Eliwana Project

Subterranean Fauna Assessment

Biologic Environmental Survey

Fortescue Metals Group Ltd

May 2018

Eliwana Project

Subterranean Fauna Assessment 2017

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1 EXECUTIVE SUMMARY

Fortescue Metals Group (Fortescue) is proposing to develop the Eliwana Iron Ore Mine Project (the Proposal), 90 km west-north-west of Tom Price, in the Pilbara region of Western Australia in the Pilbara region of Western Australia. The Proposal includes the development of mine pits and associated infrastructure, processing facilities, water management infrastructure for groundwater abstraction and surplus water disposal, temporary and permanent waste landforms and tailings storage facilities. The Proposal involves disturbance of up to 8,560 ha within a 53,368 ha Study Development Area (the Study Area).

The Study Area comprises two main areas: Eliwana, which is located centrally, extending west towards the Edge (another Western Hub tenement); and Flying Fish, which extends west towards Rio Tinto Iron Ore's Nammuldi and Brockman 4 mines. The mining of approximately 25Mtpa Iron Ore within the Study Area has been proposed as the most likely prospect to replace the Firetail orebody, an existing mining operation at Fortescue's Solomon Hub (approximately 80 km north-east of the Study Area), which is projected to be exhausted by the year 2020.

Fortescue commissioned Biologic Environmental Survey Pty Ltd (Biologic) to conduct a level 2 subterranean fauna (stygofauna and troglofauna) assessment at the Study Area. The assessment aimed to provide:

- a desktop review of previous subterranean fauna surveys at the Study Area and existing data on a local and regional scale;
- an assessment of the suitability and extent of subterranean habitats within the Study Area and potential wider connectivity beyond the Study Area;
- results of a two-phase stygofauna and troglofauna survey within the Study Area, including detailed identifications of all species collected, estimation of their distribution ranges and a discussion of their conservation status; and
- an assessment of the potential risks to troglofauna and stygofauna species and their habitats arising from the proposed development of the Study Area.

Fortescue has previously commissioned significant subterranean fauna surveys within the sub-regional area to the north east of the Study Area around the Solomon mine and Central Pilbara Project areas, revealing troglofauna and stygofauna assemblages of considerable diversity and abundance. The results from sub-regional surveys were used for regional comparisons where appropriate, while the Western Hub survey results (Bennelongia 2015) provided immediately relevant local context.

The Western Hub Baseline Survey comprised subterranean fauna sampling across three zones; Delphine, The Edge, and the Study Area (Eliwana and Flying Fish). More than half of the Western Hub survey effort (totalling 631 samples across the three zones) was conducted in the current Study Area; comprising 240 troglofauna samples and 78 stygofauna samples, resulting in 20 troglofauna species (120 specimens) and 15 stygofauna species (423 specimens) being recorded.

During the current survey, a total of 223 troglofauna samples and 76 stygofauna samples were collected over the course of four field trips (a two-phase survey). A total of 523 subterranean fauna specimens were recorded throughout the Study Area. Troglofauna comprised nearly half of these records with 242 specimens collected, representing 31 species from eleven higher taxa; these were mites, schizomids, spiders, centipedes, pauropods, myriapods, diplurans, silverfish, cockroaches, hemipterans and beetles. This represents a slightly richer troglofauna assemblage than recorded during the Western Hub Survey (20 species). A total of 281 stygofauna specimens were collected from the current survey, representing 15 species from five higher groups; these were oligochaetes, ostracods, copepods, syncarids and amphipods. This represents a very similar stygofauna assemblage as previously recorded (15 species belonging to the same five groups). Thus, a combined sample effort of 463 troglofauna samples and 154 stygofauna samples have been collected from the previous and current surveys of the Study Area.

The combined troglofauna results (comprising Western Hub survey and current survey results) recorded a total of 365 troglofauna specimens, representing 45 morphospecies belonging to 15 higher taxa; Diplura (8 species), Schizomida (6 species), Pauropoda (6 species), Coleoptera (6 species), Araneae (4 species), Isopoda (2 species), Thysanura (2 species), Hemiptera (2 species), Symphyla (2 species), Chilopoda (2 species) and single species of Acari, Palpgradi, Polyxenida, Blattodea and Diptera. An additional three (3) indeterminate taxa were recorded that may represent species already known from the Study Area, including Thysanura sp., *Nocticola* sp. and *Macranillus* sp. indet.

The combined stygofauna results to date comprise a total of 694 potential stygofauna specimens. This represents 26 stygofauna morphospecies belonging to 6 higher order groups; Amphipoda (8 species), Copepoda (6 species), Oligochaeta (5 species), Ostracoda (2 species), Syncarida (4 species) and Nematoda (single species). An additional two indeterminate taxa (Enchytraeidae sp. and *Parastenocaris* sp.) were recorded that may represent species already known from the Study Area.

The combined troglofauna results to date show that 17 troglofauna taxa are known only from proposed pit boundaries (or the TSF in the case of Projapygidae sp. B14):

- Eleven (11) of these taxa were assessed as ‘low’ risk, *Paradraculoides* sp. B12A, *Prethopalpus* sp. MW21, *Troglarmadillo* sp. B46, Pauropodidae sp. B42 and B43, *Symphyella* sp. 'EW', Campodeidae sp. 'EW', Projapygidae sp. B14 and B17, *Lepidospera* sp. B10, and *Macranillus* sp. 'EW';
- Two troglofauna taxa Pauropodidae sp. B29 and B41 were assessed as ‘low – moderate’ risk (based on their less certain ecological status); and
- Four taxa (true troglobites) were assessed as ‘moderate’ risk (Palpigradi sp., *Paradraculoides* sp. ‘new2’, *Paradraculoides* sp. ‘new3’ and *Anapistula* sp. 'EW').

The risks assigned to troglofauna species were based on detailed habitat assessment information (a combination of geological cross sections, drill logs and core photos), which strongly indicated that, for each of the species detected only from inside impact areas, suitable, well-connected habitats appeared to extend beyond the proposed impact areas.

The combined stygofauna results to date show that nine stygofauna species are currently known only from the Eliwana Study Area and may be at risk from proposed groundwater drawdown impacts:

- Three taxa were assessed as 'low' risk, *Areacandona* nr *triangulum, Brevisomabathynella* sp. C and *Bogidiella* sp. B05 (species occur beyond or only on the margins of predicted drawdown);
- Three taxa, *Parastenocaris* sp., *Brevisomabathynella* sp. B, and Paramelitidae sp. B58, were assessed as 'low-moderate' risk (species known to occur within aquifers only partially affected by drawdown);
- One taxon, *Brevisomabathynella* sp. A, was assessed as 'moderate' risk (species currently known only from aquifer significantly, but not fully depleted by drawdown); and
- Two taxa, *Brevisomabathynella* sp. B03 and *Areacandona* sp. BOS1020, were assessed as 'high' risk (species currently known only from aquifers likely to be completely dewatered).

The risk assessment for stygofauna was informed by detailed habitat assessment information (including geological cross sections, bore logs, core photos, and hydrogeological reports), which indicated that suitable habitats for stygofauna appeared to occur beneath the predicted drawdown within several hydrogeological compartments, where the species regarded as 'low-moderate' to 'moderate' risk occur. Some of these stygofauna species occurred across the inferred hydrogeological barriers throughout the Eliwana Valley, suggesting some potential for wider local occurrence. In addition, two considerable knowledge gaps remain due to a lack of sampling immediately beyond the Eliwana Valley to the north and south, which may provide useful context to the current patterns of stygofauna occurrence within the Study Area. Nevertheless, based on current fauna data and groundwater drawdown modelling, the two taxa regarded as 'high' risk are currently known only from aquifers that are likely to be completely dewatered.

2 INTRODUCTION

2.1 Background / Project Summary

Fortescue Metals Group (Fortescue) is proposing to develop the Eliwana Iron Ore Mine Project (the Proposal), 90 km west-north-west of Tom Price, in the Pilbara region of Western Australia in the Pilbara region of Western Australia. The Proposal includes the development of mine pits and associated infrastructure, processing facilities, water management infrastructure for groundwater abstraction and surplus water disposal, temporary and permanent waste landforms and tailings storage facilities. The Proposal involves disturbance of up to 8,560 ha within a 53,368 ha Study Development Area (the Study Area).

The Study Area comprises two main areas: Eliwana, which is located centrally, extending west towards the Edge (another Western Hub tenement); and Flying Fish, which extends west towards Rio Tinto Iron Ore's Nammuldi and Brockman 4 mines. The mining of approximately 25Mtpa Iron Ore within the Study Area has been proposed as the most likely prospect to replace the Firetail orebody, an existing mining operation at Fortescue's Solomon Hub (approximately 80 km north-east of the Study Area), which is projected to be exhausted by the year 2020.

Fortescue has commissioned Biologic Environmental Survey Pty Ltd (Biologic) to conduct a level 2 subterranean fauna (stygofauna and troglofauna) assessment at the Study Area (Figure 2.2). The survey was designed and conducted in accordance with relevant EPA for subterranean fauna assessments as described in:

- EPA (2016a) Environmental Assessment Guideline 12 for Consideration of subterranean fauna in environmental impact assessment in Western Australia;
- EPA (2016b) Guidance Statement 54a. Sampling Methods and Survey Considerations for Subterranean Fauna in WA; and

2.2 Aims

The aims of this assessment were to provide:

- a desktop review of previous subterranean fauna surveys at the Study Area and existing data on a local and sub-regional scale;
- an assessment of the suitability and extent of subterranean habitats within the Study Area and potential wider connectivity beyond the Study Area;
- results of a two-phase stygofauna and troglofauna survey within the Study Area, including detailed identifications of all species collected, estimation of their likely occurrence relative to habitat units and impact areas, and a discussion of their conservation status; and
- an assessment of the potential risks to troglofauna and stygofauna species and their habitats arising from the proposed development of the Study Area.

150000 200000 250000 300000 350000 400000 450000 500000 550000 600000 650000 700000 750000 800000 850000

7750000 7700000 7650000 7600000 7550000 7500000 7450000 7400000

Pindanland
McLarty
Roebourne
Chichester
Fortescue
Hamersley
Ashburton
Cape Range
Wooramel
Augustus

Karratha
Roebourne
Marble Bar
Onslow
Mesa A/ Warramboo
Pannawonica
Mesa J
Red Hill
Exmouth
Flinders
Solomon
Cloudbreak
Christmas Creek
Brockman 2/ Nammuldi/ Silvergrass
Marandoo
Brockman 4
Western Turner Syncline
Tom Price
Mt Tom Price
Western Pilbara Stage 2
Nydinghu
Paraburdoo
Turee Syncline
Paraburdoo
Channar
Newman

Legend

Mining locations
- Fortescue
- Third Party
- Pilbara Towns
- Pilbara Rail
- Development Envelope
- Pilbara Highway

IBRA Subregion
- Ashburton
- Augustus
- Cape Range
- Chichester
- Fortescue
- Hamersley
- McLarty
- Pindanland
- Roebourne
- Wooramel

biologic Environmental Survey

N

1:1,800,000

0 25 50 100 km

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Fig. 2.1: Regional location and IBRA subregions

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 30/01/2018

460000 470000 480000 490000 500000 510000 520000 530000

7540000 7530000 7520000 7510000 7500000

Exploration Camp

Brockman 4

Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Legend

- Mining Locations
- Development Envelope
- **Indicative Disturbance**
- Infrastructure
- Mining Pit (150m buffer)
- Stockpile
- Tailings Storage
- Pilbara Rail

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N

1:200,000

0 2.75 5.5 11 km

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Fig. 2.2: Development envelope and proposed layout of mining pits

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 31/01/2018

2.3 Subterranean Fauna

Subterranean fauna are animals that predominantly live underground; the group is mainly represented by invertebrates such as crustaceans, insects, arachnids, myriapods, worms, and snails, but also includes some vertebrates such as fish and reptiles. Subterranean fauna are commonly classed into two ecological categories:

- stygofauna - aquatic animals that inhabit groundwater in caves, aquifers and water-saturated interstitial voids; and
- troglofauna - air-breathing animals that inhabit caves and smaller voids or micro-caverns.

Invertebrate ecologists recognise a series of gradients from fully aquatic to fully terrestrial (air-filled) habitats, as well as completely above-ground (epigean) to completely below-ground (hypogean) habitats. There are invertebrate taxa (and, indeed vertebrate taxa) that are known to move between these habitats at different times in their life cycles (trogloxenes and stygoxenes), and yet others that can be found within any of these habitat strata at any given time (troglophiles or stygophiles) (Christiansen 2005, Stanford and Ward 1993). Nevertheless, the EPA (2016a) assessment guidelines for subterranean fauna consider only obligate subterranean fauna during environmental impact assessment (EIA): respectively, troglobites and stygobites which live their entire lifecycle in hypogean environments and are thus considered more susceptible to short-range endemism) (following Harvey 2002, Eberhard et al. 2009).

Obligate subterranean species, which cannot occur on the surface or in soil habitats, are considered most likely to be short-range endemic (SRE), based on the often-restricted extent of their geological or hydrogeological habitats (Harvey 2002; Holsinger 2000; Howarth 1983; Humphreys 2000). This high propensity for short-range endemism in troglobites and stygobites increases the background likelihood that any given species may be negatively impacted by proposed developments (EPA 2016a).

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

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

2.3.1 Legislation and Guidance

Western Australia's subterranean fauna is considered globally significant due to an unprecedented richness of species and high levels of short-range endemism (EPA 2013). The EPA's primary objective for subterranean fauna is to "maintain representation, diversity, viability and ecological function at the species, population and assemblage level" (EPA 2013). Protection for listed (conservation significant) subterranean species and/ or Threatened or Priority Ecological Communities is provided under State and Federal legislation, including:

- Environmental Protection Act 1986 (EP Act 1986) (WA);
- Wildlife Conservation Act 1950 (WC Act 1950) (WA); and
- Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act 1999) (Commonwealth).

However, most subterranean species and communities are not listed, due to incomplete taxonomic or ecological knowledge. Consideration of subterranean fauna species during EIA is not limited to listed species or ecological communities, but also may include species or communities that occur only within restricted habitats, as per short-range endemic (SRE) species (Harvey 2002, Eberhard et al. 2009).

This survey/ assessment of subterranean fauna was conducted in consideration of the following EPA guidance statements:

- EPA (2016a) EAG#12 Environmental Assessment Guideline for consideration of subterranean fauna in environmental impact assessment in Western Australia (superseding Guidance Statement 54 – Consideration of Subterranean Fauna in Groundwater and Caves during Environmental Impact Assessment in Western Australia);
- EPA (2016b) Guidance Statement #54A (Draft) Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia (Technical Appendix to Guidance Statement No. 54); and
- EPA (2004) Guidance Statement #56 Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia.

3 HABITAT CHARACTERISATION OF THE STUDY AREA

3.1 Geology

The Hamersley Basin overlays most of the southern portion of the Archaean granite-greenstone Pilbara Craton and is composed of sedimentary and volcanic deposits known as the Mount Bruce Supergroup (Golder, 2017). The stratigraphy of the Hamersley Basin is comprised broadly of the Fortescue, Hamersley and Turee Creek Groups; with most iron mineralisation occurring in the Brockman Iron Formation (BrIF) and Marra Mamba Iron Formations (MMIF) of the Hamersley Group (Golder, 2017).

A generalised stratigraphy of the Hamersley Basin is shown in Table 3.1, with notes relating to the generalised suitability for subterranean fauna based on regional knowledge. The project hosts several bedded (BID) and detrital (DID) iron deposits within and overlying Mt Bruce Supergroup stratigraphy. The valley occurs as generally south-dipping Hamersley Group stratigraphy along the northern limb of the Brockman Syncline with the geometry defined by the basement architecture of the Archaean Pilbara Craton and subsequent deformation events occurring between 2.45 – 2.2 Ga.

The geomorphology of the valley is controlled by the erosional characteristics of these units, with the more resistive Brockman Iron Formation to the south, forming high, steep ridges and the Marra Mamba Iron Formation forming lower rounded hills along the northern flank of the valley. The softer Wittenoom Formation forms the valley floor. The bedded stratigraphy dips to the south at between 30-45° with the oldest bedded metasediments to the north, progressing through overlying younger metasediments to the south (Figure 3.1). Figure 3.2 (parts A and B) shows the surface geology of the Development Envelope and proposed mining pits based on GSWA 1:250,000 mapping.

Mineralisation within the Eliwana and Flying Fish deposits is predominantly hosted by BID (Brockman and Marra Mamba Formations) with some mineralisation in DID (e.g. Red Ochre Detritals). Channel Iron Deposit (CID) mineralisation does occur in the area, but at this stage, is not considered of economic significance. The BID material is formed in outcropping Mount Newman and MacLeod Members of the Marra Mamba Iron Formation, the West Angela Member of the Wittenoom Formation, as well as Dales Gorge, Whaleback Shale and Joffre Members of the Brockman Iron Formation.

Mineralisation is predominantly formed by supergene weathering/ enrichment of hematite-martite-goethite. The secondary weathering/ enrichment processes that drive mineralisation in the uppermost layers of the Marra Mamba, Wittenoom, and Brockman Iron Formations are also generally responsible for creating vugs and cavities that provide potential habitat for troglofauna and stygofauna. Secondary weathering processes also commonly create voids and cavities within Tertiary detrital deposits (both within CIDs and calcrete deposits) in the valley fill, and in some cases, within karstic dolomites of the Wittenoom Formation. Deeper habitats for subterranean fauna can also occur in proximity to faulting and folding zones because of large fractures within BIF and dolomite.

Table 3.1: Stratigraphy of mine area and generalised suitability for subterranean fauna

Unit			Description	Suitability for subterranean fauna (generalised)
Tertiary Detritals (Qa/Ta/Td)			Overlying the calcrete and silcrete are mainly poorly sorted, unconsolidated gravels, comprising banded iron, ironstone or dolerite in a clay matrix. Considered to be colluvium and alluvial sheet wash from the surrounding hills. Calcrete (or dolomite) and silcrete is commonly found along drainage lines and buried within valley sediments. Older red ochre detritals, exist as remnant stands exposed within deeply incised gorges.	High beneath WT (stygofauna), Med-High above WT (troglofauna), where sufficient vugs, cavities or void spaces occur.
Channel Iron Deposits (CID)			Robe Pisolite unaltered hematite-goethite pisoliths. Thickness is highly variable and dependent on associated beds and its exposure and erosion Lignite and siderite (Fe carbonate) from lacustrine deposition occur sporadically but have not been identified at the mine area	High beneath WT (stygofauna), High above WT (troglofauna), where sufficient vugs, cavities, fractures, or void spaces occur.
Dolerite dykes (PD)			Near vertical trend NW-SE, NNW-SSE and NE-SW	Negligible (potential barrier to species dispersal).
Dolerite sill (PS)			Intrudes into the J3 units	Negligible (potential barrier to species dispersal).
Hamersley Group				
Brockman Iron Formation (HB)	Yandicoogina Shale Member (BY)		Alternating chert and shale up to 60 m thick, does not occur in waste	Low (potential barrier to species dispersal).
	Joffre Member (BJ)	Unit 6 (J6)	Brockman Iron Formations consist of the highest grade bedded iron deposits. Homogeneous with approximately 330 m of alternating banded iron formation and shale bands. The banded iron comprises interbedded chert and iron rich material.	High beneath WT (stygofauna), High above WT (troglofauna), where sufficient vugs, cavities, fractures, or void spaces occur. Shale bands expected to be relatively impermeable (except where deeply fractured or faulted) and may act as barrier to dispersal. Dolerite sill is inferred to occur throughout the J3 band that may form a potential barrier for subterranean species.
		Unit 5 (J5)		
		Unit 4 (J4)		
		Unit 3 (J3)		
		Unit 2 (J2)		
		Unit 1 (J1)		
	Whaleback Shale Member (BW)		Approximately 50 m thick, this member consists of thinly bedded shales with thicker chert or BIF bands, weathered with supergene enrichment of BIF bands	Med beneath WT (stygofauna), Med above WT (troglofauna), weathered/ enriched BIF bands likely to provide suitable habitat, but shale bands may be impermeable.
	Dales Gorge Member (BD)	Unit 4 (D4)	An alternating sequence of BIF and shale macro-bands. The BIF bands comprise of centimetre thick bands of chert and iron rich material in a chert matrix. The shale bands comprise primarily volcanogenic and carbonate turbidite. Member is ~ 142 m thick	High beneath WT (stygofauna), High above WT (troglofauna), where sufficient vugs, cavities, fractures, or void spaces occur. Shale bands expected to be relatively impermeable (except where deeply fractured or faulted) and may act as barrier to dispersal.
		Unit 3 (D3)		
		Unit 2 (D2)		
		Unit 1 (D1)		
Mount McRae Shale Formation (HR)			Comprises thinly laminated, fissile shale with minor subordinate amounts of chert, dolomite and BIF. Unweathered unit occurs as black graphitic and chloritic shale with significant pyrite that represents a potential spontaneous combustion and acid forming material risk when exposed through mining	Low (potential barrier to species dispersal).

Unit		Description	Suitability for subterranean fauna (generalised)
Mount Silvia Formation (HS)	(Bruno's Band)	Three prominent banded iron formation (BIF) bands, separated by laminated mudstone and minor chert and dolomite with the upper a recognisable regional marker known as Bruno's band. Thickness varies from 30 to 45 m	Low (potential barrier to species dispersal) - assumed to be massive, impermeable.
Wittenoom Formation (HD)	Bee Gorge Member (HG)	A thinly laminated fissile argillite also contains subordinate thickness of carbonate, chert, volcaniclastics and iron formation with distinct marker bed: The Main Tuff Interval. Member ranges in thickness from 100 to 227 m	Med beneath WT (stygofauna), Med above WT (troglofauna), possibility of weathered carbonates/ iron formations.
	Paraburdoo Member (HP)	Comprises a majority of dolomite with minor amounts of chert and argillite (clay, mudstone, shale), thickness between 260 and 420 m.	High beneath WT (stygofauna), High above WT (troglofauna), where sufficient vugs, cavities, fractures, or void spaces in dolomite.
	West Angela Member (DA)	Predominantly massive to laminated dolomite interbedded with shaley dolomite with pyrite and chert, between 30 and 50 m thick.	Moderate where Dolomite is sufficiently weathered/fractured and Low where shale bands are tight/massive.
Marra Mamba Iron Formation (HM)	Mount Newman Member (MN)	Banded iron interbedded with carbonate and shale, between 45 and 60 m thick containing eight identified shale bands	High beneath WT (stygofauna), High above WT (troglofauna), where sufficient vugs, cavities, fractures, or void spaces occur. Shale bands expected to be relatively impermeable (except where deeply fractured or faulted) and may act as barrier to dispersal.
	McLeod Member (MM)	Banded iron, chert and carbonate along with interbedded shales, 25 to 45 m. The upper most beds contain the most shale units, closely spaced together.	High beneath WT (stygofauna), High above WT (troglofauna), where sufficient vugs, cavities, fractures, or void spaces occur. Shale bands expected to be relatively impermeable (except where deeply fractured or faulted) and may act as barrier to dispersal.
	Nammuldi Member (MU)	Cherty, banded iron formation interbedded with thin shales. The un-mineralised Nammuldi Member is between 75 and 100 m thick	Low (potential barrier to species dispersal) - assumed to be mainly massive, impermeable (except where fractured/ faulted.
Fortescue Group			
Jeerinah Formation (FJ)		Dark grey to black shale, commonly with spheroidal pyrite concretions.	Low (potential barrier to species dispersal).
Roy Hill Shale Member (JR)			

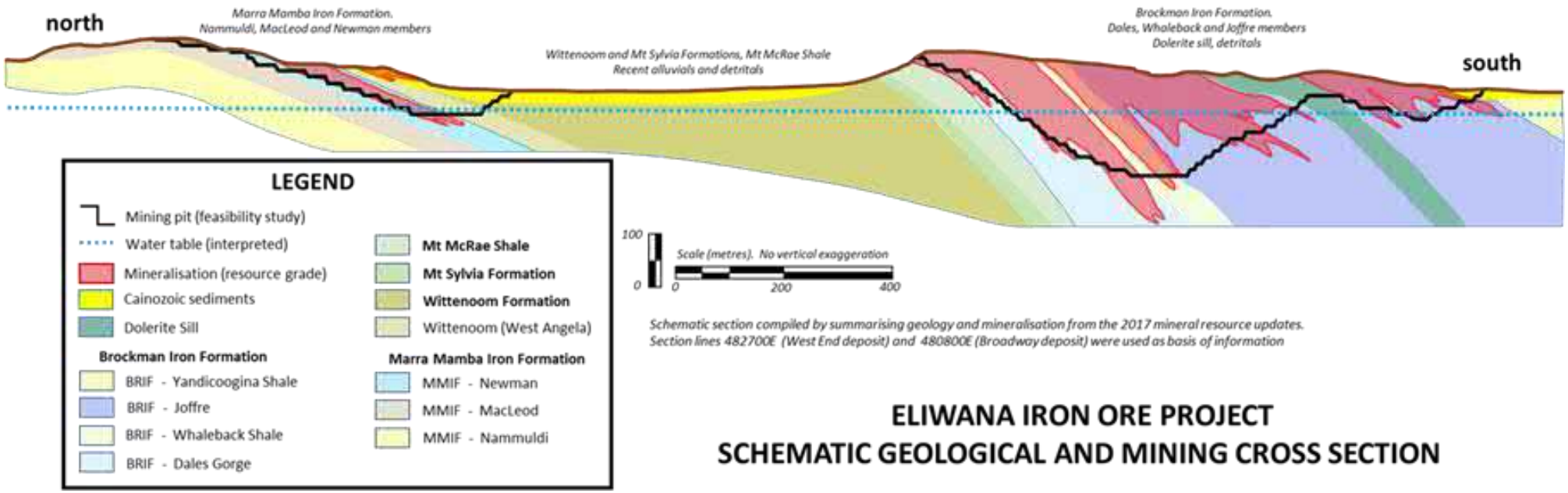

Figure 3.1. Conceptual generalised cross-section of the Eliwana Iron Ore Project (Figure provided by Fortescue).

470000

480000

490000

7520000

7510000

503 m

400 m

543 m

591 m

500 m

600 m

731m

691 m

734 m

513m

Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Legend

- Development Envelope

Indicative Disturbance

- Mining Pit (150m buffer)
- Potential dykes (interpreted)

Pooled geology

- Brockman Iron Formation
- Dolerite dykes
- Jeerinah Formation
- Marra Mamba Formation
- Mt McRae Shale
- Mt Sylvia Formation
- Wittenoom Iron Formation

biologic Environmental Survey

N

1:80,000

0 1 2 4 km

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Eliwana Subterranean Fauna Survey 2017

Fig. 3.2a: Surface geology and interpreted dykes of the proposed development envelope (west)

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 31/01/2018

500000

510000

520000

7520000

7510000

676 m

537 m

615 m

729 m

589 m

642 m

616 m

838 m

700 m

757 m

Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Legend

- Development Envelope

Indicative Disturbance

- Mining Pit (150m buffer)
- Potential dykes (interpreted)

Pooled geology

- Boolgeeda Iron Formation
- Brockman Iron Formation
- Dolerite dykes
- Dolerite sills
- Jeerinah Formation
- Marra Mamba Formation
- Mt McRae Shale
- Mt Sylvia Formation
- Weeli Wolli Formation
- Wittenoom Iron Formation
- Woongarra Rhyolite

biologic Environmental Survey

N

1:80,000

0 1 2 4 km

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Fig. 3.2b: Surface geology and interpreted dykes of the proposed development envelope (east)

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 31/01/2018

3.2 Hydrogeology

The hydrogeological environment of the Study Area is inferred from the Eliwana geological model, airborne total magnetic intensity interpretation, and information from hydrogeological and resource bores (Golder, 2017). Up to 12 GL/a groundwater is proposed for abstraction for mine use from a combination of dewatering and water supply bore fields. Up to 4 GL/a of surplus water will be required to be managed by surface discharge and aquifer reinjection.

A summary of local aquifers and aquitards/ aquicludes appears below. The groundwater system of the Development Envelope and the valley mining area is complex and appears to be compartmentalised into several discrete groundwater sub-catchments (Figure 3.3). The water table throughout the Development Envelope is highly variable, depending on the associated aquifer compartment. For ease of discussion, the groundwater sub catchments have been named for their respective groundwater levels (Figure 3.4).

3.2.1.1 Tertiary detrital aquifer

A shallow Tertiary Detrital Aquifer occurs in the alluvial/ colluvial in-fill of valleys which may contain calcrete deposits and is considered unconfined, however, Tertiary clays in the valley may act as a local aquiclude (potential barriers to stygofauna movement). Channel Iron Deposits (CID) of unknown and limited extent occur in the Flying Fish area. As indicated in Table 3.1, these superficial aquifers are expected to be highly suitable for stygofauna where sufficiently porous and transmissive.

3.2.1.2 Mineralised Brockman aquifer

The mineralised Brockman Iron Formation is considered to form an aquifer and will be referred to as the “Mineralised Brockman Aquifer”. The hypergene enrichment that causes bedded mineralisation in the Hamersley Basin involves groundwater replacement of silicate and carbonate minerals with goethite, which results in stratigraphic thinning and associated increases in porosity and permeability. The Whaleback Shale Member is assumed to be part of the aquifer where it is weathered/mineralised. As indicated in Table 3.1, these weathered layers are expected to be moderately to highly suitable for stygofauna where sufficiently porous, vuggy or fractured.

3.2.1.3 Wittenoom aquifer

The Wittenoom Aquifer comprises all weathered Members of the Wittenoom Formation as well as the mineralised upper Newman Member of the underlying Marra Mamba Iron Formation which is connected. The West Angela Member comprises shaley dolomite and interbedded banded iron formation. Where weathered or karstic, Wittenoom dolomite is known to form highly porous/ transmissive aquifers that provide suitable habitat for stygofauna, although the degree of weathering/ karstification of these units within the development envelope is not fully known.

The upper Mount Newman Member is sometimes separated from the lower Mount Newman Member by an impermeable shale band which would be expected to form an aquitard/ aquiclude, and thus a potential barrier to stygofauna dispersal (Table 3.1).

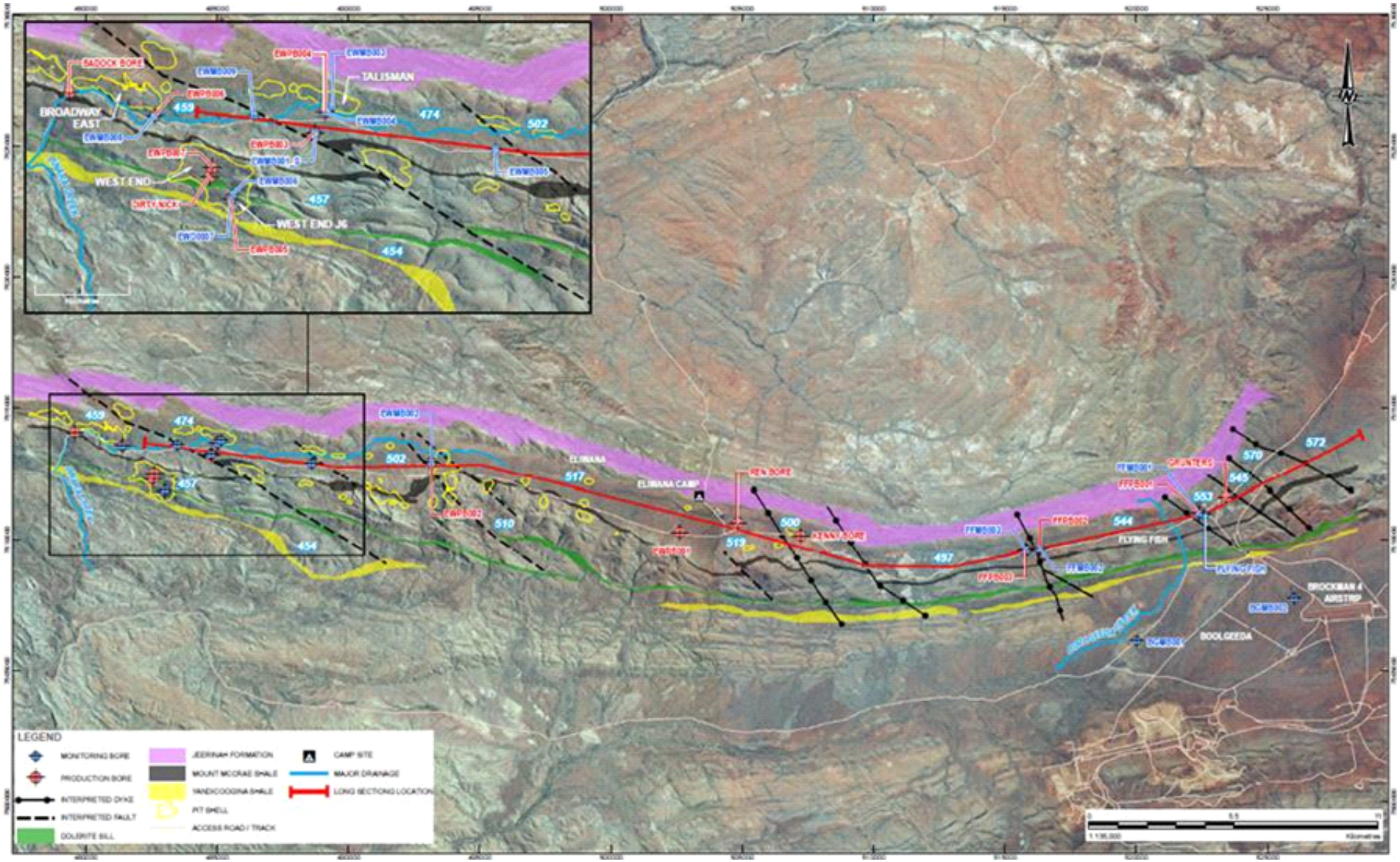


Figure 3.3. Aquifers numbered by water level, bounding and structures across mining area (Figure supplied by Golder 2017)

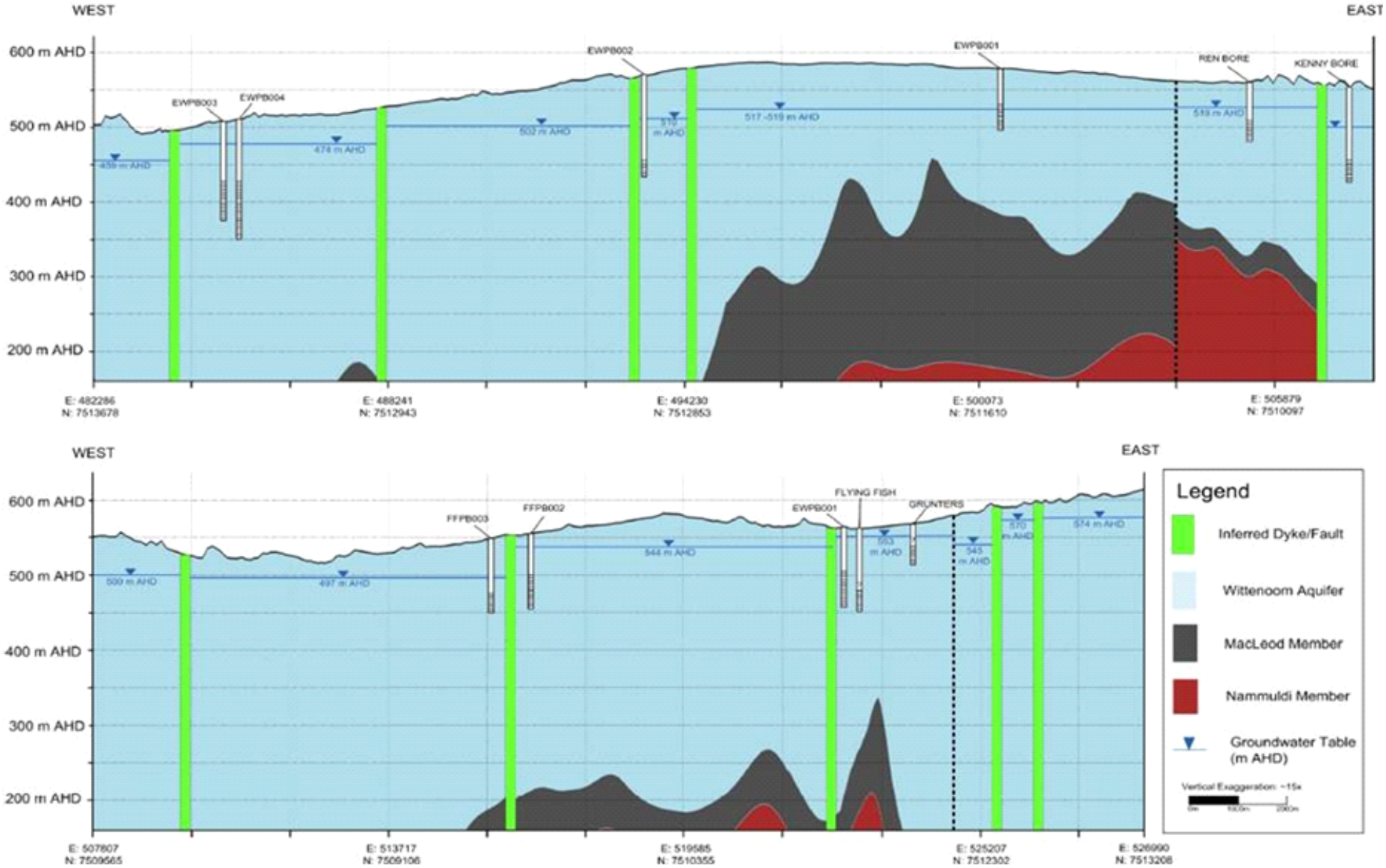


Figure 3.4. Aquifer compartmentalisation across the mining area (Figure supplied by Golder 2017)

3.2.2 Aquitards

Aquitards are regions of lower porosity/ transmissivity which slow the flow of groundwater from one aquifer to another. The unmineralised Brockman Iron (HB) Formation, Marra Mamba Iron (HM) Formation, Mount Sylvia (HS) Formation, Yandicoogina Shale (BY), Roy Hill Shale (JR) Member and unweathered members of the Wittenoom Formation are considered aquitards. The Mount McRae Shale (HR) is also considered an aquitard and acts as a boundary that partitions the Mineralised Brockman Aquifer from the Wittenoom Aquifer. Aquitards are not considered to provide suitable habitat for stygofauna, although within units considered to be largely aquitard (e.g. unmineralised Brockman Iron Formation), there may still be some potential for stygofauna to exist with smaller patches of more suitable (aquifer) habitat within fractures and fault zones.

Numerous dolerite dykes and sills occurring throughout the development envelope are also considered aquitards. A prominent sill occurs in the J3 unit of the Joffre (BJ) Member on the southern limb of the Brockman Syncline. This sill is considered an aquitard and creates significant differences between groundwater south of the sill, in the lower Joffre and Dales Gorge Members, and north of the sill in the upper Joffre Member.

The mining area is further bounded to the south by the Yandicoogina Shale (BY) Member of the Brockman Iron Formation and to the north by Roy Hill Shale (JR) Member of the Jeerinah Formation (FJ), resulting in little to no movement of groundwater perpendicular to the strike of the valley. In addition, NW-SE and NE-SW trending, dolerite dykes associated with the D3 Dales Gorge (BD) Member appear to form hydraulic barriers and may compartmentalise the groundwater aquifers such that little to no connection occurs from east to west. It is assumed that such compartmentalisation would prevent movement and dispersal of stygofauna between the various groundwater habitats, although whether this has resulted in different species occurring within the different compartmentalised aquifers is dependent upon a range of historical and evolutionary factors regarding the species in question and their habitats.

3.3 Potential Habitat Summary

In summary, the existing geological and hydrogeological information indicates that several prospective habitats for troglofauna (above water table) and stygofauna (below water table) are likely to occur throughout the Study Area. Based on available information, these have been classified as:

- Highly suitable potential habitat – Tertiary detritals (e.g. unconsolidated alluvium/ colluvium, calcrete, and CID), weathered/ enriched upper iron ore members featuring hydrated hard cap (e.g. Mt Newman Member of MMIF, Dales Gorge and Joffre Members of BrIF), karstic dolomite (e.g. Paraburdoo or Bee Gorge Members of Wittenoom Frm);
- Moderately suitable potential habitat – Deeper fractured zones within bedded iron ore formations (e.g. McLeod or Nammuldi Members of MMIF, parts of Dales Gorge, Joffre, and Whaleback Members of BrIF), fractured zones within fresh dolomite (e.g. Wittenoom Formation);
- Possible habitat (under some circumstances) – parts of Mt Sylvia Formation, parts of Whaleback Shale (BrIF), parts of West Angela Member (Wittenoom Frm) where sufficiently weathered or fractured; and

- Low suitability habitat or potential barriers to habitat/ species dispersal – Dolerite dykes/ sills, Shale bands/ members such as Yandicoogina Member (BrIF), Mt McRae Shale, parts of the Whaleback Shale (BrIF) and West Angela Member (Wittenoom Frm), Jeerinah Formation and Roy Hill Shale.

4 METHODS

4.1 Previous reports and surveys

Reports and data from previous Fortescue surveys within and immediately surrounding the Study Area were reviewed for local and sub-regional context where necessary. Reports from previous surveys in the sub-regional and local area are listed below:

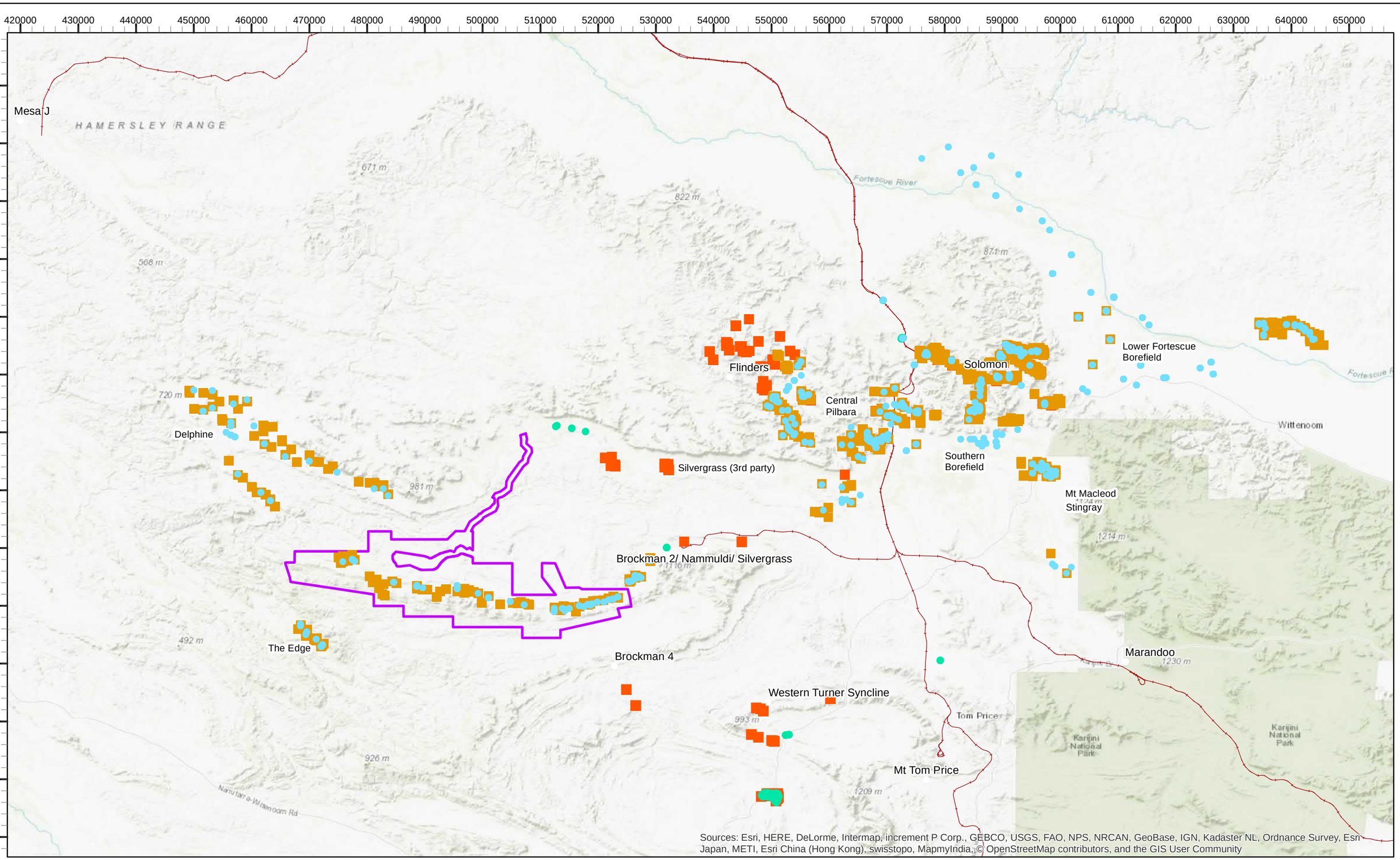
4.1.1 Sub-regional Fortescue survey reports

- Troglofauna Assessment for the Solomon Project: Firetail Deposits (Bennelongia 2010);
- Solomon Project: Kings Deposits Subterranean Fauna Survey & Assessment (Sub. Ecology 2010);
- Central Pilbara Project Stage One Subterranean Fauna Survey (Sub. Ecology 2011);
- Solomon Project: Regional Subterranean Fauna Survey (Sub. Ecology 2011);
- Central Pilbara Project Stage One Subterranean Fauna Survey (Sub. Ecology 2012);
- Solomon Iron Ore Project: Troglofauna Survey at Zion Deposit (Bennelongia 2013);
- Solomon Iron Ore Project: 30 Month Troglofauna Report at Kings Mine (Bennelongia 2013);
- Mt Macleod Subterranean Fauna Assessment (Ecologia 2014);
- Solomon: Stygofauna Assessment of Northern and Southern Borefields (Bennelongia 2014);
- Stingray Subterranean Fauna Assessment (Ecologia 2014);
- Addendum to Stygofauna Assessment of Northern and Southern Borefields (Bennelongia 2015);
- Solomon Mine Castle Valley Deposit: Level 2 Subterranean Survey (Bennelongia 2016); and
- Solomon Mine Frederick's Deposit: Troglofauna Survey (Bennelongia 2016).

4.1.2 Local Fortescue survey report

- Western Hub Baseline Subterranean Fauna Assessment (Bennelongia 2015).

Subterranean fauna records from the WA Museum and Fortescue databases within the local and sub-regional area of the Study Area are shown in Figure 4.1. The most significant survey effort within the sub-regional area has been conducted to the north east of the Study Area around the Solomon, Central Pilbara, and Flinders project areas, revealing troglofauna and stygofauna assemblages of considerable diversity and abundance in these areas. The results from studies within the wider sub-regional area were used for regional comparisons where appropriate, while the sampling and results from the Western Hub survey (Bennelongia 2015), which provides a more relevant local context for species occurring within the Study Area was reviewed in more detail, as below.



Legend

- Pilbara Rail
- Development Envelope

Records from WAM databases

- Stygofauna
- Troglofauna

Sampling locations (FMG Database)

- Stygofauna
- Troglofauna

biologic Environmental Survey

N

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Fortescue Metals Group Ltd

Eliwana Subterranean Fauna Survey 2017

Fig. 4.1: Locations of previous subterranean fauna sampling (available data)

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

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The Western Hub Baseline Subterranean Fauna Assessment (Bennelongia 2015) conducted subterranean fauna sampling across three survey zones - Delphine, The Edge, and the Study Area (Eliwana and Flying Fish). During the Western Hub survey, at total of 491 troglofauna sampling events (comprising scraping and trapping) were recorded across the three survey zones (Table 4.1). Of these, 240 troglofauna samples, (120 scraping and 120 trapping), were collected over two rounds from the Study Area (Eliwana/Flying Fish), 180 samples collected from Delphine (90 scraping, 90 trapping) and the remaining 71 samples collected from The Edge (36 scraping, 35 trapping). A total of 140 stygofauna samples were collected across the three survey areas at Western Hub. A majority of these were collected from net hauling within the Study Area (78), with an additional 62 samples collected from Delphine (42) and The Edge (20).

