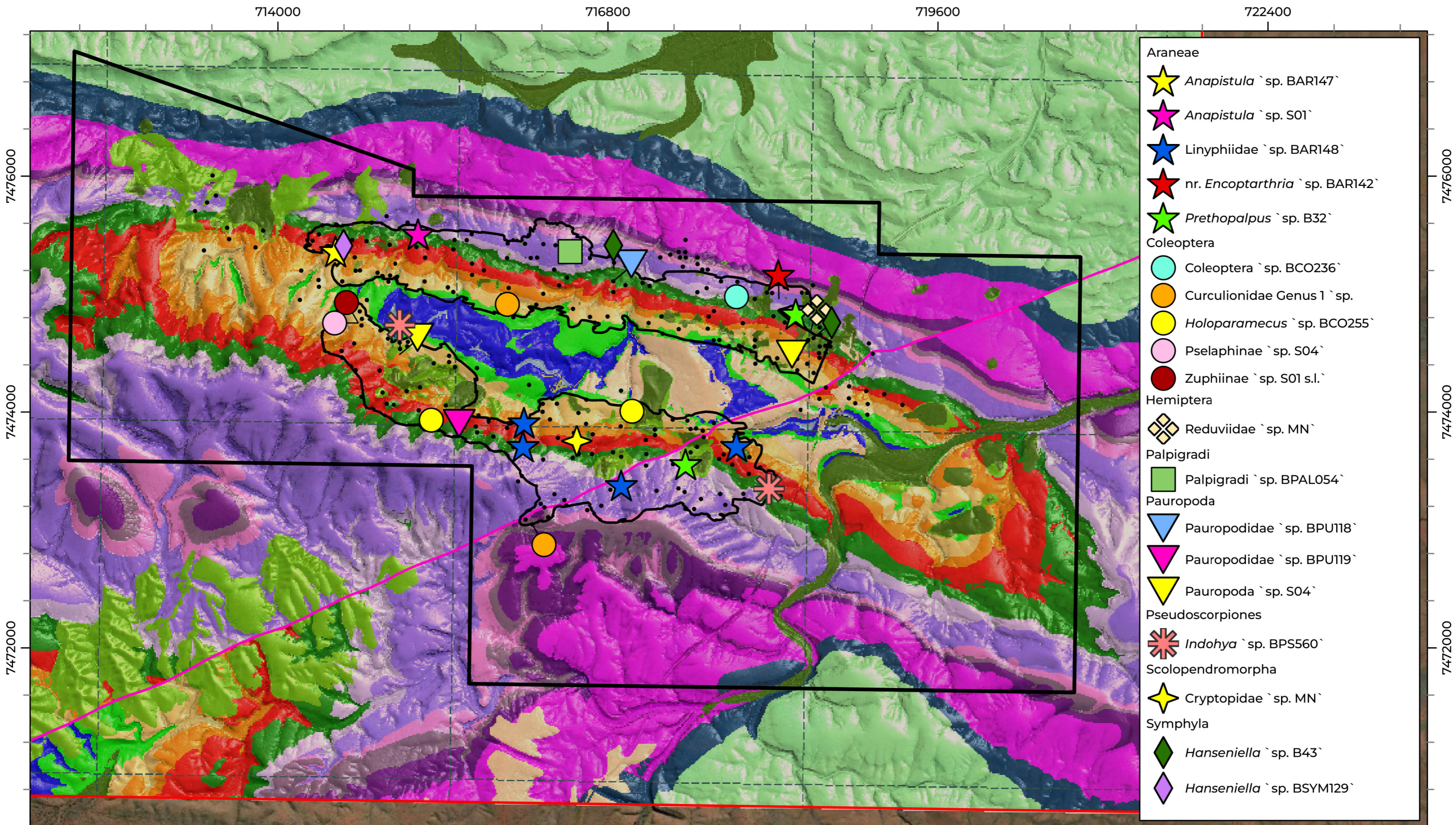


Figure 3.11: Longitudinal-section (W-E) through the stratigraphy and suitable subterranean habitats within the southern pit, based on 3D modelling

4 Impact assessment

Nineteen troglofauna taxa currently only known from the proposed pits were the focus of the impact assessment (Figure 4.1, Figure 4.2, Table 2.2). The 19 taxa belong to eight higher order groups comprising spiders (Araneae), palpigrades, pseudoscorpions, beetles (Coleoptera), true bugs (Hemiptera), pauropods, chilopods and symphylans (Table 2.2). None of the troglofauna taxa, nor troglofauna communities occurring within the Study Area, are listed or recognised as conservation priorities under state or federal legislation.

A detailed 3D assessment of the potential impacts to suitable habitats for each of the 19 target troglofauna taxa is outlined below.



LEGEND

- Study Area
- Tenement M 266SA
- Proposed Pit
- Keystone Fault
- Troglofauna Sampling Site (Bennelongia, 2024)

Biologic

Scale 1:30,000

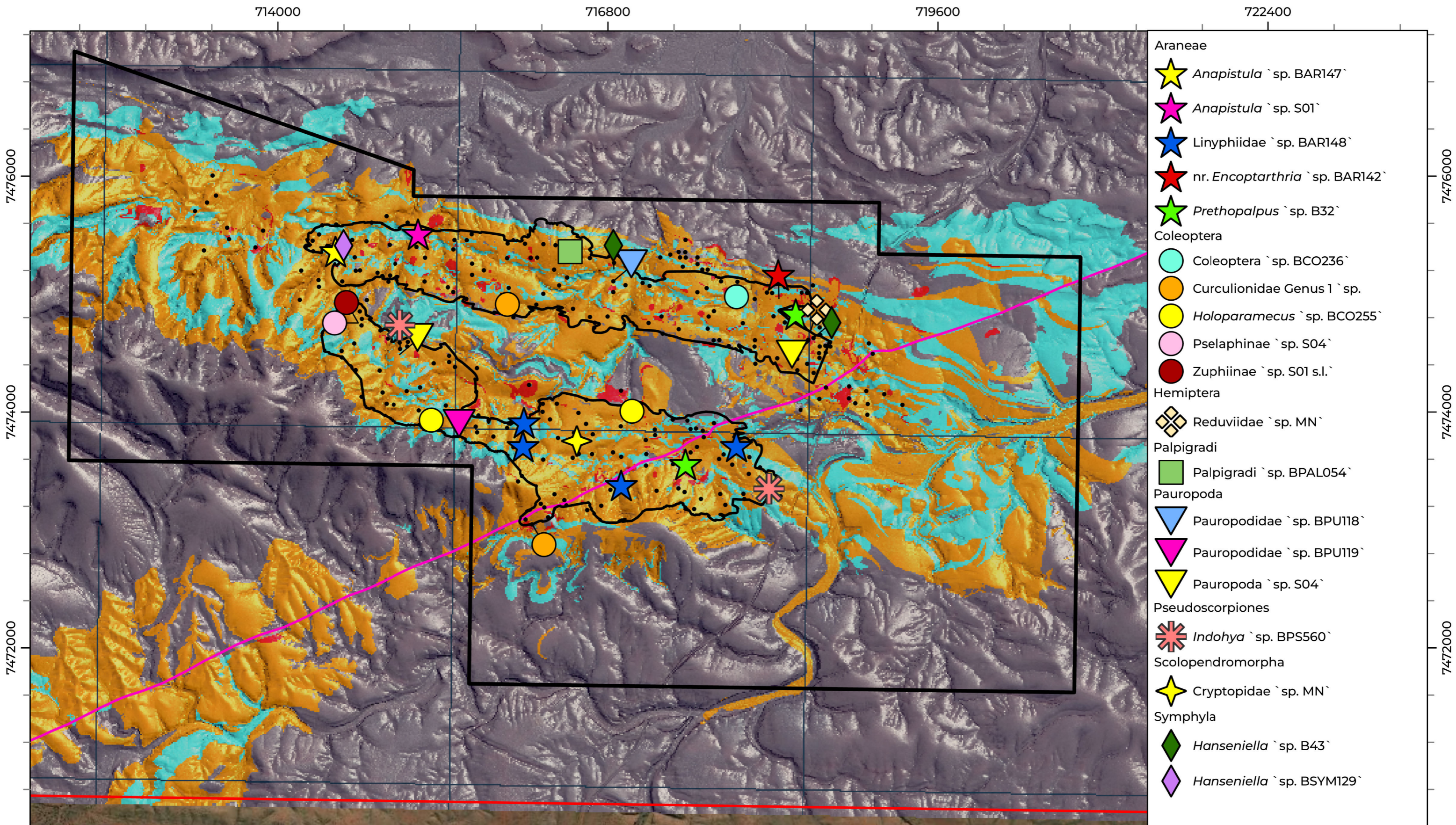
0 0.4 0.8 1.2 Km

Coordinate System: GDA 1994 MGA Zone 50 Transverse Mercator Created: 27/06/2025



BHP WAI0
Ministers North
Subterranean Fauna
Habitat Assessment

Figure 4.1: Target taxa and modelled stratigraphic units



LEGEND

- Study Area
- Tenement M 266SA
- Proposed Pit
- Keystone Fault
- Troglifauna Sampling Site (Bennelongia, 2024)

Biologic

Scale 1:30,000

Coordinate System: GDA 1994 MGA Zone 50
Transverse Mercator Created: 27/06/2025



BHP WAIO
Ministers North
Subterranean Fauna
Habitat Assessment

Figure 4.2: Target taxa and modelled suitable AWT habitat

4.1 Araneae

4.1.1 *Anapistula* `sp. BAR147`

The spider *Anapistula* `sp. BAR147` was collected from a single site within the proposed northern pit (Figure 4.1, Figure 4.2). The genus *Anapistula* belongs to a family of dwarf spiders (Symphytognathidae) which are relatively infrequently collected during subterranean fauna surveys. There are currently no *Anapistula* OTU sequences available in Biologic's DNA sequence database for distribution comparisons at the time of writing. However, most troglobitic *Anapistula* OTUs recorded in the Pilbara are singleton records or have limited known linear ranges of only up to several kilometres (WAM, 2025).

3D modelling showed that the drill hole where this species was detected intercepted the following stratigraphic units (Figure 4.3):

- D3 – Brockman Iron Formation, Dales Gorge Member – Shaly
- D2 - Brockman Iron Formation, Dales Gorge Member – BIF-rich

Both the D2 and the D3 units showed sufficient fracturing/weathering to provide thick and well-connected medium suitability habitats near the location of the species record (Figure 4.3). Whilst both units also contained some localised zones of lower suitability habitat (less weathered rock), these medium suitability habitats are predicted to extend widely below the pit boundary along section to the east and west (Figure 4.3).

This species was recorded near the edge (within 40 m) of the proposed northern pit where mining will be relatively shallow (Figure 4.1, Figure 4.2). The 3D model shows that proposed mining will only remove a thin layer of medium suitability habitat (D2 unit) at the location of the species record, with thick and well-connected medium suitability habitats remaining intact underneath and extending beyond the pit shell post mining (Figure 4.3).

The impacts of the Proposal to *Anapistula* `sp. BAR147` have been classified as low, because:

- The species has been collected from the edge of the pit, and thick and well-connected AWT habitat will remain intact underneath the known record location following mining;
- Further suitable AWT habitats within the D2 and D3 units have been shown to extend beyond the proposed pit; and
- 3D modelling showed no potential dispersal barriers between impacted and non-impacted habitats.

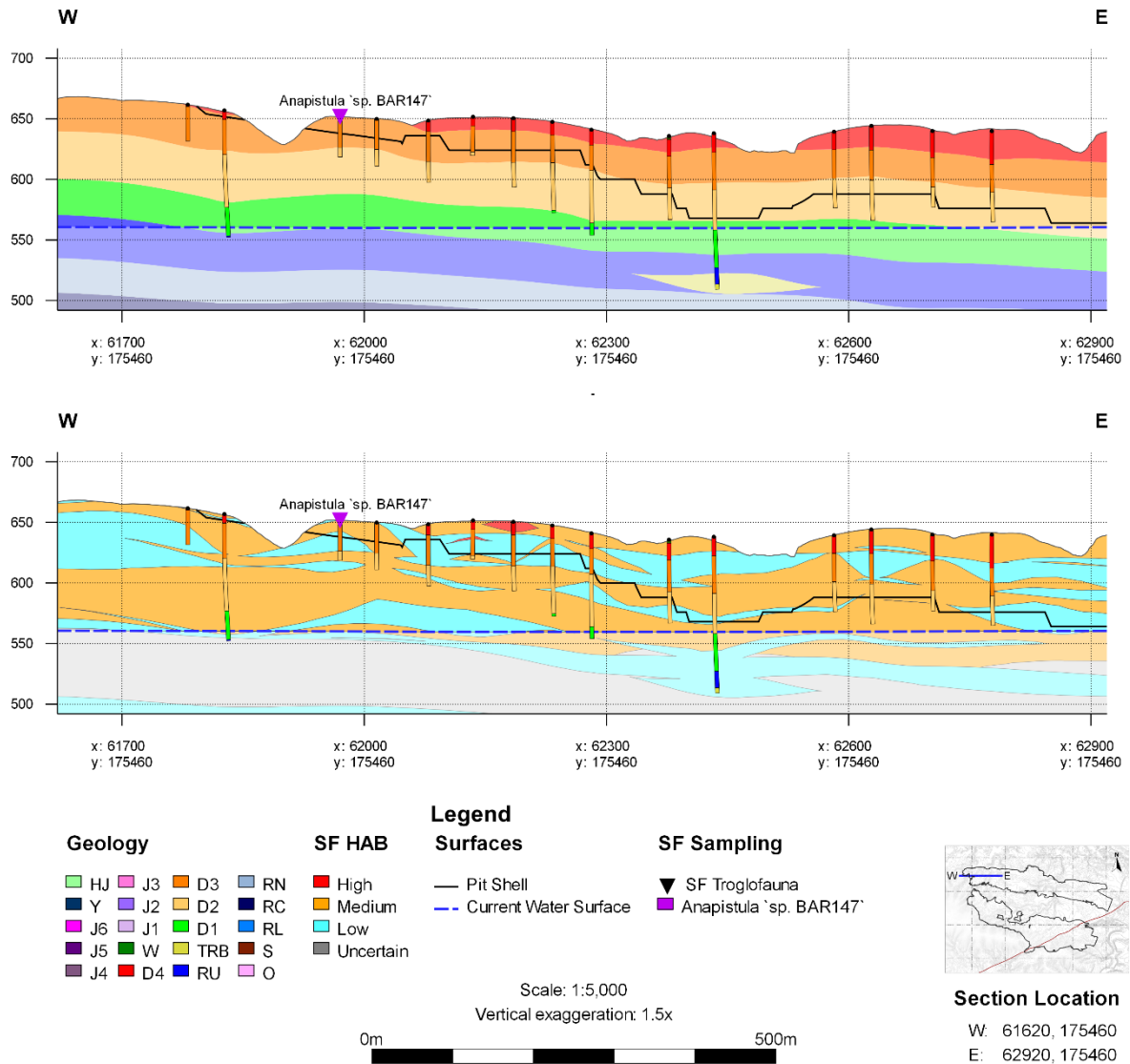


Figure 4.3: Cross-section showing potential AWT habitats for *Anapistula* sp. BAR147 at Ministers North

4.1.2 *Anapistula* `sp. S01`

Anapistula `sp. S01` was recorded from a single site within the proposed northern pit by Subterranean Ecology (2010) (Figure 4.1, Figure 4.2). Data limitations (refer section 2.3) have prevented direct comparisons of *Anapistula* `sp. S01` and *Anapistula* `sp. BARI47` via genetics or morphology, therefore they are treated as separate species herein, following a precautionary approach.

3D modelling showed that the drill hole where this species was detected intercepted the following stratigraphic units above the water table (Figure 4.4):

- J1 – Brockman Iron Formation, Joffre Member – Shaly
- W – Brockman Iron Formation, Whaleback Shale
- D4 - Brockman Iron Formation, Dales Gorge Member – BIF-rich

Of these units, the D4 and J1 represent the most likely habitat for troglofauna near the species location, though some medium suitability habitats are also predicted to occur in the upper parts of the W unit due to localised variability in weathering (Figure 4.4).

This species was recorded near the edge (within 70 m) of the proposed northern pit (Figure 4.1, Figure 4.2). 3D habitat modelling predicts that suitable and relatively thick (approximately 15 to 25 m thickness) habitat within the D4 unit will remain below the proposed pit shell, extending widely underneath the pit in an east-west direction (Figure 4.4). Further extensive medium and high suitability habitats are also predicted to occur immediately north of the species record beyond the pit within the J1 and J2 units (Figure 4.4).

The impacts of the Proposal to *Anapistula* `sp. S01` have been classified as low, because:

- The species has been collected from the edge of the pit, and thick and well-connected AWT habitat will remain intact underneath the known record location following mining which extends widely underneath the pit shell in an east-west direction;
- Further suitable AWT habitats within the J1 and J2 units have been shown to occur beyond the proposed pit; and
- 3D modelling showed no potential dispersal barriers between impacted and non-impacted habitats.

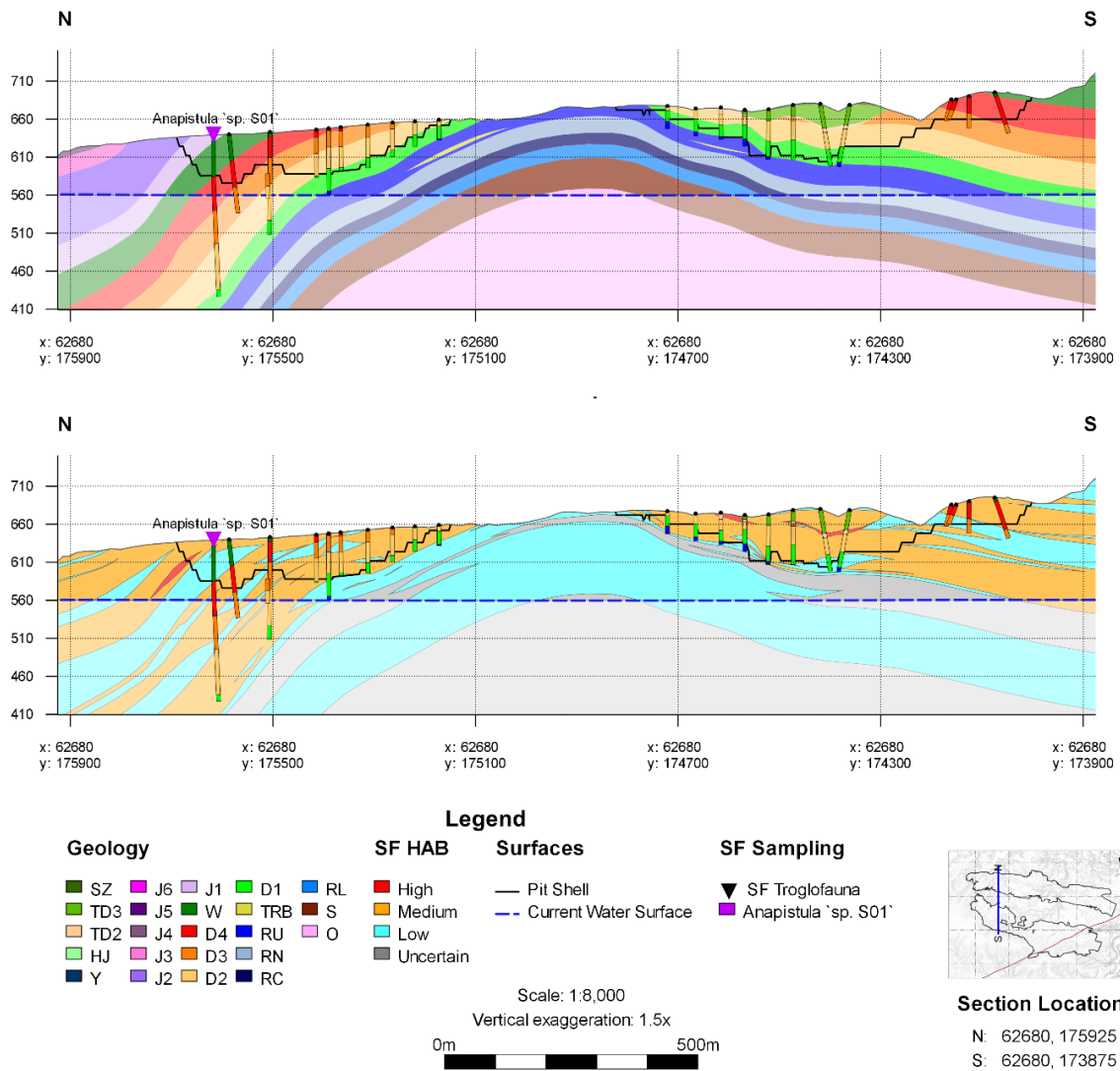


Figure 4.4: Cross-section showing potential AWT habitats for *Anapistula`sp. S01`* at Ministers North

4.1.3 Linyphiidae `sp. BAR148`

A single species of spider belonging to the Linyphiidae family was collected from four sites in the southern pit (Figure 4.1, Figure 4.2) and has a current known linear range of 2 km (Table 2.2).

Troglofaunal Linyphiidae are relatively rare, and only three Linyphiidae OTU sequences are available in Biologic's DNA sequence database for distribution comparisons at the time of writing. Of these, one is a singleton record whereas the other two have current known linear ranges of 400 m and 700 m, respectively.

3D modelling showed that the drill holes where this species was detected intercepted the following stratigraphic units (Figure 4.5):

- J2 – Brockman Iron Formation, Joffre Member – BIF-rich
- J1 – Brockman Iron Formation, Joffre Member – Shaly
- W – Brockman Iron Formation, Whaleback Shale
- D4 - Brockman Iron Formation, Dales Gorge Member – BIF-rich
- D3 – Brockman Iron Formation, Dales Gorge Member - Shaly
- D2 - Brockman Iron Formation, Dales Gorge Member – BIF-rich
- D1 – Brockman Iron Formation, Dales Gorge Member

The D2, D4, D1, and J2 units collectively provide thick bands of medium suitability AWT habitat near the species locations due to the prevalence of void spaces within these units (Figure 4.5). Further medium suitability habitats are also predicted to occur in the upper parts of the J1, D3, and W units on a localised scale due to localised variability in weathering (Figure 4.5).

Three of the species records were recorded near the edge (within 20 to 70 m) of the proposed southern pit (Figure 4.1, Figure 4.2), where mining will be relatively shallow. The 3D model shows that suitable AWT habitats (within D1 and D2) will remain below the proposed pit shell at these locations. The 3D modelling also shows direct connectivity of suitable habitats between impacted and non-impacted areas for these three records, with suitable habitats extending widely beyond the area of the proposed pit (Figure 4.5).

This species has been recorded in several sites on both sides of the Keystone fault (current linear range approx. 2 km) and occurs throughout a well-connected network of suitable habitat that extends beyond the impact area. Given the lack of habitat barriers and the concentration of sampling sites mainly within the proposed pits, it is considered likely that this species should occur more widely beyond the pit.

