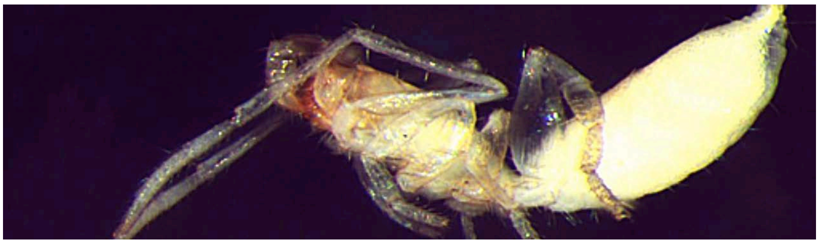
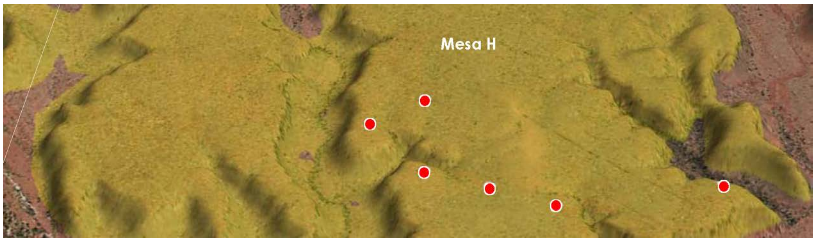
Biota Environmental Sciences

Mesa H Project Subterranean Fauna Habitat and Impact Risk Assessment





Prepared for Rio Tinto

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Mesa H Project Subterranean Fauna Habitat and Impact Risk Assessment

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1.0 Introduction

1.1 Project Background

Rio Tinto is evaluating the potential development of a number of iron ore deposits within the Robe River valley in the Pilbara region of Western Australia. This includes the development of the Mesa H deposit (15 km southwest of Pannawonica) (Figure 1.1).

Previous studies have documented the occurrence of subterranean fauna communities within the Robe River valley, including both troglofauna (air-breathing species living below ground but above the water table) and stygofauna (species living in groundwater systems). Troglofauna, in particular, demonstrate extreme short-range endemism as a result of geological barriers, with many Robe River valley species being isolated to individual mesa formations (Biota 2006a, Harvey et al. 2008). Some stygofauna species can also represent short-range endemic (SRE) taxa and all are restricted to groundwater habitats. Given these considerations, subterranean fauna are of relevance to the environmental impact assessment (EIA) of proposed developments affecting their habitat (EPA 2016a).

The development of the Mesa H deposit has the potential to impact subterranean fauna, and Rio Tinto commissioned Biota Environmental Sciences (Biota) to complete subterranean fauna surveys to collect baseline data to inform the assessment of these impacts (Biota 2019). This report draws on the findings of those surveys, and combines this with project definition provided by Rio Tinto, to assess the potential impacts on troglofauna and stygofauna of the Mesa H project.

1.2 Terminology

For the purposes of this report, the following terms are used as defined below:

- development envelope – the Mesa H project boundary, which will accommodate the full extent of the physical components of the project (Figure 1.1);
- desktop review area – an area encompassing the development envelope, and a 15 km square around it, used by Biota (2019) to take account of data from previous surveys undertaken near Mesa H (Figure 1.1);
- drawdown extent – the spatial extent of the maximum groundwater dewatering influence for the base case for the Mesa H project, which extends beyond the development envelope to the east and southeast (Figure 1.1); and
- survey area – the area surveyed for subterranean fauna by Biota (2019), including the development envelope and drawdown extent, and reference sites outside of this areas within the Robe River valley (Figure 1.1).

1.3 Purpose and Scope of this Report

The purpose of this report is to inform the impact assessment of proposed mining activities within the Mesa H development envelope. It is intended as a supporting study to the Environmental Review Document Rio Tinto is preparing for the formal assessment of the proposed Mesa H project under Section 38 of the *Environmental Protection Act 1986*.

This report consolidates the results of all subterranean fauna data from the survey area with available habitat information to develop a model of demonstrated and inferred fauna distributions and habitat connectivity. The key characteristics of the Mesa H project, and their potential impact mechanisms, are then considered against this, to provide a risk-based assessment of the impacts on subterranean ecosystems within the development envelope, consistent with current Environmental Protection Authority (EPA) guidance (Section 2.1).

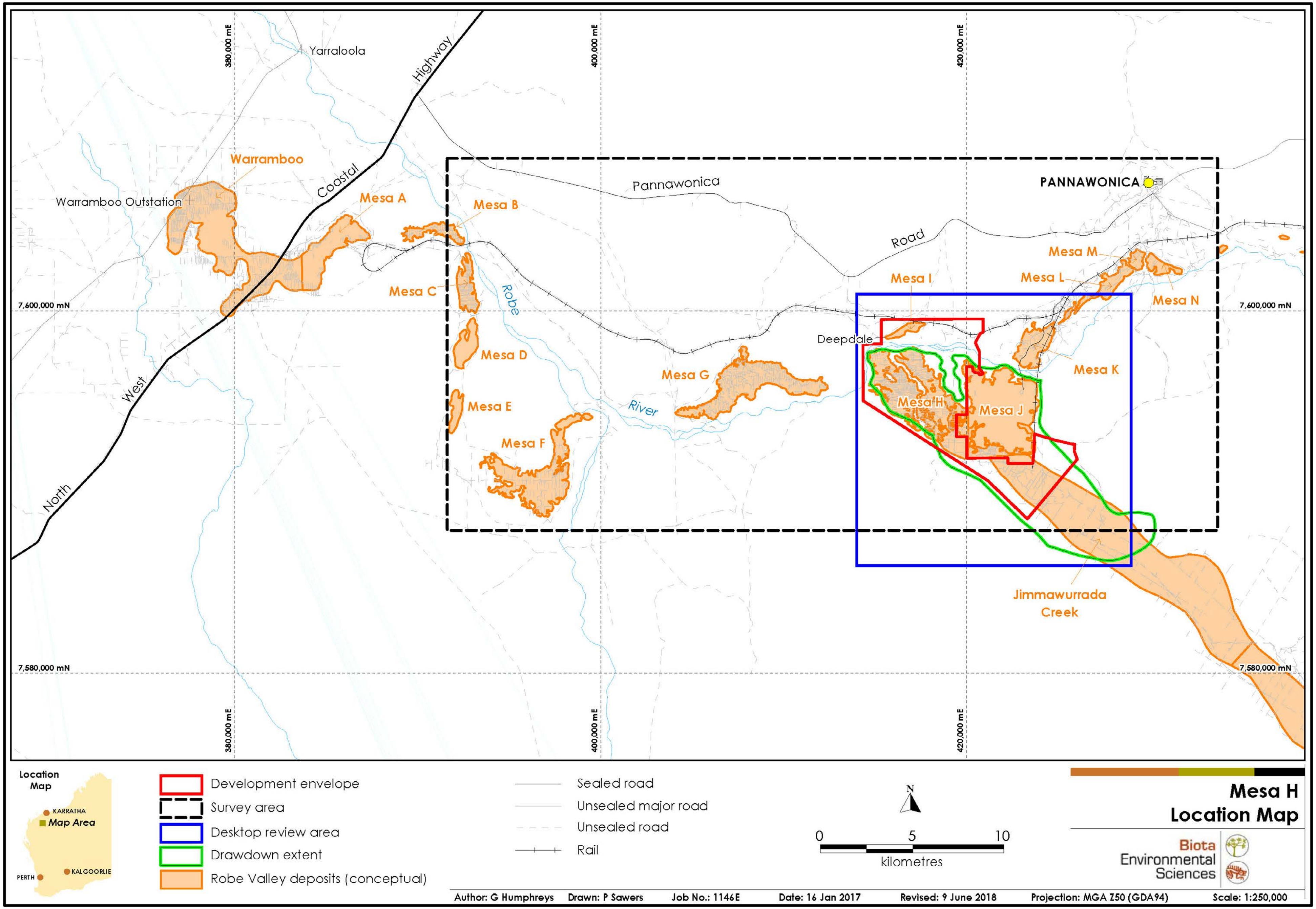

Figure 1.1: Location map of the Mesa H project area.

2.0 Methodology

2.1 Policy Framework

The impact assessment was completed in accordance with:

- EPA Statement of Environmental Principles, Factors and Objectives (EPA 2018);
- Environmental Factor Guideline – Subterranean Fauna (EPA 2016a);
- Technical Guidance - Subterranean fauna survey (EPA 2016b); and
- Technical Guidance - Sampling methods for subterranean fauna (EPA 2016c).

2.2 Approach

This impact assessment has adopted an overall approach of initially identifying all subterranean fauna receptors relevant to the EPA assessment of the Mesa H project (on the basis of the Biota (2019) surveys) and defining the habitats within which they occur. Key receptors were then identified and the predicted impacts of the project, including extent, consequences and resilience of the key receptors, were then assessed, including the level of confidence in predictions.

This approach is aligned with EPA (2018) guidance on determining the significance of impacts: in the case of species or habitats that are more widespread than the impact area, are not of conservation significance, or otherwise unlikely to be impacted, the project would be considered unlikely to have a significant impact in the context of EPA's objective for subterranean fauna.

While all subterranean fauna were considered, the species, communities or habitats that are of restricted distribution, or otherwise of conservation significance, were treated as the key receptors for more detailed evaluation of potential impacts, which is consistent with the guidance provided by EPA (EPA 2016a, 2018).

The logical sequence followed by this document then is to:

1. review, characterise and quantify the key aspects of the Mesa H project to define potential impact sources and pathways (Section 2.3);
2. document all subterranean fauna species and communities present in the development envelope (for troglofauna and stygofauna) and the drawdown area (for stygofauna only), and determine if they represent key receptors (Section 2.4); and
3. delineate the habitats occupied by the key receptors and assess the risk of significant impacts arising from the proposal (Section 2.5 and 2.6).

2.3 Impact Sources and Pathways

2.3.1 Impact Sources

Impact sources inherent to the Mesa H project were identified by collating and reviewing relevant project aspects and attributes. These were compiled from the proposal definition provided by Rio Tinto, comprising the key characteristics, development envelope, indicative arrangement, pit and dump designs, and modelling information.

2.3.2 Impact Pathways

Impact pathways are the mechanisms by which the impact sources result in an impact on subterranean receptors, and these can be broadly categorised as either direct or indirect (EPA 2016a). The most important, direct impact pathways are well recognised and have regularly arisen during past EPA assessments involving impacts on subterranean fauna.

These direct pathways, such as troglofauna habitat removal for mine pits, can typically be spatially quantified and are thereby the clearest to assess. Direct impacts were addressed here through the use of MapInfo Professional Geographical Information System (GIS) v12 (MapInfo). The components of the indicative arrangement and groundwater modelling outputs provided by Rio Tinto were intersected in GIS with subterranean fauna habitats, records of key receptors and other ecological data to quantify impact extents and identify the predicted influence of the proposal.

2.4 Identification of Subterranean Fauna Key Receptors

Key subterranean fauna species and habitat receptors in this impact assessment were those from the list of all relevant subterranean receptors that:

1. meet the criteria outlined in Section 2.4.1 and 2.4.2 below; and/or
2. the basis for their conservation listing and identified threatening processes are relevant to the proposed development; and/or
3. their known distribution, habitat requirements and ecology suggest they may be significantly affected by the impact pathways arising from the project.

This provided a means of focussing the list of all subterranean species known from the development envelope and drawdown extent down to those species most relevant to the impact assessment. Other species recorded during subterranean fauna surveys determined by Biota (2019) as widespread were excluded from the final impact assessment, and records where species level determinations could not be made were excluded from consideration altogether.

Similarly, some subterranean habitats occurring in the development envelope would not be considered key receptors. The criteria applied for determining habitats to be key receptors, and therefore considered in this impact assessment, are detailed in Section 2.4.3.

2.4.1 Species and Communities of Conservation Significance

All species or ecological communities occurring or likely to occur in the development envelope and drawdown extent that are currently listed as:

1. Threatened species under the Commonwealth *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*;
2. Schedule species under the State *Wildlife Conservation Act 1950*;
3. Priority species by the Department of Biodiversity, Conservation and Attractions (DBCA); or
4. Priority Ecological Communities (PECs) recognised by DBCA.

All qualified as key receptors for this impact assessment.

2.4.2 Other Species of Significance

Consistent with Biota (2019), for the purposes of this report, other subterranean fauna known from the development envelope that are relevant to impact assessment but not formally listed as conservation significant were categorised as:

- **Confirmed short-range endemic (SRE) species**: Species where sufficient taxonomic expertise is available, and with adequate representation in the Western Australian Museum collections or genetic databases, that are known to be limited in distribution.
- **Potential SRE species**: Species where there is insufficient taxonomic knowledge, or there are too limited a number of collections, to determine SRE status. Habitat, morphology, molecular or taxonomic data is deficient for these species, but they belong to groups that may display short-range endemism.

Where species recorded by Biota (2019) are either confirmed or potential SREs, they were treated as key receptors.

2.4.3 Subterranean Habitat Receptors

Subterranean fauna habitats treated as key receptors were identified as either Medium or High prospectivity for stygofauna or troglofauna, following the methodology detailed in Section 2.5.

2.5 Habitat Assessment

2.5.1 Stygofauna Habitat Information Review

The suitability of geological formations as core habitat for subterranean fauna is predominantly determined by the availability of cavities and spaces within the rock type, and potential for water and nutrient infiltration and movement. In the case of stygofauna, this may be refined to where such rock formations occur below the water table and, in the Pilbara, where the depth from the ground surface to the water table does not exceed approximately 40-50 m (Halse et al. (2014); Eberhard et al. (2009); Biota (unpublished data)).

Several geological units are now well recognised as being core habitat for stygofauna as they characteristically form fractures, interstices, cavities and vugs, which allows for fauna dispersal and nutrient infiltration. These units include limestone karstic systems, calcrete, alluvium, gravels, fractured rock aquifers, limonite and dolomite (Marmonier et al. 1993, Humphreys 1999, Halse et al. 2014). In the broader Robe Valley setting, important habitat that has also been well documented with diverse stygofauna communities occurring in the locality includes valley fill units where alluvium, gravels, calcrete and channel iron deposits (CID) occur below the water table (Biota 2010, 2015, 2016a). Where these units occur below water table in the Mesa H development envelope, they were also identified here as potential key habitat receptors for stygofauna (Section 2.5.3).

Hydrogeological and stratigraphic information was used to identify and delineate stygofauna habitat, by considering inputs both:

1. spatially (2D) – including accounts of the aquifers and host rock types documented in Rio Tinto hydrogeology reports, Rio Tinto surface geology mapping and regional Geological Survey of WA (GSWA) surface geology; and
2. vertically (3D) – using Rio Tinto drill logs and stratigraphic cross-sections, a digital elevation model constructed from contour data (to identify units associated with valleys and drainage systems), depth to water table, and hydrogeological descriptions of the vertical arrangement, hydrogeological conductivity and connectivity of aquifers.

2.5.2 Troglofauna Habitat Information Review

Like stygofauna, core habitat for troglofauna is also a function of available spaces within the rock formation, along with the ability to maintain a consistently high humidity and the potential for nutrient input from surface systems (Humphreys 1991, Dole-Oliver et al. 2009, Biota and DC Blandford & Associates 2013)

Geological units previously recognised as primary troglofauna habitat include karstic limestone systems, calcrete and CID above water table (Humphreys 1991, Marmonier et al. 1993, Biota 2006a). Physical characteristics common to these formations again include fractures, caverns, vugs, or interstices of sufficient size to physically accommodate troglobitic fauna. Many of these formations include lithologies with important hydrological functions, such as impeding layers and clay lenses which store infiltrated water from recharge events, maintaining humidity in the system (Biota and DC Blandford & Associates 2013).

The importance of above water table CID formations as troglofauna habitat in the Robe Valley, particularly when occurring as mesa landforms, has now been well established (Biota 2006a, 2007, 2009a, Harvey et al. 2008, Biota and DC Blandford & Associates 2013). All CID units above water table were therefore treated as potential key habitat receptors for more detailed assessment here, with other rock types present that had suitable physical characteristics also considered (Section 2.5.4).

Troglofauna habitat was determined in a similar fashion to stygofauna, by consideration of inputs both:

1. spatially (2D) – Rio Tinto surface geology mapping and the spatial extent of Rio Tinto CID ore body strands (which provide more detailed descriptions of CID structure, grade and texture); and

2. vertically (3D) – CID thickness modelling completed by Rio Tinto (see Appendix 1), Rio Tinto drill logs and stratigraphic cross-sections, a digital elevation model (to identify units associated with elevated mesa landforms), downhole geophysical data including cavities and depth to water table (which effectively sets the lower limit of troglofauna habitat) (Appendix 1).

2.5.3 Stygofauna Habitat Characterisation

The habitat units identified from the inputs consolidated in Section 2.5.1 were assigned a likelihood to support stygofauna of Low, Moderate or High, based on the following attributes:

A) Presence of interstitial spaces or vugs.

B) Structural continuity, hydraulic connectivity and transmissivity of the local occurrence of the geological unit below the water table.

C) Demonstrated occurrence of stygofauna in equivalent rock types during previous surveys.

D) Fine sediments such as clays and silts do not dominate the geological unit.

E) Surface conditions permit infiltration of surface water and nutrients.

F) The geological unit is saturated and occurs below the water table.

Likelihood categories were then determined for each geological unit as:

High – Majority (five or more) of attributes confirmed for the unit, including the presence of continuous, transmissive aquifer (A, B, D). Surface geology sufficiently porous to allow nutrient infiltration from surface inputs (E), and unit partially or completely saturated below the water table (F). Stygofauna routinely recorded from the same rock type (C)

Medium – Unit at least partially saturated below the water table (F). Presence of interstitial spaces and cavities (A), with limited fine sediments within the unit (D). Stygofauna occasionally recorded from this geology during previous surveys (C).

Low – Suitable geological unit may occur only above the water table within the study area. Rock type may have limited interstitial spaces (A) however the unit may also be dominated by fine sediments, which reduce usability of spaces (D). Stygofauna not known from previous studies sampling of the same geology (C).

The adequacy of the habitat characterisation was then assessed by plotting all available stygofauna records from the survey area within the High and Medium likelihood habitat extents in MapInfo GIS software. This enabled a more accurate delineation of areas of prospective habitat on the combined basis of physical habitat attributes and the presence of confirmed fauna records.

Spatial correlation between the records and the habitat units assessed as High and Medium likelihood for stygofauna was then used to infer other prospective stygofauna habitat in the same units outside of sampling locations.

2.5.4 Troglofauna Habitat Characterisation

Similar to stygofauna, the habitat units identified as likely troglofauna habitat from the information consolidated in Section 2.5.2 were assigned a likelihood to support troglofauna of Low, Moderate or High, based on the following attributes:

A) Presence of cavities, vugs and interstitial spaces.

B) Known hydration, weathering or significant cavity zones.

C) Presence of clay lenses or impeding layers to maintain stable humidity.

D) Demonstrated occurrence of troglofauna in equivalent rock types during past surveys.

E) Occurs above water table within the survey area.

Likelihood categories were then assigned to the geological units as:

High – Majority (four or more) of habitat attributes confirmed for the unit, including, known to occur above water table (E), presence of interstitial spaces (A) and significance cavity zones (B), and troglofauna routinely recorded from the same rock type (D).

Medium – Suitable geology likely or known to occur above the water table in the survey area (E). Geology known to have interstices or vugs (A) and troglofauna have occasionally been detected in similar rock types previously (D). Geology may be subject to seasonal inundation (e.g. alluvium and colluvium). Where known, units of high prospectivity were categorised as medium if less than 5 m in thickness.

Low – Suitable geology only occurs below water table in the survey area. Rock type may have B), C) and E) characteristics but locally lacking suitable habitat space. Few or no troglofauna records from previous sampling of the same rock type (D).

Similar to stygofauna, the adequacy of the troglofauna habitat characterisation was then assessed by plotting all available troglofauna records from the survey area within the High and Medium habitat extents in MapInfo. Spatial correlation between the records and the High and Medium likelihood habitats both validated their status as troglofauna habitat, and was used to infer other prospective habitat in the same units outside of sampling locations.

2.6 Impact Assessment

2.6.1 Impact Assessment Model

This document considers impacts in a hierarchical framework, with outcomes for the key receptors treated as a consequence of the generalised impact stages shown in Figure 2.1.

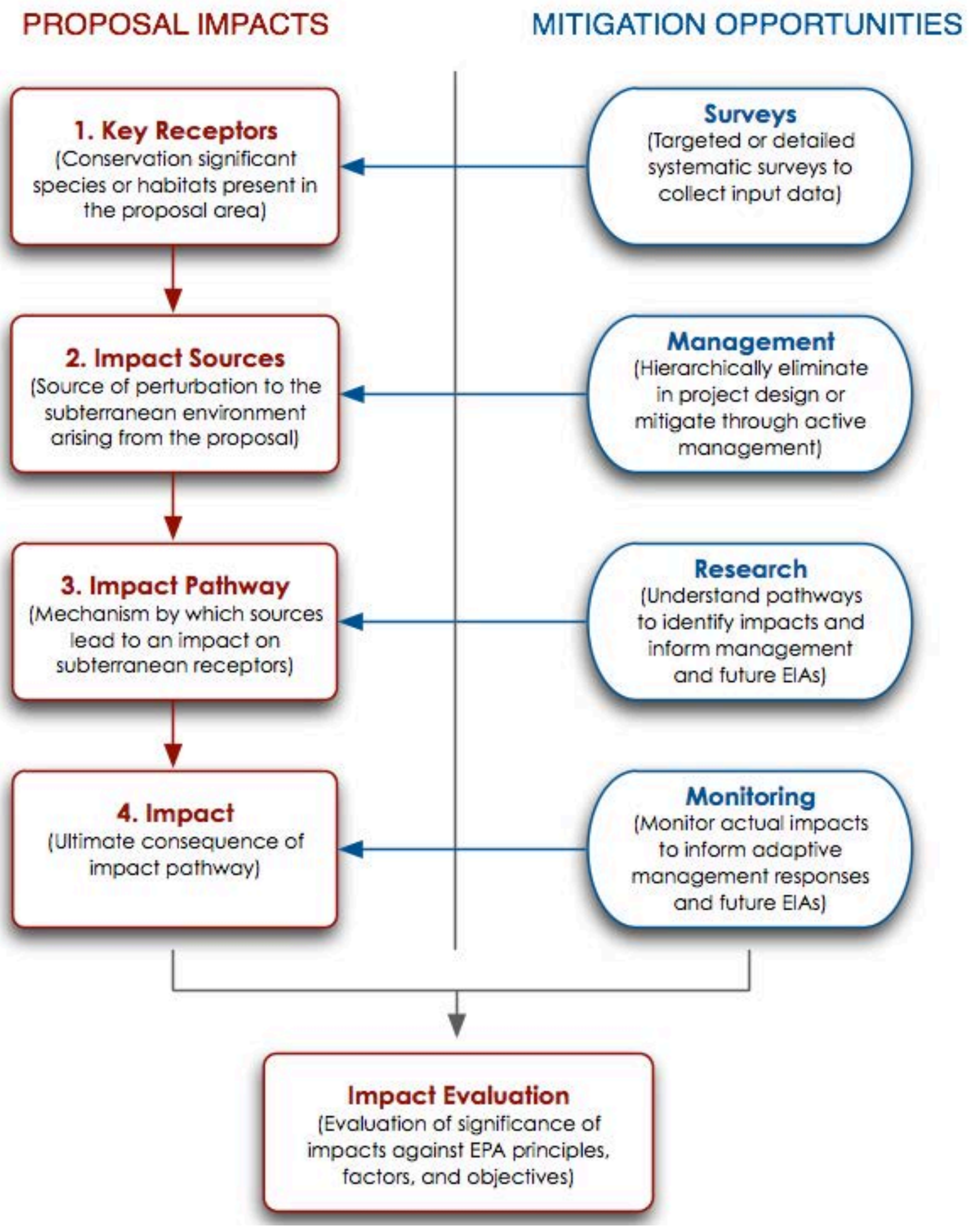

Figure 2.1: Environmental impacts assessment model used in this report.

Opportunities exist at each of the impact stages to address the impact sequence and mitigate the ultimate impact, via project design, management, research or appropriate monitoring and management response (Figure 2.1).

The identification of primary impact sources provides the first opportunity to reduce or eliminate potential impacts at the early project feasibility stage through design modifications (Figure 2.1). The Rio Tinto project design for the Mesa H proposal, and the adjustments already made by the proponent to eliminate impacts, have therefore been considered as part of this impact assessment.

Literature reviews for indirect impact pathways have been conducted previously and were leveraged to inform these assessments where relevant. Anecdotal observations and inference-based information on impact pathways from existing mining operations have also been considered in this impact assessment where informative for particular pathways and key receptors.

Opportunities usually exist for research or monitoring to better document the nature of actual impacts arising from identified pathways and to inform management at the final impact source tier (Figure 2.1). As these are effectively a lagging mitigation approach, they have not been considered in this impact assessment, given the current stage of the proposal's formal assessment.

2.6.2 Impacts

Impacts are the ultimate consequences of project impact pathways, and at a generic level they are reasonably well recognised. These consequences include impacts on key receptors such as:

- individual mortality;
- habitat loss;
- habitat fragmentation and population subdivision;
- reduced population viability; and
- local extinction.

The prediction of impacts should ideally be evidence-based, but the documentation of impacts is often subjective or anecdotal and there is a general paucity of empirical data from field programs that adequately quantify the impacts on subterranean ecosystems.

In recognition of this, impacts on key receptors were conservatively assessed on the basis of the identified impact pathways and giving consideration to two key criteria comprising:

1. spatial extent of the predicted impact (where this could be quantified), as a surrogate for population impacts; and
2. duration of the impact, considered as short-term (less than one year), long-term (years to decades), or permanent.

