REPORT

MT WELD LEVEL 1 SUBTERRANEAN FAUNA ASSESSMENT

PREPARED FOR **LYNAS CORPORATION LTD**

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Stantec

QUALITY STATEMENT

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Executive Summary

Background

Lynas Corporation Ltd (Lynas) is proposing to expand the Mt Weld Project (MWP) under Section 45C of the *Environmental Protection Act 1986*. The MWP is located approximately 35 km southeast of Laverton in the Goldfields region of Western Australia. Stantec Australia Pty Ltd (Stantec) was engaged by Lynas in May 2019 to undertake a Level 1 Subterranean Fauna Assessment (the Assessment), incorporating a desktop review and verification (pilot) survey. The primary objectives of the Assessment were to establish whether subterranean fauna represent an environmental factor for the MWP expansion and environmental approvals.

Survey Effort

During the pilot survey, 24 sites were sampled, including expoloration drill holes, monitoring bores and infiltration bores within the MWP area. The sampling regime comprised:

- 12 stygofauna net haul samples from 12 sites, collected between the 17th and 19th of june 2019
- 19 litter trap samples (deployed for eight weeks from 17th June to 8th August 2019 and nine scrape samples, collected in conjunction with the stygofauna samples, between 17th and 19th of June 2019.

The survey effort exceeded the recommended survey effort for subterranean fauna for this survey type by the Environmental Protection Authority (EPA). The survey intensity undertaken, in conjunction with the habitat characterisation, was considered more than sufficient to enable a reliable verification of the stygofauna and troglofauna values for the MWP, in accordance with EPA guidance.

Stygofauna Findings

No stygofauna (stygobites) were collected from the 12 sites sampled within the MWP, with the survey effort considered sufficient to provide a reliable overview of prospectivity. The survey findings were consistent with the literature review and habitat characterisation, which suggested that the area was unlikely to support stygofauna. This was based on a general lack of suitable interconnected voids, vugs or adequate pore spaces at favourable depths within the aquifer systems, as determined from geological and hydrogeological information. Lacustrine clays which form a discontinuous semi-confining layer in the area were also a consideration, with the semi-confining layer, albeit discontinuous, likely to at least partially restrict the input of resources (nutrients and organic matter) to the regolith aquifer and where present, underlying fractured rock aquifers.

Troglofauna findings

There were no obligate subterranean taxa (troglobites) recorded from the MWP mining area during the pilot survey. Cementation and/or clay matrices within the unsaturated strata are unlikely to support the interconnected vugs and voids requiredto support troglofauna (troglobites). The only potential troglobite, an isopod (slater) *Paraplatyarthrus* nr *pallidus* OES26, was recorded as singleton from the low, outcropping ridge over 5 km west of the Mt Weld pit and more than 2 km away from the proposed disturbance area. This outcropping, which has a linear extent of at least 5 km, occurs in a different geological domain to the MWP mining area and is unlikely to be impacted by additional drawdown linked to the pit expansion. The only taxon recorded from the mining area was a non-troglobitic isopod (slater) *Paraplatyarthrus crebesconiscus.* This widespread taxon has been recorded from several calcrete systems throughout the broader region.

Conclusion

The Assessment indicates that the MWP mining area is not prospective for stygofauna (stygobites) or troglofauna (troglobites). Accordingly, subterranean fauna will not represent an environmental factor for future regulatory approvals for the MWP. The results of the pilot survey, supported by habitat characterisation, suggest that the proposed expansion of the MWP will not impinge on the representation, diversity, viability and ecological function of subterranean fauna at the species, population or assemblage level, in line with EPA objectives. It is therefore considered that no further stygofauna or troglofauna assessment of subterranean fauna is necessary, for environmental approvals to proceed.

Lynas Corporation Ltd

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1. Introduction

The Mt Weld Project (MWP) is a rare earth open cut mining operation, owned and operated by Mt Weld Mining Pty Limited (MWM), a subsidiary of Lynas Corporation Ltd (Lynas). The MWP is located on mining leases M38/58.38/59, M38/326 and L38/98, approximately 35 km southeast of Laverton in the Goldfields region of Western Australia, and 725 km northeast of Perth (**Figure 1-1**). The Granny Smith Gold Mine (Granny Smith), owned by the Granny Smith Gold Mining Company (GSM), is located 10 km southeast of the MWP.

Lynas is proposing to expand the Mt Weld operation under Section 45C of the *Environmental Protection Act 1986*. This will include expansion of the pit, tailings storage facility (TSF), waste rock landform (WRL) and creation of alluvium stockpile areas (**Figure 1-2**). There will also be a requirement for increased dewatering of the underlying aquifer to maintain safe and dry working conditions within the pit.

Stantec Australia Pty Ltd (Stantec) was engaged by Lynas in May 2019 to undertake a Level 1 Subterranean Fauna Assessment (the Assessment). The Assessment incorporated a desktop review and verification (pilot) survey.

1.1 Scope and Objectives

The primary objective of the Assessment was to determine whether subterranean fauna represent an environmental factor that may be impacted by the proposed expansion of the MWP. The specific objectives were to:

- evaluate the likelihood of subterranean fauna existing within the MWP area and adjacent regional area;
- assess whether subterranean fauna will represent an environmental factor for the MWP expansion and environmental approvals; and
- determine if a Level 2 Baseline survey of subterranean fauna values would be required.

The objectives were addressed through the following:

- a desktop study including database searches and literature review;
- characterisation of habitat to determine subterranean values of the MWP area; and
- verification (pilot) survey for subterranean fauna.

The principles, objectives and survey methodology are aligned with relevant regulatory guidelines. These include, but are not limited to:

- Environmental Protection Authority (EPA) (2016a) Technical Guidance – Sampling Methods for Subterranean Fauna Survey; and
- EPA (2016b) Technical Guidance – Subterranean Fauna Survey.

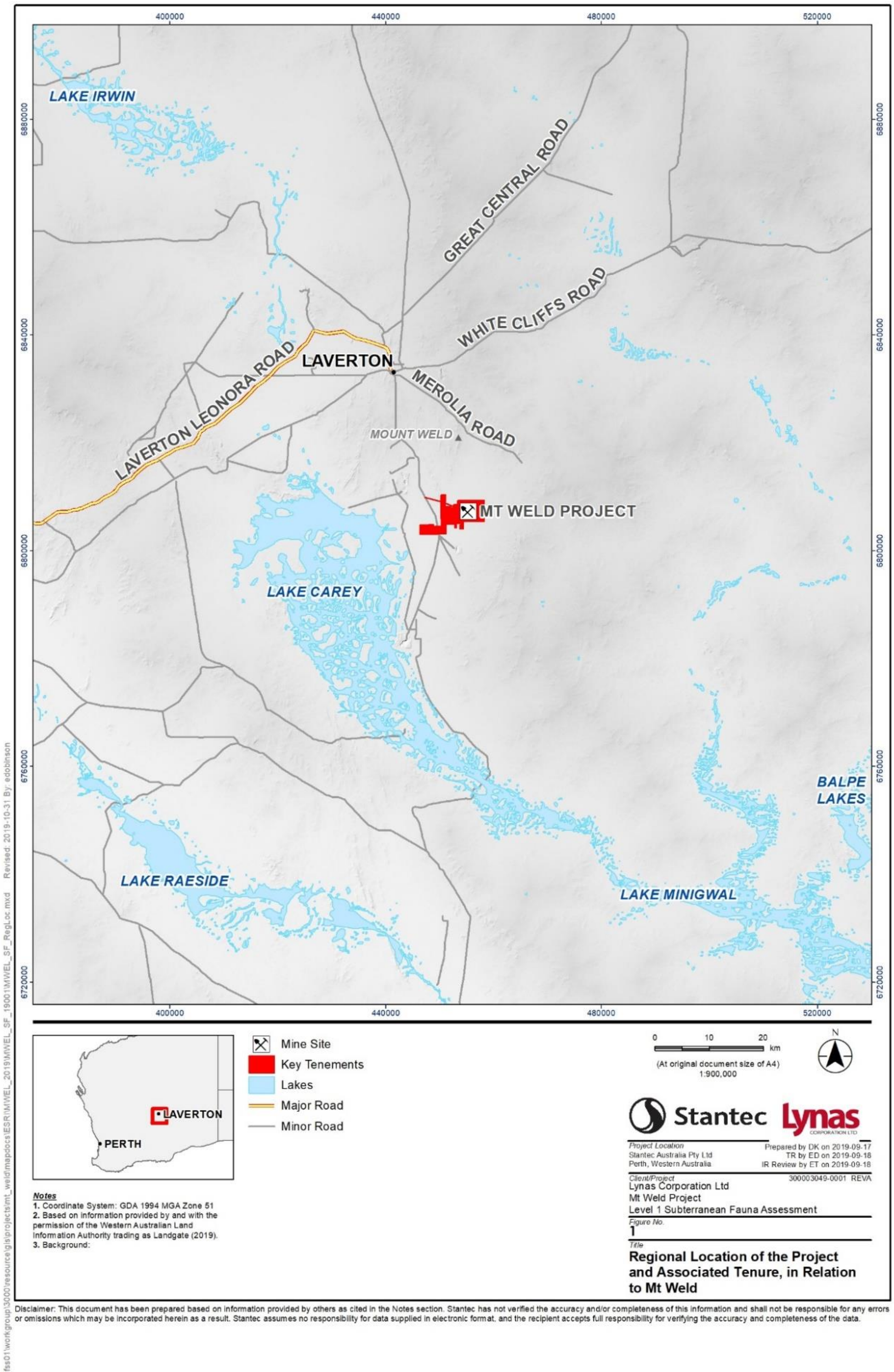

Figure 1-1: Regional location of the MWP.

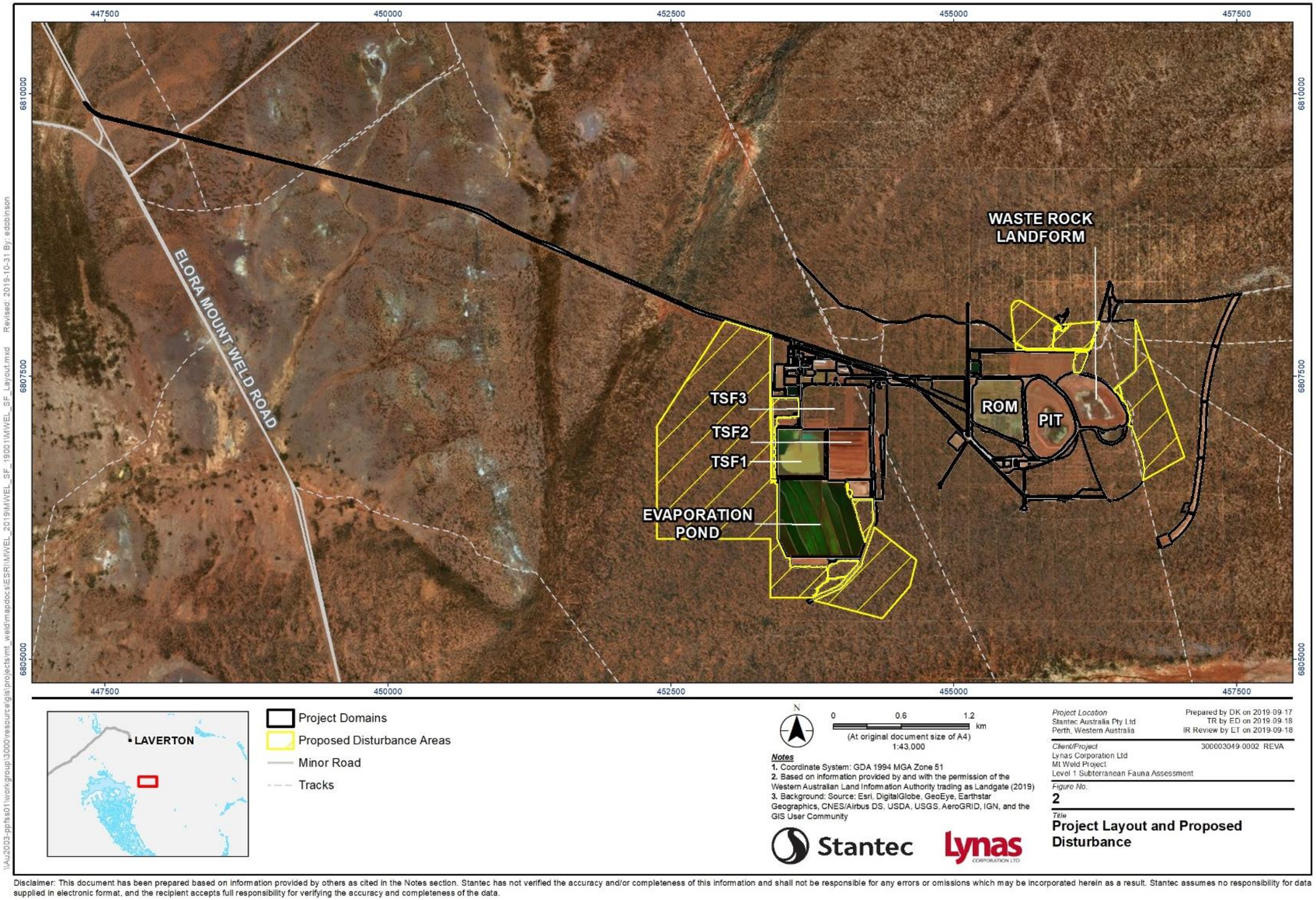

Figure 1-2: Layout of the MWP, indicating key project domains and proposed disturbance areas.

2. Existing Environment

2.1 Biogeographical Context and Land Use

The MWP lies within East Murchison subregion of the Murchison bioregion (**Figure 2-1**), as defined by the Interim Biogeographic Regionalisation for Australia (IBRA) classification system (Thackway and Cresswall 1995). The subregion covers an area of 7,847,996 ha and is characterised by internally draining salt lakes within palaeodrainage systems.

The subregion hosts extensive areas of elevated sandplains with minimal dune development. Broad plains of red-brown soils, and breakaway complexes are also common across the landscape. Vegetation associations are dominated by mulga woodlands, hummock grasslands, saltbush shrublands and *Tecticornia* shrublands, particularly adjacent to salt lakes. There are numerous listed flora and fauna species known to occur within the subregion, as well as potentially important habitat hosting diverse biological assemblages (Thackway and Cresswall 1995).

The East Murchison subregion is subject to grazing of native pastures which, together with mining (mostly gold and nickel) accounts for approximately 86% of total land use. The MWP lies within Mt Weld Station, an historic sheep station, which has been destocked. Unallocated Crown Land and Crown Reserves accounts for a further 11%, while conservation estates account for less than 2% of total land use. The majority of the subregion has been extensively degraded by grazing (Cowan 2001; McKenzie *et al.* 2003). The introduction of feral animals and subsequent predation on native fauna is also of concern (Cowan 2001).

2.2 Drainage and Hydrology

The MWP is situated within the Carey Palaeodrainage, one of the three broad drainage systems in the region, flowing to the southeast towards the Eucla Basin (Johnson *et al.* 1999) (**Figure 2-2**). Within the MWP area, land gently slopes west from the ranges to the northeast, towards Lake Carey, located on one of these broad drainage systems. Windich Creek is situated west of the MWP area and is a predominant tributary of the lake (Environ 2006).

There is also a large catchment to the east of the MWP, the eastern-most portion of which has undulating topography, with runoff via a system of natural drainage channels. The lower portion of the catchment is much flatter, and drainage is poorly defined, with runoff likely driven by sheet flow in a westerly direction during heavy rainfall. Management of surface water flow across the MWP is via protection measures including bunding and diversion channels (Environ 2006).