In total, 631 subterranean fauna sampling events, comprising troglofauna scraping, troglofauna trapping and stygofauna net hauling, were collected from the previous Western Hub Survey. More than half (318 – comprising 240 troglofauna and 78 stygofauna sampling events) were collected from the Study Area with the remaining collected from deposits Delphine and The Edge (222 and 91 respectively – Table 4.1).

Table 4.1. Previous subterranean fauna sampling at Western Hub (including the Study Area)

SAMPLE EFFORT	WESTERN HUB SURVEY			
Sampling method	**Eliwana /Flying Fish**	**Delphine**	**The Edge**	**Total**
Scraping	120	90	36	246
Net hauling	78	42	20	140
Trapping	120	90	35	245
Total, all samples	**318**	**222**	**91**	**631**
Total troglofauna samples	**240**	**180**	**71**	**491**
Total stygofauna samples	**78**	**42**	**20**	**140**

4.2 Survey methods

4.2.1 Survey timing and weather conditions

The timing of surveys was proposed to maximise survey effort and fauna activity; the wet season survey was undertaken towards the end of the wet season, allowing time for moisture to infiltrate down to subterranean habitats and capitalising on warmer conditions expected to result in higher activity. The dry season survey was carried out when the conditions were beginning to warm up and cold air entering drill holes would have been less likely to lower troglofauna activity.

The current Level 2 subterranean fauna survey was conducted as a two-phase survey, in accordance with guidelines for subterranean fauna assessments (EPA 2016a, 2016b). The first phase (wet season) of sampling was undertaken over the months March – May 2017, with the second phase (dry season) was undertaken August – November 2017. Each phase was comprised of two field trips as follows:

Phase 1-

- Trip 1, 10 – 16 March 2017 (trap deployment and scrape/ haul sampling); and

- Trip 2, 26 April - 1 May 2017 (trap retrieval and scrape/ haul sampling).

Phase 2-

- Trip 3, 30 August – 4 September 2017 (trap deployment and scrape/ haul sampling); and
- Trip 4, 30 October – 3 November 2017 (trap retrieval and scrape/ haul sampling).

The Pilbara region has a tropical semi-arid climate. Rainfall events within the region are sporadic and highly variable from year to year. Although considerable rainfall can occur within both summer and winter months, most rainfall is during summer (Australian Natural Resources Atlas 2008).

Detailed long-term climatic data is not available for the Study Area itself, although the nearest Bureau of Meteorology (BoM) weather station at Paraburdoo Aero (Station 7185), approximately 90 km south east of the Study Area, provides an indication of the long term climatic conditions (Figure 4.2).

The daily maximum temperatures during Trip 1 to the Study Area ranged from 33.1°C to 40.0°C between 10 - 16 March 2017, this reflected the slightly warmer than average temperatures experienced during March 2017. Conversely, during Trip 2 (between 26 April - 1 May 2017), the daily maximum temperatures ranged from 28°C to 31.4°C, these were slightly lower than the average temperature recorded during April 2017. During Trip 3 (30 August – 4 September 2017) slightly cooler daily maximum temperatures were recorded (ranging 25.3°C to 34.5°C) than the monthly average for September 2107. Trip 4 ranged from 40.0°C to 41.5°C between 30 October – 3 November 2017 and exceeded average monthly temperatures for both October and November in 2017.

Paraburdoo recorded only 9mm of rainfall in the two weeks prior to Phase 1, however, both the months of February (147.8 mm) and March (91.4 mm) had greater rainfall than the long-term averages for those months (75.5 mm and 50.7 mm respectively). Approximately 22 mm of rainfall was recorded at Paraburdoo during Trip 1 sampling, with an additional 70 mm recorded prior to Trip 2. Only 3.2 mm of rainfall was recorded prior to the Phase 2 survey. This represented lower than the long-term average rainfall during the months of May – August. In contrast, 21.6 mm of rain was recorded during Phase 2 of sampling, with 19 mm recorded over a three-day period between Trip 3 and Trip 4. This was much higher than the combined long term monthly average (7.6 mm) for September and October (BoM 2017)

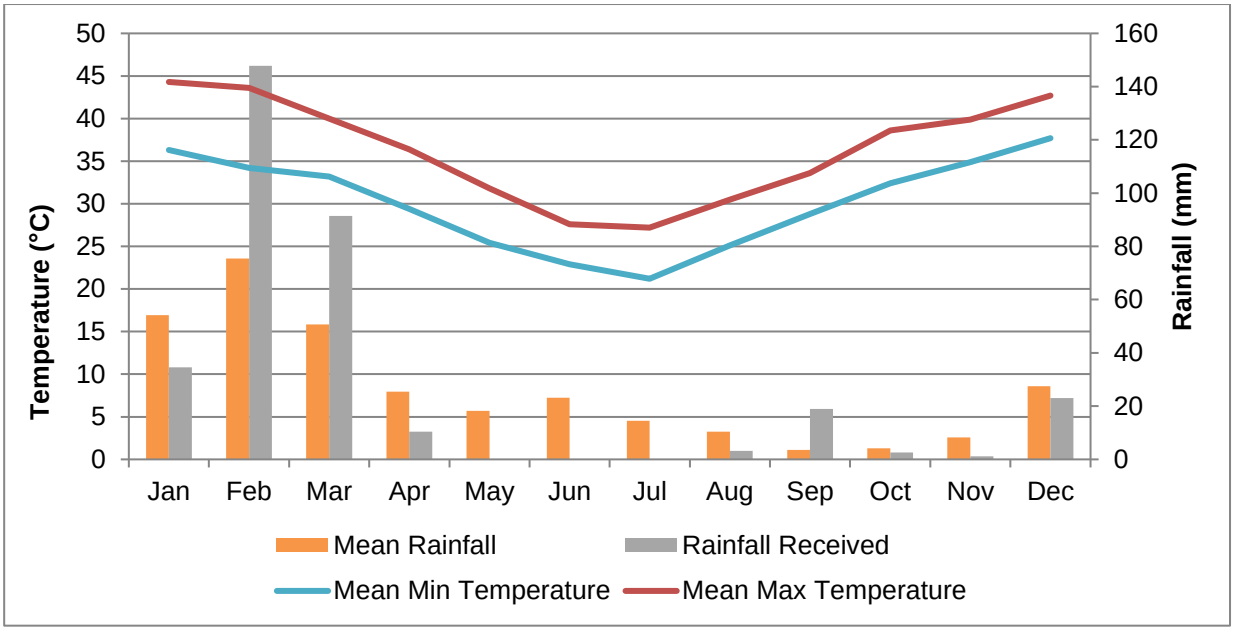

Figure 4.2. Long-term average rainfall (mean rainfall) and current climatic data for the Study Area (Rainfall Received, Mean Min Temperature and Mean Max Temperature).

4.2.2 Site selection and survey effort

Indicative locations of bores and drill holes sampled during the current and previous surveys of the Study Area to date are shown in Figure 4.3 (West Study Area) and Figure 4.4 (East Study Area). Sub-regional survey effort was shown, for comparison, in Figure 4.1. The number and location of sampling holes were determined in consultation with Fortescue's project management and field personnel and based upon:

- the location of suitably constructed, accessible drill holes, contingent on track accessibility and the level of drill hole rehabilitation undertaken throughout the Study Area;
- ensuring good spatial and geographical spread throughout the Study Area, particularly in relation to areas within and outside of proposed pits (as per Fortescue's and EPA guidelines in relation to sampling intensity);
- the extent of all prospective geological and hydrogeological habitat units within and near the proposed pits;
- reference areas outside proposed pits that were considered likely to support the same or similar troglofauna and stygofauna assemblages;
- targeting outside impact areas close to the locations of species known only from Eliwana (collected during Western Hub Survey, Bennelongia 2015); and
- filling spatial gaps left over from Western Hub survey (Bennelongia 2015).

A total of 299 subterranean fauna samples were collected over the course of four field trips (two phases, each comprising a field trip for troglofauna trap deployment and a subsequent trip for trap retrieval) within the Study Area (Table 4.2). Note that some sites (e.g. uncased bores) were sampled using two methods, scraping and net hauling, and each sample was counted separately as a troglofaunal sample (scraping)

and a stygofauna sample (net hauling). During Phase 1, a total of 94 troglofauna samples and 27 stygofauna samples were collected over two field trips, (10 – 16 March, and 26 April – 1 May 2017). Phase 2 saw an increase in sampling intensity due to additional rehabilitated holes being recovered and made accessible for sampling. Over two field trips (30 August – 1 September, and 30 October – 3 November 2017), 129 troglofauna samples and 49 stygofauna samples were collected. Three troglofauna traps (excluded from survey sample numbers) were lost because of disturbance.

Table 4.2. Sample effort for subterranean fauna in the Study Area (current survey)

PHASE 1	**ELIWANA**		
TRIP 1 SAMPLING	**Impact**	**Reference**	**Total**
Scraping	5	13	18
Net hauling	2	6	8
Karaman		1	1
Trap deployed	11	26	37
Total (Trip 1 - exc. traps deployed)	**7**	**20**	**27**
TRIP 2 SAMPLING	**Impact**	**Reference**	**Total**
Scraping	15	26	41
Net hauling	4	14	18
Trap retrieved	10	25	35
Total (Trip 2)	**29**	**65**	**94**
PHASE 2			
TRIP 3 SAMPLING	**Impact**	**Reference**	**Total**
Scraping	20	30	50
Net hauling	9	13	22
Trap deployed	20	31	51
Total (Trip 3 - exc. traps deployed)	**29**	**43**	**72**
TRIP 4 SAMPLING	**Impact**	**Reference**	**Total**
Scraping	12	17	29
Net hauling	6	21	27
Trap retrieved	19	31	50
Total (Trip 4)	**37**	**5769**	**106**
Grand total, all samples	**102**	**197**	**299**
Total troglofauna samples	81	142	223
Total stygofauna samples	21	55	76

In summary, a total of 223 troglofauna samples and 76 samples stygofauna samples were collected from 42 bores and holes during the two-phase survey. One hundred and two of these samples were taken from the proposed development footprint (mining pits) with the remaining 197 samples taken from reference areas throughout the Study Area, with special consideration given to areas nearby the locations of species known only to occur at Eliwana (Bennelongia 2015), and areas considered likely to contain similar subterranean fauna assemblages to the development footprint.

470000

480000

490000

7520000

7510000

543 m

591 m

731 m

691 m

734 m

513 m

586 m

613 m

708 m

812 m

678 m

Legend

- Development Envelope

Indicative Disturbance

- Infrastructure
- Mining Pit (150m buffer)
- Stockpile
- Tailings Storage
- Potential dykes (interpreted)

Previous sampling (Western Hub)

- Stygo net hauling
- Trog Scraping
- Trog Trapping

Current Survey

- Trog Scraping
- Stygo net hauling
- Trog Trapping

biologic Environmental Survey

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Fortescue Metals Group Ltd

Eliwana Subterranean Fauna Survey 2017

Fig. 4.3a: Subterranean fauna sampling of the Study Area to date - current and previous (west)

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 31/01/2018

500000

510000

520000

7520000

7510000

676 m
537 m
615 m
729 m
690 m
589 m
716 m
642 m
600 m
616 m
789 m
757 m
838 m
756 m
717 m
Boolgeeda

Legend

- Development Envelope
- **Indicative Disturbance**
  - Infrastructure
  - Mining Pit (150m buffer)
  - Stockpile
  - Tailings Storage
  - Potential dykes (interpreted)
- **Previous sampling (Western Hub)**
  - Stygo net hauling
  - Trog Scraping
  - Trog Trapping
- **Current Survey**
  - Trog Scraping
  - Stygo net hauling
  - Trog Trapping

biologic Environmental Survey

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Fortescue Metals Group Ltd

Eliwana Subterranean Fauna Survey 2017

Fig. 4.3b: Subterranean fauna sampling of the Study Area to date - current and previous (east)

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 31/01/2018

4.2.3 Cumulative sample effort of the Study Area

The cumulative sample effort, including the distribution and intensity of sampling, was designed in accordance with EPA guidelines (EPA 2016a, 2016b) to reflect the large geographical area of the Study Area, the diversity of hydrological/geological habitats, and the spread of proposed mining impact areas.

A total of 617 subterranean fauna samples have been collected from the previous and current surveys of the Study Area (Table 4.3). The indicative sampling locations and spread is highlighted in Figure 4.3 (West Study Area) and Figure 4.4 (East Study Area) above.

A combined sample effort of 463 troglofauna samples, (comprising 258 scraping and 205 trapping) have been collected to date (Table 4.3). A total of 154 stygofauna samples (including 153 net hauling and 1 Karaman) have been collected from the previous and current surveys of the Study Area.

Table 4.3. Cumulative sample effort for subterranean fauna in the Study Area (previous and current survey)

SAMPLE EFFORT	ELIWANA STUDY AREA		
Sampling method	**Previous survey**	**Current survey**	**Total**
Scraping	120	138	258
Net hauling	78	75	153
Karaman		1	1
Trapping	120	85	205
Total, all samples	**318**	**299**	**617**
Total troglofauna samples	240	223	**463**
Total stygofauna samples	78	76	**154**

4.2.4 Sampling methods

The sampling methods used were consistent with EAG #12 (EPA 2016a), Guidance Statement #54A (EPA 2016b) and the Stygofauna Sampling Protocol developed for the Pilbara Biodiversity Study Subterranean Fauna Survey (Eberhard *et al.* 2005, 2009). The field work sampling was undertaken by Dean Main, Erich Volschenk and Mike Brown.

Water physicochemistry

Prior to stygofauna sampling, a groundwater sample was collected using a 1m plastic cylindrical bailer, for the purposes of physicochemical measurements. A bailer is lowered down the hole until reaching groundwater level and collecting a water sample. As such the results are not indicative of water parameters throughout the entire bore but rather, provide general surface groundwater indicators. Once brought to the surface, the groundwater physicochemical data (including EC, pH, TDS, Redox, and Dissolved O_2) was measured using a multi-parameter water meter. Groundwater physicochemical data was collected for each hole (where possible) that was sampled for stygofauna. Unfortunately, due to the considerable depth of the water table at some sites (60-120+m), groundwater was unable to be collected due to water completely discharging before reaching the surface. Constrictions in piezometer bores as well as blockages and root material also inhibited the collection of groundwater and physicochemical measurement at some sites.

Stygofauna Net Hauling

Stygofauna were sampled by standard net hauling methods, using a plankton net of a diameter to suit each bore or drill hole (in most cases 90 mm). Each hauling sample comprised a total of six hauls from the bottom of the hole to the top, including three hauls using a 150 µm mesh and three hauls using a 50 µm mesh. The base of the net was fitted with a lead weight and a sample receptacle with a base mesh of 50 µm. To stir up sediments, the net was raised and lowered at the bottom of the hole prior to retrieval and hauled at an even pace through the water column to maximise filtration of the water. The sample from each haul was emptied into a bucket, which was elutriated after the final haul to remove coarse sediments and filtered back through the 50 µm net/ sample receptacle to remove most of the water. The sample was transferred to a 50-120 mL preservation vial (depending upon the quantity of sediment) and preserved in 100% ethanol. The ethanol and the samples were kept chilled on ice to facilitate cool-temperature DNA fixation.

Karaman-Chappuis Sampling

Stygofauna occupying near-surface groundwater habitats beneath gravelly stream beds (hyporheos) may be sampled by the Karaman-Chappuis method. This involves excavation of a hole in the stream bed (either near an existing pool or at a site where a pool has recently dried up) approximately 50-100 cm diameter, and 30-50 cm depth below groundwater level. Care must be taken to choose substrates with mainly larger gravels and sand, rather than sand and silt/ clay. Water is then bailed out of the hole using a bucket and sieved through a standard stygofauna net as described above. As buckets of water are removed, care must be taken to avoid the same water flowing back into the hole – inflow of new hyporheic groundwater is usually observed as clearer water entering from the upstream side of the hole. This process can be continued for any length of time depending on how quickly groundwater inflow continues to fill the hole, usually with the aim of sampling approximately 20-50L in total.

Karaman-Chappuis sampling can be a very useful method of achieving samples where no or few bores/ drill holes exist (as long as there is a suitable stream) and can also be helpful to assess the potential for stygofauna species or communities to be more widely dispersed throughout the hyporheic zone of local drainage networks. These samples tend also to collect an abundance of surface fauna, which can be difficult to distinguish from stygofaunal taxa where characters of eyelessness and pale cuticle are inherent throughout the group (e.g. worms, some crustaceans, mites).

Troglofauna Trapping

Trapping utilised custom made cylindrical PVC traps (approximately 50 mm x 300 mm) baited with decaying leaf litter (dead spinifex / acacia sourced from the Pilbara region), which had been sterilised with boiling water and inoculated with cooking yeast for a month leading up to the survey. Traps were lowered via a nylon cord to a depth approximately 25 – 30 m below surface, or within 1 m above the water table if closer. Holes were sealed while the traps were set, to minimise incursions of surface fauna and to maintain a humid atmosphere within the drill hole. The traps were collected after eight weeks and stored in paper bags (to alleviate excess moisture) within zip-lock bags for transport back to the laboratory in Perth. Samples were kept cool in insulated boxes during transport.

Troglofauna Scraping

Scraping was undertaken at vertical, uncased drill holes using a reinforced 150 µm weighted stygofauna net, with a specialised scraping attachment used above the net to maximise gentle contact with the walls of the hole. The net was lowered and raised through the full length of the hole at least three (3) times for holes where no water was present, with each haul being emptied into a sample bucket as per net hauling. Where the water table was

intercepted, a combined net haul / scrape sample was taken using the scraping attachment, comprising six (6) hauls throughout the full length of the hole from top to bottom, including both the air filled and below water subterranean habitats. The contents of the sample were elutriated, processed, and stored in 100 % ethanol as per net hauling.

Sorting and taxonomy

Sorting and parataxonomy were undertaken in-house using dissecting microscopes. The personnel involved (D. Main, E. Volschenk and N. Gunawardene) were suitably trained and experienced in both sorting and parataxonomy of subterranean fauna. Parataxonomy of the specimens utilised published literature and taxonomic keys where available. Each morphospecies from each sample was assigned a separate labelled vial and labelled with a specimen tracking code. Taxonomic groups were examined in as much detail as possible using in-house expertise, before sending a reference collection to specialist taxonomists for detailed taxonomic advice. Species comparisons and alignments were performed using previously collected specimen of the Study Area as well as regional comparisons with known species extending beyond the Study Area. The taxonomists undertaking specialist identifications included J. McRae, S. Halse and M. Scanlon.

4.3 Conservation status and SRE classification

Despite the high diversity of subterranean fauna species known to occur throughout the Pilbara region, relatively Few species or assemblages are listed under relevant legislation as Threatened Species or Threatened/Priority Ecological Communities. Any listed subterranean species or community is automatically regarded as conservation significant, although due to a lack of taxonomic certainty for most subterranean taxa in the region, there are potentially many highly range-restricted (SRE) subterranean species and communities are not currently included on these lists.

The following DBCA lists (current at time of writing) do not feature any subterranean species or communities known to occur within the Study Area:

- Threatened Species: https://www.dpaw.wa.gov.au/images/documents/plants-animals/threatened-species/Listings/threatened_and_priority_fauna_list.xlsx
- Priority Ecological Communities: https://www.dpaw.wa.gov.au/images/documents/plants-animals/threatened-species/Listings/priority_ecological_communities_list.pdf ; and
- Threatened Ecological Communities: https://www.dpaw.wa.gov.au/images/plants-animals/threatened-species/threatened_ecological_communities_endorsed_by_the_minister_october_2016.pdf

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

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

The SRE status categories used in this report follow the WAM's categorisation for SRE invertebrates. This system is based upon the 10,000 km^2 range criterion proposed by Harvey (2002) and uses three broad categories to deal with

varying levels of taxonomic certainty that may apply to any given taxon (Table 4.3). As most subterranean fauna are poorly-known taxonomically, and there are many limitations to achieving a high rate of sampling subterranean fauna, most taxa invariably fall within one (or several) of the five Potential SRE sub-categories. A species is considered widespread (i.e. not an SRE), if it has a known distribution of greater than 10,000 km^2, the taxonomy is well-known, and the group is well represented in collections and/or via comprehensive sampling.

Table 4.4: SRE categorisation used by WAM taxonomists (WAM 2016)

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

The degree of stygomorphy or troglomorphy (observable physical adaptations to subterranean habitats such as eyelessness, depigmentation, elongation of sensory appendages and thinning of the cuticle) is assessed to determine each morphospecies' 'subterranean status', *i.e.* whether a taxon was likely to be an obligate subterranean species (stygobite / troglobite). It is acknowledged that the current EPA guideline for subterranean fauna does not account for non-obligate subterranean fauna, stating, *"…subterranean fauna are defined as fauna which live their entire lives (obligate) below the surface of the earth.... Fauna that use a subterranean environment for only part of the day or season (e.g. soil-dwelling or burrowing species, cave-dwelling bats and birds) are not considered as subterranean fauna for this EAG*" (EPA 2013). Nevertheless, there may be fauna with restricted distributions <10,000 km^2 following Harvey (2002), or <1,000 km^2 following Eberhard *et al.* (2009) that are of interest because of their SRE status, regardless of whether they can be definitively regarded as 'obligate' subterranean fauna. For this reason, this report presents an assessment of both the subterranean status and the SRE status of each taxon collected, to the best available knowledge.

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

4.4 Limitations

Many subterranean species (particularly troglofauna) are rare and difficult to detect. Subterranean taxa inhabit cryptic, concealed habitats which renders them inherently difficult to sample and assess, relative to surface fauna.

Much remains uncertain regarding the taxonomy and ecological status of many of the faunal groups. For some groups, the taxonomic framework is very poorly developed or lacking entirely, which provides additional challenges for the interpretation of sampling results and species distributions. These general factors were considered when designing the survey and analysing the data, although in some cases, residual uncertainty was unavoidable. The results and key findings of the survey are based upon the best information available under these conditions, including independent advice from taxonomic specialists.

Specific limitations relating to the current and previous survey data include:

- Specimens unable to be identified to species level by morphology alone (damaged, juvenile or wrong sex for identification to species) were assessed by genetic analyses where possible. Nevertheless, the success rates of genetic sequencing are limited by the state of preservation of the specimens and their handling during collection, sorting and parataxonomy. Despite utilising best practises in the field and lab to ensure adequate specimen preservation for genetic analysis, in many cases DNA sequencing was affected by contamination or sequencing failed, particularly with older specimens intended for local and regional comparisons.
- Not all holes were suitable for each of the various subterranean sampling techniques, and the layout of sampling sites was contingent upon the location and suitability of different types of bores and holes, inside and outside of proposed pits. All drill holes (excluding water bores) had been rehabilitated several years prior to the current survey, which created difficulties for locating and accessing desirable holes during the first phase of sampling. Prior to the second phase of sampling, additional holes were located and repegged by Fortescue staff, which greatly enhanced the spread and intensity of sampling in the second phase.
- The availability of holes intercepting groundwater was a limiting factor for stygofauna sampling across the Study Area. Many of the drilled holes within certain pit areas did not intercept groundwater. Many other holes originally drilled beneath groundwater level were dry at the time of survey, possibly due to blockages or collapses often seen following rehabilitation. This restricted net hauling to holes in lower areas of the Eliwana Valley, as well as hydrological bores (monitoring, production, piezometers), which can be affected by the type of bore construction (steel vs PVC, diameter of slotting and gravel pack) and the depth of the slotted interval vs the target aquifer/s.
- The habitat assessment and risk assessment were limited to available geological/ hydrogeological information and information regarding extent and magnitude of impacts at the time of writing. The hydrogeological modelling used to determine groundwater drawdown impacts is subject to its own limitations as per the Hydrogeological Conceptual Model Report (Golder 2017). Cross-sections were developed by Fortescue based on available drill data, bore logs, and geological / hydrogeological reports. The ‘pooled geologies’ layer used to show the aerial extent of geological units was a simplified layer that did not indicate finer-scale partitioning within the major formations that may have implications for subterranean habitat suitability, as was used for the geological cross sections. Despite the variety of detailed information available to the assessment, there are always some residual knowledge gaps, and inferences were made between data points. As a precaution, the current extent of mining pits was buffered by 150 m for maps and assessment within this report. This represents a conservative assessment of species potentially effected by proposed mining impacts.

5 RESULTS

5.1 Previous survey of the Study Area

The results of the previous survey of the Eliwana and Flying Fish areas are presented in Bennelongia's (2015) Western Hub Baseline Subterranean Fauna Assessment, in combination with results of two other nearby survey areas; Delphine and The Edge (refer Figure 4.1). A total of 120 troglofauna specimens were collected from the Study Area, representing 20 species (Bennelongia 2015). A quarter (5) of these species (including millipedes, cockroaches, bugs, beetles and flies), were known to have wide ranging distributions extending beyond the Study Area. Four (4) species (nr *Cryptops* sp. B36, Japygidae sp. B37, *Gracilanillus cordatus*, *Paradraculoides* sp. B12), had locally wide-ranging distributions (37, 23, 19 and 15 km respectively) but were known only from the Study Area. The remaining troglofauna species were known only from a single record or single drill-hole.

A total of 423 stygofauna specimens, representing 15 species, were also collected from surveys in the Study Area (Bennelongia 2015). Except for three species, *Areacandona* nr *triangulum*, *Brevisomabathynella* sp. B03 and *Bogidiella* sp. B05), all the stygofauna species were known to occur beyond the Study Area.

5.2 Current survey of the Study Area

The current two-phase survey recorded a total of 523 subterranean fauna specimens from 42 bores and holes throughout the Study Area.

5.2.1 Troglofauna

A total of 242 troglofauna and potential troglofauna specimens were collected, representing 31 species/ morphospecies and 3 indeterminate species from 11 higher taxa (Table 5.1); this represents a slightly richer troglofauna assemblage than recorded during the Western Hub Survey (20 species) (Bennelongia 2015). The troglofauna collected during the current survey was comprised of nine insect taxa (orders Thysanura, Blattodea, Hemiptera, Coleoptera), nine arachnid taxa (orders Acari, Schizomida, Araneae), five dipluran taxa (Diplura), five pauropod taxa (Tetramerocerata), two symphylan taxa (Cephalostigmata) and one centipede (Scolopendromorpha).

Table 5.1. Troglofauna species recorded from the Study Area (Current Survey)

Higher Taxon	Order	Morphospecies	No. Spmns	Subterranean Status
Arachnida				
	Acari	Acari sp. 'EW'	2	Potential Troglofauna
	Schizomida	*Paradraculoides* sp. B12	6	Troglofauna
	Schizomida	*Paradraculoides* sp. 'new1'	3	Troglofauna
	Schizomida	*Paradraculoides* sp. 'new2'	1	Troglofauna
	Schizomida	*Paradraculoides* sp. 'new3'	1	Troglofauna
	Schizomida	*Paradraculoides* sp. 'new4'	1	Troglofauna
	Araneae	*Anapistula* sp. 'EW'	2	Troglofauna
	Araneae	Araneomorphae sp. 'EW'	1	Troglofauna
	Araneae	*Prethopalpus* sp. MW21	1	Troglofauna
Chilopoda				
	Scolopendromorpha	*Australiophilus* sp. 'EW'	1	Troglofauna
Pauropoda				
	Tetramerocerata	Pauropodidae sp. B33	2	Troglofauna
	Tetramerocerata	Pauropodidae sp. B33A	2	Troglofauna
	Tetramerocerata	Pauropodidae sp. B41	1	Troglofauna
	Tetramerocerata	Pauropodidae sp. B42	2	Troglofauna
	Tetramerocerata	Pauropodidae sp. B43	1	Troglofauna
Symphyla				

Higher Taxon	Order	Morphospecies	No. Spmns	Subterranean Status
	Cephalostigmata	*Hanseniella* sp. B23	1	Troglofauna
	Cephalostigmata	*Symphyella* sp. 'EW'	3	Troglofauna
Entognatha				
	Diplura	Anajapygidae sp. B05	1	Troglofauna
	Diplura	Campodeidae sp. 'EW'	1	Troglofauna
	Diplura	Japygidae sp. ?B37	1	Troglofauna
	Diplura	Japygidae sp. B36	2	Troglofauna
	Diplura	Projapygidae sp. ?B14	1	Troglofauna
Insecta				
	Thysanura	*Lepidospora* sp. B15	1	Troglofauna
	Thysanura	Thysanura sp. indet.*	1	Potential Troglofauna
	Blattodea	*Nocticola quartermainei*	40	Troglofauna
	Blattodea	*Nocticola* sp indet.*	8	Troglofauna
	Hemiptera	Hemiptera sp. B02	77	Troglofauna
	Hemiptera	*Phaconeura* sp.	66	Troglofauna
	Coleoptera	Cryptorhynchinae sp. 'EW'	1	Troglofauna
	Coleoptera	*Gracilanillus cordata*	6	Troglofauna
	Coleoptera	*Macranillus* sp. 'EW'	1	Troglofauna
	Coleoptera	*Macranillus* sp. HCCA021	1	Troglofauna
	Coleoptera	*Macranillus* sp. indet.*	2	Troglofauna
	Coleoptera	Pselaphinae sp. B01	1	Troglofauna
Total	**11 orders**	**31 morphospecies**	**242**	

Note indeterminate taxa such as 'Thysanura sp. indet.' are not included in species counts as they represent specimens that cannot be allocated to the other known species based on current taxonomic information.

Six troglofauna species recorded during the current survey are known from beyond the Study Area. Three of these (*Nocticola quartermainei*, Hemiptera sp. B02, Pselaphinae sp. B01) are regionally wide-ranging, while another three species; Anajapygidae sp. B05, Japygidae sp. B36 and *Macranillus* sp. HCCA021, have distributions extending beyond the Study Area (respectively 71 km, 58 km and 15 km).

An additional six species are known from multiple locations in the Study Area, these including Acari sp. 'EW' (2 sites – 44 km linear range), *Paradraculoides* sp. B12 (5 sites – 9 km linear range), *Paradraculoides* sp. 'new1' (2 sites – 2 km linear range) Pauropodidae sp. B33 (2 sites – 37 km linear range), *Hanseniella* sp. B23 (2 sites – 2km linear range) and *Gracilanillus cordata* (3 sites – 48 km linear range). *Phaconeura* sp. likely represents the previously collected *Phaconeura* sp. B03 which is regionally widespread (Bennelongia 2015). Of the other three indeterminate taxa, these may be representatives of other morphospecies known from elsewhere within the Study Area (Thysanura sp. indet., *Nocticola* sp. indet., and *Macranillus* sp. indet.). Ten (10) taxa were detected only from within mining pits and potentially represent restricted species. These were, *Paradraculoides* sp. 'new2', *Paradraculoides* sp. 'new3', *Anapistula* sp. 'EW', *Prethopalpus* sp. MW21, Pauropodidae sp. B41, Pauropodidae sp. B42, Pauropodidae sp. B43, *Symphyella* sp. 'EW', Campodeidae sp. 'EW', *Macranillus* sp. 'EW'. The remaining eight troglofauna taxa were known only from single sites or single specimens within the Study Area.

5.2.2 Stygofauna

A total of 281 stygofauna specimens were collected from the current survey, representing 17 species/morphospecies and 2 indeterminate species from five higher groups; oligochaetes, ostracods, copepods, syncarids and amphipods (Table 5.2). This represents a very similar stygofauna assemblage as previously recorded (15 species belonging to the same five groups) (Bennelongia 2015). Three higher groups (oligochaetes, copepods and amphipods) formed

most of the species richness, however, amphipods and copepods were the most abundant groups with 112 and 80 specimens respectively (Table 5.2).

Table 5.2. Stygofauna species recorded from the Study Area (Current Survey)

Higher taxon	Morphospecies	No. Spmns	Status
Oligochaeta			
Enchytraeida	*Enchytraeus* AP PSS1 s	1	Stygofauna
Enchytraeida	Enchytraeidae sp. indet.*	1	Stygofauna
Haplotaxida	Phreodrilidae AP DVC spp.	2	Stygofauna
Haplotaxida	Phreodrilidae AP SVC spp.	8	Stygofauna
Haplotaxida	*Pristina longiseta*	20	Stygofauna
Ostracoda			
Podocopida	*Areacandona* sp. BOS1020	32	Stygofauna
Copepoda			
Cyclopoida	*Diacyclops humphreysi humphreysi*	45	Stygofauna
Cyclopoida	*Microcyclops varicans*	20	Stygofauna
Cyclopoida	*Orbuscyclops westaustraliensis*	11	Stygofauna
Harpacticoida	*Parastenocaris* sp. B42	3	Stygofauna
Harpacticoida	*Parastenocaris* sp. indet..*	1	Stygofauna
Syncarida			
Bathynellacea	*Brevisomabathynella* sp. A	4	Stygofauna
Bathynellacea	*Brevisomabathynella* sp. B	1	Stygofauna
Bathynellacea	*Brevisomabathynella* sp. C	20	Stygofauna
Amphipoda			
Melitidae	*Nedsia* sp. B04	22	Stygofauna
Paramelitidae	Paramelitidae sp. B36	61	Stygofauna
Paramelitidae	Paramelitidae sp. B58	23	Stygofauna
Paramelitidae	Paramelitidae sp. H-AMP023	3	Stygofauna
Paramelitidae	*Pilbarus* sp. B03	3	Stygofauna
Total	**17 morphospecies**	**281**	

*Note indeterminate taxa such as 'Enchytraeidae sp. indet..' are not included in species counts as they represent specimens that cannot be allocated to the other known species based on current taxonomic information.

Most of the stygofauna species collected during the survey were known from beyond the Study Area. All the oligochaete and cyclopoid species are known to be regionally wide-ranging, while a four amphipod morphospecies (*Nedsia* sp. B04, Paramelitidae sp. B36, Paramelitidae sp. H-AMP023 and *Pilbarus* sp. B03) are known from outside the Study Area. A further three species were collected from multiple sites across the Study Area including syncarids *Brevisomabathynella* sp. A (2 sites – 10 km linear range), amphipod Paramelitidae sp. B58 (3 sites – 12km linear range) and ostracod *Areacandona* sp. BOS1020 (2 sites – 150m linear range). The remaining two species *Brevisomabathynella* sp. B and *Brevisomabathynella* sp. C, were collected from single sites at the Study Area. In addition, two indeterminate taxa that may possibly represent known species from the Study Area (Enchytraeidae sp. and *Parastenocaris* sp.) were recorded from single sites at the Study Area.

5.3 Combined troglofauna occurrence and distributions

The combined troglofauna results (including previous current survey of the Study Area) show a total of 365 troglofauna specimen were recorded. This represents 45 troglofauna morphospecies belonging to 15 higher order groups; Diplura (8 species), Schizomida (6 species), Pauropoda (6 species), Coleoptera (6 species), Araneae (4 species), Isopoda (2 species), Thysanura (2 species), Hemiptera (2 species), Symphyla (2 species), Chilpoda (2 species) and single species of Acari, Palpgradi, Polyxenida, Blattodea and Diptera. An additional three (3)

indeterminate taxa were recorded that may represent species already known from the Study Area, including Thysanura sp., *Nocticola* sp. and *Macranillus* sp. indet.

Table 5.3 shows all combined troglofauna results to date outlining the occurrence of troglofauna species relative to potential impact area as well as known linear ranges.

Table 5.3. Combined troglofauna results to date, known linear ranges and number of specimens collected in relation to potential impact areas. Highlighted cells indicate taxon known only from impact areas.

Taxon	Direct impacts	Outside direct impacts	Previous survey of Study Area	Comments	Known linear range (km)
Acari					
Acari sp. 'EW'	1	1		Potential troglofauna. Known from 2 sites at Study Area	44
Palpigradi					
Palpigradi sp.	1		1	Known only from single record.	Uncertain (taxonomic resolution)
Schizomida					
Paradraculoides sp. B12	3	4	1	Known from 5 sites at the Study Area	9
Paradraculoides sp. B12A	1		1	Known from a single site at the Study Area	-
Paradraculoides sp. 'new1'	1	2		Known from 2 sites at the Study Area	2
Paradraculoides sp. 'new2'	1			Known from a single site at the Study Area	-
Paradraculoides sp. 'new3'	1			Known from a single site at the Study Area	-
Paradraculoides sp. 'new4'		1		Known from a single record outside impacts at the Study Area	
Araneae					
Anapistula sp. 'EW'	2			Known only from a single site at the Study Area	-
Araneomorphae sp. 'EW'		1		Known from a single record outside impact areas at the Study Area	-
Prethopalpus sp. B25 (nr *boltoni)*		1	1	Known from a single record outside impact areas at the Study Area	-
Prethopalpus sp. MW21	1			Known from a single site at the Study Area. Genetically different to *Prethopalpus* sp. B25 (nr *boltoni)*	-
Isopoda					
Stenoniscidae gen. nov. sp. B05		1	1	Known from a single record outside impact areas at the Study Area	-
Troglarmadillo sp. B46	9		9	Known only from single site at the Study Area	-
Chilopoda					
nr *Cryptops* sp. B36	3	2	5	Known from 3 sites at the Study Area[2]	37
Australiophilus sp. 'EW'		1		Known from a single record outside impact areas at the Study Area	-
Polyxenida					
Lophoturus madecassus	3	47	50	Trogloxene. Widespread in the Pilbara[2.]	1000+
Pauropoda					

Taxon	Direct impacts	Outside direct impacts	Previous survey of Study Area	Comments	Known linear range (km)
Pauropodidae sp. B29	1		1	Known only from single record at the Study Area	-
Pauropodidae sp. B33	1	1		Known from 2 sites at the Study Area	37
Pauropodidae sp. B33A		2		Known from a single site at the Study Area	-
Pauropodidae sp. B41	1			Known only from single record at the Study Area	-
Pauropodidae sp. B42	2			Known only from a single site at the Study Area	-
Pauropodidae sp. B43	1			Known only from single record at the Study Area	-
Symphyla					
Hanseniella sp. B23		2	1	Known from 2 sites at the Study Area	2
Symphyella sp. 'EW'	3			Known only from a single site at the Study Area	-
Diplura					
Anajapygidae sp. B05		2	1	Known from 2 sites at the Study Area and beyond (Delphine)	71
Campodeidae sp. 'EW'	1			Known only from single record at the Study Area	-
Projapygidae sp. ?B14		1		Possibly represents Projapygidae sp. B14 (Awaiting results from further molecular studies - taxonomic consistencies though some diagnostic characters have been removed from previous DNA)	-
Projapygidae sp. B14	1*		1	*Known only from a single record within TSF - Tailings Storage Facility. Awaiting results from further molecular studies.	-
Projapygidae sp. B17	1		1	Known only from single record at the Study Area	-
Japygidae sp. B36		3		Known from 3 sites at the Study Area and beyond (Delphine)	58
Japygidae sp. ?B37		1		Known from a single record outside impacts at the Study Area	-
Japygidae sp. B37	1	1	2	Known from 2 sites at the Study Area	23
Thysanura					
Lepidospera sp. B10	2		2	Known only from single site at the Study Area (*Likely to represent *Lepidospera* sp. from the same bore)	-
Lepidospera sp. B15		1		Known from a single record outside impacts at the Study Area	-
Thysanura sp.		1		Higher level identification, potential troglofauna.	Uncertain (taxonomic resolution)
Blattodea					
Nocticola quartermainei	39	5	4	Widespread in the Pilbara[2]	369
Nocticola sp.*	7	8	7	Higher level identification, *likely to represent *Nocticola quartermainei* from Study Area and beyond	Uncertain (taxonomic resolution)
Hemiptera					
Hemiptera sp. B02	32	53	8	Widespread in the Pilbara[2]	410
Phaconeura sp.*	62	20	14	Higher level identification, *likely to represent *Phaconeura* sp. B03 which is widespread in the Pilbara[2]	Uncertain (taxonomic resolution)

Taxon	Direct impacts	Outside direct impacts	Previous survey of Study Area	Comments	Known linear range (km)
Coleoptera					
Pselaphinae sp. B01		2	1	Widespread in the Pilbara[2]	334
Gracilanillus cordatus	6	3	3	Known from 3 sites at the Study Area	48
Macranillus sp. 'EW'	1			Known only from single record at the Study Area. May possibly be same as other *Macranillus* sp. collected at Study Area	-
Macranillus sp. H-CCA021	1			Known from the Study Area and beyond ('Marra Mamba')	15
Macranillus sp. indet.*		2		Higher level identification, known from single record outside impacts at the Study Area.	Uncertain (taxonomic resolution)
Cryptorhynchinae sp. B15		1	1	Known from a single record outside impacts at the Study Area	-
Cryptorhynchinae sp. 'EW'		1		Known from a single record outside impacts at the Study Area	-
Diptera					
Sciaridae sp. B01	5		5	Widespread in the Pilbara[2]	417

The combined troglofauna results (including Western Hub sampling and the current survey) (Table 5.3) to date show that 17 troglofauna taxa listed below are currently known only from within direct impact areas (including proposed pits, and the TSF in the case of Projapygidae sp. B14) and are therefore considered at risk of impacts.

- Palpigradi sp. – Singleton (Talisman), poorly resolved taxon but only found in one location in the Study Area.
- *Paradraculoides* sp. B12A – Singleton (East 4).
- *Paradraculoides* sp. 'new2' – Singleton (Broadway).
- *Paradraculoides* sp. 'new3' – Singleton (P Tenement 4).
- *Anapistula* sp. 'EW' (Flying Fish West) – multiple specimens from a single site.
- *Prethopalpus* sp. MW21 - Singleton (Broadway).
- *Troglarmadillo* sp. B46 - Singleton (Flying Fish).
- Pauropodidae sp. B29 - Singleton (Talisman).
- Pauropodidae sp. B41 - Singleton (West End).
- Pauropodidae sp. B42 - Multiple specimens known only from a single site (Broadway).
- Pauropodidae sp. B43 - Singleton (Broadway).
- *Symphyella* sp. 'EW' – Multiple specimens known only from a single site (Broadway).
- Campodeidae sp. 'EW' - Singleton (Broadway).
- Projapygidae sp. B14 - Singleton (TSF - Tailings Storage Facility). This area may be subject to secondary impacts resulting from construction or use of the TSF.
- Projapygidae sp. B17 - Singleton (Flying Fish).
- *Lepidospera* sp. B10 - Singleton (Talisman), - including *Lepidospera* sp. found from the same bore hole.
- *Macranillus* sp. 'EW' - Singleton (East 3) may possibly be the same species as *Macranillus* sp. H-CCA021 and/or *Macranillus* sp. indet. specimens occurring outside impacts.

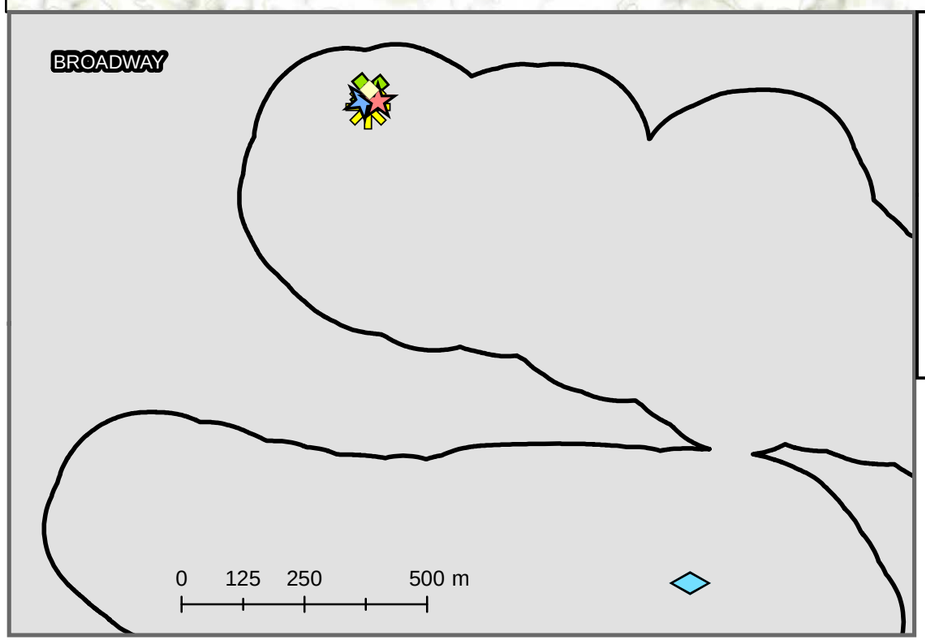
470000 480000 490000 500000 510000 520000

7520000 7510000 7500000

BROADWAY WEST
TSF
BROADWAY
TALISMAN
EAGLES NEST
P TENEMENTS
WEST END
EAST 1
EAST 3
EAST 4
FLYING FISH EAST
FLYING FISH
FLYING FISH WEST

676 m
729 m
812 m
838 m
696 m

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

- Development Envelope

Indicative Disturbance

- Infrastructure
- Mining Pit (150m buffer)
- Stockpile
- Tailings Storage

Troglofauna taxon, species

- Araneae, Anapistula sp. 'EW'
- Araneae, Prethopalpus sp. 'MW21'
- Coleoptera, Macranillus sp. 'EW'
- Diplura, Campodeidae sp. 'EW'
- Diplura, Projapygidae sp. B14
- Diplura, Projapygidae sp. B17
- Isopoda, Troglarmadillo sp. B46
- Palpigradi, Palpigradi sp.
- Pauropoda, Pauropodidae sp. B29
- Pauropoda, Pauropodidae sp. B41
- Pauropoda, Pauropodidae sp. B42
- Pauropoda, Pauropodidae sp. B43
- Schizomida, Paradraculoides sp. B12A
- Schizomida, Paradraculoides sp. new 2
- Schizomida, Paradraculoides sp. new 3
- Symphyla, Symphyella sp. 'EW'
- Thysanura, Lepidospera sp. B10

biologic Environmental Survey

N

1:140,000

0 1.75 3.5 7 km

Fortescue Metals Group Ltd

Eliwana Subterranean Fauna Survey 2017

Fig. 5.1: Troglofauna species potentially restricted to impact areas

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 02/08/2018

5.4 Combined stygofauna occurrence and distributions

The combined stygofauna results (including previous and current survey of the Study Area) show a total of 694 potential stygofauna specimen were recorded. This represents 26 stygofauna morphospecies belonging to 6 higher order groups; Amphipoda (8 species), Copepoda (6 species), Oligochaeta (5 species), Ostracoda (2 species), Syncarida (4 species) and Nematoda (single species). An additional two indeterminate taxa (Enchytraeidae sp. and *Parastenocaris* sp.) were recorded that may represent species already known from the Study Area. Table 5.4 shows all combined stygofauna results to date outlining the occurrence of stygofauna species relative to the Study Area and wider local/subregional area.

Table 5.4. Combined stygofauna results to date, known linear ranges and number of specimens collected in relation to potential impact areas. Highlighted text indicates taxon currently known only from predicted groundwater drawdown area.

Taxonomic Rank	Current survey	Previous survey of Study Area	Comments	Known linear range (km)
Nematoda				
Nematoda sp.		13	Not assessed in EIAs[1]	N/A
Oligochaeta				
Enchytraeus AP PSS1 sp.	1	23	Likely Pilbara-wide[2]	1000+
Enchytraeus AP PSS2 sp.		2	Likely Pilbara-wide[2]	700
Enchytraeidae sp. indet.*	1	39	*Likely to represent *Enchytraeus* AP PSS1 or PSS2 sp.	Uncertain (taxonomic resolution)
Phreodrilidae AP DVC spp.	2	17	Likely Pilbara-wide[2]	1000+
Phreodrilidae AP SVC spp.	2		Likely Pilbara-wide[2]	900
Pristina longiseta	20		Pilbara and beyond	1000+
Ostracoda				
Areacandona sp. BOS1020	32		Known only from 2 sites at the Study Area	0.15
Areacandona nr *triangulum*		21	Known only from 3 sites at the Study Area	4.6
Copepoda				
Stygoridgewayia trispinosa		1	House Creek Bore, western Pilbara and elsewhere in Pilbara[2]	470
Diacyclops humphreysi humphreysi	45	101	Pilbara-wide and beyond[2]	700
Microcyclops varicans	20		Pilbara and beyond	1000+
Orbuscyclops westaustraliensis	11	6	Robe River catchment and elsewhere in Pilbara[2]	700
Parastenocaris sp. B26		57	Known from the Study Area and beyond (The Edge)	56
Parastenocaris sp. B42	3		Collected from a single site outside the Study Area for regional comparisons	-

Taxonomic Rank	Current survey	Previous survey of Study Area	Comments	Known linear range (km)
Parastenocaris sp. indet.*	1		Known only from single site at the Study Area. *May possibly represent other known species *Parastenocaris* sp. B26 from Study Area	Uncertain (taxonomic resolution)
Syncarida				
Brevisomabathynella sp. B03	8	8	Known only from a single site at the Study Area	-
Brevisomabathynella sp. A	4		Known from 2 sites at the Study Area	10
Brevisomabathynella sp. B	1		Known only from a single site at the Study Area	-
Brevisomabathynella sp. C	20		Known only from a single site at the Study Area	-
Amphipoda				
Bogidiella sp. B05		1	Known only from a single record at the Study Area	-
Melitidae sp. B05 (sp. 1 group)		1	Known from the Study Area and beyond (Delphine)[2]	74
Nedsia sp. B04	22	74	Known from the Study Area and beyond (Delphine)	81
Paramelitidae sp. B36	61	46	Known from the Study Area and beyond (Delphine, The Edge)	80
Paramelitidae sp. B37		1	Known from the Study Area and beyond (Delphine)[2]	49
Paramelitidae sp. B58	23		Known only from 3 sites at the Study Area	12
Paramelitidae sp. H-AMP023	3		Known from the Study Area and beyond (Red Hill)	100
Pilbarus sp. B03	3		Known from the Study Area and beyond (Delphine)	75

The combined stygofauna results (including Western Hub sampling and current survey) to date show that eight stygofauna species are currently known only from the Eliwana Study Area.