The extent, duration and magnitude of the impacts on the key receptors were placed into local and regional context to assist in assessing significance, considering:

- the documented and inferred distribution of the species or assemblage it forms part of;
- the spatial and vertical (2D and 3D) extent of suitable subterranean fauna habitats; and
- what is known or currently hypothesised in respect of subterranean fauna ecology, particularly whether species and communities are predisposed to impacts from a given pathway.

These considerations allowed the likely consequences and magnitude of the impact to be assessed, which was categorised as:

- Negligible: displacement or loss of individual animals;
- Minor: reduction of less than 10% of the known or inferred distribution and habitat extent;
- Moderate: reduction of 10-50%[1] of the known or inferred distribution and habitat extent; or
- Major: loss of more than 50%[1] of the known or inferred distributional extent and/or change in conservation status of the species.

[1] Derived from the International Union for the Conservation of Nature (IUCN) Red List criterion whereby a species' conservation state would shift from the Least Concern category to Vulnerable (IUCN 2012).

The level of certainty with which this assessment could categorise the risk of impacts on the key receptors was then assessed as:

- High: the outcome is quantifiable and can be predicted with confidence from a reasoned evidence base or the impact has previously occurred during similar mining developments;
- Medium: a reasonable body of data exist to predict the outcome and it could reasonably be expected to arise from the current proposal;
- Low: the outcome has not previously occurred during similar mining developments, but expert opinion or other data suggest it might arise, or there is insufficient information to quantify the impact.

2.6.3 Impact Evaluation

The significance of the identified impacts on the key receptors was then evaluated by reference to the EPA's objective for subterranean fauna, which comprises: "*To protect subterranean fauna so that biological diversity and ecological integrity are maintained.*" (EPA 2016a). Ecological integrity, in this context, is "*the composition, structure, function and processes of ecosystems, and the natural range of variation of these elements*" (EPA 2016a).

In practice, this is a somewhat challenging definition to objectively measure significance against for subterranean ecosystems in particular. Instead then, this impact assessment has adopted a more reductionist approach by addressing the specific items that EPA (2018) indicates the EPA will give regard to in determining whether an impact is significant.

Paraphrasing from EPA (2018) to those relevant to subterranean fauna and the current proposal, these comprise:

1. values, sensitivity and quality of the environment which is likely to be impacted – informed by the identification of key receptors (Section 2.4);
2. extent (intensity, duration, magnitude and geographic footprint) of the likely impacts, including cumulative impacts where appropriate – addressed here through the identification of impact sources and pathways arising from the proposal (Section 2.3);
3. consequence of the likely impacts (or change), including the resilience of the environment to cope with the impacts or change – addressed here as set out in Section 2.6.2; and
4. level of confidence in the prediction of impacts and the success of proposed mitigation – qualitatively assessed but within a defined framework, as set out in Section 2.6.2.

On this basis then, this impact assessment treats a significant impact (after EPA (2016a)) as a Moderate or Major impact on a key receptor that is predicted to arise with High or Medium certainty (following the criteria in Section 2.6.2).

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3.0 Project Definition

3.1 Development Envelope

The Mesa H project includes the development of above and below water table open cut iron ore mine pits and associated infrastructure, including water management infrastructure. The current indicative project design for the proposal is shown in Figure 3.1.

Based on Rio Tinto (2017a), and subsequent information on project revisions provided by Rio Tinto, the characteristics of the proposal comprise:

1. Mine pits - development of open above water table (AWT) and below water table (BWT) iron ore pits, including advance abstraction of groundwater to lower the water table to access the ore body.
2. Dewatering infrastructure – infrastructure including but not limited to bores, pipelines, and discharge outlet(s) to effect the dewatering of the ore body (Section 3.2).
3. Surplus water management – including but not limited to use in processing, on-site use and controlled discharge to the Robe River and tributaries.
4. Mineral waste management – including but not limited to backfilling, ex-pit waste dumps, low grade ore dumps, topsoil and sub-soil stockpiles.
5. Processing facilities – the project will be supported by the existing processing facilities at Mesa J but may require other processing facilities including but not limited to waste fines storage facilities.
6. Support facilities – including but not limited to workshops, power supply infrastructure, hydrocarbon storage, laydown areas, offices and wastewater treatment plants.
7. Surface water management – including but not limited to surface water diversion drains, levees and culverts.
8. Linear infrastructure – including but not limited to heavy vehicle and light vehicle access roads, upgrades to existing vehicle access roads; pipelines and power (including sub-stations) and communications distribution networks.
9. Water supply – utilising groundwater abstracted for dewatering, surface water that reports to pits, the existing Mesa J bore field (Southern Cutback bore field) and potential additional bores.

For the purposes of this impact assessment, and in the interests of conciseness, the proposal characteristics can be functionally grouped under five headings that present essentially similar potential impacts to subterranean ecosystems (Section 4.1). In reference to project characteristics 1 to 9 listed above, these categories comprise:

- **Mine pits**: 1. Mine pits;
- **Water management**: 2. Dewatering infrastructure and dewatering (Section 3.2), 3. Surplus water management and 9. Water supply;
- **Waste dumps and stockpiles**: 4. Mineral waste management;
- **Haul roads and access roads**: 8. Linear infrastructure; and
- **Processing and support infrastructure**: 5. Processing facilities, 6. Support facilities and 7. Surface water management.

Project characteristics are grouped under the five categories above for the balance of this impact assessment.

Rio Tinto has also identified a proposed Mining Exclusion Zone (MEZ), within which no mine pits will be created (Figure 3.1). The primary purpose of the MEZ is to provide for the retention of adequate troglofauna habitat to ensure that EPA's objectives for the Subterranean Fauna factor can be met.

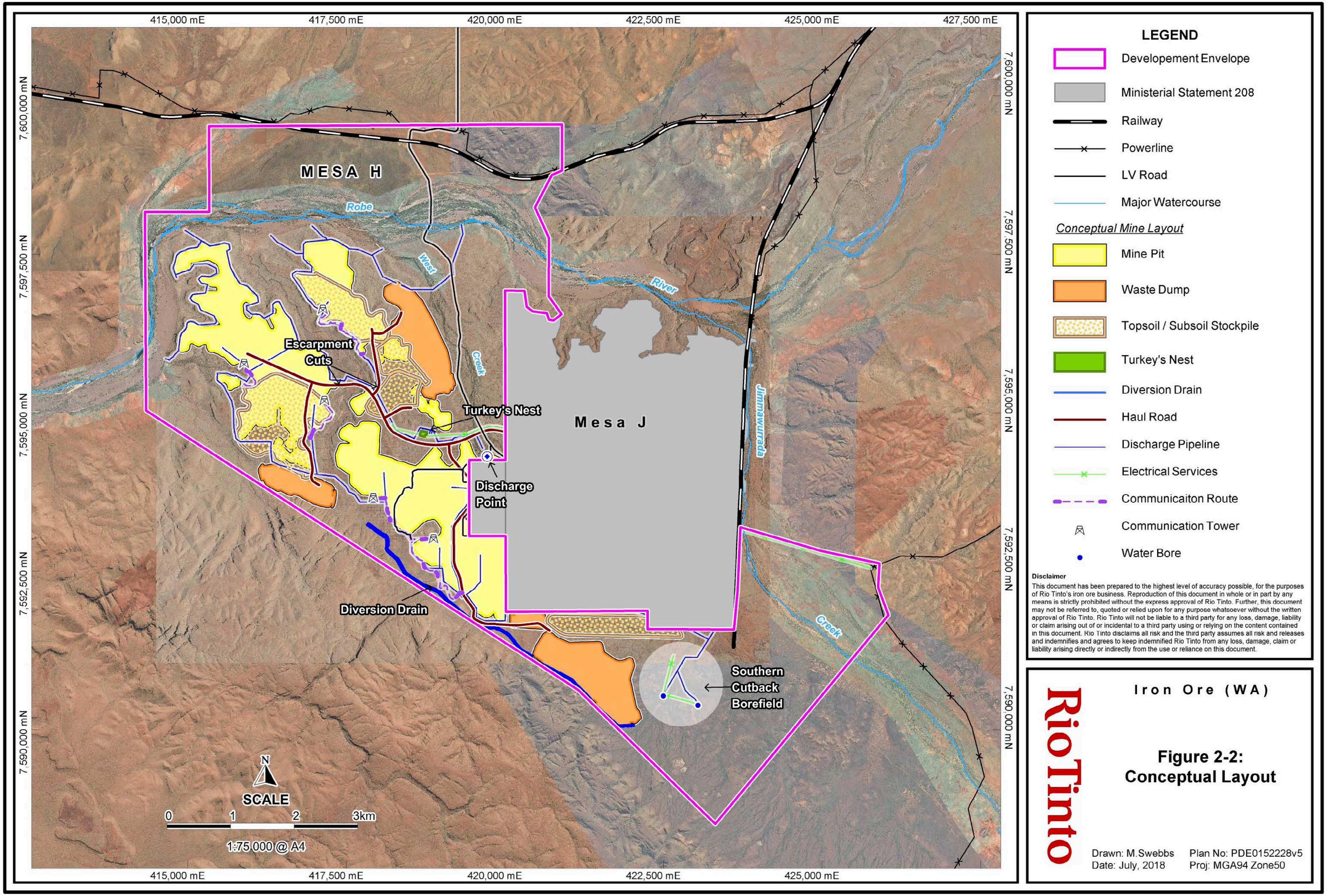


Figure 3.1: Development envelope and project footprint for the Mesa H proposal (source: Rio Tinto).

3.2 Dewatering Extent

Approximately 20% of the Mesa H ore body currently occurs BWT and dewatering will be required to access the ore. In addition, a water supply (proposed from the Southern Cutback Borefield) will be required to meet wet ore processing water demands. The combination of groundwater abstraction for BWT mining and cumulative drawdown from the borefield for operational supply will result in drawdown of the aquifer systems within the Development Envelope, with the drawdown extending outside of the Development Envelope to the east and southeast (see Figure 3.2).

In the northern portion of the development envelope, the Robe River is predicted to be impacted by less than 1 m of drawdown by the end of mining, which, given the magnitude and frequency of stream flow events, is unlikely to cause any permanent adverse impact to the alluvial aquifers of the system.

Updated hydrogeological modelling based on the inclusion of a thickener plant (Rio Tinto 2019a) estimates that drawdown will lower the water table across a 12 km section of Jimmawurrada Creek, with a maximum predicted drawdown of 9 m over a 6.5 km section (based on pre-mining water table levels) by 2030, mostly as a result of BWT mining at Mesa J. This is the base case impact prediction that is primarily assessed in this assessment. However, if natural recharge is reduced by 50% due to an extended period of drought, as per the H3 numerical model 'Uncertainty Run 2' (Rio Tinto 2019a), then the water table levels could be lowered by almost 3 m in addition to the natural seasonal fluctuations (2-3 m); this would translate to localised changes in water table depths of up to 14 m from pre-mining conditions, or ~18 m bgl by 2030. This latter drought scenario is addressed in the Environmental Review Document (ERD) for the Mesa H proposal, with the primary impact assessment scenario considered here the base case modelling for the maximum predicted drawdown under typical conditions at 2030.

Once mining is complete and dewatering ceases, groundwater levels in the Mesa J and Mesa H mining areas will recover until a balance is reached between groundwater inflows and groundwater outflows (Rio Tinto 2019a). In the event that pit voids are in-filled with waste / waste fines storage, groundwater levels will eventually recover to pre-development levels. The complete aquifer recovery is predicted to take up to 60 years, however, the majority of the drawdown along the Robe River and Jimmawurrada Creek is expected to recover after the first significant stream flow following a cyclonic event (Rio Tinto 2019a).

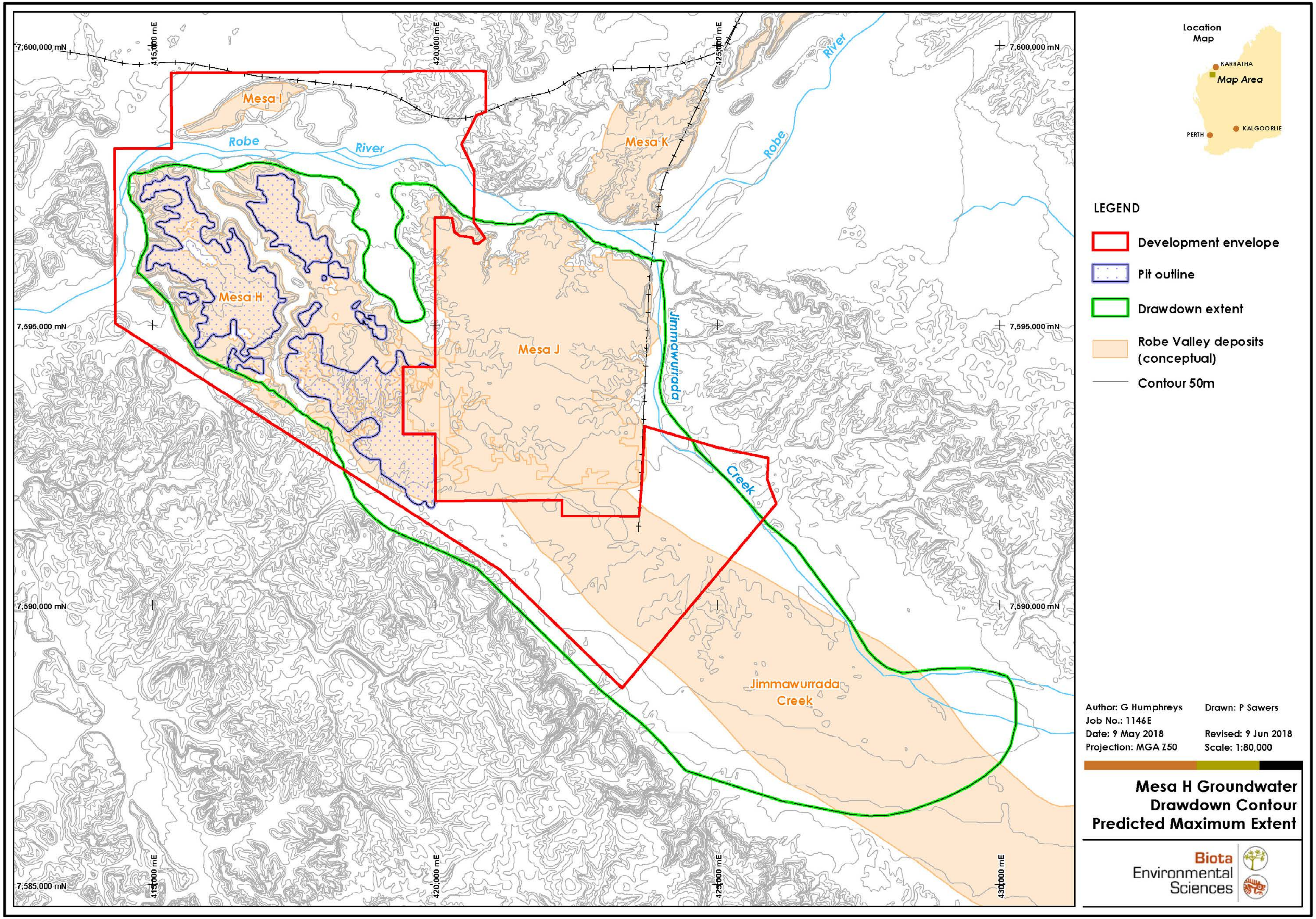


Figure 3.2: Maximum extent of predicted groundwater drawdown from the Mesa H proposal (base case year 2030, including the use of thickener in process water).

4.0 Potential Impacts

4.1 Impact Sources

A summary of the relevant characteristics of the Mesa H project, and the respective impact sources that they represent for subterranean ecosystems, is provided in Table 4.1.

Table 4.1: Summary of relevant characteristics of the Mesa H project and related impact sources.

Relevant Project Characteristics / Impact Sources					
Mine Pits	**Water Management**	**Waste Dumps and Stockpiles**	**Haul Roads and Access Roads**	**Processing and Support Infrastructure**	**Impact Pathway**
✓	-	-	-	-	Subterranean habitat excavation
✓	✓	-	-	-	Stygofauna habitat dewatering
✓	-	✓	✓	✓	Removal of vegetation
✓	✓	✓	✓	✓	Altered surface hydrology
✓	-	✓	✓	✓	Vibration
-	-	-	-	✓	Waste fines leakage
-	-	-	-	✓	Hydrocarbon spills

The pathways by which these impact sources may potentially impact on subterranean ecosystems are outlined in Section 4.2.

4.2 Impact Pathways

The sources of impact in Section 4.1 have the potential to affect key receptors via a range of impact pathways. These may either be direct (Section 4.2.1) or indirect (Section 4.2.2) and some impact sources may result in both types of impact pathways.

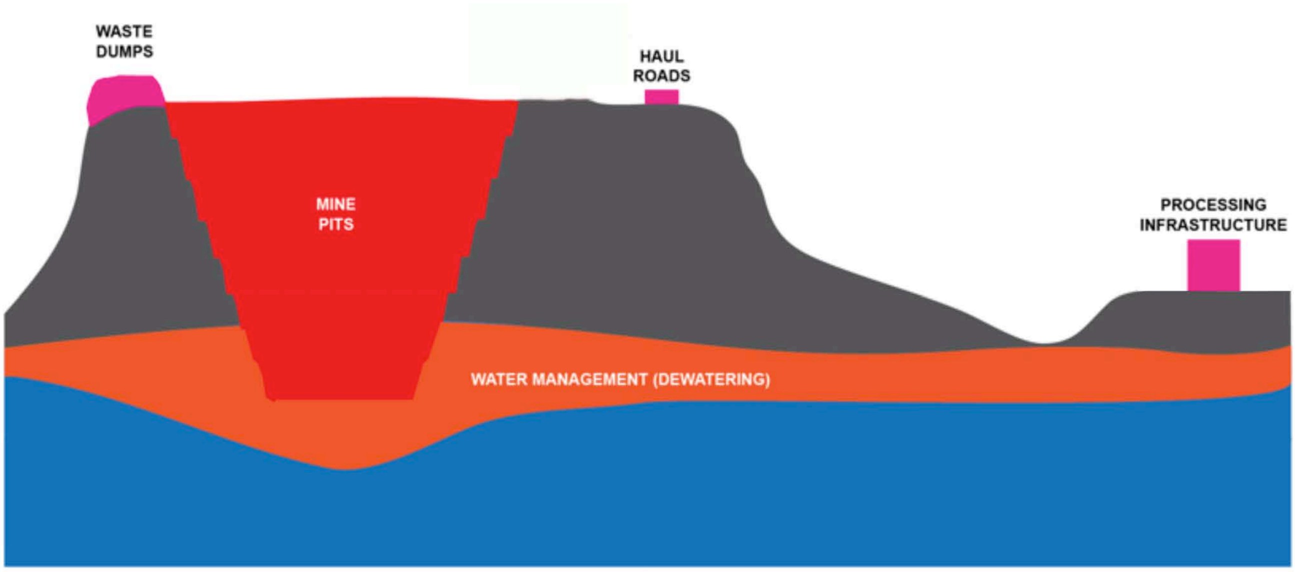
Figure 4.1 summarises the relationship between the impact sources, pathways and types of ultimate impacts on fauna that may arise from the Mesa H project.

4.2.1 Direct

The impact sources identified in Section 4.1 that may affect key receptors via direct impact pathways are:

- **Subterranean habitat excavation** – leading to habitat loss for both troglofauna and stygofauna, and direct loss of animals occupying the removed habitat, along with potential reduction in habitat quality in adjoining areas.
- **Stygofauna habitat dewatering** – leading to loss of saturated habitat for stygofauna, and presumed direct loss of animals utilising the dewatered habitat, and possible disturbance responses in individual animals to avoid dewatered areas.

These direct impacts are typically the most significant and primary impacts of the proposal on subterranean fauna receptors, and represent the key impact pathways considered in the balance of this assessment.



Impact Sources	Impact Pathways	Impacts
Mine pits	Excavation → Troglofauna and stygofauna habitat loss	Reduced diversity Reduced ecological integrity
Water management	Dewatering → Stygofauna habitat loss	Reduced diversity Reduced ecological integrity
Waste dumps and stockpiles	Removal of vegetation Sealing ground surfaces → Reduced nutrient input Reduced recharge Reduced humidity	Reduced habitat quality Reduced abundance
Processing and support infrastructure	Removal of vegetation Sealing ground surfaces → Reduced nutrient input Reduced humidity Reduced recharge Vibration Waste fines leakage → Sediment infiltration Hydrocarbon spills → Hydrocarbon infiltration	Reduced habitat quality Reduced abundance
Haul roads and access roads	Removal of vegetation Sealing ground surfaces → Reduced nutrient input Reduced humidity Vibration → Sediment infiltration	Reduced habitat quality Reduced abundance

Figure 4.1: Relationship between impact sources, pathways and impacts on subterranean ecosystems (direct impacts in red and orange; indirect impacts in pink).

4.2.2 Indirect

The impact sources identified in Section 4.1 that may indirectly affect key receptors are:

- **Removal of vegetation** – as the primary production that provides energy to subterranean ecosystems is assumed to be derived from surface autotrophy, removal of vegetation may lead to a reduction of energy and nutrient inputs, indirectly resulting in a reduction in subterranean habitat quality and the abundance and/or distribution of subterranean fauna;
- **Altered surface hydrology** – resulting in decreased recharge into water storage within troglofauna habitat (and the potential resultant long term change to humidity), increased run-off and reduced recharge to aquifers;
- **Vibration** – with the potential to generate increased sediment loads in the aquifer when sediment is mobilised into subterranean habitats during recharge events, and reduce habitat space in troglofauna habitat strata above the water table;
- **Waste fines seepage** – the proposal includes provision for a waste fines storage facility as part of product wet processing (Section 3.0), which may have some low-level leakage over time,

resulting in localised sedimentation of troglofauna habitat strata and underlying aquifers, but this will be consolidated with existing waste fines management facilities at the current Mesa J operations; and

- **Hydrocarbon spills** – resulting in localised reduction in groundwater quality and troglofauna habitat quality via small-scale pollutants spills and infiltration into subterranean habitat.

These indirect impact pathways, and the significance of their ultimate impacts, are less well demonstrated and the extent to which they actually result in impacts on subterranean fauna populations is poorly understood.

In the interests of a precautionary assessment, they have, however, been retained here as potential impacts and assessed separately in Section 7.0, but are considered lower-level, secondary impacts compared with the direct impacts identified in Section 4.2.1 above.

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5.0 Key Receptors Species and Communities

5.1 Stygofauna

5.1.1 Impact Area Species

A total of 855 stygofauna specimens were recorded over the five-phase stygofauna survey completed for the proposal, comprising at least 43 species-level taxa (Biota 2019). The recorded fauna was dominated by the Crustacea, which was represented by seven faunal groups and accounted for 98% of the specimens. Excluding indeterminate records, and allowing for species already recorded during the Mesa H survey, an additional 13 species were identified as occurring during the desktop review, bringing the total known fauna to 56 species (Biota 2019). A subtotal of 46 of these species occur within the immediate locality of Mesa H (Rio Tinto 2019b).

While the BWT mine pits are a direct impact (Section 4.2.1), the primary spatial context for the assessment of impacts on stygofauna is the wider groundwater drawdown extent that will arise from the cumulative dewatering required for the proposal (which takes into consideration groundwater drawdown from adjacent projects) (Section 3.2). The drawdown extent also encompasses the area that will be directly impacted by the pits themselves. It is therefore logical to identify the full set of stygofauna species and communities that occur within this extent as the starting point for impact assessment.

Table 5.1 lists the 32 stygofauna taxa documented by Biota (2019) that occur within the dewatering extent.

Table 5.1: All stygofauna species currently known from within the dewatering extent (Impact sites), and any records from outside of the dewatering extent (Reference sites) (species only known from the dewatering extent from desktop assessment records shown in grey; source: Biota (2019)).

Species	Impact Sites	Reference Sites
Oligochaeta		
Enchytraeus sp. 'AP PSS1'	BC186	Robe River valley
Gastropoda		
Hydrobiidae sp. 2**	JW023	-
Ostracoda		
Areacandona sp. 'BOS1039'**	BC186	31
Areacandona triangulum	BC186	MB16MEC0008, MB16MEC0009,West Pilbara
Areacandona brookanthana	JW023	Bungaroo, Ashburton plain
Areacandona lepte	JW011A	West Pilbara
Humphreyscandona fovea	JW021	Bungaroo, West Pilbara
Humphreyscandona waldockae	PSS160	West Fortescue valley
Humphreyscandona sp. 2	JW011A	West Pilbara
Pilbaracandona rosa	JW011A	West Pilbara
Pilbaracandona sp. 'BOS526'**	JW024	Dave Bore, MB17MEH0007
Candoninae sp. 'BOS541'**	JW024	-
Copepoda		
Diacyclops cockingi	JW021, JIMDD080	RR1, MB17MEH007, Common in the wider Pilbara
Diacyclops humphreysi humphreysi	DD13MEH0007, RC13MEH0007, MB17MEH0015, JW024	31, 87, RR1, MB16MEC0008, MB16MEC0009, MB17MEH0007, MB17MEH0009, MB17MEH0010, Common in the wider Pilbara
Halicyclops calm	JW023	Pilbara bioregion
Halicyclops rochai	JW023	Common in Western Australia
Stygoridgewayia trispinosa	BC186, DD13MEH0007, RC13MEH0007, RC13MEH0040, RC14MEH0018, RC14MMEH0053, JW024	25, 31, 32, 34, Dave Bore, Budgie Bore, RR1, MB16MEC0008, MB16MEC0009, MB17MEH0007, MB17MEH0009, MB17MEH0010, Common in the wider Pilbara

Species	Impact Sites	Reference Sites
*Megastygonitocrella unispinosa***	MB17MEH0015	Robe River valley
Parastenocaris sp. 'B28'**	JW023	-
Thermosbaenacea		
Halosbaena tulki	JW021, JW024	23, 31, West Pilbara, Barrow Island
Isopoda		
Kagalana tonde	JW021, JW023, JW024	RR1, 31, West Pilbara, Hardey River
Haptolana sp. 'B01'**	JW024	-
Amphipoda		
*Nedsia hurlberti**	JW021, JW011A	Bungaroo, Barrow Island
*Nedsia sculptilis**	JW021, JW011A	Bungaroo, Barrow Island
Nedsia sp. 'AMM001'	DD13MEH0007, RC12JIM0019, RC13MEH0040, RC13MEH0041, RC13MEH0097, RC14MEH0018, RC14MEH0053, RC16JIM0019, JW024	RR1, 25, 31, 32, 34, Budgie Bore
Nedsia sp. 'AMM026'**	RC13MEH0097	31
Paramelitidae sp. 'AMP003'**	RC13MEH0041	-
Paramelitidae sp. 'AMP035'**	RC13MEH0007	RR1
Paramelitidae sp. 'AMP037'**	BC186	-
Wesniphargus sp. 'AMN004'**	JW024	25
Neoniphargidae sp. 'B02'**	JW021	32
Vertebrata		
*Ophisternon candidum**	JW021, JW023, JW024, MB17MEH0015, BC186	RR1, Control, 25, RRD2, Cape Range

* Species formally listed under legislation as being of conservation significance.
** Species assessed as a potential SRE by Biota (2019) meeting potential SRE criteria.