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Figure 2-1: Location of the MWP within the IBRA East Murchison subregion of the Murchison region

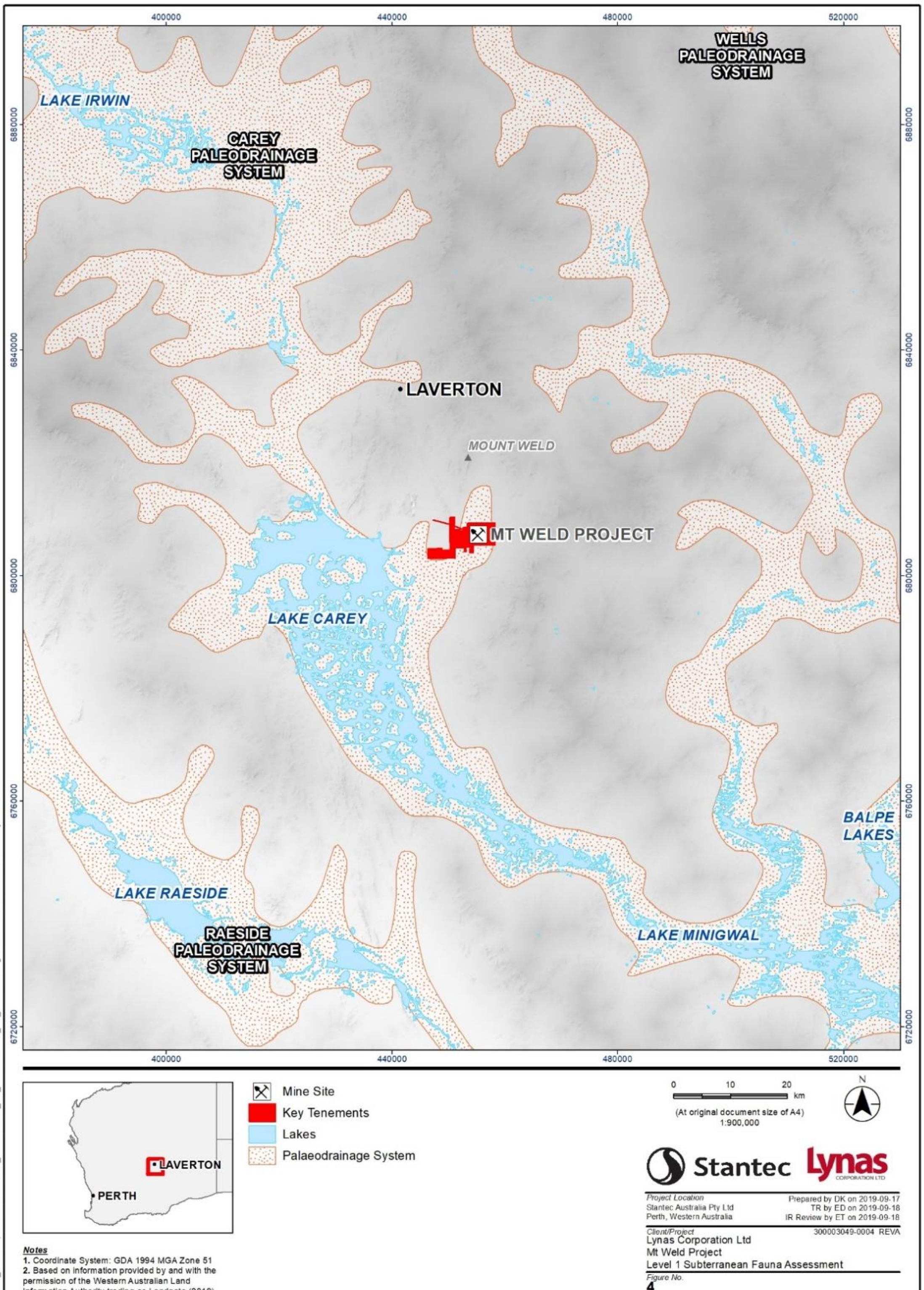

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Figure 2-2: Location of the MWP in relation to palaeodrainage systems

2.3 Geology

The MWP is associated with the Mount Weld Carbonatite complex, located in the Eastern Goldfields Province of the Yilgarn Craton, Western Australia (Hoatson *et al.* 2011). The carbonatite complex is a subcircular body of carbonate-rich rock, approximately 4 km in diameter, which intrudes Archaean sedimentary-volcanic sequences. It is centrally transected by a north-west trending vertical dolerite dyke, subdividing the complex into two parts of similar size (western and eastern). A 500 m glimmeritic alteration zone surrounds the complex (Dames and Moore 1994; Hoatson *et al.* 2011). The unweathered carbonatite is overlain by a regolith (weathered carbonatite) ranging from 10 to 70 m in thickness. The regolith hosts high-grade rare earth ores, in addition to metals such as niobium, tantalum, and zirconium (Hoatson *et al* 2011). A superficial sequence comprising transported alluvium, calcrete, and lacustrine clays cover the regolith. The superficial sequence is characterised by an irregular distribution and variable thickness, extending to 30 m in some areas. The location of the complex is structurally controlled, situated between major regional fault zones (Dames and Moore 1994).

2.4 Hydrogeology

2.4.1 Aquifer Systems

There are two main aquifer systems associated with the carbonatite complex, both overlying the fresh carbonatite:

- an unconfined, surficial aquifer of regional extent formed within the transported alluvial sediments (Dames and Moore 1994). This stratum commonly extends to 20 mbgl (AECOM 2017). It is underlain by a discontinuous layer, primarily lacustrine clays of variable thickness, which act as a relatively low permeability aquitard at the base of the alluvial aquifer. Groundwater flow direction is towards the south-west and Lake Carey (Dames and Moore 1994;1996).
- a semi-confined/confined aquifer system within the regolith of weathered carbonatite. This aquifer has a broad range of lithological and textural components, forming an irregular, heterogenous and anisotropic aquifer system. The upper strata of the aquifer predominantly comprise calcretes, goethitic/lateritic limonite and pisolitic gravels. The lower portions overlying the bedrock are associated with vuggy apatite, varying in thickness and intensity of cementing (Dames and Moore 1994). This sequence generally occurs between 40 and 80 mbgl (AECOM 2017).

Vertical leakage occurs between the two aquifers, in areas where the lacustrine clays are absent (Dames and Moore 1994). The aquifers are also hydraulically linked to fractured rock aquifers associated with the fresh carbonatite bedrock. However, the extent of the fractured rock aquifer is unknown (Dames and Moore 1996). A palaeochannel aquifer crosses above the carbonatite near the eastern margin, potentially providing substantial recharge and throughflow to the carbonatite aquifer (AECOM 2017).

The dolerite dyke subcrop transecting the carbonatite complex acts as a semi impermeable barrier to horizontal groundwater flow. It is considered likely to cut into the surrounding Archaean country rock and may have potential to act as a groundwater flow path along strike (AECOM 2017).

In addition, a palaeochannel aquifer crosses along the eastern side of the carbonatite complex, potentially providing throughflow to the carbonatite aquifer. The associated basal sands may represent a potential resource for groundwater abstraction, upgradient of the carbonatite complex (AECOM 2017).

Groundwaters associated with the carbonatite complex are typically hyposaline. Early records indicate that groundwater salinity in the western portion ranged from approximately 2,000 to 7,000 mg/L and 2,500 to 7,000 mg/L in the eastern portion (Stantec 2019). A trend of increasing groundwater salinity has since been observed for all monitoring bores in the western portion. This has been linked to sustained dewatering, with values as high as 19,000 mg/L recorded during monitoring in 2017 to2018, reflecting the increased contribution of older waters to the abstracted water. During the same period, records from the eastern portion of the carbonatite ranged from 4,000 mg/L to 11,000 mg/L. The pH of groundwaters in the area has generally ranged from circumneutral to alkaline (Lynas unpublished data).

2.4.2 GSM Mt Weld Borefield

The Mt Weld borefield was commissioned in late 1989 to provide water for the Granny Smith Project (GSM). The borefield originally comprised eight production bores (B1-B8), targeting the regolith (weathered) carbonatite of the western aquifer. An additional five production bores were installed between 1994 and 1996; two within the western aquifer (B9 and B11) and three within the eastern aquifer (B10, B12, B13) (AECOM 2017). Currently, three bores are operational as water supply production bores (B9, B10 and B13).

The abstracted groundwater is transported to the GSM process plant via a pipeline, with MWM also having access. Drawdown responses in the superficial and regolith carbonatite aquifers are monitored by GSM through a system of groundwater monitoring bores, distributed across the carbonatite aquifer (AECOM 2017).

2.4.3 MWM Dewatering Bores

The Mt Weld mine was commissioned in 2007. Dewatering operations for the mine currently include four dewatering bores (LWB1, LWB2, LWB3 and B11) (**Figure 2-3**). MWM are also responsible for up to four existing decommissioned water supply bores, under agreement from GSM. A contingency of up to four additional dewatering bores (LWB15, LWB5, LWB6 and LWB7) has also been planned (AECOM 2017).

2.4.4 Groundwater Levels

The baseline groundwater table, prior to development of the borefield, was approximately 410 to 411mAHD (11 to 15 mbgl). By 2017, groundwater levels in the superficial aquifer had been reduced to approximately 395 mAHD, in the vicinity of the pit. While drawdown was also evident beyond the carbonatite margin, it typically decreased to less than 2 m within a few kilometres (**Figure 2-4**) (AECOM 2017).

Recent records from the carbonatite aquifer (May 2018) indicate that groundwater levels in western portion ranged from approximately 359 mAHD near the pit to 367 mAHD towards the carbonatite margin. For the eastern carbonatite aquifer, groundwater levels ranged from approximately 367 mAHD to 371 mAHD (**Figure 2-5**).

The deepest part of the carbonatite aquifer has been measured as 356.3 mAHD. The proposed life of mine (LOM) pit will extent to a depth of 310 mAHD, necessitating a groundwater decrease to 308 mAHD or below (**Figure 2-6**). The additional dewatering will result in increased drawdown within the superficial aquifer. However, the extent of additional drawdown has not been determined.

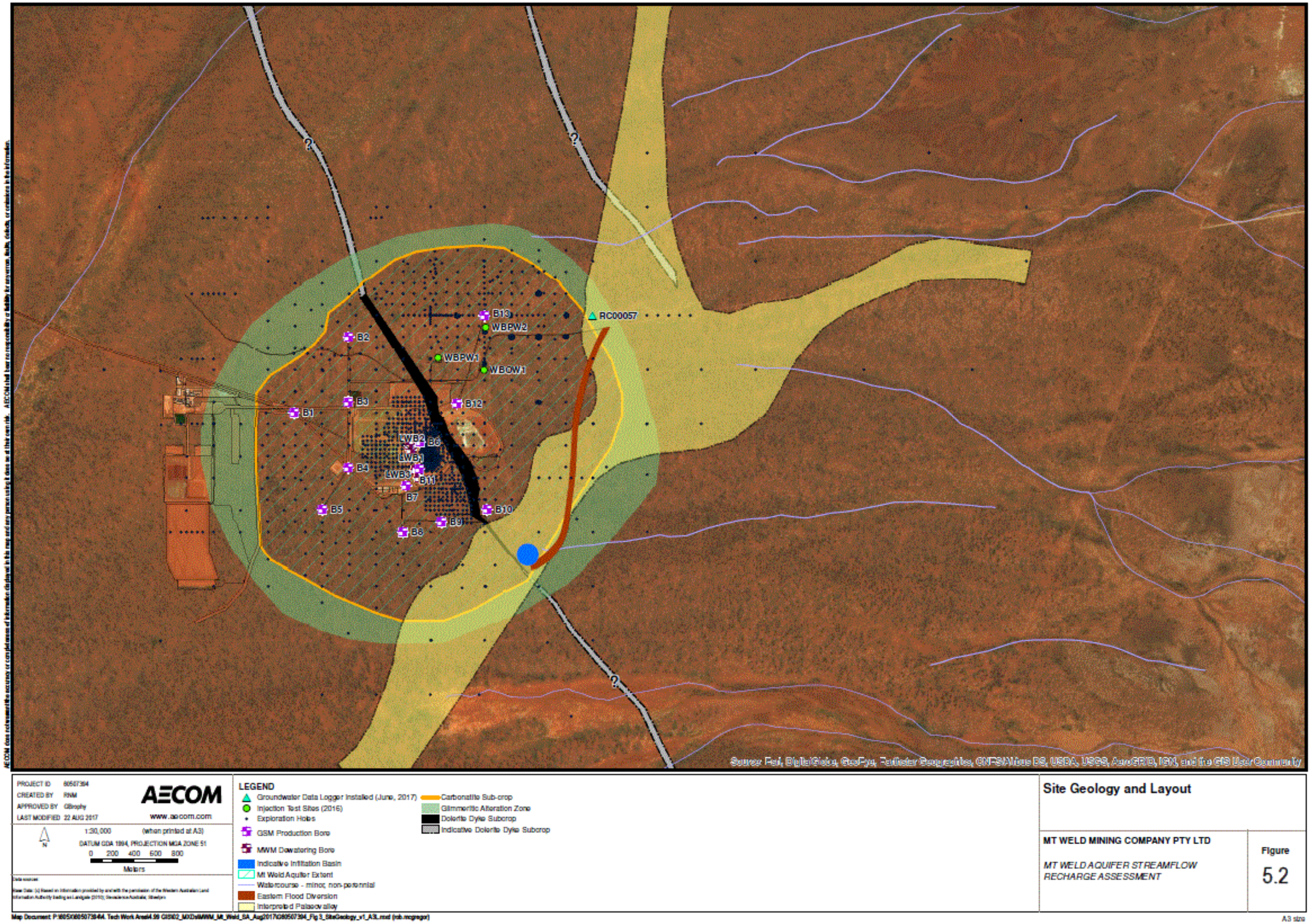

Figure 2-3: Site geology and borefield infrastructure (AECOM 2017).

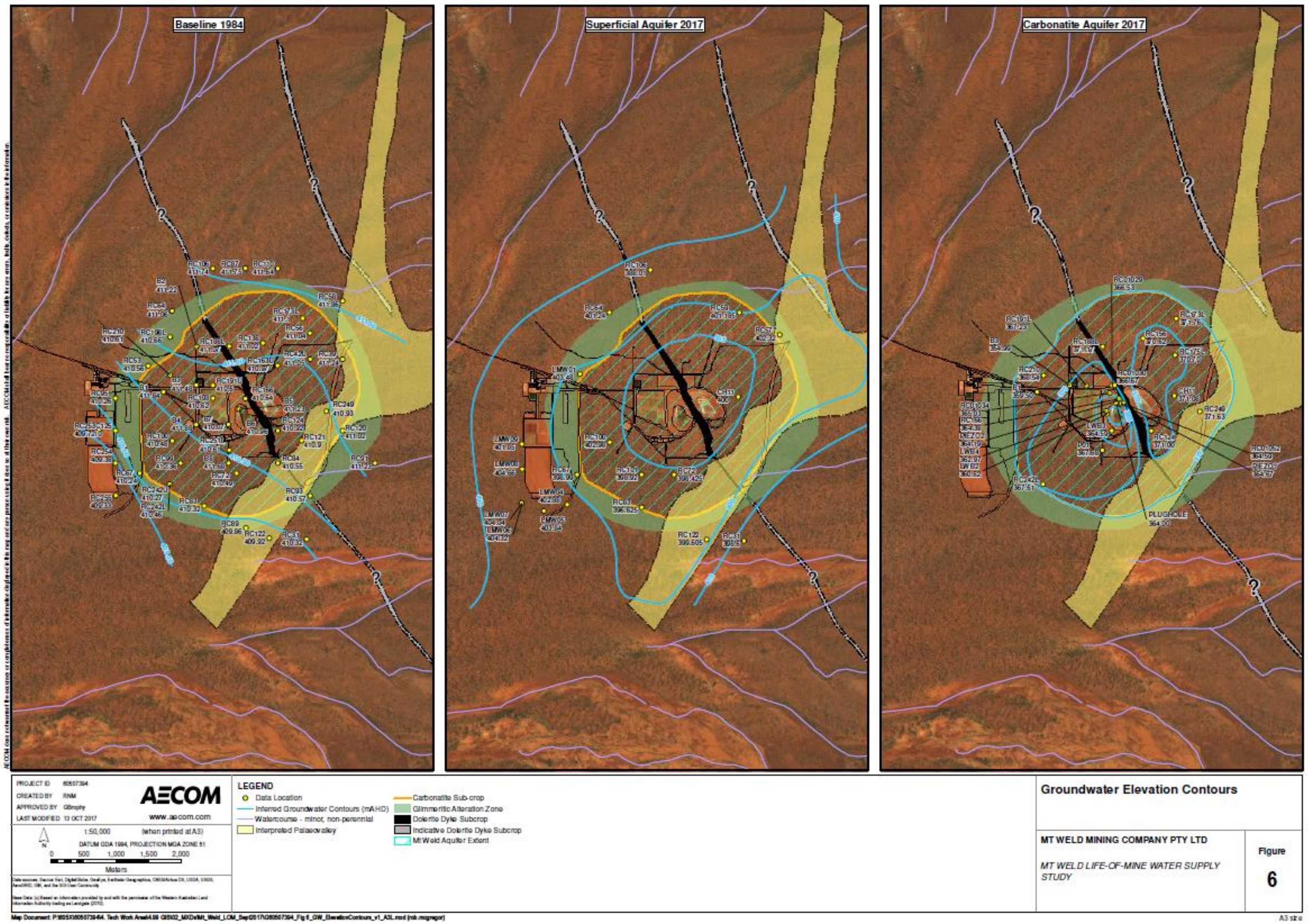

Figure 2-4: Groundwater contour elevations in 2017 (AECOM 2017).