The impacts of the Proposal to Linyphiidae `sp. BAR148` have been classified as low, because:

- Three of the species records have been collected from the edge of the pit, and thick and well-connected suitable AWT habitat will remain intact underneath these locations following mining;
- Further suitable AWT habitats have been shown to extend beyond the proposed pit in all specimen locations;
- 3D modelling showed no potential dispersal barriers between impacted and non-impacted habitats; and
- The species occurs throughout a well-connected network of suitable habitat that extends beyond the impact area, and the lack of records beyond the proposed pit is likely to be affected by sampling artefacts.

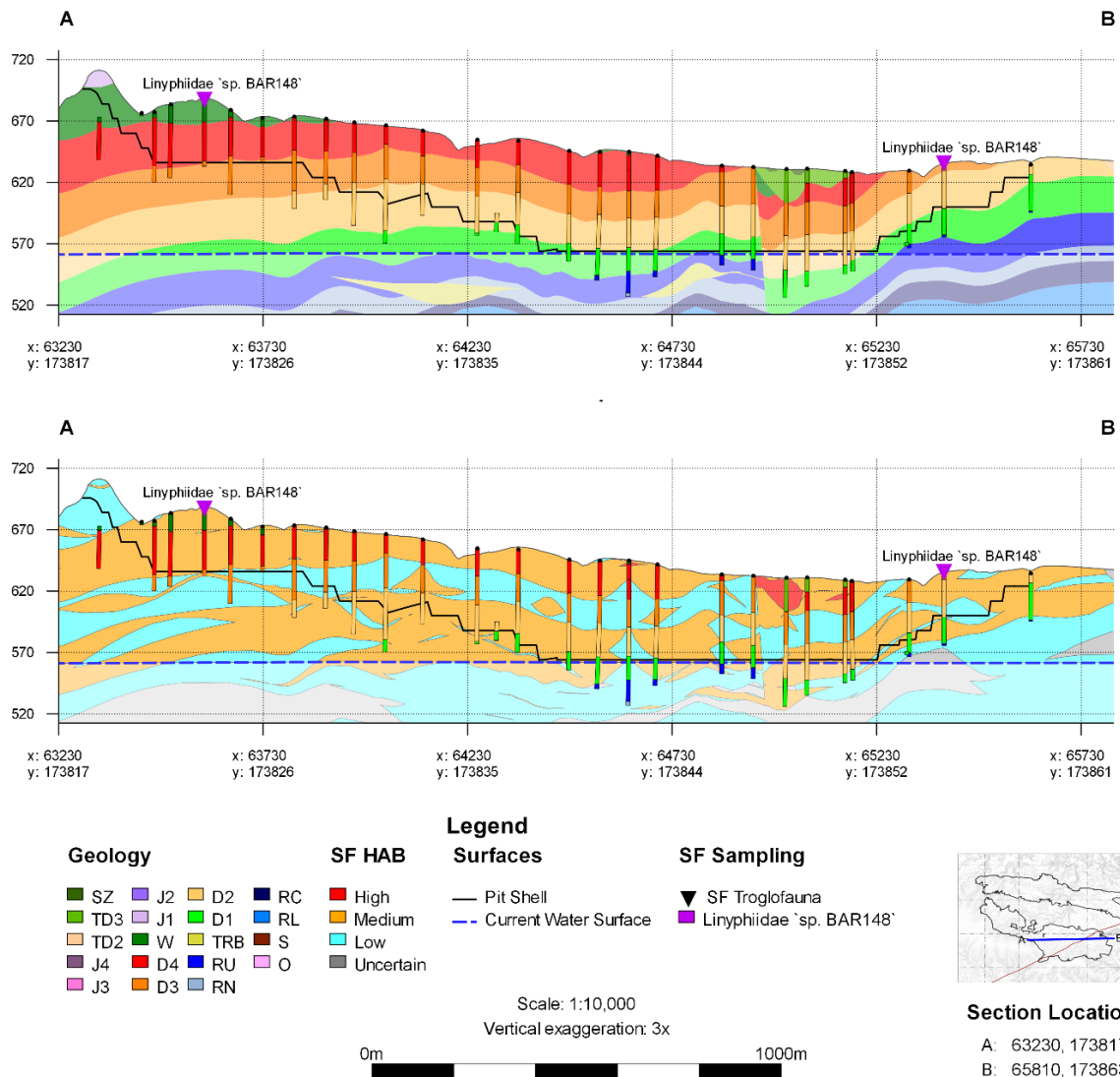


Figure 4.5: Cross-section showing potential AWT habitats for Linyphiidae `sp. BAR148` at Ministers North

4.1.4 nr. *Encoptarthria* `sp. BAR142`

The gnaphosid spider nr. *Encoptarthria* `sp. BAR142` was collected from a single site within the proposed northern pit (Figure 4.1, Figure 4.2). At the time of writing, Biologic's DNA sequence database contained 15 Gnaphosidae OTUs. Of these, more than half (9 OTUs) are known only as singleton records. Of those with linear ranges, the average linear range was approximately 17 km (min 5 km – max 34 km).

3D modelling showed that the drill hole where this species was detected intercepted the following stratigraphic units (Figure 4.6):

- J2 – Brockman Iron Formation, Joffre Member – BIF-rich
- J1 – Brockman Iron Formation, Joffre Member – Shaly

Both units showed sufficient fracturing/weathering to provide thick and well-connected medium suitability habitats near the location of the species record, and extending more widely to the east and west (Figure 4.6).

3D modelling shows that a small patch of habitat will remain near the record location underneath the pit shell following proposed mining, within the J1/J2 units (Figure 4.6). That patch of habitat is approximately 10 m thick near the species location but extends considerably to the east beyond the area of the proposed pit, where it becomes approximately 50 m thick. The modelling showed no habitat barriers between these impacted and non-impacted habitats (Figure 4.6).

The impacts of the Proposal to nr. *Encoptarthria* `sp. BAR142` have been classified as medium, because:

- Only a thin patch of suitable AWT habitat will remain intact underneath the pit in the vicinity of the known record location of the species;
- However, the suitable habitat the species was recorded from extends widely to the east beyond the pit and where it becomes thick; and
- 3D modelling showed no potential habitat barriers between impacted and non-impacted habitats.

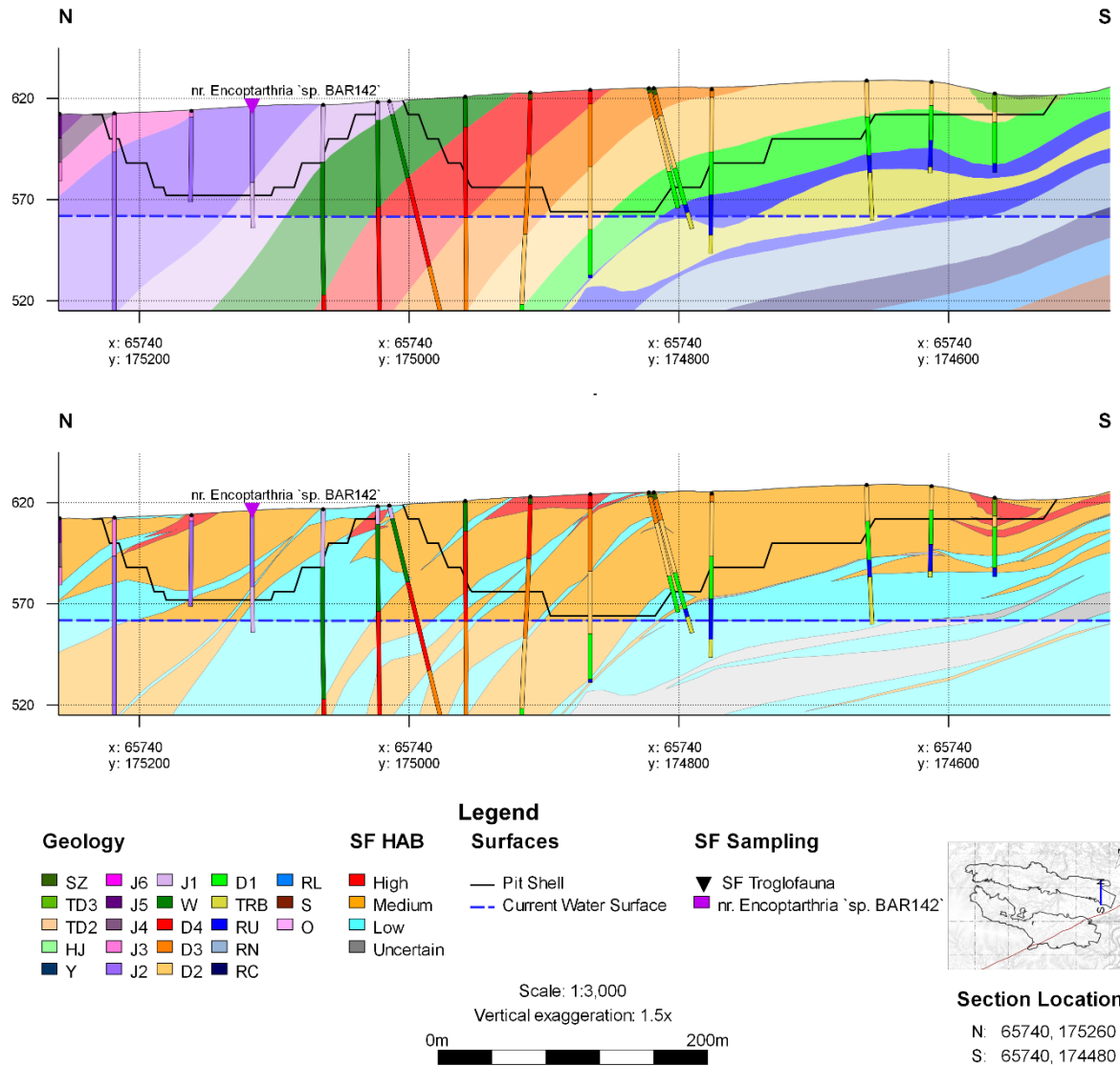


Figure 4.6: Cross-section showing potential AWT habitats for *nr. Encoptarthria* 'sp. BAR142' at Ministers North

4.1.5 *Prethopalpus* `sp. B32`

The goblin spider *Prethopalpus* `sp. B32` was collected from two sites by Subterranean Ecology (2010), one situated in the northern pit and the other within the southern pit, and has a current known linear range of 1.5 km (Figure 4.1, Figure 4.2, Table 2.2). Data limitations (refer section 2.3.2) have prevented direct comparisons of *Prethopalpus* `sp. B32` with other *Prethopalpus* species located within the Study Area (i.e. *Prethopalpus* 'BAR145' and *Prethopalpus* 'BAR146') via genetics or morphology. Therefore, they are treated as separate species herein, following a precautionary approach.

At the time of writing, Biologic's DNA sequence database contained 19 *Prethopalpus* OTUs. Approximately half of the OTUs were singleton records (12 taxa). Of those with linear ranges, the average linear range was approximately 10 km (min 1.4 km – max 22 km).

3D modelling showed that the two drill holes where this species was detected intercepted the following stratigraphic units above the water table (Figure 4.7):

- TD3 - Tertiary Detritals 3 (includes former AZ, BZ, CZ, FZ, GZ, HMZ, LLZ, LZ)
- J1 – Brockman Iron Formation, Joffre Member – Shaly
- W – Brockman Iron Formation, Whaleback Shale
- D4 - Brockman Iron Formation, Dales Gorge Member – BIF-rich
- D3 – Brockman Iron Formation, Dales Gorge Member - Shaly

The superficial tertiary detritals and the D4 unit occurring below collectively provide a thick layer of medium suitability AWT habitat near the species locations due to the prevalence of void spaces within these units (Figure 4.7). 3D modelling showed that these troglofauna habitats are supported by further nearby medium suitability AWT habitats within the upper parts of the W, J1, and D3 units (Figure 4.7).

One of the species records was recorded at the edge (within 6 m) of the proposed northern pit (Figure 4.1, Figure 4.2), where mining will be shallow (5 m from surface, Figure 4.7). The 3D model shows that only the tertiary detritals will be affected by mining at this location, with the majority of the AWT habitat below remaining completely intact (within D4) (Figure 4.7). The specimen recorded in the southern pit was recorded near the centre of the proposed pit area (Figure 4.1, Figure 4.2). 3D modelling predicts that there will only be a thin layer of AWT habitat remaining (D4) at this location following implementation of proposed mining (approximately 2 m, Figure 4.7). Nevertheless, there is high confidence in the modelling that this unit extends widely beyond the pit shell to the south (Figure 4.7).

The occurrence of the species across both pits suggests habitat connectivity and potential for species dispersal between the northern and southern pit, which is supported by 3D modelling (Figure 4.2). Although the habitat is interlayered and complex throughout the area between the two species records (Figures 4.2, 4.7), overall there are thick bands of medium suitability habitat (weathered and fractured rocks of the Brockman Iron Formation) between both pits, and extending out to the east of the Keystone fault (Figure 4.2). Considering that this species has been recorded in both pits (over approx. 1.5 km) and the Keystone fault does not provide a habitat barrier, it is considered likely that it could occur in non-impacted habitat to the east of both pits.

The impacts of the Proposal to *Prethopalpus* sp. B32 have been classified as low, because:

- One of the species records was collected from the edge of the pit where proposed mining will be shallow (~5 m), and suitable AWT habitat will remain intact at this location and extending widely beyond;
- Further suitable AWT habitats have been shown to occur in the immediate local area beyond the pit in both specimen locations;
- 3D modelling showed no potential dispersal barriers between impacted and non-impacted habitats; and
- The species occurs throughout a well-connected network of suitable habitat that extends beyond the impact area to the east, and the lack of records outside the proposed pits is likely to be affected by sampling artefacts.

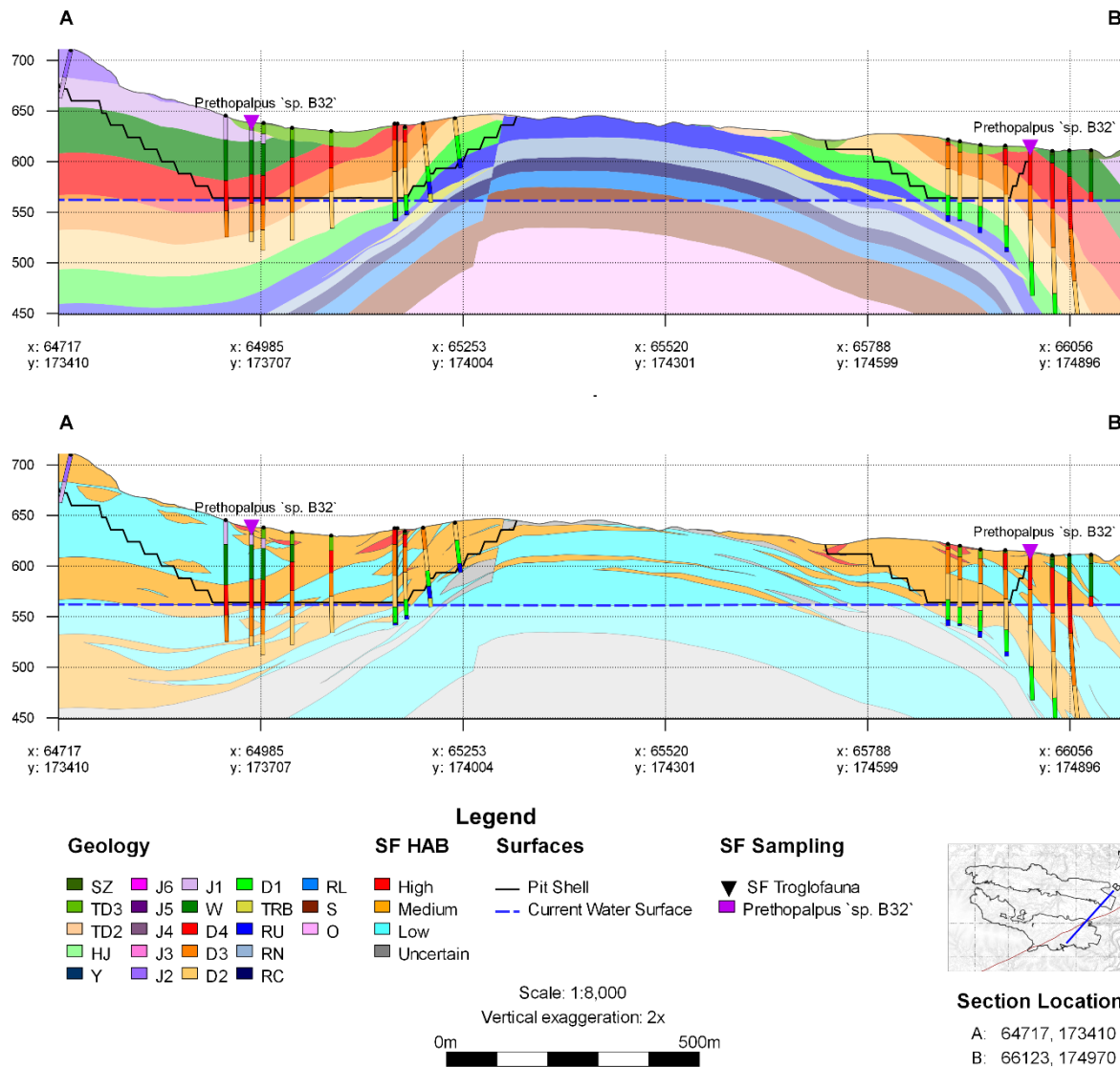


Figure 4.7: Cross-section showing potential AWT habitats for *Prethopalpus* 'sp. B32' at Ministers North

4.2 Palpigradi

4.2.1 Palpigradi `sp. BPAL054`

The palpigrade Palpigradi `sp. BPAL054` was collected from a single site within the proposed northern pit (Figure 4.1, Figure 4.2). Genetic analysis against available sequence libraries from Biologic's DNA sequence database failed to detect a wider regional match (Appendix A), therefore this OTU is currently known only from its collection record within the Study Area. Palpigrades are frequently collected during subterranean fauna surveys and are typically characterised by high species turnover over small distances. Accordingly, out of 99 palpigrade OTUs in Biologic's DNA sequence database, the vast majority (68 OTUs) are singleton records. Of those with linear ranges, the average linear range is approximately 6.5 km (min 0.2 km – max 30 km).

3D modelling showed that the drill holes where this species was detected intercepted the following stratigraphic units above the water table (Figure 4.8):

- J2 – Brockman Iron Formation, Joffre Member – BIF-rich
- J1 – Brockman Iron Formation, Joffre Member – Shaly

Both the J2 unit and the upper parts of the J1 unit showed sufficient fracturing/weathering to provide thick and well-connected medium suitability habitats near the location of the species record (Figure 4.8).

This species was recorded at the edge of the proposed northern pit where mining will be relatively shallow (Figure 4.1, Figure 4.2). The 3D model shows that suitable AWT habitat within J2 and J1 units will remain below the proposed pit shell at the species location and extending widely beyond the proposed impacts underneath (east-west direction) and to the north of the pit shell (Figure 4.8).

The impacts of the Proposal to Palpigradi `sp. BPAL054` have been classified as low, because:

- The species has been collected from the edge of the pit, and thick and well-connected suitable AWT habitat will remain intact underneath the known record location following mining;
- Further suitable and thick AWT habitats within the J2 and J1 units extend widely underneath the pit shell in an east-west direction, and beyond the area of the proposed pits; and
- 3D modelling showed no potential dispersal barriers between impacted and non-impacted habitats.

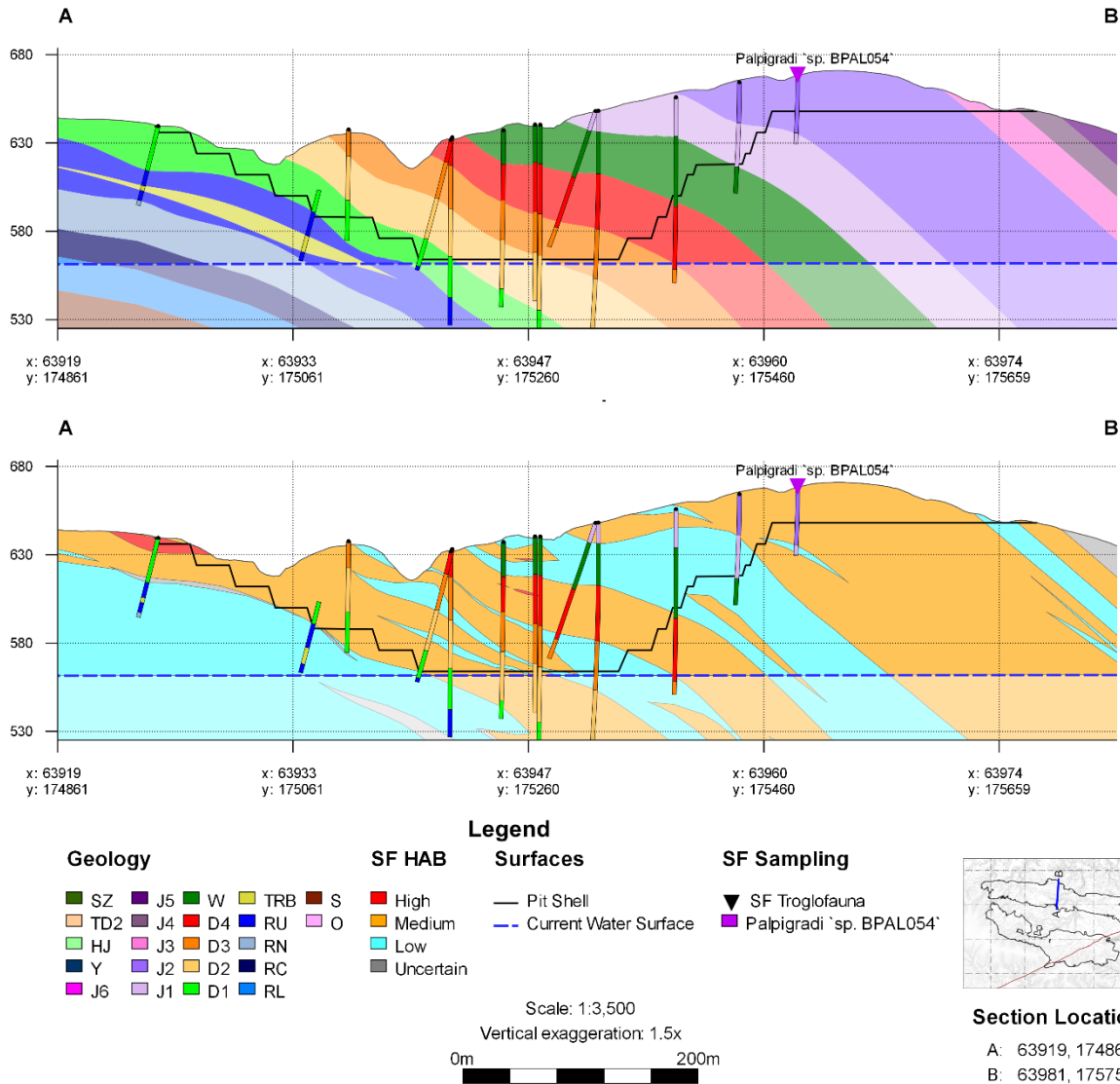


Figure 4.8: Cross-section showing potential AWT habitats for Palpigradi 'sp. BPAL054' at Ministers North

4.3 Pseudoscorpiones

4.3.1 *Indohya* sp. BPS560

The pseudoscorpion *Indohya* sp. BPS560 was collected from two sites within the proposed southern pit and has a current known linear range of 3.3 km (Figure 4.1, Figure 4.2, Table 2.2). Genetic analysis against available sequence libraries from Biologic's DNA sequence database failed to detect a wider regional match (Appendix A), therefore this OTU is currently known only from its two collection records within the Study Area. Owing to the dispersal limitations of the members within this group, troglobitic pseudoscorpions tend to be highly range restricted and are commonly only recorded from single habitats or single sites (Harvey *et al.*, 2023). From a total of 17 *Indohya* OTUs in Biologic's DNA sequence database at the time of writing, the vast majority (13 OTUs) were singletons (Biologic, unpublished data) and the average linear range of the remaining OTUs was approximately 11 km (min 0.3 km – max 43 km).