Sixteen of the 32 species known from the dewatering extent (*Enchytraeus* sp. 'AP PSS1', *Areacandona triangulum, Areacandona brookanthana, Areacandona lepte, Humphreyscandona fovea, Humphreyscandona waldockae, Humphreyscandona* sp. 2, *Pilbaracandona rosa, Diacyclops cockingi, Diacyclops humphreysi humphreysi*, *Halicyclops calm, Halicyclops rochai*, *Stygoridgewayia trispinosa, Halosbaena tulki, Kagalana tonde* and *Nedsia* sp. 'AMM001'), are all relatively abundant and frequently recorded from Reference sites outside of the drawdown extent and/or have known wider distributions in the Pilbara bioregion (Biota 2019). While still informative for context to impact assessment, they are not retained as key receptors for the balance of this assessment as they are not restricted in distribution to the drawdown extent and will remain occurring more widely with the implementation of the Mesa H proposal. This leaves 16 stygofauna species as key receptors (three of conservation significance; Section 5.1.2.1 and 13 potential SREs; Section 5.1.2.2).

5.1.2 Key Receptors

5.1.2.1 Species and Communities of Conservation Significance

Two species of amphipod that occur within the drawdown extent (Table 5.1) are of conservation significance (Biota 2019) and are thereby key receptors for this assessment:

- the amphipod *Nedsia hurlberti* – Schedule 3 (State); and
- the amphipod *Nedsia sculptilis* – Schedule 3 (State).

An additional species of conservation significance, the Blind Cave Eel *Ophisternon candidum* (Vulnerable (Commonwealth); Schedule 3 (State)), occurs within the drawdown extent (Table 5.1) and is therefore also a key receptor for this impact assessment.

One PEC listed by DBCA occurs in the southeast of the drawdown extent (Biota 2019) and is a key receptor for this impact assessment:

- Stygofaunal Community of the Bungaroo Aquifer (Priority 1): "*A unique assemblage of aquatic subterranean fauna including eels, snails and other stygofauna. Threats include groundwater drawdown and mining*" (Department of Parks and Wildlife 2016).

5.1.2.2 Other Species of Significance

Thirteen of the stygofauna species known from the drawdown extent are considered to represent potential SRE fauna, half of which are amphipod taxa (Table 5.1; Biota 2019). As potential SREs, these species are key receptors for this impact assessment and comprise:

- the snail Hydrobiidae sp. 2;
- ostracod *Areacandona* sp. 'BOS1039';
- the ostracod Candoninae sp. 'BOS541';
- the ostracod *Pilbaracandona* sp. 'BOS526';
- the copepod *Megastygonitocrella unispinosa;*
- the copepod *Parastenocaris* sp. 'B28';
- the isopod *Haptolana* sp. 'B01';
- the amphipod *Nedsia* sp. 'AMM026';
- the amphipod Paramelitidae sp. 'AMP003';
- the amphipod Paramelitidae sp. 'AMP035';
- the amphipod Paramelitidae sp. 'AMP037';
- the amphipod *Wesniphargus* sp. 'AMN004'; and
- the amphipod Neoniphargidae sp. 'B02'.

5.2 Troglofauna

5.2.1 Impact Area Species

A total of 150 troglobitic specimens were collected across the six phases of sampling of the Mesa H survey area, with 32 additional specimens from past surveys identified in desktop review (Biota 2019). The survey specimens represented five classes and nine orders, with 32 species-level taxa identified. The orders Coleoptera and Schizomida were the greatest contributors to faunal composition, accounting for 33% and 25% of the specimens, respectively (Biota 2019). Excluding indeterminate records, two additional species (*Barrowdillo* sp. 1 and *Troglarmadillo* sp. 1) were identified as occurring within the development envelope from historical surveys, bringing the total known fauna to 34 species.

Unlike stygofauna, the development envelope fully encompasses all the direct impact sources relevant to troglofauna (Section 4.1) and it therefore sets the spatial context to identify species known from within the proposal impact area. Again unlike stygofauna, there were no Reference sampling sites in the Biota (2019) survey and all sites sampled for troglofauna were inside the development envelope. All 34 species recorded at Mesa H therefore occur within the development envelope.

Table 5.2: All potential SRE troglofauna species currently known from within the development envelope (Impact sites), and any records from outside of the development envelope (Reference sites) (species only known from the development envelope from desktop assessment records shown in grey; source: Biota (2011; 2019)).

Species	Impact Sites	Reference Sites
Pseudoscorpiones		
Hyidae sp.'PH017/PH027'	RC14MEH0252, RC16MEH0264	-
Hyidae sp. 'PH026'	RC16MEH0436	-
Olpiidae sp. 'PO008'	RC15MEH0302	-
Beierolpium sp. 'PO014'	RC16JIM0026	-
Beierolpium sp. 'PO015'	RC16MEH0433	-
Atemnidae sp. 'PA004'	RC15MEH0329	-
Chthoniidae sp. 'PC014/PC015'	GR15MEH0015, RC15MEH0315, RC15MEH0335	-

Species	Impact Sites	Reference Sites
Chthoniidae sp. 'PC055'	MEHRD0834	-
Schizomida		
Paradraculoides sp. 'SCH038'	MEHRC157, RC15MEH0329, RC16MEH0264, RC16MEH0433	-
Paradraculoides sp. 'SCH039'	RC15MEJ0019	-
Hubbardiidae sp. 'SCH011'	J0866, J0867, J0928, MEJ0007, MEJ0048, MEJ0076, MEJ0085, J0866, MEJ5548alt, RC08MEJ0015, RC08MEJ0004, RC08MEJ0023, MEHRC0724	Mesa J (MEZ)
Hubbardiidae sp. 'SCH015/SCH016'	DD13MEH0007, RC12MEH0221, RC14MEH0252, RC15MEH0306, RC16JIM0026, RC16JIM0031, MEHRC0724, MEHRD0870	Redgate
Myriapoda		
Cryptopidae sp. 'SC18'	RC14MEH0388	-
Diplura		
Parajapygidae sp. 'DPA001'	RC14MEH0308	-
Parajapygidae sp. 'DPA009'	MEHRD0758	-
Projapygidae sp. 'DPR008/DPR009/DPR011'	RC15MEH0166, RC15MEH0175, RC15MEH0261, RC16JIM0005	-
Projapygidae sp. 'DPR010'	RC16JIM0005	-
Japygidae sp. 'DJA003'	RC14MEH0388	-
Japygidae sp. 'DJA011'	DD13MEH0007	-
Campodeidae sp. 'DCA005'	GR15MEH0032	-
Isopoda		
Philosciidae sp. 'ISP047'	RC15MEH0382	-
Philosciidae p. 'ISP055'	RC15MEH0427	-
Barrowdillo sp. 1	MEHRDO752, MEHRD0776	-
Troglarmadillo sp. 1	MEHDC0865	-
Troglarmadillo sp. 'ISA046'	RC15MEH0382	-
Armadillidae sp. 'ISA056/ISA057'	MEHRD0577, MEHRD0834	Mesa C
Coleoptera		
Curculionidae sp. 'CCU014'	RC12MEH0221, RC14MEH0252, RC15MEH0302	-
Ptilidae sp. 1/'CP003'	RC16MEH0264, RC12MEH0221	Warramboo
Ptilidae sp. 'Robe Valley'/'CP002'	RC14MEH0238	Robe Valley
Zygentoma		
Nicoletiinae sp. 'TN019'	RC16JIM0006	-
Nicoletiinae sp. 'TN020'	RC14MEH0252	-
Araneae		
Prethopalpus sp. 'ARA052'	RC16JIM0019	-
Gnaphosidae sp. indet. *	RC14MEH0270	-
Blattodea		
?*Nocticola* sp. 'West Pilbara Complex'	RC12MEH0221, RC16MEH0427	Red Hill

* Gnaphosidae sp. indet. was the only specimen of its family and was retained as a discrete troglobitic taxon (Biota 2019).

Six of the 34 troglofauna species known from the development envelope; Hubbardiidae sp. 'SCH011', Hubbardiidae sp. 'SCH015/SCH016', Armadillidae sp. 'ISA056/ISA057', Ptilidae sp. 1/'CP003', Ptilidae sp. 'Robe Valley'/'CP002' and ?*Nocticola* sp. 'West Pilbara Complex', all have documented wider distributions in the region (Table 5.2; Biota 2019).

While the five species of stygofauna known from outside of the dewatering extent were not retained as key receptors (Section 5.1.2), they were very widespread and common in the region, whereas the six troglofauna species with records outside of the development envelope still only have relatively restricted distributions in the Robe Valley, most of which are also subject to potential impacts from other proposals (see Table 5.2). To provide a conservative assessment, they are therefore still retained as key receptors, meaning all 34 troglofauna species known from the development envelope are treated as key receptors for this assessment (Section 5.2.2.2).

5.2.2 Key Receptors

5.2.2.1 Species and Communities of Conservation Significance

No formally listed troglofauna species are known from the Mesa H development envelope (Biota 2019).

Two PECs listed by DBCA occur within the development envelope (Biota 2019) and are key receptors for this impact assessment:

- Subterranean invertebrate communities of mesas in the Robe Valley region (Priority 1): "*A series of isolated mesas occur in the Robe Valley in the state's Pilbara Region. The mesas are remnants of old valley infill deposits of the paleo Robe River. The troglobitic faunal communities occur in an extremely specialised habitat and appear to require the particular structure and hydrogeology associated with mesas to provide a suitable humid habitat. Short range endemism is common in the fauna. The habitat is the humidified pisolitic strata. Threats include mining*" (Department of Parks and Wildlife 2016); and
- Subterranean invertebrate community of pisolitic hills in the Pilbara (Priority 1): **"***A series of isolated low undulating hills occur in the state's Pilbara region. The troglofauna are being identified as having very short range distributions. Threats include mining*" (Department of Parks and Wildlife 2016).

While two separate PECs are recognised by DBCA, for the purposes of this impact assessment they are effectively the same ecological community, being the troglofauna assemblage occurring within Mesa H. The distinction appears to largely be driven by whether the landforms with the extents mapped by DBCA are mesas (the former PEC) or less well formed mesas / hills (the latter), though in practice these landforms are not always clearly delineated in the locality and both contain subterranean assemblages of conservation value.

5.2.2.2 Other Species of Significance

The 34 development envelope species are all regarded as potential SRE fauna (Biota 2019) and are therefore key receptors for this impact assessment.

Twenty of the 34 species were singletons, making comment on their potential wider distributions difficult, but they have been conservatively retained here as potential SRE taxa and key receptors to provide a precautionary assessment.

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6.0 Key Receptor Habitats

6.1 Stygofauna Habitat

Groundwater within the Development Envelope occurs predominantly within three key aquifers:

- Robe River and Jimmawurruda Creek alluvial aquifers: extensive and unconfined superficial aquifer consisting of Quaternary alluvial sediments (shingles, conglomerates and coarse sand), deposited along the contemporary surface drainages with an approximate 20 m thickness and average width of 400 m along the Robe River (Rio Tinto 2017b). The alluvium associated with Jimmawurruda Creek varies in depth from approximately 24 m thickness in the southeast, increasing up to 40 m in thickness in the northwest reaches closest to Mesa H (see Figure 6.1).
- CID aquifer: an unconfined aquifer consisting of CID pisolitic sediments below Mesa H with an average of 20-30 m thickness below the pre-mining water table; and
- Wittenoom aquifer: a largely confined aquifer underlying the CID aquifer, consisting of weathered dolomite and dolomitic shale (Paraburdoo and Bee Gorge Member) and weathered Banded Ironstone Formation (BIF; Marra Mamba Iron Formation) with a thickness of approximately 25 m.

Pre-mining depth to groundwater within the Mesa H CID aquifer is generally between 25 and 45 m below surface within higher elevation areas, but the water table is considerably shallower in the Robe River and Jimmawurruda Creek alluvial aquifers. Depth to pre-mining groundwater in these alluvial aquifers ranges from approximately 4 – 12 m below surface along Jimmawurruda Creek, and approximately 2 – 5 m below surface along the Robe River. These groundwater levels fluctuate by up to 3 m seasonally, depending on climatic variability and rainfall patterns.

The basal Robe Pisolite (Tpb) is a 5 -10 m thick layer deposited at the base of the CID Aquifer, consisting of a variable clay-rich pisolite. While its hydraulic properties have not yet been defined, the largely impermeable physical characteristics of the unit mean it is expected to function as a partial barrier to groundwater flow between the CID Aquifer and the underlying Wittenoom Aquifer (Rio Tinto 2017b).

The Robe River and Jimmawurrada alluvium aquifers and the CID aquifers, are the most likely to provide habitat for stygofauna, based on their physical and hydraulic characteristics. In addition to the extensive data sets that exist from sampling of equivalent aquifers in the locality, the Robe River and Jimmawurrada alluvium aquifers are the primary groundwater system that provides habitat to stygofauna in the wider locality, having yielded many stygofauna records. The Mesa H CID aquifer, while deeper and thereby likely to host less fauna (Section 2.5.1), is also structurally suitable as stygofauna habitat and has some existing data to confirm that stygofauna utilise the aquifer. Given its depth, confined nature, lower transmissivity host rock, and limited connectivity to more superficial systems, the Wittenoom Aquifer is considered unlikely to represent significant habitat for stygofauna.

While detailed aquifer definition exists for the development envelope, this is not available for the wider locality. The aquifers that provide stygofauna habitat at Mesa H broadly correspond to the regional surface geology map units (1:250,000) and more detailed 1:10,000 local Rio Tinto geological mapping available for the locality and provide a means of setting wider context to the stygofauna habitats of the dewatering extent. The units that represent High or Medium likelihood stygofauna habitat within the dewatering extent and the wider locality are summarised in Table 6.1 and mapped in Figure 6.2. All stygofauna records from the locality were plotted on these habitat units (Figure 6.2) and visualised in a three-dimensional isometric view (Figure 6.3).

Table 6.1: Geology units identified as stygofauna habitat in the dewatering extent and wider locality.

Code	Unit	Description	Likelihood to Support Stygofauna (Attributes; Section 2.5.3)
Qr	Alluvium	Unconsolidated fluviatile deposits.	High (A, B, C, D, E, F)
Ql	Lacustrine deposits	Clay, silt; saline in part, flood deposits. Unconsolidated fluviatile and sheet flood deposits in levees and river terraces.	High (A, B, C, E, F)
Qg/Czc	Colluvium	Partly consolidated valley-fill deposits; Unconsolidated to loosely consolidated slope deposits	High (A, C, D, E, F)

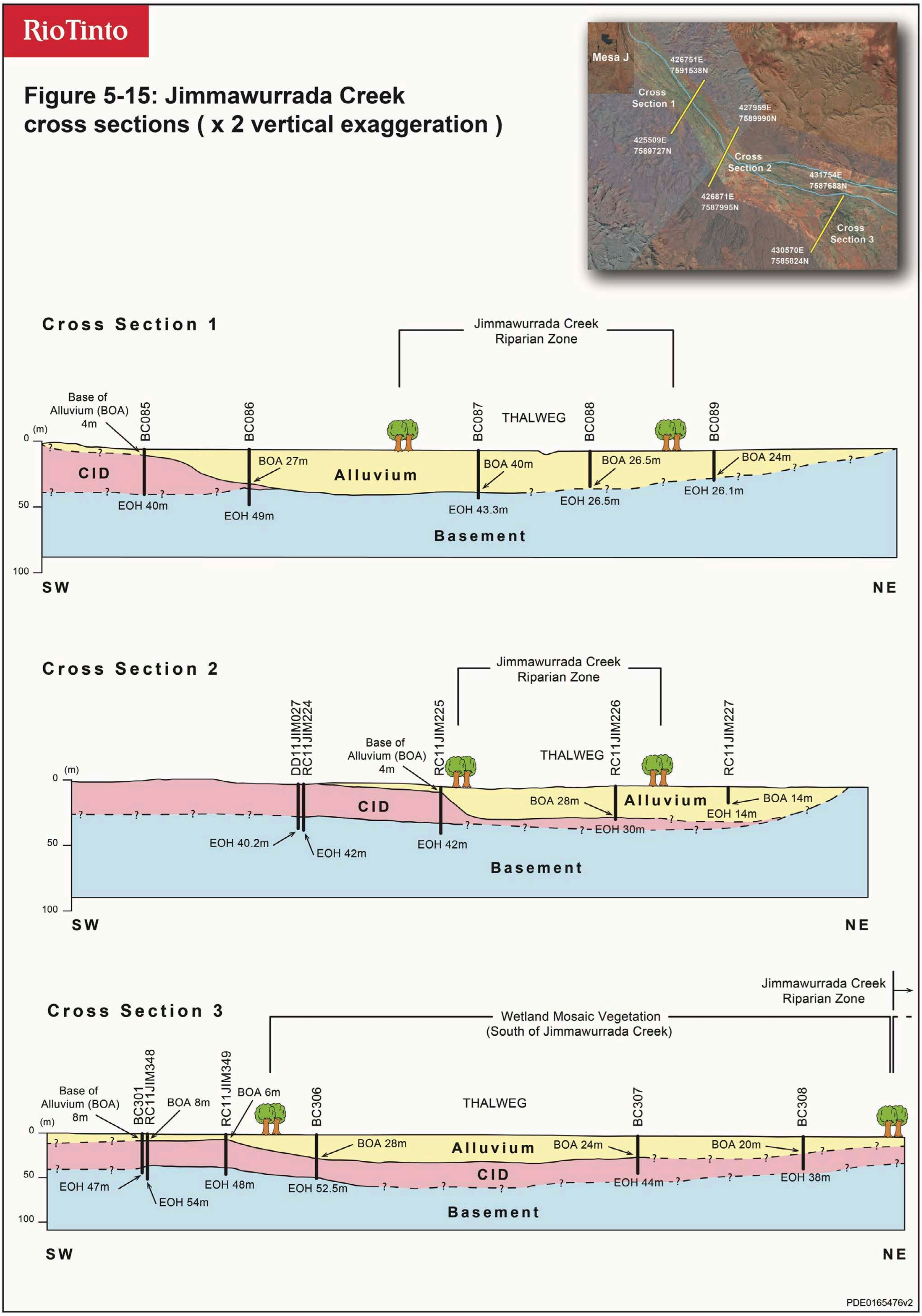

Figure 6.1: **Cross-sections of Jimmawurrada Creek, showing depth of alluvium relative to underlying CID and basement units in difference sections of the creek (source: Rio Tinto).**

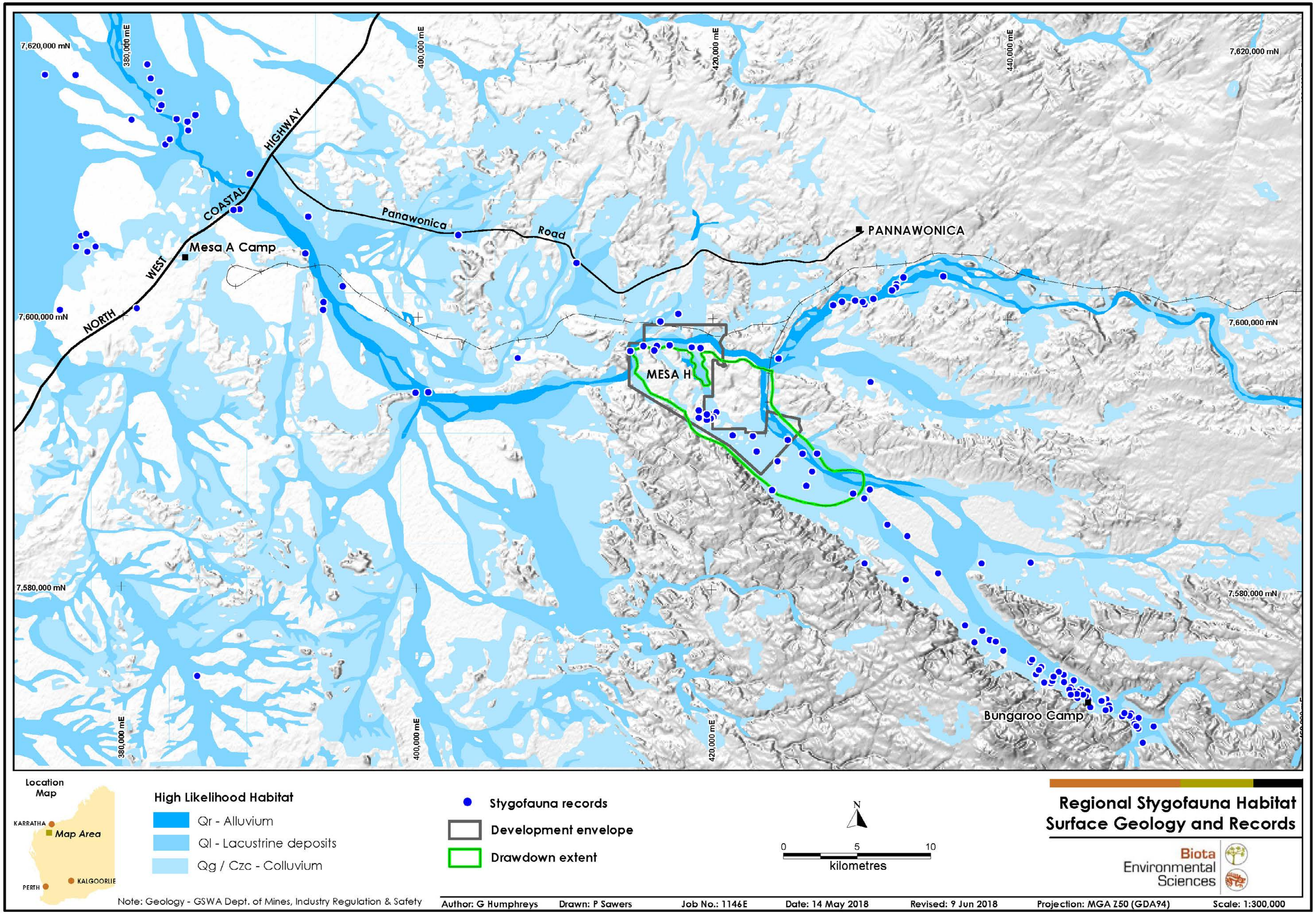

Figure 6.2: Surface geology units representing stygofauna habitat showing spatial relationship with confirmed stygofauna records.

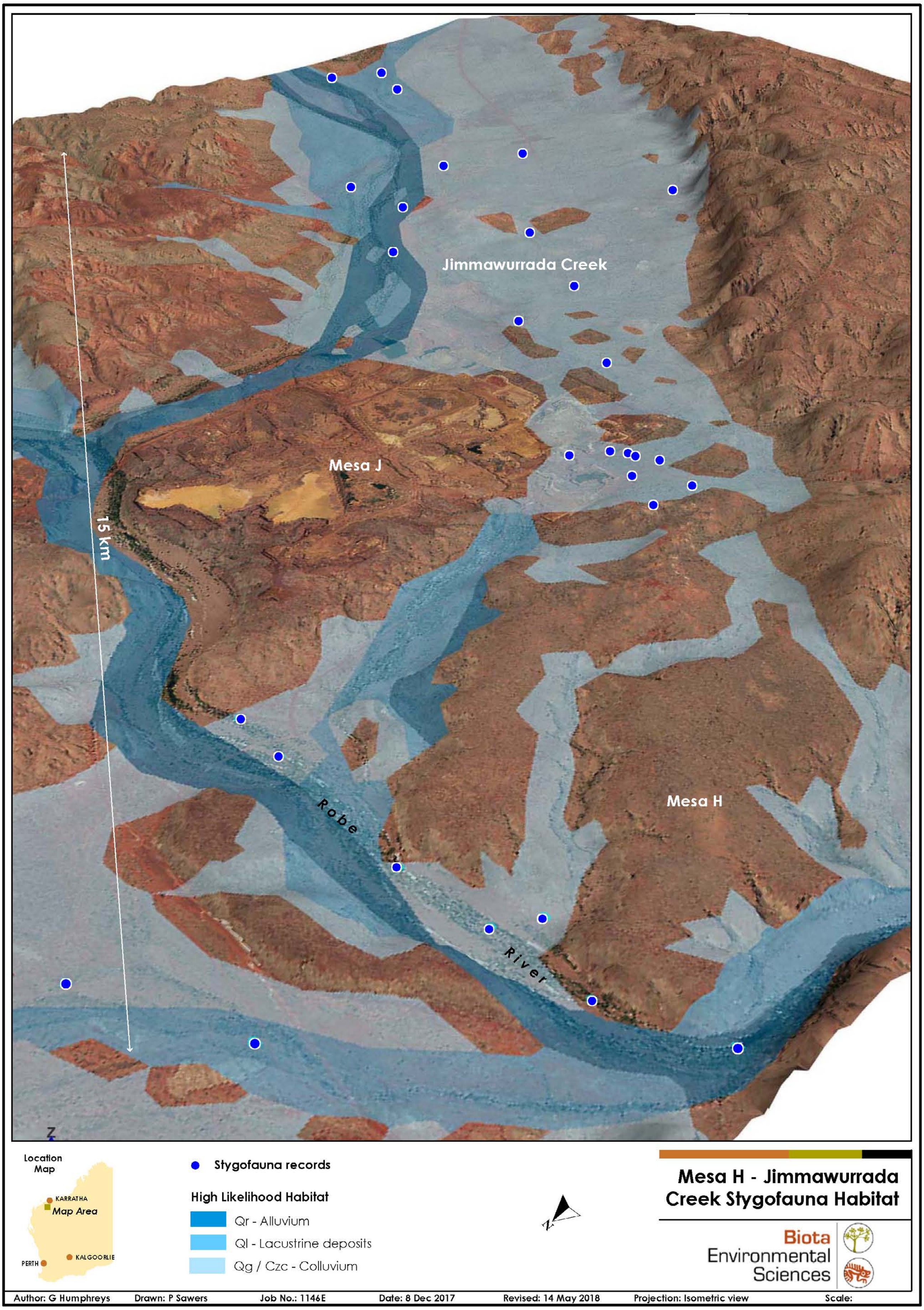

Figure 6.3: **Isometric view of stygofauna habitat at Mesa H, overlain with the locations of confirmed stygofauna records.**

These show a strong spatial correlation with stygofauna record locations, with 129 of the 133 known stygofauna locations falling within units mapped as High likelihood habitat (97%) (Figure 6.2). The landscape setting of these units also confirms that these habitats occur as low elevation valley fill units (Figure 6.2 and Figure 6.3).