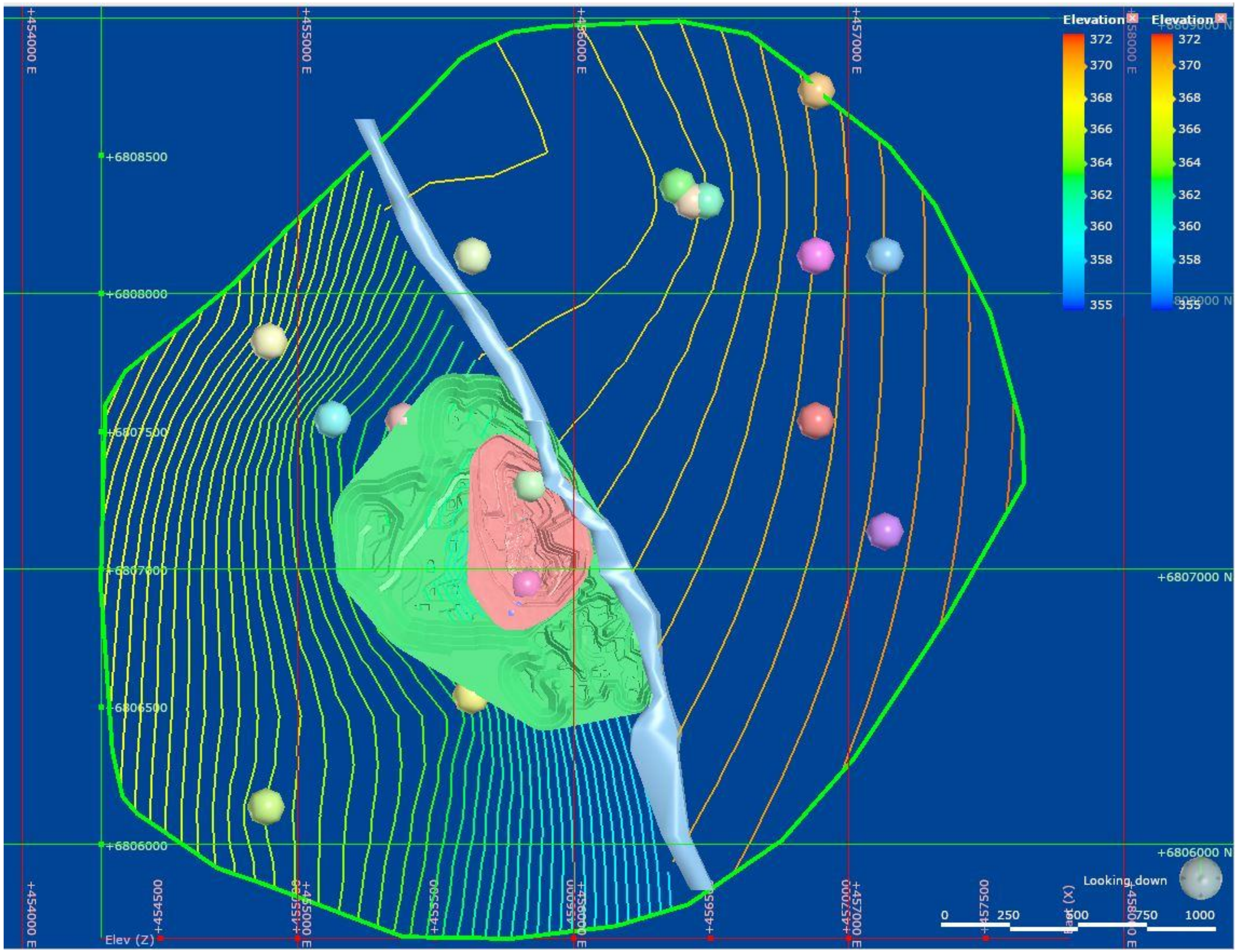

Figure 2-5: Recent groundwater levels within the carbonatite complex, May 2019 (provided by Lynas, 2019).

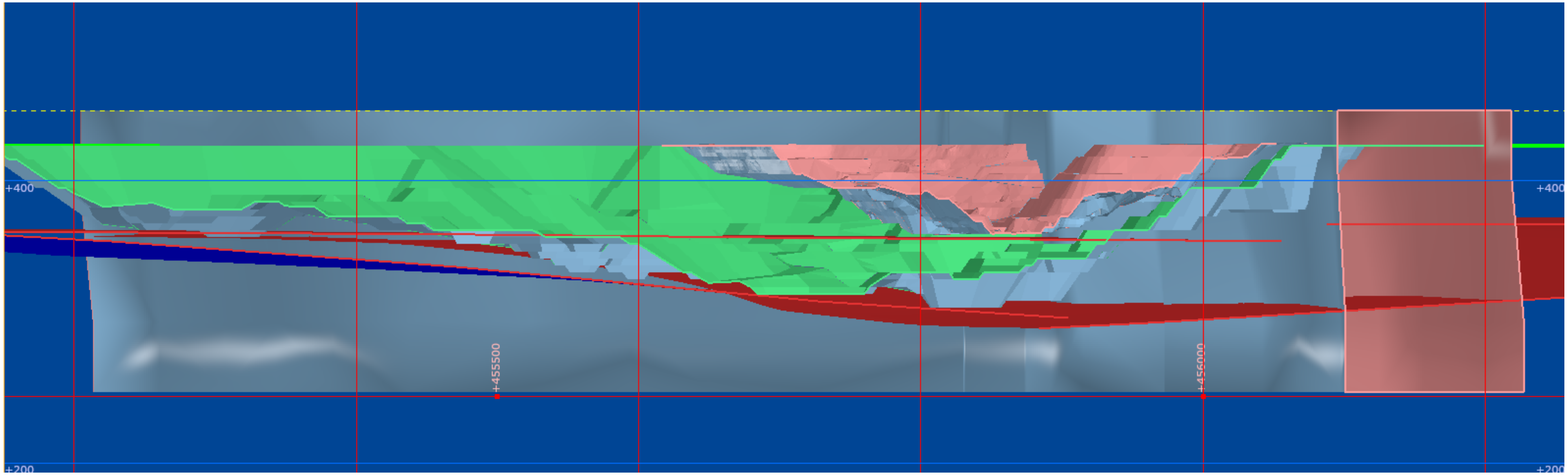

Figure 2-6: Cross section derived from Leapfrog model, indicating water table surface and predicted LOM mine surface (provided by Lynas, 2019).

2.5 Climate

The broader area surrounding the MWP is characterised by an arid climate of hot summers and cool winters (AECOM 2017; Beard 1990; Pringle *et al.* 1994). Rainfall is highly variable, with short duration rainfall events known to occur during summer months (December to February) linked to tropical lows in the north of the state.

The average annual rainfall for the area is approximately 290 mm, based on long-term data from Laverton Aero weather station (BoM 012305), 29 km to the north-west of the MWP (Bureau of Meteorology 2019). Mean maximum temperatures range from 35.6˚C in January to 18.5˚C in June and July respectively. Mean minimum temperatures also peaked in January, decreasing to less than 7˚C in June and July (**Figure 2-7**).

Rainfall in the 12 months prior to the subterranean fauna verification (pilot) survey of the MWP totalled 234 mm, more than 50 mm below the annual average. This was attributed to limited rainfall in late summer, with January and February 2019 receiving less than 5% of the respective long-term averages (**Figure 2-7**).

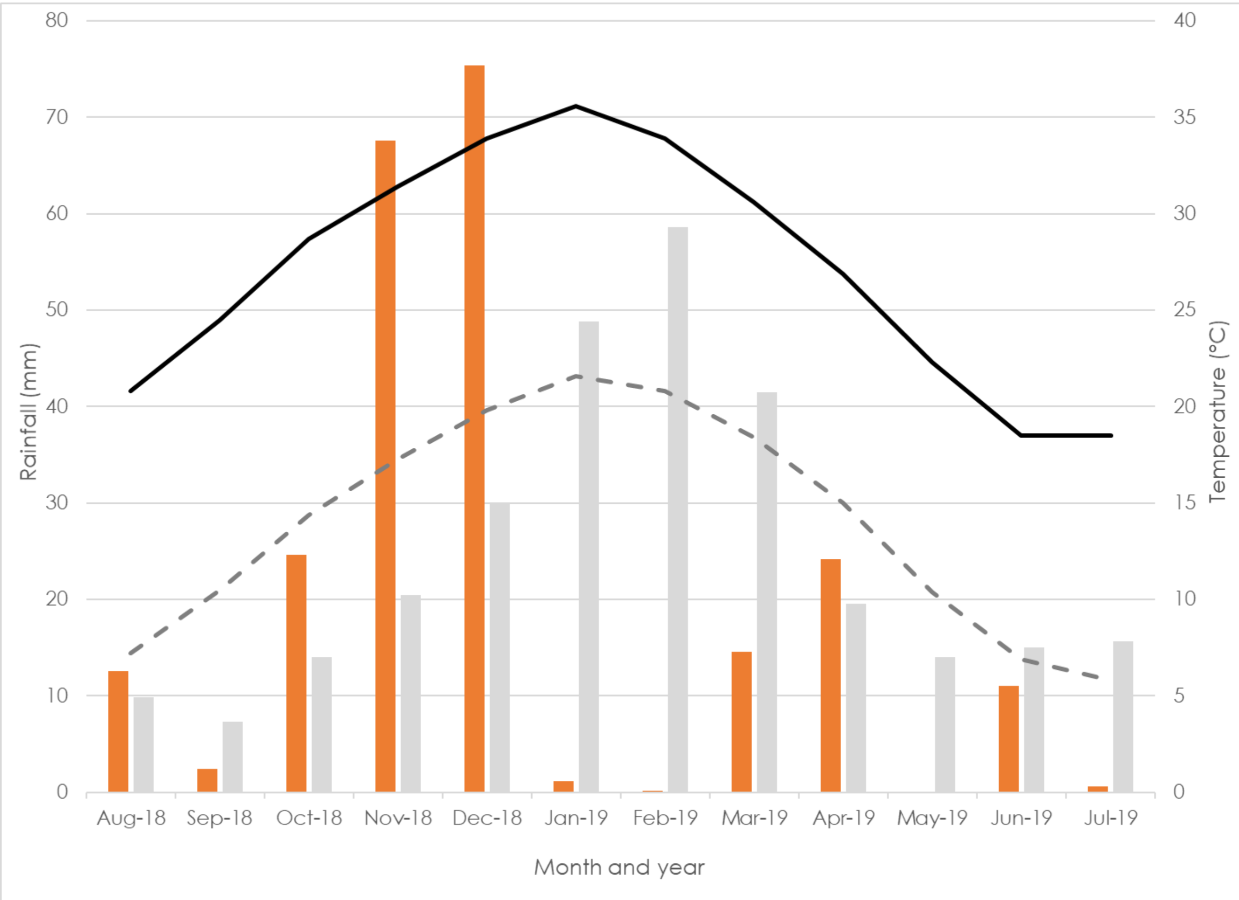

Figure 2-7: Monthly rainfall totals from August 2018 to July 2019 (■), long term mean monthly rainfall (■), long term mean monthly minimum (-----) and maximum temperatures (–) recorded from Laverton Aero Station (012305).

3. Subterranean Fauna

3.1 Habitat

The prospective habitat for subterranean fauna (stygofauna and troglofauna) is dependent on the presence of voids of suitable size and connectivity to satisfy biological requirements. Subterranean fauna were previously believed to be mostly restricted to karst landscapes that provide a relatively high degree of secondary porosity, but in more recent times have been found to occur in various types of non-karstic geologies and aquifer systems that exhibit suitable voids for colonisation (Pringle *et al.* 1994).

Stygofauna are now known to occur in non-karstic aquifers in coarse alluvial sediments, fractured rock, pisolites and thin rocky regoliths (Halse *et al.* 2014; Humphreys 2006;2008; Outback Ecology 2014). Likewise, recent surveys have identified troglofauna from non-karstic geologies such as vuggy pisolite ore beds and fractured and weathered rock formations in the Pilbara and Yilgarn regions (Barranco and Harvey 2008; Bennelongia 2009; Halse *et al.* 2002; MWH 2016; Outback Ecology 2011b; Subterranean Ecology 2008b).

The extent of subterranean fauna habitat is dependent on the interconnection of sub-surface crevices, fractures and voids, within suitable geological and hydrogeological units and aquifer systems. In addition to allowing for the movement of subterranean fauna, adequate interconnected void spaces and associated high permeability can provide pathways for infiltration (vertical or lateral) of resources such as oxygen and nutrients, key factors influencing subterranean fauna persistence and distribution (MWH 2015; Strayer 1994). Geological, hydrological, and hydrogeological studies can give an indication of the extent of subterranean fauna habitat present by providing information on the geological units and structures present, as well as recharge zones, groundwater flow or aquifer characteristics.

3.2 Stygofauna

Stygofauna (groundwater fauna) are predominantly comprised of invertebrates, particularly crustaceans. Other invertebrate groups represented can include gastropods, insects, water mites and worms. In Western Australia, studies have shown that the calcrete and alluvial aquifers associated with palaeodrainage channels of the arid and semi-arid zones can contain rich stygofauna communities. The Pilbara and to a lesser extent the Yilgarn, stand out as global hotspots for stygofauna diversity (Halse *et al.* 2014; Humphreys 2008).

Stygofauna can be categorised according to their level of dependency on the subterranean environment:

- stygoxenes are animals that enter groundwaters passively or accidentally;
- stygophiles inhabit groundwaters on a permanent or temporary basis; and
- stygobites are obligate groundwater dwellers and the focus of the stygofauna component of the Assessment.

Stygobites are restricted to their subterranean environment and as such are often classified as short range endemics. Short-range endemic species (SRE's) have geographically restricted ranges of less than 10,000 km^2 and are considered more vulnerable to extinction because of their limited distribution range (Harvey 2002; Humphreys 2008). Stygobites can often be distinguished from surface or soil dwelling animals by morphological characteristics typical of a subterranean existence, such as a reduction or absence of pigmentation, absence or reduction of eyes, and the presence of extended locomotory and sensory appendages (Harvey *et al.* 2011). They can also be defined by ecological parameters such as longer life history stages, and lower rates of metabolism and fecundity (Cooper *et al.* 2002; Humphreys 2008).