3D modelling showed that the drill holes where this species was detected intercepted the following stratigraphic units (Figure 4.9):

- D4 - Brockman Iron Formation, Dales Gorge Member– BIF-rich
- D3 – Brockman Iron Formation, Dales Gorge Member - Shaly
- D2 - Brockman Iron Formation, Dales Gorge Member– BIF-rich
- D1 – Brockman Iron Formation, Dales Gorge Member

Habitat modelling showed that the D1, D2, and D4 Dales Gorge Member units have been sufficiently weathered/fractured to collectively form a thick band of medium suitability AWT habitat that runs along the southern pit from east to west, connecting the two species records and extending beyond the pit on both sides (Figure 4.9).

Both species records were recorded near the edge (within 20 to 80 m) of the proposed southern pit (Figure 4.1, Figure 4.2). The 3D model shows that at the eastern end of the southern pit, the D4 unit mostly occurs below the proposed pit shell and will not be subject to mining (Figure 4.9). The D4 unit extends well beyond the pit to the east, providing relatively thick, well-connected suitable AWT habitat beyond the impact area (Figure 4.9).

At the western end of the southern pit, suitable habitat within the D2 unit will be removed by the proposed mining (Figure 4.9). However, a relatively thin layer of medium suitability habitat within the D1 unit will remain underneath the current record location (approximately 8 m thick, Figure 4.9). This habitat extends widely underneath the pit shell in an east-west direction, and also extends considerably beyond the pit shell to the south (Figure 4.9).

The impacts of the Proposal to *Indohya`sp. BPS560`* have been classified as low, because:

- Thick and well-connected habitats remain intact underneath at least one known record location(s) following mining.
- Further extensive suitable AWT habitats have been shown to occur in the immediate local area beyond the pit at all record locations;
- 3D modelling showed no potential dispersal barriers between impacted and non-impacted habitats; and
- The species occurs throughout a well-connected network of suitable habitat that extends beyond the impact area to the east, and the lack of records outside the proposed pits is likely to be affected by sampling artefacts.

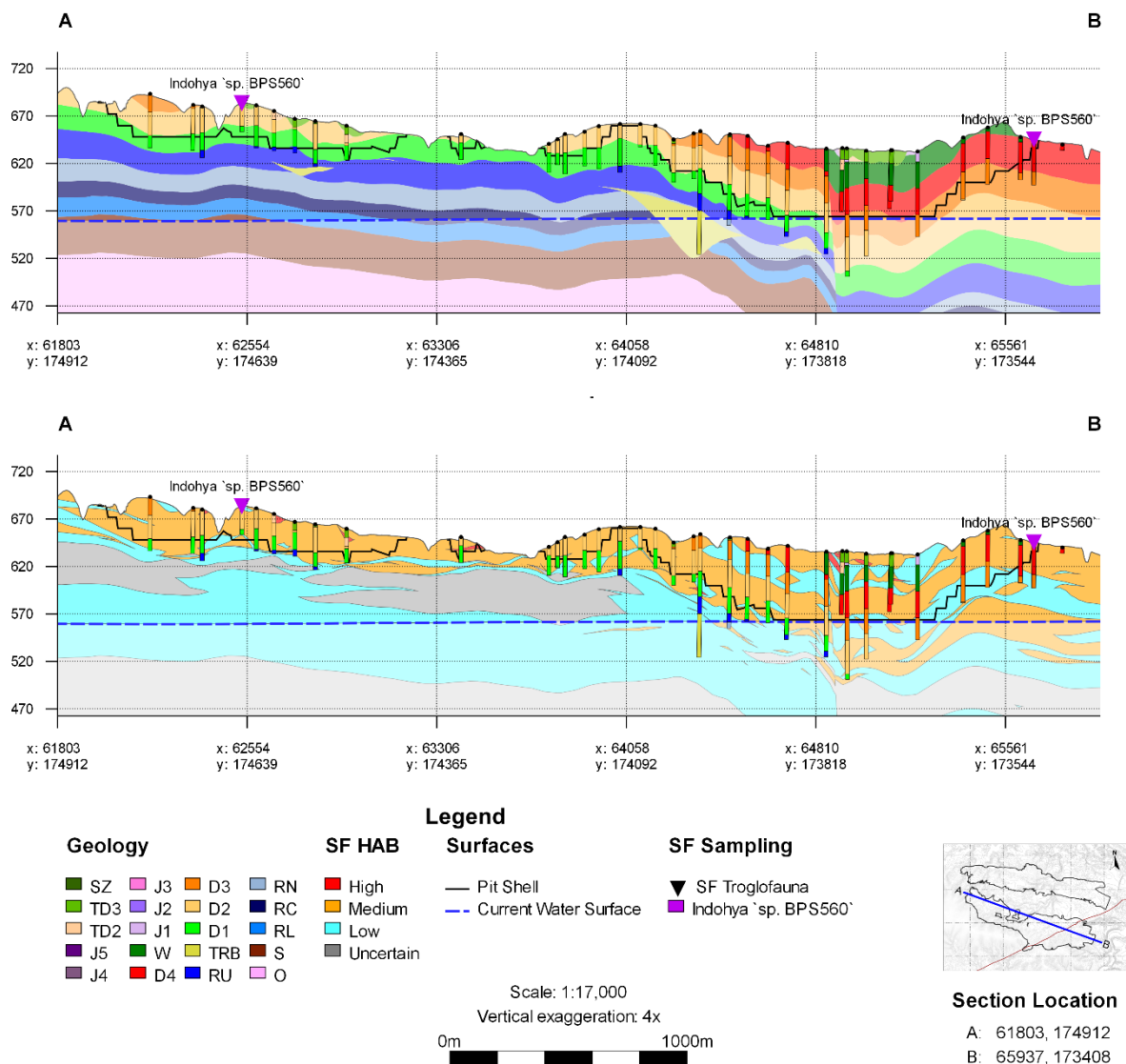


Figure 4.9: Cross-section showing potential AWT habitats for *Indohya`sp. BPS560`* at Ministers North

4.4 Coleoptera

Coleoptera (beetles) is a highly diverse order of insects, encompassing families, genera and species that have a broad range of different ecological characteristics. Troglomorphy within the Coleoptera takes many forms depending on the taxonomic group (e.g. eyelessness, partial eyelessness, elongated sensory hairs, and body shape adaptations) but rarely involves cuticle thinning or depigmentation (Deharveng & Bourdeau, 2010). Consequently, the identification of troglobitic forms from soil fauna/trogloxenic forms can be difficult. Troglofaunal beetles are diverse across many different families, but they tend to be quite vagile, regularly ranging from several kilometres to tens of kilometres across the Pilbara region (Biologic unpublished data). Such ranges may still be within the nominal limits of short range endemic taxa (SRE) (Harvey, 2002) but troglofaunal Coleoptera are not usually as highly restricted as troglofaunal arachnids or crustaceans.

4.4.1 Coleoptera `sp. BCO236`

The beetle Coleoptera `sp. BCO236` was collected from a single site within the proposed northern pit (Figure 4.1, Figure 4.2) during the most recent survey at Ministers North in 2024 (Bennelongia, 2024). The specimen was not sequenced and hence could not be compared to available sequence libraries from Biologic's DNA sequence database to potentially detect a wider regional match or improve taxonomic resolution (i.e. down to family or genus).

As Coleoptera `sp. BCO236` is an order-level morphospecies that lacks genetic sequence data, it is not possible to comment specifically on its likely troglofauna status or ecological status or undertake further work to determine whether it has been detected regionally. As a precaution, we have assessed this taxon as potential troglofauna, but the chance that it could represent soil fauna cannot be excluded.

3D modelling showed that the drill hole where this species was detected intercepted the following stratigraphic units above the water table (Figure 4.10):

- J1 – Brockman Iron Formation, Joffre Member – Shaly
- W – Brockman Iron Formation, Whaleback Shale

Compared to other units present within the Study Area, both units represent less suitable habitat for troglofauna at Ministers North (Table 3.1). Nevertheless, 3D modelling has shown some medium suitability habitat within the J1 unit and, to a lesser degree, the W unit on a localised scale near the species location due to localised variability in weathering (Figure 4.10).

This species was recorded approximately 160 m from the edge of the proposed northern pit (Figure 4.1, Figure 4.2). The 3D model shows that the medium suitability habitat within the J1 unit where the species was recorded will be removed following implementation of the proposed mining (Figure 4.10). However, the J1 unit extends widely underneath the pit shell to the north, potentially providing further suitable AWT habitats beyond the impact area. Further medium suitability habitats occur beyond the pit shell to the north within Joffre Member units J2, J3, and J4 (Figure 4.10). These habitats are directly connected to the impacted habitat within the pit shell where the species was recorded (Figure 4.10).

The impacts of the Proposal to Coleoptera `sp. BCO236` have been classified as medium, because:

- There is residual uncertainty regarding the taxonomy (order level morphospecies, with no genetic sequence available) and corresponding ecological status of this taxon;
- 3D modelling predicts that no suitable habitat will remain directly underneath the known record location following mining. However, a wider context of extensive suitable habitat has been shown to occur beyond the proposed pit;
- 3D modelling showed no potential dispersal barriers between impacted and non-impacted habitats; and
- Troglifaunal beetles tend to range over several kilometres to tens of kilometres in the Pilbara region, and it is unlikely that this taxon would be uniquely restricted to the proposed impact area.

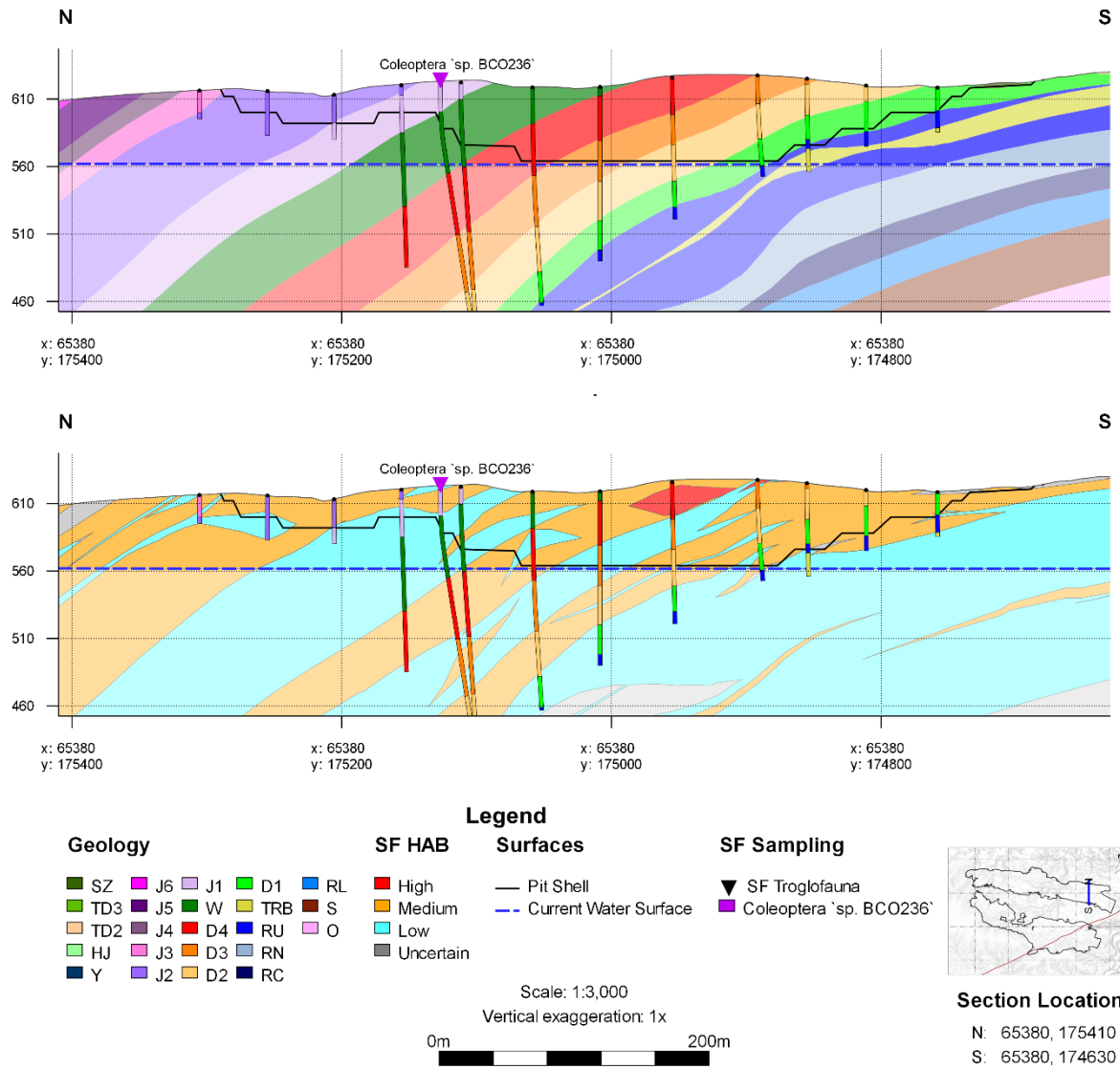


Figure 4.10: Cross-section showing potential AWT habitats for Coleoptera `sp. BCO236` at Ministers North

4.4.2 Curculionidae Genus 1 `sp. BCO228`

The weevil Curculionidae Genus 1 `sp. BCO228` was collected from two sites, one situated in the northern pit and the other within the southern pit, and has a current known linear range of 2 km (Figure 4.1, Figure 4.2, Table 2.2). The species was collected during the most recent survey at Ministers North in 2024 (Bennelongia, 2024). The specimen was not sequenced and hence could not be compared to available sequence libraries from Biologic's DNA sequence database to potentially detect a wider regional match.

At the time of writing, Biologic's DNA sequence database contained 13 Curculionidae OTUs. Five OTUs were singleton records (Biologic, unpublished data). The average linear range of the remaining eight OTUs was approximately 5 km (min 1 km – max 19 km) (Biologic, unpublished data).

3D modelling showed that the drill holes where this species was detected intercepted the following stratigraphic units above the water table (Figure 4.11):

- J4 – Brockman Iron Formation, Joffre Member – BIF-rich
- J3 – Brockman Iron Formation, Joffre Member – Shaly
- J2 – Brockman Iron Formation, Joffre Member – BIF-rich
- D2 - Brockman Iron Formation, Dales Gorge Member – BIF-rich
- D1 – Brockman Iron Formation, Dales Gorge Member
- RU – Mount McRae Shale, Upper Unit

The BIF-rich Joffre Member J4 and J2, and Dales Gorge Member D2 and D1 showed sufficient fracturing/weathering to provide thick and well-connected medium suitability habitats near the location of the species record (Figure 4.11).

One of the species records was at the edge (within 2.5 m) of the proposed southern pit (Figure 4.1, Figure 4.2), where mining will be very shallow (0.5 m from surface, Figure 4.11). The 3D model shows that only a small proportion of the J4 unit will be by affected by proposed mining at this location, with the majority of the suitable AWT habitats below remaining intact (within J4 and J2). All potential habitats for the species in the southern pit (J4 and J2) extend considerably to the south beyond the impact area, with no known habitat barriers (Figure 4.11). The specimen recorded in the proposed northern pit was recorded approximately 80 m from the pit edge (Figure 4.1, Figure 4.2). 3D modelling predicts that a layer of medium suitability habitat within the D1 unit will remain underneath the current record location (approximately 15 - 20 m thick, Figure 4.11). This habitat extends widely underneath the pit shell in an east-west direction and also extends slightly beyond the pit shell to the south (Figure 4.11).

The occurrence of the species across both pits suggests habitat connectivity between the northern and southern pit, which is supported by 3D modelling which shows well-connected thick bands of medium suitability habitat between the two species records (Figure 4.2). This species occurs across both pits (approx. 2km) and suitable habitats extend beyond the pits near both records. Given the concentration of sampling sites within the proposed pits, it is considered likely that the species current occurrence only within impacts may be attributed to sampling artefacts.

The impacts of the Proposal to Curculionidae Genus 1 `sp. BCO228` have been classified as low, because:

- One of the species records was collected from the edge of the pit where proposed mining will be shallow (~0.5 m), and suitable AWT habitat will remain intact at this location and extending widely beyond;
- Further suitable AWT habitats have been shown to occur in the immediate local area beyond the pit in both specimen locations;
- 3D modelling showed no potential dispersal barriers between impacted and non-impacted habitats; and
- The species occurs throughout a well-connected network of suitable habitat that extends beyond the impact area to the east, and the lack of records outside the proposed pits is likely to be affected by sampling artefacts.

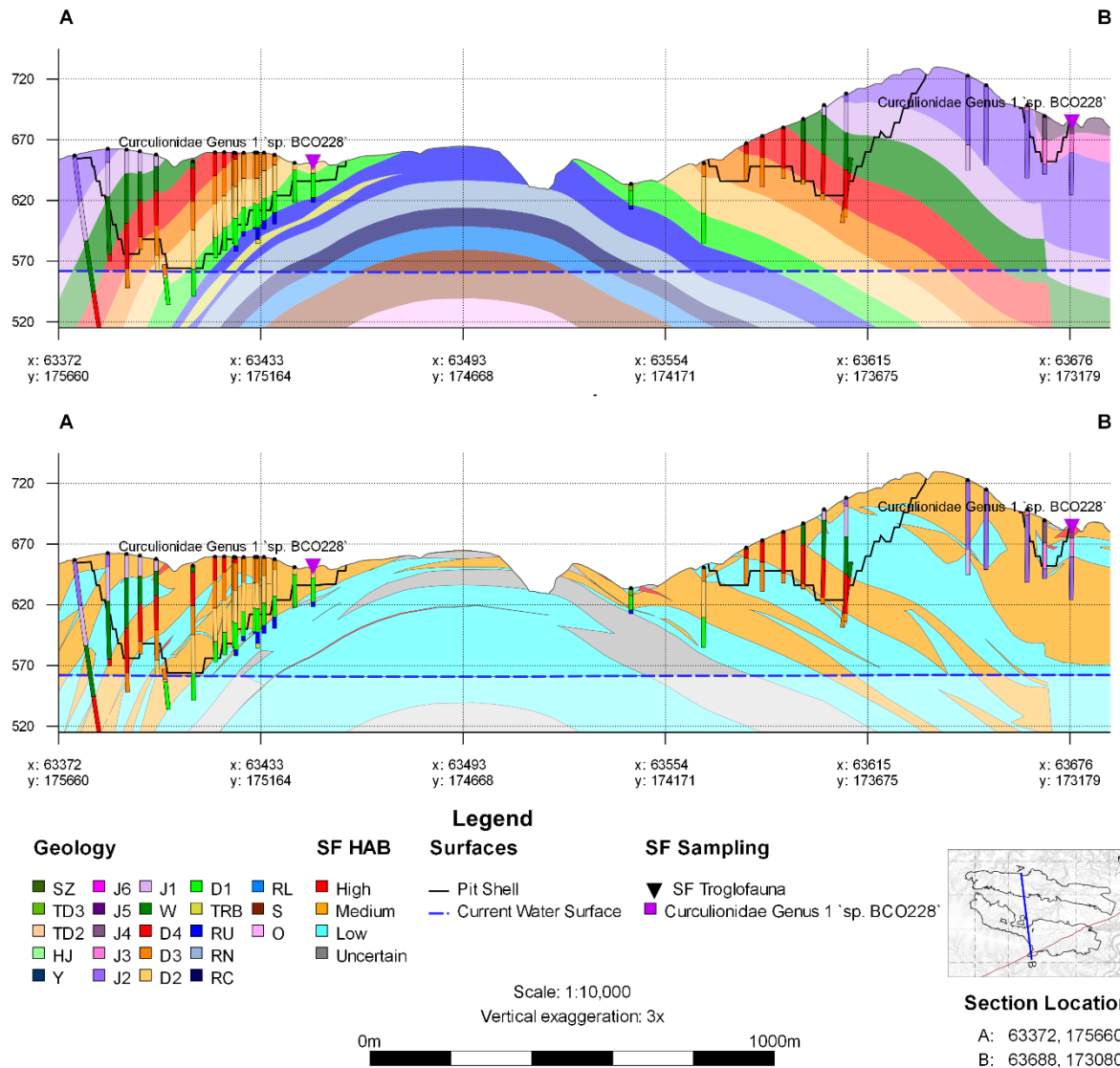


Figure 4.11: Cross-section showing potential AWT habitats for Curculionidae Genus 1 `sp. BCO228` at Ministers North

4.4.3 *Holoparamecus` sp. BCO255`*

The endomychid beetle *Holoparamecus` sp. BCO255`* was collected from two sites in the southern pit (Figure 4.1, Figure 4.2) and has a current known linear range of 1.7 km (Table 2.2). The species was collected during the most recent survey at Ministers North in 2024 (Bennelongia, 2024). There were no sequences of troglofaunal Endomychidae available in Biologic's DNA sequence database to compare ranges at the time of writing.

3D modelling showed that the drill holes where this species was detected intercepted the following stratigraphic units above the water table (Figure 4.12):

- SZ – Surface Scree
- TD3 - Tertiary Detritals 3 (includes former AZ, BZ, CZ, FZ, GZ, HMZ, LLZ, LZ)
- D4 - Brockman Iron Formation, Dales Gorge Member – BIF-rich
- D3 – Brockman Iron Formation, Dales Gorge Member – Shaly
- D2 - Brockman Iron Formation, Dales Gorge Member – BIF-rich
- D1 – Brockman Iron Formation, Dales Gorge Member
- RU – Mount McRae Shale, Upper Unit

The superficial surface scree and tertiary detritals and the D4 unit showed sufficient fracturing/weathering to provide a thick band of medium suitability habitat near surface, with further medium suitability habitats occurring at depth within the D2 unit (Figure 4.12).

Both species records were near the edge (within 50 to 80 m) of the proposed southern pit (Figure 4.1, Figure 4.2) where mining will be comparatively shallow. The 3D model shows that for the specimen located at the eastern end of the southern pit, suitable AWT habitats will remain underneath the pit shell within the D1 and RU units (approximately 16 to 30 m thick, Figure 4.12). These medium suitability habitats extend widely underneath the pit shell in an east-west direction, and beyond the area of the proposed pit to the north.