- *Areacandona* sp. BOS1020 - Known from 2 sites east of Flying Fish;
- *Areacandona* nr *triangulum* - Known from 3 sites north east of Flying Fish;
- *Brevisomabathynella* sp. B03 - Known from a single site at Flying Fish;
- *Brevisomabathynella* sp. A - Known from 2 sites outside Talisman and east of Eagles Nest;
- *Brevisomabathynella* sp. B - Known from a single site south of Broadway;
- Brevisomabathynella sp. C - Known from a single site south of the Eliwana valley;
- Bogidiella sp. B05 - Known from a single site, north east of Flying Fish; and
- Paramelitidae sp. B58 - Known from 3 sites south of Talisman, and west of Eagles Nest.

An additional indeterminate taxon *Parastenocaris* sp. may potentially represent species known from the Study Area and beyond (Table 5.4). This species is known from a single site south of Broadway, and, may possibly represent *Parastenocaris* sp. B26.

480000 490000 500000 510000 520000

7520000 7510000 7500000

BROADWAY
TALISMAN
EAGLES NEST
WEST END
EAST 3
EAST 4
FLYING FISH
FLYING FISH EAST

676 m 729 m 691 m 678 m 812 m 696 m 789 m

Legend

- Development Envelope
- Potential dykes (inferred)

Indicative Disturbance

- Mining Pit (150m buffer)

Higher taxon, species

- Amphipoda, Bogidiella sp. B05
- Amphipoda, Paramelitidae sp. B58
- Bathynellacea, Brevisomabathynella sp. A
- Bathynellacea, Brevisomabathynella sp. B
- Bathynellacea, Brevisomabathynella sp. C
- Bathynellacea, Brevisomabathynella sp. B03
- Copepoda, Parastenocaris sp.
- Ostracoda, Areacandona nr triangulum
- Ostracoda, Areacandona sp. BOS1020

Groundwater Drawdown (m)

0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85

biologic Environmental Survey

N

1:140,000

0 1.75 3.5 7 km

Fortescue Metals Group Ltd

Eliwana Subterranean Fauna Survey 2017

Fig. 5.2: Potentially restricted stygofauna species and maximum predicted groundwater drawdown

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 08/02/2018

6 SUBTERRANEAN HABITAT ASSESSMENT

The habitat assessment for potentially restricted species within the Study Area is based upon available geological and hydrogeological reports, drill logs, diamond drill cores, surface geology maps (GSWA 1: 250,000) and available geological cross sections at each of the deposits. Few groundwater physicochemical measurements were able to be taken at the time of survey, owing to the limitations of bailer sampling within deep holes, but groundwater physiochemistry was incorporated into the stygofauna habitat assessment where possible. The subterranean fauna habitat assessment was based around 12 geological cross sections at key locations throughout the Study Area, corresponding to the sampling locations of potentially restricted troglofauna and stygofauna taxa (where possible) (Table 6.1):

Table 6.1: Location and details of geological/ hydrogeological cross sections

Section number	Location	Easting; Northing (MGA50)	Distance S-N (m)	Bore/ hole on section	Stygofauna species	Troglofauna species
1	Broadway 1	478412; 7513800	1400	EW1061	*Brevisomabathynella* sp. B, Parastenocaris sp. (further east)	Pauropodidae B42 and B43, *Prethopalpus* sp. MW21, Campodeidae sp. EW, *Symphyella* sp. EW, and *Paradraculoides* sp. 'new2' (nearby east)
2	Outside Broadway 1 pit (west)	478100; 7514340	860			
3	West End	482605; 7511350	1620	EW1788		Pauropodidae B41
4	Talisman	484604; 7513540	1120	TM0015	Paramelitidae B58 (nearby east/west), *Brevisomabathynella sp.* A (nearby east)	Pauropodidae B29, Palpigradi sp. *Lepidospera* B10 (nearby east)
5	Eagles Nest	493600; 7512300	1300	EW0352	Paramelitidae B58, and *Brevisomabathynella* sp. A (further east)	
6	East 3	497316; 7510800	2410	EW0372	Paramelitidae B58, and *Brevisomabathynella* sp. A (further west)	*Macranillus* sp. EW
7	East 4	506387; 7509600	1300		*Brevisomabathynella* sp. C (further south)	*Paradraculoides* sp. B12A (nearby east)
8	Flying Fish West	513985; 7509000	960	EWD0017		*Anapistula* sp. EW
9	Flying Fish 1	516706; 7509650	650		*Brevisomabathynella* B03	*Troglarmadillo* B46 (further east)
10	Flying Fish 2	520997; 7510550	650	FF0038		Projapygidae B17, *Troglarmadillo* B46 (further west)
11	Flying Fish East	523396; 7511075	1100	FF0360	*Areacandona* nr. *triangulum*, *Areacandona* BOS1020	
12	Outside impact NE of Flying Fish	524763; 7511500	3000		*Areacandona* nr. *triangulum*, and *Bogidiella* B05 (further east)	

The water table shown within these cross sections is indicative only, based on the average depth to groundwater throughout the corresponding hydrogeological compartment of the Eliwana Valley, therefore the illustration of the water table may be unreliable in mountainous parts of the cross sections at the periphery. The groundwater drawdowns shown on the cross-sections are based upon the contours shown in Figure 5.2, mapped along section by widening the section to approximately 100 m to show lines instead of points where drawdown is modelled to occur. In some places this extends below the mapped geological layers, as the geological and hydrogeological models were independently derived. The extent of geological layers is limited by the data available for use in the geological model, which interpolates or extrapolates geological layers between data points sited at bore/ drill hole locations.

470000 475000 480000 485000 490000 495000 500000 505000 510000 515000 520000 525000

7530000 7525000 7520000 7515000 7510000 7505000 7500000

981 m 676 m 729 m 691 m 812 m 638 m 696 m

1 2 3 4 5 6 7 8 9 10 11 12

Legend

- Development Envelope
- Geological cross sections (approx.)

Indicative Disturbance

- Mining Pit (150m buffer)
- Tailings Storage

Groundwater drawdown (m)

- 10
- 50
- 80
- Potential dykes (interpreted)
- Potentially restricted troglofauna
- Potentially restricted stygofauna

Pooled geology

- Boolgeeda Iron Formation
- Brockman Iron Formation
- Dolerite dykes
- Dolerite sills
- Jeerinah Formation
- Marra Mamba Formation
- Mt McRae Shale
- Mt Sylvia Formation
- Weeli Wolli Formation
- Wittenoom Iron Formation
- Woongarra Rhyolite

biologic Environmental Survey

N

1:150,000

0 2 4 8 km

Fortescue Metals Group Ltd

Eliwana Subterranean Fauna Survey 2017

Fig. 6.1: Locations of habitat cross sections and potentially restricted subterranean fauna

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 02/08/2018

6.1 Broadway

6.1.1 Troglofauna habitat

Figures 6.2 and 6.3 show that the Broadway 1 pit is developed in MMIF, with the upper Newman and McLeod Members being the main targets for mining. Both geological units are known to provide highly suitable habitat for subterranean fauna where sufficiently weathered (Section 3.3, Table 3.1).

Hole EW1061 is shown to occur within a thin band of Macleod and Nammuldi Members on the mid slope area. Geological modelling of these layers did not extend below the end of hole at EW1061 (18m), although it is reasonable to assume that these layers are much thicker than shown in Figure 6.3 or 6.4.

Five (5) potentially restricted troglofauna taxa were detected from this site, comprising Pauropodidae 'B42' and P. 'B43', *Prethopalpus* sp. 'MW21', Campodeidae sp. 'EW', and *Symphyella* sp. 'EW'. *Paradraculoides* sp. 'new2' was detected nearby from the Broadway south, in the Dales Gorge Member of the BrIF (Figure 6.2). Figure 6.1 shows hole EW1061 is situated 100m within the indicative disturbance mining pit. As the modelled pits shown in Figure 6.1 are subject to a 150m buffer (under a precautionary approach), hole EW1061 would likely be just outside of the proposed pit boundary at Broadway 1 (as shown in Figure 6.2).

Nearby diamond drill cores EWD0034 (pictured below) and EWD0014, situated east-south-east of hole EW1061 sit within the same geological profile as EW1061 in the MMIF. Both drill cores show significant cavities, core loss (indicative of cavities and weathered geology) as well as high levels of fracturing and vugs from secondary weathering from the surface to the end of core (0 to approx. 40m). This highly weathered geology is likely to comprise highly suitable for troglofauna habitat.

Surface geology (Figure 6.2) shows the MMIF extending beyond the Broadway 1 pit along strike to the north and west. Meanwhile the BrIF occurring at EW1417 also extends further to the south and west of the Broadway south pit. Figure 6.4 shows a very similar geological profile to the immediate west of the Broadway 1 Pit, indicating that the habitat in this area is likely highly similar, and well connected to the habitats likely to be directly impacted by the Broadway pits. Overall, the current geological information suggests that the potential habitats for troglofauna species found in the Broadway pits are likely to extend beyond the pit boundaries, particularly to the west.

6.1.2 Stygofauna habitat

Sampling within the vicinity of cross sections 1 and 2 in the western part of the Broadway pits did not detect any potentially restricted stygofauna species, although *Brevisomabathynella* sp. 'B' and *Parastenocaris* sp. were detected from the eastern end of Broadway in a similar hydrogeological setting. Based on general hydrogeological information it can be assumed that there may be highly suitable habitats for stygofauna within the Newman Member of the MMIF, the Wittenoom Dolomite (and possibly some suitable habitat within the West Angela Member, if sufficiently weathered), and the Dales Gorge Member of the BrIF. These layers are predicted to be subject to approximately 15-20m of groundwater drawdown based on current modelling. Current hydrogeological information suggests that there may be a range of potentially habitable strata below the predicted drawdown. of the hydro bore log for EWPB006 (Appendix 2), where *Brevisomabathynella* sp. 'B' and *Parastenocaris* sp. were detected, shows potential habitat within weathered and fractured dolomite (Paraburdoo Member) from the water table (approx. 25m BGL) to the end of hole at approx. 80m BGL (with aquifer yields between 10-20L/sec). Given the predicted 20m maximum drawdown in this area, it is reasonable to expect that some deeper habitats for stygofauna may occur within the hydrogeological compartment surrounding the Broadway pits. .

476000 477000 478000 479000 480000 481000 482000 483000 484000 485000 486000 487000

7516000 7515000 7514000 7513000 7512000 7511000 7510000

EW1061
Broadway Pits
EW1417
EWPB006
Talisman Pit
TM0015
TM0087
EWMB009
EW1437
EW1788
West End Pit
1 2 3 4

Legend

- Development Envelope
- Geological cross sections (approx.)

Indicative Disturbance

- Mining Pit (150m buffer)
- Tailings Storage
- Hydro bore logs available
- Diamond cores available

Groundwater drawdown (m)

- 0.0 - 15.0
- 15.1 - 40.0
- 40.1 - 60.0
- Potential dykes (interpreted)

Pooled geology

- Brockman Iron Formation
- Dolerite dykes
- Jeerinah Formation
- Marra Mamba Formation
- Mt McRae Shale
- Mt Sylvia Formation
- Wittenoom Iron Formation

Stygofauna taxon, species

- Amphipoda, Paramelitidae sp. B58
- Bathynellacea, Brevisomabathynella sp. A
- Bathynellacea, Brevisomabathynella sp. B
- Copepoda, Parastenocaris sp.

Troglofauna taxon, species

- Araneae, Prethopalpus sp. 'MW21'
- Diplura, Campodeidae sp. 'EW'
- Palpigradi, Palpigradi sp.
- Pauropoda, Pauropodidae sp. B29
- Pauropoda, Pauropodidae sp. B41
- Pauropoda, Pauropodidae sp. B42
- Pauropoda, Pauropodidae sp. B43
- Schizomida, Paradraculoides sp. new 2
- Symphyla, Symphyella sp. 'EW'
- Thysanura, Lepidospera sp. B10

EW1061

0 75 150 300 m

biologic Environmental Survey

N

1:30,000

0 0.4 0.8 1.6 km

Fortescue Metals Group Ltd

Eliwana Subterranean Fauna Survey 2017

Fig. 6.2: Potentially restricted subterranean fauna and extent of suitable habitats (west)

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 08/02/2018

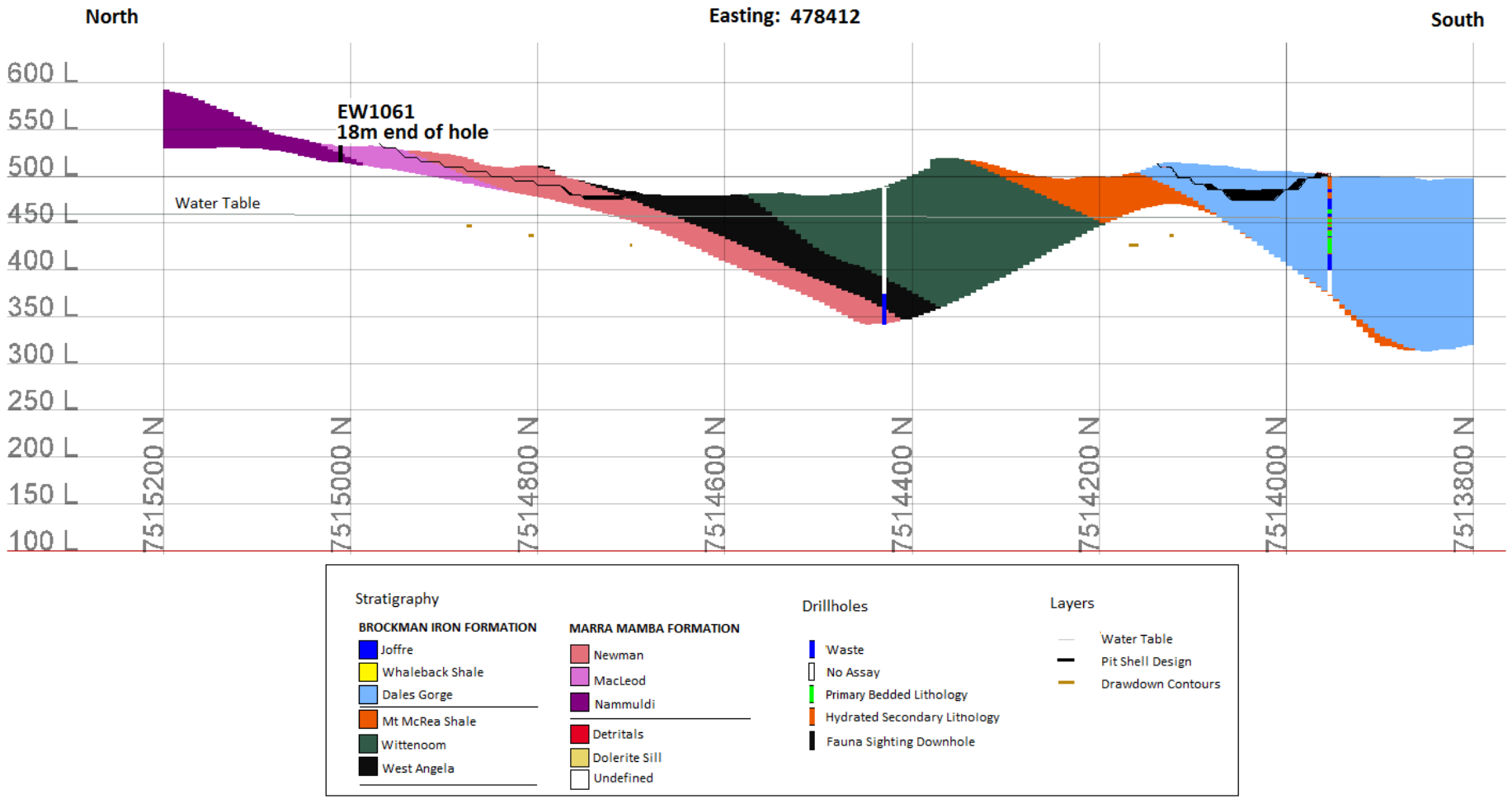


Figure 6.3: Cross section 1- Broadway 1

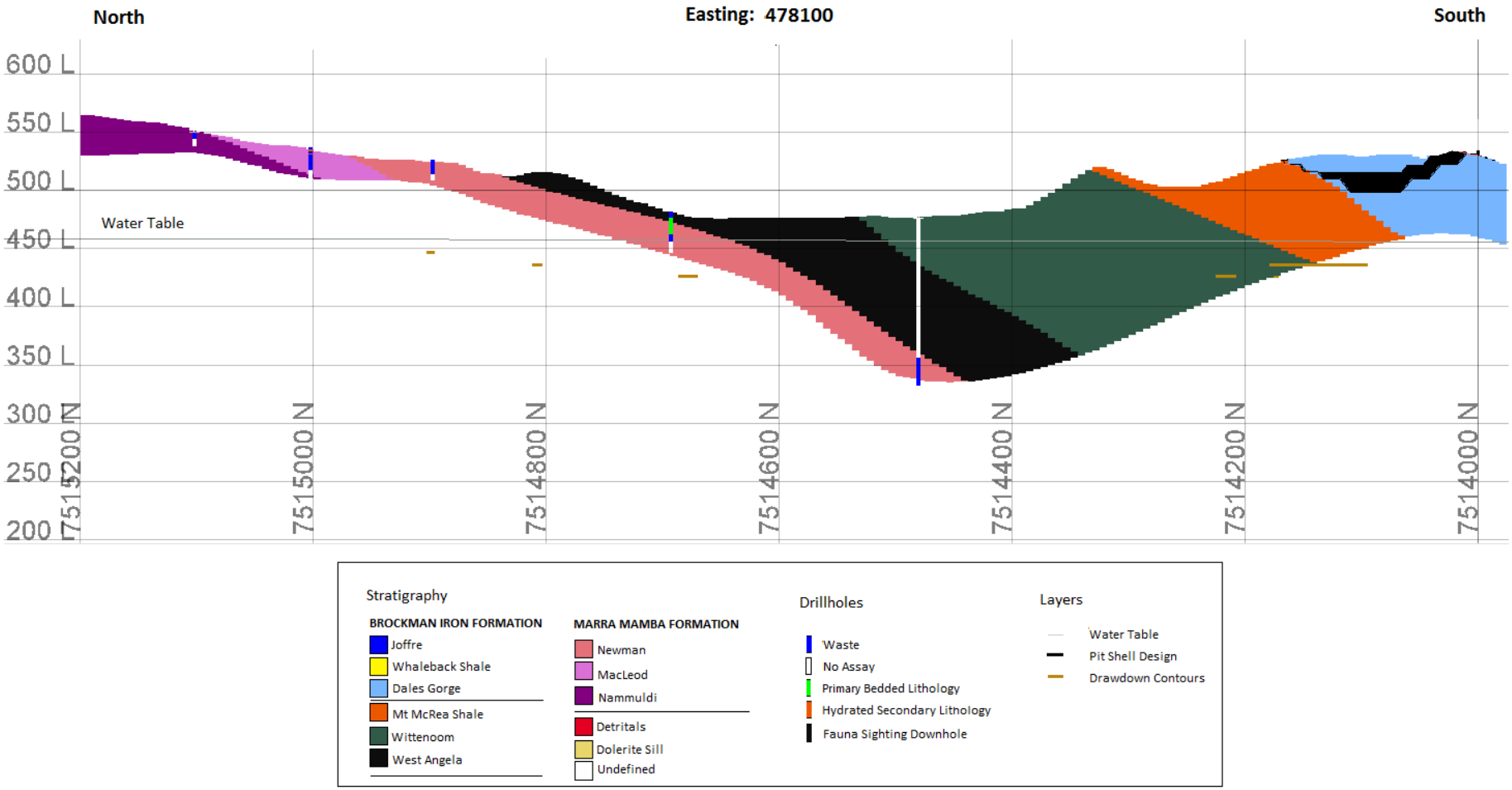


Figure 6.4: Cross section 2- Outside pit immediately west of Broadway 1

Figure 6.5: Core showing cavities and core loss (potential habitat) at EWD0034.

6.2 West End

6.2.1 Troglofauna habitat

Figure 6.4 shows that the West End pit targets the Joffre, Whaleback and Dales Gorge Members of the BrIF, as well as some detrital mineralised zones to the south. These geological units are known to provide highly suitable habitat for subterranean fauna where sufficiently weathered (Section 3.3, Table 3.1).

Based on nearby drill cores, hole EW1788 (location of the troglofauna species Pauropodidae sp. B41) intersects a relatively thick secondary hydrated zone at the top of the profile in the Joffre Member and several bedded mineralised zones deeper in the profile within the Whaleback and Dales Gorge Members of the BrIF (Figure 6.6)

Diamond cores immediately north (EWD0010, EWD0023) and south (EWD0024) of hole EW1788 within the West End pit, show characteristic high levels of weathering of the BrIF. All cores showed notable cavities, core loss (>1.5m), fractured geology, dissolution holes and vugs throughout the profile (from surface to beyond 50m), which are indicative of highly suitable troglofauna habitat (as shown in Figure 6.7 below).

Figure 6.2 shows the BrIF surface geology occurring at hole EW1788 extends along the strike west and east beyond the boundaries of West End Pit. Based on current geological information, it is likely that highly suitable habitat for the troglofauna species (see Table 3.1 and Section 3.3) found within West End Pit occurs beyond the pit boundaries to the east and west.

6.2.2 Stygofauna habitat

Based on general hydrogeological characteristics (Table 3.1), it can be assumed that there may be highly suitable habitats for stygofauna within the Dales Gorge and upper Joffre Members of the BrIF (and the Whaleback Member, where sufficiently weathered), that appear to extend below the predicted drawdown (maximum of approximately 40m below current water table) (Figure 6.6). Sampling within and surrounding West End Pit did not detect any potentially restricted stygofauna species (Figure 6.2).

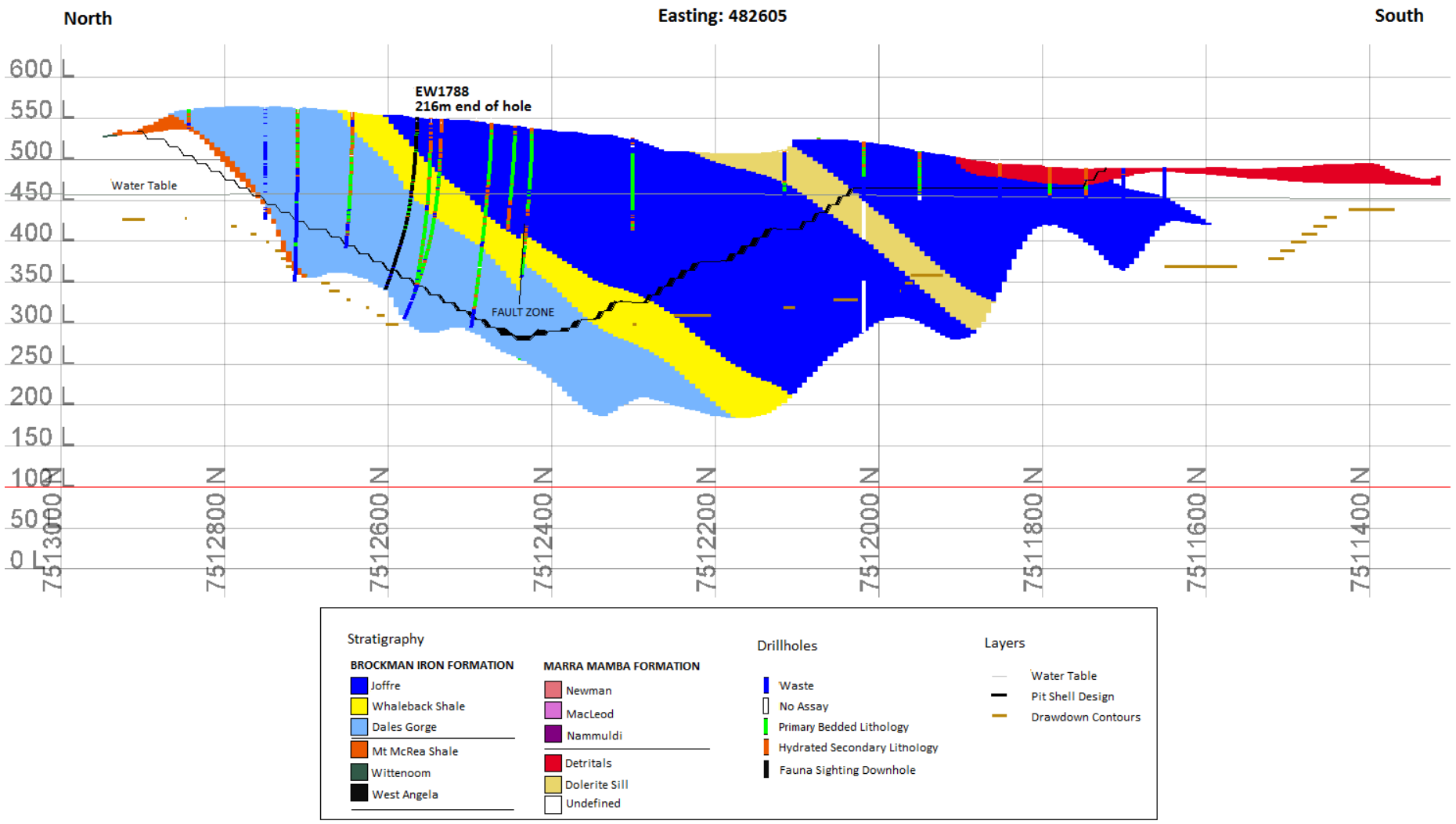


Figure 6.6: Cross section 3: West End

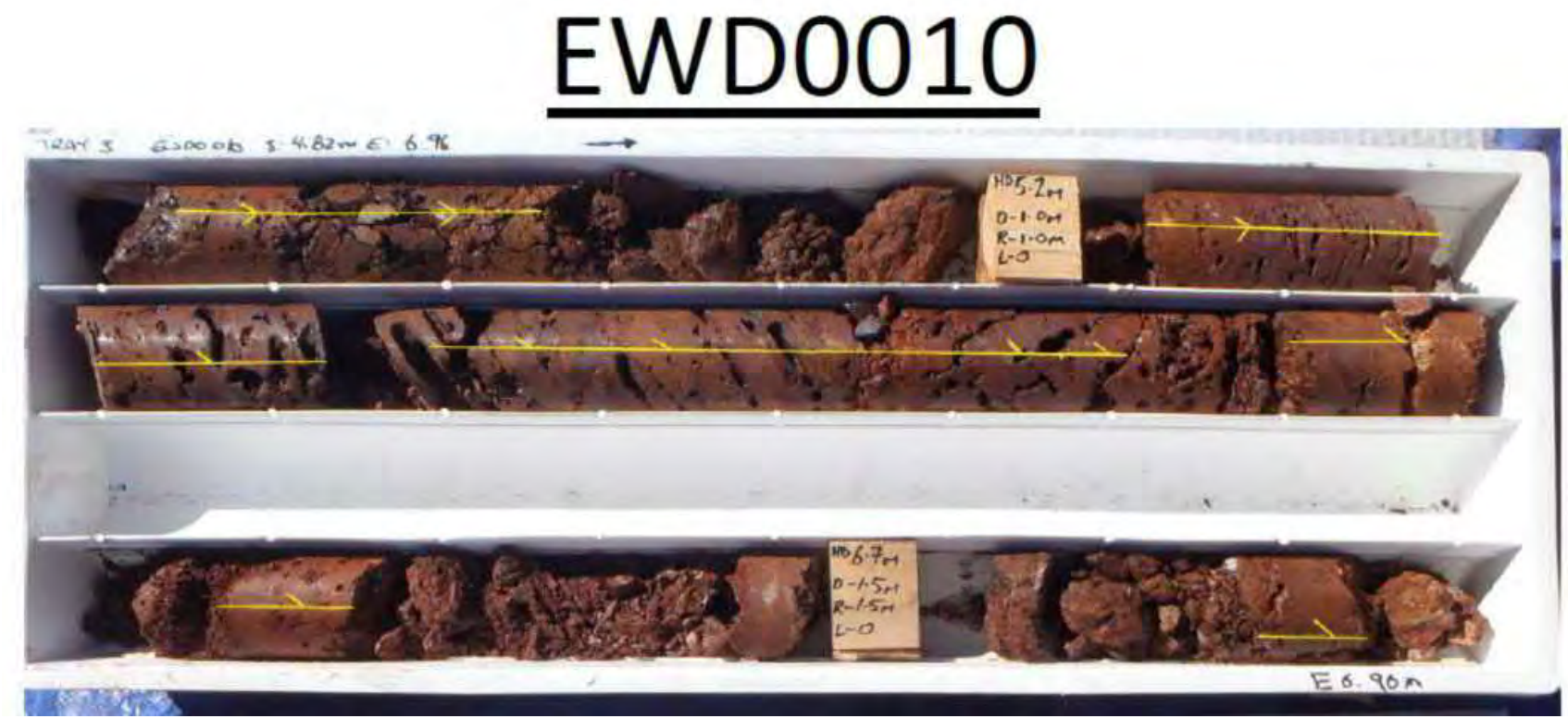


Figure 6.7: EWD0010 Core showing secondary weathering (potential troglofauna habitat) at West End Pit.

6.3 Talisman

6.3.1 Troglofauna habitat

The Talisman Pit is developed in MMIF targeting the upper Newman Member and surface detritals (Figure 6.6). These geological units are known to provide highly suitable habitat for subterranean fauna where sufficiently weathered (Section 3.3, Table 3.1).

Hole TM0015, situated in the south of Talisman, intersects surface detritals overlaying West Angela shales, terminating in the Newman Member of the MMIF (78m). Three potentially restricted troglofauna taxa were detected from the proposed Talisman pit, comprising two from hole TM0015 (Palpigradi sp. and Pauropodidae sp. 'B29') and one from hole TM0087 (*Lepidospera* sp. 'B10'), immediately east of cross section 4 (Figure 6.8).

Figure 6.8 shows only detritals and the West Angela Member above the water table near hole TM0015. It may be assumed that either the West Angela Member in this area is sufficiently weathered above water table to support troglofauna, or that troglofauna taxa collected from this hole were inhabiting the unconsolidated detritals.

Diamond cores (EWD0037, EWD0036) adjacent to holes TM0015 and TM0087 show characteristic gravels, fractures and void spaces within unconsolidated detritals near the surface. Both cores EWD0037 and EWD0036 depict surface detritals that are poorly consolidated and weathered, resulting in frequent core loss (Figures 6.7 and 6.8 below). Core loss continued throughout the profile in EWD0036, interspersed with less permeable layers of shale, whereas at EWD0037, beyond approximately 25-35m, the core showed highly consolidated rock with very little secondary porosity.

Surface geology (Figure 6.1) shows that the detritals (Tertiary colluvium) extend well outside the Talisman pit, east-west along the Eliwana Valley. The cross section in Figure 6.6 also shows a significant extent of this layer further to the south of the pit boundary, atop Wittenoom Dolomite (which may also provide potential habitat where weathered/ karstified). Based on current geological information, it is likely that suitable, well-connected habitat for the troglofauna species found within (and near) the Talisman Pit occurs beyond the pit boundaries to the east, west, and south.

6.3.2 Stygofauna habitat

Figure 6.8 shows Wittenoom Dolomite (and West Angela shales), and the Newman Member of the MMIF extending well below the water table in the Talisman area. Based on the high likelihood of secondary weathering in the dolomite and Newman Member, and the potential for some weathering within the West Angela, these units are regarded as forming highly suitable habitats for stygofauna (Table 3.1, Section 3.3).

Groundwater drawdown in the hydrogeological compartment surrounding Talisman Pit is predicted to be approximately 30m (maximum), and owing to the depth of Wittenoom dolomite, the West Angela, and Newman Members in the valley to the south, it is considered likely that there may be deeper potential habitats within these layers that are unaffected by drawdown. Hydrological bores in the southern part of Talisman Pit (EWPB004) and the valley further south (EWPB003) revealed significant depths of weathered dolomite in the Bee Gorge and Paraburdoo Members (to approximately 120m BGL) (Appendix 2). The aquifer yield from these deep weathered dolomite formations was approximately 30L/s (Golder 2017), indicating a reasonably porous aquifer despite considerable depth below surface. The quality of stygofauna habitat within these deeper aquifers may also be influenced by water physicochemistry such as dissolved oxygen, which is poorly known at present - the only data from the area was a single bailer sample taken at hole EW1437 during the survey, which recorded approximately 20% saturation dissolved oxygen from near the surface of the groundwater. Nevertheless, the general hydrogeological

characteristics of the Wittenoom aquifers at depths well below the predicted drawdown in the Talisman area are indicative of suitable habitat for stygofauna.

Despite the occurrence of an inferred hydrological barrier (dyke) to the immediate west of Talisman Pit, Paramelitidae sp. 'B58' was detected to the south east at hole EW1437, and west of the inferred dyke at bore EWMB009 (Figure 6.2). This species was also found to occur further east again in a different hydrogeological compartment at Talisman Bore (east of Eagles Nest Pit, refer Figure 6.10 further below), indicating that its potential distribution may be wider than currently recorded within the Study Area (refer section 6.11).

In contrast, two distinct species of *Brevisomabathynella* (*B*. sp. 'A' and *B*. sp. 'B') were detected either side of the inferred hydrogeological barrier to the immediate west of Talisman Pit. These species were morphologically conservative, but DNA sequencing (Appendix 1) revealed genetic divergences of 3.4-3.9% COI, indicative of either a strong population-level divergence, or a species-level difference. As a precaution, these taxa are conservatively considered different species, and as such *B*. sp. 'B' is inferred to be restricted to the hydrogeological compartment surrounding Broadway, while *B*. sp. 'A' is known from two hydrogeological compartments; surrounding Talisman Pit and further to the east surrounding East 3 and East 4 pits (refer Figure 6.10 further below).

In any case, the current hydrogeological data suggests a reasonable likelihood that suitable habitat for these species occurs below the predicted groundwater drawdown (maximum 30m surrounding Talisman Pit and 20m surrounding Broadway Pit) within the deeper MMIF and Wittenoom dolomite aquifers (Figures 6.8 and 6.3).

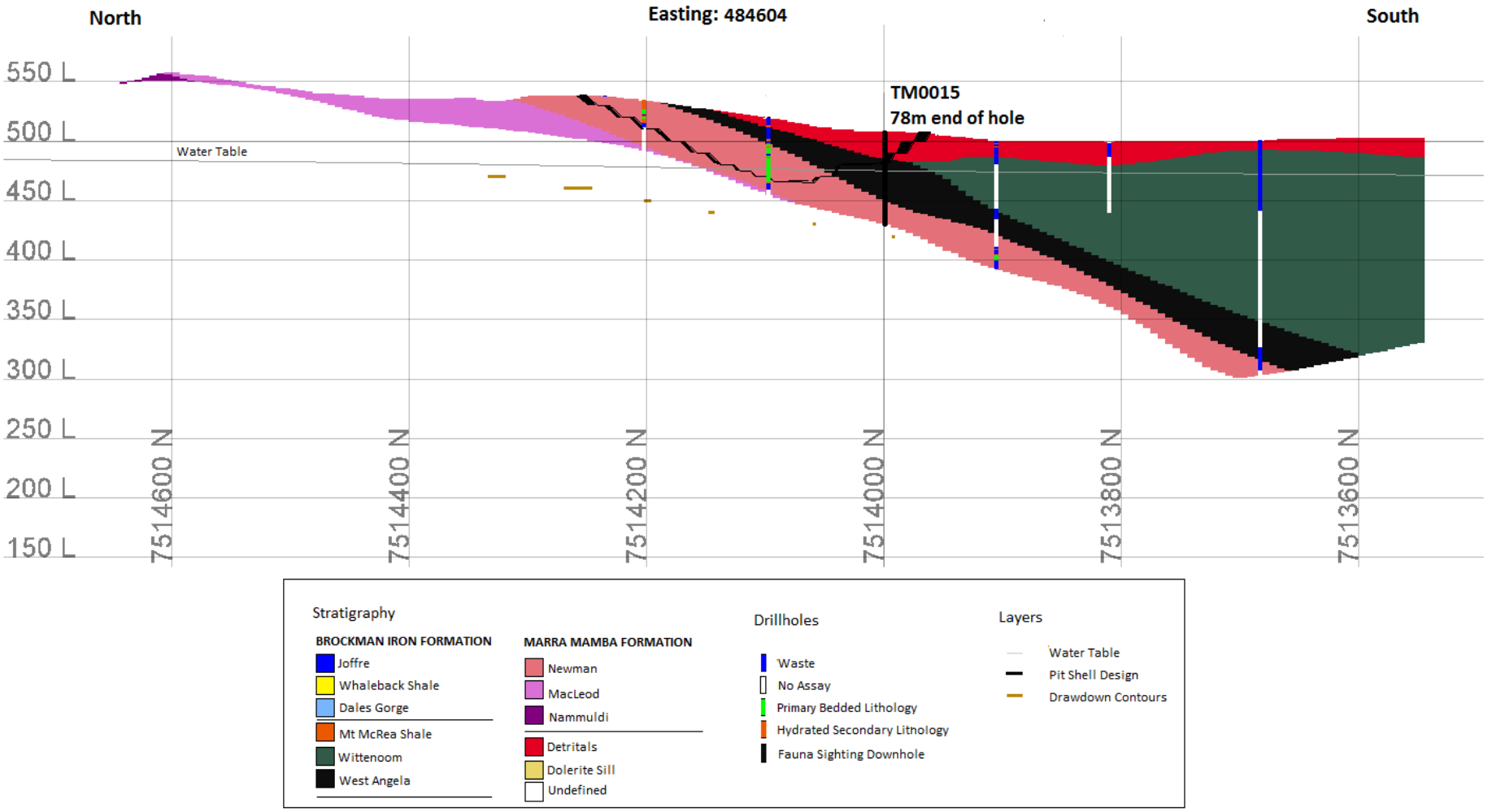


Figure 6.8: Cross Section 4- Talisman

Figure 6.9: EWD0037 Core at Talisman Pit showing core loss in surficial unconsolidated detritals (potential habitat), and fresh shale rock at depth (unsuitable habitat).

6.4 Eagles Nest

6.4.1 Troglofauna habitat

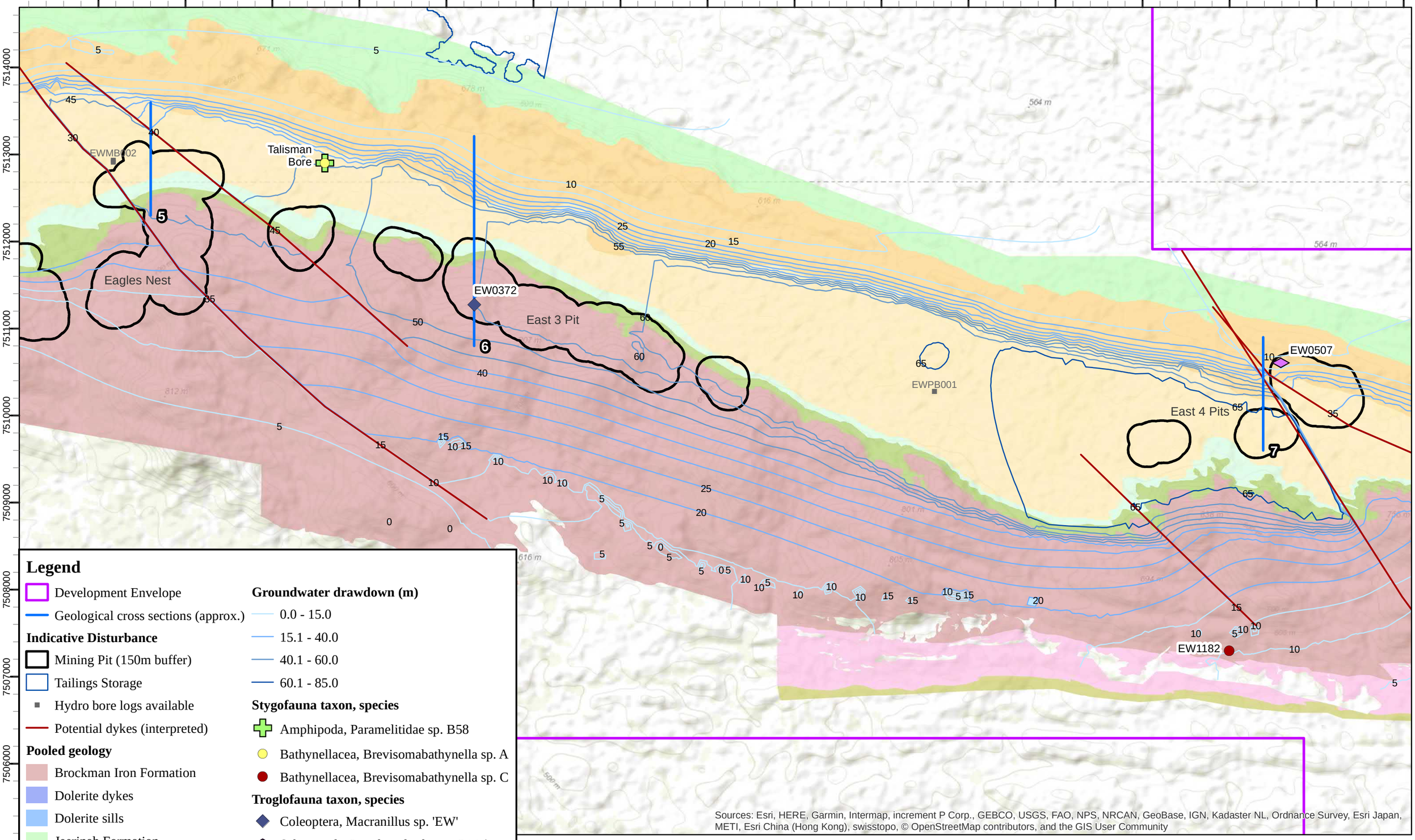
Suitable troglofauna habitats within the Eagles Nest pit may exist within a thick layer of unconsolidated detritals above the water table (Figure 6.11), with drill logs inside the pit showing hydrated mineralisation that would be expected to provide sufficient porosity for troglofauna habitat. No potentially restricted troglofauna taxa were detected from the Eagles Nest Pit (Figure 6.10).

6.4.2 Stygofauna habitat

The cross section of Eagles Nest Pit (Figure 6.11) shows thick detritals above West Angela shales in the valley, and above the Wittenoom Dolomite to the south. The Wittenoom dolomite would be expected to provide moderately to highly suitable habitat for stygofauna where sufficiently weathered (Section 3.3, Table 3.1). The groundwater appears to be well below the pit floor of Eagles Nest Pit (cross section 5) and is concentrated around two distinct 'dips' in the palaeochannel floor in the middle of the valley, respectively formed in West Angela shales, the Newman Member of the MMIF and Tertiary detritals, the latter which would be expected to provide suitable habitat for stygofauna where sufficiently weathered (Section 3.3, Table 3.1). Contingent upon the amount of weathering/ permeability in the West Angela shales (facilitating connectivity with the surface), these areas where the palaeochannel dips deeper beneath the water table would be expected to form suitable habitat for stygofauna (Figure 6.11). Hydrological bore logs for EWPB001 (Appendix 2) immediately west of Eagles Nest pit indicated mainly fresh dolomite beneath the water table, with no yield information from pump testing available.

No potentially restricted stygofauna taxa were detected from the immediate vicinity of cross section 5, but Paramelitidae sp. 'B58' and *Brevisomabathynella* sp. 'A' were detected at Talisman bore, in similar habitats between cross section 5 and cross section 6 at East 3 Pit (Figure 6.10). Based on extrapolation of habitats between these two sections, it is considered likely that these two species may inhabit the MMIF, Wittenoom Dolomite, West Angela shales or Tertiary detritals in the centre of the palaeochannel where these units dip beneath the water table.

This area is predicted to experience approximately 40-50m of groundwater drawdown during mining, which would be expected to deplete most of the potential stygofauna habitat shown on cross section 5. Some deeper habitat may remain to the north within the Newman Member and the West Angela Shales (assuming sufficient weathering) but owing to the lack of hydrological testing in this area, the quality of habitat remaining beneath drawdown is questionable. Deeper palaeochannel habitats off section further to the east of Talisman bore (shown on section 6, Figure 6.12 below) may also be less affected by drawdown, as discussed further below in section 6.4.



Legend

- Development Envelope
- Geological cross sections (approx.)