Given their structural suitability, and this high level of validation from confirmed fauna records, the regional mapping units can be reliably used to set wider context to the impacts of the proposal on stygofauna habitat (Section 7.1). Subsequent three-dimensional geological mapping completed by Rio Tinto using 'Leapfrog' modelling software (Appendix 1) has also validated this approach across the Development Envelope and within the predicted impact areas for the proposal.

6.2 Troglofauna Habitat

Mesa H is one of several CID deposits that comprise the Robe Pisolite Formation; a series of paleodrainage channels that meander through the Robe River valley. CIDs are often preserved in an inverted topography as mesas landforms which are remnants of ancient palaeochannels in the landscape (Ramanaidou et al. 2003).

The Mesa H development envelope includes 13 surface geology units (Biota 2019). By area however, the majority of the development envelope is accounted for by just two of these units: colluvium, accounting for 36%, and the CID Robe Pisolite Formation (a further 33%) (Biota 2019). (Figure 6.4; Table 6.2). Both of these geological units have been shown to represent suitable habitat for subterranean fauna in the Robe valley and the wider Pilbara region, with CID / Robe Pisolite in particular recognised as core habitat for troglofauna (Section 2.5.2).

At a finer scale, Rio Tinto classify CID deposits such as Mesa H into intra pisolite strata or 'strands', based on mineral grade, clay content and other structural and textural features (Figure 6.4; Table 6.2). The CID strands that represent troglofauna habitat at Mesa H comprise:

Tp - Tertiary pisolite;

Tpb - Basal Tertiary pisolite, which ranges from conglomeratic to clay rich, and relatively vuggy at Mesa H;

Tpc - Tertiary pisolite with clay strata;

Tpd - Denatured Tertiary pisolite, similar to Tpm but with less clay;

Tph - Hard competent pisolite (mostly below water table at Mesa H);

Tpm - 'Mixed' Tertiary pisolite composed of altered other pisolitic strands including hydrated material (mostly below water table at Mesa H); and

Htp - Hardcap – weathered / altered pisolite and goethite, containing many vugs and cavities (mostly superficial at Mesa H)

The prospectivity of the geological units within the development envelope to represent troglofauna habitat was characterised as High, Medium or Low likelihood, based on relevant habitat attributes and how these are represented within the development envelope (see Section 2.5.4).

Following these criteria, the Robe pisolite (Tp) represents core habitat for troglofauna within the development envelope, being broadly assessed as High likelihood of troglofauna occurring, with the strands present at depth within the pisolite (Figure 6.4) mostly also either High or Medium likelihood (Table 6.2). Two other units were identified as having Medium likelihood for fauna to occur, comprising colluvium and Wittenoom formation (Table 6.2; Figure 6.4), and this likelihood is increased when the units occur in contact with the adjacent and underlying Robe pisolite as they do within the development envelope. These units were considered to represent potential troglofauna habitat by EPA (2013), and the Robe Pisolite unit was also used as the basis for mapping the local extent of the two troglofauna PECs that occur in the development envelope (Section 5.1.2.1).

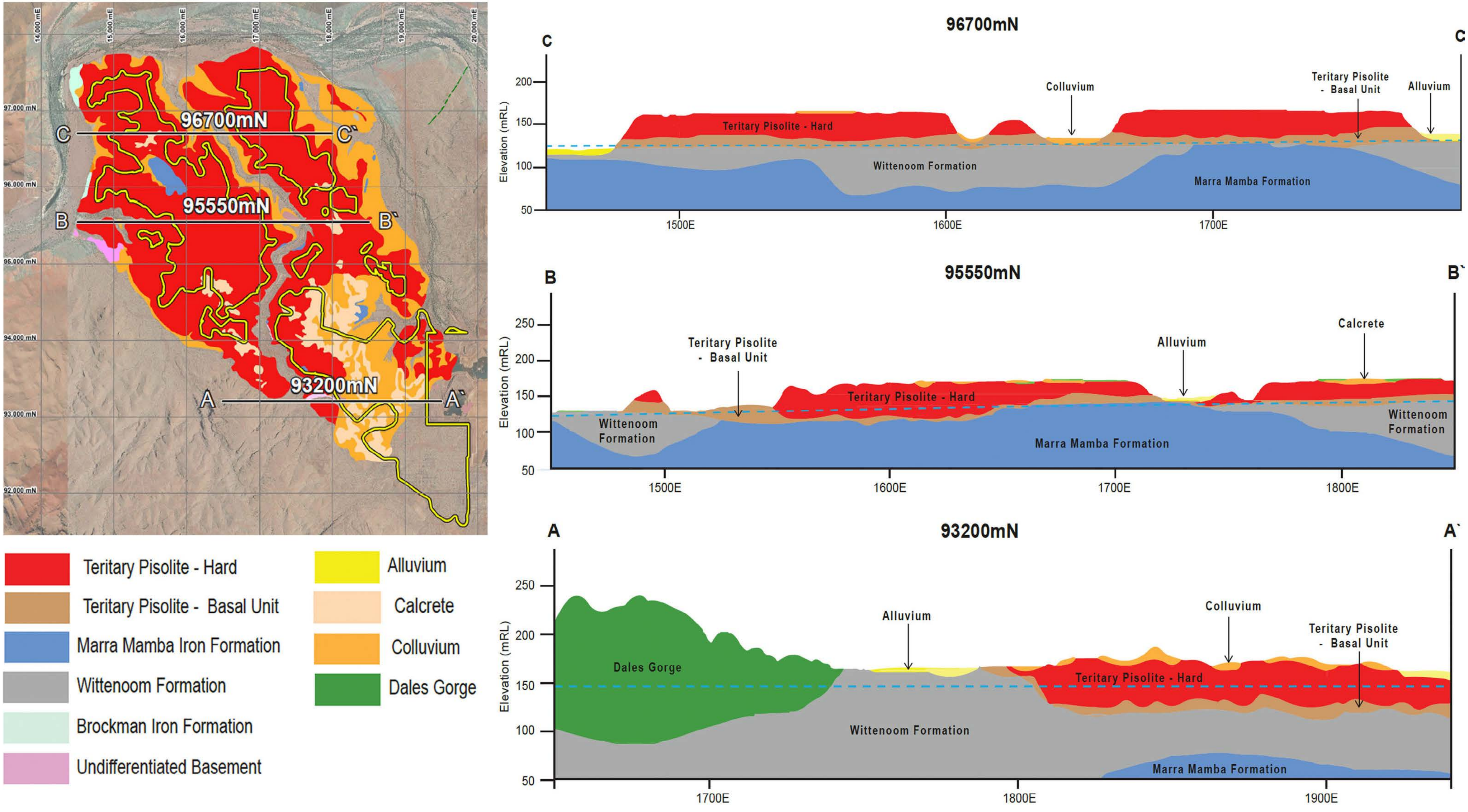

Figure 6.4: **Mesa H surface geology (left) and cross-sections (right) illustrating troglofauna habitat strata at depth across three sections of Mesa H (A, B and C)** (blue horizontal line on cross-sections represents approximate water table depth).

Table 6.2: Geological units identified as troglofauna habitat within the development envelope.

Code	Unit	Description	Likelihood to Support Troglofauna (Attributes)
Tp	Robe Pisolite	Tertiary pisolitic limonite deposits, which Rio Tinto stratigraphically classifies into strands of:	High (A, B, C, D, E)
	Tpb	Basal, clay and pisolite	Medium (A, B, C)
	Tpc	Clay bands	Low (C)
	Tpd	Denatured and friable ore	Low (C)
	Tph	Competent hard pisolitic ore	High (A, B, C, D, E)
	Tpm	Mix of Tpc, Tpd and Tph	Medium (A, C, E)
	Htp	Hydrated Tertiary pisolite	High (A, B, D, E)
Qg	Colluvium	Unconsolidated to loosely consolidated slope deposits	Medium (A, D, E)
Wd	Wittenoom Formation	Calcitic dolomite	Medium (A, D, E)

Basal pisolite (Tpb) underlies the other Tertiary pisolite strata, and is often below water table in the development envelope (e.g. cross-sections A and B on Figure 6.4). Tpb is, however, still at least Medium likelihood troglofauna habitat in the development envelope in locations where it occurs above water table (e.g. cross-section C on Figure 6.4) (Table 6.2). This is primarily due to its higher frequency of vugs and cavities at Mesa H specifically compared to basal pisolite in other parts of the Robe valley.

Cross-section C of Figure 6.4 also intersects the central creek gorge system that runs north-south through Mesa H, where Tpb outcrops to the surface and also laterally adjoins and overlies dolomite as part of the Wittenoom Formation (shown in grey on Figure 6.4). This latter unit, while not specifically identified in Table 6.2 as it is mostly below water table at Mesa H, also has potential to provide troglofauna habitat in the areas where it is above water table, given it contains cavities and vugs, and that it is in contact with the primary Tertiary pisolite habitat (a Medium likelihood rating; attributes A, D, E; Table 6.2). Additionally, the hydrological and recharge function of this central creek gorge system is likely to deliver water to the subterranean habitats of the Mesa H landform during major recharge events; a key functional process for sustaining humidity and providing organic inputs to subterranean ecosystems (Biota and DC Blandford & Associates 2013).

Rio Tinto provided modelled AWT CID (based on 3D modelling from drillhole data) from across the development envelope and surrounds (Appendix 1) and this was used to generate CID thickness contours to effectively map troglofauna habitat (using the Medium and High likelihood strands from Table 6.2 with a minimum of 5 m thickness AWT). This was then refined spatially on the basis of aerial photography overlain on a digital terrain model to inspect landforms and arrive at a mapped extent of habitat informed by both three-dimensional geology and geomorphology.

All troglofauna records from Mesa H were then plotted on the mapped habitat to provide independent validation of the intrinsic habitat assessment (Figure 6.5). This showed that the landforms associated with the mapped troglofauna habitat have a very strong spatial correlation with known troglofauna distribution, with 98% of the record locations falling within units mapped as habitat (Figure 6.5). Figure 6.6 depicts the habitat in a landscape isometric view, illustrating this strong relationship with mesa and hill landforms. This includes troglofauna records from the central creek gorge system at Mesa H, providing validation of the assessment of basal pisolite (Tpb) overlaying Wittenoom dolomite as troglofauna habitat (Figure 6.6).

The identified troglofauna habitat units can therefore be relied upon as a framework for the balance of this impact assessment.

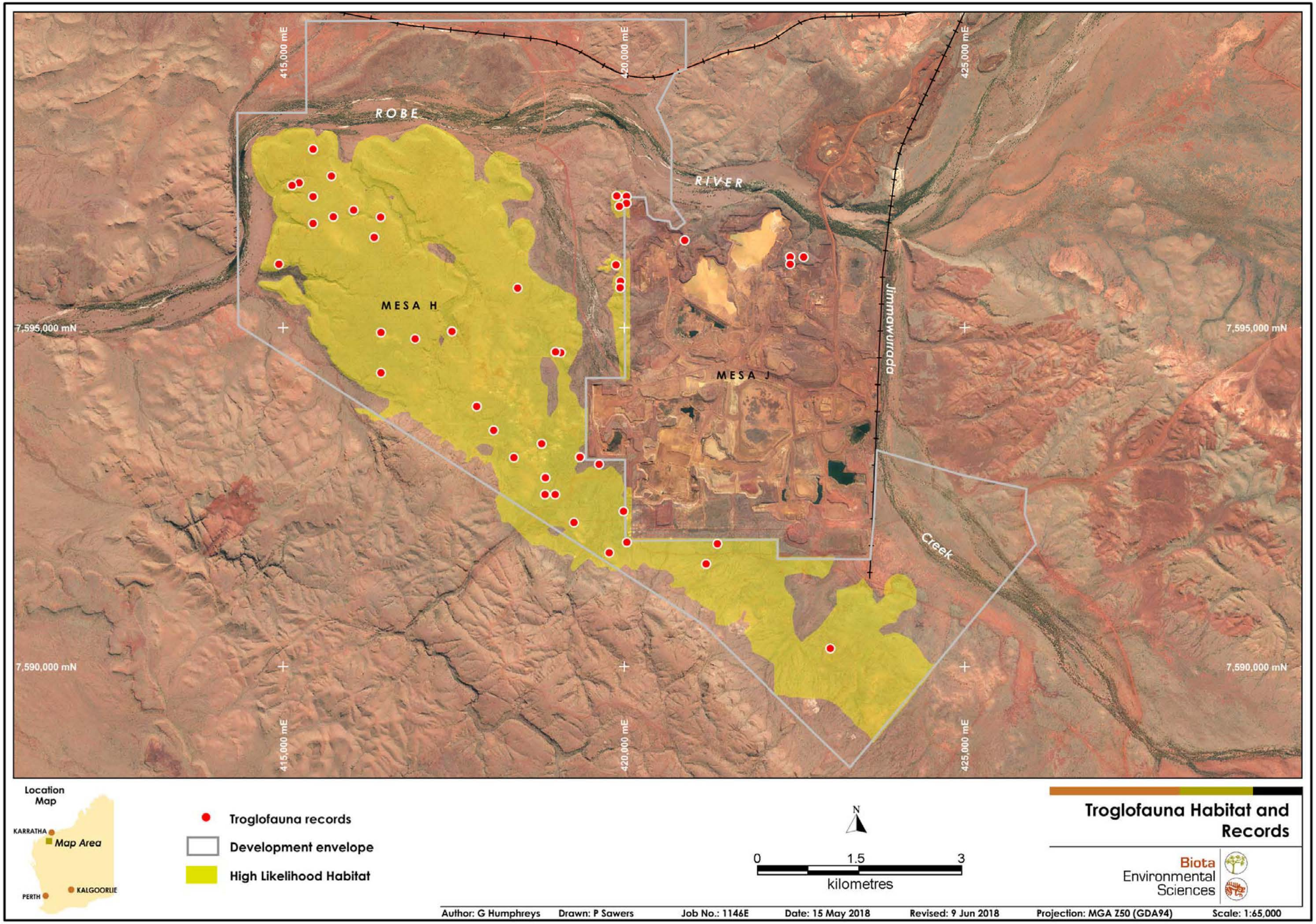

Figure 6.5: High likelihood troglofauna habitat in the development envelope showing spatial relationship with confirmed troglofauna records.

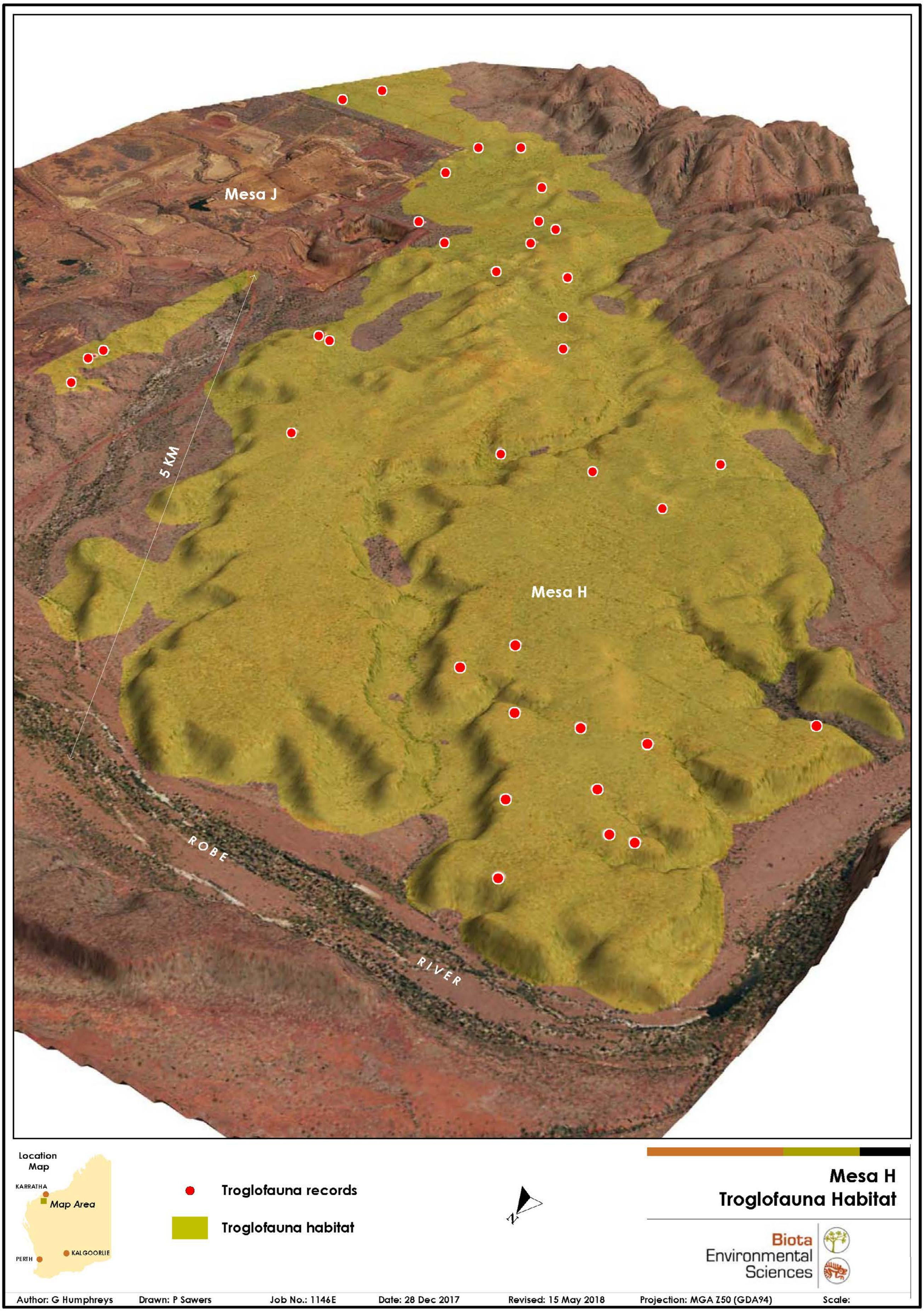

Figure 6.6: Isometric view of troglofauna habitat at Mesa H, overlain with the locations of confirmed troglofauna records.

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7.0 Impact Assessment

7.1 Stygofauna Impacts

Sixteen of the 32 stygofauna species known from the dewatering extent are either of listed conservation significance or are potential SRE taxa, and represent the key stygofauna receptors for this impact assessment (Section 5.1.2).

The 16 relevant species comprise:

- Blind Cave Eel *Ophisternon candidum* – Vulnerable (Commonwealth), Schedule 3 (State);
- the amphipod *Nedsia hurlberti* – Schedule 3 (State);
- the amphipod *Nedsia sculptilis* – Schedule 3 (State);
- the snail Hydrobiidae sp. 2 (potential SRE);
- ostracod *Areacandonda* sp. 'BOS1039' (potential SRE);
- the copepod *Megastygonitocrella unispinosa* (potential SRE);
- the ostracod Candoninae sp. 'BOS541';
- the ostracod *Pilbaracandona* sp. 'BOS526';
- the copepod *Parastenocaris* sp. 'B28';
- the isopod *Haptolana* sp. 'B01';
- the amphipod *Nedsia* sp. 'AMM026' (potential SRE);
- the amphipod Paramelitidae sp. 'AMP003' (potential SRE);
- the amphipod Paramelitidae sp. 'AMP035' (potential SRE);
- the amphipod Paramelitidae sp. 'AMP037' (potential SRE);
- the amphipod *Wesniphargus* sp. 'AMN004'; and
- the amphipod Neoniphargidae sp. 'B02' (potential SRE).

At the ecological community level, there is a single stygofauna key receptor (Section 5.1.2.1):

- Stygofaunal Community of the Bungaroo Aquifer (Priority 1).

7.1.1 Direct Impacts on Stygofauna Key Receptor Species

Direct impacts on stygofauna species comprise both habitat removal where the mine pits extend below water table and the dewatering necessary to enable this to occur (Section 4.2.1). While it is possible stygofauna may be able to actively respond to declining water table levels and move to habitat that remains viable, it is currently assumed that saturated habitat strata that are completely dewatered are no longer viable habitat and the individuals of species utilising those strata are conservatively considered to have been lost due to mortality. Where habitat strata have a substantial saturated thickness, and dewatering would only partially affect this; leaving connected viable habitat, the species would be likely to locally persist.

Sixteen of the 32 receptor species that occur within the dewatering extent have been recorded from Reference sites outside of the drawdown extent and have been commonly recorded elsewhere within the wider Pilbara bioregion (Section 5.1.1). While individuals of these species will be impacted by the mine pits and dewatering, no changes to their conservation status would be predicted given their wider distributions.

Figure 7.1 shows the distribution of the remaining 16 key receptor species relative to the mine pits and the maximum modelled drawdown extent for the proposal, and Table 7.1 summarises the sites they occur at and the level of predicted groundwater drawdown impact.

Ten of 16 key receptors have also been recorded from Reference sites outside of the drawdown extent (Table 7.1). Three of these 10 more widely-recorded species, *Ophisternon candidum*, *Nedsia hurlberti* and *Nedsia sculptilis*, are of formally listed conservation significance, so, while all three are also known from outside the drawdown extent, they are provided specific consideration in Section 7.1.2 in recognition of their elevated conservation status.

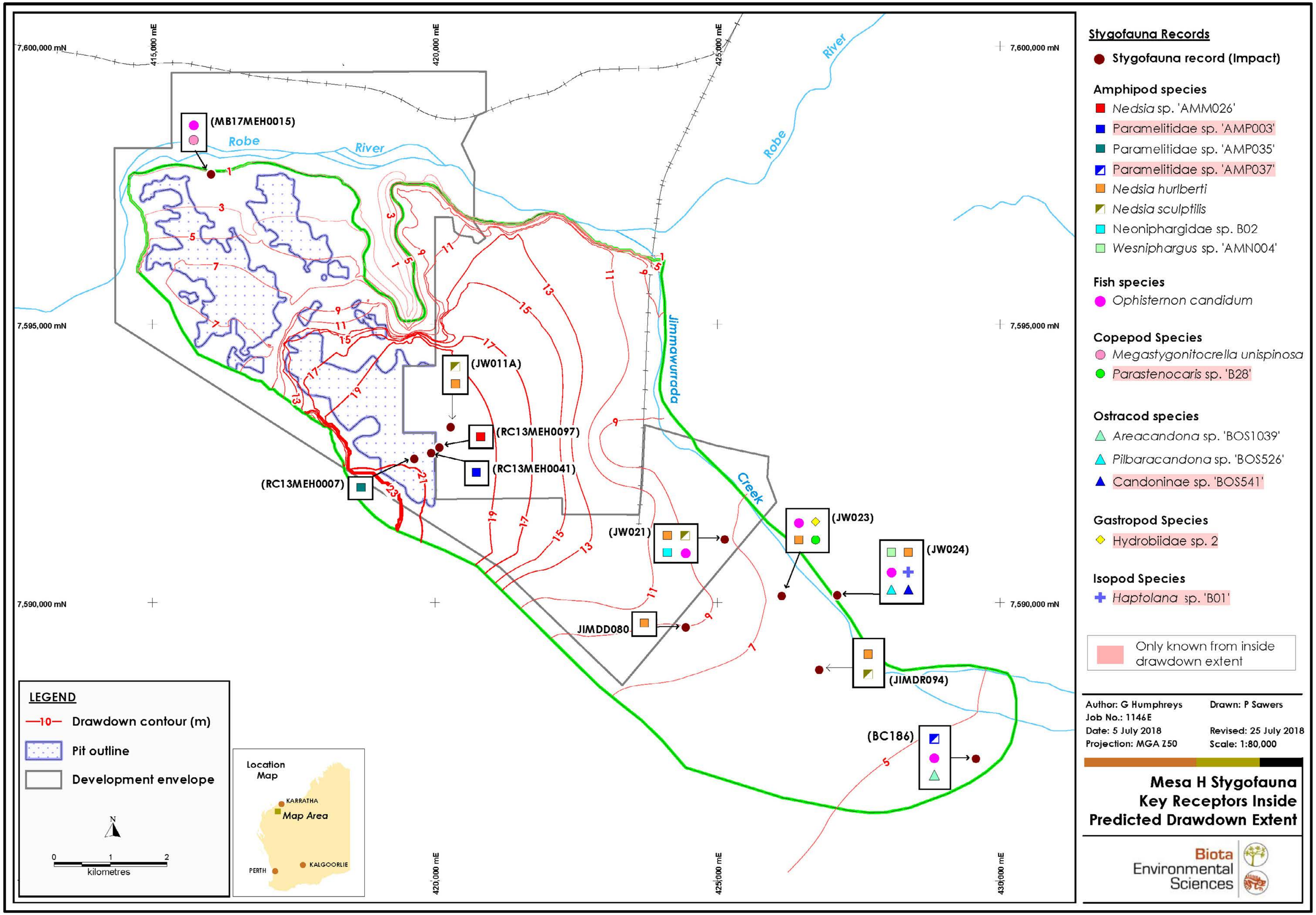

Figure 7.1: Distribution of stygofauna species key receptors within the maximum (2030 base case) proposal drawdown extent.