At the location where the specimen was recorded at the western end of the southern pit, suitable habitats within the D4 unit, which represents the most suitable and likely habitat for the species at that location, will be removed by the proposed mining (Figure 4.12). However, the D4 unit directly extends widely to the south, providing thick and well-connected suitable AWT habitat beyond the area of proposed impact (Figure 4.12). Considering the occurrence of the species across multiple sites and habitat units, it is reasonable to assume that the species may occur more widely throughout the connected habitats (D4) beyond the impact area at this location.

The impacts of the Proposal to *Holoparamesus`sp. BCO255`* have been classified as low, because:

- One of the species records was collected from near the edge of the pit (50 m), and suitable AWT habitat will remain intact at that location and extending widely beyond;
- Further extensive suitable AWT habitats have been shown to occur in the immediate local area beyond the pit at both record locations;
- 3D modelling showed no potential dispersal barriers between impacted and non-impacted habitats; and
- The species occurs across multiple sites and well-connected habitat units that directly extend beyond the pit, making it likely that it also occurs beyond the pits.

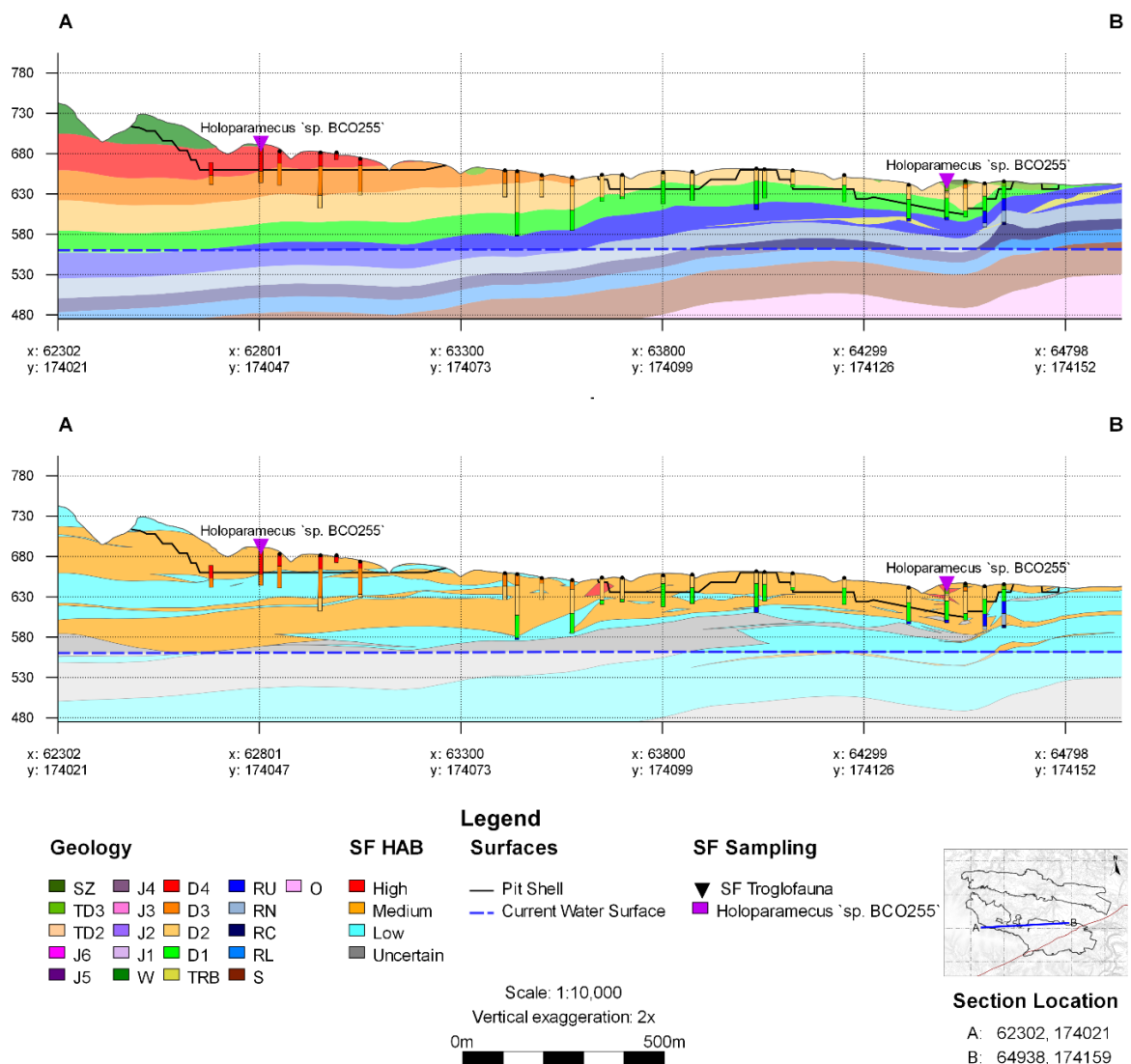


Figure 4.12: Cross-section showing potential AWT habitats for *Holoparamesus`sp. BCO255`* at Ministers North

4.4.4 Pselaphinae `sp. S04`

A staphylinid beetle, Pselaphinae `sp. S04`, was collected from a single site within the proposed southern pit (Figure 4.1, Figure 4.2). The taxon was collected during by Subterranean Ecology (2010) and has not been recollected since. The specimen was never sequenced and hence could not be compared to available sequences from Biologic's DNA sequence database to potentially detect a wider regional match. Of the five Staphylinidae OTU sequences in Biologic's DNA sequence database at the time of writing, three were singleton records whereas the other two had linear ranges of 2 km and 77 km, respectively (Biologic, unpublished data).

3D modelling showed that the drill hole where this species was detected intercepted the following stratigraphic units (Figure 4.13):

- D2 - Brockman Iron Formation, Dales Gorge Member – BIF-rich
- D1 – Brockman Iron Formation, Dales Gorge Member
- RU – Mount McRae Shale, Upper Unit

Of these units, the Dales Gorge Member D2 and, to a lesser degree, Dales Gorge Member D1 represent the most likely habitat for troglofauna (Table 3.1, Figure 4.13), and they collectively provide a thick band of medium suitability habitat extending well beyond the pit to the south.

This species was recorded approximately 95 m from the western edge of the proposed southern pit (Figure 4.1, Figure 4.2). The 3D model shows that the medium suitability habitat within the D2 and D1 units where the species was most likely recorded will be removed following implementation of the proposed mining (Figure 4.13). A relatively thin layer of habitat (D1) will remain underneath the pit shell which extends to the north beyond the area of the proposed pit (Figure 4.13).

There is high confidence in the modelling that further medium suitability habitats occur beyond the pit shell to the south within all four Dales Gorge Member units (D1, D2, D3, and D4) (Figure 4.13). These habitats are directly connected to the impacted habitat within the pit shell where the species was recorded (Figure 4.13). Combined with the dispersal characteristics and wider ranges of other members of this taxonomic group, it is reasonably unlikely that this taxon would be uniquely restricted to the impact area.

The impacts of the Proposal to *Pselaphinae* `sp. S04` have been classified as medium, because:

- 3D modelling predicts that no suitable habitat will remain directly underneath the known record location following mining. However, a wider extensive context of suitable habitat has been shown to occur beyond the proposed pit, indicating that the current habitat extent is not restricted to impacts;
- 3D modelling showed no potential dispersal barriers between impacted and non-impacted habitats; and
- Based on the dispersal characteristics and ranges of other members of this group, it is considered unlikely that this taxon would be uniquely restricted to the proposed pits.

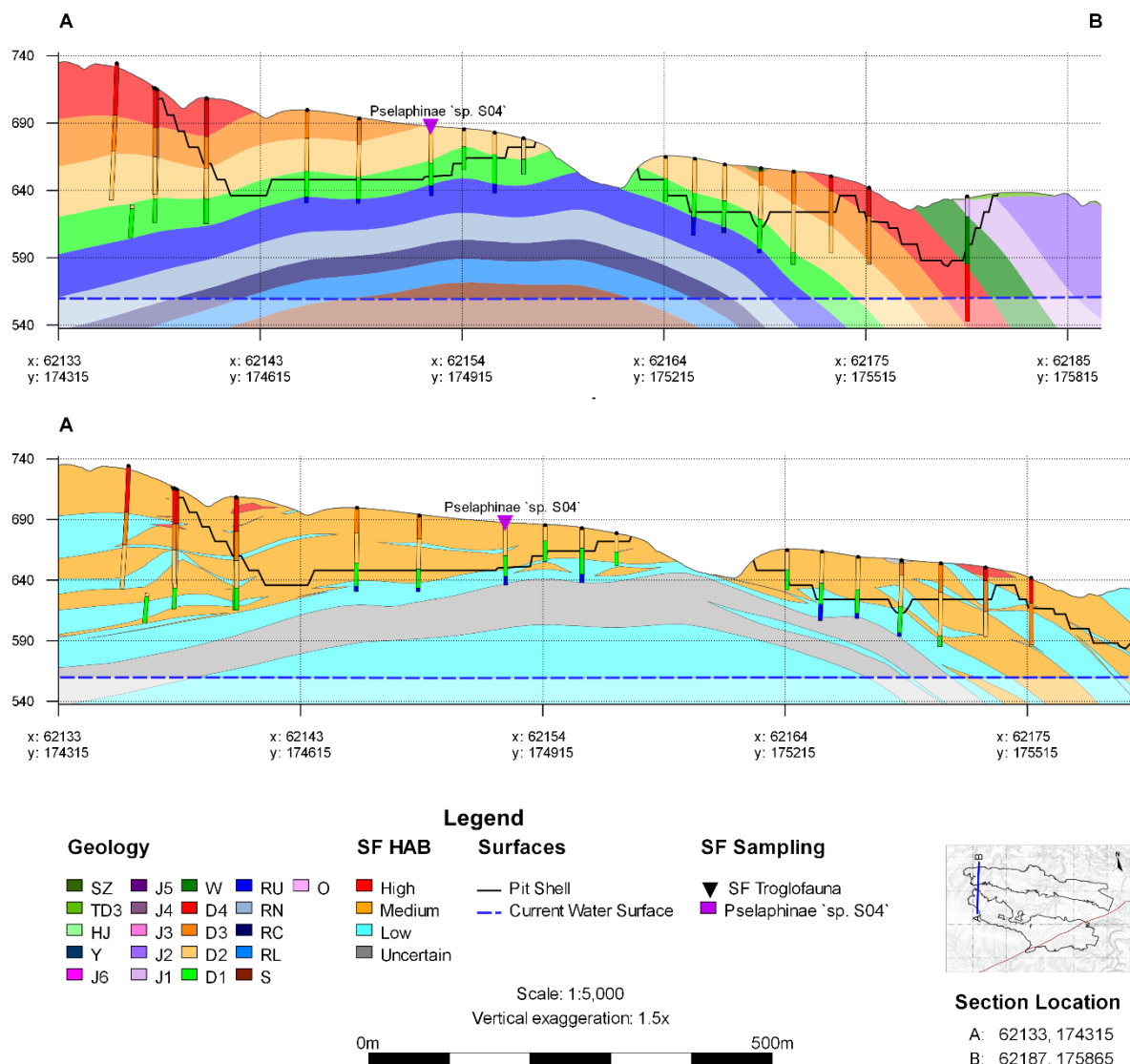


Figure 4.13: Cross-section showing potential AWT habitats for *Pselaphinae* `sp. S04` at Ministers North

4.4.5 Zuphiinae `sp. S01 s.l.`

A species of ground beetle belonging to the Zuphiini tribe in the family Carabidae, Zuphiinae `sp. S01 s.l.`, was collected from a single site within the proposed southern pit (Figure 4.1, Figure 4.2, Table 2.2). The taxon was collected by Subterranean Ecology (2010) and has not been recollected since. Bennelongia (2018) were unable to directly compare this historic record morphologically with newer specimens, but suggested that it is very likely that Zuphiinae `sp. S01 s.l.` represents *Typhlozuphium* `sp. B04` known from four sites (2.5 km linear range) within the Study Area. As a precaution, the taxon has been treated as separate species herein.

Troglofaunal Zuphiini are not as frequently collected as other Coleoptera groups but can be relatively widespread in the Pilbara region (Biologic unpublished data). Of the four Zuphiini OTUs in Biologic's DNA sequence database at the time of writing, one was a singleton whereas the other three had linear ranges of 2.5 km, 3.6 km, and 23 km, respectively.

3D modelling showed that the drill hole where this species was detected intercepted the following stratigraphic units (Figure 4.14):

- D2 - Brockman Iron Formation, Dales Gorge Member – BIF-rich
- D1 – Brockman Iron Formation, Dales Gorge Member
- RU – Mount McRae Shale, Upper Unit

3D modelling showed thick bands of medium suitability habitats within the Dales Gorge Member subunits D1, D2, D3 and D4 near the species location that extend widely beyond the pit area to the south (Figure 4.14).

This species was recorded approximately 95 m from the western edge of the proposed southern pit (Figure 4.1, Figure 4.2). The 3D model shows that the medium suitability habitat within the D2 and D1 units where the species was most likely recorded will be removed following implementation of the proposed mining (Figure 4.14). A relatively thin layer of habitat (D1) will remain underneath the pit shell and extends to the north beyond the area of the proposed pit, however, that portion of the D1 unit has mostly been classified as low suitability habitat in the 3D model (Figure 4.14).

There is high confidence in the modelling that further medium suitability habitats occur beyond the pit shell to the south within all four Dales Gorge Member units (D1, D2, D3, and D4) (Figure 4.14). This habitat is directly connected to the locations within the pit shell where the species was recorded (Figure 4.14). In combination with the typically wide linear ranges of troglofaunal Zuphiini it is considered unlikely that this taxon would be restricted to the impact area.

The impacts of the Proposal to Zuphiinae `sp. S01 s.l.` have been classified as medium, because:

- 3D modelling predicts that no suitable habitat will remain directly underneath the known record location following mining. However, a wider extensive context of suitable habitat has been shown to occur beyond the proposed pit, indicating that the current habitat extent is not restricted to impacts;
- 3D modelling showed no potential dispersal barriers between impacted and non-impacted habitats; and
- The taxon may be synonymous with *Typhlozuphium* `sp. B04`, known from four sites (2.5 km linear range) across the Study Area; and
- Based on the typical distribution characteristics of other members of this group, it is considered unlikely that the taxon is uniquely restricted to the proposed impact area.

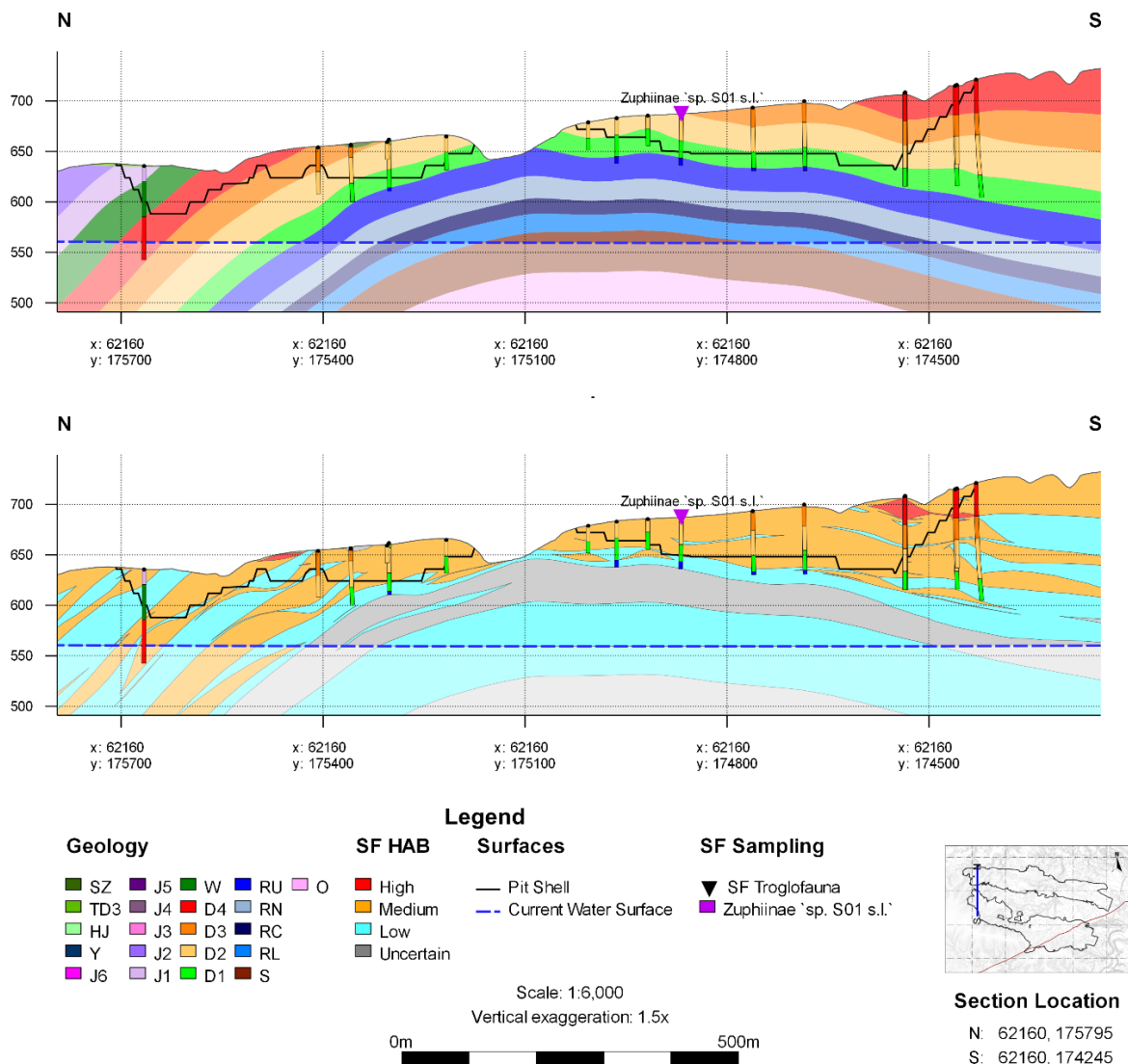


Figure 4.14: Cross-section showing potential AWT habitats for Zuphiinae `sp. S01 s.l.` at Ministers North

4.5 Hemiptera

4.5.1 Reduviidae `sp. MN`

The assassin bug Reduviidae `sp. MN` was collected by Subterranean Ecology (2010) from a single specimen at a site within the proposed northern pit (Figure 4.1, Figure 4.2). This taxon was originally referred to as `Reduviidae sp. indet. MN`, suggesting a lack of taxonomic knowledge to resolve to species level identification. Using a precautionary approach, we treat this taxon as potentially unique and have thus removed the `indet` from the name. The specimen was never sequenced and hence could not be compared to available sequence libraries from Biologic's DNA sequence database to potentially detect a wider regional match or improve taxonomic resolution (e.g. down to genus).

3D modelling showed that the drill hole where this species was detected intercepted the following stratigraphic units above the water table (Figure 4.15):

- TD3 - Tertiary Detritals 3 (includes former AZ, BZ, CZ, FZ, GZ, HMZ, LLZ, LZ)
- D4 - Brockman Iron Formation, Dales Gorge Member – BIF-rich
- D3 – Brockman Iron Formation, Dales Gorge Member - Shaly

The superficial tertiary detritals and the D4 unit occurring below collectively provide a thick layer of medium suitability AWT habitat near the species location due to the prevalence of void spaces within these units Figure 4.15). 3D modelling showed that these troglofauna habitats are supported by further nearby medium suitability AWT habitats within the upper parts of the W and D3 unit (Figure 4.15).

This species was recorded at the edge (within 6 m) of the proposed northern pit (Figure 4.1, Figure 4.2), where mining will be shallow (5 m from surface, Figure 4.15). The 3D model predicts that only the tertiary detritals will be affected by mining at this location, with the majority of the AWT habitat (within D4) below remaining completely intact (Figure 4.15). All potential habitats for the species in the northern pit (tertiary detritals and D4) occur widely beyond the pit area with no known habitat barriers (Figure 4.15).

The impacts of the Proposal to Reduviidae `sp. MN` have been classified as low, because:

- The species has been collected from the edge of the pit, and thick and well-connected AWT habitat will remain intact underneath the pit following mining;
- Further suitable AWT habitats have been shown to occur widely beyond the proposed pit; and
- 3D modelling showed no potential dispersal barriers between impacted and non-impacted habitats.

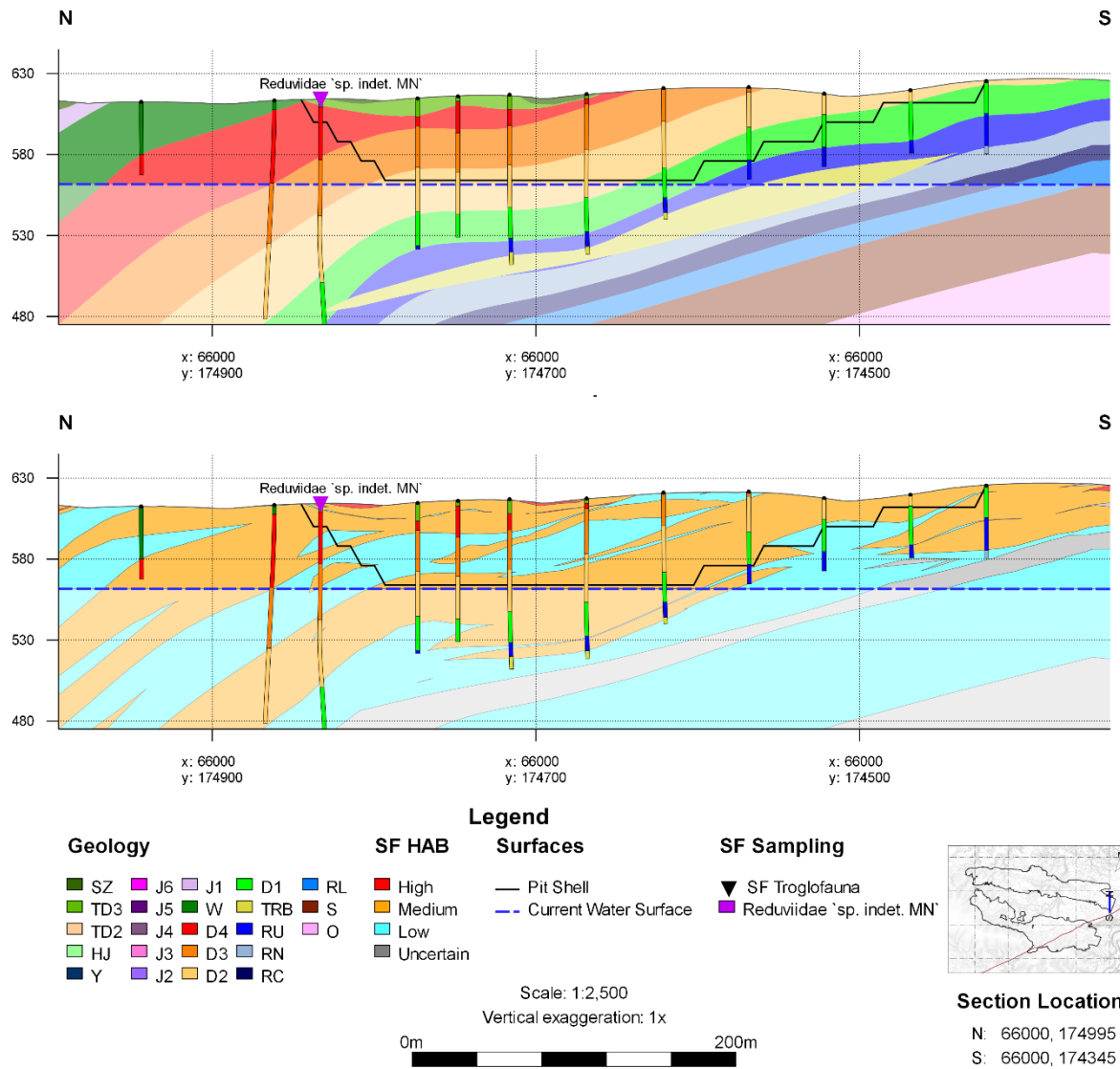


Figure 4.15: Cross-section showing potential AWT habitats for Reduviidae `sp. MN` at Ministers North

4.6 Pauropoda

Pauropods are tiny myriapods that are found in soils and subterranean habitats (Scheller, 2010, 2013). Specimens are always delicate, eyeless, and pale (Scheller, 2010; Scheller *et al.*, 1997), which makes it difficult to distinguish troglomorphy. The taxonomy of the WA pauropod fauna is poorly known, and there is typically very little information to assess whether pauropods that are detected during troglofauna sampling originate in underground cavities or from soils. As a precaution, most pauropods are considered to be potential troglofauna.