Indicative Disturbance

- Mining Pit (150m buffer)
- Tailings Storage
- Hydro bore logs available
- Potential dykes (interpreted)

Pooled geology

- Brockman Iron Formation
- Dolerite dykes
- Dolerite sills
- Jeerinah Formation
- Marra Mamba Formation
- Mt McRae Shale
- Mt Sylvia Formation
- Weeli Wolli Formation
- Wittenoom Iron Formation
- Woongarra Rhyolite

Groundwater drawdown (m)

- 0.0 - 15.0
- 15.1 - 40.0
- 40.1 - 60.0
- 60.1 - 85.0

Stygofauna taxon, species

- Amphipoda, Paramelitidae sp. B58
- Bathynellacea, Brevisomabathynella sp. A
- Bathynellacea, Brevisomabathynella sp. C

Troglofauna taxon, species

- Coleoptera, Macranillus sp. 'EW'
- Schizomida, Paradraculoides sp. B12A

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Fortescue Metals Group Ltd

Eliwana Subterranean Fauna Survey 2017

Fig. 6.10: Potentially restricted subterranean fauna and extent of suitable habitats (central)

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 08/02/2018

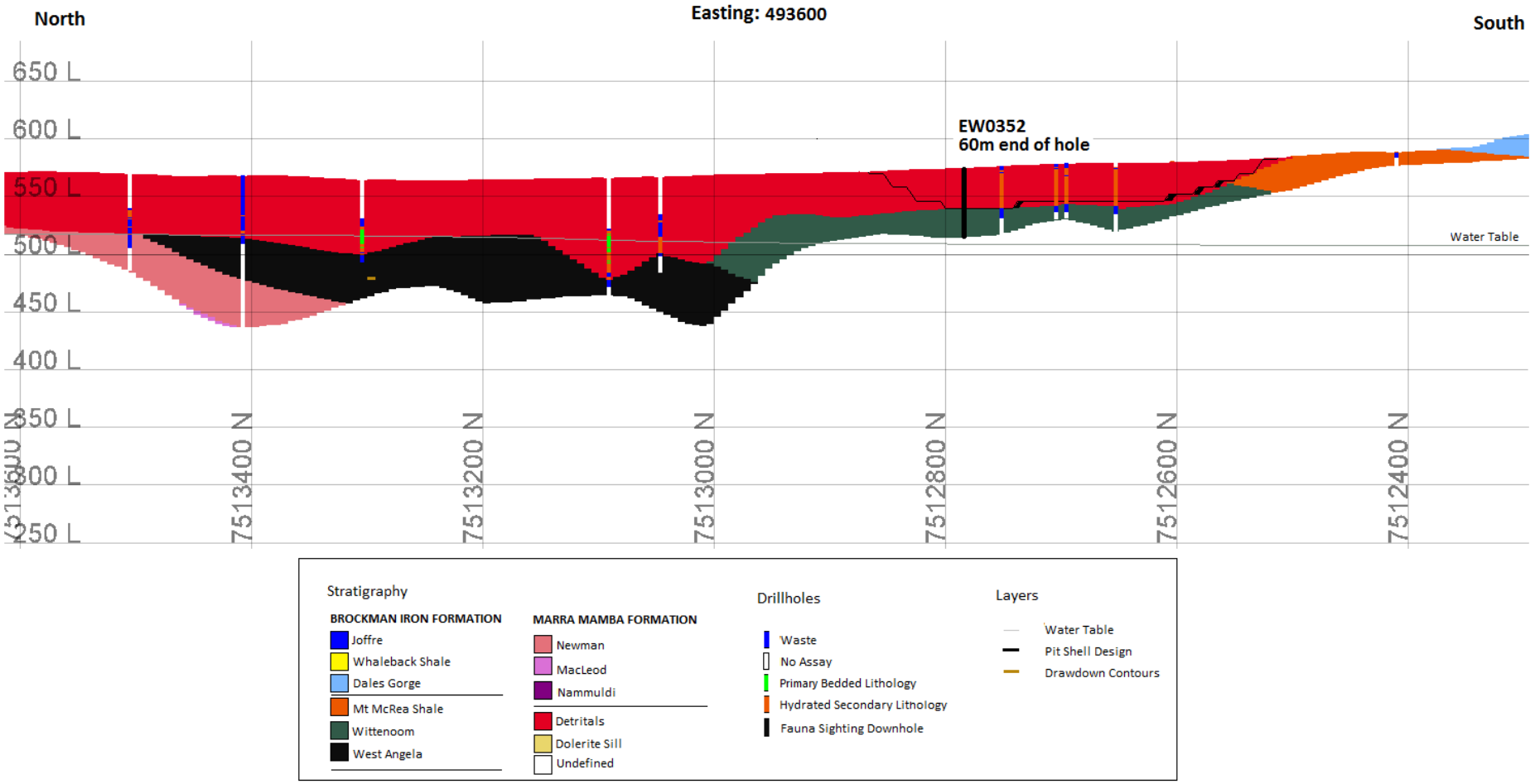

Figure 6.11: Cross section 5- Eagles Nest

6.5 East 3

6.5.1 Troglofauna habitat

East 3 Pit is developed almost entirely within the Dales Gorge Member (BrIF), with the northern margin extending slightly beneath the Tertiary detritals of the valley floor (Figure 6.12). This geological unit is known to provide highly suitable habitat for subterranean fauna where sufficiently weathered (Section 3.3, Table 3.1).

Hole EW0372, where the carabid species *Macranillus* sp. 'EW' was detected, is situated on the southern margin of East 3 pit approximately 160m within the indicative pit (Figure 6.10). As the pits shown in Figure 6.10 include a conservative 150m buffer zone, only the surface of hole EW0372 is likely to be within the pit boundary (as shown in cross-section 6) (Figure 6.12).

There were no available diamond cores within the immediate vicinity of East 3 Pit; however, the Dales Gorge Member has been shown to provide high suitability troglofauna habitat in other parts of the Study Area (e.g. West End Pit, discussed in section 6.2). Drill logs within cross section 6 showed hydrated secondary lithologies typically associated with highly suitable troglofauna habitat (Figure 6.12). Owing to the wider mapped extent of the BrIF and the relatively shallow depth of the East 3 Pit shown in cross section 6 (Figure 6.12), it is considered likely that suitable habitat for troglofauna found at East 3 Pit extends beyond the pit boundaries.

6.5.2 Stygofauna habitat

Cross section 6 (Figure 6.12) shows potential stygofauna habitats largely confined to a ‘dip’ in the centre of the palaeochannel to the north of East 3 Pit, where the MMIF, Wittenoom Dolomite, and Tertiary detritals occur beneath the water table. These geological units are known to provide moderately to highly suitable habitat for stygofauna where sufficiently weathered (Section 3.3, Table 3.1). The other potentially habitable strata shown along section are all largely above water table and not expected to provide potential stygofauna habitat. Hydro bore EWPB002 (further to the east of cross section 6 but inferred to be in the same central palaeochannel area) showed highly weathered shales in the Bee Gorge Member, and weathered dolomite in the Paraburdoo Member at depth (110-120m BGL) (Appendix 2). These layers yielded approximately 15-20L/sec, which would suggest moderate potential for stygofauna habitat, although there were thick overlying clay layers in the Bee Gorge Member (fully weathered shales) with much lower permeability.

As previously mentioned, Paramelitidae sp. ‘B58’ and *Brevisomabathynella* sp. ‘A’ were detected at Talisman bore between cross section 6 and 5 (Figure 6.10). Based on extrapolation, it is likely that these species inhabit the MMIF, Wittenoom Dolomite, or Tertiary detritals in the centre of the palaeochannel where these units dip beneath the water table. This habitat is predicted to experience approximately 50-55m of groundwater drawdown, which may leave some deeper habitats beneath the predicted drawdown as shown on cross section 6 (Figure 6.12). Both stygofauna species are also known to occur further to the west near the Talisman Pit (Figure 6.2), which is expected to experience less groundwater drawdown.

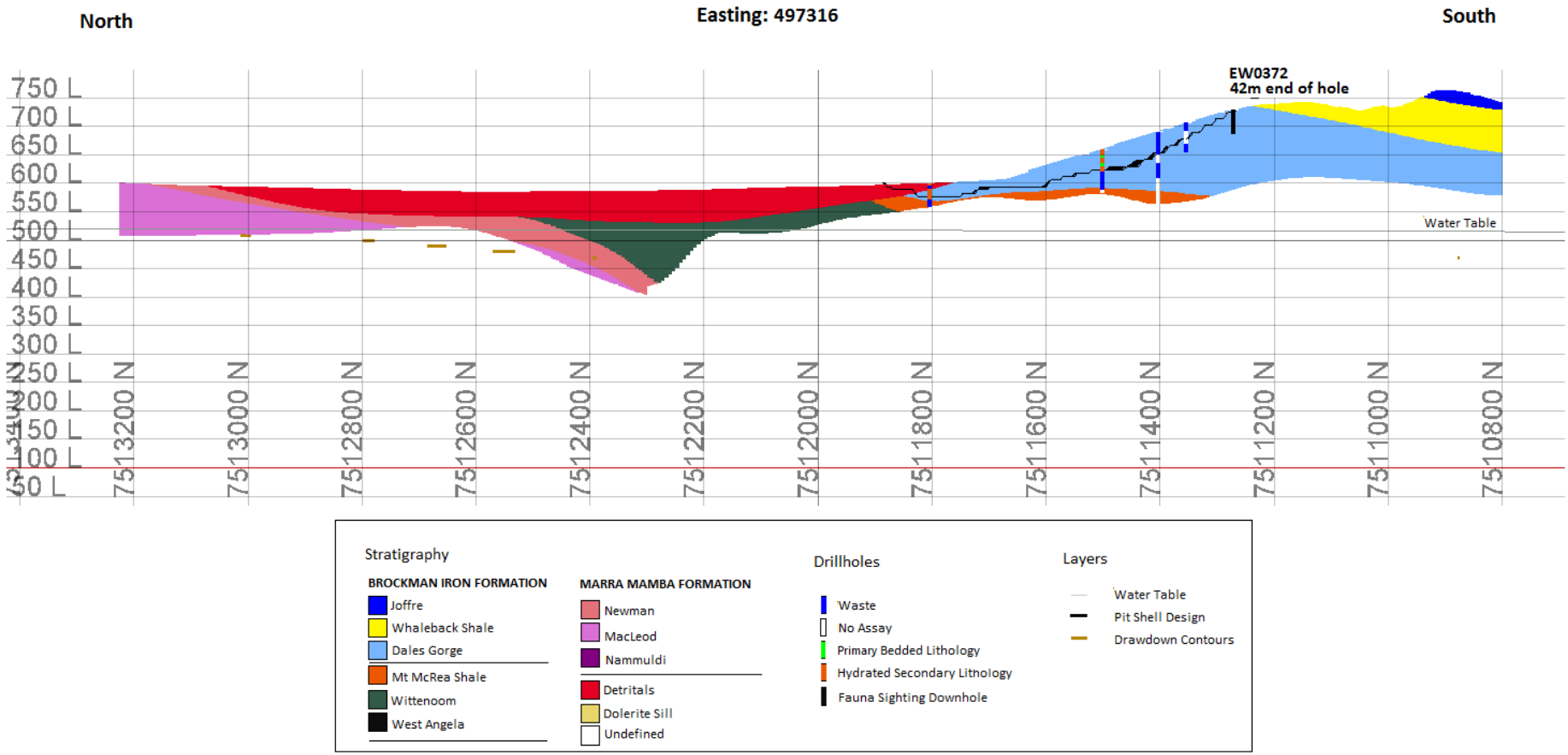

Figure 6.12: Cross section 6- East 3

6.6 East 4

6.6.1 Troglofauna habitat

Figure 6.13 shows that the southern East 4 Pits target the detrital mineralised zone in the south of cross section 7 and it can be inferred from Figure 6.10 that the northern East 4 pit targets the MMIF. Detrital formations can provide moderately to highly suitable habitat for subterranean fauna where sufficiently weathered (Section 3.3, Table 3.1).

Paradraculoides sp. B12A, known only from within northern East 4 pit, was recorded from hole EW0507 (MMIF) that is outside the proposed pit boundaries when considering the 150m disturbance buffer of the pits shown in Figure 6.10. A further indeterminate troglofauna taxon (*Macranillus* sp. indet.) was detected just outside the western boundary of the northern East 4 pit, in MMIF (Newman Member) or tertiary detrital geologies. There were no available diamond cores or drill logs in the area to incorporate into the habitat assessment, but both strata have been shown to form highly suitable habitats for troglofauna elsewhere within the Study Area (e.g. section 6.4, Eagles Nest).

Based on the wider mapped extent of the MMIF and detritals to the north along cross section 6, and to the west off section (Figure 6.13) the proposed extent of the East 4 Pits are not considered to impact a large proportion of the available habitat for troglofauna in this area.

6.6.2 Stygofauna habitat

Potential stygofauna habitats within the East 4 area appear to occur within a relatively thin layer of the Newman (and potentially the Macleod) Member that dips below water table in the centre of the palaeochannel (Figure 6.13). These geological units are known to provide highly suitable habitat for subterranean fauna where sufficiently weathered (Section 3.3, Table 3.1). No potentially restricted stygofauna taxa were detected from this immediate area (Figure 6.10).

Further south beyond the extent of cross section 6, *Brevisomabathynella* sp. ‘C’ and Paramelitidae sp. ‘H-AMP023’, were recorded from deep groundwater habitats within the BrIF (>40m depth to water) at hole EW1182. This area is only expected to experience approximately 10m of groundwater drawdown (Figure 6.10), although very little information is currently available to assess the expected depth of suitable habitat that is likely to remain following drawdown. Paramelitidae sp. ‘H-AMP023’ is known to occur regionally at Red Hill (approximately 100km west) based on the DNA results, while *Brevisomabathynella* sp. ‘C’ is considered to occur only within the Study Area based on current genetic information (Appendix 1).

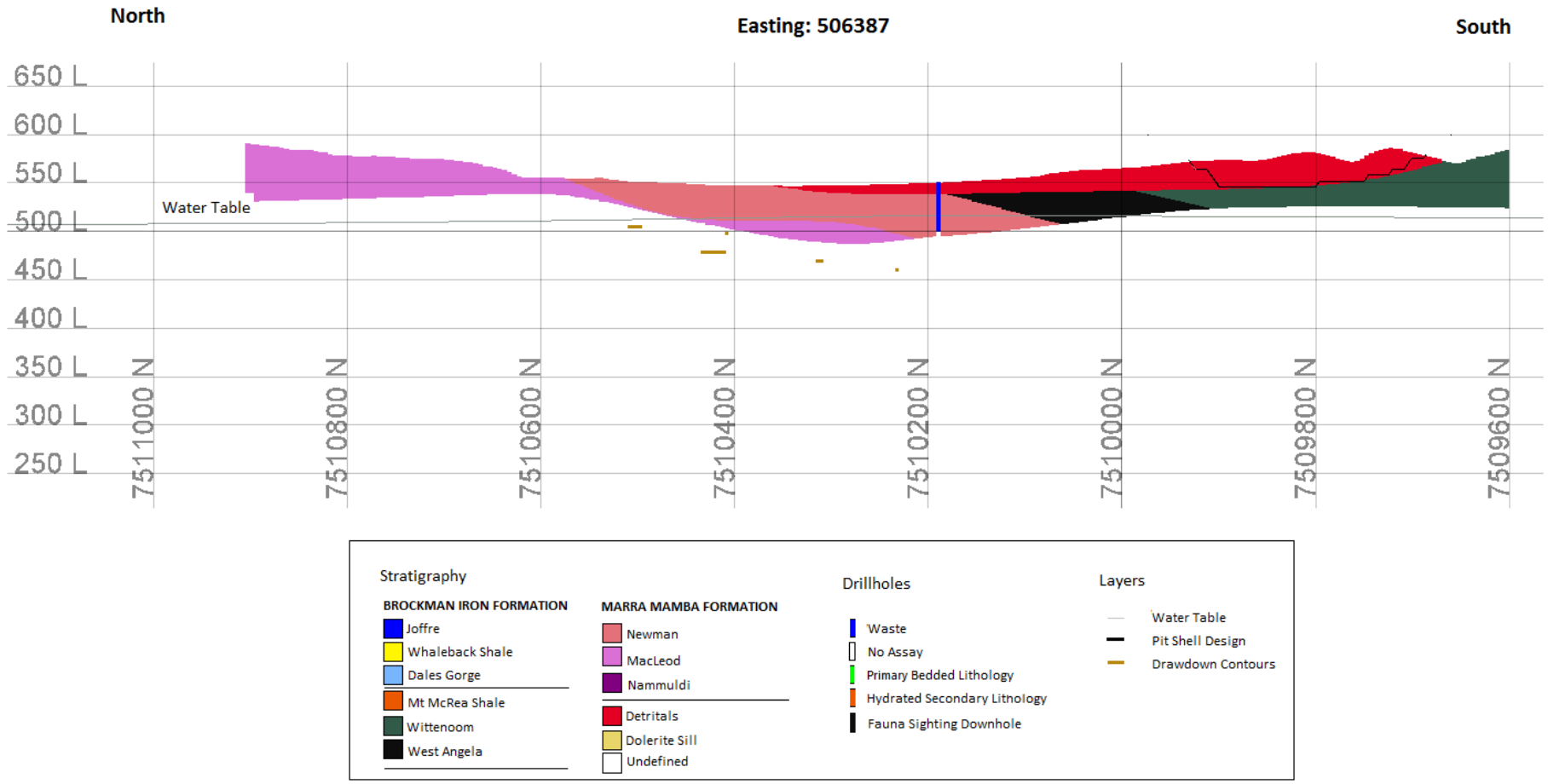

Figure 6.13: Cross section 7- East 4

6.7 Flying Fish West

6.7.1 Troglofauna habitat

Flying Fish West pit is developed within the MMIF, with the main target for mining being the upper Newman Member and mineralised zones within the Tertiary detritals (Figure 6.15). This geological unit is known to provide highly suitable habitat for subterranean fauna where sufficiently weathered (Section 3.3, Table 3.1).

Cross section 8 (Figure 6.15) showed a reasonable amount of the Newman Member and detritals outside of the pit to the south, and larger area of the Macleod and Nammuldi Members outside pit to the north that could potentially provide habitat for troglofauna, where sufficiently weathered and fractured.

Sampling at hole EWD0017 (within the Newman and Macleod Members of the MMIF) recorded one potentially restricted troglofauna taxon, *Anapistula* sp. 'EW', as well as two other taxa *Macranillus* sp. 'H-CCA021' and *Paradraculoides* sp. 'B12' that are known to occur more widely outside mining impacts.

Diamond drill core from EWD0017 revealed a high degree of vugginess from secondary weathering of the MMIF throughout the profile (Figure 6.16), indicative of highly suitable troglofauna habitat. Based on the wider extent of highly suitable MMIF habitats along strike east and west of the Flying Fish West pit (Figure 6.14), and the likelihood of some remnant habitat to the south or north of pit as indicated by cross section 8 (Figure 6.15), it is considered highly likely that suitable habitat for troglofauna species found at Flying Fish West extends locally beyond the impact areas.

6.7.2 Stygofauna habitat

Cross section 8 shows the Newman, Macleod, and Nammuldi Members of the MMIF dipping below water table from the centre to the south of the cross section (Figure 6.15). Owing to the high degree of secondary weathering throughout the profile (shown in Figure 6.16), the upper portions of the Newman Member would be expected to comprise the most suitable habitat for stygofauna, followed by the Macleod Member and the West Angela Shales, where sufficiently weathered/ fractured. Groundwater drawdown (up to 80m) is predicted to deplete most of the potential groundwater habitat in this area; however, sampling did not detect any potentially restricted stygofauna species near Flying Fish West.

515000 520000 525000

7515000 7510000

Legend

- Development Envelope
- Geological cross sections (approx.)
- Hydro bore logs available
- Diamond cores available
- Potential dykes (interpreted)

Indicative Disturbance

- Mining Pit (150m buffer)

Groundwater drawdown (m)

- 0.0 - 15.0
- 15.1 - 40.0
- 40.1 - 60.0
- 60.1 - 85.0

Pooled geology

- Boolgeeda Iron Formation
- Brockman Iron Formation
- Dolerite dykes
- Dolerite sills
- Jeerinah Formation
- Marra Mamba Formation
- Mt McRae Shale
- Mt Sylvia Formation
- Weeli Wolli Formation
- Wittenoom Iron Formation
- Woongarra Rhyolite

Stygofauna taxon, species

- Amphipoda, Bogidiella sp. B05
- Bathynellacea, Brevisomabathynella sp. B03
- Ostracoda, Areacandona nr triangulum
- Ostracoda, Areacandona sp. BOS1020

Troglofauna taxon, species

- Araneae, Anapistula sp. 'EW'
- Diplura, Projapygidae sp. B17
- Isopoda, Troglarmadillo sp. B46

FF0408 FF0023 FF0020 12 11 Grunters bore FFunk02 Flying Fish East FF0245 10 FF0038 9 Flying Fish FF0444 EWD0017 8 Flying Fish West

biologic Environmental Survey

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Fortescue Metals Group Ltd

Eliwana Subterranean Fauna Survey 2017

Fig. 6.14: Potentially restricted subterranean fauna and extent of suitable habitats (east)

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 02/08/2018

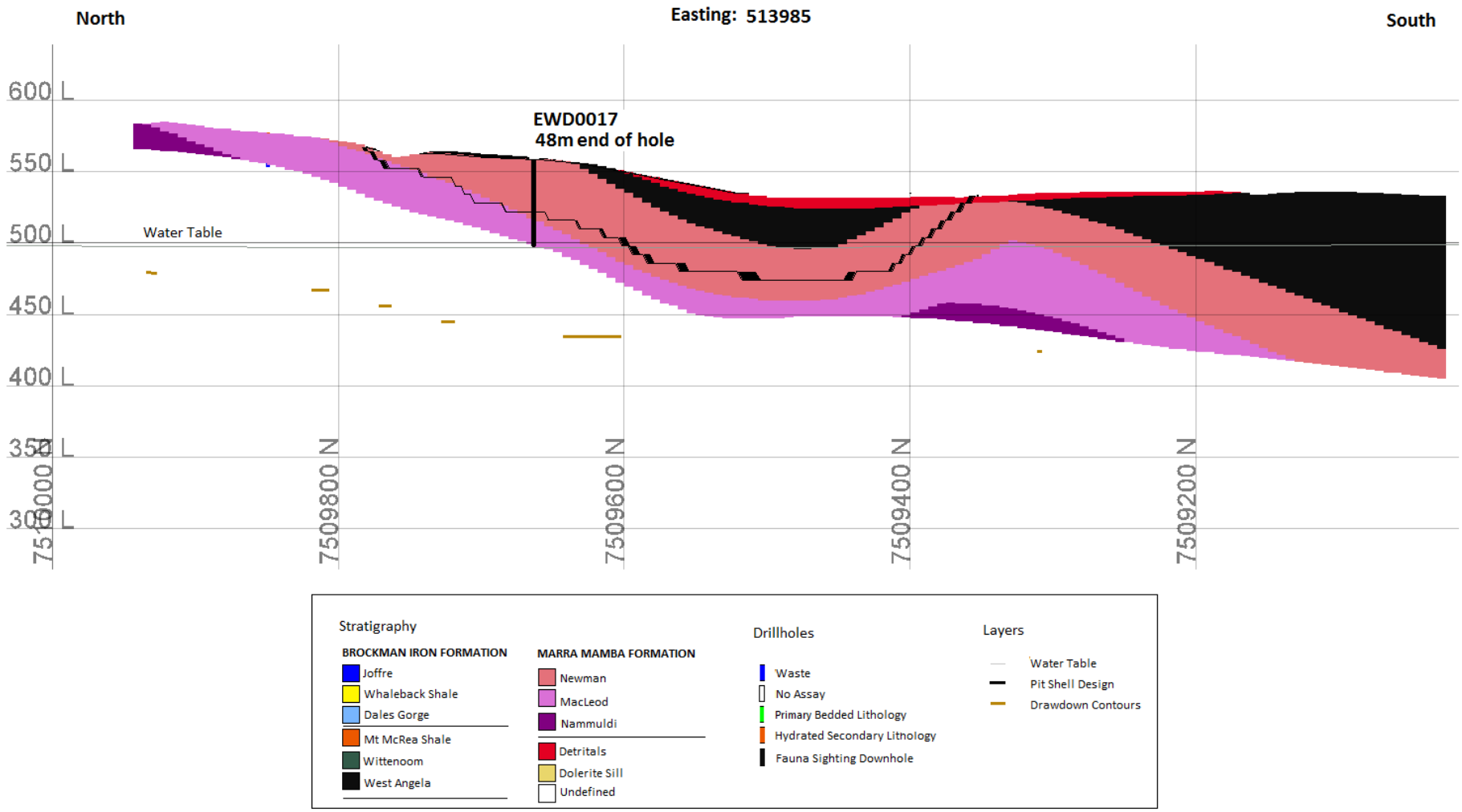

Figure 6.15: Cross section 8- Flying Fish West

Figure 6.16: Diamond core from hole EWD0017, showing vugs from secondary weathering (highly suitable habitat)

6.8 Flying Fish

6.8.1 Troglofauna habitat

Figure 6.14 shows the Flying Fish pit is developed laterally along a roughly east-west strike, with the northern margins in MMIF and the southern margins in Tertiary Detritals. These formations are known to provide highly suitable habitat for subterranean fauna where sufficiently weathered (Section 3.3, Table 3.1).

Cross sections 9 (Figure 6.17) and 10 (Figure 6.18) show the main mining target for mining as the Newman Member and mineralised zones within the detritals. Owing to the relatively high-water table through the Flying Fish area, and the occurrence of Mt McRae Shales in the profile above water table (Figures 6.17 and 6.18), the majority of troglofauna habitat is likely to be within the MMIF close to the surface, particularly to the north of these sections.

Two potentially restricted troglofauna taxa, Projapygidae sp. 'B17' and *Troglarmadillo* sp. 'B46', were recorded within pit at holes FF0038 (MMIF) and FF0245 (Wittenoom Formation) (Figure 6.14). Accounting for the conservative 150m disturbance buffer of the pits shown in Figure 6.14, both locations would be considered just outside, or very close to the proposed pit boundaries. Projapygidae sp. 'B17' was detected from the valley, where geological cross sections and drill logs showed detritals above the water table as well as Mt McRae Shales, which are generally regarded as low suitability for troglofauna (Table 3.1). It is considered likely that this species could inhabit unconsolidated detrital formations throughout the Eliwana Valley to the south of Flying Fish Pit.

Diamond drill core from hole EWD0016 (Figure 6.19), (located immediately west of FF0245 where *Troglarmadillo* sp. 'B46' was collected within MMIF), showed considerable weathering and fracturing of the upper Newman Member and vugginess throughout the profile. Further evidence of highly suitable habitat was indicated by 'hydrated secondary lithology' zones in drill logs shown on cross section 9 (Figure 6.17). As shown in most other MMIF pits within the Study Area, the Newman Member is regarded as highly suitable troglofauna habitat where occurring above water table. Figure 6.14 shows the continued extension of the MMIF east and west along the strike beyond the Flying Fish Pit, and to the north (although areas to the north may comprise a greater proportion of the less weathered Macleod and Nammuldi Members) suggesting that suitable habitat for troglofauna is likely to exist beyond the pit areas.

6.8.2 Stygofauna habitat

Groundwater levels are higher in the Flying Fish area than most other parts of the Study Area, with depth to water at drill hole FF0444 (along cross section 9, where *Brevisomabathynella* sp. 'B03' was detected) observed at 16m during the Western Hub survey (Bennelongia 2015). This depth approximates the contact point between the Newman Member, the Mt McRae Shale, and the water table in the centre of cross section 9 (Figure 6.17). No genetic information for *Brevisomabathynella* sp. 'B03' was available at the time of writing to enable comparisons with the other *Brevisomabathynella* species; however, owing to the occurrence of one of the other species *B.* sp. 'A' over two different hydrogeological compartments (i.e. surrounding Talisman Pit and surrounding East 3 and East 4 pits, Figures 6.2 and 6.10), there remains a small chance that *B.* sp. 'B03' could align genetically to one of the other known *Brevisomabathynella* species.

The hydro bore log for FFPB002 (Appendix 2), located to the immediate south west of hole FF0444 within the Flying Fish Pit, revealed a range of potential habitats beneath water table, including fractured cemented detritals (CID), weathered and fractured Bee Gorge and Paraburdoo Dolomite (including large fractures indicative of a potential fault zone) to approximately 100 m BGL, lying atop weathered West Angela shales. Hydraulic yields from these habitats

were in the range of 15-35 L/ sec, indicating highly porous/ transmissive aquifers that would be expected to provide suitable habitat for stygofauna, even at depth. Water physicochemistry data from near surface bailer samples in the Flying Fish deposit revealed dissolved oxygen levels ranging between 26-54% saturation, and although this does not provide an adequate indication of the oxygen levels lower in the profile, the readings were amongst the highest recorded within the Study Area.

Owing to the depth of mining and porosity of the MMIF, groundwater drawdown is predicted to reach a maximum of 85m in the hydrogeological compartment surrounding Flying Fish Pit. Based on current information, it appears that a small proportion of potential habitat within the Newman Member and a greater proportion of the West Angela Member are likely to remain saturated beneath the predicted drawdown. The results from the hydro bore logs in the area and aquifer yields at depths around 100 m BGL suggest that, notwithstanding potential differences in groundwater physicochemical characteristics at depth, it is reasonably likely that suitable habitats for stygofauna occur below the predicted extent of drawdown in the Flying Fish area.

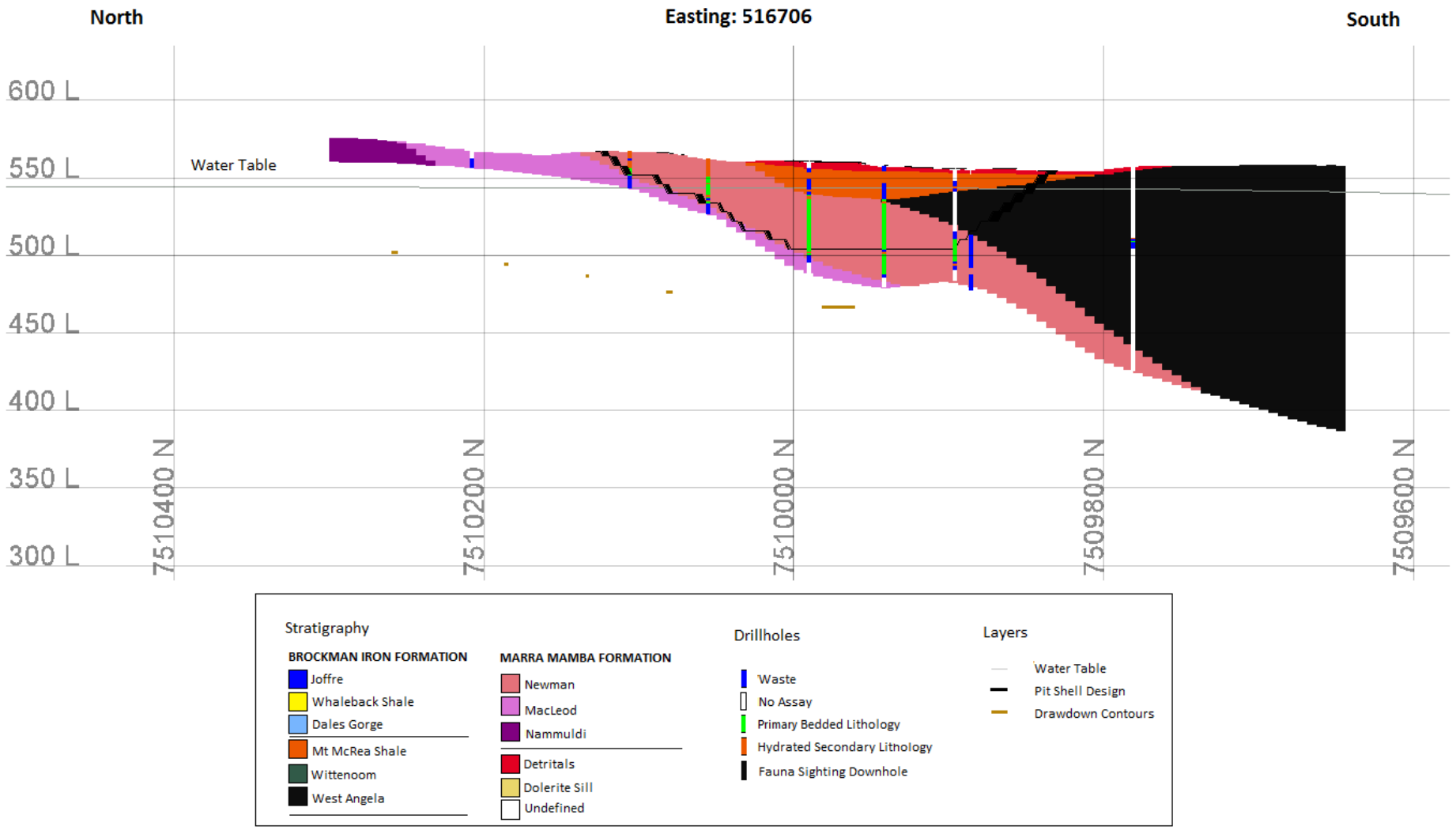

Figure 6.17: Cross section 9- Flying Fish 1

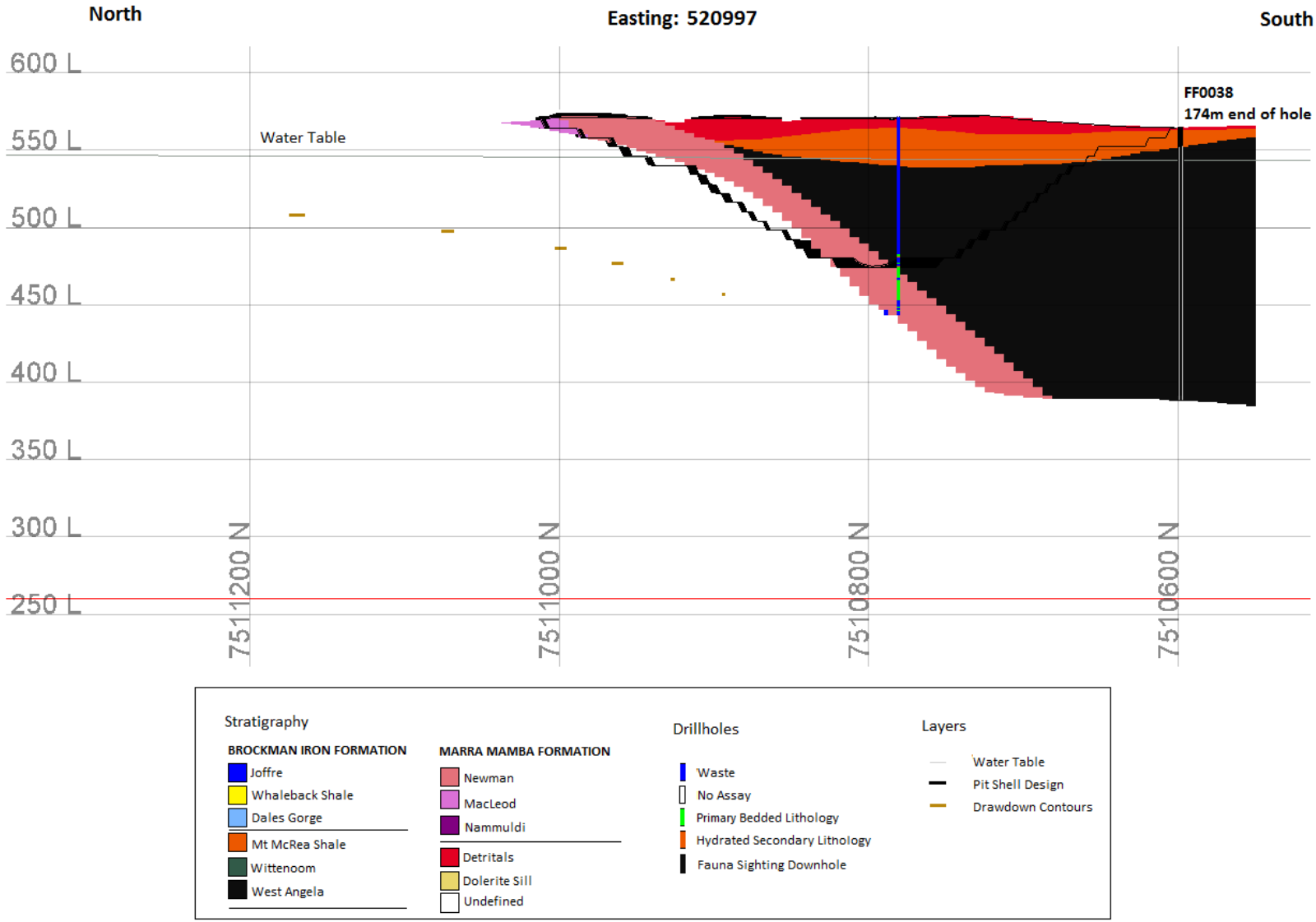

Figure 6.18: Cross section 10- Flying Fish 2

Figure 6.19: Core at EWD0016 showing vugs from secondary weathering (potential habitat)

6.9 Flying Fish East

6.9.1 Troglofauna habitat

Figure 6.14 shows the Flying Fish East pit (similarly to the other Flying Fish Pits) developed in MMIF and Tertiary Detritals. These geological units are known to provide suitable habitat for subterranean fauna where sufficiently weathered (Section 3.3, Table 3.1).

Cross section 11 (Figure 6.20), is just outside of the pit area, showing highly suitable potential habitats above water table within the MMIF to the north and Tertiary Detritals in the centre and south of the cross section above the near-surface water table. No potentially restricted troglofauna species were detected within the Flying Fish East Pit (Figure 6.14).

6.9.2 Stygofauna habitat

Cross section 11 (Figure 6.20), shows extensive highly potential stygofauna habitats within the MMIF in the centre and north of the section, and potentially, within a thin layer of Tertiary Detritals below water table in the centre and south of the cross section, and/ or West Angela Shales if suitably weathered. As previously mentioned, the Mt McRae Shales are generally regarded as having lower permeability and would not be expected to provide suitable habitat for stygofauna. Few drill cores were available in this immediate area but drilling logs for hydrological bores in the southern part of Flying Fish East Pit (bores FFPB001 and FFMB001) (Appendix 2) noted several potential groundwater habitats within fractured mudstone/ siltstone (5-25 m BWT), weathered dolomite (35-60m BWT), and high-yielding fractures within fresh dolomite at the bottom of the profile (70-90m BWT). Despite the relatively deep drawdown modelled within vicinity of Flying Fish East (approx. 65m), the hydrological bore logs and cross sections suggest that some deeper potential habitats may remain saturated below the predicted drawdown.

Sampling at three bores in the immediate vicinity of cross section 11 detected two ostracod species, *Areacandona* nr *triangulum* and *Areacandona* sp. ‘BOS1020’. The former was also detected at sites further beyond the north east of Flying Fish East, in MMIF habitats beyond three inferred dykes (Figure 6.14). Cross section 12 (Figure 6.21) indicates a change in below water table habitats between these two areas, with the valley detritals and McRae Shales becoming less prevalent, and the MMIF (from the north) and Wittenoom Dolomite (from the south) dominating the stratigraphy.

The occurrence of *Areacandona* nr *triangulum* across these inferred hydrogeological barriers, may suggest some potential for other similar species (such as *A*. sp. ‘BOS1020’) to also occur more widely (as discussed further below in section 6.10). Nevertheless, current groundwater drawdown modelling regards these areas as hydrogeologically disconnected, as shown by the abrupt end of the predicted drawdown at the inferred dykes to the immediate north-east of ‘Grunters Bore’ (Figures 5.2, 6.14). Although *Areacandona* nr *triangulum* has been morphologically identified from specimens either side of these dykes, genetic testing (Helix Molecular Solutions 2017, Appendix 1) was unable to confirm current gene flow between the known records.

For this reason, it is problematic to assume that the distribution of *Areacandona* sp. ‘BOS1020’ should be the same as *Areacandona* nr *triangulum*. If hydrogeological connectivity is assumed across the inferred dykes east of Flying Fish East, this brings into question assumptions made about the extent of predicted drawdown ending abruptly at the inferred dykes to the immediate north-east of ‘Grunters Bore’ as shown in Figures 5.2 and 6.14. Owing to the current uncertainty in habitat connectivity, *Areacandona* sp. ‘BOS1020’ is regarded as occurring only within the drawdown extent, based on current information.

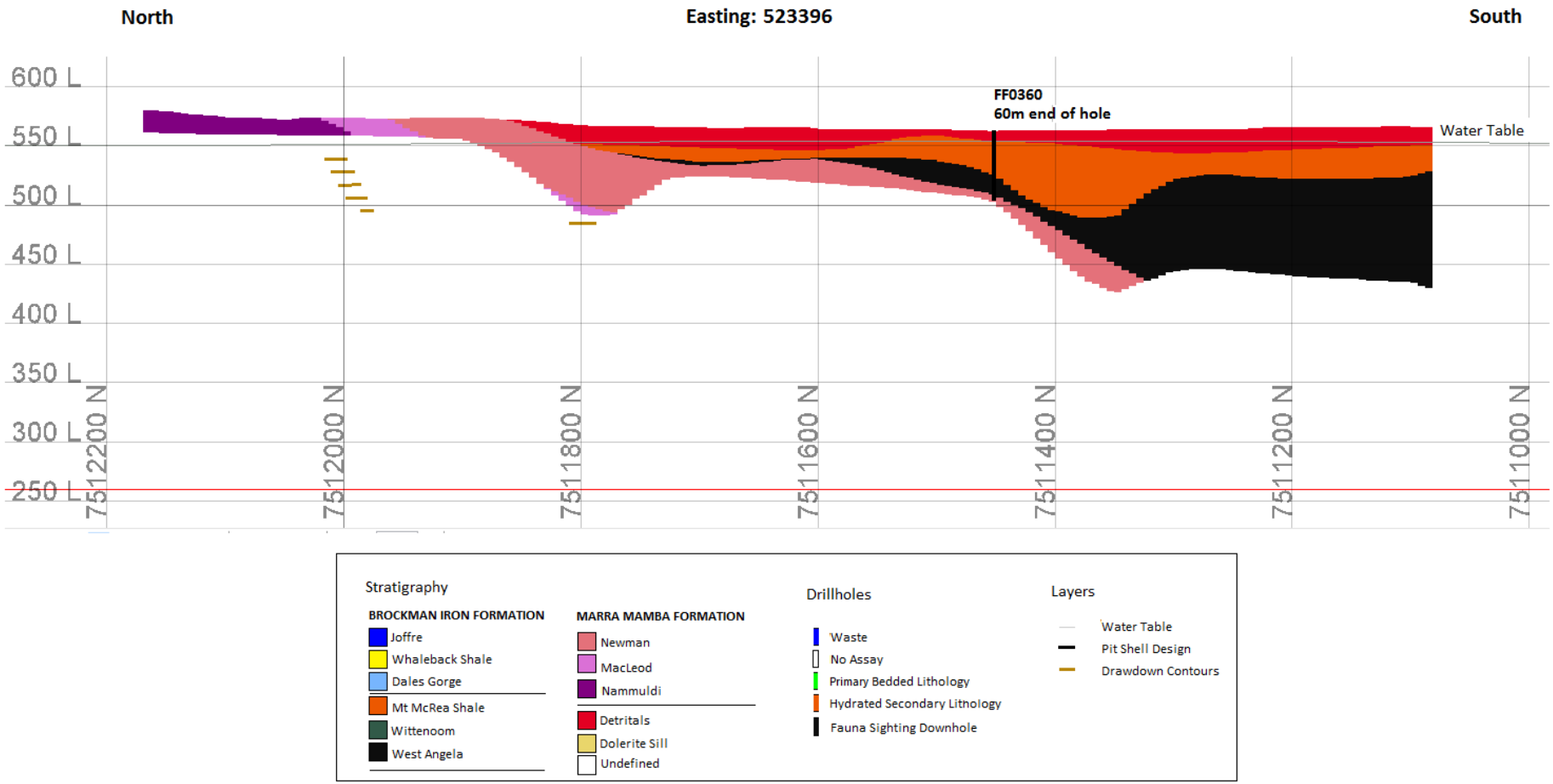

Figure 6.20: Cross section 11- Flying Fish East

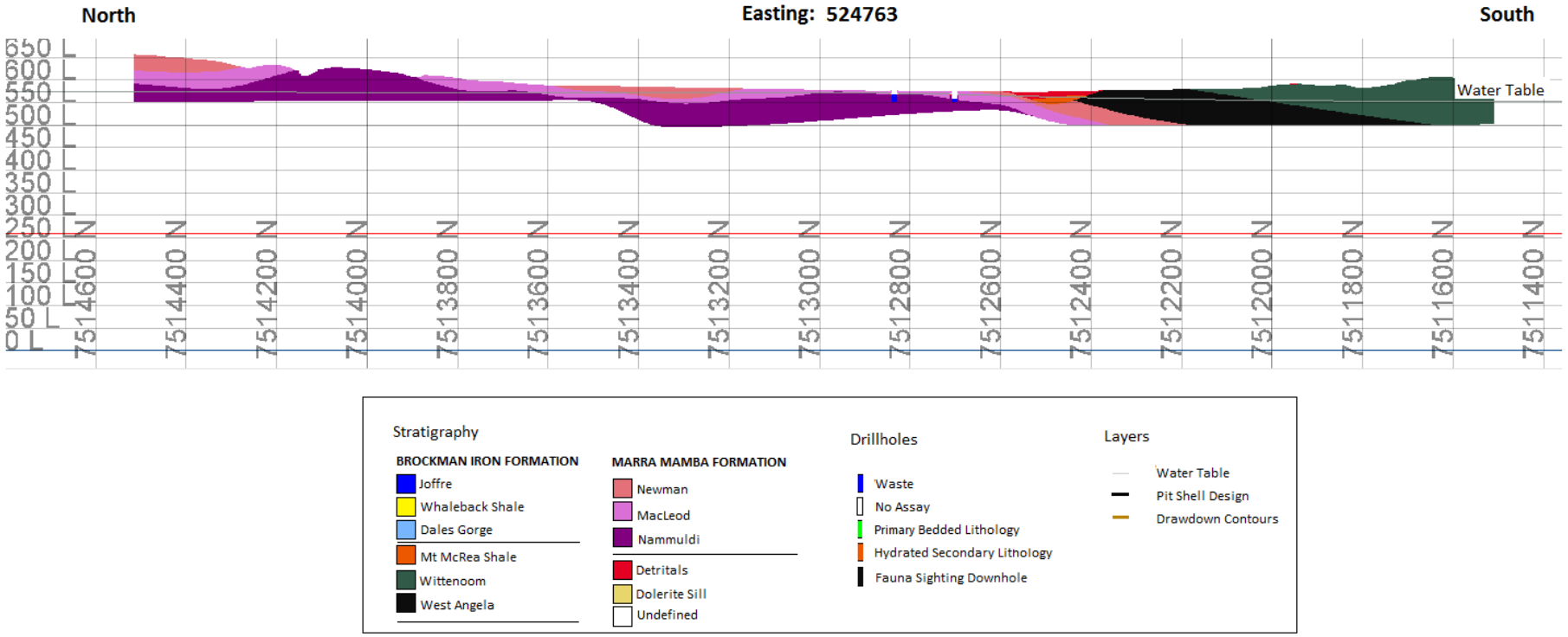

Figure 6.21: Cross section 12- Outside drawdown NE of Flying Fish

6.10 Other locations of troglofauna

An indeterminate schizomid specimen tentatively identified as *Paradraculoides* sp. 'new3', was sampled from the far western P-tenements pit, beyond the current extent of geological mapping/ cross sections (Figure 5.1 and 6.1). Schizomids are always regarded as troglobitic in the Pilbara region, and are regularly found to be highly restricted SRE troglobites. Owing to its location on the southern margin of the Eliwana Valley, it would be reasonable to assume that this proposed pit occurs within BrIF geologies and would be similar in stratigraphic profile to the West End Pit (Figure 6.6). This generalised geological profile extends throughout the Brockman Syncline, and in the absence of any information showing potential barriers to dispersal immediately outside the pit, it would be reasonable to assume that potential habitat for this species may occur locally beyond the proposed pit boundaries.

A dipluran species, Projapygidae sp. 'B14' was detected north of the Eliwana Valley within an area proposed for the Tailings Storage Facility (TSF). No detailed habitat information exists for this area at the current time, although regional geological information suggests that potential habitats for the species could occur in unconsolidated detritals or nearby Robe Pisolite, which extends to the north and east of the proposed TSF. Diplura are often sampled in troglofauna surveys but owing to inherent troglomorphic features (such as depigmentation and a lack of eyes) throughout the group, it is often difficult to tell whether species are obligate or non-obligate subterranean fauna. Owing to the species record at the edge of the proposed TSF and the wider extent of highly potential troglofauna habitats beyond the TSF area (based on the limited information currently available), it is possible that this species could occur more widely beyond the TSF than currently recorded.

6.11 Subterranean habitat connectivity

Majority of stygofauna species collected throughout the Study Area have been found to occur widely throughout the local or sub-regional area (including areas sampled during the Western Hub survey and beyond). This suggests a reasonable likelihood that the stygofauna assemblages sampled throughout the hydrogeological compartments of the Eliwana Valley are part of larger assemblages that may occur throughout the broader local catchments to the north and south of the Eliwana Valley.

Many stygofauna sampled throughout the Pilbara region have been found to have sub-regional distributions that appear to align with the major surface catchments (Halse *et al.* 2014, Brown *et al.* 2015, Reeves *et al.* 2007), which suggests potential avenues for dispersal or habitat connectivity throughout the hyporheic zone of the major drainage lines, possibly during flood events. Under this scenario, it is possible that species found only within the Eliwana Valley to date may have some potential to occur more widely to the north or south within the upper Boolgeeda Creek or Duck Creek catchments. Despite multiple inferred discontinuities throughout the Eliwana Valley from east to west, the hyporheic zones of the drainage corridors may provide opportunities for stygofauna dispersal to other hydrogeological habitats further north or south of the valley that have not yet been sampled.

The current occurrence of some stygofauna throughout the valley and beyond may also be explained by the inferred dykes offering incomplete barriers to dispersal (e.g. potential dispersal over or through dykes in times of flood). Nonetheless, the groundwater drawdown modelling considers dykes to the immediate east of Flying Fish East to be complete barriers to the propagation of drawdown (Figure 6.14). Under this scenario, species known only from single compartments (such as *Brevisomabathynella* species 'B' and 'C', and *Areacandona* 'BOS1020') may be considered potentially restricted. It is also important to note that, despite adequate baseline sampling based on EPA guidelines, the current occurrence of stygofauna species may be affected by sampling artefacts and incomplete taxonomic/ genetic results.