Ecologically, there are many factors that influence the persistence and distribution of stygofauna at a range of habitat and temporal scales (Danielopol and Pospisil 2000). Some of the more influential factors at the microhabitat (sediment) scale include suitable interstitial pore size (i.e. provision of connected network of habitable cavities), hydrological exchange inflow rates of resources (e.g. dissolved oxygen, organic carbon, biofilm growth, prey), and water quality parameters such as temperature, pH, dissolved oxygen and organic carbon levels. At the mesohabitat (catchment) scale, factors include surface water flow patterns influencing infiltration zones and hydrological exchange influx rates into the groundwater systems of energy resources or dissolved oxygen according to geomorphological features, as well as interactions with riparian vegetation and parafluvial sediments (Boulton 2000; Boulton *et al.* 1998).

3.3 Troglofauna

Troglofauna (air-breathing subterranean fauna) are often relictual forms related to surface dwelling (epigean) groups and can be distinguished by characteristics associated with a below-ground existence (Schmidt *et al.* 2007). Troglofauna can be divided into:

- troglophiles, which carry out most of their lifecycle underground but are able to survive in epigean habitats;
- trogloxenes, which can enter subsurface habitats passively or incidentally; and
- troglobites are obligate or permanent subterranean inhabitants (Humphreys 2000b) that generally lack pigmentation, are blind (or have reduced eyes), have elongated limbs and may possess enhanced non-visual sensory adaptations (Thurgate *et al.* 2001), and are the focus of the troglofauna component of the Assessment.

Troglofauna are found worldwide and historically had been generally classified as cave organisms (Culver and Sket 2000). However, the discovery of diverse troglofauna communities inhabiting sub-surface rock fractures in non-karst areas in Europe in the 1980s prompted broader consideration of potential habitat (Culver and Sket 2000). The most common environments in which troglofauna occur are those that support suitably sized and extensively connected crevices, small cavities or vugs associated with secondary porosity from erosion, fractures and shears zones, that remain relatively humid, an important condition considered to be a key requirement for troglofauna existence (Juberthie 2000). Like stygofauna (stygobites), troglobites are restricted to their subterranean environment and often have locally restricted distributions. Most species are considered to be SRE's and may be vulnerable to extinction because of their limited distribution range (EPA 2003; Harvey 2002).

The most researched areas in Western Australia are the Cape Range and Barrow Island karst cave systems where large, diverse communities have been discovered (Hamilton-Smith and Eberhard 2000; Harvey 2002; Humphreys 1991). However, extensive sampling in areas of the Pilbara Craton has identified diverse troglofauna assemblages from non-karstic geologies such as vuggy pisolite ore beds (Biota 2006; Humphreys 2000a; MWH 2014a). Diverse troglofauna assemblages are commonly collected from groundwater associated calcrete (i.e. non-pedogenic calcrete) and alluvial/colluvial geologies within palaeodrainage channels of the arid and semi-arid zones, particularly in the Pilbara and Yilgarn regions (MWH 2014b;2015; Outback Ecology 2011b;2012a;c; Platnick 2008), but less so in the more arid interior of Australia (Harrison *et al.* 2014). Less diverse troglofauna assemblages have also been recorded from weathered fractured rock (Outback Ecology 2011a;c) and metamorphic mafic rock systems (Outback Ecology 2014).

Continued studies are likely to increase the understanding of prospective troglofauna habitat in Western Australia. It is only recently that troglofauna have become a focus of environmental assessment in Western Australia, and there is still relatively little information on their distribution compared to stygofauna (Bennelongia Environmental Consultants 2009; Eberhard *et al.* 2007).

3.4 Risk and Relevant Legislation

Development and operation of mines in Western Australia pose risks to subterranean fauna and their habitat, which include:

- direct removal of, or disturbance to, habitats through mining excavation;
- lowering the groundwater table through groundwater abstraction for pit dewatering and supply; and
- altering water quality parameters, to levels which may exceed species tolerance limits.

Subterranean fauna are protected under State and Federal legislation, governed by three Acts:

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

With this legislation in mind, the EPA developed the *Technical Guidance Subterranean Fauna Survey* (Environmental Protection Authority 2016b), equivalent to EAG 12 *Environmental Assessment Guideline for Consideration of Subterranean Fauna in Environmental Impact Assessment in Western Australia* (Environmental Protection Authority 2013) and the *Technical Guidance Sampling Methods for Subterranean Fauna Survey* (Environmental Protection Authority 2016a).

(equivalent to *Guidance Statement No. 54A Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia)* (Environmental Protection Authority 2007) which outline considerations and sampling methods for subterranean fauna in Western Australia. These documents provide advice to proponents and the public on the requirements for environmental impact assessment (EIA) and management of subterranean fauna. The Assessment reported here was designed in accordance with both Environmental Protection (2016a, b) guidance documents.

Mining proposals that will potentially impact on groundwater, or hypogean habitats that support subterranean fauna, require a risk assessment to ensure mining operations do not threaten the viability of important species or communities. Proponents must demonstrate that any species existing within potential mine-related impact zones also occur outside this area. For taxa restricted to impact zones, a suitable management plan must be developed, which includes ongoing monitoring of subterranean fauna to ensure the persistence of the species.

3.5 Regulatory Survey Adequacy Guidelines

The EPA's objective for subterranean fauna is the maintain representation, diversity. viability and ecological function at the species, population and assemblage level (Environmental Protection Authority 2016b). EPA guidance to support this objective (Environmental Protection Authority 2016a) stipulates that the appropriate level of survey depends on several factors. These include the likely presence of subterranean fauna, the degree of impact proposed, and adequacy to reliably inform decisions as part of the EIA process as to whether a proposal meets the EPA's objective and is tailored to the circumstances of the proposal.

For Level 1 low intensity (pilot) surveys, the recommended survey intensity considered to provide a reliable indication of whether the area hosts subterranean fauna is:

- Troglofauna — 10 to 15 samples; and
- Stygofauna — 6 to 10 samples.

If the findings from a desktop assessment and pilot survey indicate that a study area is not prospective for subterranean fauna then no further survey would be required. If stygofauna and/or troglofauna species were collected during a pilot survey, thereby demonstrating that subterranean fauna represent a potential environmental factor, a Level 2 (baseline or comprehensive) survey would be necessary.

4. Methods

4.1 Database Searches

Searches of both state and Commonwealth databases were undertaken as part of the desktop review for the Assessment. These focused on identifying threatened or priority ecological communities (TEC's and PEC's) of subterranean fauna, as well as stygofauna or troglofauna taxa recorded from within or near the MWP. Search areas were based on a radius from the central point of the MWP, or within northwest and southeast corners, as required by the relevant database custodians (**Table 4-1**). Databases searches conducted are presented in Table 4-1

Table 4-1: Search parameters of the database searches for the Assessment.

Database Source	GPS Coordinates	Search Radius/Area	Reference
NatureMap of Western Australia	Central point -28.863173° 122.546614°	40 km	Department of Biodiversity Conservation and Attractions 2019b
Department of Biodiversity, Conservation and Attractions (DBCA) Threatened and Priority Fauna database (TEC/PEC)	Central point -28.863173° 122.546614°	50 km	Department of Biodiversity Conservation and Attractions 2019a
DBCA Threatened and Priority Fauna	Central point -28.863173° 122.546614°	150 km	Department of Biodiversity Conservation and Attractions 2019c
EPBC Protected Matters	Central point -28.863173° 122.546614°	40 km	Department of the Environment and Energy a
EPBC Act TEC List	Central point -28.863173° 122.546614°	40 km	Department of the Environment and Energy c
EPBC Act Threatened Fauna List	Central point -28.863173° 122.546614°	40 km	Department of the Environment and Energy b
WAM Collections	Northwest corner -28.386942° 121.719866° Southeast corner -29.284710° 122.894393°	~11,000 km^2	Western Australian Museum a,b,c

4.2 Literature Review

A literature review was conducted to collate existing information on subterranean fauna from within the vicinity of the MWPStudy Area. The review included technical reports, scientific journal articles and government publications, focusing on the area within 150 km of the MWP.

4.3 Field Survey

The field survey methods and sampling effort employed for the Assessment was a verification (pilot) survey, which was aligned with EPA (2016a, b) technical guidance. A Regulation 17 licence to take fauna for scientific purposes (*Wildlife Conservation Act 1950*, Regulation 17) was obtained from the DBCA prior to survey under Licence Number BA27000074. Stantec personnel involved in the field sampling were Dr

Nicholas Stevens of Stantec and Adam Cargill of Lynas. Dr Stevens has 20 years' experience (BSc Zoology(Hons), PhD) in entomology and the assessment of subterranean fauna.

4.3.1 Groundwater Sampling

Groundwater properties can have an important influence on the occurrence and distribution of stygofauna and their habitat. A number of basic groundwater physicochemical parameters (electrical conductivity;EC, pH, temperature, dissolved oxygen;DO, and reduction-oxidation potential;redox) were recorded in the field. A groundwaterwater sample was collected using a bailer from the upper portionof the aquifer (one to two metres within the bore) using a calibrated portable YSI water quality meter. Standing water level (SWL) was also measured as metres below ground level (mbgl) using a Solinst 101 meter. The end of hole depth (EoH) was estimated from the number of rotations (known distance) of the stygofauna sampling winch reel.

4.3.2 Stygofauna Sampling

Stygofauna samples were collected from exploration drill holes, monitoring bores and infiltration bores ("sites") using haul nets; found to be the most efficient retrieval method for stygofauna (Environmental Protection Authority 2016a). Details of the sites sampled are presented in **Appendix A**, including representative site images (**Figure A-1**). Sampling was consistent with the procedures outlined by the Environmental Protection Authority (2016). The sampling method was as follows:

- samples were collected using two weighted haul nets with mesh sizes of 150 µm and 50 µm. Each net was fitted with a collection vial with a base mesh of 50 µm;
- the 150 µm net was lowered first, to near the bottom of the site;
- once at the bottom, the net was gently raised up and down to agitate the sediments;
- the net was then raised slowly, to minimise the 'bow wave' effect that may result in the loss of specimens, filtering the stygofauna from the water column on retrieval;
- once retrieved, the collection vial was removed, the contents emptied into a 250 ml polycarbonate vial, and preserved with 100% undenatured ethanol;
- this process was repeated three times alternating with three samples with the 50 µm net;
- to prevent cross-contamination, all sampling equipment was washed thoroughly with Decon 90 (2 to 5% concentration) and rinsed with potable water after each site;
- in the field, samples were placed into eskies with ice bricks prior to being transferred into a refrigerated environment on-site at the end of each survey day; and
- samples were couriered back to the Stantec laboratory in Perth, where they were stored in 100% ethanol and refrigerated at approximately minus 20°C.

4.3.2.1 Survey Effort

A total of 12 stygofauna net haul samples were collected from 12 sites across the MWP from the 17th to 19th of June 2019 (**Figure 4-1**,**Figure 4-2**, **Appendix B**). The survey effort exceeded the six to 10 samples recommended by the Environmental Protection Authority (EPA) (2016a) for a pilot stygofauna survey. This intensity, supported by the habitat characterisation, was considered to be of sufficient quantity to provide a reliable verification of the stygofauna values within the MWP.

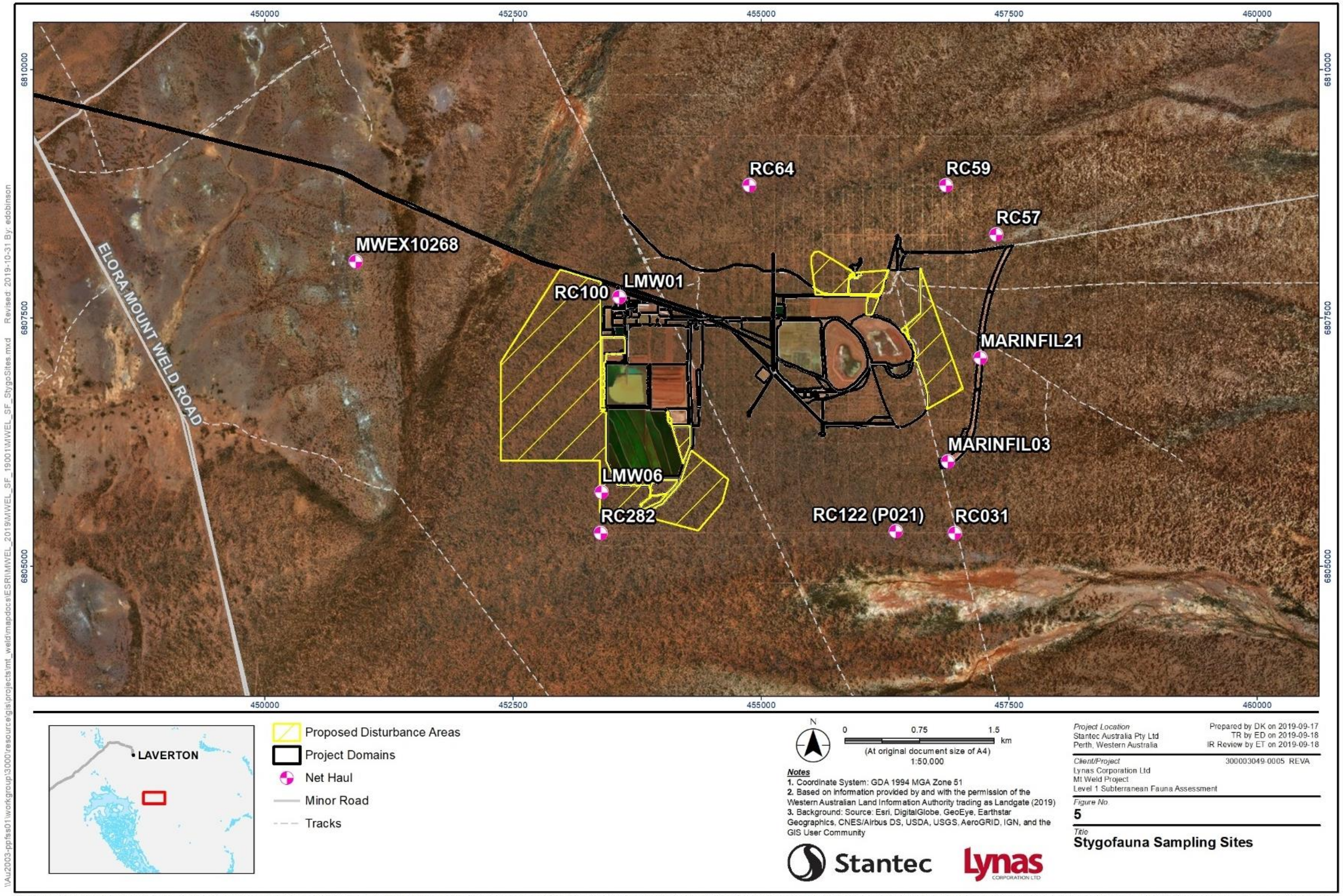

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Figure 4-1 Stygofauna sample sites in relation to MWP domains and proposed disturbance areas.