The other seven key receptors with demonstrated wider distributions would not be placed at significant risk to a change in their conservation status. Three of these species, *Areacandona* sp. 'BOS1039', *Nedsia* sp. 'AMM026' and Neoniphargidae sp. 'B02', were all recorded from outside of the drawdown extent at Reference site 31 further upstream on the Robe River, in the Pannawonica town bore field area ((Biota 2019); Table 7.1). *Megastygonitocrella unispinosa, Pilbaracandona* sp. 'BOS526', *Wesniphargus* sp. 'AMN004' and Paramelitidae sp. 'AMP035', have also been recorded more widely in the Robe River valley, outside of the drawdown extent (Table 7.1).

Table 7.1: Summary of records of impacted stygofauna key receptors relative to the maximum predicted drawdown extent at 2030 under the base case (Reference sites from Biota (2019); Species shaded grey known only from the drawdown extent).

Species	Impact Sites	Predicted Drawdown (m)	Reference Sites; Wider Distribution
*Ophisternon candidum**	MB17MEH0015	1	RR1, 25, RRD2, Control, Cape Range
	JW021	7	
	JW023	6	
	JW024	6	
	BC186	4	
*Nedsia hurlberti**	JW011A	20	Bungaroo Creek headwaters,
	JW021	7	Barrow Island
	JW023	6	
	JW024	6	
	JIMDD080	9	
	JIMDR094	6	
*Nedsia sculptilis**	JW011A	20	Bungaroo Creek headwaters,
	JW021	7	Barrow Island
	JIMDR094	6	
Hydrobiidae sp. 2	JW023	6	-
Areacandona sp. 'BOS1039'	BC186	4	31
Megastygonitocrella unispinosa	MB17MEH0015	1	Robe River valley
Candoninae sp. 'BOS541'	JW024	6	-
Pilbaracandona sp. 'BOS526'	JW024	6	Dave Bore, MB17MEH0007
Parastenocaris sp. 'B28'	JW023	6	-
Haptolana sp. 'B01'	JW024	6	-
Nedsia sp. 'AMM026'	RC13MEH0097	20	31
Paramelitidae sp. 'AMP003'	RC13MEH0041	20	-
Paramelitidae sp. 'AMP035'	RC13MEH0007	21	RR1
Paramelitidae sp. 'AMP037'	BC186	4	-
Wesniphargus sp. 'AMN004'	JW024	6	25
Neoniphargidae sp. 'B02'	JW021	7	31

* Formally listed as being of conservation significance

This leaves six species of stygofauna that are currently known only from the drawdown extent and, from the most precautionary perspective, are potentially restricted in distribution to that area: the aquatic snail Hydrobiidae sp. 2, the ostracods Candoninae sp. 'BOS541', the copepod *Parastenocaris* sp. 'B28', the isopod *Haptolana* sp. 'B01', and two amphipod species: Paramelitidae sp. 'AMP003' and Paramelitidae sp. 'AMP037' (Table 7.1; Figure 7.1).

Four of these six species, Hydrobiidae sp. 2, Candoninae sp. 'BOS541', *Parastenocaris* sp. 'B28' and *Haptolana* sp. 'B01', were recorded from two sites in close vicinity along Jimmawurruda Creek: JW023 and JW024 (Figure 7.1 and Table 7.1). The stygofauna habitat in this area is a sequence of saturated alluvium associated with the creek that is approximately 22-24 m in thickness down to the underlying CID (Figure 7.2). The two sites are on the eastern margin of the predicted drawdown for the proposal (Figure 7.1), with a maximum drawdown of >7 m on the pre-mining water table (Table 7.1 and Figure 7.1). Uncertainty in the model and seasonal water level fluctuation could have under-predicted the maximum drawdown, but it is expected that at least 15 m of alluvium will remain saturated below water table in the area where the four species have been recorded with the implementation of the proposal (see Figure 7.2). In the unlikely event that these species are restricted in distribution to this very small locality, this will still represent a refuge habitat at the time of peak dewatering for the project, which is expected to remain hydraulically connected to saturated alluvium habitat along the length of Jimmawurrada Creek, and will be seasonally connected to a greater extent during major rainfall events (Figure 7.2). These two potentially restricted key receptors are therefore not at significant risk of taxon-level impacts from the dewatering.

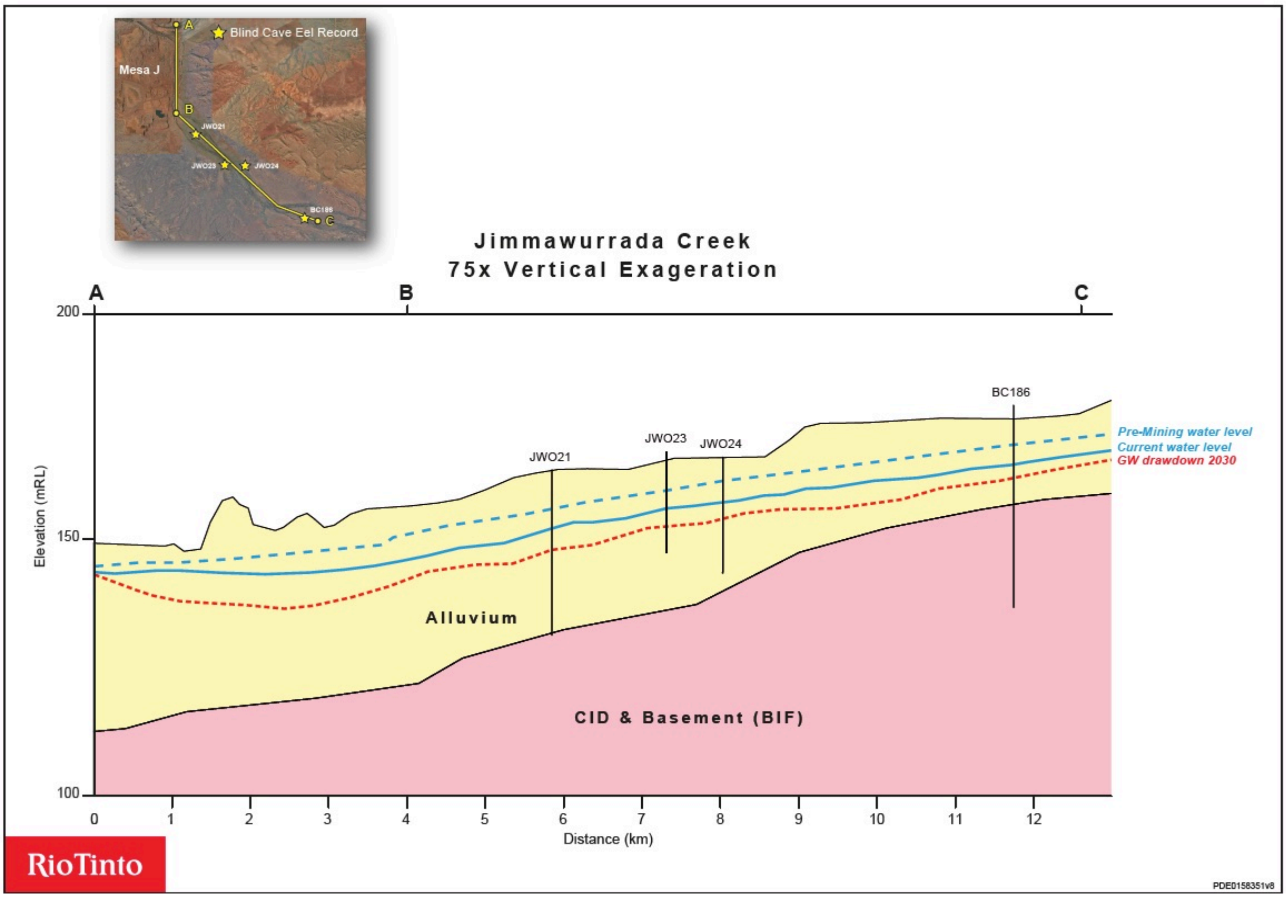

Figure 7.2: Longitudinal cross-section along Jimmawurrada Creek area, showing pre-mining water table, predicted maximum drawdown from the proposal in 2030 (dashed in red) and alluvial and CID stygofauna habitats that will remain saturated (below the red dashed line) (source Rio Tinto).

This leaves the amphipod species Paramelitidae sp. 'AMP003' and Paramelitidae sp. 'AMP037' as the last two species currently known from the drawdown extent. Both are only known from a single Impact site and both will be more substantially affected by the predicted drawdown:

- Paramelitidae sp. 'AMP003' would be the most substantially affected, having been recorded from site RC13MEH0041 within the proposed mine pit area, which will be subject to approximately 20 m drawdown in the water table (Table 7.1; Figure 7.1) and direct habitat removal from mine pit development. Given the location of the site beneath the Mesa H landform, it appears likely that this species occurs at least within the CID aquifer.
- Paramelitidae sp. 'AMP037' was recorded at the southeast limits of the drawdown extent at site BC186, which will be drawn down by >5 m below the pre-mining water table (Table 7.1; Figure 7.1). This site intersects the alluvial aquifer of the Jimmawurrada – Bungaroo Creek system, which represents the habitat the species was recorded from.

The key impact assessment question for these taxa is whether they are truly restricted to their currently recorded sites or actually occur more widely. This can be evaluated on the basis of multiple lines of evidence, utilising both physical and biological information:

1. **Animal abundance**
   Both species are represented by a single specimen only. With singleton taxa such as these it is difficult to determine if their apparent restriction is real or simply that they are actually more widespread but naturally at low abundance and/or difficult to collect with conventional methods. In cases where species are readily collected in good numbers, but are only ever detected from closely neighbouring sites, it is less likely that the restricted distribution is due to sampling effects and more likely it is genuine. This is not the case with the two amphipod species in question, with only a single individual each, therefore a probability exists that the result is due to ecological sampling effects.

2. **Groundwater habitats**
   It appears likely that Paramelitidae sp. 'AMP003' occurs within the CID aquifer, which is relatively confined and limited horizontally in the locality (Rio Tinto 2017b). The degree of hydraulic connection between the CID aquifer and the wider alluvial aquifers of the locality is not well defined, but basement groundwater flow may connect it with the Robe River aquifers to the north (Rio Tinto 2017b). The CID in this area is also inter-connected to the southeast with the broader Jimmawurrada – Bungaroo CID aquifer and overlying colluvium (Figure 6.1 and 6.2).

   Paramelitidae sp. 'AMP037' was recorded from site BC186, which intersects the widespread, highly transmissive and connected alluvial aquifer associated with Jimmawurrada Creek (Section 6.1), which overlies a substantive CID aquifer.

3. **Assemblage distribution**
   Paramelitidae sp. 'AMP003' was collected from site RC13MEH0041. Only one other stygofauna species was recorded from this same sampling site: *Nedsia* sp. 'AMM001' (Biota 2019) which, at a broad level, is morphologically and ecologically similar to Paramelitidae sp. 'AMP003' but occurs widely in the locality, covering a minimum distribution of 501 km^2 based on records from the Biota (2019) survey alone. That result does not indicate a higher risk of Paramelitidae sp. 'AMP003' being locally restricted in distribution, and conversely that it, too, may be more likely to follow a similar distribution pattern to the related, sympatric amphipod species. These observations also lend support to the view above that the CID aquifer beneath Mesa H is connected by groundwater flow to the wider Jimmawurrada – Bungaroo CID aquifer which is directly connected to the Jimmawurrada alluvial aquifer, which in turn is a tributary into (and connected to) the Robe River alluvial aquifer: if this were not the case, it would be very unlikely that *Nedsia* sp. 'AMM001' from site RC13MEH0041 would have remained so genetically similar to other individuals in the wider locality (Biota 2019).

   Multiple other stygofauna species co-occur at site BC186 with Paramelitidae sp. 'AMP037': *Enchytraeus* sp. 'AP PSS1' (which also occurs 39 km away downstream in the Robe River); *Areacandona* sp. 'BOS1039' (also at site 31 at the Pannawonica bore field); *Stygoridgewayia trispinosa* (also at 18 other sites along the length of the Robe Valley up to 59 km away); *Areacandona triangulum* (also recorded at three Reference sites up to 41 km away) and *Ophisternon candidum* (recorded from six other sites along Jimmawurrada and the Robe River) (Biota 2019). With the exception of the singleton Paramelitidae sp. 'AMP037', every other species recorded from site BC186 is more widely distributed within the Robe River valley. As these taxa span a range of body sizes, morphologies and ecologies, their locally widespread distributions do not indicate any evidence of local barriers to fauna dispersal and gene flow for stygofauna, which by inference would also apply to Paramelitidae sp. 'AMP037' at the same site.

4. **Distributions of closely-related taxa**
   Seventeen other Amphipoda species were recorded by Biota (2019), including four other taxa belonging to the same family as Paramelitidae sp. 'AMP003' and P. sp. 'AMP037'. Revisiting point 1 above regarding low frequency taxa: it is notable that all of the paramelitids were detected from few (or in many cases one) individuals, including two other singleton species (Biota 2019). The only paramelitid amphipod species that was recorded from more than one

site was Paramelitidae sp. 'AMP035', which was recorded within the drawdown extent at site RC13MEH0007 but has been shown to also occur outside of this impact area (Table 7.1). That site is immediately adjacent to site RC13MEH0041, where Paramelitidae sp. 'AMP003' was collected, and the distribution of the more widely recorded, but closely-related, Paramelitidae sp. 'AMP035' then suggests that Paramelitidae sp. 'AMP003' may also occur more widely.

The above lines of physical and biological evidence are all parallel in suggesting connectivity between site RC13MEH0041 (where Paramelitidae sp. 'AMP003' was recorded) and the wider Robe River aquifers and stygal assemblage, and similarly for BC186 (Paramelitidae sp. 'AMP037') and the wider habitats in the locality. Data from other co-occurring species, related amphipod taxa and groundwater habitat information do not signal a high degree of isolation in stygofauna species in the locality of either site where the singleton species were recorded. It appears unlikely that either of the two amphipod species would be truly restricted to the dewatering extent and more likely that their current apparently restricted distributions are due to ecological sampling effects.

7.1.2 Direct Impacts on Conservation Significant Species

Individuals of the Schedule-listed amphipods *Nedsia hurlberti* and *Nedsia sculptilis* will not be directly impacted by the mine pits, but will be impacted by the cumulative dewatering at multiple record sites, with approximately 20 m of groundwater drawdown predicted at JW011A where both species have been historically recorded (Table 7.1).

However, while both species are listed as Schedule 3 at State level, they also occur more widely, both in the west Pilbara and as far afield as Barrow Island (Table 7.1; Figure 7.3; Figure 7.4).

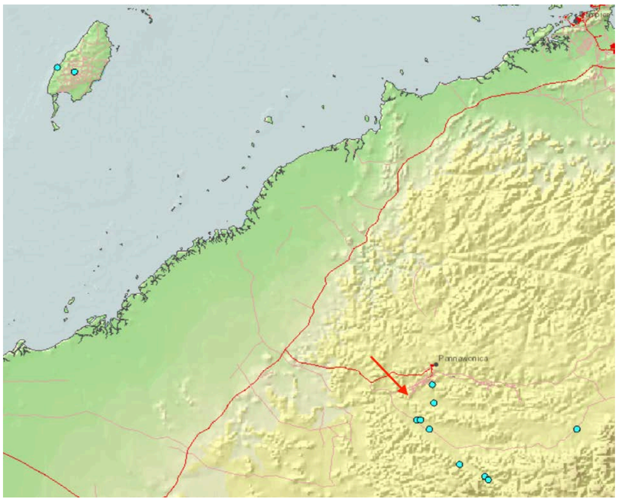

Figure 7.3: Records of *Nedsia hurlberti* on NatureMap (blue circles) (arrow indicates development envelope).

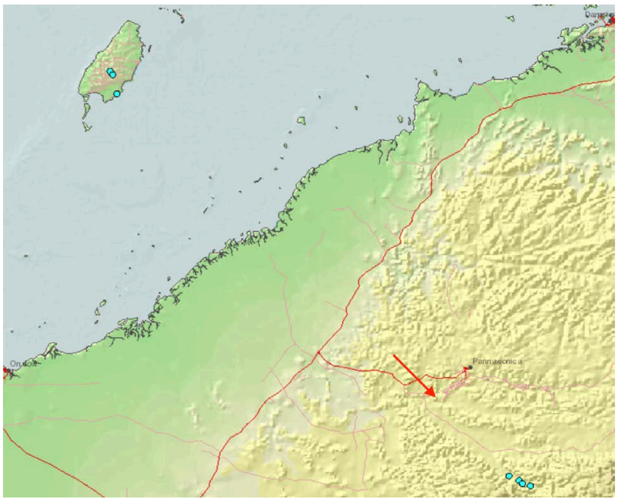

Figure 7.4: Records of *Nedsia sculptilis* on NatureMap (blue circles) (arrow indicates development envelope).

The current survey records of the two species from Mesa H are in addition to those used by DBCA to assign the species' conservation listing, and the local impact on individuals arising from the proposal would therefore not alter their overall current conservation status.

In addition, stratigraphic cross-sections along the length of Jimmawurrada Creek, where site JW021 is situated, combined with hydrogeological modelling, show that a substantial thicknesses of alluvium (a minimum of approximately 17 m) and underlying CID will remain saturated along Jimmawurrada Creek during the period of maximum drawdown for the project (Figure 7.2). While the alluvial aquifer is likely to be the primary habitat for the species, both units provide habitat for stygofauna below water table, meaning this will represent a substantial refugium habitat for both amphipod species at the time of peak dewatering for the project.

The third conservation significant species, the Blind Cave Eel (*Ophisternon candidum*), also occurs along Jimmawurrada Creek and has been recorded from four sites there, in addition to five other sites in the broader locality (Figure 7.5) (Biota 2019). The ecology and distribution of the species is poorly understood (Biota and Helix 2014), but the surveys and related investigations completed for the Mesa H proposal have substantially improved the overall knowledge base for the species in the west Pilbara (Moore et al. 2018, Biota 2019). Specimen records and eDNA evidence now indicate the species occurs within not only the Bungaroo Creek alluvial aquifer (Biota 2009b), but also in the Jimmawurrada Creek and Robe River alluvial aquifers ((Biota 2019); Figure 7.5).

Spatially then, there are five sites in the Mesa H locality where the species has been recorded that are outside of the proposal's drawdown extent (Figure 7.5). Similar to other stygofauna species, the records of *O. candidum* also show a high spatial correlation to the High likelihood stygofauna habitat units: Taking account of all confirmed record locations, the distribution of this habitat suggests that suitable connected habitat for the species occurs along the length of the Robe River catchment (Figure 7.5). It is notable that one of the Reference site eDNA records for the species came from the Control site sampled by Biota (2019): this site was a surface water pool on the Robe River and consistently yielded eDNA detections for the species from multiple replicate samples (Helix 2018). This may suggest that the species utilises shallow groundwater habitats in the alluvial sequence of the Robe River, including the phreatic zone, and this could contribute to maintenance of gene flow and population connectivity within the species' overall range. This theory is consistent with the Robe River alluvium hypotheses of Moore et al. (2018) and is supported by the subsequent and recent collection of an additional specimen from the phreatic zone of the Robe River during aquatic fauna sampling in a surface pool in the river (WRM 2018, in prep.).

In addition, one of these Reference sites (site 25; Figure 7.5) is part of the Pannawonica town bore field, which is subject to a low level of groundwater drawdown itself, being pumped at sustainable yield for water supply (Rio Tinto 2016). This alluvial aquifer habitat has been abstracted from since 1981 (Rio Tinto 2016), which is indicative of both the significant recharge capacity of the Robe River alluvial aquifer and, by inference, that *Ophisternon candidum* is at least tolerant to this level of groundwater impact in the medium term (with the bore field having being in operation for 37 years at the time the recent eDNA record was obtained; Biota 2019).

Even within the drawdown extent, the alluvial aquifer habitat of Jimmawurrada Creek where *O. candidum* occurs is subject to the same predictions as those noted above for *Nedsia hurlberti* and *N. sculptilis*: that is, when considered vertically, there will be a substantial saturated thickness remaining along the length of the creek at the peak of groundwater drawdown for the project in 2030. Similar to the *O. candidum* records from the Pannawonica town bore field, the sites on sites on Jimmawurrada Creek have also been subject to groundwater drawdown associated with the existing Mesa J operations and the species still utilises the area. Figure 7.2 shows the four sites where *O. candidum* has been recorded along Jimmawurrada Creek, illustrating that a continuous and connected saturated alluvium habitat varying between 5 and 17 m thick will remain within the system at the peak of dewatering. This is in addition to the underlying saturated CID, which may also provide potential habitat to the species (Figure 7.5).

In summary then:

- four of the known sites where *Ophisternon candidum* occurs are currently affected by groundwater drawdown, and will be subject to further groundwater drawdown from between 1 m up to a temporary peak of 6 m on the current water table but a substantial thickness of saturated alluvium and CID will remain as a refuge even within the impact areas (Table 7.1 and Figure 7.2);
- there are a further five known sites where the species occurs within the Robe Valley that are outside of the drawdown extent, including along the Robe River (Figure 7.1);
- inferences drawn from one of those sites at the Pannawonica town bore field suggest the species may be tolerant to lower levels of groundwater perturbations; and
- both the distributions of the known records, and habitat mapping with a strong evidence base from the broader stygal assemblage (Section 6.1), indicate it is likely that the species is distributed more widely along the Robe River catchment alluvial aquifer.

The above suggest that while some individuals of the species may be directly impacted by the groundwater drawdown, the species will remain locally represented within the Mesa H locality, in addition to its possible occurrence further along the connected alluvial aquifer habitats downstream along the Robe River and further afield at Cape Range (Biota 2019).

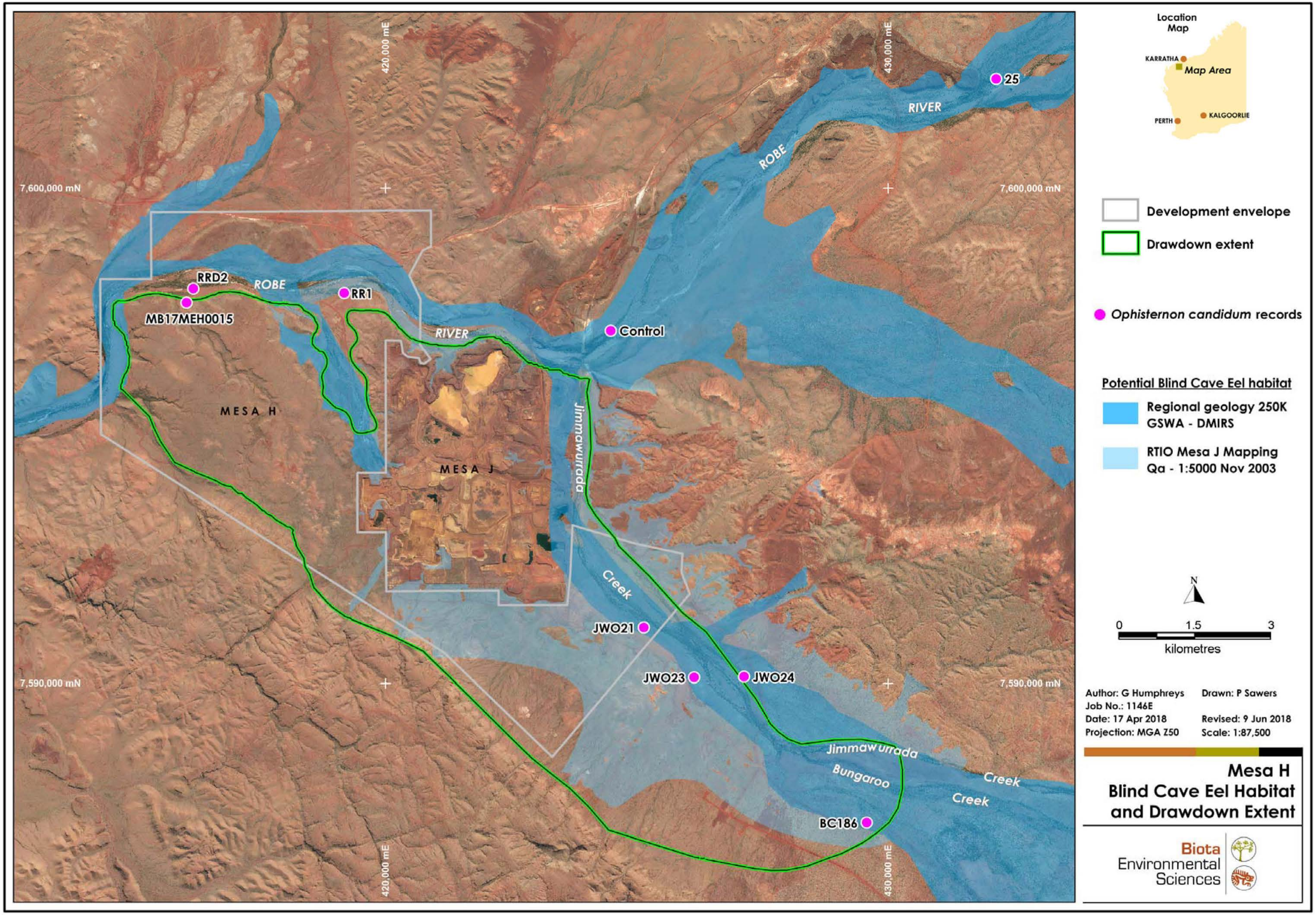

Figure 7.5: **Blind Cave Eel Records and potential habitat for the species relative to the extent of direct impacts arising from the Mesa H project.**

7.1.3 Direct Impacts on Stygofauna Community and Habitat Key Receptors

This drawdown extent relative to the Stygofaunal Community of the Bungaroo Aquifer PEC is shown in Figure 7.6.