Most pauropod OTUs in the Pilbara are singleton records or have limited known linear ranges of only several kilometres, though some more wide-ranging species are also known to occur (Biologic, unpublished data). From a total of 85 pauropod OTUs in Biologic's DNA sequence database at the time of writing, the vast majority were singletons (66 OTUs). Of those with linear ranges, the average linear range was approximately 60 km (min 0.1 km – max 406 km).

Three pauropods are currently only known from within the proposed pits at Ministers North comprising Pauropoda `sp. S04`, Pauropodidae `sp. BPU118` and Pauropodidae `sp. BPU119`. None of the pauropod taxa were able to be genetically sequenced, therefore there is less confidence that any potential synonyms have been resolved, and no capacity for regional genetic comparisons. As a precaution, all three have been treated as separate species herein.

4.6.1 Pauropodidae `sp. BPU118`

Pauropodidae `sp. BPU118` was collected from a single site within the proposed northern pit in 2024 (Figure 4.1, Figure 4.2, Table 2.2) (Bennelongia, 2024). 3D modelling showed that the drill hole where this species was detected intercepted the following stratigraphic units above the water table (Figure 4.16):

- W – Brockman Iron Formation, Whaleback Shale
- D4 - Brockman Iron Formation, Dales Gorge Member – BIF-rich
- D3 – Brockman Iron Formation, Dales Gorge Member - Shaly

Of these units, the D4 represents the most likely habitat for troglofauna near the species location, though some medium suitability habitats are also predicted to occur in the upper parts of the W and D3 unit due to localised variability in weathering (Figure 4.16).

This species was recorded approximately 160 m from the edge of the proposed northern pit (Figure 4.1, Figure 4.2). The 3D model shows that the medium suitability habitat within the D4 unit where the species was recorded will be removed underneath the record location

following implementation of the proposed mining (Figure 4.16). However, the D4 unit extends beyond the proposed pit to the north without habitat barriers, providing relatively thin (up to 15 m thick) but extensive (more than 1 km long) medium suitability AWT habitats in an east-west direction underneath the proposed pit (Figure 4.16). Further extensive and directly connected suitable AWT habitats have been modelled to the south of the proposed pit within the D1 unit of the Dales Gorge Member (Figure 4.16).

The impacts of the Proposal to *Paupodidae* `sp. BPU118` have been classified as medium, because:

- 3D modelling predicts that no suitable habitat will remain directly underneath the known record location following implementation of proposed mining. However, a wider extent of suitable habitat has been shown to occur beyond the proposed pit;
- 3D modelling showed no potential dispersal barriers between impacted and non-impacted habitats;
- The taxonomy is based on morphology alone, and potential synonymy with other local taxa cannot be resolved; and
- The ecological status is uncertain, and the taxon may not represent obligate troglofauna.

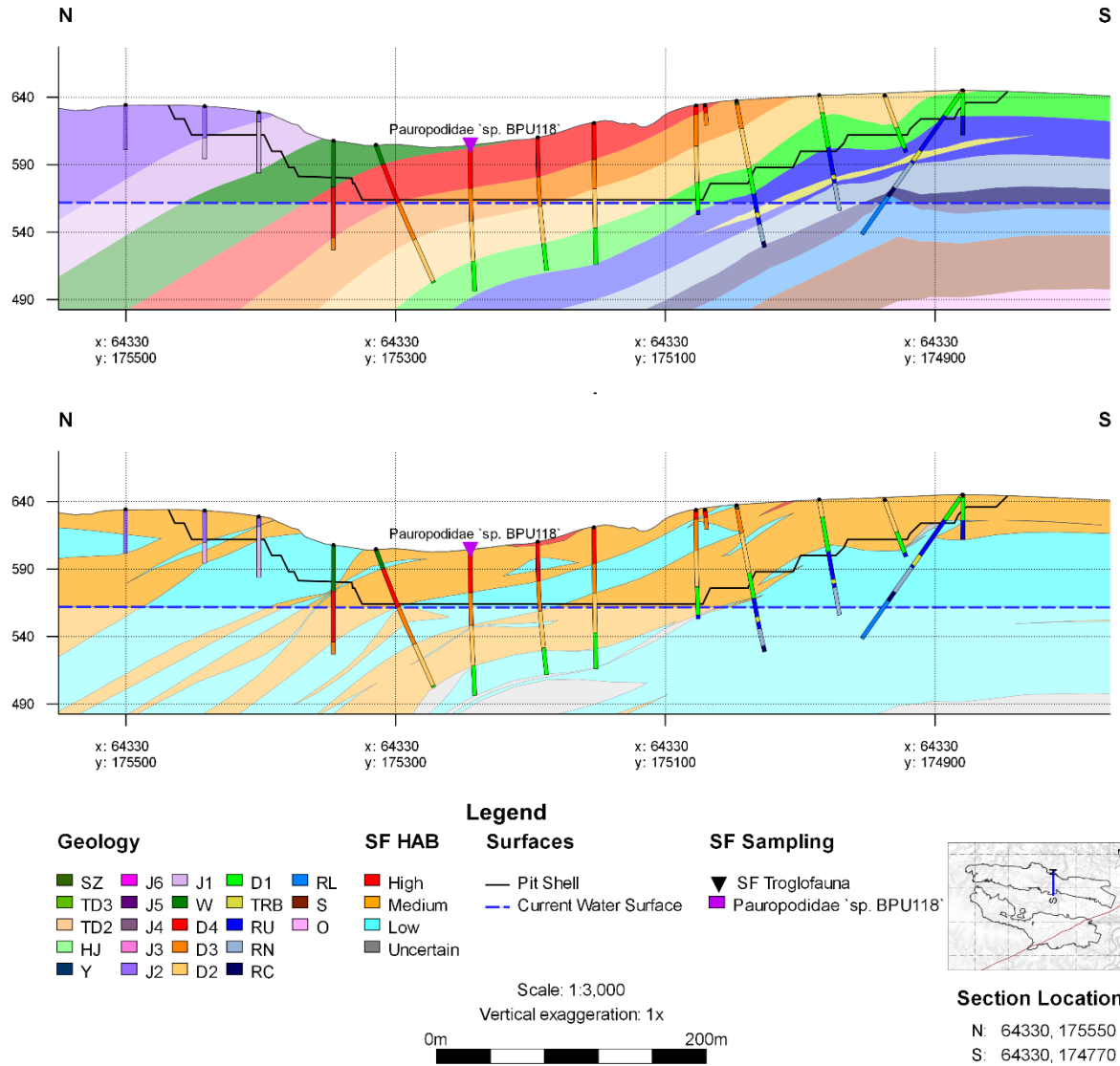


Figure 4.16: Cross-section showing potential AWT habitats for *Pauropodidae* 'sp. BPU118' at Ministers North

4.6.2 Pauropodidae `sp. BPU119`

Pauropodidae `sp. BPU119` was collected from a single site within the proposed southern pit in 2024 (Figure 4.1, Figure 4.2, Table 2.2) (Bennelongia, 2024). 3D modelling showed that the drill hole where this species was detected intercepted the following stratigraphic units above the water table (Figure 4.17):

- D4 - Brockman Iron Formation, Dales Gorge Member – BIF-rich
- D3 – Brockman Iron Formation, Dales Gorge Member - Shaly

Of these units, the BIF-rich Dales Gorge Member D4 showed sufficient fracturing/weathering to provide a thick layer of medium suitability habitat near the species record (Figure 4.17). Further suitable AWT habitats are predicted to exist at depth within the D2 habitat unit (Figure 4.17).

This species was recorded approximately 90 m from the edge of the proposed southern pit (Figure 4.1, Figure 4.2). The 3D model shows that the medium suitability habitat within the D4 unit where the species was recorded will be removed underneath the record location by the proposed mining (Figure 4.17). However, that unit directly extends beyond the proposed pit to the south without habitat barriers, providing extensive medium suitability AWT habitat beyond the area of the proposed pit (Figure 4.17). Further extensive suitable AWT habitat within the D2 unit have been modelled at greater depth underneath the current record location and extending beyond the pit to the south (Figure 4.17).

The impacts of the Proposal to Pauropodidae `sp. BPU119` have been classified as medium, because:

- At present, 3D modelling predicts that no suitable habitat will remain directly underneath record location within the unit the species was recorded from (D4) following implementation of proposed mining. However, a wider extent of suitable habitat has been shown to occur beyond the proposed pit;
- Further suitable AWT habitat (within D2) occur at greater depth underneath the record location and extend southwards beyond the pit shell;
- 3D modelling showed no potential dispersal barriers between impacted and non-impacted habitats;
- The taxonomy is based on morphology alone, and potential synonymy with other local taxa cannot be resolved; and
- The ecological status is uncertain, and the taxon may not represent obligate troglofauna.

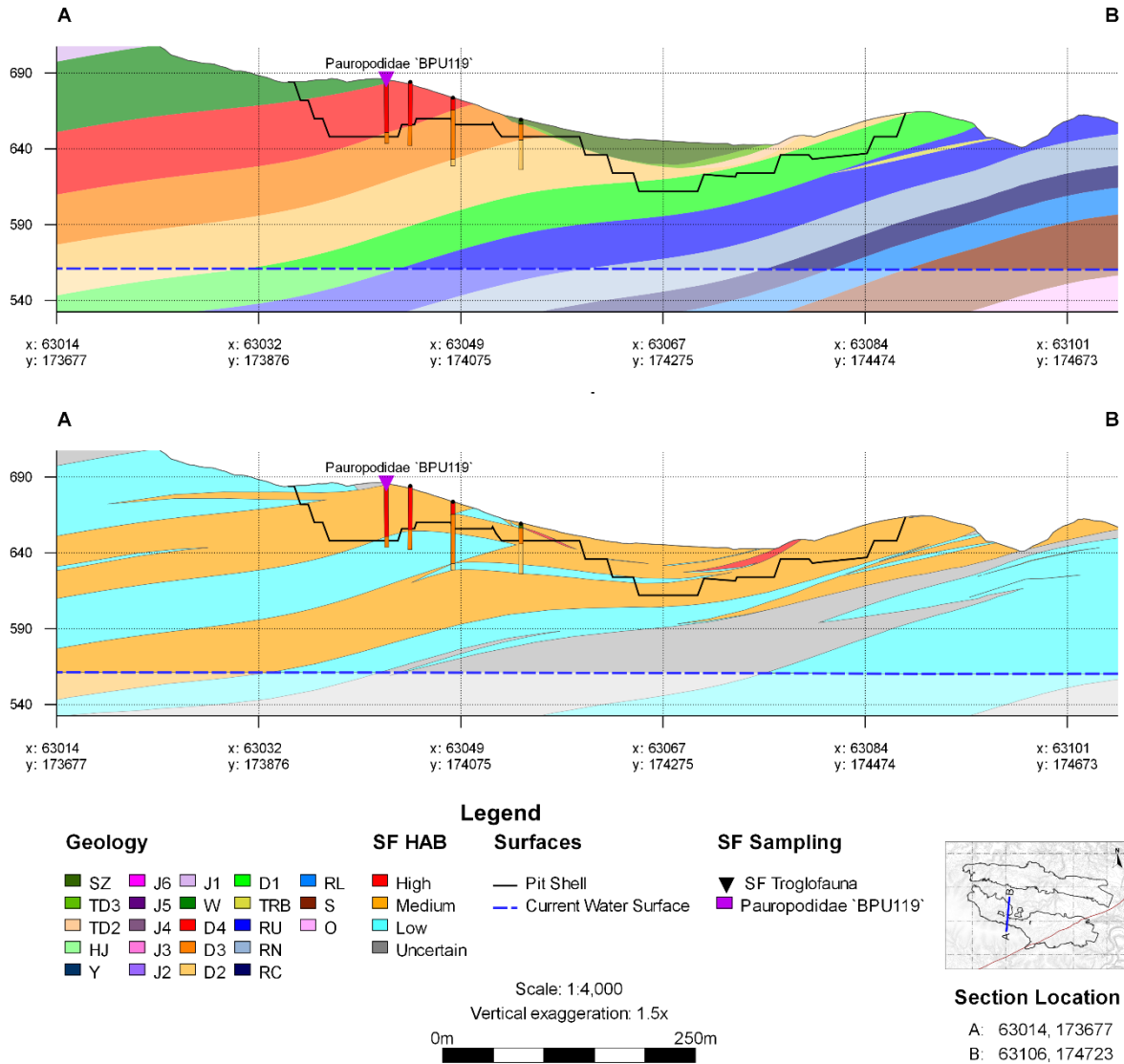


Figure 4.17: Cross-section showing potential AWT habitats for Paupodidae `sp. BPU119` at Ministers North

4.6.3 Pauropoda `sp. S04`

Pauropoda `sp. S04` was recorded from two sites within the proposed northern and southern pits and has a current known linear range of 3.5 km (Figure 4.1, Figure 4.2, Table 2.2). The taxon was collected by Subterranean Ecology (2010) and has not been recollected since. Bennelongia (2024) were unable to directly compare specimens and therefore could not resolve potential synonymy between this taxon and Pauropodidae `sp. BPU118` or Pauropodidae `sp. BPU119`. Nevertheless, as a precaution, the taxon is treated as a separate species herein.

3D modelling showed that the drill holes where this species was detected intercepted the following stratigraphic units (Figure 4.18):

- TD3 - Tertiary Detritals 3 (includes former AZ, BZ, CZ, FZ, GZ, HMZ, LLZ, LZ)
- D4 - Brockman Iron Formation, Dales Gorge Member – BIF-rich
- D3 – Brockman Iron Formation, Dales Gorge Member – Shaly
- D2 - Brockman Iron Formation, Dales Gorge Member – BIF-rich
- D1 – Brockman Iron Formation, Dales Gorge Member
- RU – Mount McRae Shale, Upper Unit

The tertiary detritals and the Dales Gorge Member D4, D2, and D1 occurring below showed sufficient fracturing/weathering to provide thick and well-connected medium suitability habitats near the location of the species record that extend widely beyond the proposed pits (Figure 4.18).

The 3D model shows that the medium suitability habitat within the D4 and D2 units, where the species was recorded, will be mostly removed underneath the record location by the proposed mining (Figure 4.18). However, a thin layer of medium suitability habitat within the D1 and D3 units will remain at both record locations following implementation of the Proposal. Further directly connected medium suitability habitats within the Dales Gorge Member units D1, D2, D3, and D4 extend beyond the proposed pits at both record locations (Figure 4.18).

The impacts of the Proposal to Pauropoda `sp. S04` have been classified as low, because:

- 3D modelling predicts that only a thin layer of suitable habitat will remain directly underneath the record locations following mining. However, a wider extent of suitable habitat has been shown to occur beyond the proposed pits;
- 3D modelling showed no potential dispersal barriers between impacted and non-impacted habitats;

- The species occurs across a network of suitable habitat that extends well beyond the impact area, and the lack of records outside the proposed pits is likely to be affected by sampling artefacts or taxonomic limitations;
- The taxonomy is based on morphology alone, and potential synonymy with other local taxa cannot be resolved; and
- The ecological status is uncertain, and the taxon may not represent obligate troglofauna.

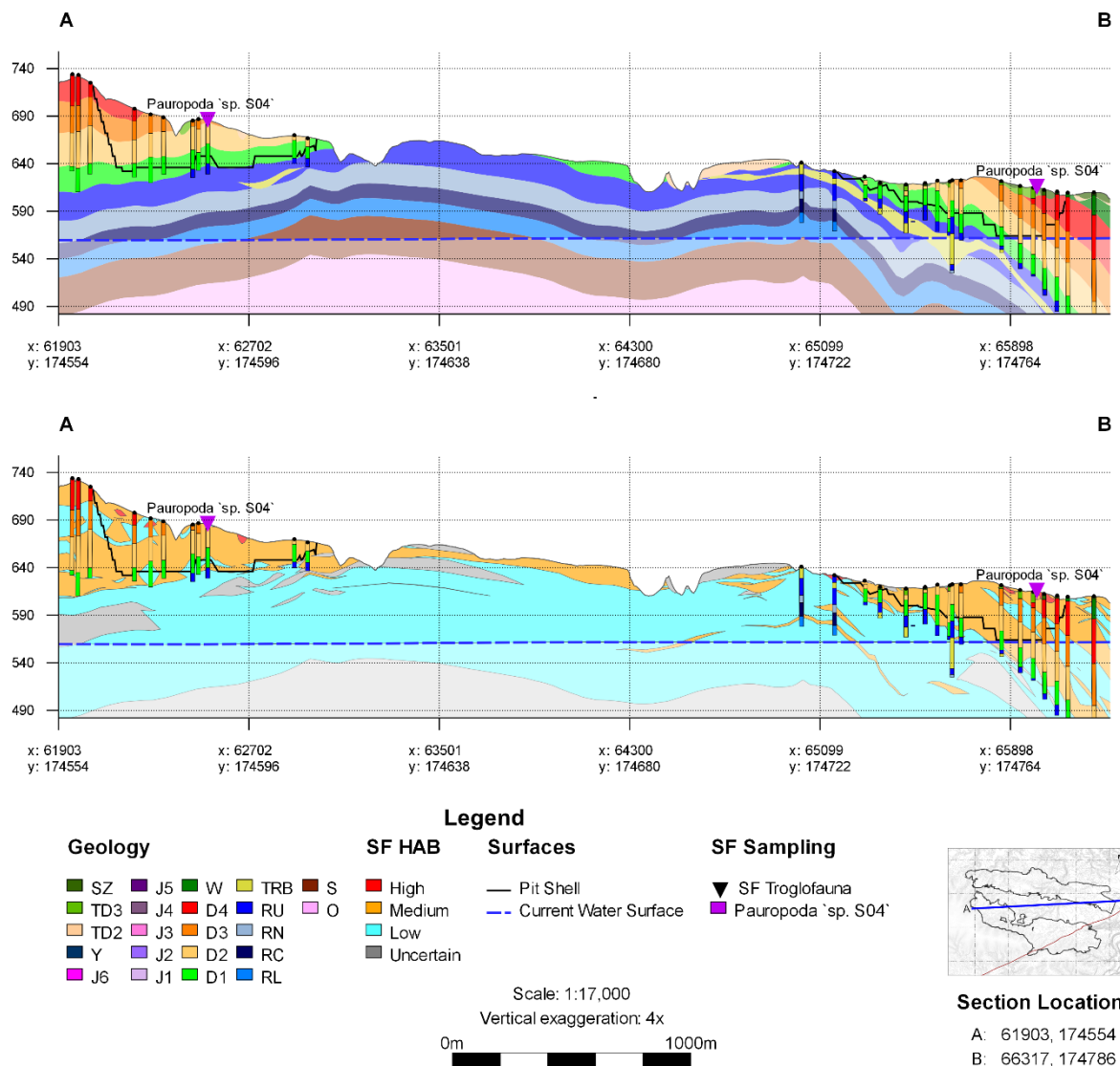


Figure 4.18: Cross-section showing potential AWT habitats for *Pauropoda* 'sp. S04' at Ministers North

4.7 Chilopoda

4.7.1 Cryptopidae `sp. MN`

The centipede Cryptopidae `sp. MN` was collected from a single site within the proposed southern pit (Figure 4.1, Figure 4.2). The taxon was collected by Subterranean Ecology (2010), genetically sequenced by Helix Molecular Solutions, and has not been recollected.

This taxon was originally referred to as `Cryptopidae sp. indet. MN` by Subterranean Ecology (2010), and in the Helix molecular report, while Bennelongia renamed the taxon to Scolopendridae sp. S05 in its report (Bennelongia, 2018). No explanation was provided for this reclassification. As part of the current assessment, the molecular sequence was reanalysed (Appendix A) and formed part of a clade with other *Cryptops* OTUs, supporting the original family assignment (Appendix A). No regional match was detected at the species level, and the taxon was renamed Cryptopidae `sp. MN`.

Cryptopidae centipedes are always eyeless and pale, which makes it difficult to determine whether the apparent troglomorphy is indicative of obligate subterranean status. Recent genetic research has revealed many highly divergent lineages from the Pilbara and Yilgarn regions (Edgecombe et al., 2019), and unpublished information suggests that even terrestrial and soil dwelling *Cryptops* can be SRE. From the 22 *Cryptops* OTUs in Biologic's DNA sequence database at the time of writing, the majority were singletons, although a few widely occurring OTUs were recorded with distributions up to 44 km (Biologic, unpublished data).

3D modelling showed that the drill hole where this species was detected intercepted the following stratigraphic units above the water table (Figure 4.19):

- D4 - Brockman Iron Formation, Dales Gorge Member – BIF-rich
- D3 – Brockman Iron Formation, Dales Gorge Member – Shaly
- D2 - Brockman Iron Formation, Dales Gorge Member – BIF-rich
- D1 – Brockman Iron Formation, Dales Gorge Member
- RU – Mount McRae Shale, Upper Unit

Of these units, the BIF-rich Dales Gorge Member D4 and D2, and Dales Gorge Member D1 occurring below showed sufficient fracturing/weathering to collectively provide thick and well-connected medium suitability habitats near the location of the species record that extend below and widely beyond the proposed pits (Figure 4.19).

This species was recorded near the centre (approximately 360 m from the edge) of the proposed southern pit (Figure 4.19). 3D habitat modelling predicts that suitable habitat

within the D3 and D1 units will remain intact AWT below the proposed pit shell at that location, extending widely underneath the pit in an east-west direction (up to 55 m thick) and also beyond the impact area of the pits to the north (Figure 4.19).

The impacts of the Proposal to *Cryptopidae`sp. MN`* have been classified as medium, because:

- The species has been collected from the middle of the proposed pit. However, 3D modelling predicts that thick medium suitability habitats will remain intact at this location following implementation of proposed mining;
- Well-connected AWT habitats extend widely underneath the pit shell in an east-west direction, and beyond the pit to the north; and
- 3D modelling showed no potential dispersal barriers between impacted and non-impacted habitats.