Owing to the comparative rarity and lower sampling rates of troglofauna (relative to stygofauna), it is even more difficult to rule out sampling artefacts from the observed patterns of troglofauna occurrence to assess habitat continuity. For example, morphological results suggested that some troglofauna species such as the schizomid *Paradraculoides* sp. B12, occurred within several different geological habitats (e.g. MMIF and BrIF) as well as in different areas separated by inferred dykes (which would normally be expected to form potential barriers). Nevertheless, genetic testing of the specimens considered to align to *P*. sp. B12 showed considerable variability at the COI (0.1-3.5%) and 12s (0-4%) genes, indicating a potential species complex within the putative 'B12' specimens, with divergent populations occurring in geographically separated areas. These results highlight the difficulties in using fauna results achieved via uneven taxonomic methods (i.e. without sending all available specimens for DNA analysis) to infer broader patterns of occurrence and habitat connectivity throughout complex habitats.

7 SUBTERRANEAN FAUNA RISK ASSESSMENT

7.1 Impacts to troglofauna

Direct impacts on troglofauna occur because of the excavation and removal of subterranean habitat during mining. It can therefore be inferred that the direct impact areas for troglofauna are the proposed pit boundaries at each of the deposits. For the purposes of this risk assessment, cumulative secondary impacts that may occur in the location of the Tailings Storage Facility (TSF) (such as shallow excavation of habitat, habitat flooding, and potential for localised contamination from mine tailings) are regarded as potentially equivalent to the direct impacts of mining.

Other indirect impacts such as shock/ vibration from blasting, changes to infiltration beneath stockpiles and waste dumps, and habitat desiccation from nearby excavation areas or groundwater drawdown, may occur beyond the pit boundaries; however, these risks are more difficult to assess on current information and are omitted from the current risk assessment. Potential impacts from aquifer re-injection or surface infiltration of excess water produced during the proposed development have not been considered based on a lack of information at the time of writing.

7.2 Risks to troglofauna species

Seventeen troglofauna taxa recorded during current and previous surveys of the Study Area are known only from within proposed pit boundaries (and the TSF as stated above), comprising:

- six (6) arachnids: Palpigradi sp., *Paradraculoides* sp. B12A, *Paradraculoides* sp. ‘new2’, *Paradraculoides* sp. ‘new3’*, Anapistula* sp. 'EW', and *Prethopalpus* sp. MW21;
- one (1) isopod: *Troglarmadillo* sp. B46;
- four (4) pauropods: Pauropodidae sp. B29, Pauropodidae sp. B41, Pauropodidae sp. B42, and Pauropodidae sp. B43;
- one (1) symphylan: *Symphyella* sp. 'EW';
- three (3) diplurans: Campodeidae sp. 'EW', Projapygidae sp. B14, and Projapygidae sp. B17; and
- two (2) insects: *Lepidospera* sp. B10 and *Macranillus* sp. 'EW'.

Based on current taxonomic and ecological information, and the likely extent of suitable habitats for troglofauna beyond pit boundaries (buffered by 150 m disturbance zone), the risks to these taxa are presented in Table 7.1. Figures 6.2, 6.10, and 6.14 show the current records of each of these taxa and the inferred extent of geological habitats relative to the proposed pit boundaries (based on current geological information).

Eleven of the 17 troglofauna taxa were assessed as ‘low’ risk due to current knowledge of taxonomy and habitats, and their distributions near to or just beyond the boundaries of proposed pits: *Paradraculoides* sp. B12A, *Prethopalpus* sp. MW21, *Troglarmadillo* sp. B46, Pauropodidae sp. B42 and B43, *Symphyella* sp. 'EW', Campodeidae sp. 'EW', Projapygidae sp. B14 and B17, *Lepidospera* sp. B10, and *Macranillus* sp. 'EW' (Table 7.1).

Two taxa (Pauropodidae sp. B29 and B41) were assessed as ‘low – moderate’ risk mainly due to the location of their only records further within the boundaries of mining pits (relative to the other Pauropodidae species above).

The remaining four taxa were assessed as ‘moderate’ risk (Palpigradi sp., *Paradraculoides* sp. ‘new2’, *Paradraculoides* sp. ‘new3’ and *Anapistula* sp. 'EW'), as these taxa are more likely to represent troglobitic SRE fauna, and their only records are well within the boundaries of mining pits, although their habitat is likely to continue beyond impact areas (Table 7.1).

Table 7.1: Troglofauna risk assessment based on current taxonomic factors, habitat factors, and distribution relative to impacts.

Potentially restricted taxon	Taxonomic factors	Distribution factors	Habitat factors	Risk level
Palpigradi				
Palpigradi sp.	Troglobitic potential SRE - genus includes both widespread and restricted species. Taxonomic uncertainty precludes assessment of species distribution.	Singleton known only within pit (Talisman). Collected during Western Hub survey, specimen not available for further examination.	Recorded from unconsolidated detritals - habitat extends well beyond pit boundaries to the east, west and south along the Eliwana valley.	Moderate
Schizomida				
Paradraculoides sp. 'B12A'	Troglobitic SRE - typically highly restricted. Sister species (*Paradraculoides* sp. B12) occurs over range of 9km (populations divergent 3-4% COI). Species B12A is 6-8% divergent (COI) from other B12 specimens.	Singleton known only from within pit buffer, hole just beyond pit shell (East 4). Collected during Western Hub survey. Current distribution potentially affected by sampling/ sub-sampling artefacts.	Hole located just beyond proposed pit boundaries. Recorded from MMIF - habitat appears to extend east-west (and north) along strike beyond pit boundaries.	Low
Paradraculoides sp. 'new2'	Troglobitic SRE - typically highly restricted. Species 'new2' is 4.5-8.2% divergent (COI)/ 4.1-8.8% (12s) from other local *Paradraculoides*.	Singleton known only from within pit (Broadway EW1417).	Hole located within proposed pit boundaries. Recorded from BrIF – habitat appears to extend south and west of the Broadway pit.	Moderate
Paradraculoides sp. 'new3'	Troglobitic SRE - typically highly restricted. Species 'new3' is 4.8-7.3% divergent (COI)/ 5.2-9.6% (12s) from other local *Paradraculoides*.	Singleton known from within pit (P Tenement 4).	Recorded from BrIF – habitat appears to extend beyond the pit to the south and east.	Moderate
Araneae				
Anapistula sp. 'EW'	Troglobitic SRE – genus known only from a few restricted species (when subterranean).	2 records known from a single site inside pit (Flying Fish West).	Recorded from MMIF - habitat appears to extend east-west along strike beyond pit boundaries.	Moderate
Prethopalpus sp. 'MW21'	Troglobitic SRE – genus known only from restricted species (Pilbara and Yilgarn).	Singleton within pit buffer, hole located just beyond pit boundary (Broadway).	Recorded from MMIF - habitat extends beyond pit along strike to north and west.	Low
Isopoda				
Troglarmadillo sp. B46	Taxon SRE – genus represented by many troglobitic SRE species.	9 records known only within pit buffer, hole located just beyond pit boundary (Flying Fish).	Recorded in MMIF – habitat appears to extend along strike north and west outside pit.	Low
Pauropoda				
Pauropodidae sp. B29	Taxon may represent troglofauna/ deep soil fauna (uncertain ecological status).	Singleton known only within pit (Talisman).	Recorded from detritals or deeper MMIF –habitat appears to extend beyond pit boundaries to the east, west and south along the Eliwana valley.	Low - moderate
Pauropodidae sp. B41	Taxon may represent troglofauna/ deep soil fauna (uncertain ecological status).	Singleton known only within pit (West End).	Recorded from BrIF - habitat appears to extend along the strike west and east beyond pit boundaries.	Low - Moderate

Potentially restricted taxon	Taxonomic factors	Distribution factors	Habitat factors	Risk level
Pauropodidae sp. B42	Taxon may represent troglofauna/ deep soil fauna (uncertain ecological status). Other local species not closely related divergence (B33 divergent ~20% COI, >20% 12s).	2 records known only within pit buffer, hole located just beyond pit boundary (Broadway north).	Recorded from MMIF - habitat extends beyond pit along strike to north and west.	Low
Pauropodidae sp. B43	Taxon may represent troglofauna/ deep soil fauna (uncertain ecological status).	Singleton known only within pit buffer, hole located just beyond pit boundary (Broadway north).	Recorded from MMIF - habitat extends beyond pit along strike to north and west.	Low
Symphyla				
Symphyella sp. 'EW'	Troglobitic potential SRE – genus known mainly from restricted troglobites.	Singleton known only within pit buffer, hole located just beyond pit boundary (Broadway north).	Recorded from MMIF - habitat appears to extend beyond pit along strike to north and west.	Low
Diplura				
Campodeidae sp. 'EW'	Taxon may represent troglofauna/ deep soil fauna (poor taxonomic resolution).	Singleton known only within pit buffer, hole located just beyond pit boundary (Broadway north).	Recorded from MMIF - habitat extends beyond pit along strike to north and west.	Low
Projapygidae sp. B14	Taxon may represent troglofauna/ deep soil fauna (poor taxonomic resolution). Possibly represented outside impact area by Projapygidae sp. ?B14.	Singleton known only just within TSF boundary	Recorded in Jeerinah Formation bordering Robe Pisolite - habitat appears to extend beyond TSF impact area.	Low
Projapygidae sp. B17	Taxon may represent troglofauna/ deep soil fauna (poor taxonomic resolution).	Singleton known only within pit buffer, hole located just beyond pit boundary (Flying Fish).	Recorded from detritals – habitat appears to extend south and east beyond pit boundaries. Hole located on margin of pit boundary.	Low
Thysanura				
Lepidospera sp. B10	Troglobitic potential SRE or troglophile (uncertain ecological status). *L*. sp. indet. from the same bore assumed to be same species.	Singleton known only within pit, near boundary (Talisman).	Recorded from detritals or deeper MMIF –habitat appears to extend beyond pit boundaries to the east, west and south along the Eliwana valley.	Low
Coleoptera				
Macranillus sp. 'EW'	Taxon may represent troglofauna/ deep soil fauna (uncertain ecological status). Potentially known elsewhere from species indet. or species 'H-CCA021' (15km linear range).	Singleton known only within pit, near boundary (East 3).	Recorded from BrIF - Habitat appears to extend south beyond pit boundaries	Low

7.3 Impacts to stygofauna

Direct impacts on stygofauna comprise the removal of porous hydrogeological strata from mining below the water table, and removal or reduction of available groundwater by dewatering and abstraction. The propagation of groundwater drawdown may extend well beyond the mining pit areas throughout other suitable habitats, regardless of whether these habitats are formed within the same geology as the mining target. Potential impacts from aquifer re-injection (including impacts to groundwater quality and quantity) or surface infiltration of excess water produced during the proposed development have not been considered herein based on a lack of information at the time of writing.

7.4 Risks to stygofauna

Current and previous surveys recorded nine (9) stygofauna taxa known only from the Study Area. These comprised;

- two (2) ostracods: *Areacandona* sp. BOS1020, and *Areacandona* nr *triangulum*;
- one (1) copepod: *Parastenocaris* sp.;
- four (4) syncarids: *Brevisomabathynella* sp. B03, *Brevisomabathynella* sp. A and *Brevisomabathynella* sp. B and *Brevisomabathynella* sp. C;
- two (2) amphipods: *Bogidiella* sp. B05 and Paramelitidae sp. B58.

Based on current taxonomic and ecological information, modelling of groundwater drawdown and likely extent of suitable habitats for stygofauna beyond these impacts, the risks to these taxa are presented in Table 7.2. Figures 6.2, 6.10, and 6.14 show the current records of each of these taxa and the potential dykes/ hydrological barriers (interpreted) relative to modelled groundwater drawdown (based on current and available hydrological information).

Three of the nine taxa were assessed as ‘low’ risk, comprising *Areacandona* nr *triangulum, Brevisomabathynella* sp. C and *Bogidiella* sp. B05, owing to their known occurrence beyond the predicted groundwater drawdown (or within minimal drawdown areas) (Table 7.2).

Three other taxa, *Parastenocaris* sp., *Brevisomabathynella* sp. B, and Paramelitidae sp. B58, were assessed as ‘low-moderate’ risk owing to the likely extent of suitable habitat below the moderate level of drawdown in the Broadway/ West End area (Table 7.2).

Brevisomabathynella sp. A was assessed as ‘moderate’ risk owing to its occurrence only within aquifer compartments likely to be affected by considerable drawdown (30-50m), and the reasonable likelihood of some suitable habitat below the predicted drawdown near Talisman Pit (Table 7.2).

An additional two taxa, *Brevisomabathynella* sp. B03 and *Areacandona* sp. BOS1020, were assessed as ‘high’ risk owing to their current occurrence only within aquifer compartments likely to be completely dewatered (55-65m) in the Flying Fish and Flying Fish East areas (Table 7.2).

Table 7.2: Stygofauna risk assessment based on taxonomic factors, habitat factors, and distribution relative to current predicted groundwater drawdown

Potentially restricted taxon	Taxonomic factors	Distribution factors	Habitat factors	Risk level
Ostracoda				
Areacandona sp. BOS1020	Stygobitic, potential SRE. Genus is known to include restricted and wide-ranging species in region. Genetic testing unable to confirm relationship to *A.* nr *triangulum*.	Recorded only from 2 sites (0.15 km linear range). Single / narrow aquifer compartment east of Flying Fish East, within predicted groundwater drawdown (65m).	Approx. 65m predicted drawdown - limited potential habitat (MMIF, possibly West Angela shale) expected to remain below drawdown.	High
Areacandona nr *triangulum*	Stygobitic, potential SRE. Genus is known to include restricted and wide-ranging species in region. Genetic testing unable to confirm gene flow between different aquifer compartments.	Known from 3 sites near Flying Fish East and NE of Flying Fish beyond predicted drawdown (4.6 km linear range). Three different aquifer compartments despite inferred hydrogeological barriers, suggests potential for other populations beyond Eliwana Valley (North/South).	Limited habitat expected to exist below predicted drawdown (~65m) at Flying Fish East, but population NE of Flying Fish is outside of predicted drawdown.	Low
Copepoda				
Parastenocaris sp.	Stygobite, uncertain SRE. Genus usually represented by wide ranging species in the region. Poorly resolved taxon may represent other known species such as *P.* sp. B26 (56 km linear range).	Known from single site near Broadway pit.	Recorded from aquifer compartment around Broadway/ West End (15-20m predicted drawdown). Potential habitat (MMIF or Wittenoom Dolomite) likely to occur below predicted drawdown.	Low-moderate
Syncarida				
Brevisomabathynella sp. B03	Stygobitic, potential SRE. Genus often represented by stygobitic SREs elsewhere in the region. Genetic testing failed, unable to align to other local *Brevisomabathynella* species.	Known from a single site within Flying Fish pit. Potential to be additional record of one of the other *Brevisomabathynella* sp. A, B or C.	Recorded from a single aquifer compartment. Potential habitat (MMIF or dolomite) habitat expected to exist below predicted drawdown (~65m at Flying Fish) although habitat quality uncertain at increasing depth.	High
Brevisomabathynella sp. A	Stygobitic, potential SRE. Genus often represented by stygobitic SREs elsewhere in the region. Genetic testing showed varying divergence to other local *Brevisomabathynella* species (3.5-12.3% COI, 10.6% 12s).	Recorded from 2 aquifer compartments (Talisman, Eagles Nest) despite hydrogeological barriers. Distribution in two separated aquifer compartments suggests possibility of other populations beyond Eliwana Valley (North/South).	Potential habitat (MMIF and Wittenoom dolomite) likely to exist below predicted drawdown (30m) near Talisman Pit. Limited habitat expected to exist below predicted drawdown (40-50m) east of Eagles Nest	Moderate
Brevisomabathynella sp. B	Stygobitic, potential SRE. Genus often represented by stygobitic SREs elsewhere in the region. Genetic testing showed moderate divergence to other local species (3.5% COI).	Known from a single site south of Broadway pit. Recorded from a single aquifer compartment.	Potential habitat (MMIF, Wittenoom dolomite or West Angela) likely to exist below predicted drawdown (15-20m) east / west of Broadway.	Low-moderate

Potentially restricted taxon	Taxonomic factors	Distribution factors	Habitat factors	Risk level
Brevisomabathynella sp. C	Stygobitic, potential SRE. Genus often represented by stygobitic SREs elsewhere in the region. Genetic testing showed high divergence to other local species (11.4-12.8% COI).	Known from a single site south of East 4 pit. Recorded from a single aquifer compartment.	BrIF habitat south of East 4 pit likely to be relatively unaffected by drawdown (5m). Habitat likely to occur more widely than predicted drawdown.	Low
Amphipoda				
Bogidiella sp. B05	Stygobitic, potential SRE. Genus is known to include stygobitic SREs elsewhere in the region. Genetic sequencing failed.	Known from a single site NE of Flying Fish East outside of predicted drawdown	Species recorded NE of Flying Fish outside of predicted drawdown (modelled drawdown does not extend beyond inferred hydrogeological barriers).	Low
Paramelitidae sp. B58	Stygobitic, potential SRE. Genus is known to include stygobitic SREs elsewhere in the region. Genetic sequencing showed high level of divergence with other local species (>20% COI), and low population level divergence between different aquifer compartments (0-1.2% COI).	Known from 3 sites near Talisman and Eagles Nest, 3 aquifer compartments despite inferred hydrogeological barriers. Distribution in three separate aquifer compartments suggests possibility of other populations beyond Eliwana Valley (North/South).	MMIF or Wittenoom dolomite aquifer habitats exists below predicted drawdown near Talisman Pit (30m) and Broadway/ West End (15-20m). Limited habitat expected to occur below predicted drawdown (40-50m) east of Eagles Nest.	Low-moderate

8 KEY FINDINGS

The key findings are based on results of all sampling to date (previous and current surveys), available habitat information and current knowledge of the impacts to subterranean fauna from the proposed mining at the Study Area. These findings may be subject to change following the receipt of further molecular studies of subterranean fauna from the Study Area and beyond.

8.1.1 Risks to Troglofauna Species

Of the 45 troglofauna species detected from sampling at the Study Area to date, 17 troglofauna taxa are known only from proposed impact areas. Based on current taxonomic and ecological information, and the likely extent of suitable habitats for troglofauna beyond pit boundaries, the following risk categories were assigned to these taxa.

- **Low risk** (10 taxa): *Paradraculoides* sp. B12A, *Prethopalpus* sp. MW21, *Troglarmadillo* sp. B46, Pauropodidae sp. B42, Pauropodidae sp. B43, *Symphyella* sp. 'EW', Campodeidae sp. 'EW', Projapygidae sp. B14, Projapygidae sp. B17, *Lepidospera* sp. B10, and *Macranillus* sp. 'EW'.

These taxa were regarded as low risk as they were recorded from locations outside proposed pit boundaries (though inside the 150m buffer of disturbance), from areas where suitable habitat appears to extend beyond pit boundaries.

- **Low – moderate risk** (2 taxa): Pauropodidae sp. B29 and Pauropodidae sp. B41.

These taxa were regarded as low-moderate risk as they were recorded from locations either on the margin of the pit boundaries, or from secondary impact areas (i.e. TSF), and there is some uncertainty regarding their ecological status (i.e. uncertain whether troglobitic or troglophilic/ trogloxenic). Both taxa are known from areas where suitable habitat appears to extend beyond pit boundaries.

- **Moderate risk** (4 taxa): Palpigradi sp., *Paradraculoides* sp. ‘new2’, *Paradraculoides* sp. ‘new3’ and *Anapistula* sp. 'EW'.

These taxa were regarded as moderate risk as they are known within pit boundaries and are likely to be Potential SRE troglobites (i.e. higher inherent likelihood of being restricted to subterranean habitats). The risks to these taxa are moderated by the fact that suitable habitat appears to extend beyond the impact areas in each case.

Troglofauna have been recorded from a diverse range of geological habitats throughout the Study Area. This in part, is due to the size of the Study Area and extensive spread of proposed pits across a range of different habitable geologies within the Brockman Syncline. The richness of troglofauna species within the Study Area is not surprising, given the diverse range of habitable geologies and the heterogeneity of subterranean habitats within the Study Area. Nevertheless, the number of potentially restricted troglofauna species could also be attributed to sampling artefacts such as higher numbers of available holes within proposed pits and the low capture rates often associated with troglofauna sampling. Based on current habitat information, no troglofauna species detected at the Study Area was recorded from impact areas where suitable habitat did not appear to extend beyond the proposed impact boundaries.

8.1.2 Risks to Stygofauna Species

Current and previous surveys recorded nine (9) stygofauna taxa known only from the Study Area. Based on current taxonomic and ecological information, modelling of groundwater drawdown and likely extent of suitable habitats for stygofauna beyond the modelled extent of drawdown, the following risk categories were assigned to these taxa.

- **Low risk** (3 taxa): *Areacandona* nr *triangulum, Brevisomabathynella* sp. C and *Bogidiella* sp. B05;

These taxa were regarded as low risk as they are known from locations outside of the predicted drawdown or from localities relatively unaffected by groundwater drawdown.

- **Low-Moderate risk** (3 taxa): *Parastenocaris* sp., *Brevisomabathynella* sp. B and Paramelitidae sp. B58;

These taxa were regarded as low to moderate risk as records occur throughout the Eliwana Valley (some across multiple aquifer compartments), and suitable habitats appear to occur below the modelled drawdown (particularly in the Broadway/ West End area).

- **Moderate risk**: *Brevisomabathynella* sp. A

This species was assessed as moderate risk owing to its occurrence only within a single aquifer compartment likely to be affected by considerable drawdown, with limited habitat beneath the drawdown extent.

- **High risk** (2 taxa): *Areacandona* sp. BOS1020 and *Brevisomabathynella* sp. B03

These species were assessed as high risk, as they are known only from a single aquifer compartment likely to be completely dewatered, with limited habitat (of unknown quality at increasing depth) expected to remain below the predicted drawdown.

Stygofauna have also been recorded from a diverse range of aquifer habitats throughout the Study Area. Despite the inferred hydrogeological discontinuities within the Study Area, most stygofauna species are known to occur throughout multiple aquifer compartments within the Study Area, or more widely within the local / sub-regional area. Owing to gaps in the sampling of stygofauna to the north and south of the Study Area, the wider local occurrence of some of the stygofauna species remains unconfirmed. Based on current groundwater drawdown modelling and hydrogeological information, suitable habitats for stygofauna appear to occur beneath the predicted drawdown in most hydrogeological compartments. Nevertheless, there are some species only known from areas as that maybe at a moderate or high risk of impacts from proposed groundwater drawdown.

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10 APPENDICES

10.1 APPENDIX 1 – HELIX DNA REPORT

Helix
Molecular
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6 February, 2018

Andrew Winzer
Fortescue Metals Group LTd.
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Via email

Re. Report on the molecular systematics of subfauna from the Eliwana development

Dear Andrew,

Following is a summary of the results of the subfauna study we have completed on 12 taxonomic groups of subfauna (stygofauna and troglofauna) from the Eliwana development.

Of the 26 species detected with COI, 12s and 28s, three have been detected previously in the Pilbara (Paramelitidae sp. H-AMP023, Carabidae sp. H-CCA02, Paradraculoides sp. B12), whereas the other 15 appear to be restricted to Eliwana, based on the material available for comparison.

Specimens of Amphipoda, Bathynellacea, Coleoptera, Copepoda,Isopoda, Ostracoda and Schizomida from Western Hub will be sequenced and added to the analysis for regional comparison.

Thanks once again for collaborating on this project with Helix. We hope we can continue to provide you with useful information, and feel free to contact us if you have any questions or would like to discuss the results in detail.

Sincerely,

Dr. Terrie Finston and Yvette Hitchen
Helix Molecular Solutions

Background and Objective

A subset of the subfauna collected at Eliwana appear to be restricted to the Eliwana development envelope, based on morphological examination by others. We used molecular data (DNA sequences) to assess whether these species have been found during previous surveys elsewhere in the Pilbara. We compared the DNA sequences of the new material from Eliwana to our regional database.

Fifty-six specimens of subfauna from Eliwana belonging to 12 taxonomic groups were sequenced for variation at the mitochondrial COI and 12s genes, and the nuclear gene 28s. Some specimens were also sequenced for 18s when one of the other genes failed.

Executive summary

- Fifty-six specimens from Eliwana belonging to 12 taxonomic groups were sequenced for variation at the COI and 12s genes – these are the primary "barcoding" genes used for species discrimination.
- The nuclear genes 18s and 28s were also sequenced to help aid in species discrimination.
- Of the 26 species detected with COI, 12sand 28s, three have been detected previously in the Pilbara (Paramelitidae sp. H-AMP023, Carabidae sp. H-CCA02, Paradraculoides sp. B12), whereas the other 15 appear to be restricted to Eliwana, based on the material available for comparison.

Methods

Fifty-six specimens of subfauna from 12 taxonomic groups (Amphipoda, Araneae, Bathynellacea, Coleoptera, Copepoda, Diplura, Isopoda, Ostracoda, Pauropoda, Schizomida, Symphyla, Thysanura) collected from the Eliwana development area (Table 1) were sequenced for variation at the mitochondrial cytochrome oxidase subunit I gene (COI) using two pairs of primers (LCOI/HCO2, LCOI1/HCOoutout, and the 12s gene using primers 12Sai and 12SRJ. The 28s gene was amplified using the primers 28sf-mal/28sr-mal.

Table 1. The specimens analysed in the present study.

BES no.	Borehole	Order	Lowest taxonomic ID	Helix ID
ESV17:0140	EWD0017	Araneae	Anapistula sp. 'EW'	MW01
ESV17:0085	EWD0017	Araneae	Anapistula sp. 'EW'	MW02
ESV17:0091	FF0007	Araneae	Aranomorphae sp. 'EW'	MW03
3337	EW1061	Diplura	Campodeidae sp. 'EW'	MW04
3352	FF0271	Thysanura	Lepidospora sp. B15	MW05
3359	EW0372	Coleoptera	Macranilus sp. 'EW'	MW06
3327	FFunk04	Coleoptera	Macranilus sp. indet.	MW07
2185	EWD0017	Coleoptera	Macranilus sp. indet.	MW08
3357	BG0498	Schizomida	Paradraculoides sp. indet.	MW09
3332	EW0310	Schizomida	Paradraculoides sp. indet.	MW10
3440	EW0310	Schizomida	Paradraculoides sp. indet.	MW11
3622	EW0372	Schizomida	Paradraculoides sp. indet.	MW12
ESV17:0170	EW1189	Schizomida	Paradraculoides sp. indet.	MW13
ESV17:0080	EW1190	Schizomida	Paradraculoides sp. indet.	MW14
ESV17:0099	EW1190	Schizomida	Paradraculoides sp. indet.	MW15
3679	EW1417	Schizomida	Paradraculoides sp. indet.	MW16
ESV17:0133	EW1848	Schizomida	Paradraculoides sp. indet.	MW17
ESV17:0064	EWD0017	Schizomida	Paradraculoides sp. indet.	MW18
2187	EWD0017	Schizomida	Paradraculoides sp. indet.	MW19
3350	FFunk02	Schizomida	Paradraculoides sp. indet.	MW20
3802	EW1061	Araneae	Prethopalpus sp. Indet.	MW21
ESV17:0134	EW1437	Diplura	Projapygidae sp. ?B14	MW22
3333	EW1061	Symphyla	Symphyella sp. 'EW'	MW23
ESV17:0074	EW1189	Thysanura	Thysanura sp.	MW24
3378	EW1061	Pauropoda	Pauropodidae sp. indet.	MW25

3976	EW1788	Pauropoda	Pauropodidae sp. B41	MW26
3338	EW1061	Pauropoda	Pauropodidae sp. B42	MW27
3479	EW1061	Pauropoda	Pauropodidae sp. B43	MW28
3330	Ff0062	Pauropoda	Pauropodidae sp. B33	MW29
4041	Ff0062	Pauropoda	Pauropodidae sp. B33	MW30
ESV17:0157	EW1177	Pauropoda	Pauropodidae sp. B33	MW31
3346	FF0360	Ostracoda	Areacandona sp. BOS1020	MW32
3981	Grunters bore	Ostracoda	Areacandona sp. BOS1020	MW33
3619	EW1437	Bathynellacea	Brevisomabathynella sp. B03	MW34
ESV17:0135	EW1437	Bathynellacea	Brevisomabathynella sp. B03	MW35
ESV17:0165	EW1182	Bathynellacea	Brevisomabathynella sp. B03	MW36
3331	EWPB006	Bathynellacea	Brevisomabathynella sp. B10	MW37
3355	Talisman Bore	Bathynellacea	Brevisomabathynella sp. B10	MW38
ESV17:0167	EW1182	Amphipoda	Paramelitidae sp.	MW39
3556	Talisman	Amphipoda	Paramelitidae sp. B58	MW40
3678	EW1437	Amphipoda	Paramelitidae sp. B58	MW41
3917	Talisman Bore	Amphipoda	Paramelitidae sp. B58	MW42
4026	EWMB009	Amphipoda	Paramelitidae sp. B58	MW43
ESV17:0137	EW1437	Amphipoda	Paramelitidae sp. B58	MW44
3340	EWPB006	Harpacticoida	Parastenocaris sp.	MW45
	FF0408	Amphipoda	Bogidiella sp. B05	MW46
	EW0540	Harpacticoida	Parastenocaris sp. B26	MW47
	TM0087	Thysanura	Lepidospera sp. B10	MW48
	FF0023	Araneae	Prethopalpus sp. B25 (nr boltoni)	MW49
	EW0300	Diplura	Projapygidae sp. B14	MW50
	FF0038	Diplura	Projapygidae sp. B17	MW51
	FF0245	Isopoda	Troglarmadillo sp. B46	MW52
636670	SM4530	Pauropoda	Pauropodidae sp. B01	MW53
622670	DL0003	Ostracoda	Areacandona bluffi	MW54
	FF0020	Ostracoda	Areacondona nr triangulum	MW55
	FF0020	Ostracoda	Areacondona nr triangulum	MW56

Sequences were edited using GENEIOUS software (Drummond *et al.* 2011). Alignment was performed with CLUSTAL W (Thompson *et al*. 1994) using default parameters. Genetic distances between unique genetic sequences (haplotypes) were measured using uncorrected p-distances (total percentage of nucleotide differences between sequences).

Phylogenetic trees were constructed using the neighbour-joining algorithm and p-distances in MEGA.

For the purposes of this report, lineages were defined as haplotypes or groups of haplotypes differing from other such groups by >3% sequence divergence. This cut-off was selected based on bar-coding data, which indicates that intra-specific variation rarely exceeds 3% (Hebert et al., 2003b).

Results

Amphipoda - COI

Three species of amphipods were identified on the basis of morphology:
Bogidiella sp. B05
Paramelitidae sp.
Paramelitidae sp B58

Six specimens were sequenced for COI, one assigned to Bogidiella sp. B05, one to Paramelitidae sp. and four to Paramelitidae sp B58.

The five Paramelitdae specimens were compared with 59 specimens of regional Paramelitidae using a phylogenetic analysis and genetic distances. The five specimens formed two distinct

genetic groups (=lineages; Figure 1). The four specimens of Paramelitidae B58 clustered together, however the specimen of Paramelitidae sp. formed a distinct group (Figure 1).

The four specimens of Paramelitidae B58 differed from one another by 0 to 1.1 sequence divergence, thus they represent a single species (Table 2)

The specimen of Paramelitidae sp. differed from Paramelitidae B58 by 20.0% sequence divergence, thus they belong to two separate species (Table 2).

Paramelitidae sp. B58 differed from the reference specimens by ≥16% sequence divergence, thus B58 appears to be restricted to the Eliwana area, although specimens were not available for comparison from Western Hub.

Paramelitidae sp. was genetically similar to a specimen of Paramelitidae (H-AMP023) from Red Hill (genetic distance = 1.6%), thus they represent the same species.

The Eliwana Bogidiella was compared with six specimens of regional Bogidiellidae using a phylogenetic analysis and genetic distances. The Eliwana Bogidiella specimen formed a distinct genetic group that did not contain any of the reference specimens (Figure 1a).

The Eliwana Bogidiella specimen differed from the reference specimens by >18% sequence divergence (Table 2a), thus it appears to be restricted to the Eliwana area, based on the limited data available for comparison.

In summary, the following Amphipoda species were detected with COI:
Paramelitidae sp. H-AMP023 (detected previously at Red Hill)
Paramelitidae sp B58 (appears restricted to Eliwana based on material available for comparison)
Bogidiella sp. B05 (appears restricted to Eliwana based on material available for comparison)

Specimens of Amphipoda from Western Hub will be sequenced and added to the analysis for regional comparison.

Amphipoda – 12s
Helix lacks a regional database for 12s, however the 12s data verifies that all the specimens of Paramelitidae sp. B58 belong to a single species, and that Paramelitidae sp. belongs to a second species. The two morphotypes belong to two distinct genetic groups (Figure 1b) and distances between the groups range from 16.4 to 17.8% sequence divergence (Table 2b).

Amphipoda – 28s
Helix lacks a regional database for 28s, however the 28s data verifies that all the specimens of Paramelitidae sp. B58 belong to a single species, and that Paramelitidae sp. belongs to a second species. The two morphotypes belong to two distinct genetic groups (Figure 1c) and distances between the groups range from 3.8 to 4.3% sequence divergence (Table 2c).

Table 2. COI pairwise distances between Eliwana and reference specimens of Paramelitidae sp. and Paramelitidae sp. B58 (Amphipods). Distances between Eliwana specimens are highlighted in blue. Distances between Eliwana and the reference specimens are highlighted in yellow.

Specimen ID	MW39	MW40	MW41	MW42	MW43	MW44
MW39 P. sp.		0.014	0.014	0.014	0.014	0.014
MW40 P. sp. B58	0.209		0.003	0.000	0.004	0.003
MW41 P. sp. B58	0.209	0.010		0.003	0.004	0.000
MW42 P. sp. B58	0.209	0.000	0.010		0.004	0.003
MW43 P. sp. B58	0.209	0.012	0.010	0.012		0.004
MW44 P. sp. B58	0.208	0.010	0.000	0.010	0.010	
AM3	0.216	0.212	0.212	0.212	0.213	0.212
AM4	0.214	0.201	0.201	0.201	0.199	0.201

AM13	0.209	0.190	0.190	0.190	0.196	0.190
BX32	0.219	0.182	0.184	0.182	0.187	0.184
DZ24	0.079	0.215	0.211	0.215	0.213	0.211
EF118232	0.186	0.161	0.163	0.161	0.167	0.163
G187	0.207	0.216	0.213	0.216	0.219	0.213
G496	0.088	0.207	0.207	0.207	0.208	0.207
GO82	0.206	0.185	0.184	0.185	0.191	0.183
IS39	0.016	0.210	0.210	0.210	0.210	0.210
J9_3	0.109	0.195	0.195	0.195	0.195	0.195
JF19	0.128	0.193	0.193	0.193	0.199	0.192
KD63	0.082	0.221	0.218	0.221	0.220	0.218
L10	0.143	0.238	0.236	0.238	0.240	0.236
W6	0.223	0.218	0.223	0.218	0.217	0.223

Table 2a. COI pairwise distances between Eliwana and reference specimens of Bogidiellidae (Amphipods). Distances between Eliwana and the reference specimens are highlighted in yellow.

Specimen ID	MW46	JF278086	JF278089	EV10	L31	GY21	B3 60b	GY71	BL20	JF278088
MW46 Bogidiella sp. B05		0.018	0.019	0.016	0.016	0.015	0.016	0.015	0.014	0.016
JF278086	0.210		0.018	0.019	0.020	0.019	0.018	0.018	0.016	0.017
JF278089	0.247	0.223		0.020	0.020	0.020	0.019	0.019	0.020	0.019
EV10	0.185	0.273	0.309		0.002	0.002	0.011	0.010	0.015	0.018
L31	0.189	0.279	0.307	0.003		0.003	0.011	0.011	0.016	0.019
GY21	0.184	0.272	0.307	0.003	0.007		0.011	0.010	0.015	0.018
B3 60b	0.189	0.282	0.295	0.088	0.090	0.087		0.000	0.015	0.018
GY71	0.184	0.277	0.295	0.086	0.088	0.086	0.000		0.015	0.017
BL20	0.181	0.202	0.220	0.247	0.246	0.244	0.246	0.249		0.014
JF278088	0.220	0.248	0.238	0.256	0.254	0.255	0.261	0.265	0.194	

Table 2b. 12s pairwise distances between Eliwana specimens of Paramelitidae sp. and Paramelitidae sp. B58 (Amphipods). Distances between Paramelitidae sp. B58 specimens are highlighted in blue.

Specimen ID	MW40	MW41	MW42	MW43	MW44	MW39
MW40 B58		0.003	0.000	0.000	0.003	0.022
MW41 B58	0.003		0.003	0.003	0.000	0.022
MW42 B58	0.000	0.003		0.000	0.003	0.022
MW43 B58	0.000	0.003	0.000		0.003	0.023
MW44 B58	0.003	0.000	0.003	0.003		0.023
MW39 sp.	0.164	0.167	0.167	0.178	0.171	

Table 2c. 28s pairwise distances between Eliwana specimens of Paramelitidae sp. and Paramelitidae sp. B58 (Amphipods). Distances between Paramelitidae sp. B58 specimens are highlighted in blue.

Specimen ID	MW40	MW41	MW42	MW43	MW39
MW40 Paramelitidae sp. B58		0.000	0.000	0.000	0.010
MW41 Paramelitidae sp. B58	0.000		0.000	0.000	0.007
MW42 Paramelitidae sp. B58	0.000	0.000		0.000	0.008
MW43 Paramelitidae sp. B58	0.000	0.000	0.000		0.009
MW39 Paramelitidae sp.	0.043	0.032	0.034	0.038	

Figure 1. Phylogenetic analysis of Paramelitidae based on variation at the COI gene. The specimens from Eliwana are highlighted in yellow. Species defined by genetic results are enclosed by red boxes. Only the relevant portion of the phylogeny is shown.

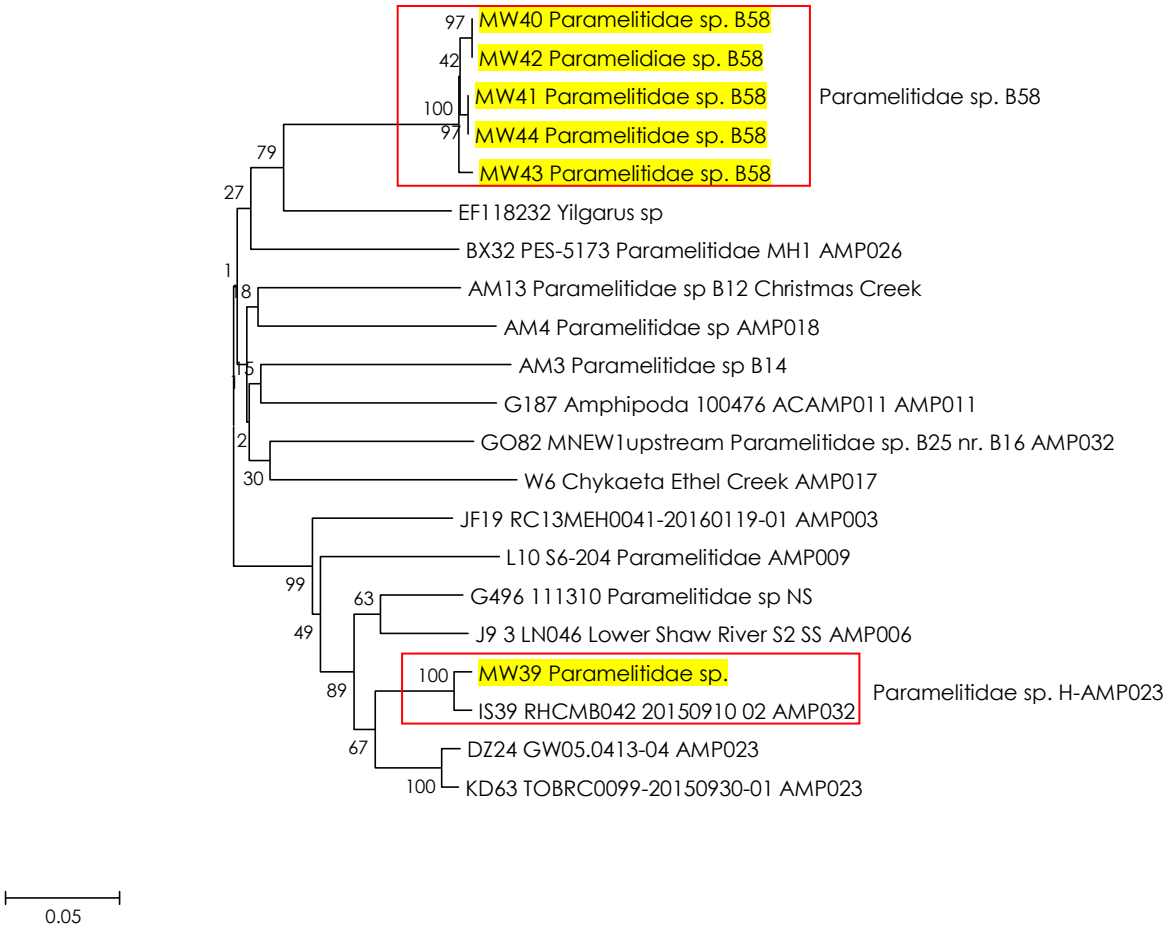


Figure 1a. Phylogenetic analysis of Bogidiellidae based on variation at the COI gene. The specimens from Eliwana are highlighted in yellow. Species defined by genetic results are enclosed by red boxes.

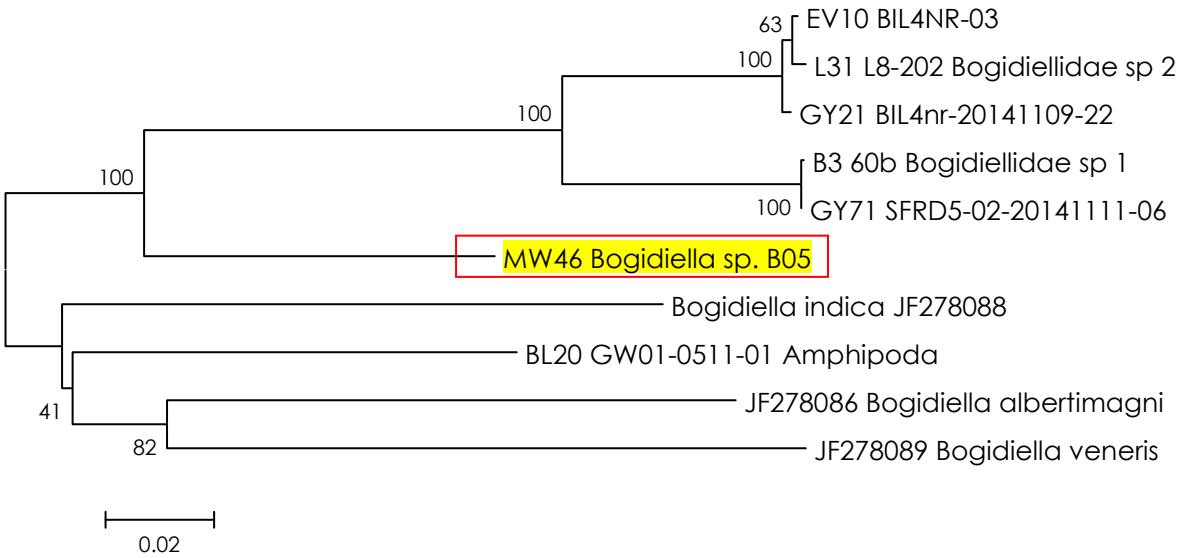


Figure 1b. Phylogenetic analysis of Paramelitidae based on variation at the 12s gene. Species defined by genetic results are enclosed by red boxes.

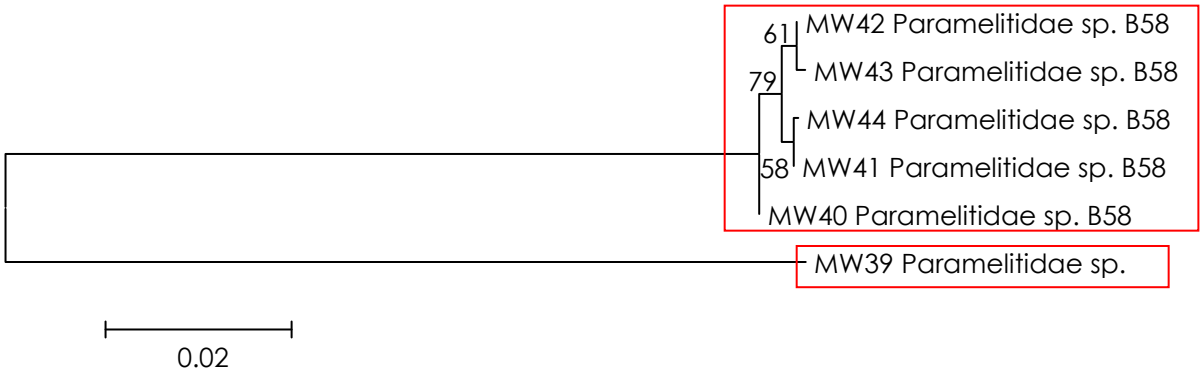
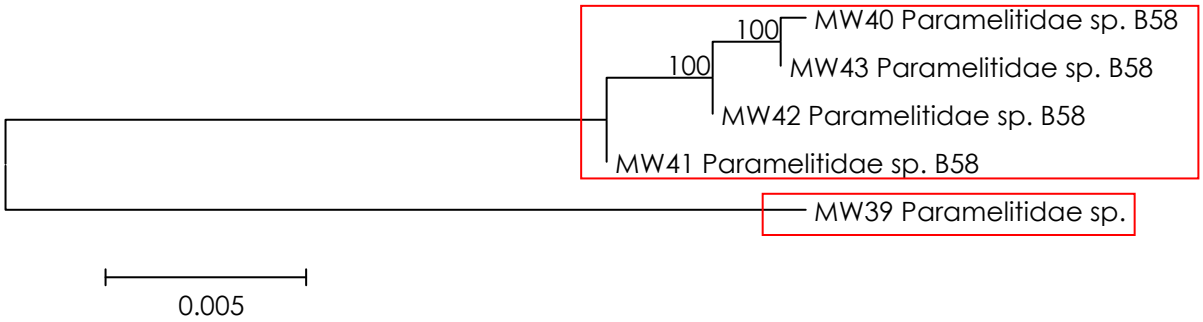


Figure 1c. Phylogenetic analysis of Paramelitidae based on variation at the 28s gene. Species defined by genetic results are enclosed by red boxes.



Araneae - COI

Two specimens of Araneae were assigned on the basis of morphology to Anapistula sp. 'EW'. A third specimen, Araneomorphae sp. 'EW', could not be identified, but may belong to Anapistula sp. 'EW'.

Two specimens were assigned to the genus Prethopalpus, one identified as Prethopalpus sp. indet and one as Prethopalpus sp. B25 (nr boltoni)

The five specimens were sequenced for COI, however two (one Anapistula sp. 'EW' and Prethopalpus sp. B25), failed to yield a COI sequence.

The two remaining specimens, Anapistula sp. 'EW' and Araneomorphae sp. 'EW', were compared with 52 specimens of regional Araneae using a phylogenetic analysis and genetic distances. The two specimens formed two distinct genetic groups that did not contain close reference specimens (=lineages; Figure 2).

The two specimens of Araneomorphae differed from one another by 21.5% sequence divergence, thus they represent two distinct species (Table 3)

Both Araneomorphae specimens differed from the reference specimens by ≥12% sequence divergence, thus the two species appear to be restricted to the Eliwana area, although specimens were not available for comparison from Western Hub.

Prethopalpus sp. indet was compared with 21 regional specimens using a phylogenetic analysis and genetic distances. The specimen formed a distinct genetic group (lineage) that did not contain any close reference specimens (Figure 2a).

Prethopalpus sp. indet from Eliwana differed from the reference specimens by >18% sequence divergence (Table 3a), thus the species appears to be restricted to the Eiliwana area, based on the material available for comparison.