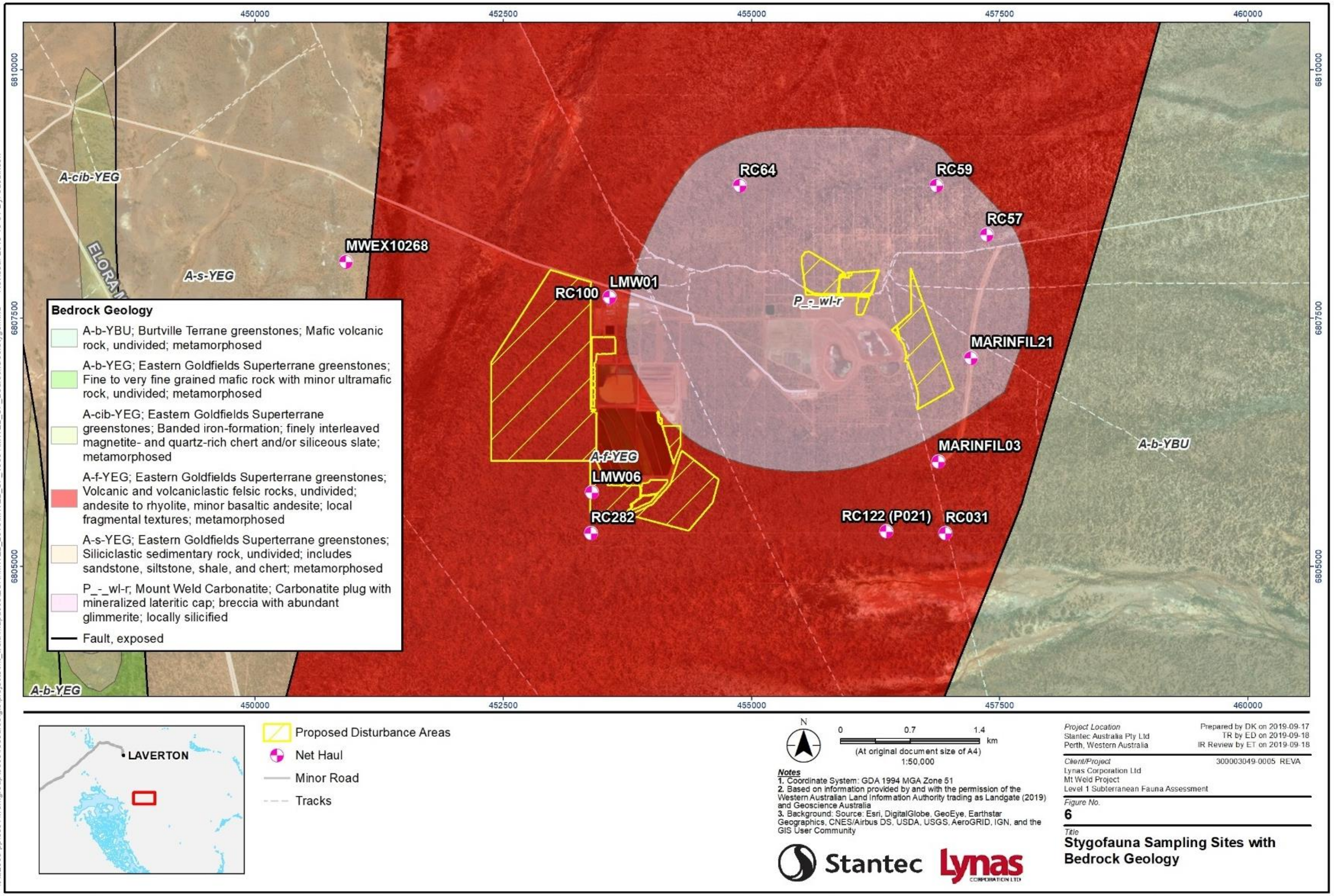

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Figure 4-2 Stygofauna sample sites in relation to sub-surface geology for the MWP.

4.3.3 Troglofauna Sampling

Troglofauna samples were primarily taken from exploration drill holes ("sites") using litter traps and net haul scrapes. The details of sites sampled are presented in **Appendix A**, including representative site images (**Plate A-1).**

4.3.3.1 Litter Traps

Troglofauna were sampled using litter traps as follows:

- litter traps were packed with sterilised organic material and sealed to maintain moist, sterile conditions prior to field deployment;
- traps were then moistened with water prior to deployment in sites;
- once installed in the sites, traps were left in place for eight weeks to allow adequate time for colonisation by troglofauna; and
- on retrieval, traps were sealed in zip lock bags, labelled, and couriered to the Stantec laboratory in Perth for sorting and identification.

Tullgren Funnels

In the laboratory, troglofauna specimens were extracted from the litter using Tullgren funnels. Litter was placed into funnels, and light and low heat was applied from overhead lamps to create a temperature gradient of approximately 14°C in the litter **(Plate 4-1).** This method was applied to encourage any troglofauna, which are light sensitive and prefer humid conditions, to migrate downwards through the litter as it dried. Troglofauna specimens then fall through a mesh layer into collection vials at the base of the funnels, containing 100% ethanol. After collection of troglofauna in the vials, the litter was removed from the funnels and manually searched under magnification for any troglofauna specimens that might be remaining.

Plate 4-1: Troglofauna collection and extraction methods: A) Litter trap; B) Tullgren funnels.

4.3.3.2 Net Haul Scrapes

Net haul scraping for troglofauna is employed as a complementary method to troglofauna trapping (Allford *et al.* 2008; Halse and Pearson 2014; Outback Ecology 2011b; Stantec 2017; Subterranean Ecology 2008a). Net haul scraping was conducted during the Assessment as follows:

- a stygofauna net was lowered to the bottom of a dry site or at least 1 m below the standing water level if groundwater is present.
- the net was scraped up along the uncased wall surface of the site on retrieval with the aim of dislodging and collecting any invertebrates that may be present.
- this process was repeated four times per site with each scrape sampling a different side of the wall surface of the site.

Scraping for troglofauna was also conducted simultaneously when sampling uncased bores with water present for stygofauna, increasing the number of troglofauna scrape samples. The only difference was the sample effort, with six net hauls taken per sample rather than four in line with stygofauna sampling

All haul samples were preserved in 100% ethanol prior to shipment back to the Stantec laboratory in Perth for processing. To enhance preservation of specimens and their DNA, samples were kept cool onsite in eskies with ice bricks then refrigerated at the end of each survey day. All samples were then shipped back to Perth in eskies with ice bricks then placed in freezers (-20°C) to further promote fixation of DNA.

4.3.3.3 Survey Effort

A total of 19 litter trap samples and nine scrape samples were collected from 19 sites (**Figure 4-3, Figure 4-4, Appendix C**). All troglofauna litter traps were deployed over single phase eight-week period between June to August 2019. Scrape samples were collected in conjunction with stygofauna sampling between the 17th and 19th of June 2019.

The survey effort exceeded the recommended number of ten to fifteen samples for a pilot survey, by the EPA (Environmental Protection Authority 2016a). The survey intensity, supported by habitat characterisation, was considered to be of a sufficient quantity to provide a reliable verification of the troglofauna values within the MWP.

4.4 Sorting and Identification of Specimens

Preserved samples were processed using Leica MZ6, MZ7.5, M80 and M205C stereomicroscopes by Jake Daviot (BSc Marine Science,Hons). Once sorted, any potential subterranean fauna specimens found were preserved in 100% ethanol and stored at -20°C to ensure viability for future DNA analysis (as required). Identication to species or morpho-species was undertaken by Dr Nicholas Stevens of Stantec using published keys, where available.

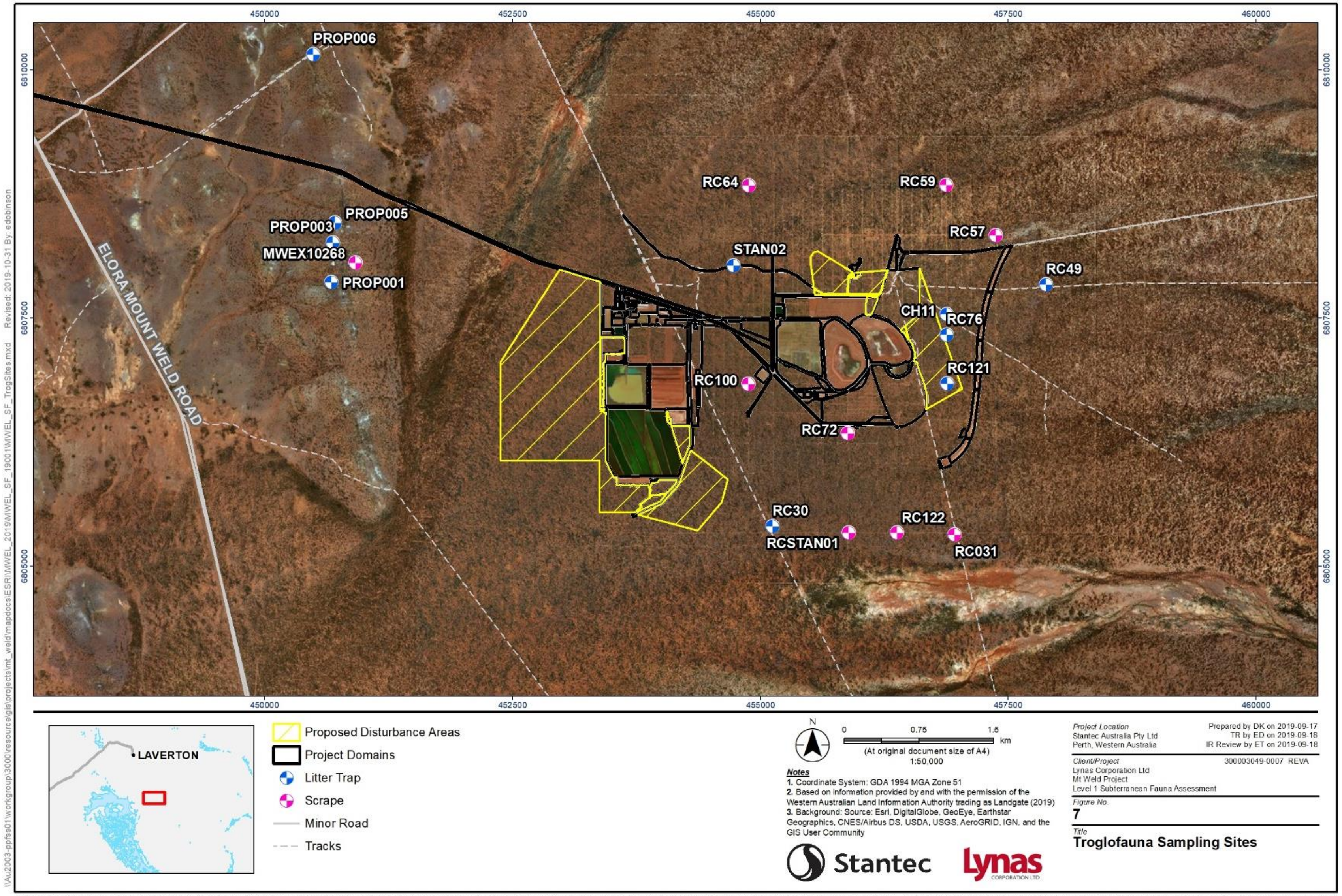

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Figure 4-3: Troglofauna sample sites in relation to MWP domains and proposed disturbance areas.

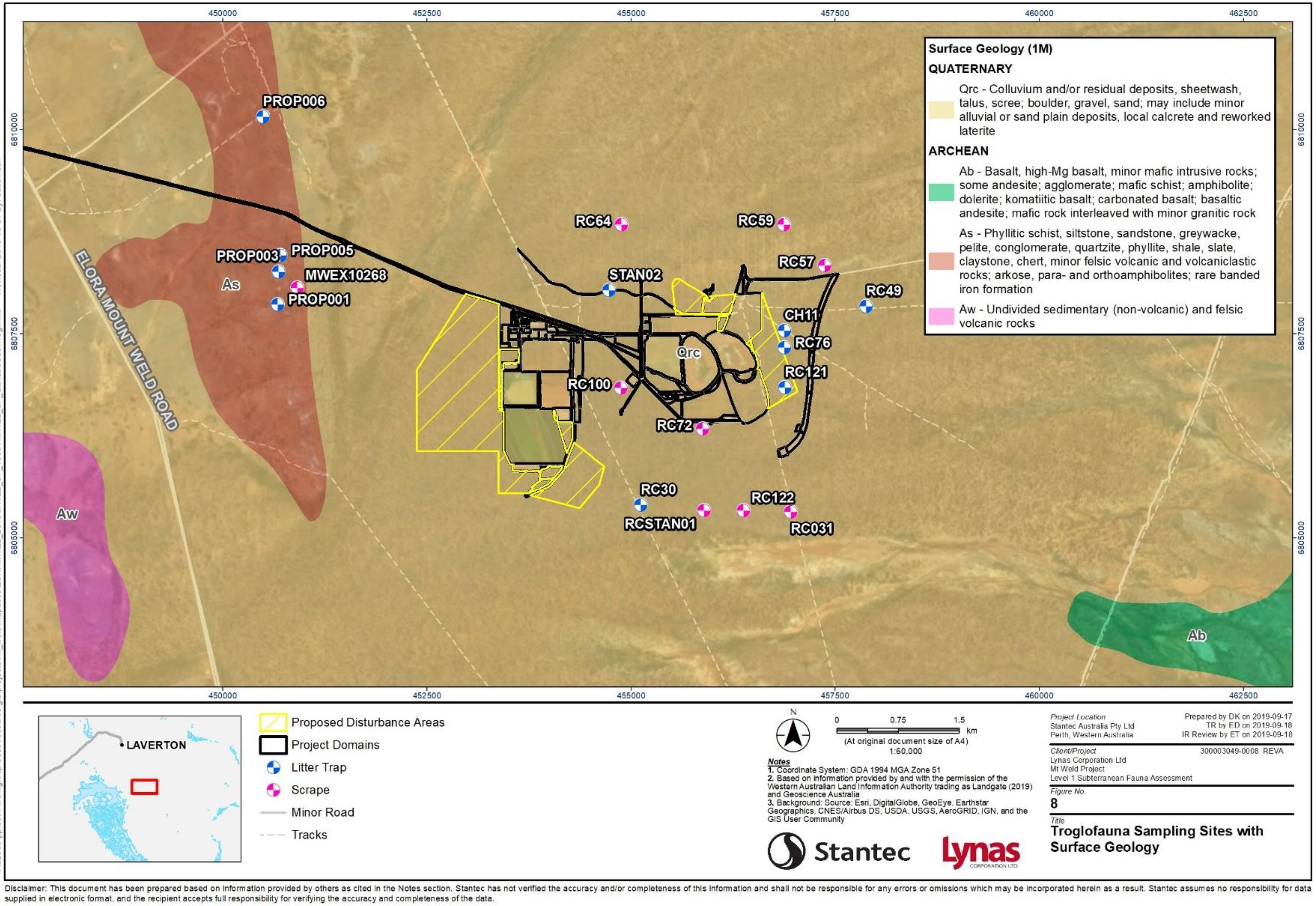

Figure 4-4: Troglofauna sample sites in relation to surface geology.

5. Results and Discussion

5.1 Database Searches and Literature Review

5.1.1 Database Searches

A search of the DBCA's TECs and PECs database identified three PECs within 50 km of the MWP. Of these, two were priority subterranean fauna communities, associated with the Carey palaeodrainage system. These included the Mount Morgan calcrete groundwater assemblage, approximately 25 WNW of the MWP and the Laverton Downs calcrete groundwater assemblage, approximately 46 km NW (**Figure 5-1; Figure 5-2)**. Both are classified as Priority 1 under the *Biodiversity Conservation Act 2016* (Department of Biodiversity, Conservation and Attractions 2019b), a ranking allocated to poorly known ecological communities of restricted distribution (Department of Environment and Conservation 2013). The third PEC identified in the area was the vegetation community associated with the Mt Jumbo Banded Ironstone Formation (BIF).

A single subterranean fauna taxon was listed in the DBCA's threatened and priority fauna database, for the area surrounding the MWP (Department of Biodiversity, Conservation and Attractions 2019c). This priority 1 taxon, the isopod *Paraplatyarthrus subterraneus*, was recorded approximately 52 km from the MWP, in the Laverton Downs calcrete. Searches of the DBCA's NatureMap and the Commonwealth's EPBC Act Protected Matters database and threatened fauna List did not reveal any threatened or priority fauna.