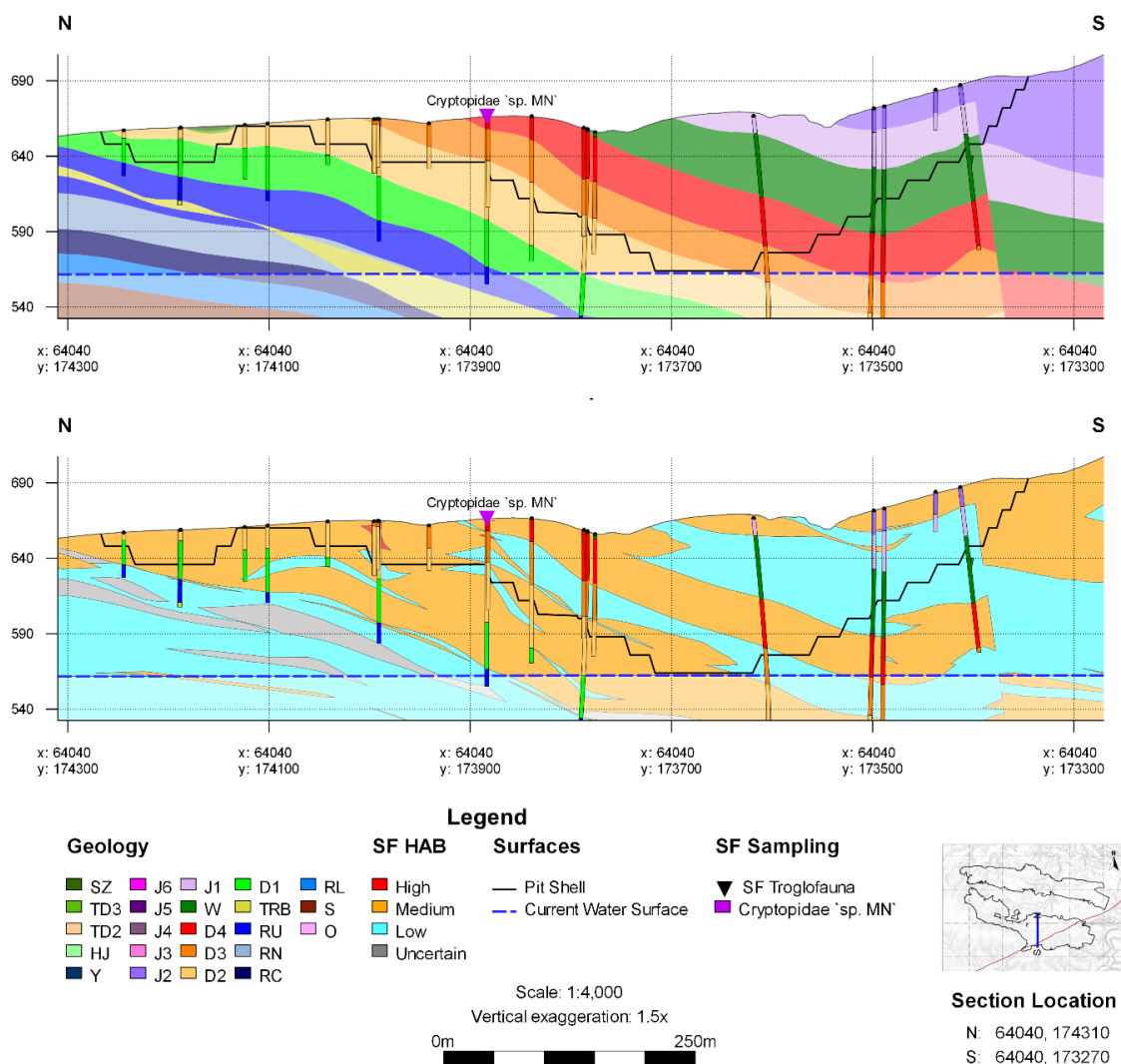


Figure 4.19: Cross-section showing potential AWT habitats for *Cryptopidae`sp. MN`* at Ministers North

4.8 Symphyla

Symphylans are small detritivores that are found in deep leaf litter, soils, and subterranean habitats (Greenslade, 2002). Specimens are always elongated, eyeless, and pale (Greenslade, 2002), which makes it difficult to distinguish troglomorphy. As a precaution, most Symphyla collected during troglofauna surveys are considered to be potential troglofauna. Species in the genus *Hanseniella* are commonly recorded from subterranean surveys across the Pilbara region. From a total of 60 *Hanseniella* OTUs in Biologic's DNA sequence database at the time of writing, approximately half (33 OTUs) were singletons. Of those with linear ranges, the average linear range was approximately 7 km (min 0.1 km – max 22 km).

4.8.1 *Hanseniella* `sp. B43`

Hanseniella `sp. B43` was collected from two sites within the proposed northern pit and has a current known linear range of 1.8 km (Figure 4.1, Figure 4.2, Table 2.2). The specimen was collected in the 2018 survey at the Study Area (Bennelongia, 2018) and was unable to be recollected in 2021 (Bennelongia, 2021). Genetic analysis against available sequence libraries from Biologic's DNA internal sequence database failed to detect a wider regional match (Appendix A), therefore this OTU is currently known only from the Study Area.

3D modelling showed that the drill holes where this species was detected intercepted the following stratigraphic units above the water table (Figure 4.20):

- SZ – Surface Scree
- W – Brockman Iron Formation, Whaleback Shale
- D4 - Brockman Iron Formation, Dales Gorge Member – BIF-rich
- D3 – Brockman Iron Formation, Dales Gorge Member - Shaly

Of these units, the superficial surface scree and the BIF-rich Dales Gorge Member D4 occurring below represent the most likely habitat for troglofauna, though localised weathering and fracturing have also provided some additional smaller pockets of medium suitability habitat in the Dales Gorge Member D3 and the Whaleback Shale on a localised scale near the species location (Figure 4.20).

Both specimen records were near the edge (within 27 m to 95 m) of the proposed northern pit (Figure 4.1, Figure 4.2), where mining will be relatively shallow. The 3D model shows that at the location of one of the specimen records, the D4 unit which represents the most suitable and likely habitat for the species at that location occurs below the proposed pit shell and will not be subject to mining (Figure 4.20). Further suitable habitats within the D4 unit extend widely underneath the pit shell in an east-west direction.

At the location where the specimen was recorded at the eastern end of the northern pit, suitable habitat within the D4 unit will be removed by the proposed mining (Figure 4.20). Nevertheless, 3D modelling shows that further pockets of medium suitability habitat will remain underneath the pit shell within the D3 unit (Figure 4.20). There is also high confidence in the modelling that the Dales Gorge Member (D4) extends beyond the pit shell to the north (Figure 4.20).

The impacts of the Proposal to *Hanseniella* `sp. B43` have been classified as low, because:

- Both specimen records were collected near the edge of the pit where proposed mining will be relatively shallow;
- Suitable AWT habitats will remain at both locations following implementation of proposed mining, either within the D4 or D3 unit;
- Further suitable AWT habitats within the D4 unit have been shown to occur in the immediate local area beyond the pit at both locations; and
- 3D modelling showed no potential dispersal barriers between impacted and non-impacted habitats.

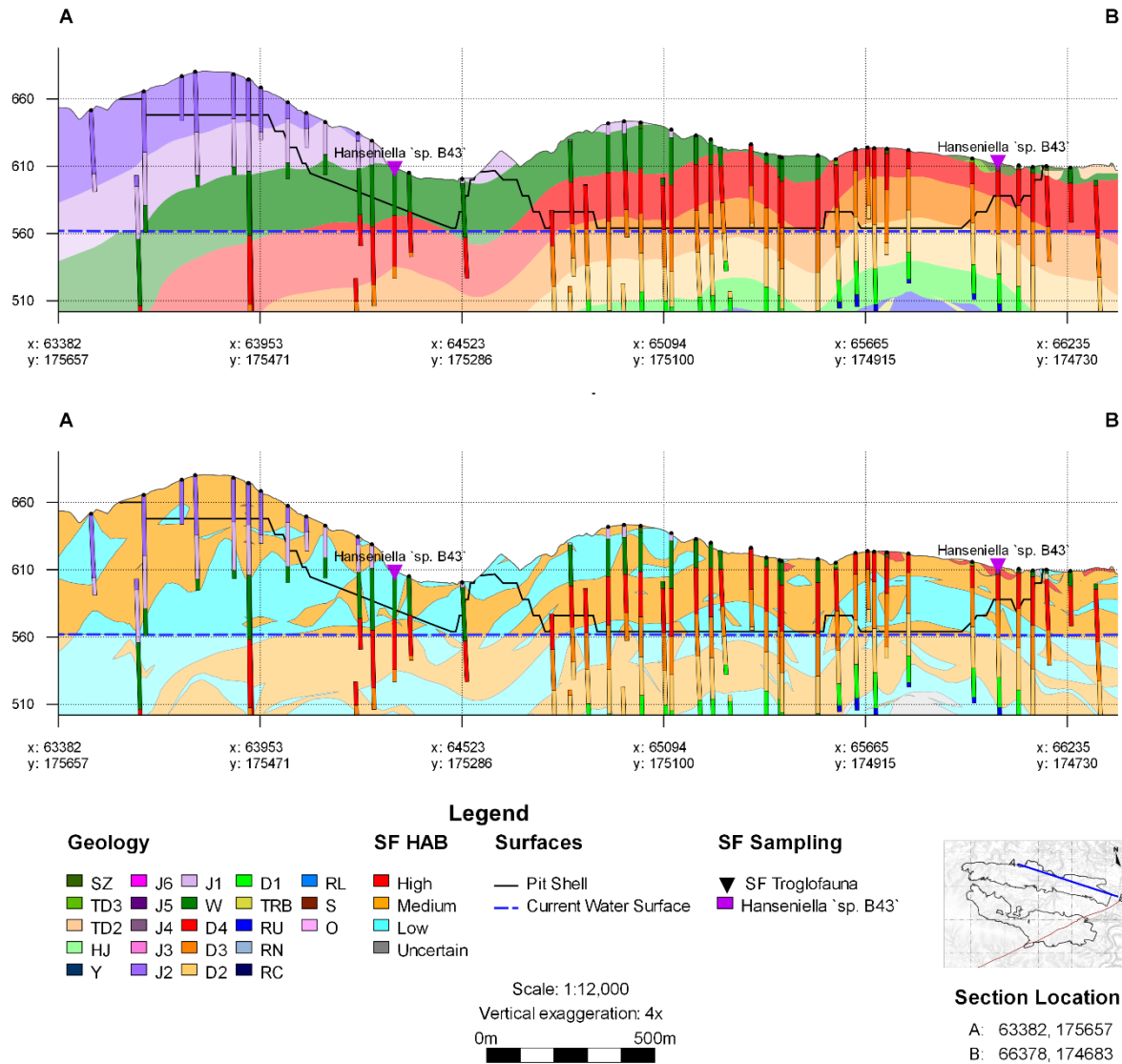


Figure 4.20: Cross-section showing potential AWT habitats for *Hanseniella`sp. B43`* at Ministers North

4.8.2 *Hanseniella* `sp. BSYM129`

Hanseniella `sp. BSYM129` was recorded from a single site within the proposed northern pit (Figure 4.1, Table 2.2) by Bennelongia (2024). Genetic analysis against available sequence libraries from Biologic's DNA sequence database failed to detect a wider regional match (Appendix A), therefore this OTU is currently known only from its current record location within the Study Area.

3D modelling showed that the drill hole where this species was detected intercepted the following stratigraphic units (Figure 4.21):

- D4 - Brockman Iron Formation, Dales Gorge Member – BIF-rich
- D3 – Brockman Iron Formation, Dales Gorge Member - Shaly

Of these units, the BIF-rich Dales Gorge Member D4 represents the most likely habitat, though some suitability is also predicted to occur in the upper parts of the D3 unit due to localised variability in weathering (Figure 4.21).

This species was recorded approximately 110 m from the edge of the proposed northern pit (Figure 4.1, Figure 4.2). The 3D model shows that the medium suitability habitat within the D4 unit where the species was recorded will be removed following implementation of the proposed mining (Figure 4.21). However, that unit directly extends beyond the proposed pit to the north without habitat barriers, providing extensive medium suitable AWT habitat beyond the proposed pit (Figure 4.21). Further extensive suitable AWT habitat within the D2 unit have been modelled at greater depth underneath the current record location and extending beyond the pit to the north (Figure 4.21).

The impacts of the Proposal to *Hanseniella* `sp. BSYM129` have been classified as medium, because:

- At present, 3D modelling predicts that no suitable habitat will remain directly underneath record location within the unit the species was recorded from (D4) following implementation of proposed mining;
- However, the D4 unit extends to the north, providing directly connected AWT habitat beyond the impact area;
- Further suitable AWT habitat (within D2) occur at greater depth underneath the record location and extend northwards beyond the pit shell; and
- 3D modelling showed no potential dispersal barriers between impacted and non-impacted habitats.

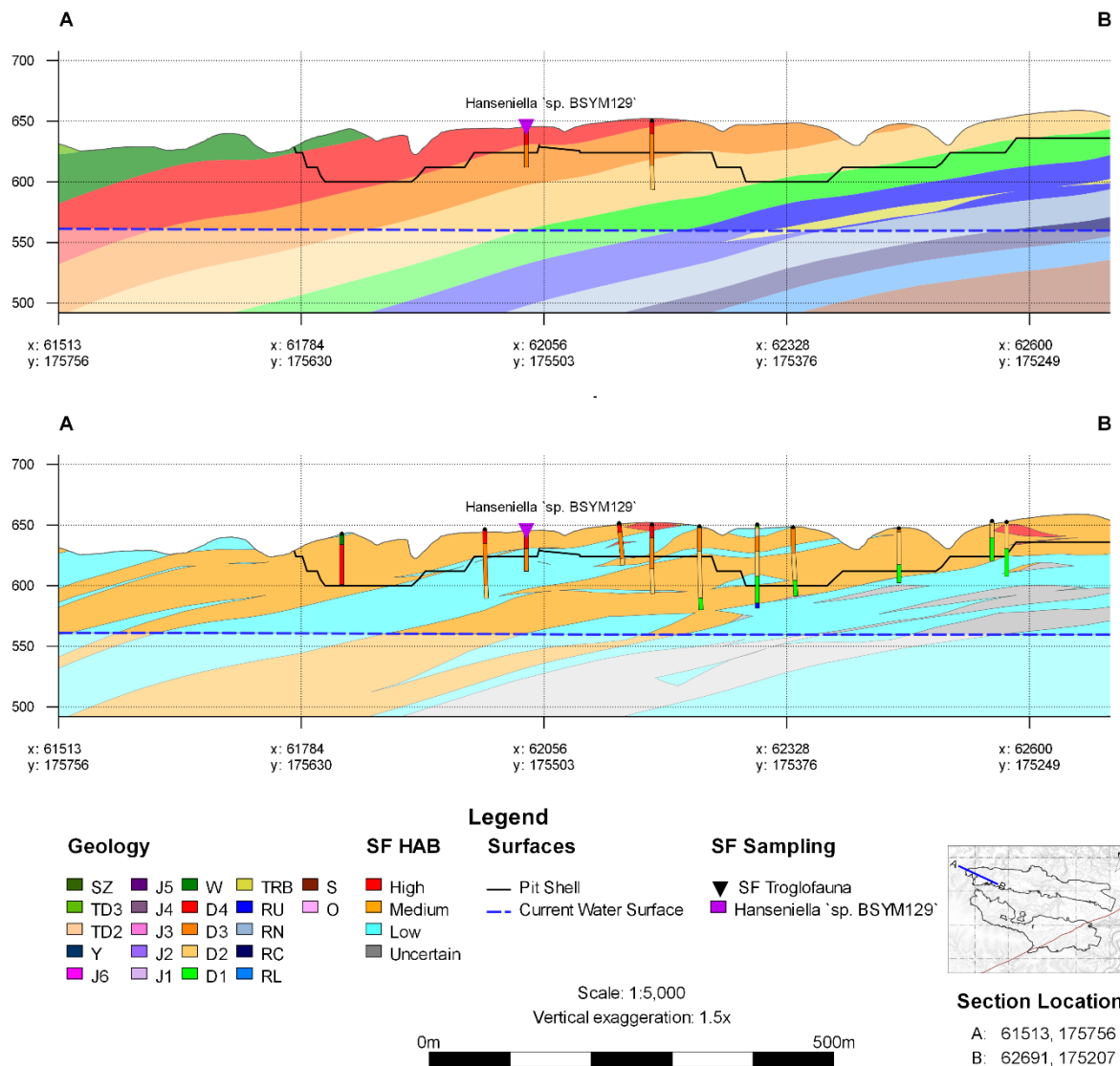


Figure 4.21: Cross-section showing potential AWT habitats for *Hanseniella* 'sp. BSYM129' at Ministers North

5 Key Findings

The habitat modelling and impact assessment focused on 19 troglofauna taxa recorded only within the proposed pits at the time of writing. Suitable habitats AWT were modelled beneath the proposed mining at the periphery of each pit, where most of the target troglofauna taxa were recorded.

The proposed mining is predicted to result in a localised reduction of troglofauna habitat, but a wider extent of well-connected, suitable habitat will remain intact outside of the proposed pits. There are no structural barriers that could affect potential troglofauna dispersal between impacted and non-impacted habitats throughout the Study Area. However, the majority of holes available for survey occurred within the proposed pit boundaries, therefore the current troglofauna species distributions are likely to be influenced by sampling artefacts within the impact areas.

Overall, the Proposal is predicted to have a low impact on 11 of the 19 target troglofauna taxa, comprising:

- *Anapistula* `sp. BAR147`;
- *Anapistula* `sp. S01`;
- Linyphiidae `sp. BAR148`;
- *Prethopalpus* `sp. B32`;
- Palpigradi `sp. BPAL054`;
- *Indohya* `sp. BPS560`;
- Curculionidae Genus 1 `sp. BCO228`;
- *Holoparamecus* `sp. BCO255`;
- Reduviidae `sp. MN`;
- Paupoda `sp. S04`; and
- *Hanseniella* `sp. B43`.

The suitable habitat remaining intact at the locations of each of these taxa was thick and well-connected to a wider extent of non-impacted suitable habitat outside the proposed pits.

The Proposal is predicted to have a medium impact on the remaining eight target troglofauna taxa, comprising:

- nr. *Encoptarthria* `sp. BAR142`;
- Coleoptera `sp. BCO236`;
- Pselaphinae `sp. S04`;
- Zuphiinae `sp. S01 s.l.`;

- Pauropodidae `sp. BPU118`;
- Pauropodidae `sp. BPU119`;
- Cryptopidae `sp. MN`; and
- *Hanseniella* `sp. BSYM129`.

For each of these eight troglofauna taxa, the proposed mining will remove the local extent of suitable habitat AWT at their known locations. Nevertheless, a wider context of well connected, suitable habitats will remain intact following mining. In the context of the taxonomic and ecological factors for each of these taxa, and the acknowledged sampling artefacts within the proposed pits, it is considered unlikely that these taxa would be highly restricted at small spatial scales to the 3D impact area only.

Throughout the Study Area, an extensive interconnected network of suitable habitat is predicted to remain intact following the proposed mining. The direct reduction of suitable habitat within the proposed pits is not expected to result in the loss of any troglofauna species following the implementation of the Proposal.

6 References

- Bennelongia. (2018). *Ministers North subterranean fauna survey*. Unpublished report prepared for BHP WAIO. Bennelongia Environmental Consultants, Jolimont, WA.
- Bennelongia. (2021). *Ministers North targeted troglofauna survey*. Unpublished report prepared for BHP WAIO. Bennelongia Environmental Consultants, Jolimont, WA.
- Bennelongia. (2024). *Ministers North Subterranean Fauna Survey*. Final report prepared for BHP Western Australian Iron Ore. Bennelongia Environmental Consultants, Jolimont, WA.
- BHP. (2023). *FY23 Ministers North SUR Phase 1. Hydrogeological Drilling Completion Report*.
- BHP. (2024). *Ministers North Aquifer - Numerical groundwater modelling*.
- Deharveng, L., & Bourdeau, C. (2010). A molecular phylogeny shows the single origin of the Pyrenean subterranean Trechini ground beetles (Coleoptera: Carabidae). *Molecular Phylogenetics and Evolution*, 54(1), 97-106.
- Dempers, G., Nguyen, T., & Seymour, C. (2019). Advanced methodology for geotechnical televiewer interpretation. *Civil Engineering*, 27(3), 36-43.
- EPA, Environmental Protection Authority. (2016). *Environmental factor guideline: subterranean fauna*. Perth, Western Australia: Environmental Protection Authority.
- EPA, Environmental Protection Authority. (2021). *Technical guidance: subterranean fauna surveys for environmental impact assessment*. Perth, Western Australia: Environmental Protection Authority.
- EPA, Environmental Protection Authority. (2023). *Statement of environmental principles, factors, objectives and aims of EIA*. Perth, WA.
- Greenslade, P. (2002). Class: Symphyla. In. Australian Faunal Directory: Australian National University.
- Halse, S. A., & Pearson, G. B. (2014). Troglofauna in the vadose zone: comparison of scraping and trapping results and sampling adequacy. *Subterranean Biology*, 13, 17-34.
- Harvey, M. S. (2002). Short range endemism in the Australian fauna: some examples from non-marine environments. *Invertebrate Systematics*, 16, 555-570.
- Harvey, M. S., Burger, M. A. A., Abrams, K. M., Finston, T. L., Huey, J. A., & Perina, G. (2023). The systematics of the pseudoscorpion genus *Indohya* (Pseudoscorpiones: Hyidae) in Australia. *Zootaxa*, 5342(1), 1-119.

- Perring, C., & Hronsky, J. (2019). *Guide to the Geology of the Hamersley Iron Ore Province. The Blue Book II: BHP.*
- RPS. (2022). *Hydrogeological drilling and test pumping report. Ministers North DEW Phase 1, FY21.*
- Scheller, U. (2010). Pauropods (Myriapoda: Pauropoda) from Western Australia, with descriptions of a new family, a new genus and three new species. *Records of the Australian Museum*, 26, 001-010.
- Scheller, U. (2013). Pauropoda (Myriapoda) in Australia, with descriptions of new species from Western Australia. *Records of the Western Australian Museum*, 1-133.
- Scheller, U., Ćurčić, B. G. M., & Makarov, S. E. (1997). *Pauropus furcifer* Silvestri (Pauropodidae, Pauropoda): towards an adaptation for life in caves. *Revue Suisse de Zoologie*, 104(3), 517-522.
- Subterranean Ecology. (2010). *Pilbara regional subterranean fauna survey: Area C North Mining Area - Ministers North.* Unpublished report prepared for BHP Billiton Iron Ore. Subterranean Ecology, Greenwood, WA.
- WAM, Western Australian Museum. (2025). Arachnida and Myriapoda Collection Database (custom search). Retrieved 2025 <http://www.museum.wa.gov.au>

7 Appendices

Appendix A: Ministers North Molecular Memo

8 July 2025

Attn: Trent Betts

Specialist Biodiversity

BHP Western Australian Iron Ore – Health, Safety and Environment

125 St Georges Tce Perth WA 6000 Australia

Re: Ministers North Subterranean Habitat Assessment – Molecular Memo

Dear Trent

Please find attached our DNA sequence analysis, utilising Biologic's DNA sequence database to clarify species identification and to detect any potential matches and update linear range distributions for target troglafauna taxa in the Ministers North Study Area.