The drawdown extent for the proposal will have a relatively minor effect on the northwestern limit of the PEC as mapped by DBCA. The total mapped extent of the Bungaroo aquifer PEC is 106,703 ha, of which 3,287 ha falls within the drawdown extent (3.1% by area; Figure 7.6). Therefore, while the proposal will have an impact on the PEC, 97% of its extent as currently recognised by DBCA, or over 100,000 ha in real terms, will remain unaffected by the Mesa H proposal.

At the scale of stygofauna habitats in the wider Robe River catchment (as illustrated in Figure 6.2), the proportion of aquifer habitat impacted by the dewatering is an order of magnitude smaller than the PEC impact, and is thereby not considered further in this assessment.

7.1.4 Indirect Impacts

The pathways by which the proposal that may indirectly impact stygofauna comprise:

1. clearing of terrestrial vegetation and hardstand sealing of surfaces, leading to changes to groundwater recharge and nutrient infiltration;
2. increased sedimentation of the aquifers beneath the project footprint due to the creation of waste landforms and waste fines management; and
3. risk of hydrocarbon or other groundwater contamination (see Section 4.2.2).

All of these impact pathways are likely to be secondary tier impacts by comparison to the direct impacts (Section 7.1.1 to 7.1.3) and their effects can typically be minimised through project design and operational environmental management measures that are now well-established and effective. The primary focus for the assessment of the impacts then remains the direct impacts of the proposal on stygofauna from mine pit construction and dewatering.

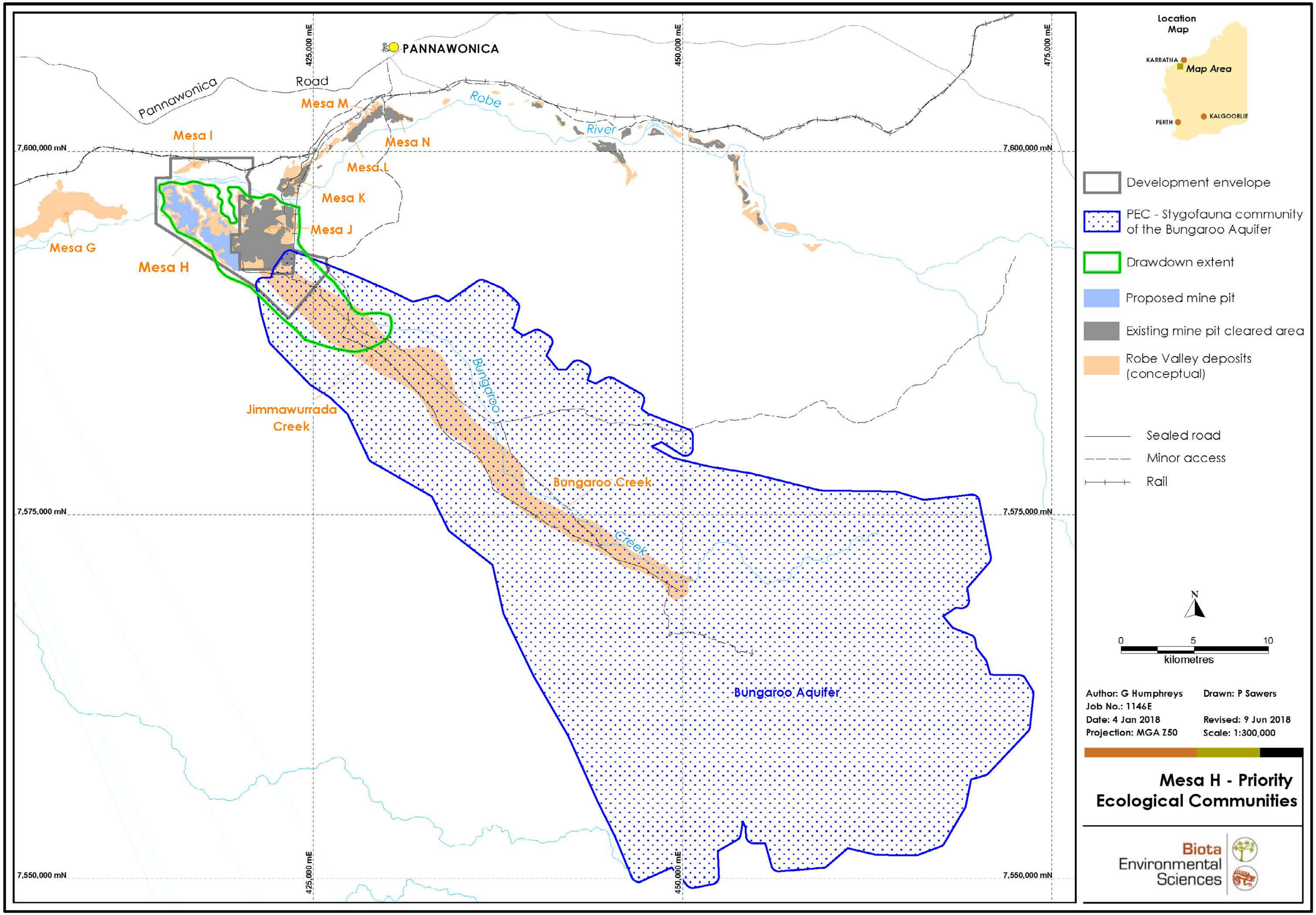

Figure 7.6: **Mapped extent of stygofauna community key receptor relative to the extent of direct impacts arising from the Mesa H project.**

7.2 Troglofauna Impacts

This assessment identified 33 development area species that are potential SRE taxa and represent the troglofauna key receptors for this impact assessment.

These comprise:

- eight pseudoscorpion species (Hyidae sp.'PH017/PH027', Hyidae sp. 'PH026', Olpiidae sp. 'PO008', *Beierolpium* sp. 'PO014', *Beierolpium* sp. 'PO015', Atemnidae sp. 'PA004', Chthoniidae sp. 'PC014/PC015' and Chthoniidae sp. 'PC055');
- four schizomid species (*Paradraculoides* sp. 'SCH038', *Paradraculoides* sp. 'SCH039', Hubbardiidae sp. 'SCH011' and Hubbardiidae sp. 'SCH015/16');
- one centipede species (Cryptopidae sp. 'SC018');
- seven dipluran species (Parajapygidae sp. 'DPA001', Parajapygidae sp. 'DPA009', Projapygidae sp. 'DPR008/DPR009/DPR011', Projapygidae sp. 'DPR010', Japygidae sp. 'DJA003', Japygidae sp. 'DJA011', and Campodeidae sp. 'DCA005');
- five isopod species (Philosciidae sp. 'ISP047', Philosciidae p. 'ISP055', *Troglarmadillo* sp. 1, *Troglarmadillo* sp. 'ISA046'; and Armidillidae sp. 'ISA056/ISA057');
- three beetle species (Curculionidae sp. 'CCU014', Ptilidae sp. 1/'CP003' and Ptilidae sp. 'Robe Valley'/'CP002');
- two silverfish species (Nicoletiinae sp. 'TN019' and Nicoletiinae sp. 'TN020');
- two spider species (*Prethopalpus* sp. 'ARA052' and Gnaphosidae sp. indet.); and
- one cockroach species *(?Nocticola* sp. 'West Pilbara Complex').

Taken together, the higher order taxonomic composition of the fauna of the development envelope is representative of virtually all components of the best-sampled pisolitic mesa habitats of the Robe valley (Biota 2006a, 2016b, 2017). The development area can therefore be considered adequately sampled (Biota 2019) and the survey data inputs (the first tier of the impact assessment model followed here; Figure 2.1) adequate for the purposes of the current assessment.

At this troglofauna ecological community level, there are also two key receptors for this impact assessment (following the criteria in Section 2.4):

- Subterranean invertebrate communities of mesas in the Robe Valley region (Priority 1); and
- Subterranean invertebrate community of pisolitic hills in the Pilbara (Priority 1) (Section 5.2.2.1).

7.2.1 Direct Impacts on Troglofauna Species Key Receptors

The clearest direct impact on both troglofauna species and communities key receptors is the habitat removal that will occur to accommodate the proposed mine pits (Section 4.2.1). This will result in the loss of troglofauna habitat and the mortality of individual animals occurring within it.

Records of the 33 troglofauna species known from the development envelope are show in Figure 7.7. Six of these 33 have also been recorded from outside of the development envelope and have demonstrated wider distributions:

- two schizomid species: Hubbardiidae sp. 'SCH011' (also known from remnant CID habitat north of Mesa J; Figure 7.7) and Hubbardiidae sp. 'SCH015/SCH016' (previously recorded from 6 km southwest of the development envelope; Biota (2019));
- the isopod species Armadillidae sp. 'ISA056/ISA057' (also known from 27 km to the west at Mesa C (Biota 2019) and is therefore likely to occur more widely at other locations);
- the blattodean ?*Nocticola* sp. 'West Pilbara Complex' (relatively widespread in the locality, including up to 60 km to the south (Biota 2019)); and
- two beetle species: Ptilidae sp. 1/'CP003' and P. sp. 'Robe Valley'/'CP002' (both of which have been recorded more widely within the Robe River valley (Biota 2019).)

The remaining 27 key receptor species have currently only been recorded from within the development envelope (Biota 2019). The key question for this assessment in respect of these species then becomes their distribution relative to the proposed extent of the mine pits.

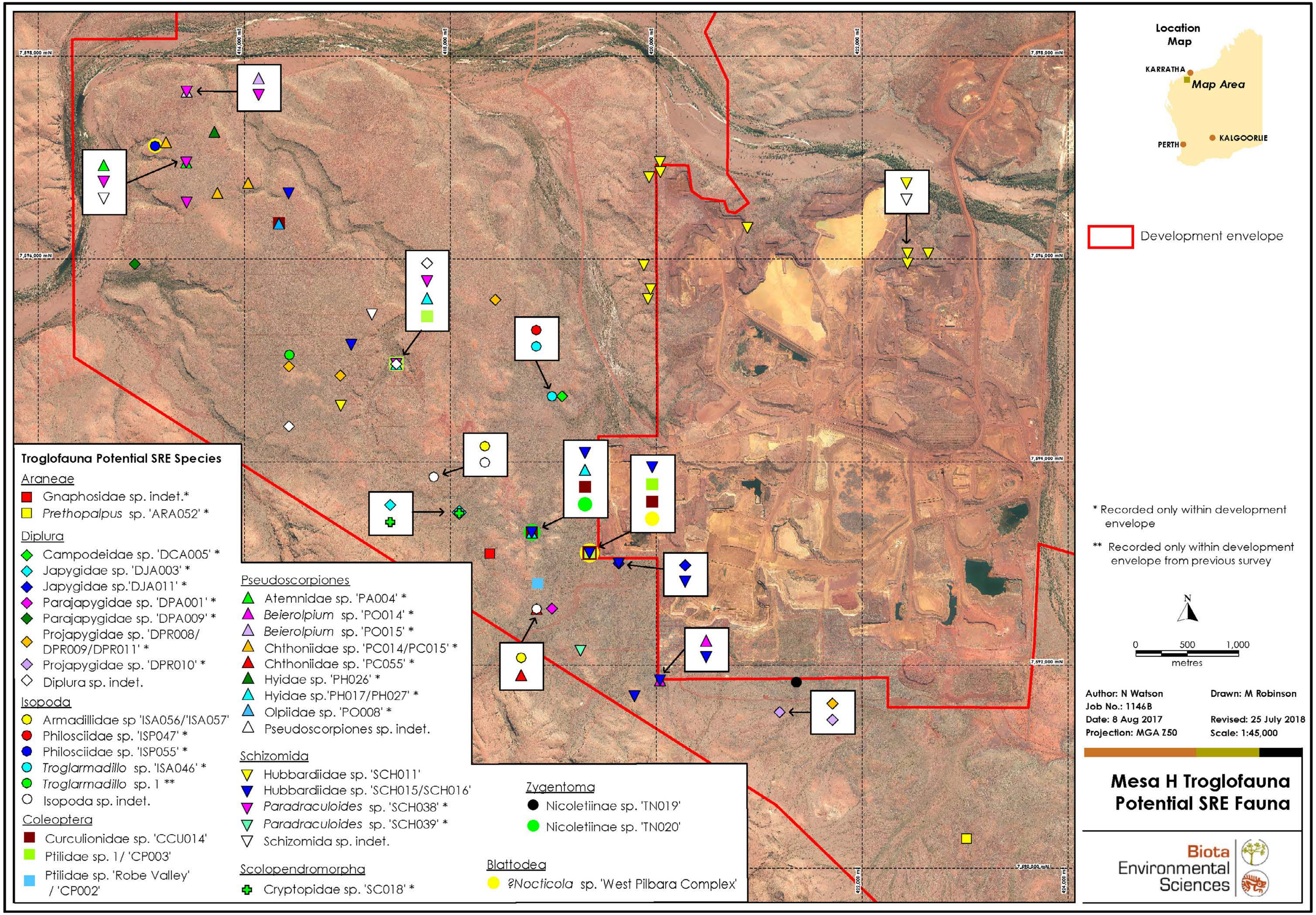

Figure 7.7: Distribution of all troglofauna key receptor species within the development envelope.

The records of the 27 species only known from the development envelope are summarised in Table 7.2, which categorises the sites where they have been recorded into sites within the mine pits and sites outside of this that will not be directly impacted. These data show that 23 of the 27 species have only been recorded from habitat outside of the proposed pit areas, with the proposed pits not directly impacting them at all from current data, and half of those 23 un-impacted species are also confirmed within the MEZ (Table 7.2).

This avoidance of direct impact on most species occurring within the development envelope is due to Rio Tinto's elimination of impacts during the project design (the 'Management' tier mitigation opportunity in the impact assessment model; see Figure 2.1): the design of the mine pit boundaries was specifically tailored to avoid troglofauna species records where feasible, and the MEZ was designed to incorporate locations where species were recorded; adopting a precautionary approach to their distributions. This has resulted in 70% of the development envelope troglofauna species being avoided entirely by the proposed mine pit footprint.

Table 7.2: Troglofauna species currently known only from within the development envelope and their distribution relative to the proposed mine pits (species shaded grey currently only known from the mine pits).

Species	In-pit Sites	Sites outside of Mine Pits	
		Inside MEZ	Other Remnant Habitat
Pseudoscorpiones			
Hyidae sp.'PH017/PH027'	-	RC14MEH0252	- RC16MEH0264
Hyidae sp. 'PH026'	-	RC16MEH0436	-
Olpiidae sp. 'PO008'	-	RC15MEH0302	-
Beierolpium sp. 'PO014'	-	-	RC16JIM0026
Beierolpium sp. 'PO015'	-	RC16MEH0433	-
Atemnidae sp. 'PA004'	-	RC15MEH0329	-
Chthoniidae sp. 'PC014/PC015'	RC15MEH0315	RC15MEH0335	-
Chthoniidae sp. 'PC055'	-	-	MEHRD0834
Schizomida			
Paradraculoides sp. 'SCH038'	MEHRC157	RC15MEH0329, RC16MEH0433	RC16MEH0264
Paradraculoides sp. 'SCH039'	-	-	RC15MEJ0019
Myriapoda			
Cryptopidae sp. 'SC018'	-	RC14MEH0388	-
Diplura			
Parajapygidae sp. 'DPA001'	-	-	RC14MEH0308
Parajapygidae sp. 'DPA009'	-	MEHRD0758	-
Projapygidae sp. 'DPR008/DPR009/DPR011'	RC15MEH0166	-	RC15MEH0261, RC15MEH0175, RC16JIM0005
Projapygidae sp. 'DPR010'	-	-	RC16JIM0005
Japygidae sp. 'DJA003'	-	RC14MEH0388	-
Japygidae sp. 'DJA011'	DD13MEH0007	-	-
Campodeidae sp. 'DCA005'	-	-	GR15MEH0032
Isopoda			
Philosciidae sp. 'ISP047'	-	-	RC15MEH0382
Philosciidae p. 'ISP055'	-	RC15MEH0427	-
Troglarmadillo sp. 1	-	-	MEHDC0865
Troglarmadillo sp. 'ISA046'	-	-	RC15MEH0382
Coleoptera			
Curculionidae sp. 'CCU014'	RC12MEH0221	RC14MEH0252, RC15MEH0302	-
Zygentoma			
Nicoletiinae sp. 'TN019'	-	-	RC16JIM0006
Nicoletiinae sp. 'TN020'	-	RC14MEH0252	-
Araneae			
Prethopalpus sp. 'ARA052'	-	-	RC16JIM0019
Gnaphosidae sp. indet.	-	RC14MEH0270	-

Five of the remaining six species that occur within the mine pits have distributions demonstrated to extend beyond the pit boundaries (Table 7.2; Figure 7.8). Again, this is a function of the proposed mine pit and MEZ design having been specifically modified in response to the troglofauna survey data to avoid or minimise direct impacts.

With the pit design mitigation already undertaken, there is only one species currently known only from within the proposed pit outlines: the dipluran Japygidae sp. 'DJA011' (Table 7.2; Figure 7.8). A key impact assessment question that arises for this proposal, and has arisen for numerous previous proposals where Subterranean Fauna has been a relevant factor, is whether this species is truly restricted to the mine pit impact areas. This can be addressed by consideration of the survey data, distributional records of all troglofauna species known from Mesa H, and the extent and configuration of interconnected troglofauna habitat in the locality.

Both the results of the current Biota (2019) investigations, and past work in the Robe valley (Biota 2006a, 2016b, 2017), indicate that the appropriate spatial scale at which to evaluate this is the CID landforms and associated AWT troglofauna habitat of Mesa H itself. This is due to the endemism common in the fauna, with over 80% of the recorded species only known to occur at Mesa H. This is consistent with the configuration and extent of troglofauna habitat, with the habitats identified for Mesa H bounded by major geomorphological features; comprising the Robe River to the north and Jimmawurrada Creek to the east, and southerly limits on AWT habitat, where the CID habitat abuts the Brockman Iron Formation ranges rising to the southwest (Section 6.2). The context for assessing the risk to the potentially restricted species is therefore to consider whether very small scale and localised restrictions in species distributions could exist within the extent of troglofauna habitat mapped for Mesa H (Figure 6.5 and Figure 6.6 of Section 6.2).

The risk that the species in question is truly restricted to the mine pits can consider:

1. **Animal abundance**
   The species is represented by a single specimen only. As discussed for the equivalent stygofauna singleton taxa (Section 7.1.1), this makes assessing its true distribution more difficult and introduces the probability that the apparent isolation to the record site is an artefact of ecological sampling effects.
2. **Troglofauna habitats**
   The combination of surface geology habitat mapping, AWT CID thickness data, and stratigraphic cross-sections (Figure 6.5 and Figure 6.6), all indicate continuity and connectivity of AWT troglofauna habitats across the extent mapped within the development envelope.
3. **Assemblage distribution**
   Other troglofauna species recorded from the same drillhole as the species in question have demonstrated distributions that extend beyond the direct impact areas. Japygidae sp. 'DJA011' was recorded from DD13MEH0007, where it co-occurs there with Hubbardiidae sp. 'SCH015/SCH016'; a species that has been recorded both inside and outside the pits, including in habitat that will remain unmined 1.2 km to the south (Figure 7.3) and is also known from outside the development envelope (Biota 2019).

   At the overall assemblage level, there are 11 troglofauna species known to occur within the mine pit boundaries and 10 of these have proven wider distributions within Mesa H or further afield, with records from either the MEZ or other troglofauna habitat that will remain unmined (Figure 7.3). This pattern in the fauna indicates connectivity of habitat across the extent of the landform and across the mine pit boundaries, rather than a pattern of very localised isolation. Consistent with this, past surveys at other Robe River valley mesas has shown that troglofauna species typically have distributions equivalent to at least the extent of contiguous, AWT CID landforms, once sufficient sampling has been undertaken to demonstrate this (e.g. Biota 2006b, 2007, 2016c).

The above lines of physical and biological evidence are parallel in suggesting that the dipluran Japygidae sp. 'DJA011' appears unlikely to be truly restricted to the small portions of the Mesa H landform from which it has currently been recorded. Data from other co-occurring species, and the broadly continuous nature of AWT CID habitats within Mesa H, suggest that the apparent restriction of the species is due to ecological sampling effects and that it occurs more widely within the local habitat extent.

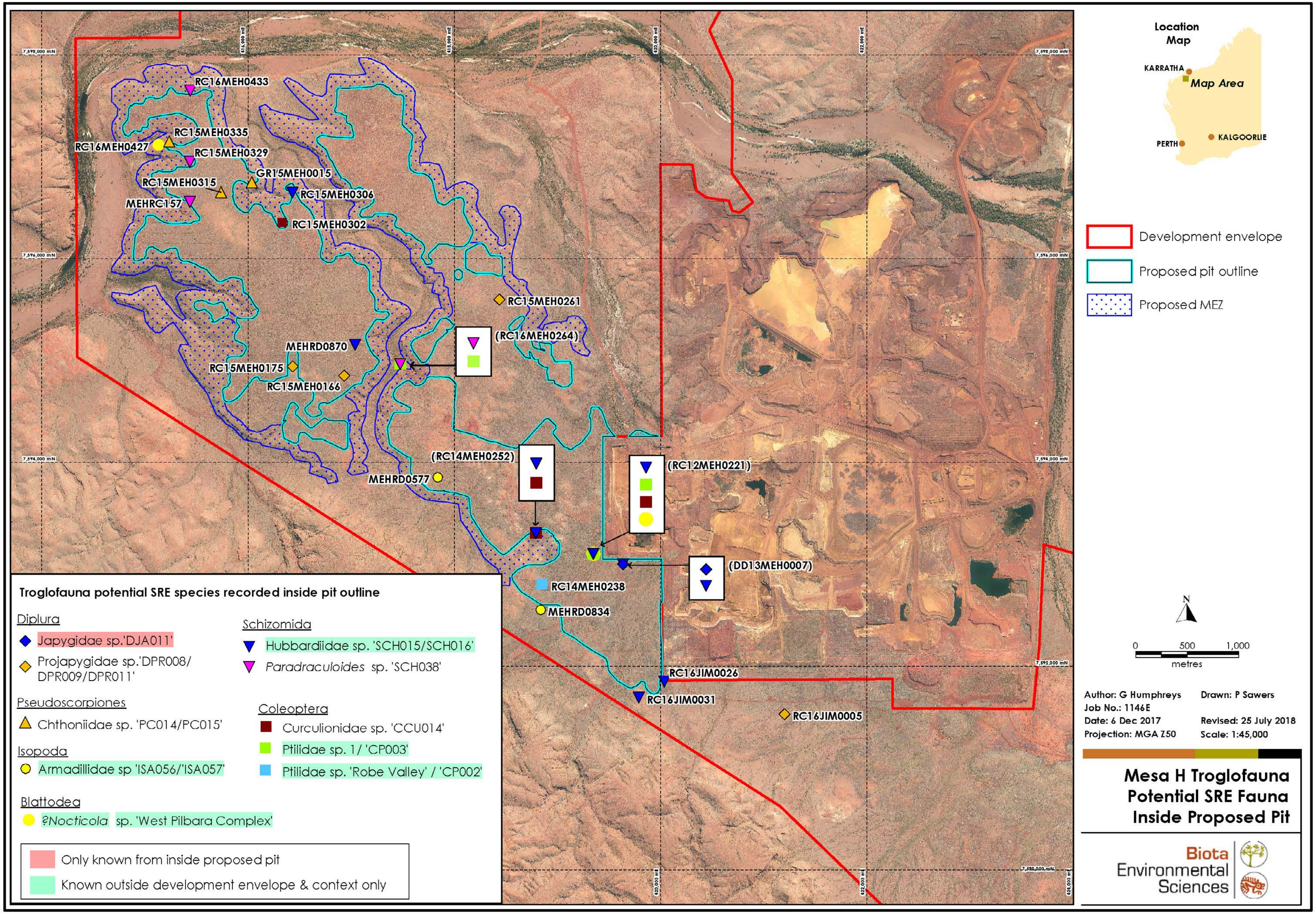

Figure 7.8: **Distribution of troglofauna key receptor species relative to the extent of direct impacts arising from the Mesa H project.**

7.2.2 Direct Impacts on Troglofauna Community and Habitat Key Receptors

The extents of the two troglofauna PECs relevant to this impact assessment are shown in Figure 7.9, which are the assumed original extent of these PECs, prior to any past disturbance, as mapped by the now DBCA.

As discussed in Section 5.2.2.1, the two PECs appear to have only been distinguished on the basis of perceived landform differences ('mesas' versus 'hills'; Table 7.3), but in reality both actually represent troglobitic communities of elevated CID landform habitats along the Robe River palaeodrainage. This somewhat arbitrary naming has caused spatial overlaps between the buffers of the two PECs; including small areas within the western and eastern parts of the development envelope (Figure 7.9). Given these overlaps, and that DBCA still recognise the PECs as separate entities, the potential impacts of the proposal on each of the PECs have been considered separately.

With the history of resource development in the Robe valley, and consistent with the guidance of EPA (2016a), it is appropriate to place potential impacts on the PECs into a cumulative impact context. Table 7.3 and Figure 7.9 summarise the extent of proportionate habitat loss that has already occurred due to previously approved (in grey on Figure 7.9) and reasonably foreseeable projects (outlined blue on Figure 7.9), and quantify the additional direct loss of PEC extent that will arise as a result of the Mesa H proposal.