Araneae – 12s

The 12s data confirmed the distinctiveness of Anapistula sp. EW and Prethopalpus sp. indet. The two specimens were compared with 33 regional specimens using phylogenetic analysis and genetic distances. Both species formed distinct genetic groups (lineages) that did not contain close reference specimens and both differed from the nearest reference specimens by 14% sequence divergence, indicating that they are likely to be restricted to the Eliwana area based on the material available for comparison.

Araneae – 28s

Helix lacks a regional database for 28s, however sequences were obtained from both Prethopalpus sp. indet. and Prethopalpus sp. B25 (nr boltoni), allowing us to assess whether they represent the same species.

The two specimens differed from one another by 4.6% sequence divergence at 28s. Because 28s is a conserved gene, we expect genetic distances between species to be smaller than COI or 12s. For example, the two distinct species of Paramelitidae differed by between 3.8 to 4.3% at 28s. Therefore it is likely that the two specimens of Prethopalpus represent two distinct species.

In summary, three species of Araneae were detected with COI:
Anapistula sp. 'EW' (appears restricted to Eliwana based on material available for comparison)
Araneomorphae sp. 'EW' (appears restricted to Eliwana based on material available for comparison)
Prethopalpus sp. indet (appears restricted to Eliwana based on material available for comparison)

A fourth species was detected with 28s:
Prethopalpus sp. B25 (nr boltoni) (appears restricted to Eliwana based on material available for comparison)

Table 3. COI pairwise distances between Eliwana and reference specimens of Araneomorphae. Distances between Eliwana specimens are highlighted in blue. Distances between Eliwana and the reference specimens are highlighted in yellow.

Specimen ID	MW01	MW03
MW01 Anapisutla sp. 'EW'		0.015
MW03 Araneomorphae sp. 'EW'	0.215	
LI29	0.235	0.207
Zelanda_sp.	0.233	0.202
KD01	0.215	0.176
KD02	0.213	0.177
EU068037	0.252	0.213
EU068043	0.240	0.207
AY231053	0.184	0.158
BP013	0.229	0.192
BP013	0.229	0.192
BX1	0.112	0.222
CA6	0.238	0.229
DF8	0.146	0.222
DF9	0.264	0.238
EJ0003R	0.237	0.200
EO30	0.229	0.273
EO33	0.244	0.295

EO7	0.254	0.294
EO8	0.242	0.278
FG1100	0.243	0.204
G135	0.254	0.241
G136	0.263	0.245
G137	0.272	0.234
G139	0.281	0.243
G140	0.261	0.243
G141	0.249	0.236
G142	0.225	0.212
G145	0.218	0.207
G209	0.147	0.236
G210	0.128	0.245
G226	0.123	0.232
G227	0.120	0.213
G307	0.226	0.237
G308	0.228	0.237
G309	0.231	0.208
G78	0.251	0.237
G79	0.255	0.242
G81	0.264	0.246
G84	0.221	0.210
GH12	0.235	0.172
GU456913	0.230	0.192
AY297410	0.227	0.190
JN018125	0.259	0.251
JN018199	0.275	0.270
AY297373	0.227	0.197
IV272	0.247	0.234
IV273	0.282	0.230
IV275	0.234	0.172
IV276	0.154	0.236
IV345	0.244	0.233
IV346	0.235	0.235
KX537094	0.220	0.170

Table 3a. COI pairwise distances between Eliwana and reference specimens of Prethopalpus (Araneomorphae). Distances between Eliwana and the reference specimens are highlighted in yellow.

Specimen ID	MW21
MW21 Prethopalpus sp. indet	
CA6	0.210
DF9	0.229
EO30	0.219
EO33	0.222
EO7	0.232
EO8	0.230
G135	0.217
G136	0.223
G137	0.223
G139	0.220
G140	0.217

G141	0.196
G307	0.235
G308	0.226
G309	0.205
G78	0.197
G79	0.218
G81	0.224
IV272	0.190
IV345	0.221
IV346	0.216

Table 3b. 12s pairwise distances between Eliwana and reference specimens of Anapistula (Araneomorphae). Distances between Eliwana and the reference specimens are highlighted in yellow.

Specimen ID	MW01
MW01 Anapistula sp. EW	
Achaearanea tepidariorum	0.324
Anoteropsis senica	0.277
BP013	0.333
EJR0247	0.358
EJP0232	0.355
EXR0969	0.141
EXR0968	0.314
EXR1148 J20-3	0.292
EXR1148 J20-4	0.317
FG1100 J8 6 .	0.346
FG1100 J4 8	0.350
GD0080R	0.341
Herennia sp	0.300
JIN0070R	0.329
PS0165R	0.307
PS0165R	0.307
PSC0165R	0.307
WH051 J	0.342
WAM T91747	0.337

Table 3c. 12s pairwise distances between Eliwana and reference specimens of Prethopalpus (Araneomorphae). Distances between Eliwana and the reference specimens are highlighted in yellow.

Specimen ID	MW21
MW21 Prethopalpus sp indet	
Ecowise J8 3	0.414
EJ003R 4 23 6	0.358
EJ003R J8 2	0.353
EJR0237	0.353
EXR0793	0.399
EJ0391R	0.353
EXR0791	0.399
EXR0980	0.399

FG633	0.391
FG633	0.388
GDR0070 J8 4	0.378
HH0118R	0.404
HH0118R J8 5	0.408
MCM0120	0.408

Figure 2. Phylogenetic analysis of Araneomorphae based on variation at the COI gene. The specimens from Eliwana are highlighted in yellow. Species defined by genetic results are enclosed by red boxes.

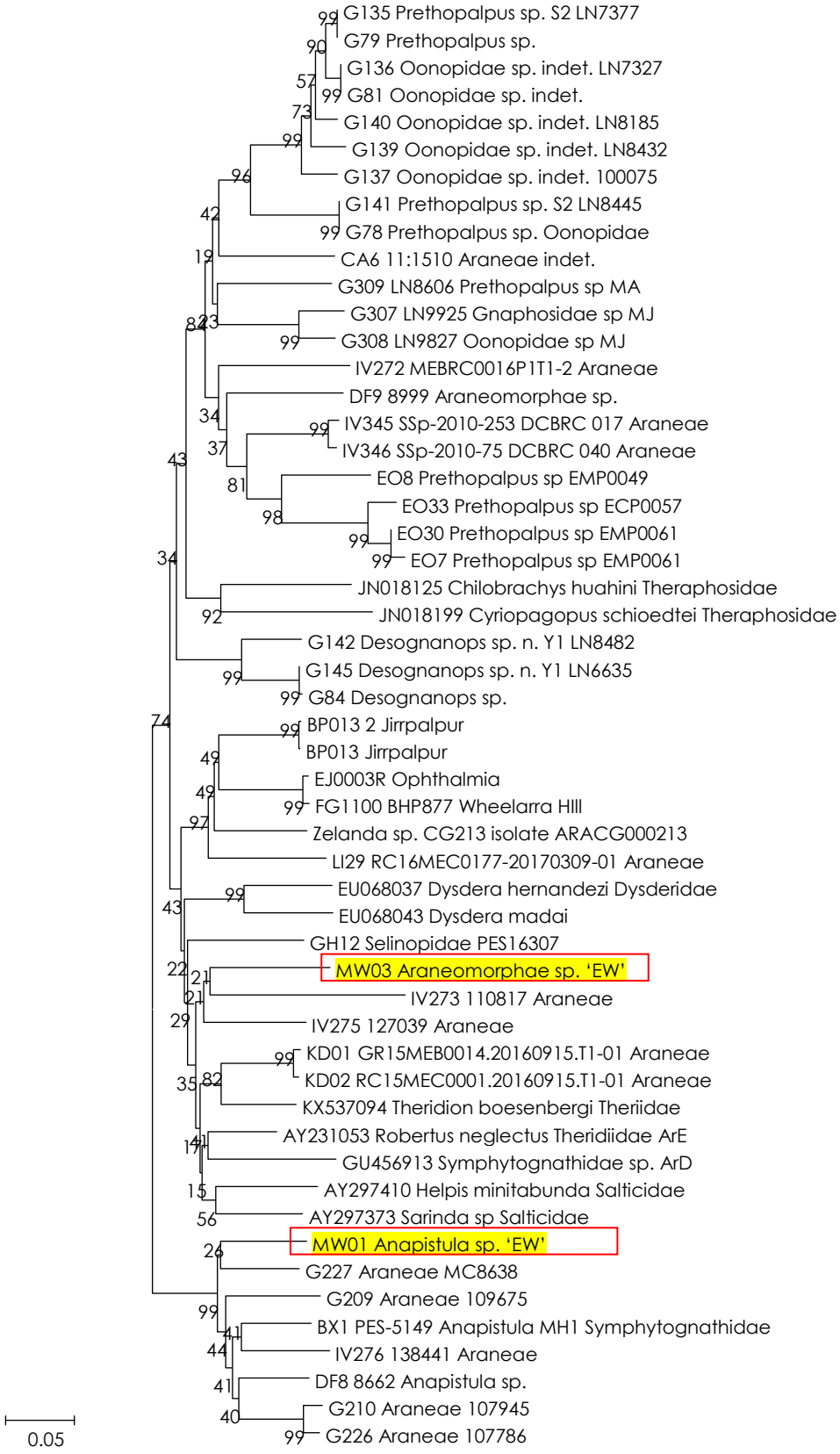


Figure 2a. Phylogenetic analysis of Prethopalpus (Araneomorphae) based on variation at the COI gene. The specimens from Eliwana are highlighted in yellow. Species defined by genetic results are enclosed by red boxes.

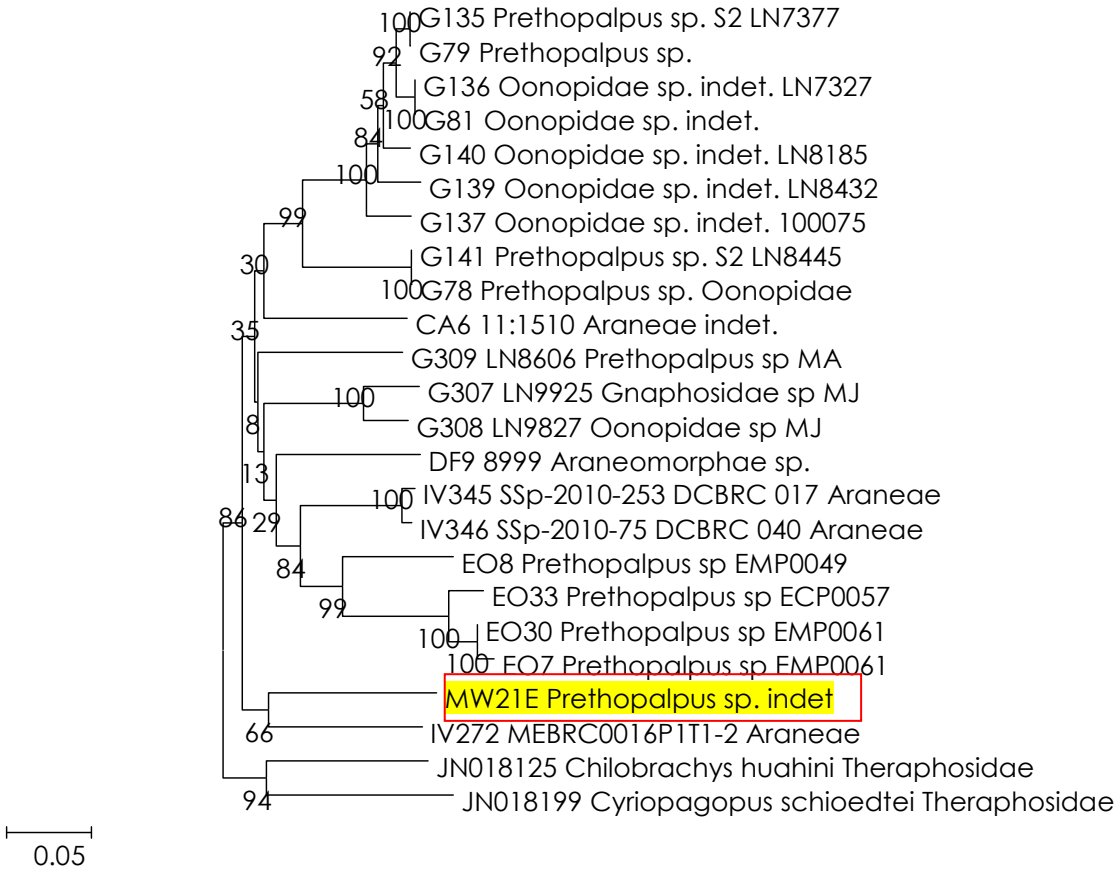
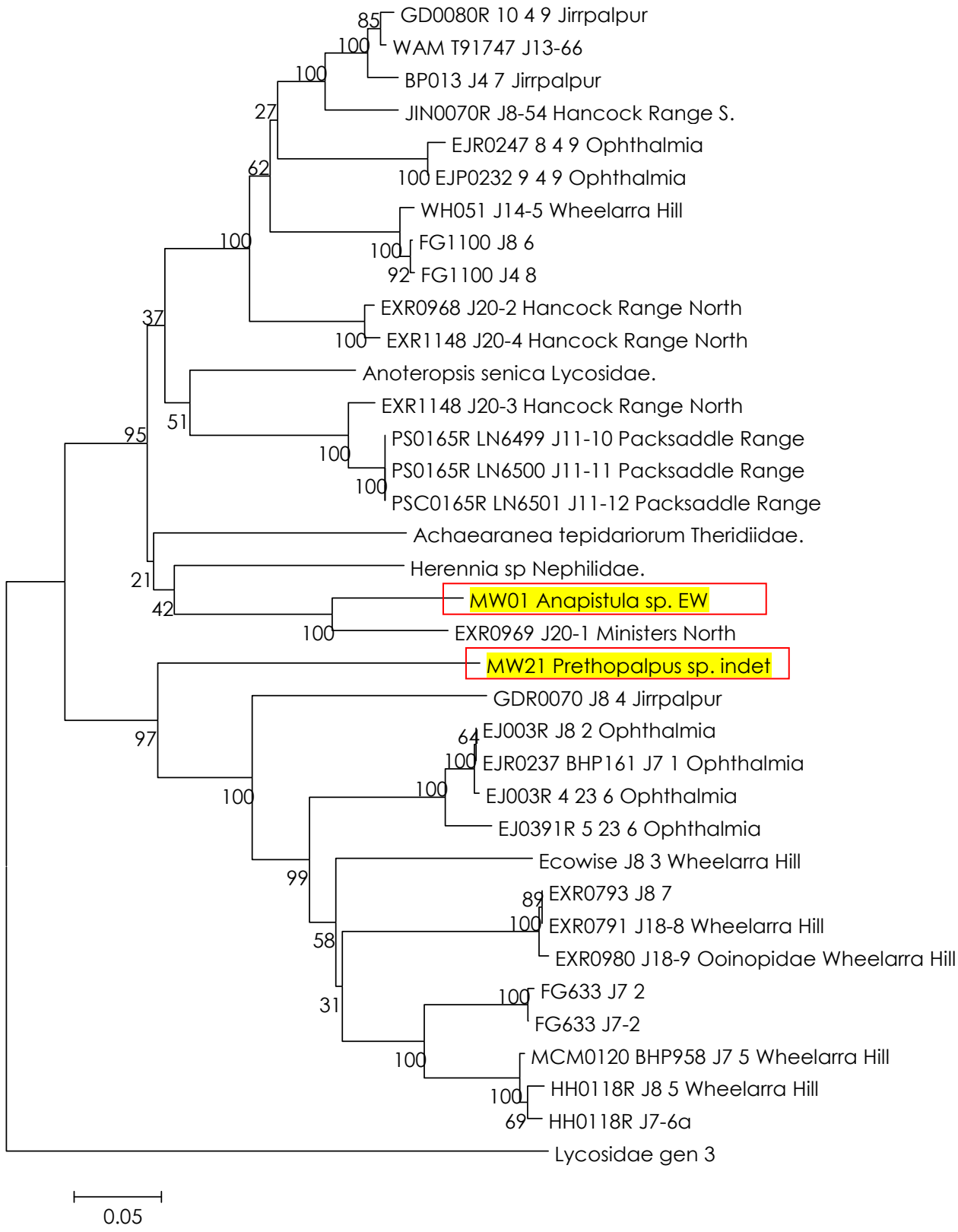


Figure 2b. Phylogenetic analysis of Araneomorphae based on variation at the 12s gene. The specimens from Eliwana are highlighted in yellow. Species defined by genetic results are enclosed by red boxes.



Bathynellacea

Two species of Bathynellacea were detected on the basis of morphology and assigned to:
Brevisomabathynella sp. B03
Brevisomabathynella sp. B10

Five specimens were sequenced for COI, three assigned to B03 and two to B10 (Table 1).

The five specimens were compared with 22 specimens of regional Parabathynellidae using a phylogenetic analysis and genetic distances. The five specimens formed three distinct genetic

groups (=lineages; Figure 3). The three specimens of B03 clustered together, however the two specimens of B10 formed two distinct groups (Figure 3).

The three specimens of B03 differed from one another by 0 to 0.85 sequence divergence, thus they represent a single species (Table 4)

The two specimens of B10 differed from one another by 14.1% sequence divergence, thus they belong to two separate species (Table 4).

All five Bathynellacea specimens, representing three species (B03, B10a, B10b) differed from the reference specimens by ≥17% sequence divergence, thus all three species appear to be restricted to the Eliwana area, although specimens were not available for comparison from Western Hub.

In summary, three species of Bathynellacea were detected with COI:
Brevisomabathynella sp. B03 (appears restricted to Eliwana, based on material available for comparison)
Brevisomabathynella sp. B10a (appears restricted to Eliwana, based on material available for comparison)
Brevisomabathynella sp. B10b (appears restricted to Eliwana, based on material available for comparison)

Specimens of Bathynellacea from Western Hub will be sequenced and added to the analysis for regional comparison.

Bathynellacea – 12s
Helix lacks a regional database for 12s, however the 12s data verifies that the two specimens of Brevisomabathynella sp. B03 belong to a single species, and that Brevisomabathynella sp. 10 belongs to a second species. The two morphotypes belong to two distinct genetic groups (Figure 3a) and distances between the groups range from 16.4 to 17.8% sequence divergence (Table 4a).

Bathynellacea – 28s
Only a single specimen of Bathynellacea was successfully sequenced for 28s, so no phylogenetic or genetic distance analyses were conducted.

Table 4. COI pairwise distances between Eliwana and reference specimens of Brevisomabathynella species B03 and B10 (Bathynellaceae). Distances between Eliwana specimens are highlighted in blue. Distances between Eliwana and the reference specimens are highlighted in yellow.

Specimen ID	MW34	MW35	MW38	MW37	MW36
MW34 B03		0.000	0.002	0.007	0.012
MW35 B03	0.000		0.002	0.007	0.012
MW38 B03	0.004	0.005		0.007	0.011
MW37 B10	0.035	0.036	0.039		0.012
MW36 B10	0.118	0.123	0.114	0.128	
AK11	0.246	0.246	0.241	0.236	0.236
BX28	0.208	0.213	0.209	0.212	0.212
EU350221	0.190	0.196	0.184	0.188	0.180
EU350243	0.174	0.176	0.168	0.172	0.190
EU350247	0.186	0.191	0.180	0.188	0.199
EU350249	0.188	0.194	0.182	0.195	0.199
EU350250	0.186	0.191	0.180	0.188	0.197
G119	0.181	0.187	0.174	0.183	0.174
G196	0.163	0.168	0.161	0.161	0.169
G197	0.169	0.174	0.163	0.182	0.177

G380	0.181	0.186	0.176	0.184	0.169
G384	0.209	0.215	0.204	0.216	0.214
G385	0.175	0.180	0.173	0.173	0.173
G386	0.179	0.183	0.178	0.175	0.173
G387	0.197	0.201	0.196	0.197	0.203
G388	0.217	0.221	0.215	0.212	0.220
G466	0.202	0.209	0.200	0.200	0.199
G467	0.173	0.177	0.171	0.165	0.178
G468	0.167	0.171	0.165	0.159	0.162
KR131690	0.266	0.268	0.269	0.277	0.290
KR131709	0.251	0.253	0.250	0.257	0.274
LR01	0.198	0.201	0.194	0.194	0.203
LR02	0.198	0.201	0.194	0.194	0.203
LR04	0.200	0.203	0.195	0.194	0.205

Table 4a. 12s pairwise distances between Eliwana specimens of Brevisomabathynella species B03 and B10 (Bathynellaceae). Distances between Brevisomabathynella species B03 are highlighted in blue.

Specimen ID	MW34	MW35	MW36
MW34 B03		0.000	0.002
MW35 B03	0.000		0.002
MW36 B10	0.106	0.106	

Figure 3. Phylogenetic analysis of Parabathynellidae based on variation at the COI gene. The specimens from Eliwana are highlighted in yellow. Species defined by genetic results are enclosed by red boxes.

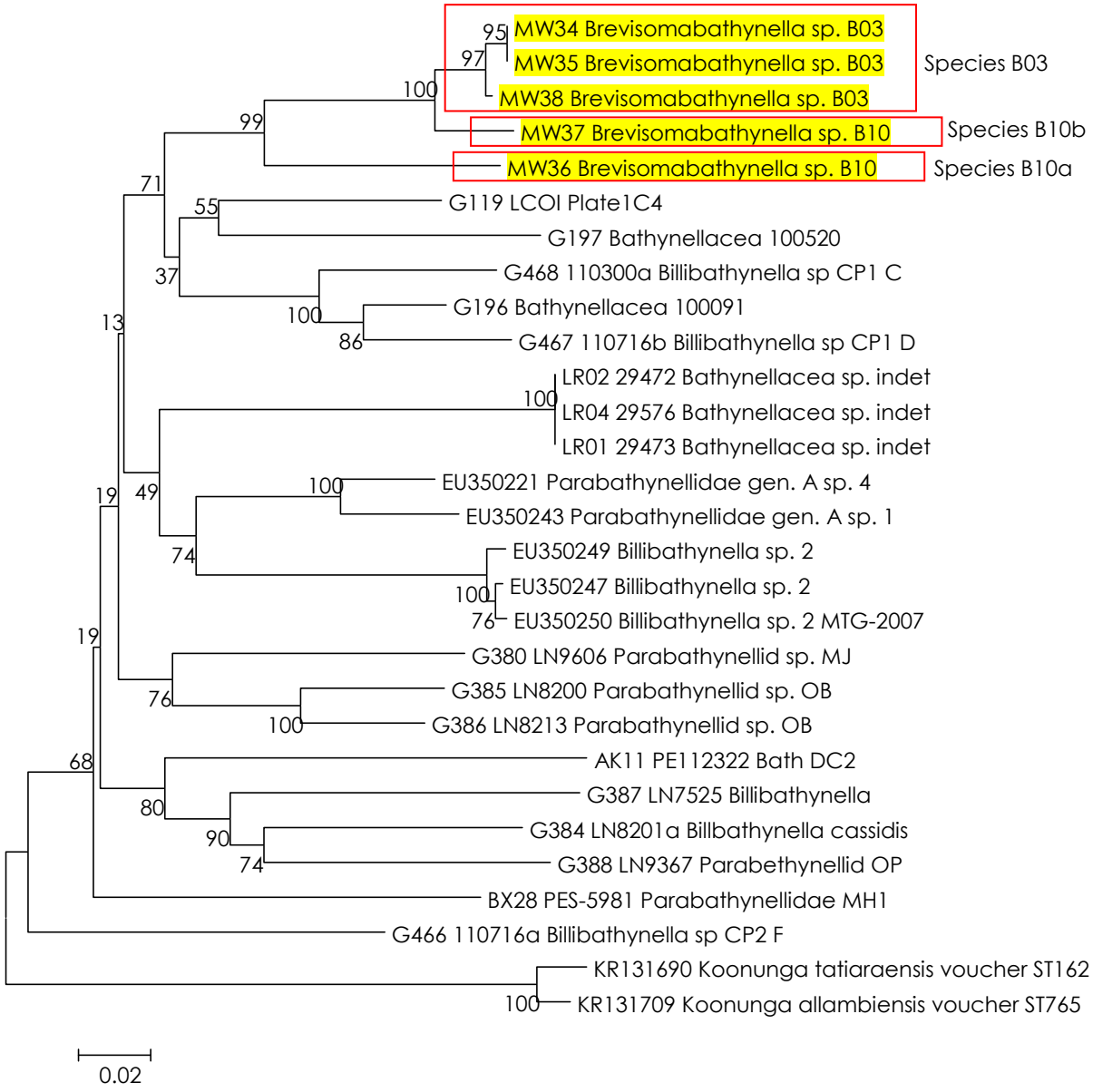
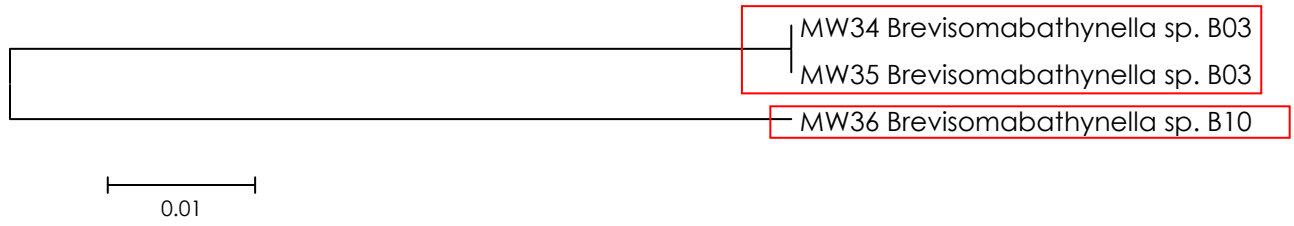


Figure 3a. Phylogenetic analysis of Parabathynellidae based on variation at the 12s gene. Species defined by genetic results are enclosed by red boxes.



Coleoptera

Three species of Carabidae from Eliwana were detected and assigned to the following species on the basis of morphology:
Macranilus sp. 'EW' (one individual)
Macranilus sp. indet (two individuals)

The three specimens were sequenced for COI, however the Macralinus sp. 'EW' and one specimen of Marcralinus sp. indet failed to amplify.

The one specimen of Marcralinus sp. indet was compared with 32 specimens of regional Carabidae, using a phylogenetic analysis and genetic distances. Previously collected specimens of Coleoptera from Western Hub belonged to the Curculiondiae so were not included in the analysis. The Eliwana specimen of Marcralinus sp. indet was placed in a genetic group (=lineage) with a species of Carabidae from Marra Mamba, H-CCA021 (Figure 4). The Macralinus sp. from Eliwana differed from the H-CCA021 by 0.9% sequence divergence, thus they represent a single species (Table 5).

In summary, one species of Carabidae was detected with COI:
Macranilus sp. H-CCA021 (detected previously at Marra Mamba)

Additional specimens of Coleoptera from Western Hub will be sequenced and added to the analysis for regional comparison.

Coleoptera – 12s
Only a single specimen of Coleoptera was successfully sequenced for 12s, so no phylogenetic or genetic distance analyses were conducted.

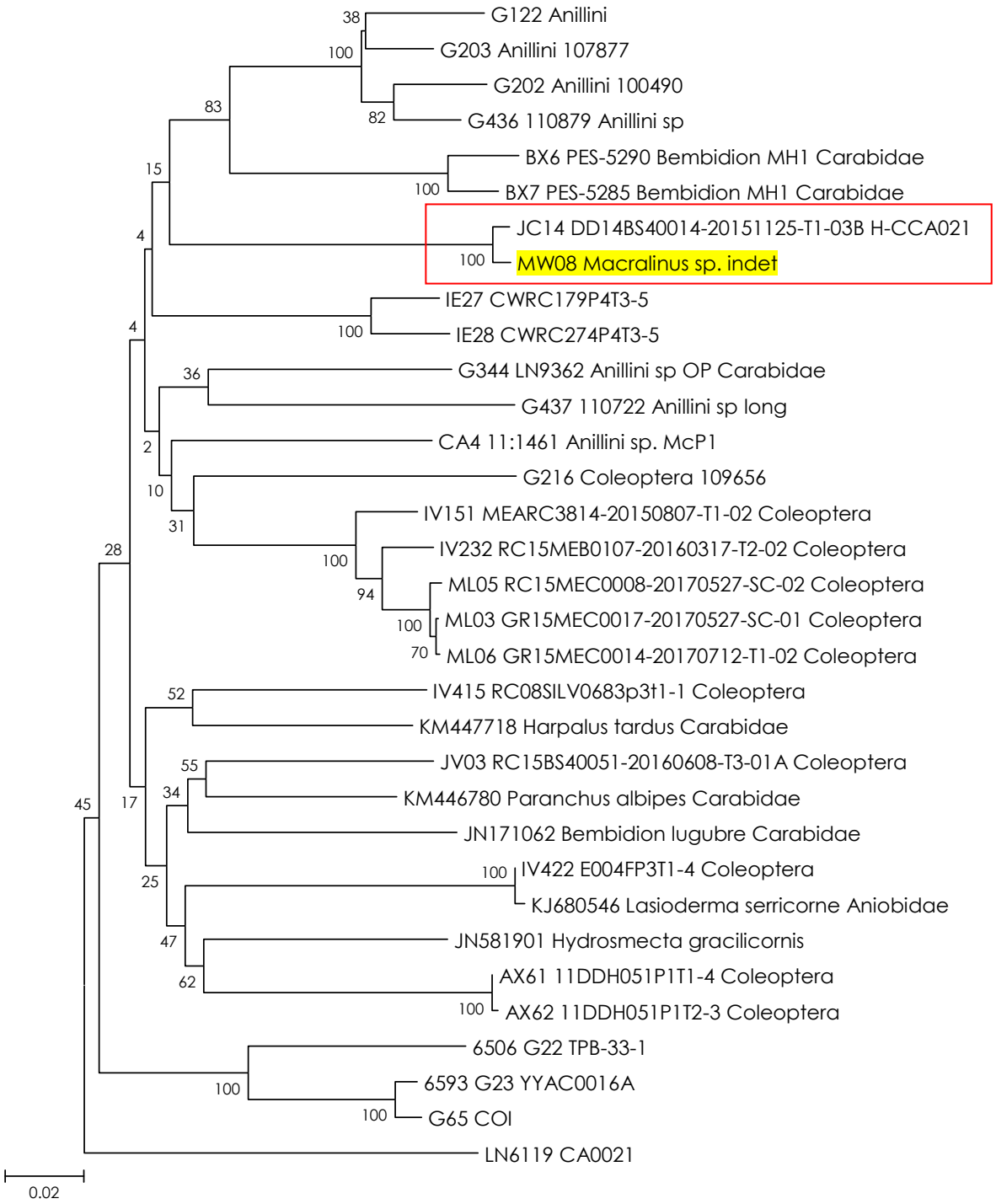
Coleoptera – 28s
None of the specimens of Coleoptera was successfully sequenced for 28s, so no phylogenetic or genetic distance analyses were conducted.

Table 5. COI pairwise distances between Eliwana and reference specimens of Carabidae (Coleoptera). Distances between Eliwana and the reference specimens are highlighted in yellow.

Specimen ID	MW08
MW08 Macralinus sp. indet	
6506 G22	0.182
6593 G23	0.181
AX61	0.176
AX62	0.178
BX6	0.180
BX7	0.178
CA4	0.168
G122	0.163
G202	0.165
G203	0.145
G216	0.207
G344	0.174
G436	0.148
G437	0.193
G65	0.181
IE27	0.172
IE28	0.174
IV151	0.161
IV232	0.158
IV415 R	0.173
IV422	0.183
JC14	0.009
JN171062	0.179

JN581901	0.168
JV03	0.172
KJ680546	0.187
KM446780	0.172
KM447718	0.178
LN6119	0.203
ML03	0.164
ML05	0.165
ML06	0.164

Figure 4. Phylogenetic analysis of Carabidae (Coleoptera) based on variation at the COI gene. The specimens from Eliwana are highlighted in yellow. Species defined by genetic results are enclosed by red boxes.



Copepoda - COI

The Harpactocoid copepods assigned to the species Parastenocaris sp. B26 and Parastenocaris sp. on the basis of morphology required a different set of primers to achieve amplification however the sequences ultimately failed, so no analyses were conducted.

Specimens of Copepoda from Western Hub will be sequenced and added to the analysis for regional comparison.

Copepoda – 12s

No sequences were obtained for the Harpactacoids for 12s

Copepoda – 28s

No sequences were obtained for the Harpactacoids for 28s

Diplura

Four species of Diplura were identified from Eliwana on the basis of morphology:

Campodeidae sp. 'EW'

Projapygidae sp. indet (? B14)

Projapygidae sp. B14

Projapygidae sp. B17

The four specimens were sequenced for COI, however only Campodeidae sp. EW and Projapygidae sp. indet were successfully sequenced.

The two specimens (Campodeidae sp. EW and Projapygidae sp. indet) were compared with 64 regional Diplura, including two specimens of Projapygidae from a previous survey at Western Hub, using a phylogenetic analysis and genetic distances. The specimens of Projapygidae from Western Hub were assigned to the species Projapygidae sp. B14, however they differed from one another by >15% sequence divergence, so were considered to represent two species. The Eliwana specimens of Campodeidae sp. EW and Projapygidae sp. indet were placed in two distinct genetic groups (=lineages) neither of which contained reference specimens (Figure 5).

Campodeiidae sp. EW from Eliwana differed from the reference specimens by >20% sequence divergence, thus it represents a species that hasn't been detected before, based on the material available for comparison (Table 6a).

Projapygidae sp. indet from Eliwana differed from the reference specimens by >14% sequence divergence, including the specimens from Western Hub, thus it represents a species that hasn't been detected before, based on the material available for comparison (Table 6b).

In summary, two species of Diplura were detected with COI:
Campodeidae sp. 'EW' (appears restricted to Eliwana, based on material available for comparison)
Projapygidae sp. indet (? B14) (appears restricted to Eliwana, based on material available for comparison and is not closely related to either specimen of Projapygidae sp. B14 from Western Hub)

Diplura – 12s

One specimen of Campodeidae sp 'EW' was successfully sequenced for 12s. Helix lacks a database of Campodeidae for 12s so no phylogenetic or genetic distance analyses were conducted.

Diplura – 28s

Only one of the specimens of Diplura, Campodeidae sp. 'EW' was successfully sequenced for 28s, so no phylogenetic or genetic distance analyses were conducted.

Table 6a. COI pairwise distances between Eliwana and reference specimens of Campodeiidae (Diplura). Distances between Eliwana and the reference specimens are highlighted in yellow.

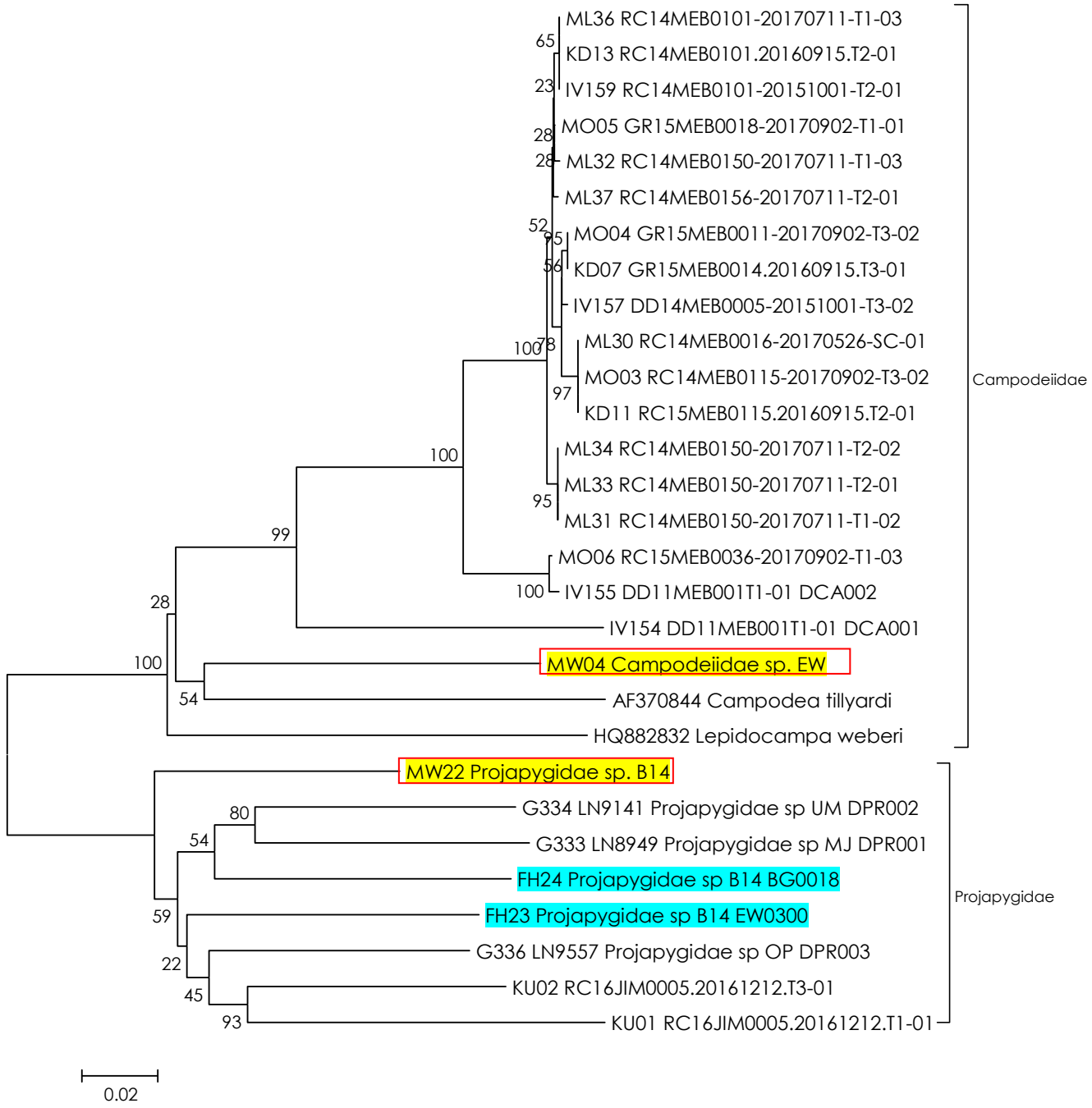
Specimen ID	MW04
MW04 Campodeiidae sp. EW	
MO06	0.204
MO05	0.202
MO04	0.197
MO03	0.199
ML37	0.202

ML36	0.201
ML34	0.198
ML33	0.198
ML32	0.199
ML31	0.198
ML30	0.198
KD13	0.202
KD11	0.199
KD07	0.197
IV159	0.200
IV157	0.197
IV155	0.202
IV154	0.197
HQ882832	0.210
FH23	0.153
FH24	0.165
AF370844	0.195

Table 6b. COI pairwise distances between Eliwana and reference specimens of Projapygidae (Diplura). Distances between Eliwana and the reference specimens are highlighted in yellow.

Specimen ID	MW22
MW22 Projapygidae sp. B14	
KU02	0.153
KU01	0.179
G336	0.145
G334	0.158
G333	0.155

Figure 6. Phylogenetic analysis of Campodeiidae and Projapygidae (Diplura) based on variation at the COI gene. The specimens from Eliwana are highlighted in yellow; specimens from Western Hub are highlighted in turquoise. Species defined by genetic results are enclosed by red boxes.



Isopoda

One specimen was assigned to the species Troglarmadillo sp. B46 based on morphology

The specimen failed to amplify for COI, 12s, 28s and 18s.

Specimens of Isopoda from Western Hub will be sequenced and added to the analysis for regional comparison.

Ostracoda - COI

Three species of Ostracoda were detected on the basis of morphology and assigned to:
Areacandona bluffi
Areacandona nr triangulum
Areacandona sp. BOS1020

Three specimens failed to amplify, so two specimens were sequenced for COI, one each assigned to Areacandona nr triangulum and Areacandona sp. BOS1020.

One specimen (Areacandona nr triangulum) was contaminated and the sequence discarded.

The one remaining specimen was compared with four specimens of regional Candonidae using a phylogenetic analysis and genetic distances. The specimen of Areacandona sp. BOS1020 formed a distinct genetic group that did not show genetic similarities to the reference specimens (Figure 6).

Areacandona sp. BOS1020 differed from the reference specimens by ≥17% sequence divergence (Table 7). Thus Areacandona sp. BOS1020 appears to be restricted to the Eliwana area, although reference specimens were limited.

In summary, one species of Ostracoda was detected using COI:
Areacandona sp. BOS1020 (appears restricted to Eliwana, based on material available for comparison)

Specimens of Ostracoda from Western Hub will be sequenced and added to the analysis for regional comparison.

Ostracoda – 12s

Only one specimen of Ostracoda, Areacandona sp. BOS1020, was successfully sequenced for 12s. It was analysed with ten regional specimens of Candonidae, assigned to Oregocandona. Areacandona sp. BOS1020 was placed in a distinct genetic group that did not contain any reference specimens (Figure 6a), and differed from the reference specimens by >19% sequence divergence (Table 7a), indicating that it is distinct from Oregocandona.

Ostracoda – 28s

Only one specimen of Ostracoda was successfully sequenced for 28s; no further analyses were conducted.

In summary, 12s verified the distinctiveness of Areacandona BOS1020 against limited reference material.

Table 7. COI pairwise distances between Eliwana and reference specimens of Ostracods. Distances between Eliwana and the reference specimens are highlighted in yellow.

specimen ID	MW32	G200	G201	J8-21	J8-20	KY091648	LC110444
MW32 BOS1020		0.012	0.012	0.014	0.014	0.016	0.016
G200	0.170		0.004	0.014	0.014	0.016	0.016
G201	0.175	0.018		0.014	0.014	0.016	0.016
J8-21a	0.196	0.205	0.207		0.000	0.014	0.016
J8-20a	0.196	0.205	0.207	0.000		0.014	0.016
KY091648	0.229	0.223	0.226	0.229	0.229		0.014
LC110444	0.209	0.211	0.215	0.225	0.225	0.208	

Table 7a. 12s pairwise distances between Eliwana and reference specimens of Ostracods. Distances between Eliwana and the reference specimens are highlighted in yellow.

Specimen ID	MW32
MW32 Areacandona BOS1020	
J8-48a	0.195
J8-47a	0.195
J8-46a	0.195
J8-45a	0.195
J8-44a	0.195

J8-43a	0.195
J8-21c	0.195
J8-21b	0.195
J8-21a	0.195
J8-20	0.195
Fabaeformiscandona kushiroensis	0.199

Figure 6. Phylogenetic analysis of Ostracoda based on variation at the COI gene. The specimens from Eliwana are highlighted in yellow. Species defined by genetic results are enclosed by red boxes.

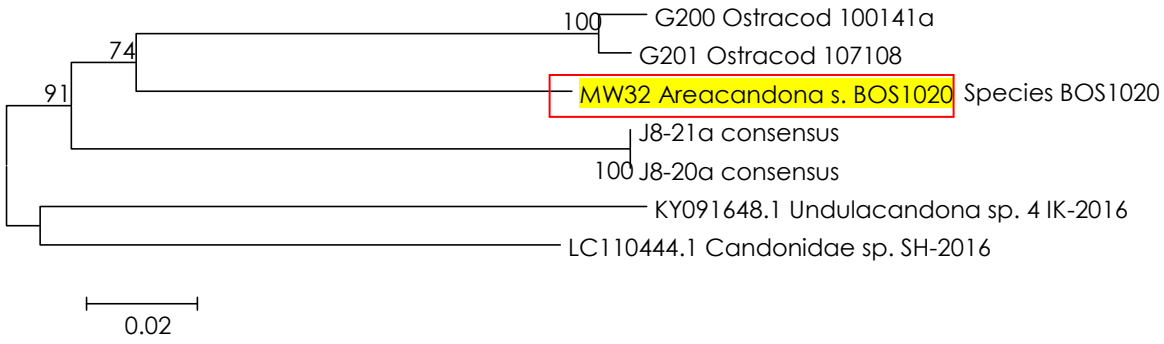
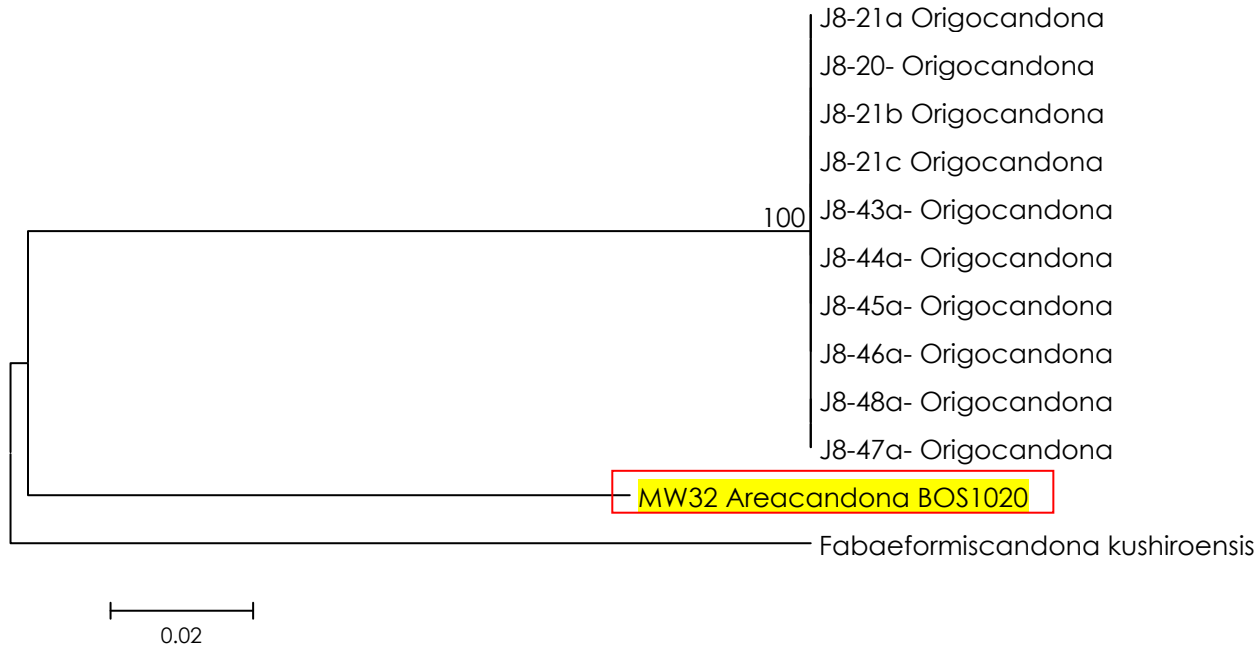


Figure 6a. Phylogenetic analysis of Ostracoda based on variation at the 12s gene. The specimens from Eliwana are highlighted in yellow. Species defined by genetic results are enclosed by red boxes.



Pauropoda - COI

Eight specimens of Pauropoda were assigned to five species on the basis of morphology: Pauropodidae sp. B01

Pauropodidae sp. B33
Pauropodidae sp. B41
Pauropodidae sp. B42
Pauropodidae sp. B43

In addition, one specimen was not assigned to a species but may belong to Pauropodidae sp. 41 or 42 as it was collected in the same bore.

Two specimens yielded COI sequences, and four were contaminated and were discarded.

One specimen each of Pauropoda sp. B33 and B42 were compared to five regional specimens of Pauropoa using phylogenetic analysis and genetic distances. The specimens were placed in two distinct genetic groups (lineages) that did not contain any reference specimens (Figure 7).

The two specimens, Pauropoda sp. B33 and B42 differed from one another by 20% sequence divergence (Table 8). Pauropoda sp. B33 differed from the reference specimens by >18% sequence divergence (Table 8). It appears to be a appears restricted to Eliwana, based on the material available for comparison.

Pauropoda sp. B42 differed from the reference specimens by >20% sequence divergence (Table 8). It appears to be restricted to Eliwana, based on the material available for comparison.

In summary, two species of Pauropoda were detected using COI:
Pauropoda sp B33 (appears restricted to Eliwana, based on material available for comparison).
Pauropoda sp B42 (appears restricted to Eliwana, based on material available for comparison).