If would like to discuss any details further, please do not hesitate to contact me or Shae Callan (Manager, Modelling and Impact Assessment, shae@biologicenv.com.au).

Yours sincerely

JOEL HUEY

Manager Molecular Systematics | Principal Geneticist

joel@biologicenv.com.au

0423 626 382

Introduction

BHP WAIO (the Client) requested Biologic undertake a subterranean fauna habitat assessment at Ministers North (the Study Area). One objective of this project is to review troglofauna molecular genetic information (available DNA sequences) from Ministers North to determine any potential wider distributions of target species.

BHP WAIO provided sequence data generated by Bennelongia from the Study Area (including some stygofauna sequences), which could be compared against Biologic's sequence libraries (using BLAST - Basic Local Alignment Search Tool) to potentially extend the known distribution of Operational Taxonomic Units (OTUs).

Additional to these sequences provided from Bennelongia was a single sequence of Cryptopidae, originally collected by Subterranean Ecology. This sequence was also compared to all available sequences.

This memo outlines the outcomes of these analyses.

Methods

Bennelongia Sequence Data

DNA sequence data (.fasta format) and data standards were provided by the Client, which were imported into GENEIOUS Prime (Kearse et al., 2012) with the Biocode plugin used to manage metadata (<http://www.mooreabiocode.org>). Sequences were checked to ensure they were on target (i.e. no contamination), and that primers were removed. Coding regions were checked for stop codons.

In total, 122 sequences were provided from Bennelongia from 87 specimens from 27 species/OTUs ([Appendix A Table](#)). All specimens had a COI sequence, the standard gene used in DNA barcoding and the region with the most DNA sequence data in GenBank and Biologic's DNA sequence libraries. A further 35 sequences of the 12S region of the mtDNA genome was also provided, from seven OTUs. Both COI and 12S were BLASTed against available datasets. All data were on target and of an adequate quality for analysis. Some COI sequences had indels at the 3' end of the sequence but were easily cleaned before analysis.

The cryptopid 12S sequence, originally sampled by Subterranean Ecology, was found in BHP's sequence data, originally provided by BHP. The specimen appears to correspond to the registered specimen WAMT140037, collected on the 23/05/2009, with a troglofaunal trap from bore MN0013R (-22.82998454, 119.1099551). The 12S sequence of this specimen was compared to available datasets using the methods described below.

Appendix A Table 1: Sequences provided by Bennelongia

Taxa	Target*	12S	COI	Total Specimens
Araneae				
Oonopidae				
<i>Prethopalpus</i> `BAR145`	No		3	3
<i>Prethopalpus</i> `BAR146`	Yes		1	1
Blattodea				
Nocticolidae				
<i>Nocticola</i> `BBL038 / B10` (cockingi s.l.)	No		4	4
<i>Nocticola</i> `BBL038` (cockingi s.l.)	No		2	2
<i>Nocticola</i> `BBL044` (quartermainei gp)	No		3	3
Cephalostigmata				
ScutigereLLidae				
<i>Hanseniella</i> `BSYM129`	Yes		1	1
<i>Hanseniella</i> sp. B42-DNA	No		3	3
<i>Hanseniella</i> sp. B43-DNA	Yes		1	1
Coleoptera				
Carabidae				
<i>Typhlozuphium</i> sp. B04	No		1	1
Diplura				
Japygidae				
Japygidae sp. B34	No		3	3
Projapygidae				
Projapygidae `BDP239`	Yes		1	1
Enchytraeida				
Enchytraeidae				
Enchytraeidae `E06`	No	5	6	6
Enchytraeidae sp. OB3	No	1	2	2
Hemiptera				
Meenoplidae				
Meenoplidae sp. WAM-PHAC001/H-HEM003	No		1	1
<i>Phaconeura</i> Biologic HEMI002	Yes		1	1
<i>Phaconeura</i> sp. B13	No	2	3	3
Isopoda				
Armadillidae				
<i>Troglarmadillo</i> sp. B03	No		1	1
Palpigradi				
Palpigradi `BPAL054`	Yes		1	1
Pseudoscorpiones				
Chthoniidae				

Taxa	Target*	12S	COI	Total Specimens
<i>Lagynochthonius</i> sp. B20 (= sp. S04)	No		3	3
<i>Tyrannochthonius</i> `BPS499`	No		1	1
Hyidae				
<i>Indohya</i> `BPS560`	Yes		2	2
Schizomida				
Hubbardiidae				
<i>Draculooides</i> `BSC036` (SCH030 complex)	No	1	2	2
<i>Draculooides</i> `BSC042-DNA`	No	4	5	5
<i>Draculooides</i> `SCH002`	No	19	22	22
<i>Draculooides</i> `SCH065`	No	3	5	5
Zygentoma				
Nicoletiidae				
<i>Dodecastyla</i> `BZY111`	No		3	3
<i>Trinemura</i> `BZY112`	No		6	6
Grand Total		35	87	87

*target taxa are those restricted to the pit in Bennelongia (2024).

BLAST Analysis

Once DNA sequences were checked for quality, they were compared to GenBank (a publicly available DNA sequence database) and Biologic's unpublished DNA sequence libraries, using BLAST and taxonomic curation.

- BLAST: 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.

Where necessary to assist interpretation, sequences were aligned using the MAFFT (Multiple Alignment using Fast Fourier Transform) algorithm (Katoh *et al.*, 2002) and trees were constructed on resulting alignments using the RaxML (Stamatakis, 2014) plugin in GENEIOUS Prime, using 1,000 bootstrap replicates and the GTR+G substitution model.

To identify OTUs and species using molecular data, we integrated multiple lines of evidence, including genetic distance (<8%, Hebert *et al.*, 2003) and tree topology. The resulting

matches had spatial data exported and mapped to explore patterns of spatial distribution and identify if OTU/species' distributions were restricted to impacts.

In some instances, Bennelongia and Biologic have applied different names to the same OTU (based on our assessment of OTU/species boundaries). This is rarely due to differences in species boundary interpretations between companies. Rather, this occurs because the OTU was independently sequenced before names were public, and so different names have been applied, following each company's standard approach. We have provided the Bennelongia and Biologic name where this has occurred and discussed possible disagreements about species boundaries where necessary.

Results

Eighteen of the 27 taxa matched taxa in Biologic's sequence databases, or GenBank (Appendix A Table). Many Bennelongia taxa had matches to sequences with different names. We have detailed these in Appendix A Table. Of these 27 taxa, matching sequence data significantly extended the linear range reported in Bennelongia (2024) of nine taxa (increasing the linear range more than 10 km). We discuss these in more detail below.

Nocticola `BBL038 / B10` (cockingi s.l.) and *Nocticola* `BBL038` (cockingi s.l.) are treated as separate taxa in Bennelongia (2024), despite both being linked to the described species *Nocticola cockingi* in the OTU name. These OTUs are between 5.4% and 5.8% divergent from each other. We consider these a single taxon, *Nocticola cockingi*, with a linear range of 67.4 km, similar to the 64 km reported for *Nocticola* `BBL038 / B10` (cockingi s.l.). Similarly, we consider *Nocticola* `BBL044` (quartermainei gp) to belong to the regionally widespread *Nocticola quartermainei*, which is found across the southern Pilbara. The decision to err on the side of lumping moderately divergent lineages in *Nocticola* COI datasets follows the publication of a genomic dataset showing widespread gene flow in *Nocticola quartermainei*, despite lineage diversification in mtDNA (Ewart *et al.*, 2023). This may be due to accelerated substitution rates in *Nocticola* mtDNA genomes (Kovacs *et al.*, 2024), or sex-biased dispersal, whereby restricted female dispersal causes mtDNA datasets to be more structured than nuDNA (e.g., Eberle *et al.*, 2019).

Enchytraeidae `E06`, Enchytraeidae sp. OB3, and Meenoplidae sp. WAM-PHAC001/H-HEM003 did not have linear distances reported in Bennelongia (2024), but are all widespread based on sequences in Biologic's available genetic databases.

Phaconeura sp. B13 was detected ~60 km southwest of the Study Area, extending its linear distance by 28.8 km. This taxon was not restricted to the pit in Bennelongia (2024). *Trinemura* `BZY112` had its linear range extended to 45 km, with records ~40 km southeast and ~30 km south of the Study Area. This taxon was not restricted to the pit in Bennelongia (2024).

Phaconeura Biologic HEMI002 was the only taxon considered to be restricted to the pit in Bennelongia (2024), that also had sequence data in Biologic's database and matched sequences in the analyses. This taxon's linear range is 78.7 km, with records ~75 km south of the Study Area.

The cryptopid 12S sequence (WAMT140037) did not match any available sequences. However, the identification history of this specimen was able to be reviewed. The specimen was originally identified as Cryptopidae indet. MN by Subterranean Ecology, which was supported with molecular data from Helix (Subterranean Ecology, 2010). Subsequently, Bennelongia renamed this specimen Scolopendridae sp. S05 (Bennelongia, 2018). There is no explanation for why this taxon was assigned a new name, in a different family. Our analysis confirms that it forms a clade with other *Cryptops* lineages, supporting the original assignment of Cryptopidae.

Appendix A Table 2: Results of BLAST analysis

Taxa	Target*	Bennelongia Linear Range	Matches based on Biologic BLAST	Biologic Linear Range	Distribution Comment
Araneae					
Oonopidae					
<i>Prethopalpus</i> `BARI45`	No	2.5 km	No	2.5 km	Area 0.9 km ² , restricted to impact
<i>Prethopalpus</i> `BARI46`	Yes	single bore	No	singleton	Restricted to impact
Blattodea					
Nocticolidae					
<i>Nocticola</i> `BBL038 / B10` (cockingi s.l.)	No	64 km	Yes	67.4 km [†]	Area 1,954 km ² , regionally widespread [†]
<i>Nocticola</i> `BBL038` (cockingi s.l.)	No	26.8 km	Yes	67.4 km [†]	Area 1,954 km ² , regionally widespread [†]
<i>Nocticola</i> `BBL044` (quartermainei gp)	No	14 km	Yes	441.9 km	Distributed across southern Pilbara
Cephalostigmata					
Scutigerellidae					
<i>Hanseniella</i> `BSYM129`	Yes	singleton	No	singleton	Restricted to impact
<i>Hanseniella</i> sp. B42-DNA	No	3 km	Yes	3.0 km	Area 1.4 km ² , restricted to impact
<i>Hanseniella</i> sp. B43-DNA	Yes	1.8 km	Yes	1.8 km	Restricted to impact
Coleoptera					
Carabidae					
<i>Typhlozuphium</i> sp. B04	No	2.5 km	Yes	2.5 km	Restricted to impact
Diplura					
Japygidae					
Japygidae sp. B34	No	26.5 km	Yes	32.3 km	Area 95 km ² , recorded 10 km NW and 9 km SE of study area
Projapygidae					
Projapygidae `BDP239`	Yes	singleton	No	singleton	Restricted to impact
Enchytraeida					

Taxa	Target*	Bennelongia Linear Range	Matches based on Biologic BLAST	Biologic Linear Range	Distribution Comment
Enchytraeidae					
Enchytraeidae `E06`	No	not reported	Yes	483.6 km	Area 89,520 km ² , distributed across Pilbara
Enchytraeidae sp. OB3	No	not reported	Yes	280.8 km	Area 9,992 km ² , distributed across southern Pilbara
Hemiptera					
Meenoplidae					
Meenoplidae sp. WAM-PHAC001/H-HEM003	No	not reported	Yes	680.3 km	Area 81,999 km ² , distributed across Pilbara and south to Wiluna
<i>Phaconeura</i> Biologic HEMI002	Yes	single bore	Yes	78.7 km	Area 866 km ² , distributed 75 km S of study area
<i>Phaconeura</i> sp. B13	No	34 km	Yes	62.8 km	Area 1,105 km ² , distributed 60 km SW of study area
Isopoda					
Armadillidae					
<i>Troglarmadillo</i> sp. B03	No	27 km	Yes	14.8 km	Recorded ~14 km S of study area
Palpigradi					
Palpigradi `BPAL054`	Yes	singleton	No	singleton	Restricted to impact
Pseudoscorpiones					
Chthoniidae					
<i>Lagynochthonius</i> sp. B20 (= sp. S04)	No	4.3 km	No	3.5 km	Area 1.2 km ² , restricted to impact
<i>Tyrannochthonius</i> `BPS499`	No	singleton	No	singleton	Restricted to impact
Hyidae					
<i>Indohya</i> `BPS560`	Yes	3.3 km	No	3.3 km	Restricted to study area, one site in impact and one site just outside

Taxa	Target*	Bennelongia Linear Range	Matches based on Biologic BLAST	Biologic Linear Range	Distribution Comment
Schizomida					
Hubbardiidae					
<i>Draculoides</i> `BSC036` (SCH030 complex)	No	16.5 km	No	1.0 km	Restricted to impact
<i>Draculoides</i> `BSC042-DNA`	No	3 km	Yes	3.0 km	Area 1.9 km ² , restricted to study area, eight sites inside impact, one just outside impact
<i>Draculoides</i> `SCH002`	No	5 km	Yes	5.2 km	Area 6.4 km ² , restricted to study area, many sites inside impact, one just outside impact
<i>Draculoides</i> `SCH065`	No	5 km	Yes	11.1 km	Area 4.7 km ² , recorded 5 km W of study area
Zygentoma					
Nicoletiidae					
<i>Dodecastyla</i> `BZY111`	No	14.5 km	Yes	15.1 km	Area 45.2 km ² , recorded 8 km S of study area
<i>Trinemura</i> `BZY112`	No	2 km	Yes	45.0 km	Area 715 km ² , recorded 40 km SE and 30 km S of study area

*target taxa are those restricted to the pit in Bennelongia (2024). †analysed as a single taxon *Nocticola cockingi*

Appendix A Table 3: Synonyms

Bennelongia Name	Biologic Database Name	Other Names
Blattodea		
Nocticolidae		
<i>Nocticola</i> `BBL038 / B10` (cockingi s.l.)	<i>Nocticola cockingi</i>	
<i>Nocticola</i> `BBL038` (cockingi s.l.)	<i>Nocticola cockingi</i>	
<i>Nocticola</i> `BBL044` (quartermainei gp)	<i>Nocticola quartermainei</i>	
Cephalostigmata		
Scutigerellidae		
<i>Hanseniella</i> sp. B42-DNA	<i>Hanseniella</i> `sp. B42`	
<i>Hanseniella</i> sp. B43-DNA	<i>Hanseniella</i> `sp. B43`	
Coleoptera		
Carabidae		
<i>Typhlozuphium</i> sp. B04	<i>Typhlozuphium</i> `sp. B04`	
Diplura		
Japygidae		
Japygidae sp. B34	Japygidae `sp. B34`	
Enchytraeida		
Enchytraeidae		
Enchytraeidae `E06`	Enchytraeidae `sp. E6 LB-2015`	
Enchytraeidae sp. OB3	Enchytraeidae `sp. Biologic-OLIG004`	
Hemiptera		
Meenoplidae		
Meenoplidae sp. WAM-PHAC001/H-HEM003	<i>Phaconeura</i> `sp. WAM-PHAC001`	
<i>Phaconeura</i> Biologic HEMI002	<i>Phaconeura</i> `sp. Biologic-HEMI002`	
<i>Phaconeura</i> sp. B13	<i>Phaconeura</i> `sp. Biologic-HEMI003`	

Bennelongia Name	Biologic Database Name	Other Names
Isopoda		
Armadillidae		
<i>Troglarmadillo</i> sp. B03	<i>Troglarmadillo</i> `sp. B03`	
Schizomida		
Hubbardiidae		
<i>Draculoides</i> `BSC036` (SCH030 complex)		
<i>Draculoides</i> `BSC042-DNA`	<i>Draculoides</i> `sp. BSC042`	
<i>Draculoides</i> `SCH002`	<i>Draculoides</i> `sp. WAM-SCH002`	<i>Draculoides</i> `sp. BSC037`
<i>Draculoides</i> `SCH065`	<i>Draculoides</i> `sp. WAM-SCH065`	<i>Draculoides</i> `sp. BSC027`
Zygentoma		
Nicoletiidae		
<i>Dodecastyla</i> `BZY111`	Atelurinae `sp. Biologic-ZYGE071`	
<i>Trinemura</i> `BZY112`	<i>Trinemura</i> `sp. Biologic-ZYGE038`	

References

- Bennelongia. (2018). *Ministers North subterranean fauna survey*. Unpublished report prepared for BHP WAIO. Bennelongia Environmental Consultants, Jolimont, WA.
- Bennelongia. (2024). *Ministers North Subterranean Fauna Survey*. Final report prepared for BHP Western Australian Iron Ore. Bennelongia Environmental Consultants, Jolimont, WA.
- BHP. (2023). *FY23 Ministers North SUR Phase 1. Hydrogeological Drilling Completion Report*.
- BHP. (2024). *Ministers North Aquifer - Numerical groundwater modelling*.
- Deharveng, L., & Bourdeau, C. (2010). A molecular phylogeny shows the single origin of the Pyrenean subterranean Trechini ground beetles (Coleoptera: Carabidae). *Molecular Phylogenetics and Evolution*, 54(1), 97-106.
- Dempers, G., Nguyen, T., & Seymour, C. (2019). Advanced methodology for geotechnical televiewer interpretation. *Civil Engineering*, 27(3), 36-43.
- Eberle, J., Bazzato, E., Fabrizi, S., Rossini, M., Colomba, M., Cillo, D., . . . Warnock, R. C. (2019). Sex-biased dispersal obscures species boundaries in integrative species delimitation approaches. *Systematic Biology*, 68(3), 441-459.
- EPA, Environmental Protection Authority. (2016). *Environmental factor guideline: subterranean fauna*. Perth, WA: Environmental Protection Authority.
- EPA, Environmental Protection Authority. (2021). *Technical guidance: subterranean fauna surveys for environmental impact assessment*. Perth, WA: Environmental Protection Authority.
- EPA, Environmental Protection Authority. (2023). *Statement of environmental principles, factors, objectives and aims of EIA*. Perth, WA.
- Ewart, K. M., Kovacs, T. G. L., Walker, J., Tatarnic, N. J., Clark, H., & Lo, N. (2023). Considerable gene flow in troglomorphic cockroach species across a vast subterranean landscape. *Journal of Biogeography*. doi:10.1111/jbi.14707
- Greenslade, P. (2002). Class: Symphyla. In. *Australian Faunal Directory*: Australian National University.
- Halse, S. A., & Pearson, G. B. (2014). Troglifauna in the vadose zone: comparison of scraping and trapping results and sampling adequacy. *Subterranean Biology*, 13, 17-34.
- Harvey, M. S. (2002). Short range endemism in the Australian fauna: some examples from non-marine environments. *Invertebrate Systematics*, 16, 555-570.
- Harvey, M. S., Burger, M. A. A., Abrams, K. M., Finston, T. L., Huey, J. A., & Perina, G. (2023). The systematics of the pseudoscorpion genus *Indohya* (Pseudoscorpiones: Hyidae) in Australia. *Zootaxa*, 5342(1), 1-119.
- Hebert, P. D., Cywinska, A., Ball, S. L., & deWaard, J. R. (2003). Biological identifications through DNA barcodes. *Proceedings of the Royal Society B*, 270(1512), 313-321.
- Katoh, K., Misawa, K., Kuma, K., & Miyata, T. (2002). MAFFT: a novel method for rapid multiple sequence alignment based on fast Fourier transform. *Nucleic Acids Research*, 30(14), 3059-3066.
- Kearse, M., Moir, R., Wilson, A., Stones-Havas, S., Cheung, M., Sturrock, S., . . . Drummond, A. (2012). Geneious Basic: An integrated and extendable desktop software platform for the organization and analysis of sequence data. *Bioinformatics*, 28(12), 1647-1649.
- Kovacs, T. G., Walker, J., Hellemans, S., Bourguignon, T., Tatarnic, N. J., McRae, J. M., . . . Lo, N. (2024). Dating in the Dark: Elevated Substitution Rates in Cave Cockroaches

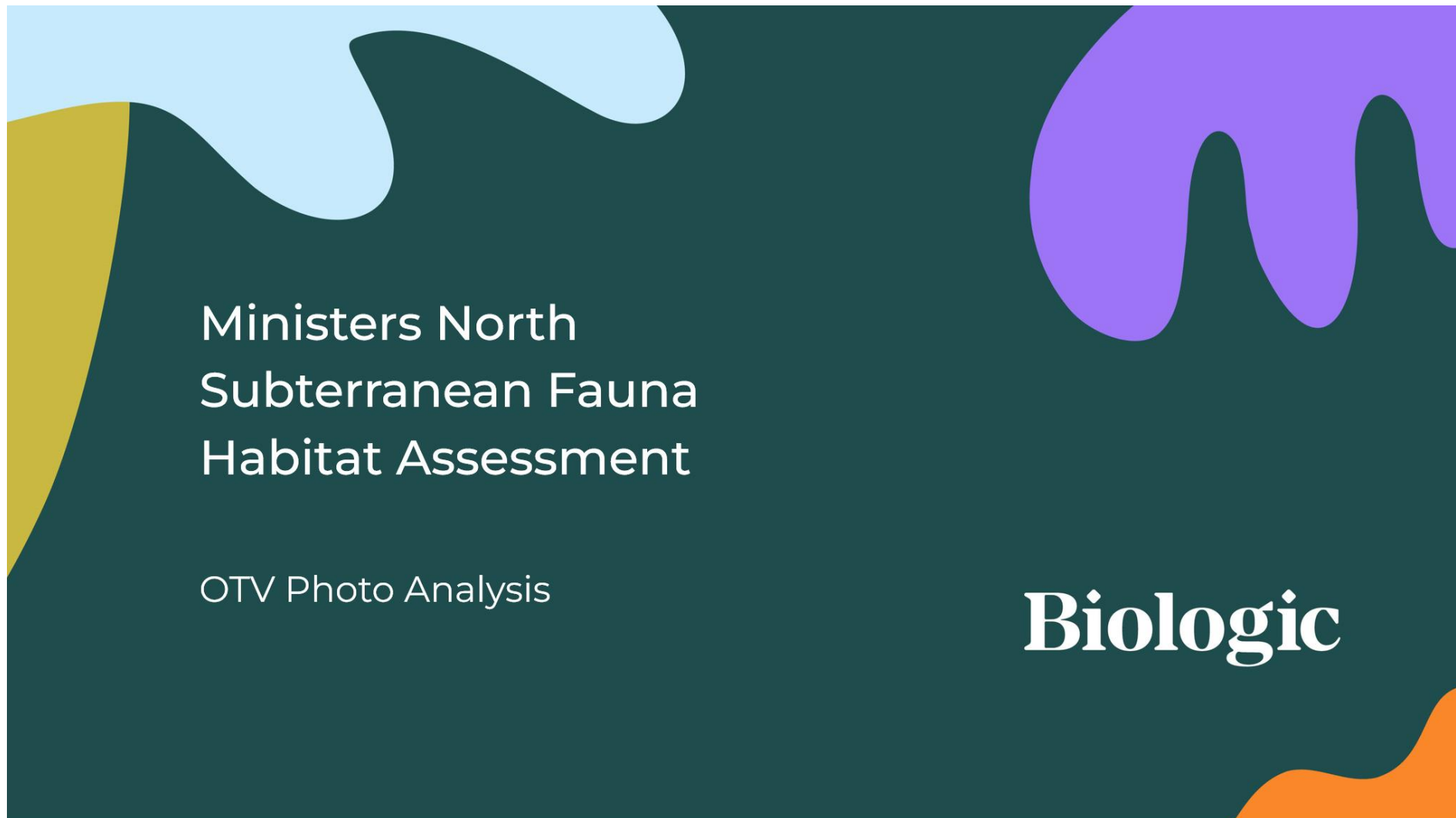
- (Blattodea: Nocticolidae) Have Negative Impacts on Molecular Date Estimates. *Systematic Biology*, syae002.
- Perring, C., & Hronsky, J. (2019). *Guide to the Geology of the Hamersley Iron Ore Province. The Blue Book II: BHP.*
- RPS. (2022). *Hydrogeological drilling and test pumping report. Ministers North DEW Phase 1, FY21.*
- Scheller, U. (2010). Pauropods (Myriapoda: Pauropoda) from Western Australia, with descriptions of a new family, a new genus and three new species. *Records of the Australian Museum*, 26, 001-010.
- Scheller, U. (2013). Pauropoda (Myriapoda) in Australia, with descriptions of new species from Western Australia. *Records of the Western Australian Museum*, 1-133.
- Scheller, U., Ćurčić, B. G. M., & Makarov, S. E. (1997). *Pauropus furcifer* Silvestri (Pauropodidae, Pauropoda): towards an adaptation for life in caves. *Revue Suisse de Zoologie*, 104(3), 517-522.
- Stamatakis, A. (2014). RAxML version 8: a tool for phylogenetic analysis and post-analysis of large phylogenies. *Bioinformatics*, 30(9), 1312-1313.
- Subterranean Ecology. (2010). *Pilbara regional subterranean fauna survey: Area C North Mining Area - Ministers North.* Unpublished report prepared for BHP Billiton Iron Ore. Subterranean Ecology, Greenwood, WA.
- WAM, Western Australian Museum. (2025). Arachnida and Myriapoda Collection Database (custom search). Retrieved 2025 <http://www.museum.wa.gov.au>