An area of approximately 11,000 km^2 around the MWP was investigated during searches of WAM Arachnida/Myriapoda, Insecta and Crustacea databases. While records of subterranean fauna were identified, none were within 20 km of the MWP. For Crustacea, records included cyclopoid and harpacticoid copepod taxa, isopods, ostracods and parabathynellid syncarids. Potential subterranean examples from the Arachnida/Myriapoda database included a pauropod and a cryptopid centipede while subterranean coleopterans (beetles) were confirmed by the Insecta database search. The subterranean fauna were primarily reported from groundwater (valley) calcrete systems (**Figure 5-1,Figure 5-2**). Subterranean records such as isopods from other lithological units, examples including colluvium and lunette dunes, were less common.

5.1.2 Stygofauna

The literature review identified several stygofauna surveys that have been undertaken in the area surrounding the MWP, within a 150 km radius (**Table 5-1**). The majority of these have focused on aquifers associated with groundwater calcretes; environments which are commonly associated with diverse stygofauna assemblages (Allford *et al* 2008, Bennelongia 2015, Outback Ecology 2012b,d). The closest of these calcrete systems is Mt Morgan, approximately 25 km west northwest of the MWP, with Laverton Downs, Melita and Nambi between 46 km to 119 km away, respecitvely. Available literature indicates that these calcrete systems collectively support stygofauna including subterranean coleopterans (dytiscids or diving beetles), amphipods and isopods Allford *et al* 2008, Watts and Humphreys 2006).

Few surveys have been undertaken in other hydrogeological units of the area, with records to date indicating a less favourable environment for stygal communities. Sampling at Gwalia/Tower Hill within colluvium over fractured rock did not yield any stygofauna (Subterranean Ecology 2008a). At comparable strata from St Barbara (Subterranean Ecology 2008a), only stygophilic (temporary groundwater taxa) copepods were recorded. No stygobitic taxa (obligate groundwater taxa) were documented (**Table 5-1**).

5.1.3 Troglofauna

Compared to stygofauna, troglofauna surveys in the area surrounding the MWP were limited to two studies. Sampling within the Laverton Downs Calcrete, approximately 46 km from the MWP identified several isopod taxa including the troglobitic species *Pararplatyarthrus subterraneaus.* The colluvial profile at St Barbara, approximately 113 km west of the MWP, also yielded isopods. The presence of troglofauna such as isopods, centipedes and thysanurans in non-calcrete associated lithologies has also been demonstrated in surveys within the broader region (Bennelongia 2016, Rockwater 2012). However, in general, calcretes have been found to host more diverse troglofauna communities (Bennelongia 2015).

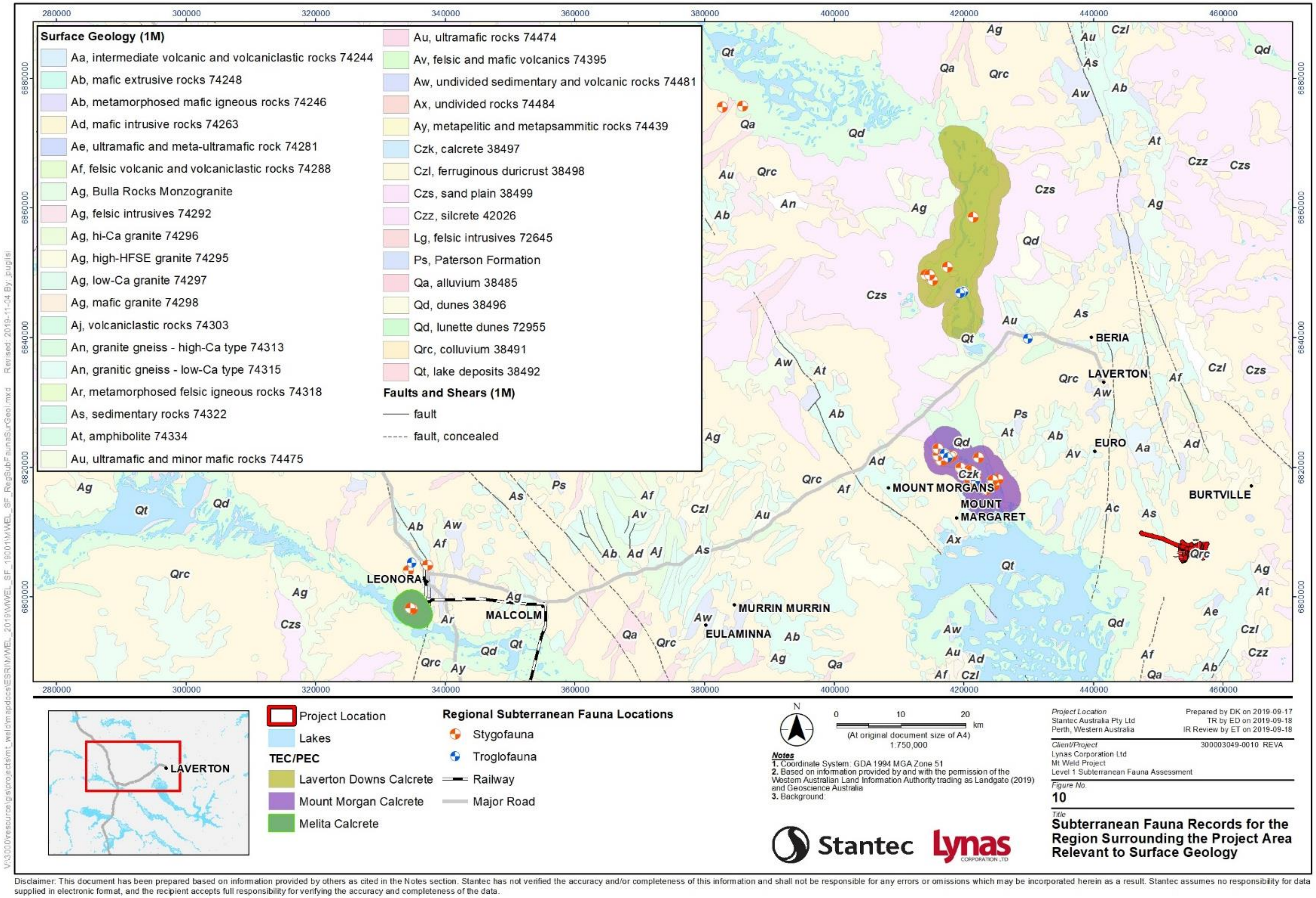

Figure 5-1: Subterranean fauna records from database and literature searches for the region surrounding the MWP, in relation to surface geology.

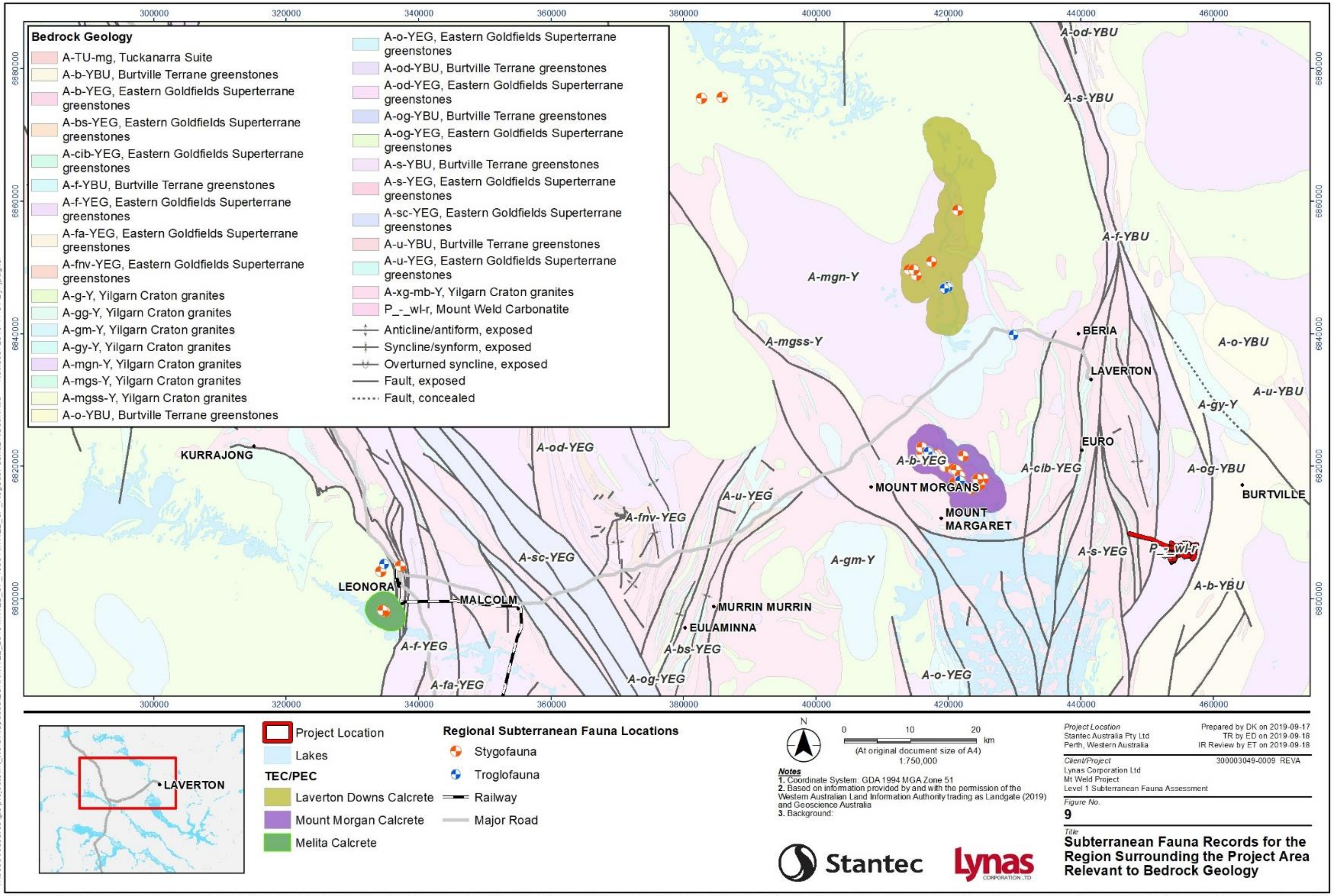

Figure 5-2: Subterranean fauna records from database and literature searches for the region surrounding the MWP, in relation to bedrock geology

Table 5-1: Literature review search results of subterranean fauna surveys undertaken in the wider vicinity of the MWP (<150 km).

	Area	Distance from Mt Weld	Taxa	Geology	Reference
Stygofauna	Gwalia & Tower Hill	116 km W	No stygofauna collected	Colluvium over fractured rock system	Subterranean Ecology 2008a
Stygofauna	Melita Calcrete (PEC)	119 km W	Coleoptera (Dytiscidae)	Calcrete system	Watts and Humphreys 2006
Stygofauna	St Barbara	113 km W	Stygophilic Copepoda (Cyclopoida)	Colluvium over fractured rock system	Subterranean Ecology 2008a
Stygofauna	Nambi	96 km NW	Coleoptera (Dytiscidae)	Calcrete system	Watts and Humphreys 2006
Stygofauna	Mt Morgan	25 km WNW	Coleoptera (Dytiscidae), Isopoda	Calcrete system	Watts and Humphreys 2006, Cooper *et al.* 2008
Stygofauna	Laverton Downs	46 km NW	Amphipoda, Coleoptera (Dytiscidae), Isopoda	Calcrete system	Watts and Humphreys 2006, Guzik *et al.* 2011, Bradford *et al.* 2013
Troglofauna	St Barbara	113 km W	Isopoda	Colluvium over fractured rock system	Subterranean Ecology 2008b
Troglofauna	Laverton Downs	46 km NW	Isopoda	Calcrete system	Javidkar *et al* 2015

5.2 Subterranean Fauna Habitat Characterisation

Under natural conditions, the superficial aquifer is hosted within transported sediments, primarily alluvium (**Figure 5-3).** Transported cover in the area has been largely deposited by intermittent sheet wash from the east and is widely distributed within the MWP and beyond (**Figure 4-4**). In contrast, the carbonatite complex is locally confined (**Figure 4-2**).

The quartz, sand and gravel forming the upper layer of the transported alluvium (approximately 12 to 15 m) are strongly cemented by carbonate and iron oxides. The strongest cementing occurs between 9 and 12 metres, softening at the historic water table (Lynas Corporation Ltd 2004). The underlying zone, typically extending to ≤24 m, is characterised by a higher proportion of ironstone detritus, with a silty clay matrix. Discontinuous and typically insignificant bands of calcretised alluvium; hard cemented to indurated calcrete cemented ironstone alluvium, also occur within the profile. In areas of limited drawdown, the vadose (unsaturated) zone would generally correspond with a limited portion of the cemented quartz alluvium, with the majority occurring within the ironstone alluvium, with the silt clay matix Lynas Corporation Ltd 2004). In areas impacted by substantial drawdown, the unsaturated strata would extend into the clay units of the lacustrine sediments or, carbonatite regolith (**Figure 5-3**).

The hard cementation and/or clay matrices within the alluvial and clay profiles may limit the suitable vugs and voids required for diverse troglofauna communities. Where inundated, the clay matrices would also potentially limit the pore spaces available to stygofauna. The underlying lacustrine sediments, predominantly hematitic clay and plastic clay form a discontinuous layer below the transported cover, forming a semi-confining layer to the carbonatite regolith below (Dames and Moore 1994). These units can extend to depths of up 70 mbgl, although more typically occur less than 50 mbgl. The former contains irregular masses, lenses and stains of hematite-limonite ironstone while the latter is a massive grey to mottled clay of very low permeability. These units would be unlikely to provide the structural requirements for either troglofauna or stygofauna habitation.

Calcrete also occurs as part of the lacustrine sediment zone (**Plate 5-1)**. These calcretised sediments are commonly recorded towards the palaeochannel and lacustrine areas, below 30 mbgl Lynas Corporation Ltd 2004). The calcrete, which formed in association with an old water table zone (AECOM 2017), is considered unlikely to represent prospective subterranean fauna habitat. Calcrete bodies in the region with diverse subterranean fauna communities are typically surficial; examples including Hinkler Well, Barwidgee and Yeelirrie (Bennelongia 2015; Outback Ecology 2011; Outback Ecology 2012a,b,c). The calcrete within the lacustrine sediments of the Mt Weld area mostly occurs at depths of 30 mbgl or lower and is often overlain a semi-confining hematitic and/or plastic clay (**Plate 5-1**).

The regolith (oxidised basement) beneath the clay ranges from weathered carbonatite and derivatives to Archaean rocks such as meta-volcanics, ultramafics and metasediments outside the carbonatite margins Lynas Corporation Ltd 2004). The clay and regolith profiles are illustrated in the diamond drill core logs and images from within the carbonatite margin (bore holes CH0027 and CH0029) (**Appendix E**). The regolith aquifer represents one of the primary groundwater sources associated with the carbonatite complex. It is probable that the semi-confining clay units, although discontinuous, at least partially restricts the input of nutrients and organic matter required for stygofauna communities.

The presence of suitable interconnected voids, vugs or fractures is another factor to be considered. Units such as caprock occur within the oxidised carbonatite regolith (**Plate 5-1**) and have been shown to contain vugs, voids and solution tubes. However, these spaces are typically filled with clay or pisolitic gravel from the overlying sediments or alluvium Lynas Corporation Ltd 2004). Vugs have also been identified in regolith units such as limonitic ironstone (**Appendix E**) and the transition zone to unoxidized carbonatite (Lynas Corporation Ltd 2004) yet may lack adequate interconnectivity for stygofauna. Large solution cavities can occur within the oxidised carbonatite sub-zone at depth, for example at 80 mbgl for CH029, although are unlikely to represent favourable stygofauna habtitat (**Appendix E**). Other units in the regolith zone, for example, soft siltstone, weathered glimmerite and residual apatite, commonly present as silts and sands, would be unlikely to contain adequate pore space.

Secondary porosity associated with fractures and vugs exists in the fresh bedrock underlying the oxidised zone (**Appendix E**) (AECOM 2017). While there a degree of hydraulic connection between the fractured rock and the other aquifers, the depth from the surface and semi-confining clay layer, albeit discontinuous, are likely to reduce the prospectivity of this unit for stygofauna.