Pauropoda – 12s
Five 12s sequences were obtained from the Pauropodidae specimens, however two were contaminated. The three remaining specimens, one each of Pauropodidae B33, B42 and sp. indet, were compared with phylogenetic and genetic distance analyses. The distinctiveness of species B33 and B42 was confirmed with the 12s data. The two morphotypes were placed in two distinct genetic groups (Figure 7a) and distances between the groups ranged from 21.8 to 22.4% sequence divergence (Table 8b). Pauropodidae sp. indet was placed in the same genetic group (lineage) with Pauropodidae sp. B42, and the two were genetically identical (Table 8a), indicating that they belong to the same species.

In summary, in addition to confirming the distinctiveness of Pauropodidae sp. B33 and B42, we were able to identify Pauropodidae sp. indet as belonging to Paruopodidae sp. B42.

Pauropoda – 28s
Five 28s sequences were obtained from the Pauropodidae specimens. Helix lacks a 28s database for Pauropoda, so the five were compared with Genbank specimens using phylogenetic analysis and genetic distances. The five specimens were placed in four distinct genetic groups (Figure 7b). Again, Pauropodidae sp. indet was placed with Paruopodidae sp. B42 (genetic distances = 1.2%; Table 8b), indicating that they represent a single species.

The two specimens of Paruipodidae sp. B33 were placed in separate, distinct genetic groups (genetic distance= 12%; Table 8b), indicating that they represent two different species.

In summary, four species were detected with 28s:
Pauropoda sp B33a
Pauropoda sp B33b
Pauropoda sp B41
Pauropoda sp B42

In addition, we were able to assign Pauripodidae sp. indet to Pauropodidae sp. B42.

Table 8. COI pairwise distances between Eliwana and reference specimens of Pauropoda. Distances between Eliwana and the reference specimens are highlighted in yellow.

Specimen ID	MW31	MW27	BX36	Decapauropus	DF28	G360	GH24	GH26
MW31 Pauropoda sp. B33		0.017	0.018	0.019	0.017	0.017	0.017	0.017
MW27 Pauropoda sp. B42	0.204		0.019	0.019	0.019	0.018	0.018	0.019
BX36	0.188	0.225		0.020	0.016	0.018	0.017	0.016
Decapauropus	0.220	0.259	0.232		0.017	0.017	0.017	0.013
DF28	0.210	0.245	0.201	0.195		0.018	0.016	0.015
G360	0.210	0.229	0.195	0.238	0.212		0.016	0.017
GH24	0.220	0.257	0.228	0.196	0.163	0.226		0.015
GH26	0.211	0.261	0.228	0.196	0.187	0.221	0.201	

Table 8a. 12s pairwise distances between Eliwana specimens of Pauropoda.

Specimen ID	MW25	MW27	MW31
MW25 Paruopodidae sp. indet		0.000	0.024
MW27 Pauropodidae sp. B42	0.000		0.024
MW31 Pauropodidae sp. B33	0.224	0.218	

Table 8b. 28s pairwise distances between Eliwana specimens of Pauropoda.

Specimen ID	MW25	MW27	MW31	MW26	MW30
MW25 Pauropodidae sp. indet		0.005	0.009	0.014	0.015
MW27 Pauropodidae sp. B42	0.015		0.008	0.014	0.016
MW31 Pauropodidae sp. B33	0.029	0.021		0.017	0.017
MW26 Pauropodidae sp. B41	0.091	0.098	0.123		0.014
MW30 Pauropodidae sp. B33	0.102	0.111	0.120	0.089	

Figure 7. Phylogenetic analysis of Pauropoda based on variation at the COI gene. The specimens from Eliwana are highlighted in yellow. Species defined by genetic results are enclosed by red boxes.

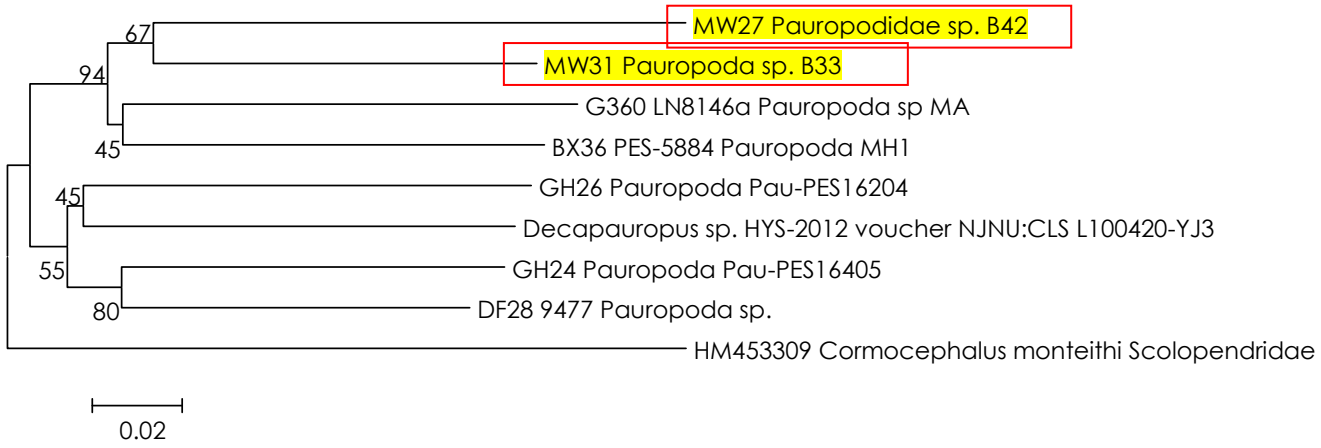


Figure 7a. Phylogenetic analysis of Pauropoda based on variation at the 12s gene. Species defined by genetic results are enclosed by red boxes.

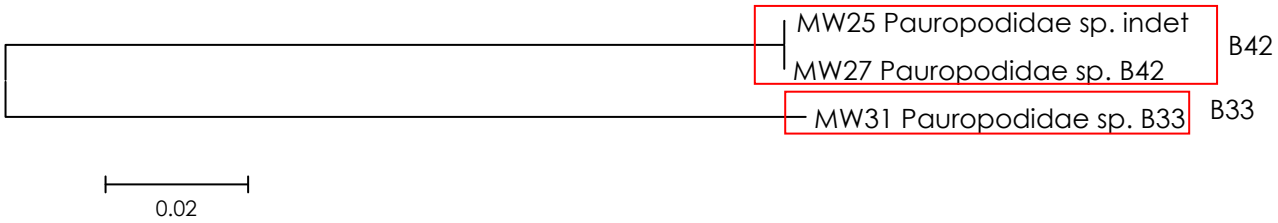
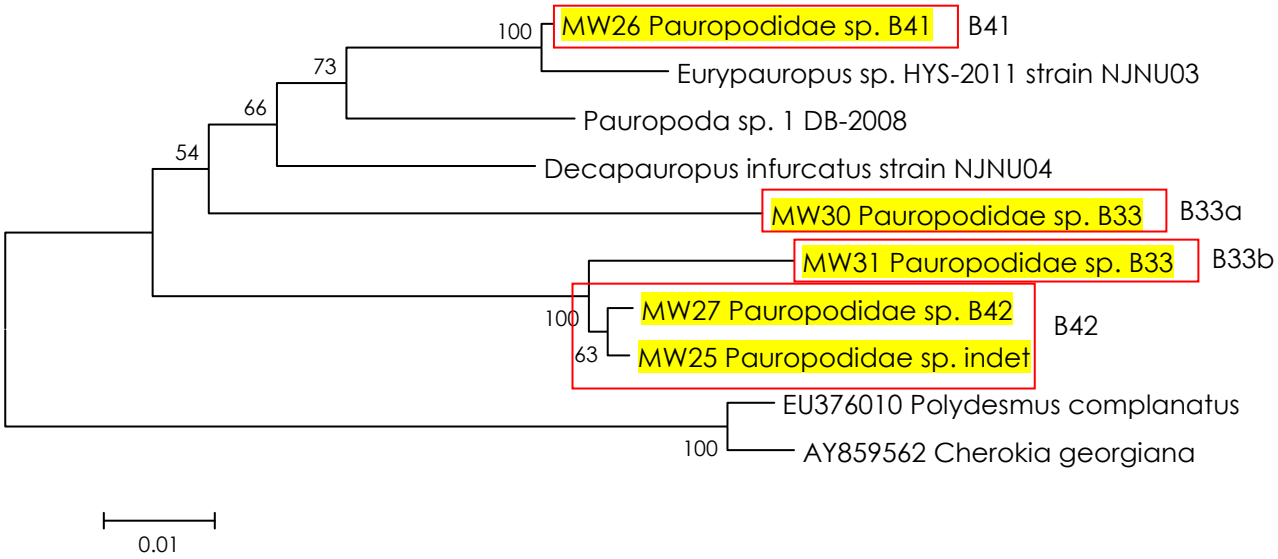


Figure 7b. Phylogenetic analysis of Pauropoda based on variation at the 28s gene. Species defined by genetic results are enclosed by red boxes.



Schizomida- COI

Twelve specimens assigned to Paradraculoides sp. indet. on the basis of morphology

One specimen failed to amplify. The remaining 11 specimens were compared with over 200 specimens of regional Schizomida using a phylogenetic analysis and genetic distances. In particular, specimens from a previous survey at Western Hub were included (Paradraculoides species B09, B10, B11, B12). Five specimens were placed with Paradraculoides sp. B12 from Western Hub, but the remaining six specimens were placed in four distinct genetic groups that did not show close genetic similarities to the reference specimens (Figure 8).

The specimens placed in the B12 group differed from one another by between 0.1 and 3.5% sequence divergence (Table 9), thus the species appears to be found in both the Eliwana and Western Hub area. A second specimen of B12 from the previous survey (FH19/EW0507) was more genetically divergent, differing by 6-8% from the remaining B12 specimens (Table 9). Its status should probably be re-evaluated.

The remaining specimens from Eliwana differed from the reference specimens by greater than 6% and are likely to represent new species (Table 9).

In summary, fives species of Schizomida were detected using COI:
Paradraculoides indet sp 1 (appears restricted to Eliwana, based on material available for comparison)
Paradraculoides indet sp 2 (appears restricted to Eliwana, based on material available for comparison)
Paradraculoides indet sp 3 (appears restricted to Eliwana, based on material available for comparison)
Paradraculoides indet sp 4 (appears restricted to Eliwana, based on material available for comparison)
Paradraculoides sp B12 (previously detected at Western Hub)

Additional specimens of Schizomida from Western Hub will be sequenced and added to the analysis for regional comparison.

Schizomida- 12s

Nine specimens were successfully sequenced for 12s. The sequences were placed in five genetic groups (lineages; Figure 8a), corresponding to the same five groups detected with COI.

The specimens placed in the B12 group differed from one another by between 0 and 4.0% sequence divergence (Table 9a), suggesting they are likely to belong to a single species.

In summary, the same five genetic groups were detected with 12s that were detected with COI, indicating the presence of five species of Paradraculoides.

Schizomida- 28s

Eleven of the 12 Schizomida were successfully sequenced for 28s. All eleven specimens were genetically identical at 28s. 28s is a conserved gene (very few genetic mutations occur in this gene region), so the results suggest that the group of Paradraculoides species from Eliwana are closely related and recently evolved, likely from a single common ancestor.

Table 9. COI pairwise distances between Eliwana and Western Hub specimens of Schizomids. Distances between Eliwana specimens belonging to the same genetic group bare highlighted in blue. Distances between Eliwana and the reference specimens are highlighted in yellow.

		New sp. 1			Sp. B12					Sp. B12	
Specimen ID	MW09	MW10	MW11	MW12	MW13	MW14	MW15	MW16	MW17	MW18	MW20
MW09		0.009	0.009	0.009	0.010	0.010	0.010	0.008	0.007	0.010	0.010
MW10	0.069		0.000	0.001	0.010	0.010	0.010	0.008	0.009	0.010	0.010
MW11	0.069	0.000		0.001	0.010	0.010	0.010	0.008	0.009	0.010	0.010
MW12	0.070	0.001	0.001		0.010	0.010	0.010	0.008	0.009	0.010	0.010
MW13	0.072	0.073	0.073	0.074		0.001	0.000	0.010	0.009	0.006	0.007
MW14	0.073	0.074	0.074	0.076	0.001		0.001	0.010	0.009	0.007	0.007
MW15	0.072	0.073	0.073	0.074	0.000	0.001		0.010	0.009	0.006	0.007
MW16	0.067	0.045	0.045	0.047	0.077	0.079	0.077		0.008	0.010	0.010
MW17	0.048	0.064	0.064	0.066	0.064	0.066	0.064	0.066		0.010	0.009
MW18	0.073	0.070	0.070	0.072	0.034	0.035	0.034	0.082	0.069		0.006
MW20	0.072	0.074	0.074	0.076	0.032	0.034	0.032	0.079	0.067	0.031	
FH3	0.066	0.072	0.072	0.073	0.080	0.082	0.080	0.076	0.069	0.079	0.077
FH17	0.083	0.089	0.089	0.088	0.092	0.093	0.092	0.093	0.083	0.089	0.091
FH18	0.077	0.082	0.082	0.083	0.076	0.077	0.076	0.083	0.080	0.072	0.074
FH19	0.080	0.082	0.082	0.083	0.060	0.061	0.060	0.079	0.079	0.054	0.053
FH20	0.073	0.076	0.076	0.077	0.034	0.035	0.034	0.080	0.069	0.032	0.001
FH21	0.069	0.072	0.072	0.073	0.072	0.073	0.072	0.079	0.067	0.067	0.073
FH22	0.077	0.085	0.085	0.086	0.085	0.086	0.085	0.088	0.083	0.077	0.077

Table 9a. 12s pairwise distances between Eliwana and reference specimens of Schizomids. Distances between specimens from Eliwana in the same genetic group are highlighted in blue. Distances between Eliwana and the reference specimens are highlighted in yellow.

		New sp. 1				Sp. B12			
Specimen ID	MW09	MW10	MW11	MW16	MW17	MW13	MW14	MW18	MW20
MW09		0.014	0.014	0.015	0.011	0.014	0.014	0.013	0.013
MW10	0.072		0.000	0.010	0.016	0.014	0.014	0.016	0.015
MW11	0.072	0.000		0.010	0.016	0.014	0.015	0.016	0.015
MW16	0.081	0.041	0.041		0.017	0.014	0.014	0.015	0.015

MW17	0.052	0.091	0.091	0.085		0.013	0.014	0.013	0.013
MW13	0.096	0.077	0.078	0.085	0.085		0.000	0.007	0.009
MW14	0.075	0.060	0.061	0.068	0.082	0.000		0.008	0.010
MW18	0.090	0.084	0.085	0.088	0.074	0.030	0.031		0.009
MW20	0.072	0.073	0.074	0.076	0.075	0.038	0.040	0.026	
Psp OFB-2007	0.132	0.115	0.117	0.102	0.142	0.126	0.123	0.125	0.111
WAM T63343	0.106	0.110	0.111	0.108	0.116	0.117	0.113	0.110	0.093
WAM T63344	0.106	0.110	0.111	0.108	0.116	0.117	0.113	0.110	0.093
WAM T63345	0.138	0.125	0.127	0.120	0.149	0.126	0.123	0.125	0.114
WAM T63371	0.135	0.122	0.124	0.117	0.145	0.123	0.119	0.122	0.111
WAM T65797	0.132	0.122	0.124	0.120	0.125	0.126	0.122	0.119	0.108
WAM T65802	0.132	0.122	0.124	0.120	0.125	0.126	0.122	0.119	0.108
WAM T66235	0.132	0.131	0.134	0.123	0.142	0.135	0.132	0.128	0.105
WAM T66236	0.137	0.131	0.133	0.128	0.136	0.132	0.128	0.124	0.109

Figure 8. Phylogenetic analysis of Schizomids based on variation at the COI gene. The specimens from Eliwana are highlighted in yellow and those from Western Hub are highlighted in turquoise. Species defined by genetic results are enclosed by red boxes. Dashes indicate groups where further investigation is necessary. Only the relevant portion of the phylogeny is shown.

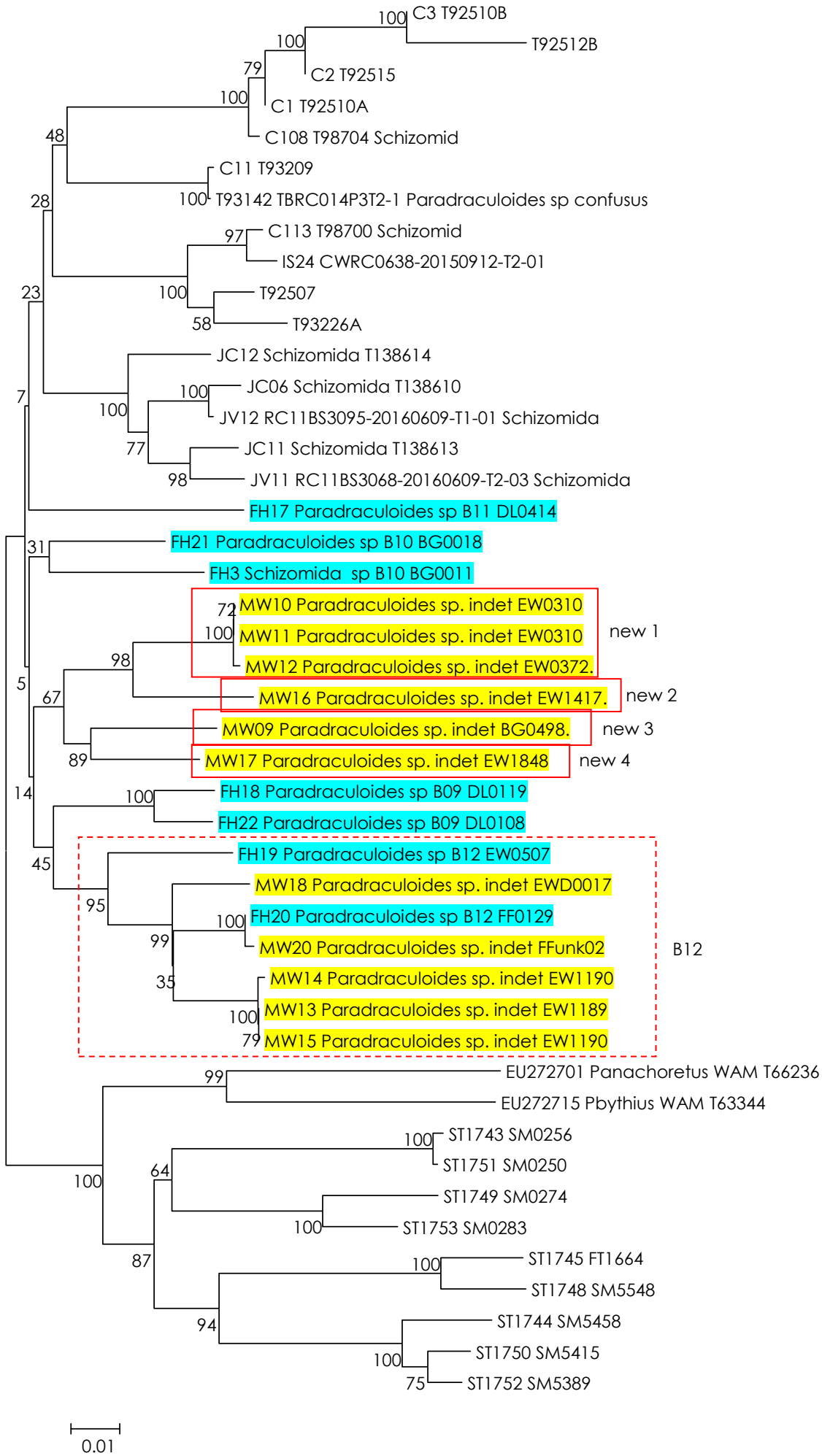
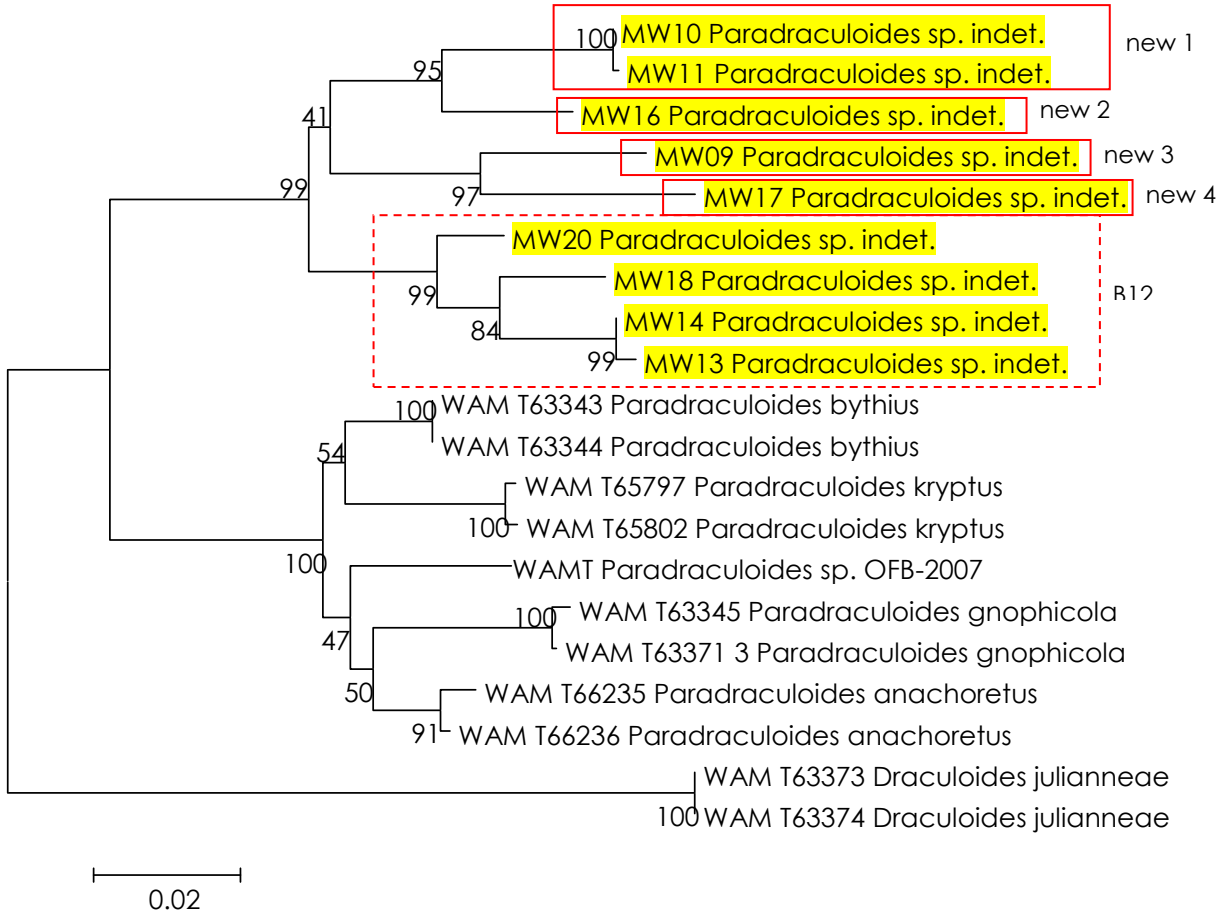

C3 T92510B
T92512B
C2 T92515
C1 T92510A
C108 T98704 Schizomid
C11 T93209
T93142 TBRC014P3T2-1 Paradraculoides sp confusus
C113 T98700 Schizomid
IS24 CWRC0638-20150912-T2-01
T92507
T93226A
JC12 Schizomida T138614
JC06 Schizomida T138610
JV12 RC11BS3095-20160609-T1-01 Schizomida
JC11 Schizomida T138613
JV11 RC11BS3068-20160609-T2-03 Schizomida
FH17 Paradraculoides sp B11 DL0414
FH21 Paradraculoides sp B10 BG0018
FH3 Schizomida sp B10 BG0011
MW10 Paradraculoides sp. indet EW0310
MW11 Paradraculoides sp. indet EW0310
MW12 Paradraculoides sp. indet EW0372.
new 1
MW16 Paradraculoides sp. indet EW1417.
new 2
MW09 Paradraculoides sp. indet BG0498.
new 3
MW17 Paradraculoides sp. indet EW1848
new 4
FH18 Paradraculoides sp B09 DL0119
FH22 Paradraculoides sp B09 DL0108
FH19 Paradraculoides sp B12 EW0507
MW18 Paradraculoides sp. indet EWD0017
FH20 Paradraculoides sp B12 FF0129
MW20 Paradraculoides sp. indet FFunk02
B12
MW14 Paradraculoides sp. indet EW1190
MW13 Paradraculoides sp. indet EW1189
MW15 Paradraculoides sp. indet EW1190
EU272701 Panachoretus WAM T66236
EU272715 Pbythius WAM T63344
ST1743 SM0256
ST1751 SM0250
ST1749 SM0274
ST1753 SM0283
ST1745 FT1664
ST1748 SM5548
ST1744 SM5458
ST1750 SM5415
ST1752 SM5389
0.01

Figure 8a. Phylogenetic analysis of Schizomids based on variation at the 12s gene. The specimens from Eliwana are highlighted in yellow. Species defined by genetic results are enclosed by red boxes. Dashes indicate groups where further investigation is necessary.



Symphyla - COI

One specimen of Symphyla was assigned to Symphyella on the basis of morphology: Symphyella sp. EW

The one specimen was compared with 59 specimens of regional Symphyla using a phylogenetic analysis and genetic distances. The specimen of Symphyla sp. EW formed a distinct genetic group that did not show close genetic similarities to the reference specimens (Figure 9).

Symphyla sp. EW differed from the reference specimens by ≥16% sequence divergence (Table 10), thus the species appears to be restricted to the Eliwana area, although specimens were not available for comparison from Western Hub.

In summary, one species of Symphyla was detected using COI:
Symphyla sp. EW (appears restricted to Eliwana, based on material available for comparison)

Symphyla-12s

The one specimen of Symphyla was successfully sequenced for 12s. Helix is lacking a reference dataset for Symphyla for 12s, so nor further analysis was conducted.

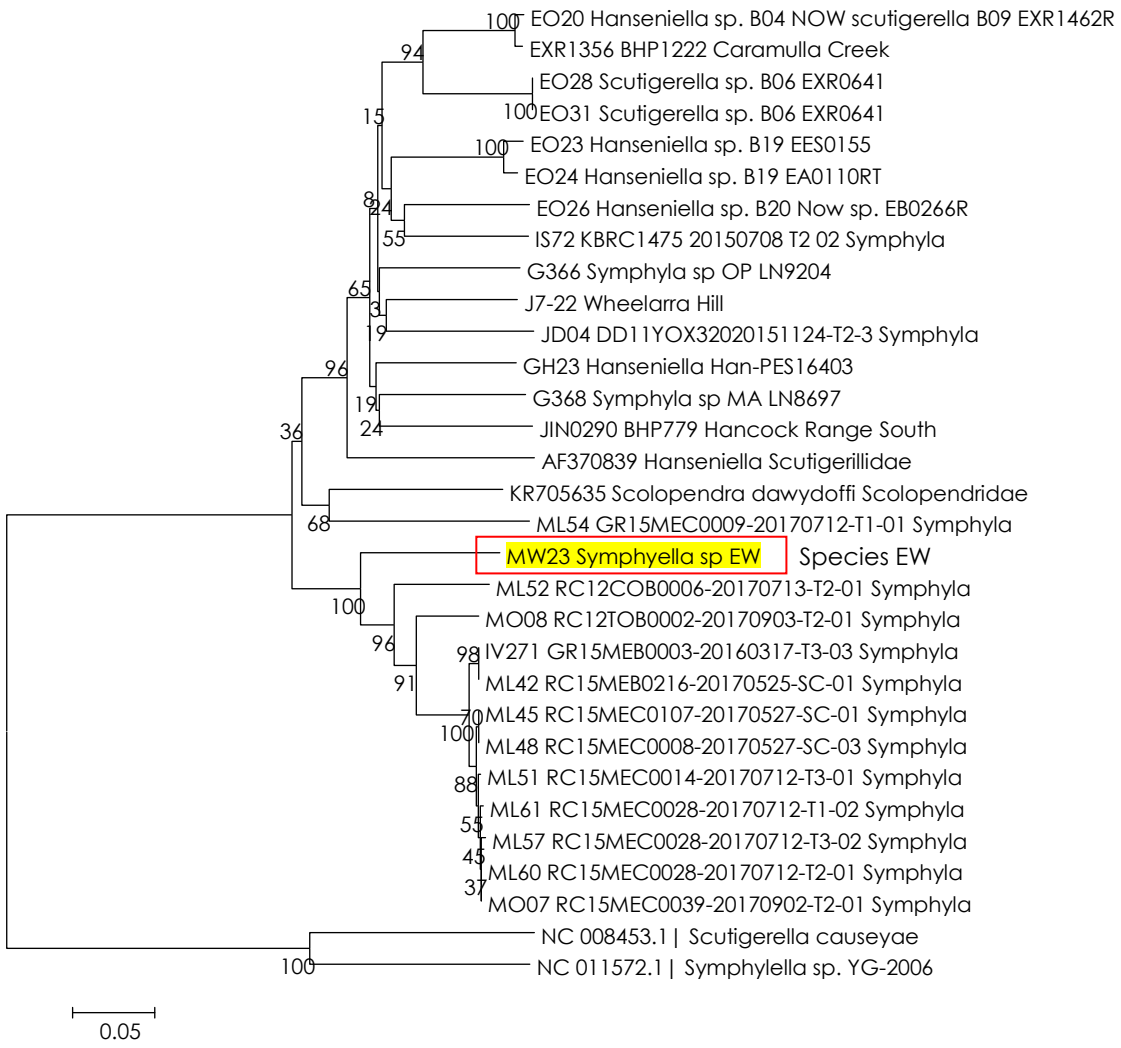
Symphyla 28s

The specimen of Symphyla did not amplify for 28s.

Table 10. COI pairwise distances between Eliwana and reference specimens of Symphyla (highlighted in yellow).

Specimen ID	MW23
MW23	
AF370839	0.270
EO20	0.242
EO23	0.236
EO24	0.233
EO26	0.251
EO28	0.267
EO31	0.267
EXR1356	0.246
G366	0.251
G368	0.251
GH23	0.250
IS72	0.236
IV271	0.161
J7-22	0.235
JD04	0.260
JIN0290	0.278
KR705635	0.234
ML42	0.163
ML45	0.163
ML48	0.163
ML51	0.163
ML52	0.164
ML54	0.262
ML57	0.166
ML60	0.163
ML61	0.166
MO07	0.164
MO08	0.168

Figure 9. Phylogenetic analysis of Symphyla based on variation at the COI gene. The specimen from Eliwana is highlighted in yellow. Species defined by genetic results are enclosed by red boxes.



Thysanura-COI

Three specimens of Thysanura were assigned to three species based on morphology:
Lepidospora sp. B10
Lepidospora sp. B15
Thysanura sp. (may be same as B10)

One specimen, Lepidospora sp. B10, amplified for COI and the remaining two specimens failed to amplify. Owing to a lack of suitable reference data set for COI for Thysanura, no further analysis was conducted. Previously collected specimens of Thysanura from Western Hub belonged to the Nicoletiidae, but were sequenced for 12s only.

Thysanura-12s

Sequencing of Thysanura failed for 12s.

Thysanura-28s

Two specimens of Thysanura yielded 28s sequences, Lepidospera B10 and Thysanura sp. The two specimens differed by 10.5% sequence divergence, indicating that they belong to two different species. Lepidospora B10 and Thysanura sp. both showed the best match to species of Nicoletiidae on Genbank.

In summary, in addition to the species detected with COI (Lepidospora B10), we detected a second species of Thysanura (Thysanura sp.) using 28s,

Final summary

Of the 26 species detected with COI, 12s and 28s, three have been detected previously in the Pilbara (Paramelitidae sp. H-AMP023, Carabidae sp. H-CCA02, Paradraculoides sp. B12),

whereas the other 23 appear to be restricted to Eliwana, based on the material available for comparison.

References

Drummond AJ, Ashton B, Buxton S, Cheung M, Cooper A, Duran C, Field M, Heled J, Kearse M, Markowitz S, Moir R, Stones-Havas S, Sturrock S, Thierer T, Wilson A (2011) Geneious v5.4, http://www.geneious.com/

Harvey, M. S., Berry, O. Edward, K. L., Humphreys, G. (2008) Molecular and morphological systematics of hypogean schizomids (Schizomida: Hubbardiidae) in semiarid Australia. Invertebrate Systematics 22: 167-194.

Hebert, P.D.N., Cywinska, A., Ball, S.L., deWaard J.R. (2003a). Biological identifications through DNA barcodes. Proceedings of the Royal Society of London B 270: 313-321.

Hebert, P.D.N., Ratnasingham, S., deWaard J.R. (2003b). Barcoding animal life: cytochrome c oxidase subunit 1 divergences among closely related species. Proceedings of the Royal Society of London B (supplement) 270: S96-S99.

Posada, D., Crandall, K.A. (1998). MODELTEST: testing the model of DNA substitution. Bioinformatics 14: 817-818.

Thompson, J., Higgins, D., and Gibson, T. (1994). CLUSTAL W: improving the sensitivity of progressive multiple sequence alignment through sequence weighting, position-specific gap penalties and weight matrix choice. Nucleic Acids Research 22: 4673–4680. doi:10.1093/nar/ 22.22.4673

10.2 APPENDIX 2 - DRILL LOGS REFERENCED IN REPORT:

WESTERN HUB BORE LOG

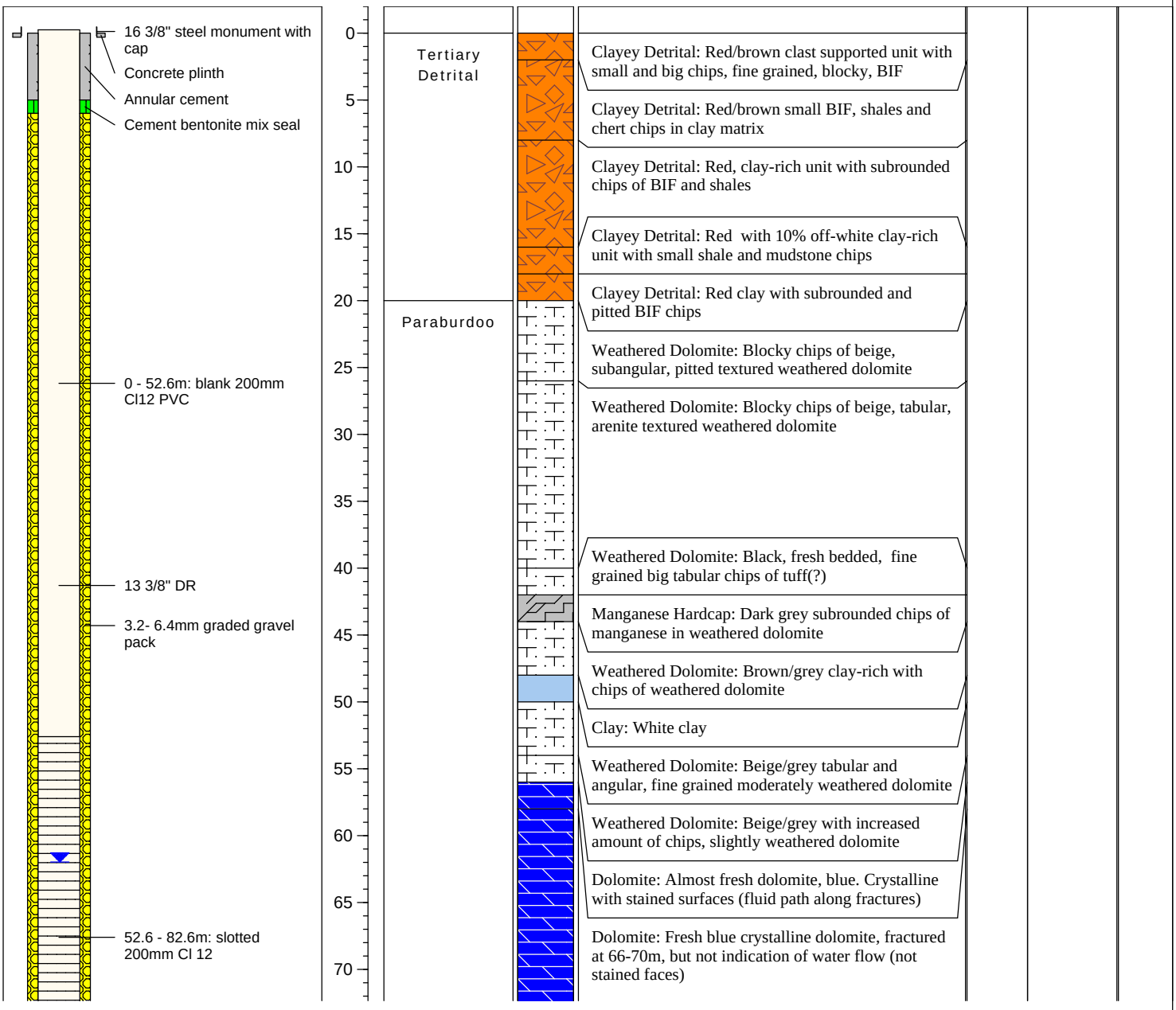
BOREHOLE NUMBER
EWPB001

Fortescue Metals Group Ltd
Level 2, 87 Adelaide Terrace
East Perth, WA 6004
PH: 08 62188888 FAX: 08 62188880

PROJECT NAME:	**Western Hub Feasibility Assessment**
LOCATION:	**Site 08**
DRILLING CO:	**Eastern Well**
DRILLING METHOD:	**DR**
LOGGED BY:	**MjRS**
EASTING (m):	**502608.95**
NORTHING (m):	**7510275.88**
ELEVATION (mAHD):	**581.44**
DRILLING DIAMETER(S) (mm):	**304.8**
COLLAR STICKUP (m)	**0.461**

DATE BEGUN: **16/11/2016** DATE COMPLETED: **19/11/2016**

FINAL BORE DETAILS		
Drilled Depth (mbgl):	82.6	
Cased Depth (mbgl):	82.6	
Casing Stick Up (magl):	0.25	
Development Yield (l/s):	0	
Water Level (mbgl) & Date:	61.97	5/12/2016
Quality - pH & EC (µS/cm):	N/A	N/A



Comments: Very little yield. SWL after drilling at 81m. End of casing probably acting as sump and water seeping from 56-58m. Bore developed by flushing

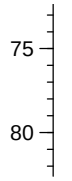
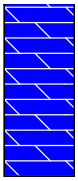
WESTERN HUB BORE LOG

BOREHOLE NUMBER
EWPB001

Fortescue Metals Group Ltd
Level 2, 87 Adelaide Terrace
East Perth, WA 6004
PH: 08 62188888 FAX: 08 62188880

PROJECT NAME: **Western Hub Feasibility Assessment**
LOCATION: **Site 08**
DRILLING CO: **Eastern Well**
DRILLING METHOD: **DR**
LOGGED BY: **MjRS**
EASTING (m): **502608.95**
NORTHING (m): **7510275.88**
ELEVATION (mAHD): **581.44**
DRILLING DIAMETER(S) (mm): **304.8**
COLLAR STICKUP (m) **0.461**
DATE BEGUN: **16/11/2016** DATE COMPLETED: **19/11/2016**

FINAL BORE DETAILS		
Drilled Depth (mbgl):	82.6	
Cased Depth (mbgl):	82.6	
Casing Stick Up (magl):	0.25	
Development Yield (l/s):	0	
Water Level (mbgl) & Date:	61.97	5/12/2016
Quality - pH & EC (µS/cm):	N/A	N/A

BORE CONSTRUCTION	DEPTH	STRATIGRAPHY	LITHOLOGY	DESCRIPTION	YIELD (l/s)	EC (µS/cm)	pH
							

Comments: Very little yield. SWL after drilling at 81m. End of casing probably acting as sump and water seeping from 56-58m. Bore developed by flushing

WESTERN HUB BORE LOG

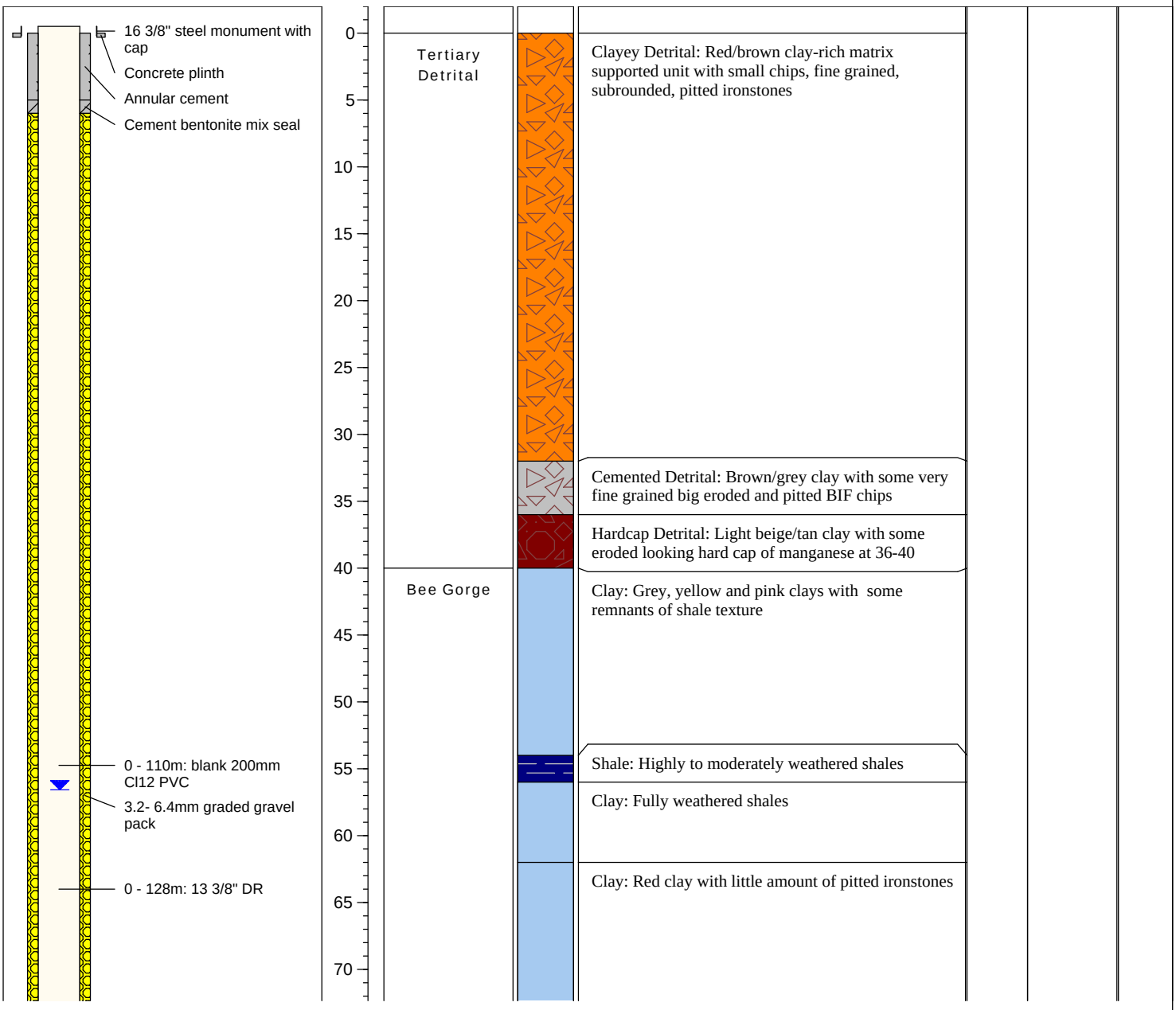
BOREHOLE NUMBER
EWPB002

Fortescue Metals Group Ltd
Level 2, 87 Adelaide Terrace
East Perth, WA 6004
PH: 08 62188888 FAX: 08 62188880

PROJECT NAME:	**Western Hub Feasibility Assessment**
LOCATION:	**Site 07**
DRILLING CO:	**Eastern Well**
DRILLING METHOD:	**DR**
LOGGED BY:	**MjRS**
EASTING (m):	**493167.82**
NORTHING (m):	**7512915.44**
ELEVATION (mAHD):	**566.26**
DRILLING DIAMETER(S) (mm):	**340.8**
COLLAR STICKUP (m)	**0.51**

DATE BEGUN: **20/11/2016** DATE COMPLETED: **25/11/2016**

FINAL BORE DETAILS		
Drilled Depth (mbgl):	128	
Cased Depth (mbgl):	128	
Casing Stick Up (magl):	0.505	
Development Yield (l/s):	15	
Water Level (mbgl) & Date:	56.565	26/11/2016
Quality - pH & EC (µS/cm):	8.03	1081



Comments: Water intersected at 104m after drilling through low yielding shales.

WESTERN HUB BORE LOG

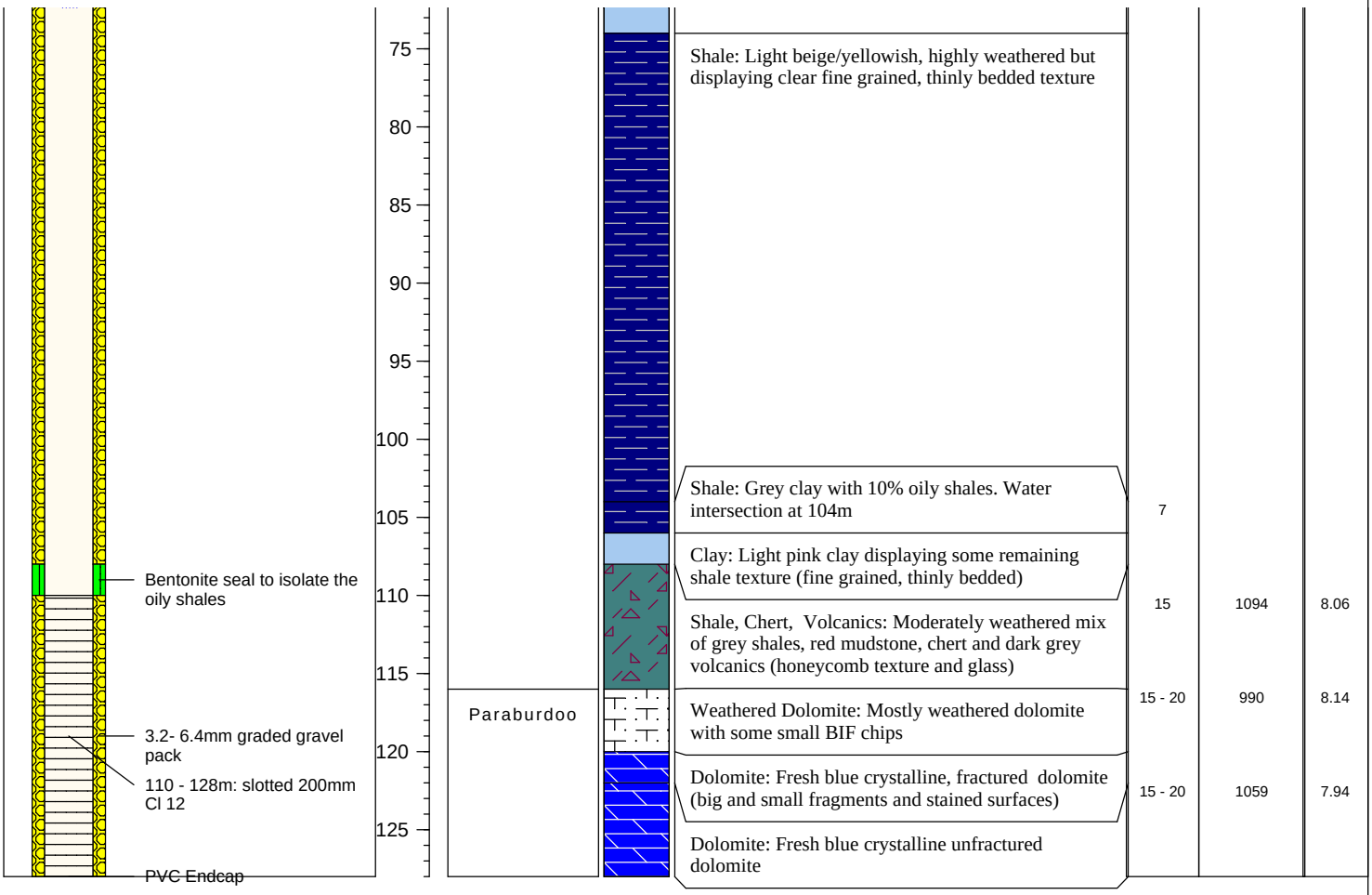
BOREHOLE NUMBER
EWPB002

Fortescue Metals Group Ltd
Level 2, 87 Adelaide Terrace
East Perth, WA 6004
PH: 08 62188888 FAX: 08 62188880

PROJECT NAME:	**Western Hub Feasibility Assessment**
LOCATION:	**Site 07**
DRILLING CO:	**Eastern Well**
DRILLING METHOD:	**DR**
LOGGED BY:	**MjRS**
EASTING (m):	**493167.82**
NORTHING (m):	**7512915.44**
ELEVATION (mAHD):	**566.26**
DRILLING DIAMETER(S) (mm):	**340.8**
COLLAR STICKUP (m)	**0.51**

DATE BEGUN: **20/11/2016** DATE COMPLETED: **25/11/2016**

FINAL BORE DETAILS		
Drilled Depth (mbgl):	128	
Cased Depth (mbgl):	128	
Casing Stick Up (magl):	0.505	
Development Yield (l/s):	15	
Water Level (mbgl) & Date:	56.565	26/11/2016
Quality - pH & EC (µS/cm):	8.03	1081



Comments: Water intersected at 104m after drilling through low yielding shales.