Table 7.3: Cumulative direct impacts from the Mesa H mine pits on troglofauna PECs, in context with other habitat removal (ignoring overlaps in mapped PEC extents within the development envelope).

PEC	Original Assumed Extent of PEC	Current Extent after Other Habitat Loss *	Extent after Habitat Loss from this Proposal	Incremental Impact
Subterranean invertebrate communities of mesas in the Robe Valley region	13,753.9 ha (100%)	11,773.4 ha (85.60%)	11,764.2 ha (85.53%)	**9.20 ha** **(0.07%)**
Subterranean invertebrate community of pisolitic hills in the Pilbara	9,889.7 ha (100%)	7,952.3 ha (80.41%)	7,164.2 ha (72.44%)	**788.1 ha** **(7.97%)**

*Including both impacts that have already occurred or are reasonably foreseeable from other proposed developments.

The incremental impact of the proposal on the 'Subterranean invertebrate communities of mesas in the Robe Valley region' PEC is very minor at 0.07% of its original extent (Table 7.3). This is especially the case when the mapping of this PEC that falls within the development envelope is almost certainly only a buffer area on the true extent of the PEC itself (Figure 7.9).

The incremental loss of habitat from the 'Subterranean invertebrate community of pisolitic hills in the Pilbara' PEC is greater at 7.97% of its original extent (Table 7.3). This is largely a function of this second PEC being restricted to just Mesa H and the Warramboo locality (Figure 7.9), as both were considered by DBCA to represent 'hills' rather than mesas. Even with this, over 72% of the original assumed extent of this PEC, at 7,164.2 ha, would still remain with the implementation of the Mesa H proposal (Table 7.3). Combining both PECs, given that they both represent effectively the same types of troglobitic communities within elevated CID landform habitats along the Robe River palaeodrainage, provides a total incremental impact of 3.4 % of the combined PECs.

Within the spatial extent of Mesa H itself, a key assessment question relates to the viability of troglofauna populations in the habitat that will remain once mining is complete; particularly in respect to the in-pit troglofauna species remaining at Mesa H. This is likely to be a function of the extent, configuration and intactness of the portions of the Mesa H landforms left undisturbed by proposed mining activities; both within the proposed MEZ and in other remnant habitat within and adjoining the development envelope.

Figure 7.10 shows the mapped extent of troglofauna habitat at Mesa H, and the area that would be directly impacted by the mine pits. The total area of troglofauna habitat within the development envelope is 2,497.3 ha, and 751.5 ha of this falls within the mine pit boundaries, leaving approximately 70% of the spatial habitat unmined (1,745.8 ha) (Figure 7.10). The MEZ, which Rio Tinto has committed to not mine and thereby has greater certainty of retention, accounts for approximately a quarter of this habitat area at 443.3 ha. Overall, the unmined habitat would include records of 33 of the 34 troglofauna species known from the development envelope in a relatively well connected and contiguous extent of AWT troglofauna habitat (Figure 7.10).

From a three-dimensional habitat volume perspective, Rio Tinto mine planning and modelling has also calculated the remaining volume of the CID strands representing habitat for troglofauna on completion of the project: this will exceed 50% of the current pre-mining habitat volume, similar to past Robe Valley projects which have been approved to proceed (e.g. EPA 2007).

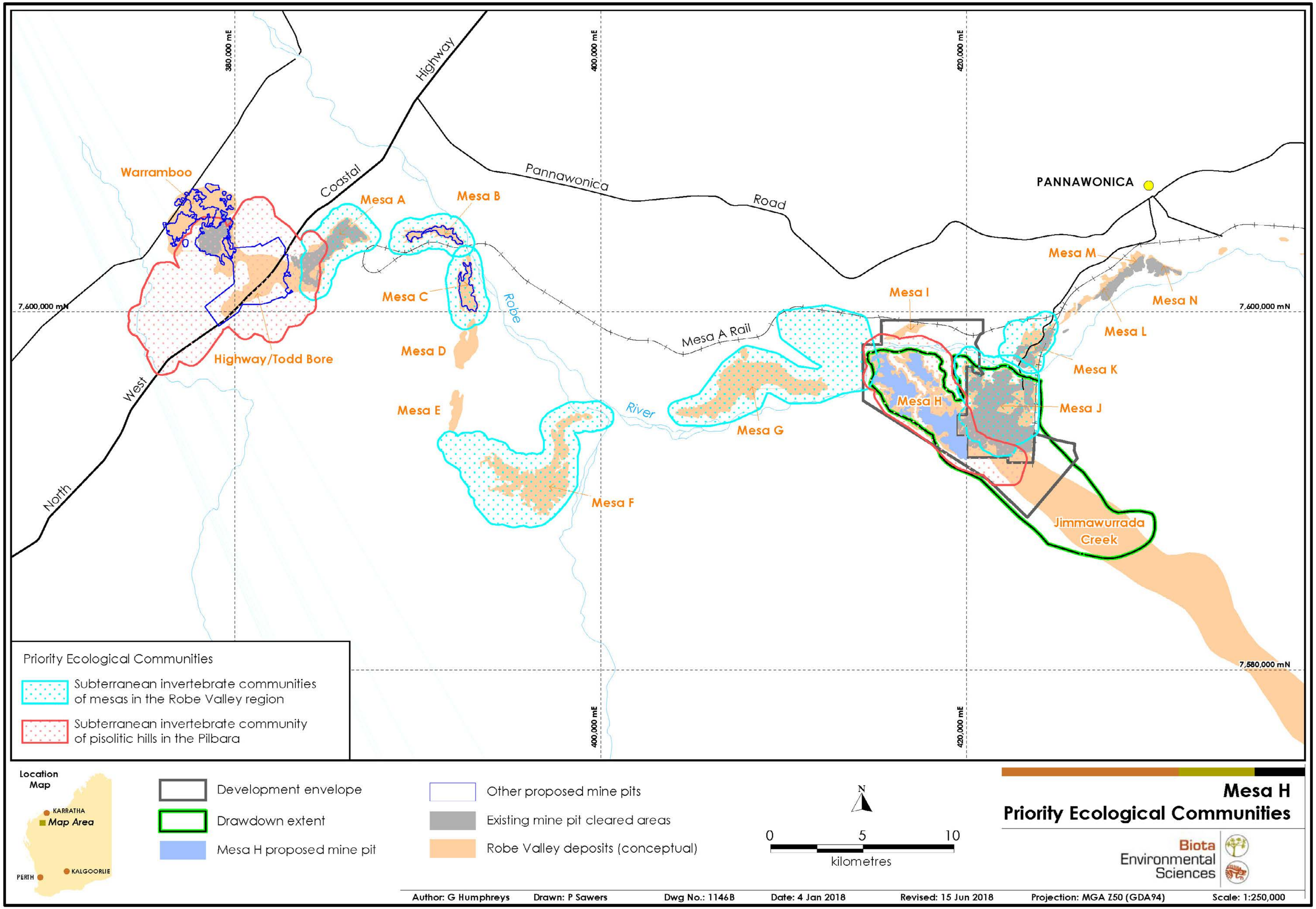

Figure 7.9: **Mapped extent of troglofauna communities key receptors relative to the extent of direct impacts arising from the Mesa H project.**

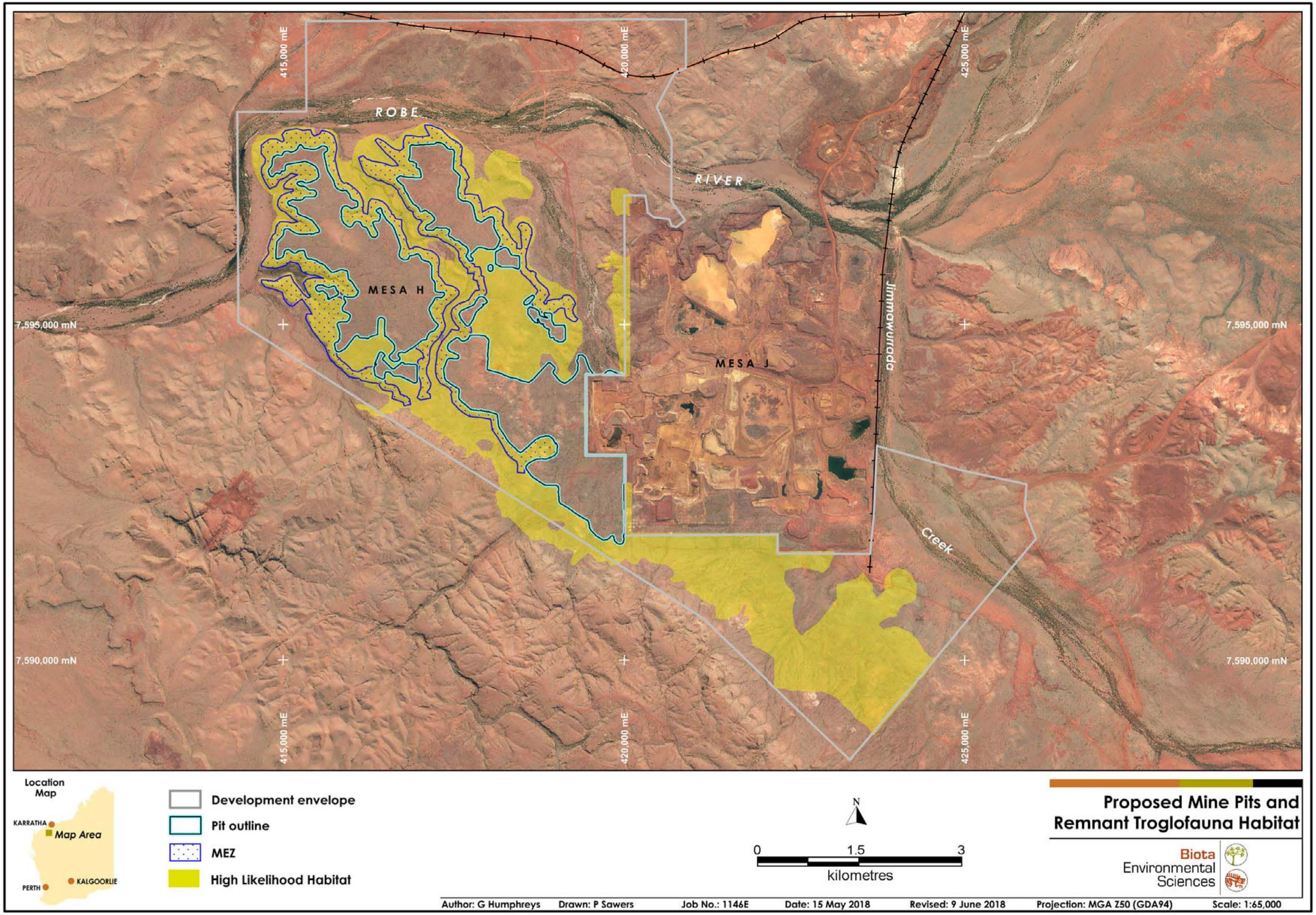

Figure 7.10: Extent of proposed mine pits and troglofauna habitat that will remain intact within the development envelope.

7.2.3 Indirect Impacts

In addition to the primary impact of habitat removal for mining pits, other indirect impacts could also affect troglofauna habitat retained within the development envelope outside of the pit outlines (as identified in Section 4.2.2). The ongoing suitability of habitat to support troglofauna in these ex-pit areas is linked to the maintenance of the existing biophysical conditions and processes that contribute to the stable and humid conditions that characterise troglofauna habitat. Indirect impact pathways have the potential to degrade habitat quality by reducing, or locally altering, these conditions and processes (Section 4.2.2).

The only indirect potential impact that will remain in operation for the long term will be the effect of the waste dumps arising from the proposal (Section 3.0; Figure 3.1). The waste dumps have the potential to reduce hydrological and nutrient inputs to underlying troglofauna habitat, which could in turn reduce habitat quality or animal abundance (Section 4.2.2; Figure 4.1). This impact mechanism has not, however, been empirically demonstrated to occur, and some limited data suggest that troglofauna persist beneath waste dumps in at least the medium term (with schizomid records from beneath waste dumps at nearby Mesa K, decades after their creation; Biota (2007)). Despite this, and in the interests of a precautionary assessment, a GIS spatial analysis was conducted for this assessment, intersecting the proposed waste dump footprints shown on Figure 4.1 with the records of all troglofauna species known from the development envelope. This analysis showed that not only are none of the 33 species known from Mesa H restricted in distribution to the waste dump footprints, but there are in fact no records of any troglofauna from either the Biota (2019) survey or desktop sources. This result, combined with the earlier observations that this impact process has not been clearly proven, suggest that the indirect impact of the waste dumps would not be significant (a Negligible impact with at least a Medium level of certainty, following the framework set out in Section 2.6.2).

Compared to direct impacts, the spatial extent, duration and magnitude of the impact footprints that could arise from the other indirect impact pathways are all relatively limited (Section 3.0). The majority of the indirect impact pathways can also be further mitigated through project design, environmental management controls and monitoring during project implementation. The primary focus for the assessment of the impacts then remains the direct impacts of the proposal on troglofauna.

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8.0 Conclusions

This impact assessment followed a series of defined criteria to identify species and ecological community key receptors of potential impacts from the Mesa H project. The impact sources and pathways arising from the proposal have been imposed on the known distributions of the species and community key receptors to identify potentially significant impacts. Sections 8.2 and 8.1 synthesise these outcomes with the models of subterranean fauna habitat presented earlier in Section 6.0, to arrive at an assessment of the risk of significant impacts on troglofauna and stygofauna respectively.

To recap Section 2.6.2, the framework used for reaching an assessment on the significance of the potential impacts was based on consequences and magnitudes of the impact for the receptors, and level of certainty:

Consequences of Impact	Criteria
Negligible	Displacement or loss of individual animals
Minor	Reduction in less than 10% of the known or inferred distribution and habitat extent
Moderate	Reduction in 10-50% [2] of the known or inferred distribution and habitat extent
Major	Loss of more than 50% [2] of the known or inferred distribution and habitat extent and/or change in conservation status of the species

Level of Certainty	Criteria
High	The outcome is quantifiable and can be predicted with confidence from a reasoned evidence base or the impact has previously occurred during similar mining developments
Medium	A reasonable body of data exists to predict the outcome and the outcome could reasonably be expected to arise from the current proposal
Low	The outcome has not previously occurred during similar mining developments, but expert opinion or other data suggest it might arise, or there is insufficient information to quantify the impact

A significant impact (after EPA (2016a)) is considered for the purposes of this review to be a Moderate or Major impact on a key receptor that is predicted to arise with High or Medium certainty (following the criteria in Section 2.6.2).

The concluding assessment is summarised for species and ecological community receptors for stygofauna and troglofauna in Sections 8.1 and 8.2, respectively.

8.1 Stygofauna

8.1.1 Species Receptors

A total of 32 species of stygofauna occur within the modelled dewatering extent for the proposal, which sets the spatial limit of predicted direct impacts.

Sixteen of these species are widely distributed in the region and not of listed conservation significance and the impact of the dewatering would not be significant at taxon level; assessed as Minor with a High degree of certainty (the extent and duration of the impact has been quantitatively predicted, approached conservatively and a sound data set exists to demonstrate the species' wider occurrence).

[2] Derived from the International Union for the Conservation of Nature (IUCN) Red List criterion whereby a species' conservation state would shift from the Least Concern category to Vulnerable (IUCN 2012).

Thirteen of the remaining 16 species are potential SREs that occur within the dewatering extent, with the other three being species of conservation significance that are addressed separately in Section 8.1.2 below.

Seven of the 13 potential SRE species occurring within the drawdown extent (*Areacandona* sp. 'BOS1039', *Pilbaracandona* sp. 'BOS526', *Megastygonitocrella unispinosa, Nedsia* sp. 'AMM026', Paramelitidae sp. 'AMP035', *Wesniphargus* sp. 'AMN004' and Neoniphargidae sp. 'B02') were recorded outside of the drawdown extent, or have demonstrated wider distributions in the locality, and would not be placed at significant risk to a change in their conservation status. Based on this, and the considerable extent of stygofauna habitat in the locality (Figure 6.2), the impact of the dewatering on these seven taxa would not be considered significant at species level (a Minor impact with a High degree of certainty).

Four of the remaining six potential SREs within the drawdown extent (Candoninae sp. 'BOS541', *Haptolana* sp. 'B01', Hydrobiidae sp. 2 and *Parastenocaris* sp. 'B28') were all recorded from the alluvial habitats of Jimmawurrada Creek at sites JW023 and JW024. With the wider distributions of other potential SRE stygofauna species in the survey area, it is unlikely that these species are truly restricted to the vicinity of these two sites, but even if this was the case, refugial habitat will be retained there at the peak of modelled dewatering. The predicted drawdown at these sites is moderate at a less than 7 m below the pre-mining water table level, leaving a saturated alluvial sequence varying between 5 and 17 m in thickness connected along the length of the creek at the peak of the proposal impact (Section 7.1.1). These refugia would also be additionally hydraulically connected and supplemented during flooding and seasonal recharge events along Jimmawurrada Creek. Based on this, and recognising that the species are likely to be more widely distributed, the impact of the dewatering on these four taxa would not be considered significant at species level (a Minor impact with a High degree of certainty).

The final two potential SRE species, Paramelitidae sp. 'AMP003' and Paramelitidae sp. 'AMP037', are currently known only from the drawdown extent from several areas that would be more significantly dewatered (drawdowns of 20 m and 4 m on the pre-mining water table respectively, and direct removal of habitat for Paramelitidae sp. 'AMP003'; Section 7.1.1). Both biological and physical evidence suggests connectivity of aquifer habitats and stygofauna populations to at least the local catchment scale, and that the apparent very small distributions of these two species is due to ecological sampling effects (Section 7.1.1). Assuming this is the case, these species would also not be significantly impacted (Minor impact with a High degree of certainty).

However, as this is a risk-based approach, the distribution of these singleton species cannot be assessed with confidence with the available data, and a more precautionary approach may be to assess the impact on the assumption that they are locally restricted and a greater proportion of their known distribution would be impacted by the dewatering, meaning the predicted impact would be significant (a Moderate or Major impact with a High degree of certainty).

8.1.2 Species of Conservation Significance

Three stygofauna species occurring within the drawdown extent are of formally listed conservation significance, but two (the Schedule 3 amphipods *Nedsia hurlberti* and *N. sculptilis*) also occur far more widely in the region. The dewatering extent would represent less than 10% of the known distributional extent for both species, and would thereby represent a Minor impact, in addition to the likelihood that refugia habitat will be retained locally within the alluvial aquifer of Jimmawurrada Creek (Section 7.1.2). Given the level of hydrogeological investigation completed to understand the predicted impacts and habitat change, and the distributional data for both species, the assessment of a Minor level of impact would be regarded as having a High degree of certainty, which would not be significant for most stygofauna species. However, given the Schedule listing of the two *Nedsia* taxa, it is possible that the impact may be elevated on that basis to be deemed significant.

The impact assessment context and predictions for the third conservation significant species, the Blind Cave Eel *Ophisternon candidum*, is broadly similar to that for *Nedsia hurlberti* and *N. sculptilis*: *O. candidum* was recorded from the same site as the two amphipod species (JW021) and appears to have a similar distribution, with additional records following the alluvial aquifer of the Jimawurrada-Bungaroo Creek system and into the Robe River aquifer (Section 7.1.2). It appears possible that all three species may occur further downstream on the Robe River. Sequencing data from multiple genes have also shown that the *O. candidum* specimen from drawdown extent site BC186 had a very low level of divergence from specimens at Cape Range; at the level typically seen within the same species (Foster and Humphreys 2011, Moore et al. 2018).

Quantitative predictions from hydrogeological modelling indicate that a substantial thickness of alluvial habitat between 5 and 17 m thick will remain saturated along Jimmawurrada Creek (Section 7.1.2). The species also occurs locally along the habitats of the Robe River – which will not be affected by the drawdown greater than natural water table fluctuations – and this distribution may extend downstream in the same system (with a population of apparently the same species also occurring at Cape Range). The consequences of the dewatering on that basis could therefore be assessed as a Minor impact (less than 10% of the known distribution) with Medium certainty. However, there are several factors that indicate the certainty with which impacts on *O. candidum* can be predicted differs from that for *Nedsia hurlberti* and *N. sculptilis*. These include, that:

- the species has a higher conservation status than the two amphipod species (listed at Commonwealth as well as State level); and
- the much larger body size of the species compared to the amphipods, which could affect the ability of individuals to move horizontally or vertically through cavities and interstices within saturated habitat.

These considerations suggest that additional caution is warranted regarding the confidence with which impacts can be predicted for *O. candidum*. A more precautionary position might be to assume that the same species only occurs within the local habitat extent within the Robe River valley (as shown in Figure 7.5) and that the quality and availability of this habitat would be reduced. Hydrogeological modelling suggests this scenario is unlikely, but this conservatism provides some balance to the uncertainties in predictions listed above. Within this framework then, the impact on *O. candidum* would be significant, amounting to a Moderate impact with High certainty.

8.1.3 Ecological Community Receptors

The impacts on both the Stygofaunal Community of the Bungaroo Aquifer PEC would not be considered significant within the framework used here (Minor (<10%); with a maximum impact on the PEC of 3.1% by area, with much of the drawdown being relatively minor compared to the scale of the aquifer).

8.2 Troglofauna

8.2.1 Species Receptors

A total of 33 troglofauna species are known from the development envelope. Six of these have been recorded from outside of the development envelope and have demonstrated wider distributions in at least the Robe River valley (Hubbardiidae sp. 'SCH011', Hubbardiidae sp. 'SCH015/SCH016', Armadillidae sp. 'ISA056/ISA057', ?*Nocticola* sp. 'West Pilbara Complex', Ptilidae sp. 1/'CP003' and Ptilidae sp. 'Robe Valley'/'CP002'; Section 5.2.2.2). At 751.5 ha in extent, the direct impact of the mine pits on these six taxa would not be significant at the species level (<10% of known distribution with a High degree of certainty).

The remaining 27 key receptor species have currently only been recorded from within the development envelope and their distributions cannot be assumed to extend beyond the habitat mapped at Mesa H. The consequence of the direct impact of the mine pits on these species can be assessed on the basis of their record locations within Mesa H and the proportional habitat loss predicted for the proposal. Based on current data there are no records of 22 of the 27 species recorded at Mesa H from within the mine pit areas. Taken at face value, this would indicate a Negligible impact but it is also likely that the species actually occur more widely within the landform; including within the mine pit boundaries. Thus at present, those 22 species would not be significantly impacted by the proposal, but a more precautionary assessment may treat them as equivalent to the remaining seven species known to occur within the mine pits. Six of these latter species confirmed within the pits also have records within the MEZ or other habitat that will remain intact post-mining. While the direct impact of habitat removal for the mine pits on these species would still be considered significant (Moderate at 10-50% of their known distributions with a High degree of certainty), 1,745.8 ha of mapped troglofauna habitat, and more than 50% of the pre-mining volume, remaining unmined on completion of the project, which would include known records of 32 of the 33 troglofauna species known from Mesa H.

Only one of the 33 development envelope species has thus far been recorded solely from within proposed pits: the dipluran Japygidae sp. 'DJA011' (Section 5.2.2.2). It is possible that this species only occurs within these direct impact areas, which would represent a Major impact on this species (loss of more than 50% of the known or inferred distributional extent) and thereby a significant impact following EPA (2016a).

However, available biological and physical connectivity evidence indicates that it is far more likely that the species is distributed to at least the scale of the troglofauna habitat mapped for Mesa H and the impacts on it at taxon level is likely to be equivalent to the other key receptor species known only from the development envelope (remaining as a significant impact, but at the Moderate consequence level rather than Major).

8.2.2 Ecological Community Receptors

The cumulative and incremental impact of the proposal on the 'Subterranean invertebrate communities of mesas in the Robe Valley region' PEC is very minor at 0.07% of its original extent and would not be significant under the framework used in this assessment.

The cumulative and incremental loss of habitat from the 'Subterranean invertebrate community of pisolitic hills in the Pilbara' PEC is greater at 7.96% of its original extent, but this would still not be assessed as a significant impact following the framework here (>10% of known distribution with a High degree of certainty).

8.3 Summary of Significant Impacts

8.3.1 Stygofauna

While all stygofauna species and ecological community receptors occurring within the drawdown extent will be impacted to some degree, impacts on five of the 16 stygofauna species present have been identified here as being potentially significant. As discussed in Section 8.1.1 and 8.1.2, impacts on four of these five species would only be considered significant if a precautionary position is adopted to the assessment, which is the context within which these final conclusions are presented. The species in question comprise:

1. Paramelitidae sp. 'AMP003' and Paramelitidae sp. 'AMP037' (Moderate or Major impact with High certainty);
2. the Schedule 3 amphipods *Nedsia hurlberti* and *N. sculptilis* (a Minor impact with High certainty, but still considered significant given the species Schedule listing); and
3. Schedule 3 Blind Cave Eel *Ophisternon candidum* (Moderate impact with High certainty).

8.3.2 Troglofauna

There are 27 species of troglofauna currently known only from the development envelope and 22 of these do not have any records from within the mine pit areas, which, taken on the basis of existing data, would indicate they would not be significantly impacted (Section 8.2.1).

However, again in the interests of providing a precautionary assessment, all 27 could be considered likely to occur more widely within Mesa H, as the 22 species possibly also occur within habitat inside the mine pit boundaries. The troglofauna species and ecological community receptors that would be significantly impacted within this precautionary context then comprise:

1. 26 potential SRE troglofauna species known only from within the development envelope but with confirmed records outside of the mine pits (Moderate impact with High certainty); and
2. a single potential SRE troglofauna species known only from within the mine pits: the dipluran Japygidae sp. 'DJA011' (Major impact with High certainty).

8.3.3 Conclusions

While Section 8.3.1 and Section 8.3.2 above present precautionary assessments (consistent with EPA (2018)), a more realistic assessment is provided here in closing. These conclusions adopt a balanced appraisal based on the combined survey and desktop data sets, and the body of biological and physical evidence collated in this assessment for both ecological groups.