A palaeochannel that crosses over the carbonatite represents another potential source of groundwater for the wider area however is not considered likely to support stygofauna (**Figure 2-4**). The presence of this feature is evidenced by basal sands intersected in sites near the eastern margin of the carbonatite such as RC57 and RC122 (67.5 mbgl and 38 mbgl respectively) (AECOM 2017; Lynas Corporation Ltd 2004)

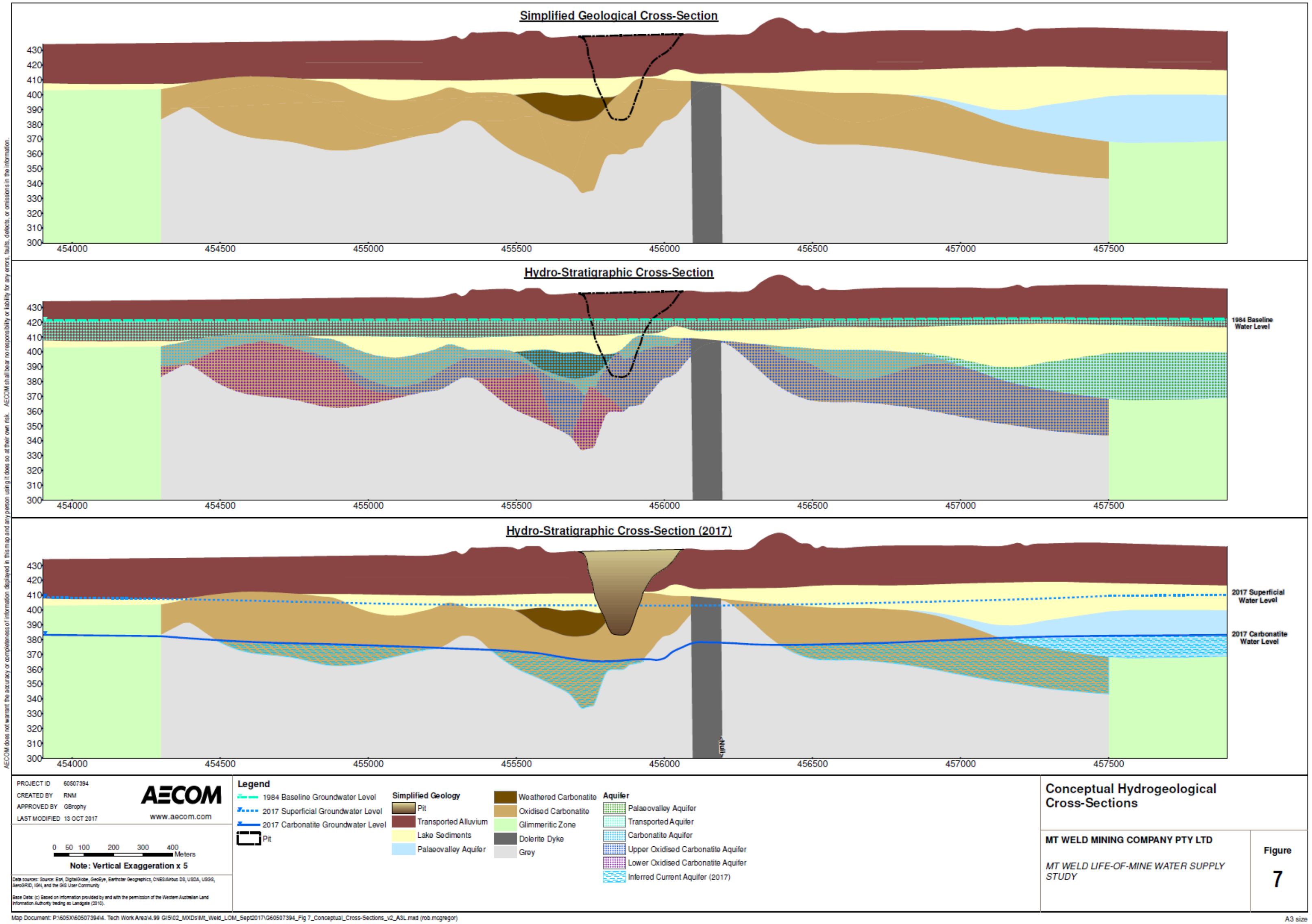

Figure 5-3: Conceptual hydrogeological cross-sections (AECOM 2017).

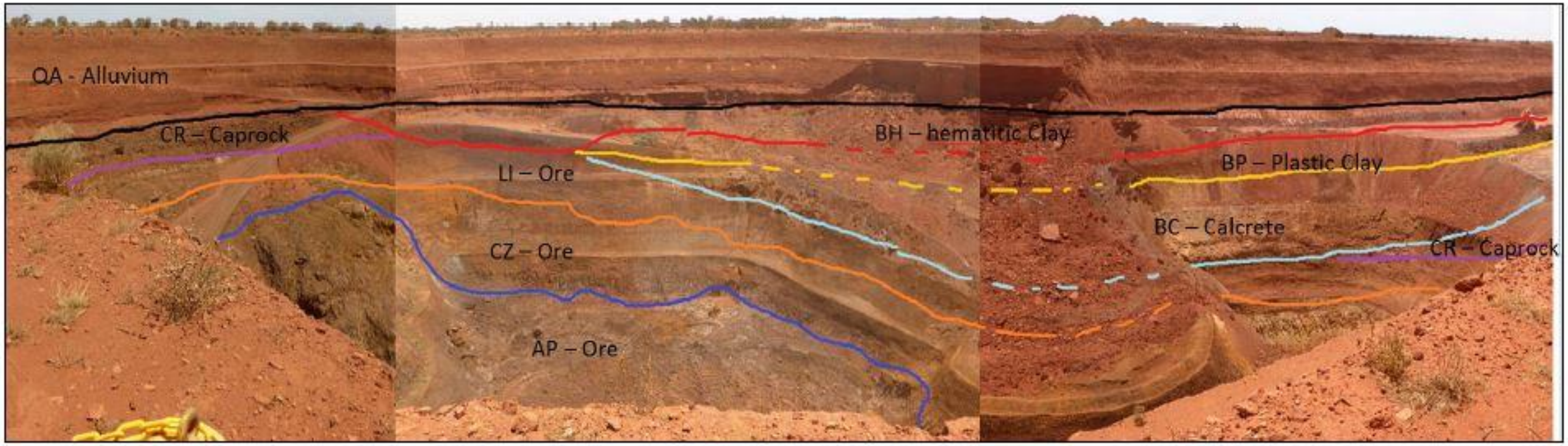

Plate 5-1: View of main pit showing lithological classification (CSA Global 2018).

5.3 Survey Results

5.3.1 Groundwater

The static water levels (SWL) recorded during the Assessment ranged from 13.36 to 59.38 mbgl (approximately 404 to 370 mAHD), with the majority less than 30 mbgl (**Appendix D**). The water table was closest to the surface at sites located to the west of the carbonatite complex. Depth to groundwater was greatest at CH11, located within the carbonatite complex, approximately 1 km from the pit.

Groundwater salinity (EC), ranged from 150.7 µS/cm to 3,151 µS/cm, classified as fresh to hyposaline conditions (*sensu* Hammer 1986) (**Appendix D**). These values are well within the range known to support stygofauna, which spans from fresh to hypersaline (Humphreys 2008, Outback Ecology 2012d). The pH of the groundwater was generally circumneutral (6.5 to 7.5), with limited records of slightly acidic (pH<6.5) or alkaline (>7.5) conditions (**Appendix D**). Groundwater pH values between 7.2 and 8.2 are commonly associated with the most diverse stygofauna communities in the Yilgarn (Humphreys 2008). Acidic conditions do not completely preclude stygofauna taxa however, with stygal ostracods recorded from groundwaters below pH5 (Reeves *et al* 2007).

The levels of DO were variable (0.67 to 6.01 mg/L) (**Appendix D**), reflecting the patchiness of this parameter across macro and micro spatial and temporal scales (Malard and Hervant 1999). However, typically, records reflected DO concentrations of >1 mg/L at most sites.

The groundwater quality at most sites, as represented by the basic suite of physico-chemical parameters, indicate suitable conditions for pH, salinity and DO, for stygofauna within the MWP. Based on these parameters, groundwater quality is unlikely to represent a barrier to stygofauna habitation of the area.

5.3.2 Stygofauna

There were no stygofauna recorded from the 12 sites sampled during the pilot survey of the Assessment. This included sites from within the MWP; either proximal to the pit or mining infrastructure, and from reference areas to the north, north-east (east) and west of the pit (**Figure 4-1;Figure 4-2**).

The survey effort was considered sufficient to provide a reliable verification of the likely prospectivity of the area for stygofauna. The survey findings were consistent with the literature review and habitat characterisation, which suggested that the area was unlikely to support stygofauna. While groundwater quality was suitable for stygofauna, the primary hydrogeological units generally lack suitable interconnected voids, vugs or adequate pore spaces for stygofauna colonisation. Where vugs, voids or solution cavities do exist, they tend to be infilled or at depth, decreasing the potential for stygofauna habitat. Lacustrine clays discontinuously overlying the regolith are also likely to at least partially restrict the input of resources (nutrients and organic matter) to the regolith aquifer and where present, underlying fractured rock aquifers.

5.3.3 Troglofauna

A single potential troglofauna (troglobite) taxon was collected during pilot survey of the Assessment. The taxon, an isopod *Paraplatyarthrus* nr *pallidus* OES26 (**Plate 5-2**), was recorded as singleton from PROP005 (**Figure 5-4**). This site is situated along a low, outcropping ridge (**Plate A-1 H**), 5.2 km to the west of the existing Mt Weld pit and more than 2 km away from the proposed disturbance area. This outcropping, also observed at PROP006, 1.7 km to the north (**Plate A-1 I**), occurs to varying degrees over a linear extent of at least 5 km (**Figure 5-4**). While, additional dewatering for the pit expansion is expected to increase drawdown extent in the superficial aquifer, it is unlikely to impact upon troglofauna habitat along the ridge, an area located in a different geological domain to the MWP.

There were no troglobitic taxa documented from the comparatively low-lying MWP area (pit or infrastructure areas). A non-troglobitic isopod (slater) *Paraplatyarthrus crebesconiscus* was the only taxon recorded from this area. This taxon, which is closely related to *Paraplatyarthrus pallidus,* is slightly pigmented and has a wide distribution, with records from several calcrete systems in the region including Halfpenny, Nambi and Laverton Downs (Javidkar *et al* 2017). While troglobitic taxa require the higher humidity of the deeper vadose zone, taxa such as *Paraplatyarthrus crebesconiscus* are less restricted, likely utilising the soil and upper alluvial strata, where weathering, plant roots and surface leaf litter provide habitat opportunities.

Plate 5-2: *Paraplatyarthrus* nr *pallidus* OES26 recorded from PROP005 during the Assessment.

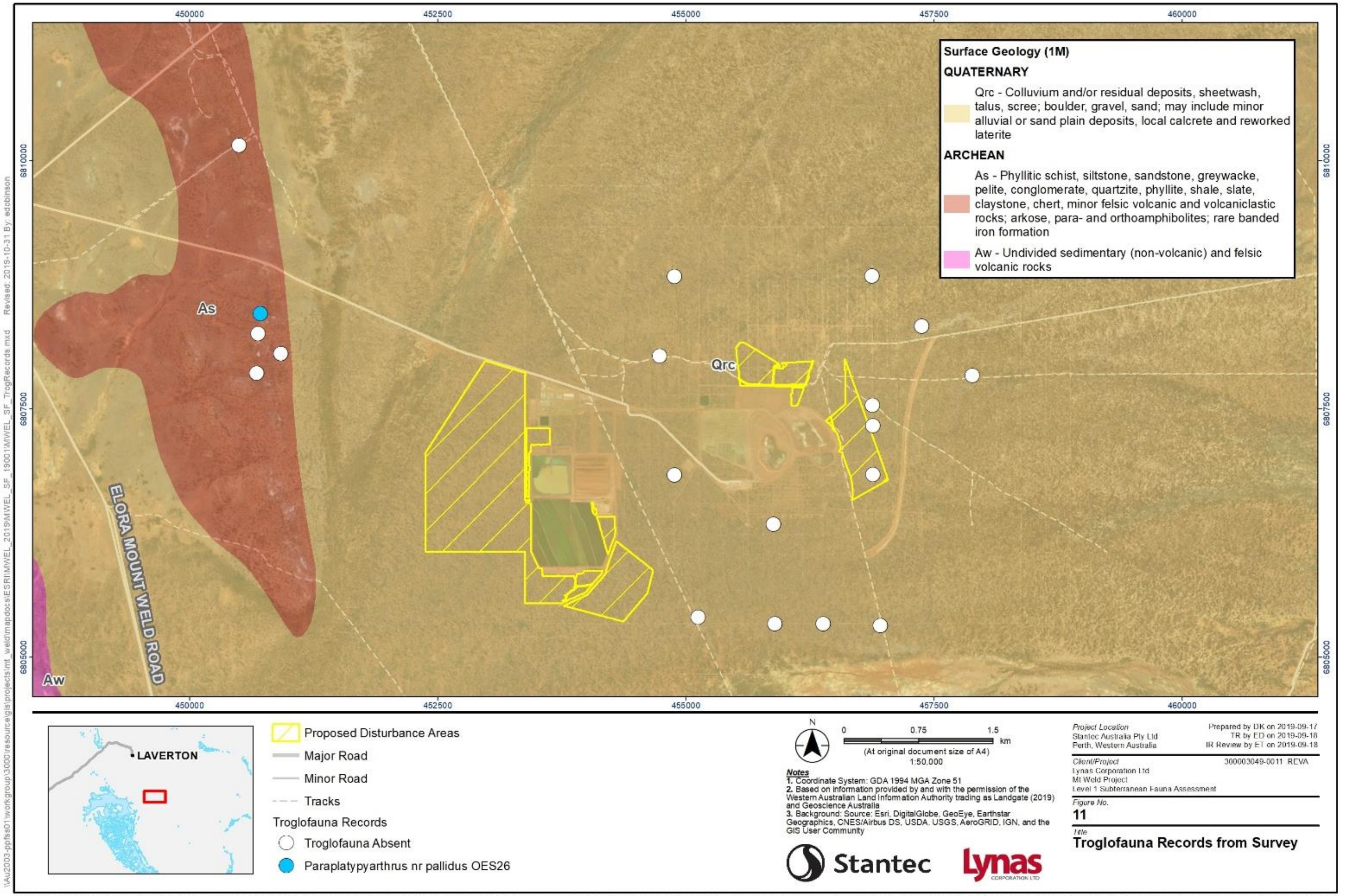

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Figure 5-4: Troglofauna records from the subterranean fauna pilot survey of the MWP, in relation to surface geology.

6. Conclusion

The Assessment demonstrated that the mining area of the MWP does not provide prospective habitat for stygofauna (stygobites) or troglofauna (troglobites), with key findings summarised in **Table 6-1**. Database searches and a literature review did not identify any subterranean taxa within the immediate vicinity of the MWP, with most taxa in the broader area associated with shallow calcrete systems. Similarly, the desktop review of hydrogeological information indicated that the mining area would be unlikely to support subterranean fauna.

The habitat characterisation indicated that the cemented and/or clay dominated alluvial strata, which account for most of the unsaturated zone (under natural conditions) are likely to lack the extensive, interconnected vugs and voids required for troglofauna (troglobites). For stygofauna, while the groundwater quality is suitable, the cementation and/or clay matrices of the alluvium and underlying clay strata would likely limit the pore spaces available for stygofauna, namely stygobites. Vugs, voids, solution cavities and fractures, where present in the regolith or underlying fresh bedrock tend to be infilled or occur at depth, also decreasing the prospectivity for stygofauna habitat. The discontinuous, semi-confining clay layer is also expected to at least partially restrict the input of resources; nutrients and organic matter, to the regolith aquifer and, where present, the underlying fractured rock aquifer.