WESTERN HUB BORE LOG

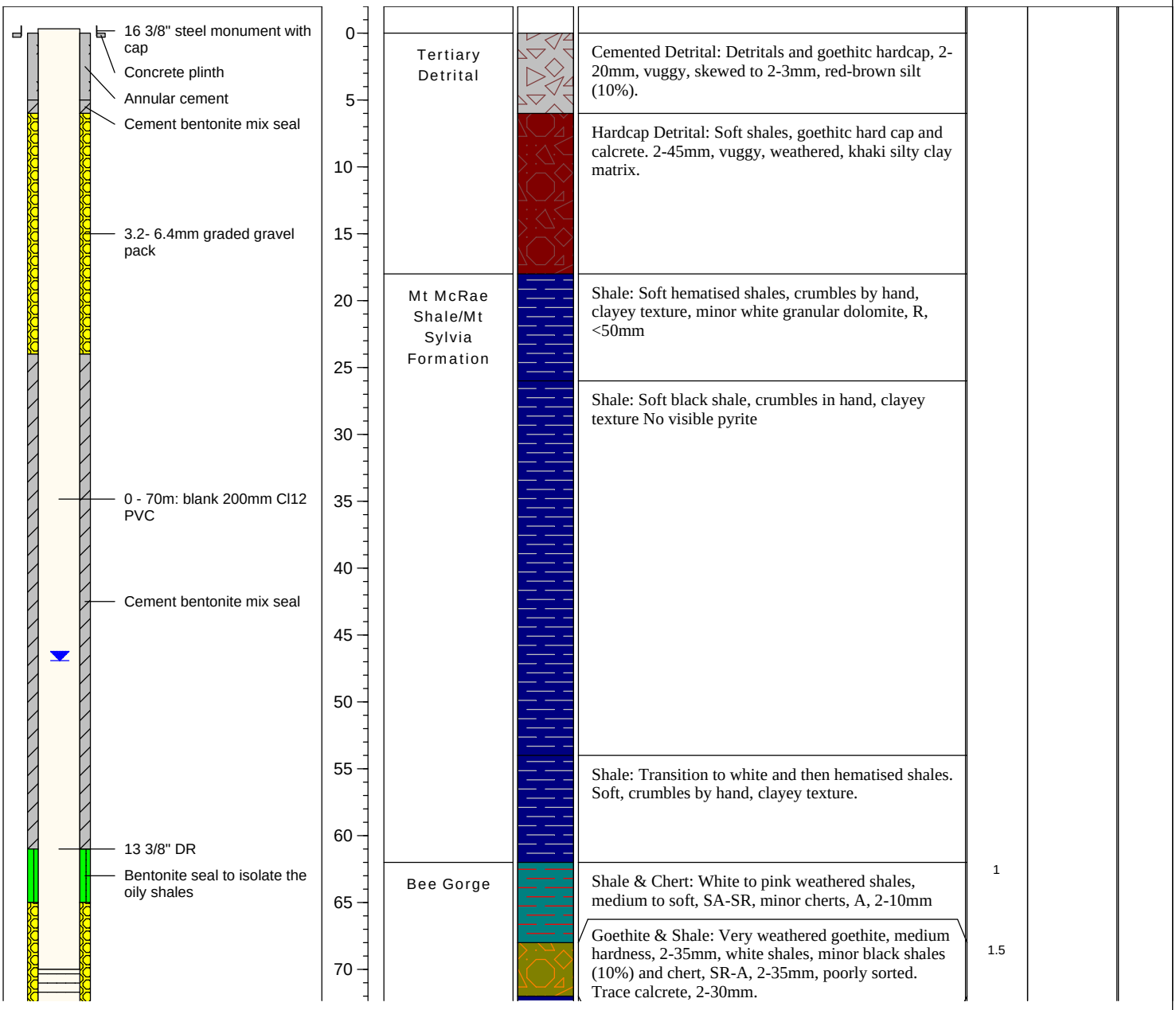
BOREHOLE NUMBER
EWPB003

Fortescue Metals Group Ltd
Level 2, 87 Adelaide Terrace
East Perth, WA 6004
PH: 08 62188888 FAX: 08 62188880

PROJECT NAME:	**Western Hub Feasibility Assessment**
LOCATION:	**Site 03**
DRILLING CO:	**Eastern Well**
DRILLING METHOD:	**DR**
LOGGED BY:	**GL**
EASTING (m):	**484771.41**
NORTHING (m):	**7513230.54**
ELEVATION (mAHD):	**512.03**
DRILLING DIAMETER(S) (mm):	**304.8**
COLLAR STICKUP (m)	**0.545**

DATE BEGUN: **26/11/2016** DATE COMPLETED: **7/12/2016**

FINAL BORE DETAILS		
Drilled Depth (mbgl):	122	
Cased Depth (mbgl):	122	
Casing Stick Up (magl):	0.327	
Development Yield (l/s):	12	
Water Level (mbgl) & Date:	46.92	12/11/2016
Quality - pH & EC (µS/cm):	8.33	936



Comments: Intercepted 28m of black shale above water table and another horizon of 6m below water table. 10 L/s yield from shales. During construction, a length of the outside steel casing fall, smashing the PVC; the PVC had to be drilled out and the bore re-cased and re-packed. Hole should be considered partially penetrating

WESTERN HUB BORE LOG

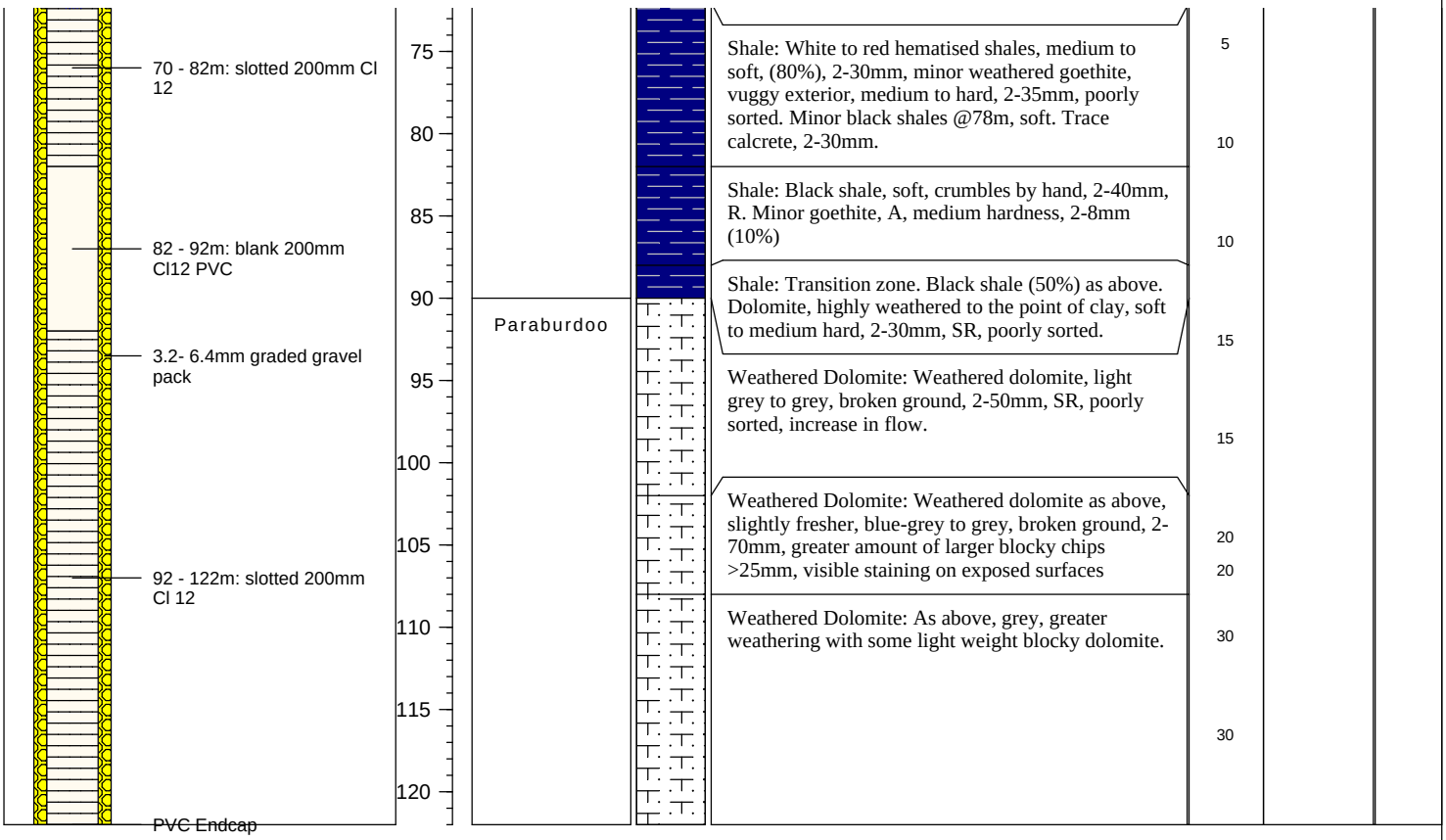
BOREHOLE NUMBER
EWPB003

Fortescue Metals Group Ltd
Level 2, 87 Adelaide Terrace
East Perth, WA 6004
PH: 08 62188888 FAX: 08 62188880

PROJECT NAME:	**Western Hub Feasibility Assessment**
LOCATION:	**Site 03**
DRILLING CO:	**Eastern Well**
DRILLING METHOD:	**DR**
LOGGED BY:	**GL**
EASTING (m):	**484771.41**
NORTHING (m):	**7513230.54**
ELEVATION (mAHD):	**512.03**
DRILLING DIAMETER(S) (mm):	**304.8**
COLLAR STICKUP (m)	**0.545**

DATE BEGUN: **26/11/2016** DATE COMPLETED: **7/12/2016**

FINAL BORE DETAILS		
Drilled Depth (mbgl):	122	
Cased Depth (mbgl):	122	
Casing Stick Up (magl):	0.327	
Development Yield (l/s):	12	
Water Level (mbgl) & Date:	46.92	12/11/2016
Quality - pH & EC (µS/cm):	8.33	936



Comments: Intercepted 28m of black shale above water table and another horizon of 6m below water table. 10 L/s yield from shales. During construction, a length of the outside steel casing fall, smashing the PVC; the PVC had to be drilled out and the bore re-cased and re-packed. Hole should be considered partially penetrating

WESTERN HUB BORE LOG

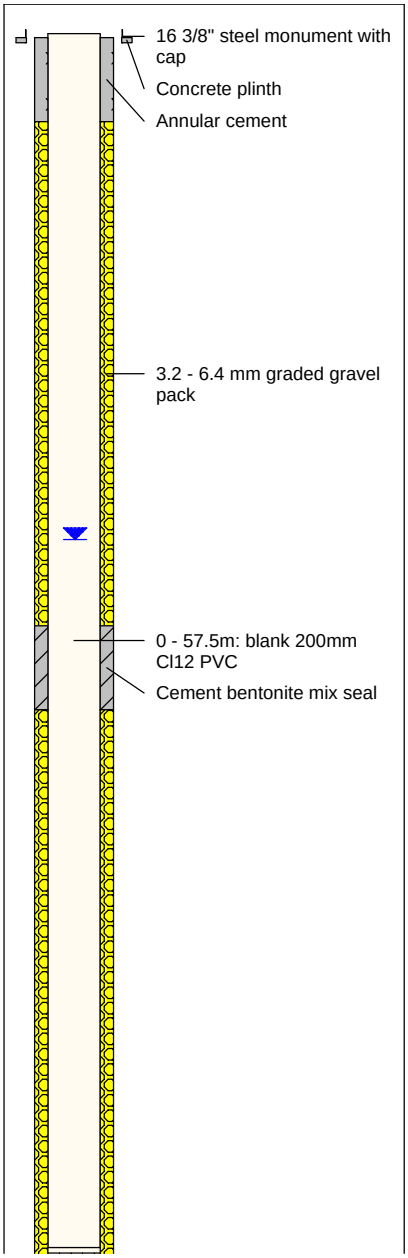
BOREHOLE NUMBER
EWPB004

Fortescue Metals Group Ltd
Level 2, 87 Adelaide Terrace
East Perth, WA 6004
PH: 08 62188888 FAX: 08 62188880

PROJECT NAME:	**Western Hub Feasibility Assessment**
LOCATION:	**Site 02**
DRILLING CO:	**Eastern Well**
DRILLING METHOD:	**DR**
LOGGED BY:	**MjRS**
EASTING (m):	**484994.99**
NORTHING (m):	**7513687.57**
ELEVATION (mAHD):	**503.19**
DRILLING DIAMETER(S) (mm):	**304.8**
COLLAR STICKUP (m)	**0.465**

DATE BEGUN: **25/10/2016** DATE COMPLETED: **26/11/2016**

FINAL BORE DETAILS		
Drilled Depth (mbgl):	158	
Cased Depth (mbgl):	156	
Casing Stick Up (magl):	0.241	
Development Yield (l/s):	35	
Water Level (mbgl) & Date:	29.87	11/12/2016
Quality - pH & EC (µS/cm):	8.1	1013



DEPTH	STRATIGRAPHY	DESCRIPTION	YIELD (l/s)	EC (µS/cm)	pH
0	Tertiary Detrital	Clayey Ironstone: Mid red/brown clay with f.gr massive textured angular ironstones up to 1cm and 10% magnetite			
5		Clayey Ironstone: Light brown/pink clay with small chips of ironstone and trace of grey shales			
10	Tertiary Detrital/CID	Hardcap Detrital: Same but with very little clay			
15		Clay: Mostly clay, light brown/pink colour and very small shale chips			
20	Bee Gorge	Cemented Detrital: Cemented CID; mostly goethite, hematite and limonite with very little clay and 10% reddish mudstone			
25		Cemented Detrital: Limonitic clay with goethite, limonite and hematite			
30		Weathered Shale and Chert: Grey/green clay with 1m size carbonatic grey shale			
35		Weathered Shale and Chert: Brown/grey clay with some angular very fine grained chips of chert up to 1cm size			
40		Weathered Shale and Chert: Off-white plastic clay with chert	5		
45		Weathered Shale and Chert: Highly weathered grey shales with 10% small chips of chert	5	1001	8.45
50	Paraburdoo	Clay: Off-white/light pink plastic clay (highly weathered red mudstone and chert)			
55		Weathered Shale and Chert: Grey/green plastic clay with chips up to 1 cm long of dark grey, subangular and pitted ironstones and beige, angular mudstone	12	975	8.42
60		Weathered Shale and Chert: Brown plastic clay with tabular, angular chips up to 1.5cm of ironstones and mudstone; some indication of harcap	15	965	8.25
65		Weathered Shale and Chert: Clay-rich (brown/grey colour) contact between ironstone/mudstone and dolomite (angular chips of both ironstones/mudstone and dolomite)	20	938	8.09
70		Weathered Dolomite: Moderately weathered, highly fractured dolomite (carbonate cemented arenite)	30	973	8.55

Comments: Cavity at 70m; bore needing more gravel than planned. End cap damaged during airlifting. Rest of bore confirmed intact with downhole camera. 0.5m cement endcap placed after a month delay

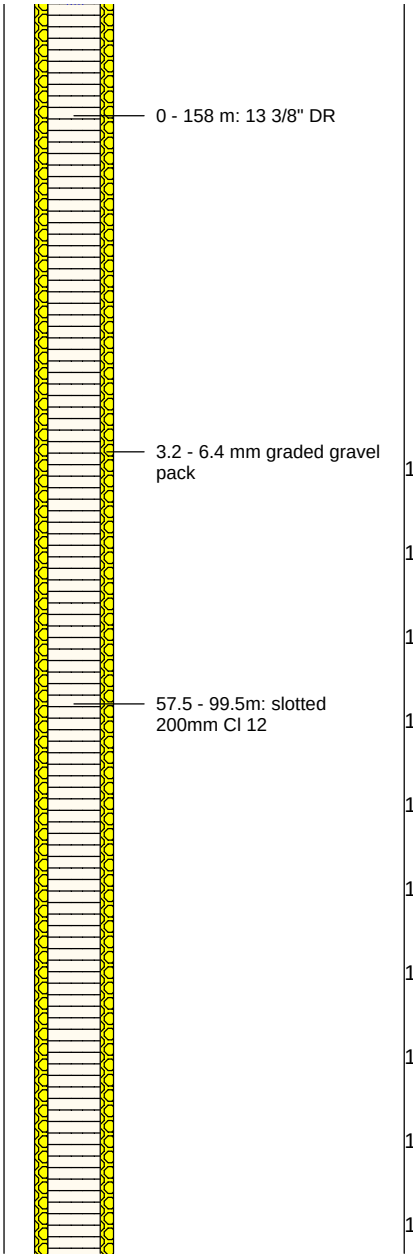
WESTERN HUB BORE LOG

BOREHOLE NUMBER
EWPB004

Fortescue Metals Group Ltd
Level 2, 87 Adelaide Terrace
East Perth, WA 6004
PH: 08 62188888 FAX: 08 62188880

PROJECT NAME: **Western Hub Feasibility Assessment**
LOCATION: **Site 02**
DRILLING CO: **Eastern Well**
DRILLING METHOD: **DR**
LOGGED BY: **MjRS**
EASTING (m): **484994.99**
NORTHING (m): **7513687.57**
ELEVATION (mAHD): **503.19**
DRILLING DIAMETER(S) (mm): **304.8**
COLLAR STICKUP (m) **0.465**
DATE BEGUN: **25/10/2016** DATE COMPLETED: **26/11/2016**

FINAL BORE DETAILS		
Drilled Depth (mbgl):	158	
Cased Depth (mbgl):	156	
Casing Stick Up (magl):	0.241	
Development Yield (l/s):	35	
Water Level (mbgl) & Date:	29.87	11/12/2016
Quality - pH & EC (µS/cm):	8.1	1013



DEPTH	STRATIGRAPHY	LITHOLOGY	DESCRIPTION	YIELD (l/s)	EC (µS/cm)	pH
75			Weathered Dolomite: Same but with limonite alteration in fracture planes and quartz crystals in small open fractures	30	943	8.39
80			Manganese Hardcap: Dark grey-blue, dull, subangular to subrounded manganese (massive, botroydal and small fibresize crystals)	30	926	8.23
85			Weathered Dolomite: Light beige, carbonate cemented arenite (dolomite) with 10% manganese chips	30	918	8.51
90			Weathered Dolomite: 5% manganese chips	30	890	8.22
95				>30	943	8.02
100				>30	923	7.86
105				>30	914	7.68
110						
115			Weathered Dolomite: Light beige, carbonate cemented , sand size (arenite) with trace of manganese chips	>30	932	7.63
120				>30	938	7.48
125				>30	913	7.48
130				>30	1056	8.13
135				>30	1113	7.9
140				>30	1224	7.81
145						

Comments: Cavity at 70m; bore needing more gravel than planned. End cap damaged during airlifting. Rest of bore confirmed intact with downhole camera. 0.5m cement endcap placed after a month delay

WESTERN HUB BORE LOG

BOREHOLE NUMBER
EWPB004

Fortescue Metals Group Ltd
Level 2, 87 Adelaide Terrace
East Perth, WA 6004
PH: 08 62188888 FAX: 08 62188880

PROJECT NAME: **Western Hub Feasibility Assessment**
LOCATION: **Site 02**
DRILLING CO: **Eastern Well**
DRILLING METHOD: **DR**
LOGGED BY: **MjRS**
EASTING (m): **484994.99**
NORTHING (m): **7513687.57**
ELEVATION (mAHD): **503.19**
DRILLING DIAMETER(S) (mm): **304.8**
COLLAR STICKUP (m) **0.465**
DATE BEGUN: **25/10/2016** DATE COMPLETED: **26/11/2016**

FINAL BORE DETAILS		
Drilled Depth (mbgl):	158	
Cased Depth (mbgl):	156	
Casing Stick Up (magl):	0.241	
Development Yield (l/s):	35	
Water Level (mbgl) & Date:	29.87	11/12/2016
Quality - pH & EC (µS/cm):	8.1	1013

BORE CONSTRUCTION	DEPTH	STRATIGRAPHY	LITHOLOGY	DESCRIPTION	YIELD (l/s)	EC (µS/cm)	pH
PVC Endcap Bottom backfill	150 155	West Angelas		Shale: Grey/brown shales	>30	1231	7.76

Comments: Cavity at 70m; bore needing more gravel than planned. End cap damaged during airlifting. Rest of bore confirmed intact with downhole camera. 0.5m cement endcap placed after a month delay

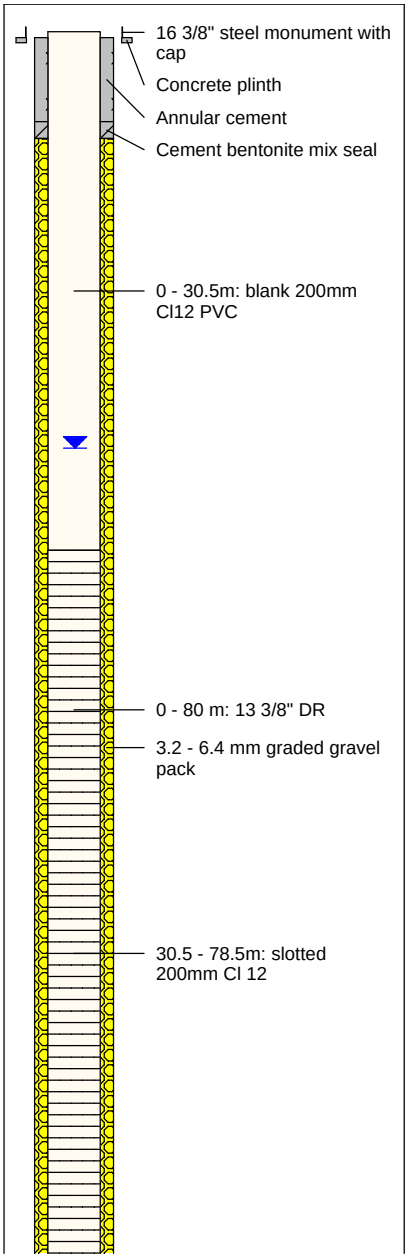
WESTERN HUB BORE LOG

BOREHOLE NUMBER
EWPB006

Fortescue Metals Group Ltd
Level 2, 87 Adelaide Terrace
East Perth, WA 6004
PH: 08 62188888 FAX: 08 62188880

PROJECT NAME: **Western Hub Feasibility Assessment**
LOCATION: **Site 04**
DRILLING CO: **Eastern Well**
DRILLING METHOD: **DR**
LOGGED BY: **MjRS**
EASTING (m): **481396.35**
NORTHING (m): **7513603.38**
ELEVATION (mAHD): **482.82**
DRILLING DIAMETER(S) (mm): **304.8**
COLLAR STICKUP (m) **0.625**
DATE BEGUN: **7/12/2016** DATE COMPLETED: **13/12/2016**

FINAL BORE DETAILS		
Drilled Depth (mbgl):	80	
Cased Depth (mbgl):	78.5	
Casing Stick Up (magl):	0.361	
Development Yield (l/s):	20	
Water Level (mbgl) & Date:	24.43	16/12/2016
Quality - pH & EC (µS/cm):	8.98	1058



DEPTH	STRATIGRAPHY	LITHOLOGY	DESCRIPTION	YIELD (l/s)	EC (µS/cm)	pH
0	Tertiary Detrital		Clayey Detrital: Light brown, clay rich detritals			
5	Bee Gorge		Clay: Dark grey, semi plastic clays after shales			
10			Weathered Dolomite: Moderately weathered dark grey dolomite.			
15	Paraburdoo					
20			Weathered Dolomite: Light brown bleyish, moderately weathered fractured dolomite			
25						
30						
35						
40						
45						
50			Weathered Dolomite: Light brown and grey, moderately to fresh, fractured dolomite. Some big chips among the small ones, indicating pervasive fracture	10	967	7.94
55				10	981	7.69
60			Weathered Dolomite: Brown and grey, equidimentional small chips clearly weathered	15	995	7.79
65				15	968	7.79
70						

Comments: During drilling of the production bore the flow of water justified drilling deeper than planned and deeper than the monitoring bore was.

WESTERN HUB BORE LOG

BOREHOLE NUMBER
EWPB006

Fortescue Metals Group Ltd
Level 2, 87 Adelaide Terrace
East Perth, WA 6004
PH: 08 62188888 FAX: 08 62188880

PROJECT NAME:	**Western Hub Feasibility Assessment**
LOCATION:	**Site 04**
DRILLING CO:	**Eastern Well**
DRILLING METHOD:	**DR**
LOGGED BY:	**MjRS**
EASTING (m):	**481396.35**
NORTHING (m):	**7513603.38**
ELEVATION (mAHD):	**482.82**
DRILLING DIAMETER(S) (mm):	**304.8**
COLLAR STICKUP (m)	**0.625**

DATE BEGUN: **7/12/2016** DATE COMPLETED: **13/12/2016**

FINAL BORE DETAILS		
Drilled Depth (mbgl):	80	
Cased Depth (mbgl):	78.5	
Casing Stick Up (magl):	0.361	
Development Yield (l/s):	20	
Water Level (mbgl) & Date:	24.43	16/12/2016
Quality - pH & EC (µS/cm):	8.98	1058

BORE CONSTRUCTION	DEPTH	STRATIGRAPHY	LITHOLOGY	DESCRIPTION	YIELD (l/s)	EC (µS/cm)	pH
PVC Endcap Bottom fallback	75 80				20	998	8.05

Comments: During drilling of the production bore the flow of water justified drilling deeper than planned and deeper than the monitoring bore was.

WESTERN HUB BORE LOG

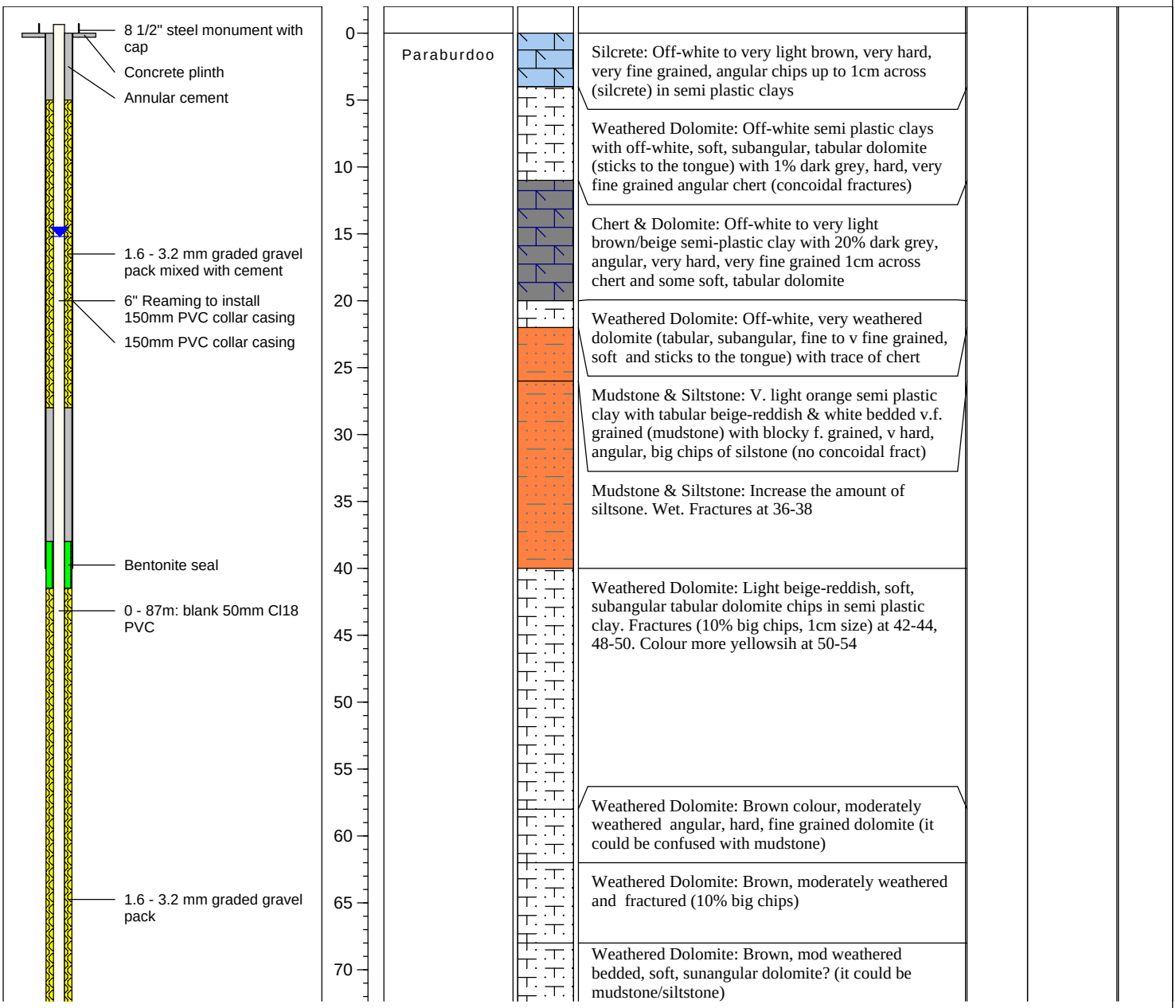
BOREHOLE NUMBER
FFMB001

Fortescue Metals Group Ltd
Level 2, 87 Adelaide Terrace
East Perth, WA 6004
PH: 08 62188888 FAX: 08 62188880

PROJECT NAME:	**Western Hub Feasibility Assessment**
LOCATION:	**Site 11**
DRILLING CO:	**Foraco**
DRILLING METHOD:	**RC**
LOGGED BY:	**JB**
EASTING (m):	**522377.46**
NORTHING (m):	**7511010.05**
ELEVATION (mAHD):	**565.12**
DRILLING DIAMETER(S) (mm):	**140**
COLLAR STICKUP (m)	**0.705**

DATE BEGUN: **14/10/2016** DATE COMPLETED: **16/10/2016**

FINAL BORE DETAILS		
Drilled Depth (mbgl):	106	
Cased Depth (mbgl):	105	
Casing Stick Up (magl):	0.651	
Development Yield (l/s):	17	
Water Level (mbgl) & Date:	15.189	20/10/2016
Quality - pH & EC (µS/cm):	8.2	2670



Comments: Annulus blocked at 88m

WESTERN HUB BORE LOG

BOREHOLE NUMBER
FFMB001

Fortescue Metals Group Ltd
Level 2, 87 Adelaide Terrace
East Perth, WA 6004
PH: 08 62188888 FAX: 08 62188880

PROJECT NAME:	**Western Hub Feasibility Assessment**
LOCATION:	**Site 11**
DRILLING CO:	**Foraco**
DRILLING METHOD:	**RC**
LOGGED BY:	**JB**
EASTING (m):	**522377.46**
NORTHING (m):	**7511010.05**
ELEVATION (mAHD):	**565.12**
DRILLING DIAMETER(S) (mm):	**140**
COLLAR STICKUP (m)	**0.705**

DATE BEGUN: **14/10/2016** DATE COMPLETED: **16/10/2016**

FINAL BORE DETAILS		
Drilled Depth (mbgl):	106	
Cased Depth (mbgl):	105	
Casing Stick Up (magl):	0.651	
Development Yield (l/s):	17	
Water Level (mbgl) & Date:	15.189	20/10/2016
Quality - pH & EC (µS/cm):	8.2	2670

BORE CONSTRUCTION	DEPTH	STRATIGRAPHY	LITHOLOGY	DESCRIPTION	YIELD (l/s)	EC (µS/cm)	pH
0 - 106m 140mm hole 87 - 105m: slotted 50mm Cl18 Annulus blocked at 88m PVC Endcap	75 80 85 90 95 100 105			Chert & Shale: Dark grey, big blocky chips, very hard, v f grained, sub-concoidal fracture, some lamination Shale: Grey (and trace of black - some oily shale) v. f grained well bedded clearly shale Dolomite: Fresh but very fractured (some very big chips, and surfaces with brown stain) Very high flows. EOH			

Comments: Annulus blocked at 88m

WESTERN HUB BORE LOG

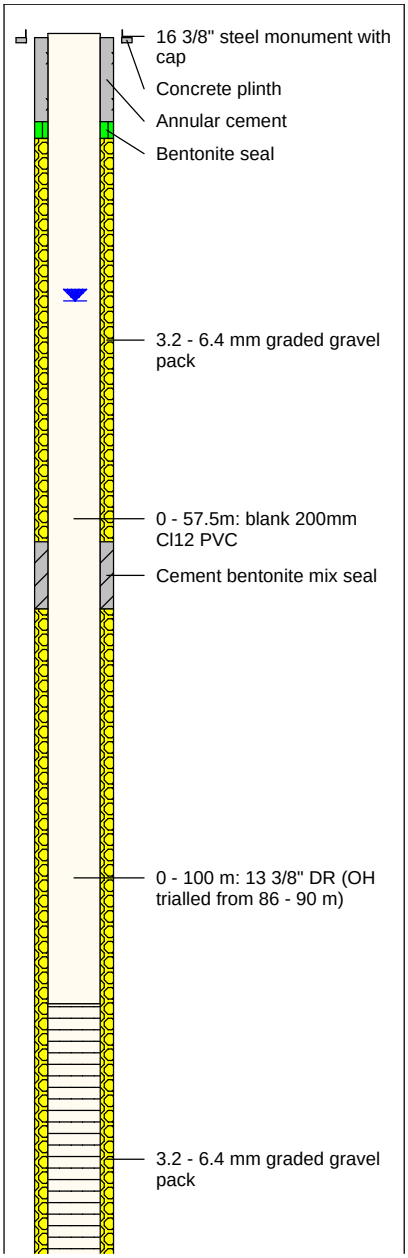
BOREHOLE NUMBER
FFPB001

Fortescue Metals Group Ltd
Level 2, 87 Adelaide Terrace
East Perth, WA 6004
PH: 08 62188888 FAX: 08 62188880

PROJECT NAME:	**Western Hub Feasibility Assessment**
LOCATION:	**Site 11**
DRILLING CO:	**Eastern Well**
DRILLING METHOD:	**DR**
LOGGED BY:	**MjRS**
EASTING (m):	**522379.66**
NORTHING (m):	**7511026.41**
ELEVATION (mAHD):	**565.39**
DRILLING DIAMETER(S) (mm):	**304.8**
COLLAR STICKUP (m)	**0.461**

DATE BEGUN: **4/10/2016** DATE COMPLETED: **11/10/2016**

FINAL BORE DETAILS		
Drilled Depth (mbgl):	100	
Cased Depth (mbgl):	99.5	
Casing Stick Up (magl):	0.253	
Development Yield (l/s):	50	
Water Level (mbgl) & Date:	15.657	20/10/2016
Quality - pH & EC (µS/cm):	8.97	2640



DEPTH	STRATIGRAPHY	LITHOLOGY	DESCRIPTION	YIELD (l/s)	EC (µS/cm)	pH
0	Paraburdoo		Silcrete: Off-white to very light brown, very hard, very fine grained, angular chips up to 1cm across (silcrete) in semi plastic clays			
5			Weathered Dolomite: Off-white semi plastic clays with off-white, soft, subangular, tabular dolomite (sticks to the tongue) with 1% dark grey, hard, very fine grained angular chert (concoidal fractures)			
10						
15			Chert & Dolomite: Off-white to very light brown/beige semi-plastic clay with 20% dark grey, angular, very hard, very fine grained 1cm across chert and some soft, tabular dolomite			
20			Weathered Dolomite: Off-white, very weathered dolomite (tabular, subangular, fine to v fine grained, soft and sticks to the tongue) with trace of chert			
25						
30			Mudstone & Siltstone: V. light orange semi plastic clay with tabular beige-reddish & white bedded v.f. grained (mudstone) with blocky f. grained, v hard, angular, big chips of silstone (no concoidal fract)	4	3140	8
35			Mudstone & Siltstone: Increase the amount of siltsone. Wet. Fractures at 36-38	5	2950	9.46
40			Weathered Dolomite: Light beige-reddish, soft, subangular tabular dolomite chips in semi plastic clay. Fractures (10% big chips, 1cm size) at 42-44, 48-50. Colour more yellowsih at 50-54	5	295	8.14
45				4 to 5	1785	8.44
50				4 to 5	2690	7.9
55						
60			Weathered Dolomite: Brown colour, moderately weathered angular, hard, fine grained dolomite (it could be confused with mudstone)	4	3030	8.15
65			Weathered Dolomite: Brown, moderately weathered and fractured (10% big chips)	5	3050	8.29
70			Weathered Dolomite: Brown, mod weathered bedded, soft, sunangular dolomite? (it could be mudstone/siltstone)	5	2690	8.41

Comments: There were some small problems with the equipment, but drilling and casing went smoothly. Drilled open hole 88-94m but changed back to DR (very slow drilling open hole due to machine

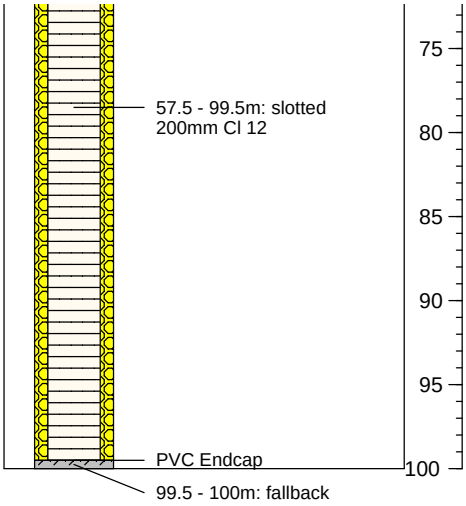
WESTERN HUB BORE LOG

BOREHOLE NUMBER
FFPB001

Fortescue Metals Group Ltd
Level 2, 87 Adelaide Terrace
East Perth, WA 6004
PH: 08 62188888 FAX: 08 62188880

PROJECT NAME: **Western Hub Feasibility Assessment**
LOCATION: **Site 11**
DRILLING CO: **Eastern Well**
DRILLING METHOD: **DR**
LOGGED BY: **MjRS**
EASTING (m): **522379.66**
NORTHING (m): **7511026.41**
ELEVATION (mAHD): **565.39**
DRILLING DIAMETER(S) (mm): **304.8**
COLLAR STICKUP (m) **0.461**
DATE BEGUN: **4/10/2016** DATE COMPLETED: **11/10/2016**

FINAL BORE DETAILS		
Drilled Depth (mbgl):	100	
Cased Depth (mbgl):	99.5	
Casing Stick Up (magl):	0.253	
Development Yield (l/s):	50	
Water Level (mbgl) & Date:	15.657	20/10/2016
Quality - pH & EC (µS/cm):	8.97	2640



DESCRIPTION	YIELD (l/s)	EC (µS/cm)	pH
Chert & Shale: Dark grey, big blocky chips, very hard, v f grained, sub-concoidal fracture, some lamination	3	2600	8.12
Shale: Grey (and trace of black - some oily shale) v. f grained well bedded clearly shale	3	2790	8.21
Dolomite: Fresh but very fractured (some very big chips, and surfaces with brown stain) Very high flows. EOH	25 - 30	2520	8.1
	~ 50	2420	8.43

Comments: There were some small problems with the equipment, but drilling and casing went smoothly. Drilled open hole 88-94m but changed back to DR (very slow drilling open hole due to machine

WESTERN HUB BORE LOG

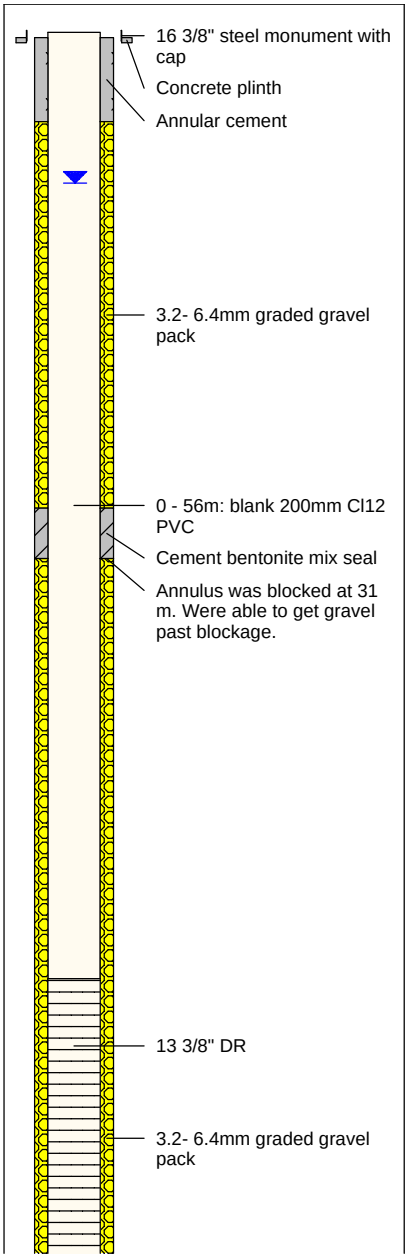
BOREHOLE NUMBER
FFPB002

Fortescue Metals Group Ltd
Level 2, 87 Adelaide Terrace
East Perth, WA 6004
PH: 08 62188888 FAX: 08 62188880

PROJECT NAME:	**Western Hub Feasibility Assessment**
LOCATION:	**Site 10**
DRILLING CO:	**Eastern Well**
DRILLING METHOD:	**DR**
LOGGED BY:	**MjRS/JB**
EASTING (m):	**516323.80**
NORTHING (m):	**7509684.06**
ELEVATION (mAHD):	**551.61**
DRILLING DIAMETER(S) (mm):	**304.8**
COLLAR STICKUP (m)	**0.43**

DATE BEGUN: **11/10/2016** DATE COMPLETED: **17/10/2016**

FINAL BORE DETAILS		
Drilled Depth (mbgl):	120	
Cased Depth (mbgl):	100	
Casing Stick Up (magl):	0.315	
Development Yield (l/s):	35	
Water Level (mbgl) & Date:	8.645	20/10/2016
Quality - pH & EC (µS/cm):	7.57	1950



DEPTH	STRATIGRAPHY	DESCRIPTION	YIELD (l/s)	EC (µS/cm)	pH
0	Tertiary Alluvium	Clayey Detrital: Red clay with big, angular, fine grained, beddedd chips of BIF			
5		Mudstone & Siltstone: Off-white big angular, very fine grained, massive textured chips			
10	Palaeochannel Sediment	Cemented Detrital: Brown semi-plastic clay with a mix of not equidimensional (5-50mm) grey and brown subangular chips			
15		Cemented Detrital: One big (60mm long) chips and most others small, eroded, subangular showing signs of being fractured; cemented detritals	0.5		
20		Cemented Detrital: Moderately fresh, cemented pysoliths (subrounded, pitted with clear "onion" texture)	15		
25					
30	Bee Gorge	Fault: Fault/shear zone: mix of BIF and dolomite; chips are a mix of subrounded and angular, weathered and fresh, diferent sizes and rock types (chert, shale, dolomite, BIF) Cavities. Also manganese botroida and masive (base of WestAng?	15	2870	7.64
35			16	2850	7.81
40			16	2310	7.71
45	Paraburdoo	Weathered Dolomite: Fractured (weathered or faulted?) dolomite; small and big chips, light grey and light beige with stain in surfaces, some trace of cavity (crystal growth)	17	2260	7.78
50			20		
55					
60			20		
65		Weathered Dolomite: Fresh grey/blue dolomite with some fractures (infilled with secondary mineralization - calcareous)	20	2241	8.09
70			20	2370	8.34

Comments: While pulling casing, EW encountered a clay at about 42 m that blocked the annular space between casing and PVC. EW was able to get gravel past the blockage and filled to about 32 m. They were unable to dip the hole to confirm gravel placement. The entire screen was covered with gravel.

WESTERN HUB BORE LOG

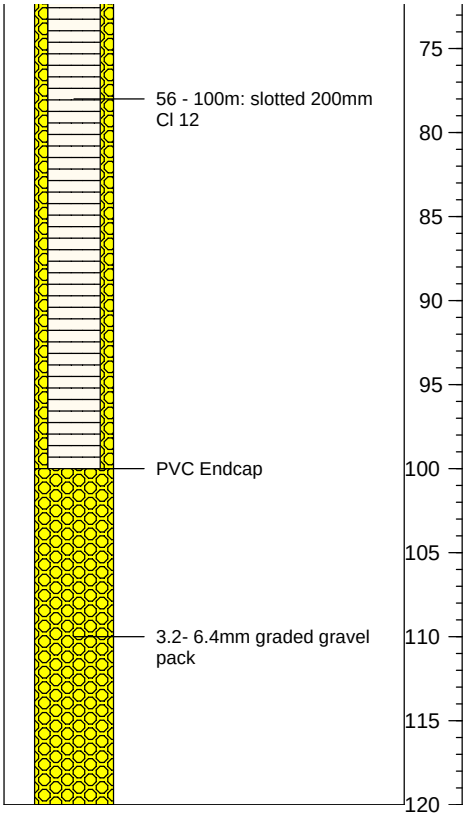
BOREHOLE NUMBER
FFPB002

Fortescue Metals Group Ltd
Level 2, 87 Adelaide Terrace
East Perth, WA 6004
PH: 08 62188888 FAX: 08 62188880

PROJECT NAME:	**Western Hub Feasibility Assessment**
LOCATION:	**Site 10**
DRILLING CO:	**Eastern Well**
DRILLING METHOD:	**DR**
LOGGED BY:	**MjRS/JB**
EASTING (m):	**516323.80**
NORTHING (m):	**7509684.06**
ELEVATION (mAHD):	**551.61**
DRILLING DIAMETER(S) (mm):	**304.8**
COLLAR STICKUP (m)	**0.43**

DATE BEGUN: **11/10/2016** DATE COMPLETED: **17/10/2016**

FINAL BORE DETAILS		
Drilled Depth (mbgl):	120	
Cased Depth (mbgl):	100	
Casing Stick Up (magl):	0.315	
Development Yield (l/s):	35	
Water Level (mbgl) & Date:	8.645	20/10/2016
Quality - pH & EC (µS/cm):	7.57	1950



DEPTH	STRATIGRAPHY	LITHOLOGY	DESCRIPTION	YIELD (l/s)	EC (µS/cm)	pH
75				25	2240	8.13
80				25	2100	7.9
85				25	1610	7.3
90				25	1320	7.5
95						
100			Weathered Dolomite: Fresh grey/beige dolomite with some fractures (infilled with secondary mineralization - calcareous)	30	2040	7.5
105	West Angelas		Shale: Dark brown, friable, firm, weathered shale. Minor chert, possibly interbedded.	30	2000	8.2
110				35	2240	8.4
115			Shale: Tan brown, friable, firm, weathered shale. Minor chert, possibly interbedded.			
120				35	2185	8.25

Comments: While pulling casing, EW encountered a clay at about 42 m that blocked the annular space between casing and PVC. EW was able to get gravel past the blockage and filled to about 32 m. They were unable to dip the hole to confirm gravel placement. The entire screen was covered with gravel.

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