That more realistic context would suggest that for:

- **Stygofauna**: Impacts 1, 2 and 5 above should be revisited, with impacts on four of the stygal species; Paramelitidae sp. 'AMP003', Paramelitidae sp. 'AMP037', *Nedsia hurlberti* and *N. sculptilis* (points 1 and 2 of Section 8.3.1) no longer assessed as significant (Minor impacts with High certainty); and
- **Troglofauna**: the impact on the troglofauna species known only from within the mine pits; Japygidae sp. 'DJA011' (point 5 of Section 8.3.2) should still be considered significant, but should be consolidated with the other 26 troglofauna taxa considered under point 4 of Section 8.3.2 as a Moderate impact with High certainty.

In closing then, the significant impacts on subterranean fauna from the Mesa H proposal comprise:

- the impact of groundwater drawdown arising from the dewatering on the Schedule 3 Blind Cave Eel *Ophisternon candidum* (a Moderate impact with High certainty); and
- the impact of habitat removal for mine pits on 27 potential SRE troglofauna species known only from within the development envelope but with confirmed records outside of the mine pits (Moderate impact with High certainty).

While these impacts would be considered significant (after EPA (2016a)), neither of the impacts would be assessed as Major under the framework used here (Loss of more than 50% of the known or inferred distribution and habitat extent and/or change in conservation status of the species), and both *Ophisternon candidum* and the 27 species of troglofauna will remain represented in subterranean fauna habitat outside of the proposal's impact footprint after the closure of the Mesa H operations.

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9.0 Glossary

Congener	Belonging to the same genus.
Development envelope	The predicted maximum ground disturbance area for the proposed development.
EIA	Environmental Impact Assessment.
EPA	Environmental Protection Authority of Western Australia.
GIS	Geographical Information System.
Ground disturbance	Any construction or operational ground disturbing activity that results in the removal of native vegetation, landforms and/or the disturbance of topsoil.
Indicative arrangement	The current conceptual design for proposed pit locations and boundaries, overburden storage areas and infrastructure.
Interstices	An opening or space, especially a small or narrow one between mineral grains in a rock or within sediments or soil.
Receptor	A subterranean fauna species, ecological community or habitat occurring or likely to occur within the development envelope that may be impacted by the proposal.
Locality	The area encompassed within a 40 km buffer on the development envelope.
Short-Range Endemic (SRE)	A species that has a naturally small distribution and is often characterised by having poor dispersal capabilities, confinement to disjunct habitats and low fecundity.
Stygobite / Stygofauna	Obligate groundwater fauna.
Taxon	A group of organisms identified as comprising a taxonomic unit (e.g. a species) (“taxa” = plural).
Taxonomy	Theory and practice of biological classification.
Troglobite / Troglofauna	Species living obligatory in caves; also blind, depigmented and often having an elongate body morphology.
Troglomorphic	Pertaining to morphological, behavioural and physiological characters that are convergent in subterranean populations (Christiansen 1962).
Troglophilic / Troglophile	Species able to live and reproduce underground as well as in the surface environment (Wilkens et al. 2000).
Vug	A small cavity in a rock or vein, often with a mineral lining of different composition from that of the surrounding rock.

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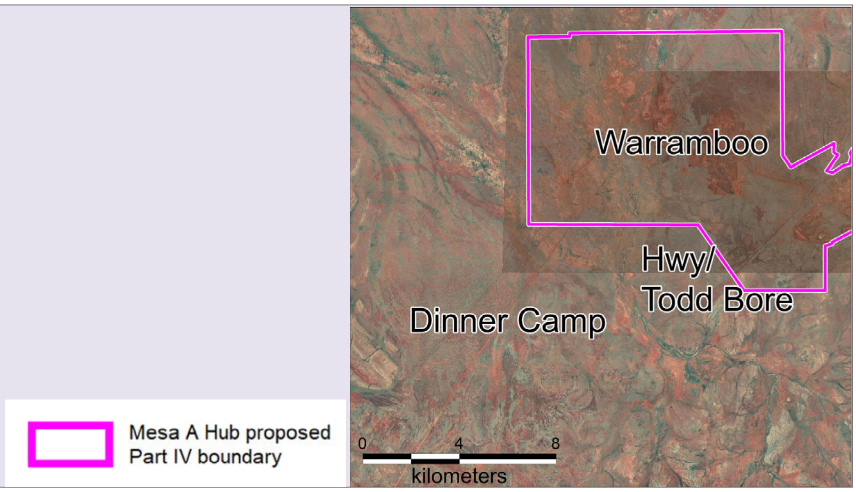
Appendix 1

Conceptual Flowchart of Troglofauna Habitat CID Modelling

Conceptual Methodology for Subterranean Fauna Habitat Modelling

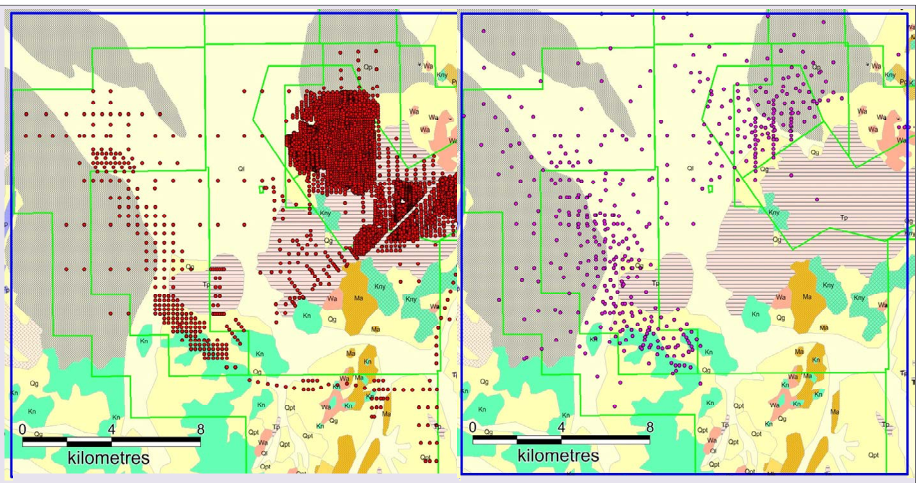
Warramboo/Highway/Tod Bore, Q1 2018

1. Define the location



2. Collate available data sources

- geological mapping
- geophysical mapping
- downhole drilling information
- geotechnical information
- core data (if available), including photos

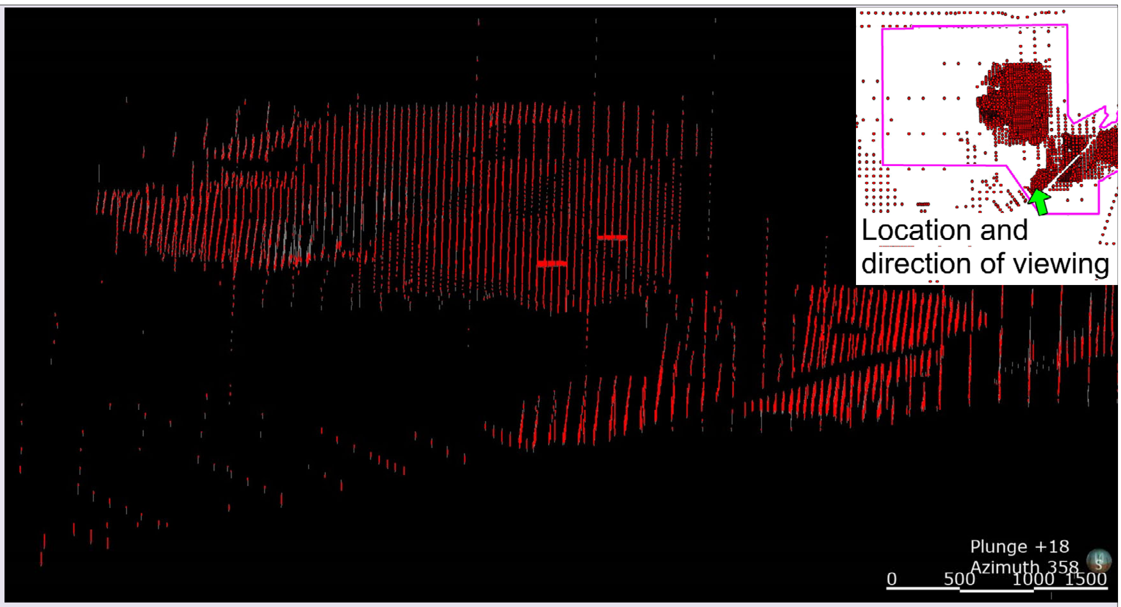


Red dots = geological drill logs available

Historical publicly available data (DMIRS)

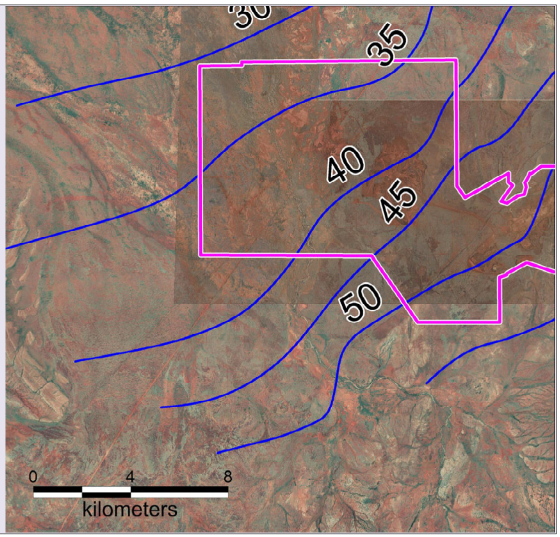
3. Calculate habitat thickness at each data point (drillhole)

In this case habitat was channel iron deposits (CID)



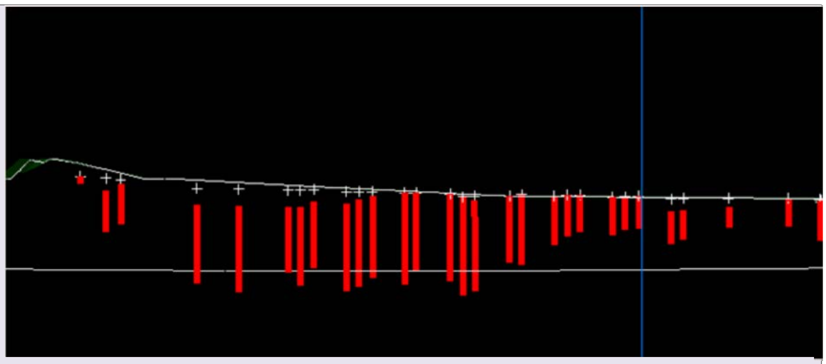
Cross section shows a 3D tilted image of CID thickness in each hole (red bars)

4. Establish water table levels using groundwater contour data

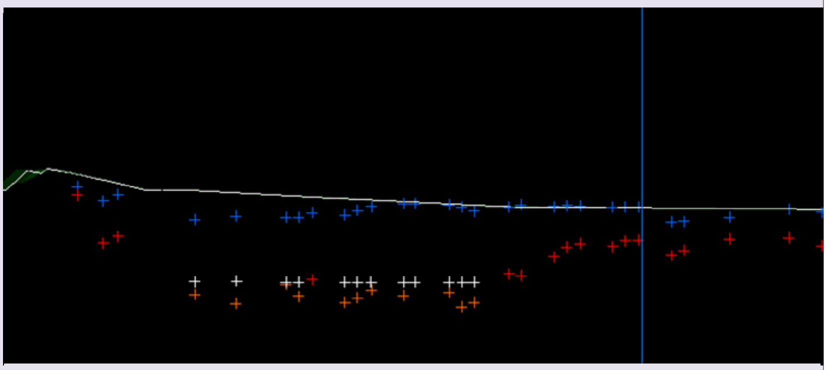


5. Calculate thickness of above water table CID

Troglofauna don't reside below the water table



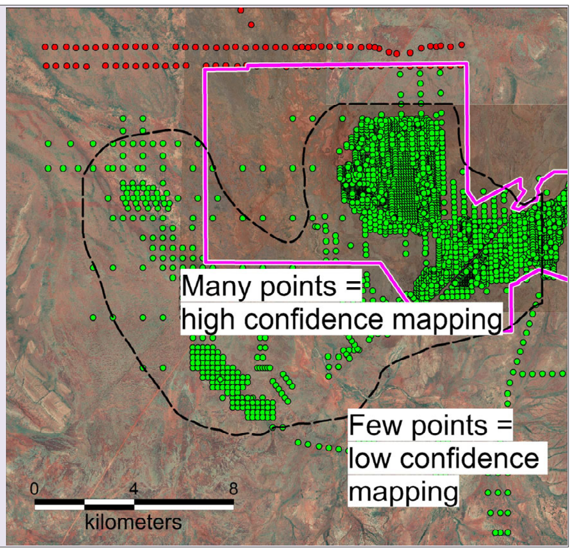
Cross section showing CID depth (red bars) in relation to the water table (lower white line)



Resulting above water table CID depth once below water table is removed. Top of CID interval (blue), bottom of CID interval (red) and water table (white).

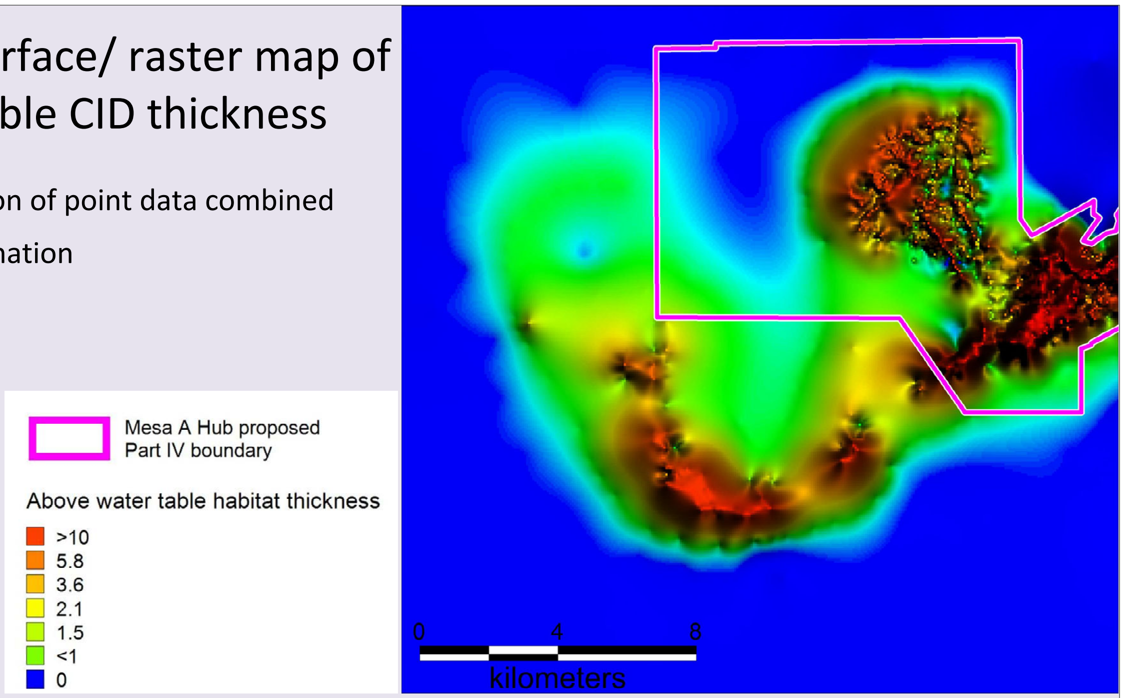
6. Determine high and low confidence areas

Based on drill hole density



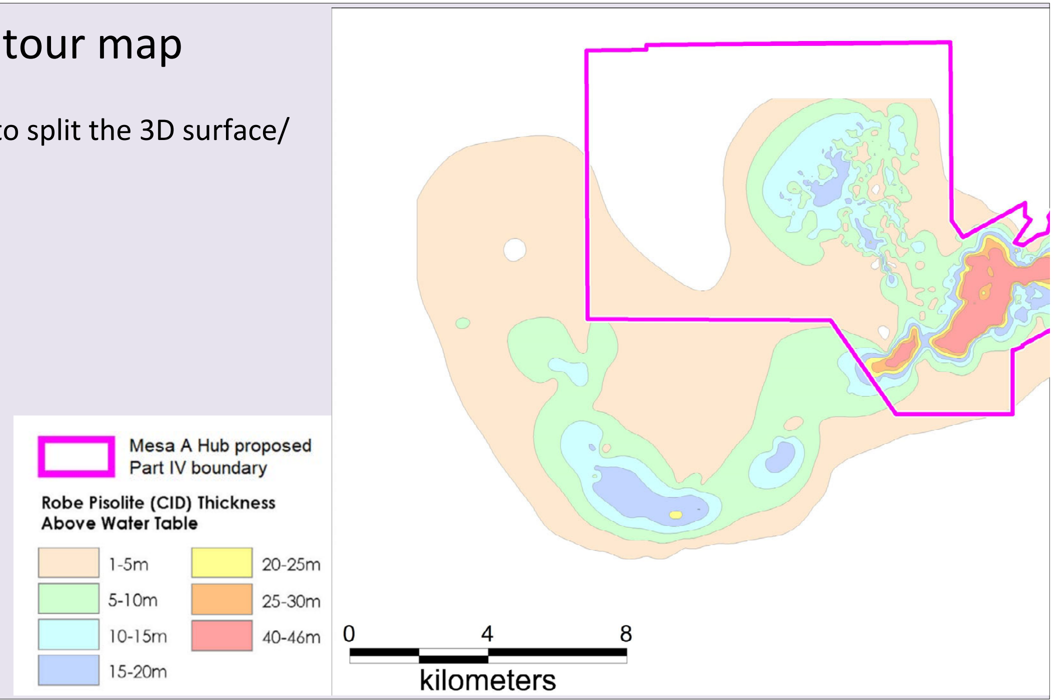
7. Create 3D surface/ raster map of above water table CID thickness

Use spatial interpolation of point data combined with confidence information



8. Produce CID contour map

Use pre-defined categories to split the 3D surface/ raster image into sections

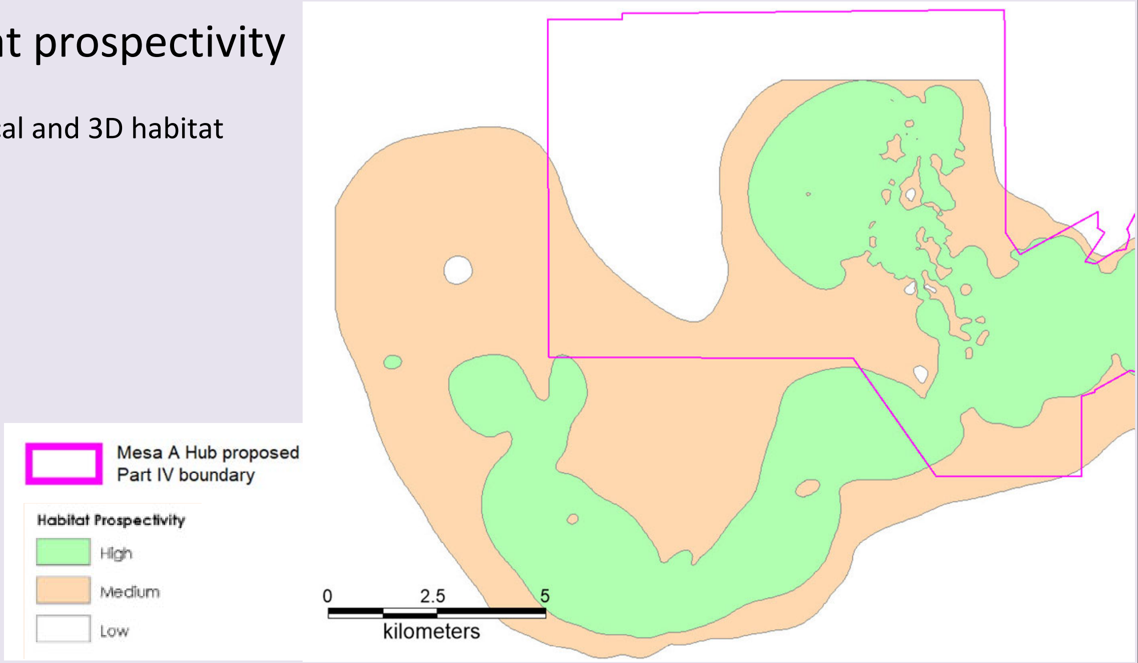


10. Determine habitat prospectivity categories

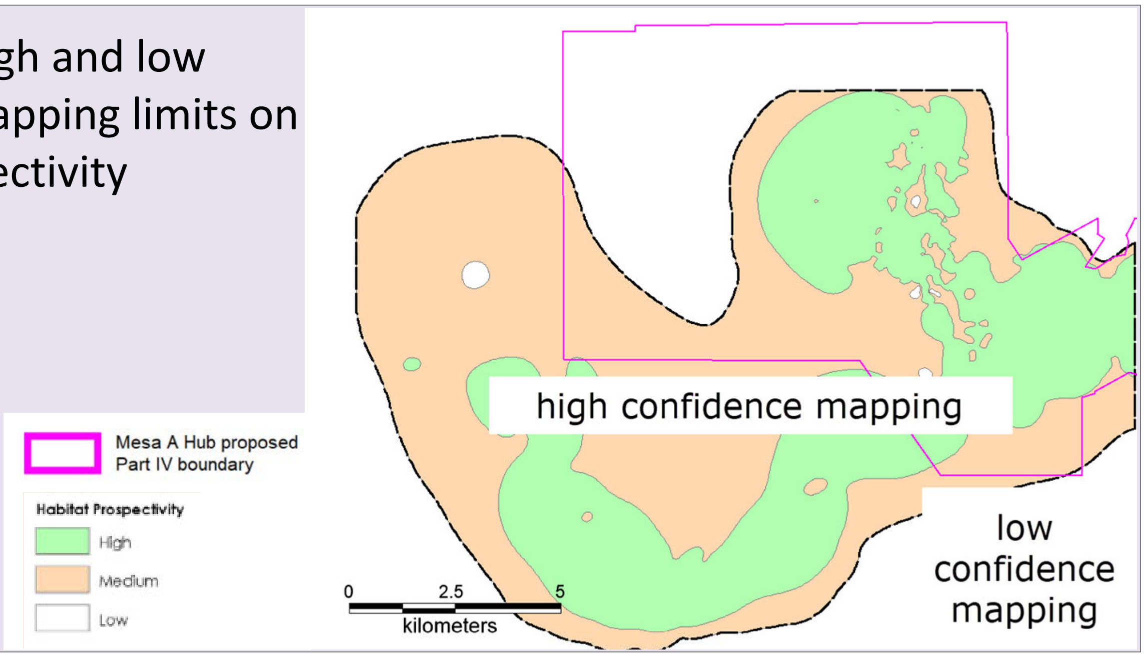
Habitat prospectivity	Geological Unit
High	Robe Pisolite (TP; >5m thickness)
Medium	Robe Pisolite (TP; 1-5m thickness)
Low	Robe Pisolite (TP; <1m thickness)

11.Map habitat prospectivity

Amalgamate geological and 3D habitat thickness maps

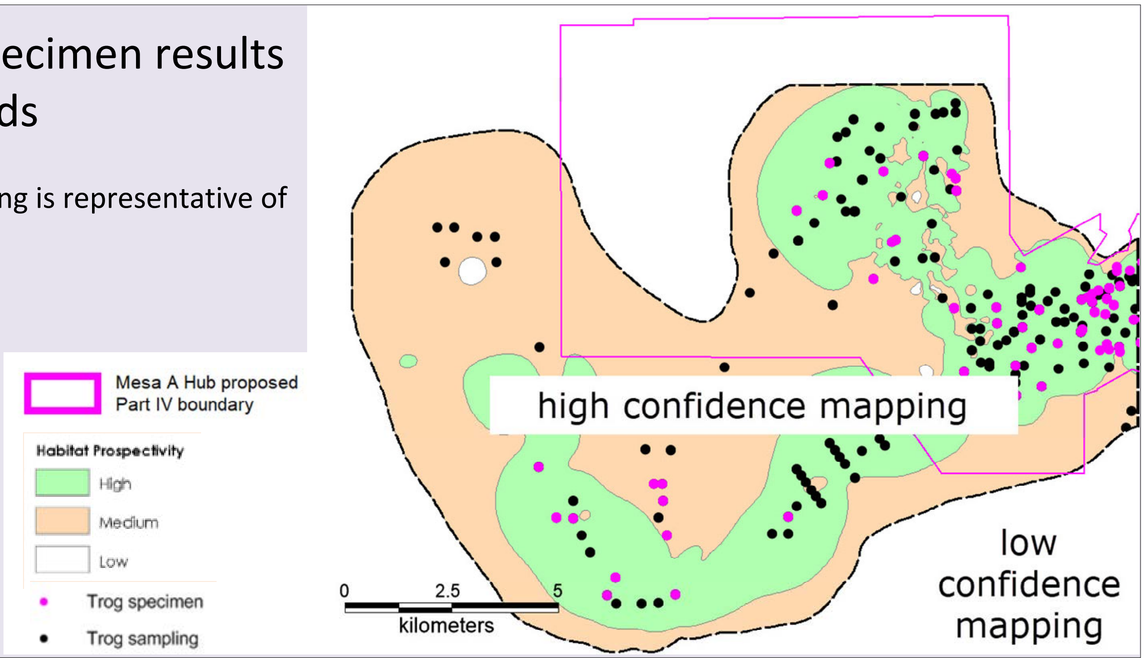


12. Overlay high and low confidence mapping limits on habitat prospectivity mapping



13. Overlay specimen results and null records

Validate that modelling is representative of actual results



*Note that troglofauna records outside the high confidence interval are located in a different geological habitat which requires a separate modelling analysis.