Appendix B: Lithology codes

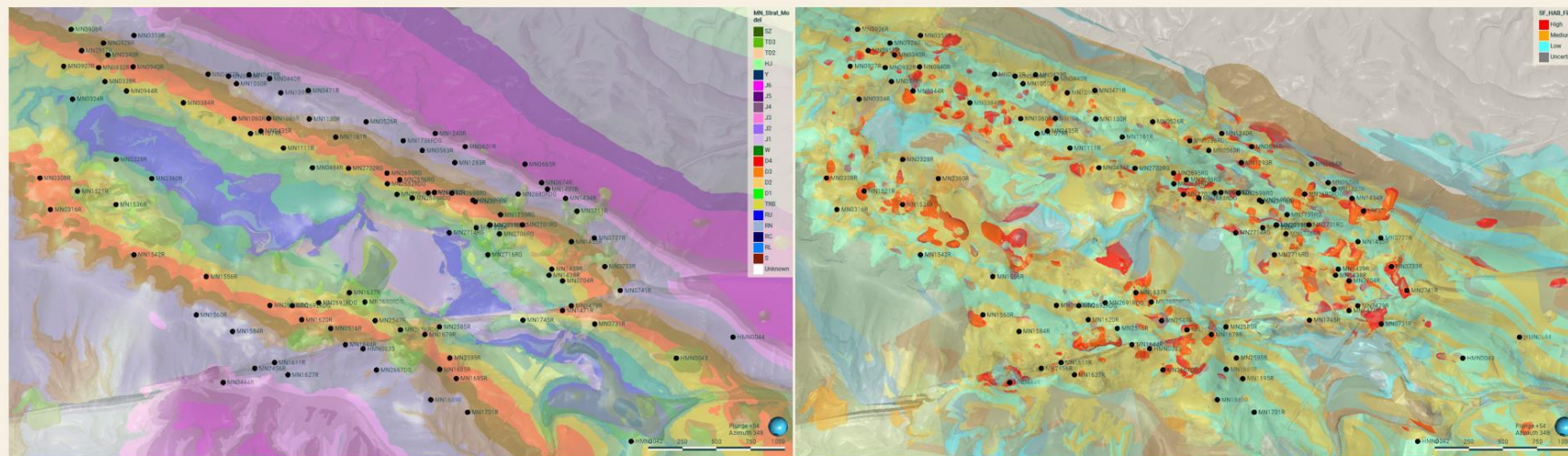
Appendix B Table 1: Logged drill metres by lithology

Group for Model	STRAT	DESCRIPTION	Count	Total Metres	% Total Metres
SZ	SZ	Surface scree - should be "Quaternary Detrital"? (cf. Mittrup, D., 2015, Geotechnical Detrital Classification Guidelines)	99	373.6	0.2%
SZ	A	Alluvials	1	3.1	0.00%
TD3	TD3	Tertiary Detritals 3 (includes former AZ, BZ, CZ, FZ, GZ, HMZ, LLZ, LZ)	5	55.8	0.03%
TD3	GS3	Gravelly Siltstone	194	1,725.7	1.0%
TD3	ST3	Siltstone	11	47.8	0.03%
TD3	WP3	Welded Pisolite	1	11.0	0.01%
TD3	T	Tertiary sediments	2	48.0	0.03%
TD2	VB2	Vuggy Breccia	43	342.4	0.2%
TD2	CA2	Calcrete	4	23.6	0.01%
HJ	HJ	Weeli Wolli Iron Formation (PHj)	2	13.4	0.01%
HJ	HE	Weeli Wolli Dolerite	2	12.4	0.01%
Y	Y	Brockman Iron Formation, Yandicoogina Shale Member (Phby)	7	295.0	0.2%
Y	YE	Brockman Iron Formation, Yandicoogina Shale Member - Dolorite Sills	2	30.8	0.02%
J6	J6	Brockman Iron formation, Joffre Member (PHbj) - J6	42	1,369.9	0.8%
J5	J5	Brockman Iron formation, Joffre Member (PHbj) - J5 – shaly	37	451.6	0.3%
J4	J4	Brockman Iron formation, Joffre Member (PHbj) - J4	55	569.3	0.3%
J3	J3	Brockman Iron formation, Joffre Member (PHbj) - J3 – shaly	89	1,112.2	0.7%
J2	J2	Brockman Iron formation, Joffre Member (PHbj) - J2	423	11,366.3	6.7%
J1	J1	Brockman Iron Formation, Joffre Member - J1 – shaly	490	11,172.8	6.6%
W	W	Brockman Iron Formation, Whaleback Shale (PHbw) – Undifferentiated	661	19,095.8	11.3%
D4	D4	Brockman Iron Formation, Dales Gorge Member (PHbd) - D4	999	27,761.6	16.4%
D3	D3	Brockman Iron Formation, Dales Gorge Member (PHbd) - D3 - middle shaly	1,232	26,992.3	16.0%
D2	D2	Brockman Iron Formation, Dales Gorge Member (PHbd) - D2	1,329	32,244.6	19.1%
D1	D1	Colonial Chert Member (Ahrc), informally the lowest unit of the Dales Gorge Member in the Newman area.	1,133	19,807.0	11.7%
TRB	TRB	Mt Silvia/Brockman Iron Formation – Undifferentiated Turbidites	186	2,078.8	1.2%
RU	RU	Mt McRae Shale – Upper	803	6,563.6	3.9%
RN	RN	Mt McRae Shale - Nodule Zone	69	691.1	0.4%
RC	RC	Mt McRae Shale – Chert	36	445.8	0.3%
RL	RL	Mt McRae Shale – Lower	24	341.5	0.2%
S	S	Mt Sylvia Formation (Ahs) – Undifferentiated	4	46.6	0.03%
No Group	OB	Wittenoom Formation, Paraburdoo Member (Ahdp) OB - Undifferentiated (Formerly WP)	1	8.0	0.005%
No Group	F	Fault Zone	24	2.4	0.001%
No Group	UN	Unknown stratigraphy (Formerly U)	31	3,745.7	2.2%
Total			8,041	168,849.7	

Appendix C: OTV Photo Logging Assessment



Ministers North - Photologged OTV sites



Habitat Classification of OTV photologging and weathering by reviewed metres

Group for Model	STRAT	Weathering	High	Medium	Low
SZ	SZ	Hardcap		1.0	
SZ	SZ	Detritals	7.4	4.5	1.0
TD3	GS3	Hardcap	0.6	2.9	
TD3	GS3	Detritals	9.8	55.1	
TD2	VB2	Detritals	14.6	16.0	1.5
J6	J6	Transitional	1.7	9.4	0.8
J6	J6	Hardcap	3.7	4.2	
J5	J5	Hardcap	0.7	7.7	2.1
J5	J5	Transitional		16.5	0.3
J4	J4	Transitional		28.2	1.8
J4	J4	Hardcap	7.4	10.4	
J3	J3	Hardcap	13.8	10.6	8.2
J3	J3	Transitional	5.2	31.1	9.5
J2	J2	Hardcap	29.1	148.8	39.9
J2	J2	Transitional	9.2	205.9	91.4
J1	J1	Hardcap	8.9	36.8	26.8
J1	J1	Transitional	9.1	245.8	282.4
W	W	Hardcap	7.6	15.7	28.7
W	W	Fresh Rock		1.5	20.6
W	W	Transitional	8.2	136.2	547.9
D4	D4	Transitional	9.1	519.1	263.0
D4	D4	Hardcap	41.2	166.1	38.7
D3	D3	Transitional	21.3	225.3	517.1
D3	D3	Hardcap	30.2	112.9	97.3
D2	D2	Hardcap	56.2	114.8	22.0
D2	D2	Transitional	25.4	679.1	292.3
D1	D1	Hardcap	13.8	20.0	30.1
D1	D1	Transitional	4.2	150.8	395.4
D1	D1	Fresh Rock			3.2
RU	RU	Fresh Rock		5.3	44.9
RU	RU	Transitional	4.5	24.2	199.5
TRB	TRB	Fresh Rock		9.7	71.8
TRB	TRB	Hardcap		1.8	4.2
TRB	TRB	Transitional		16.0	59.4
RU	RU	Hardcap	4.2	1.2	4.0
RN	RN	Fresh Rock		4.0	19.0
RN	RN	Transitional		10.0	9.7
RC	RC	Transitional			2.4
RC	RC	Fresh Rock			30.2
RL	RL	Fresh Rock			11.1

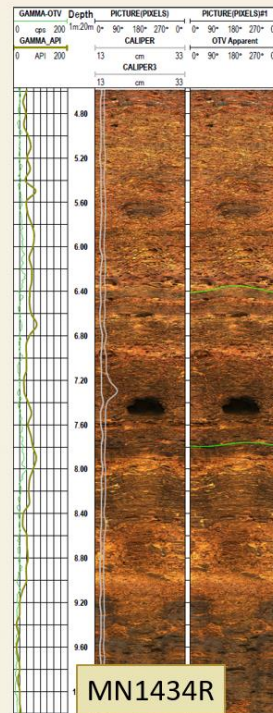
HABITAT CLASSIFICATION: HIGH

Joffre Member

J3 - Shaly

STRAT: J3
 MAJ1: L
 MAJ2: -
 Weathering: <*>

MN1434R: 4.8-10.0,
 Vuggy, coarse holes

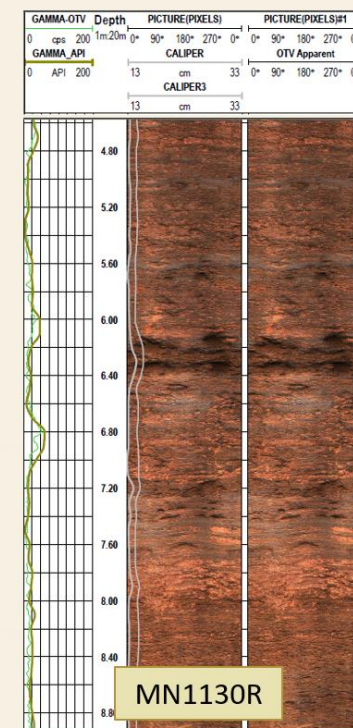


Joffre Member

J1 - Shaly

STRAT: J1
 MAJ1: <*>
 MAJ2: -
 Weathering: <*>

MN1130R: 5.6-7.6,
 Vuggy, coarse holes



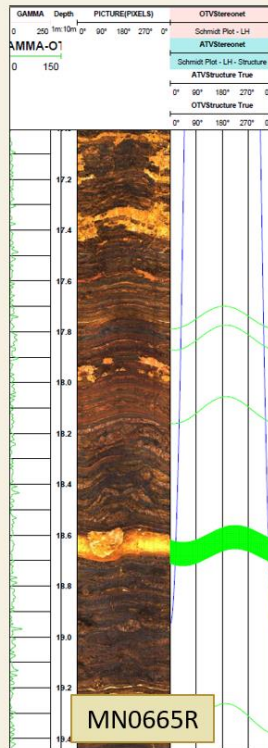
HABITAT POTENTIAL CLASSIFICATION: MEDIUM

Joffre Member

J6 - BIF rich

STRAT: J6
 MAJ1: J
 MAJ2: G
 Weathering: <*>

MN0665R: 17.2-18.0,
 Coarse texture and some fractures
 present in the interval

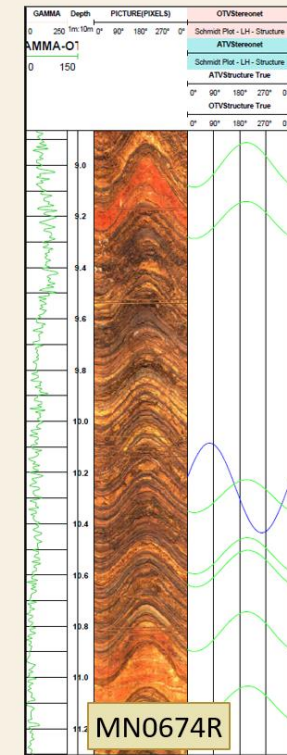


Joffre Member

J5 - Shaly

STRAT: J5
 MAJ1: G
 MAJ2: J
 Weathering: <*>

MN0674R: 9.0-11.2,
 Fractures and coarse grain texture
 throughout the interval.



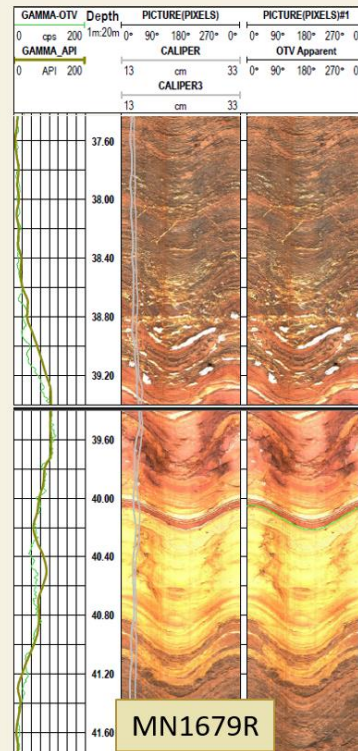
HABITAT POTENTIAL CLASSIFICATION: LOW

Dales Gorge Member

D3 - shaly

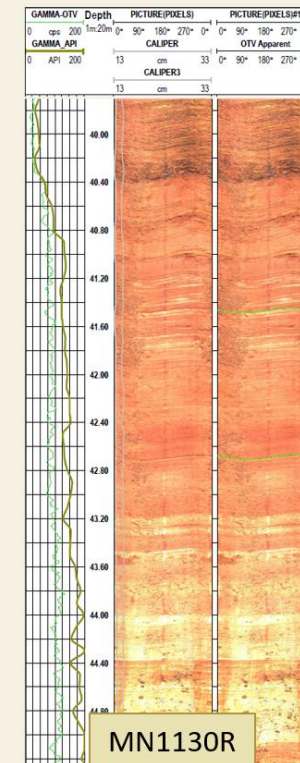
STRAT: D3
MAJ1: S
MAJ2: -
Weathering: <*>

MN1679R: 39.1-41.1, Low.



STRAT: W
MAJ1: <*>
MAJ2: -
Weathering: <*>

MN1130R: 42.0-45.0, Low



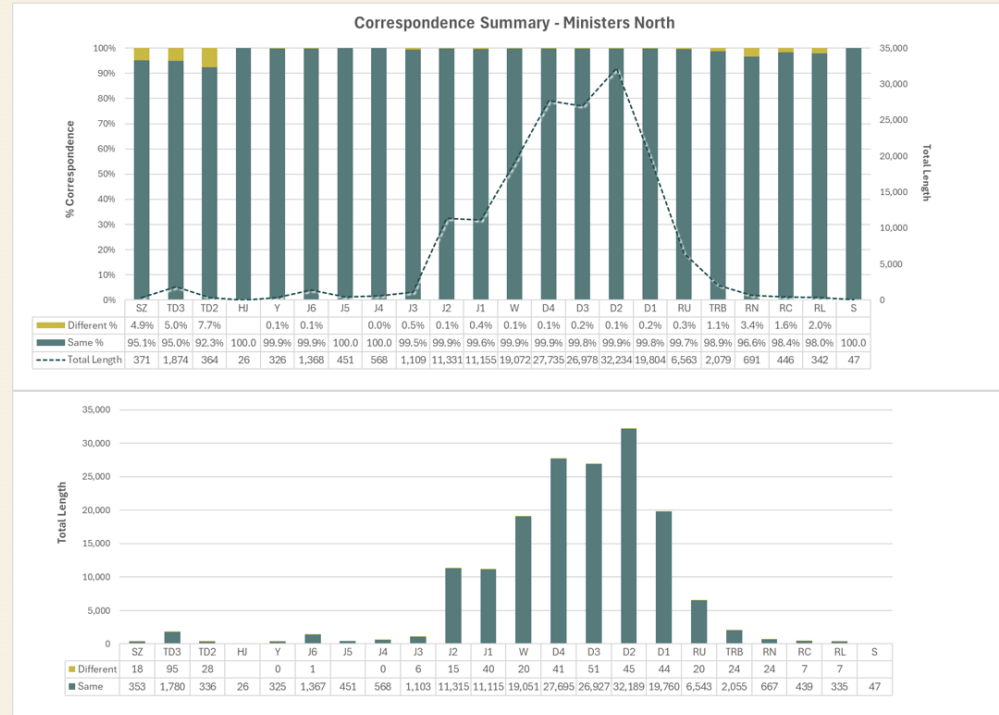
Appendix D: Model Validation



Backflagging Results

Comparison of the drilling intervals to the stratigraphic model

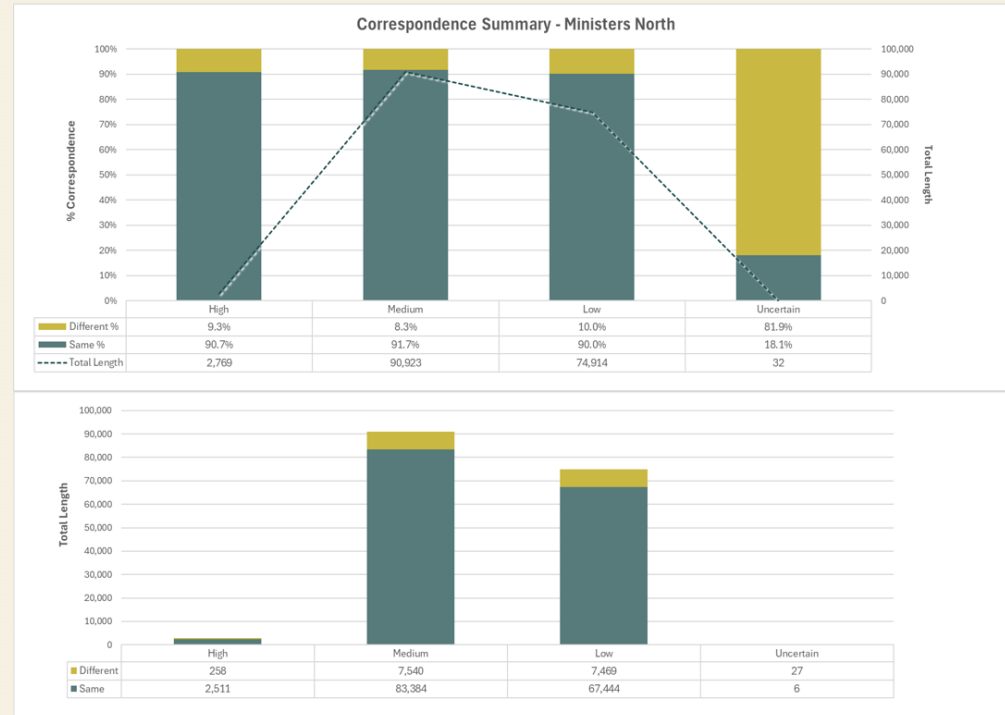
DH Data	Same	Different	Total Length	Same %	Different %
SZ	353	18	371	95.1%	4.9%
TD3	1,780	95	1,874	95.0%	5.0%
TD2	336	28	364	92.3%	7.7%
HJ	26	0	26	100.0%	0.0%
Y	325	0	326	99.9%	0.1%
J6	1,367	1	1,368	99.9%	0.1%
J5	451	0	451	100.0%	0.0%
J4	568	0	568	100.0%	0.0%
J3	1,103	6	1,109	99.5%	0.5%
J2	11,315	15	11,331	99.9%	0.1%
J1	11,115	40	11,155	99.6%	0.4%
W	19,051	20	19,072	99.9%	0.1%
D4	27,695	41	27,735	99.9%	0.1%
D3	26,927	51	26,978	99.8%	0.2%
D2	32,189	45	32,234	99.9%	0.1%
D1	19,760	44	19,804	99.8%	0.2%
RU	6,543	20	6,563	99.7%	0.3%
TRB	2,055	24	2,079	98.9%	1.1%
RN	667	24	691	96.6%	3.4%
RC	439	7	446	98.4%	1.6%
RL	335	7	342	98.0%	2.0%
S	47	0	47	100.0%	0.0%
Total	164,445	486	164,931	99.7%	0.3%



Backflagging Results

Comparison of the drilling intervals to the habitat model

DH Data	Same	Different	Total Length	Same %	Different %
High	2,511	258	2,769	90.7%	9.3%
Medium	83,384	7,540	90,923	91.7%	8.3%
Low	67,444	7,469	74,914	90.0%	10.0%
Uncertain	6	27	32	18.1%	81.9%
	153,346	15,293	168,639	90.9%	9.1%



Backflagging Results

Comparison of the drilling intervals to the weathering model

DH Data	Same	Different	Total Length	Same %	Different %
Detritals	2,451	11	2,461	99.6%	0.4%
Hardcap	24,283	67	24,350	99.7%	0.3%
Transitional	130,352	56	130,408	100.0%	0.0%
Fresh Rock	4,875	322	5,198	93.8%	6.2%
	161,961	456	162,417	99.7%	0.3%