The low prospectivity of the hydrogeology within the MWP was confirmed by the pilot survey, with no stygofauna (stygobites) or troglofauna (troglobites) recorded. The only potential obligate subterranean fauna taxon collected was the isopod *Paraplatyarthrus* nr *pallidus* OES26, associated with the outcropping low ridgeline, more than 5 km from the MWP mining pit, in the western reference area. This area, which may host limited troglofauna values, has a linear extent of at least 5 km and occurs in a different geological domain to the MWP.

The findings of the Assessment indicate that stygofauna (stygobites) and troglofauna (troglobites) do not represent an environmental factor for future regulatory approvals for the proposed expansion of the MWP, in accordance with EPA guidance. The results of the pilot survey, supported the desktop review and habitat characterisation, suggest that the proposed expansion of the MWP will not impinge on the representation, diversity, viability and ecological function of subterranean fauna at the species, population or assemblage level, in line with EPA objectives. It is therefore considered that no further assessment of subterranean fauna is necessary for environmental approvals to proceed.

Table 6-1: Summary of the Assessment indicating subterranean fauna habitat values and prospectivity in MWP mining area

Hydrogeological Unit	Key Lithologies	Characterisation	Prospectivity		Recommendation
			Stygofauna*	Troglofauna^	
Transported Sediments	• Alluvium (quartz, sand and gravel) • Alluvium (detrital ironstone, quartz)	• Aquifer of regional extent • Strong cementation and/or clay matrices likely limit interconnected vugs, voids, pore spaces for subterranean fauna • Unsaturated near pit, variable drawdown in wider area (expected to increase in with additional dewatering)	Negligible– nil found	Negligible– nil found	No further assessment required
Lacustrine Sediments	• Hemtatitic clay • Plastic clay • Calcretised sediments	• Predominantly massive • Discontinuous semi-confining layer to regolith • Saturated under natural conditions, at least partially unsaturated in impact areas • Calcretised sediments (calcrete) relatively deep, partially overlain by clay - not comparable to prospective surficial calcrete bodies	Negligible– nil found	Negligible– nil found	No further assessment required
Regolith (Oxidised Bedrock)	• Oxidised carbonatite and derivites (carbonatite complex margins) • Oxidised Archaean country rock (meta-volcanics and sediments) (outside carbonatite margins)	• One of the primary aquifers in MWP area • Overlying (discontinuous) semi-confining clays likely to at least partially restrict the input of resources • Vugs and voids present in some lithologies but commonly infilled • Other lithologies (sands, clays) may lack the physical structure for adequate vugs, pore spaces • Solution cavities at depth not favourable	Negligible– nil found	Negligible– nil found	No further assessment required

*stygobite, ^troglobite

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Appendices

Appendix A Subterranean Fauna Survey Site Details

Area	Bore Code	Latitude	Longitude	Bore Angle (°)	Internal Bore Diameter (mm)	Casing type	Elevation (mAHD)	EoH (mAHD)	EoH (mbgl)	Stygofauna	Troglofauna
Mining	CH11	-28.85908581	122.5578065	90	50	PVC	429.5				●
Mining	LMW01	-28.85752436	122.5240134	90	80	PVC	425.0		21.6	●	
Mining	LMW06	-28.87523322	122.5221322	90	80	PVC			19.8	●	
Mining	MARINFIL03	-28.87255825	122.5578834	90	200	Steel			57.6	●	
Mining	MARINFIL21	-28.86311839	122.561322	90	200	Steel			63.0	●	
Reference (Western)	MWEX10268	-28.85416898	122.4967836	60	120	None			45.0	●	●
Reference (Western)	PROP001	-28.85604575	122.4943905	60	120	None	424.8				●
Reference (Western)	PROP003	-28.8523809	122.4944773	60	120	None	424.6				●
Reference (Western)	PROP005	-28.85055498	122.4946948	60	150	None					●
Reference (Western)	PROP006	-28.83526191	122.4925379	60	120	None					●
Mining	RC031	-28.87906559	122.5585995	90	120	None	428.8	393.7	35.1	●	●
Mining	RC30	-28.85746985	122.5240083	90	120	None	422.5	422.5			●
Reference (Eastern)	RC49	-28.85646461	122.5683011	90	150	None	429.8	429.8			●
Reference (Eastern)	RC57	-28.85194088	122.5630032	90	150	None	431.3	398.9	32.4	●	●
Reference (Eastern)	RC59	-28.84743354	122.5578277	90	150	None	429.7	399.1	30.6	●	●
Reference (Northern)	RC64	-28.84738875	122.5374888	90	150	None	424.3	397.3	27.0	●	●
Mining	RC72	-28.87003165	122.5476764	90	120	None	425.1	425.1			●
Mining	RC76	-28.86541384	122.557847	90	100	None	429.1	429.1			●
Mining	RC100	-28.85744941	122.5240104	90	120	None	422.5	398.2	24.3	●	●
Mining	RC121	-28.86547102	122.5578811	90	80	None	428.7	428.7			●
Mining	RC122 (P021)	-31.94355903	115.8128983	90	100	None	428.7	382.8	45.9	●	●
Mining	RC282	-28.87892674	122.5219879	90	50	PVC	417.4	369.7	47.7	●	
Mining	RCSTAN01	-28.87900054	122.5476886	90	80	None					●
Mining	STAN02	-28.85464116	122.5358666	90	150	None					●

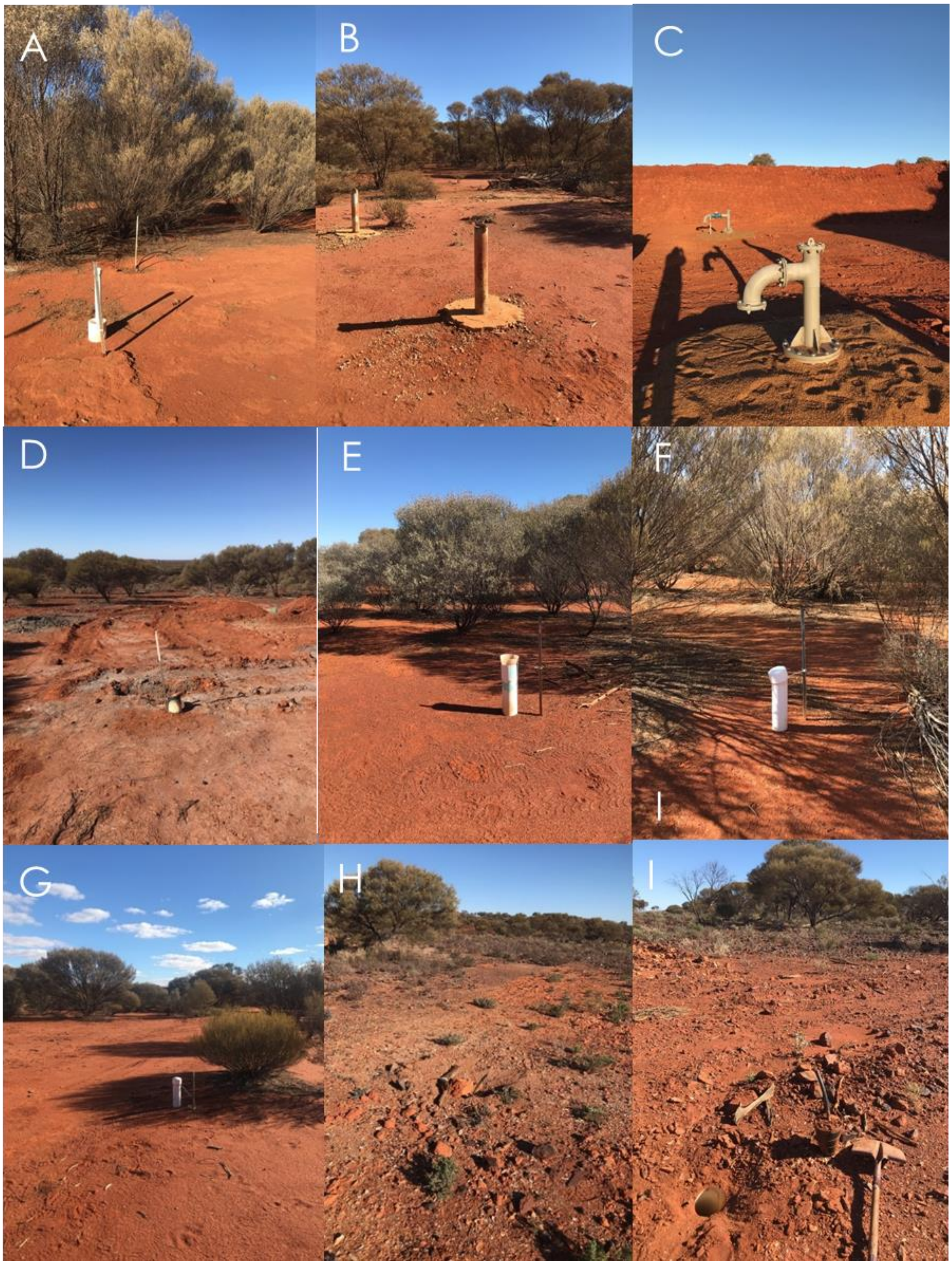


Plate A-1: Representative site photos A) CH11, B) LMW01 C) MARINFIL03 D) MWEX10268 E) RC64 F) RC121 G) RCSTAN01 H) PROP005 I) PROP006

Appendix B Stygofauna Survey Effort

Area	Bore Code	Latitude	Longitude	Sample Date	Collection Method
Mining	LMW01	-28.85752436	122.5240134	18/6/2019	Net Haul
Mining	LMW06	-28.87523322	122.5221322	18/6/2019	Net Haul
Mining	MARINFIL03	-28.87255825	122.5578834	19/6/2019	Net Haul
Mining	MARINFIL21	-28.86311839	122.561322	19/6/2019	Net Haul
Reference (Western)	MWEX10268	-28.85416898	122.4967836	19/6/2019	Net Haul
Mining	RC031	-28.87906559	122.5585995	17/6/2019	Net Haul
Reference (Eastern)	RC57	-28.85194088	122.5630032	18/6/2019	Net Haul
Reference (Eastern)	RC59	-28.84743354	122.5578277	18/6/2019	Net Haul
Reference (Northern)	RC64	-28.84738875	122.5374888	18/6/2019	Net Haul
Mining	RC100	-28.85744941	122.5240104	18/6/2019	Net Haul
Mining	RC122 (P021)	-31.94355903	115.8128983	17/6/2019	Net Haul
Mining	RC282	-28.87892674	122.5219879	17/6/2019	Net Haul

Appendix C Troglofauna Survey Effort

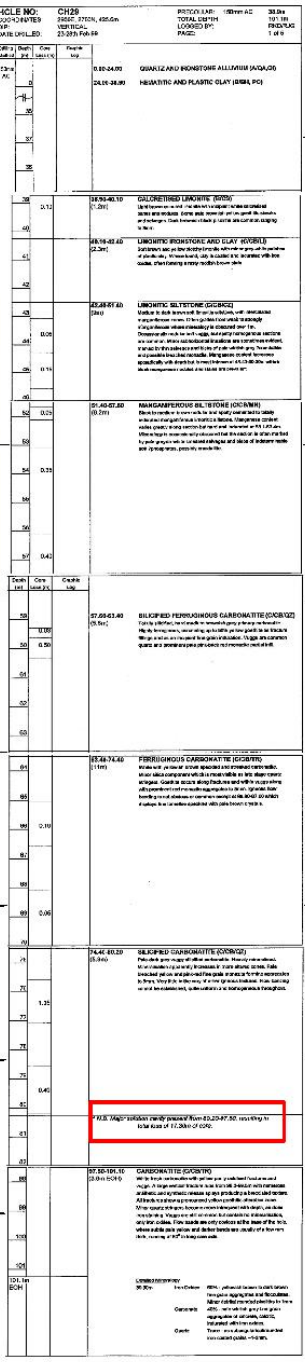
Area	Bore Code	Latitude	Longitude	Sample Start Date	Sample End Date	Collection Method
Mining	CH11	-28.85908581	122.5578065	18/6/2019	7/8/2019	Litter Trap
Reference (Western)	MWEX10268	-28.85416898	122.4967836	19/6/2019	8/8/2019	Litter Trap
Reference (Western)	MWEX10268	-28.85416898	122.4967836	19/6/2019	19/6/2019	Scrape
Reference (Western)	PROP001	-28.85604575	122.4943905	19/6/2019	8/8/2019	Litter Trap
Reference (Western)	PROP003	-28.8523809	122.4944773	19/6/2019	8/8/2019	Litter Trap
Reference (Western)	PROP005	-28.85055498	122.4946948	19/6/2019	8/8/2019	Litter Trap
Reference (Western)	PROP006	-28.83526191	122.4925379	19/6/2019	8/8/2019	Litter Trap
Mining	RC031	-28.87906559	122.5585995	17/6/2019	7/8/2019	Litter Trap
Mining	RC031	-28.87906559	122.5585995	17/6/2019	17/6/2019	Scrape
Mining	RC30	-28.85746985	122.5240083	18/6/2019	7/8/2019	Litter Trap
Reference (Eastern)	RC49	-28.85646461	122.5683011	18/6/2019	7/8/2019	Litter Trap
Reference (Eastern)	RC57	-28.85194088	122.5630032	18/6/2019	7/8/2019	Litter Trap
Reference (Eastern)	RC57	-28.85194088	122.5630032	18/6/2019	18/6/2019	Scrape
Reference (Eastern)	RC59	-28.84743354	122.5578277	18/6/2019	7/8/2019	Litter Trap
Reference (Eastern)	RC59	-28.84743354	122.5578277	18/6/2019	18/6/2019	Scrape
Reference (Northern)	RC64	-28.84738875	122.5374888	18/6/2019	7/8/2019	Litter Trap
Reference (Northern)	RC64	-28.84738875	122.5374888	18/6/2019	18/6/2019	Scrape
Mining	RC72	-28.87003165	122.5476764	18/6/2019	18/6/2019	Scrape
Mining	RC72	-28.87003165	122.5476764	18/6/2019	7/8/2019	Litter Trap
Mining	RC76	-28.86541384	122.557847	18/6/2019	7/8/2019	Litter Trap
Mining	RC100	-28.85744941	122.5240104	18/6/2019	7/8/2019	Litter Trap
Mining	RC100	-28.85744941	122.5240104	18/6/2019	18/6/2019	Scrape
Mining	RC121	-28.86547102	122.5578811	18/6/2019	7/8/2019	Litter Trap
Mining	RC122 (P021)	-31.94355903	115.8128983	17/6/2019	7/8/2019	Litter Trap
Mining	RC122 (P021)	-31.94355903	115.8128983	17/6/2019	17/6/2019	Scrape
Mining	RCSTAN01	-28.87900054	122.5476886	17/6/2019	7/8/2019	Litter Trap
Mining	RCSTAN01	-28.87900054	122.5476886	17/6/2019	17/6/2019	Scrape
Mining	Stan02	-28.85464116	122.5358666	18/6/2019	7/8/2019	Litter Trap

Appendix D Groundwater Properties Recorded During Sampling at MWP

Area	Bore Code	Sample Date	SWL (mbgl)	pH	EC (µS/cm)	DO (mg/L)	Redox (mV)	Water Temp. (C°)
Mining	CH11	18/6/2019	59.38	7.21	8279	1.76	202.9	24.2
Mining	LMW01	18/6/2019	18.71	7.3	4025	3.64	221.5	22.5
Mining	LMW06	18/6/2019	13.15	7.32	3787	3.49	186.2	21.8
Mining	MARINFIL03	19/6/2019	49.27	7.48	11890	2.12	66.4	21
Mining	MARINFIL21	19/6/2019	28.13	8.34	8826	0.91	-30.1	22
Reference (Western)	MWEX10268	19/6/2019	22.5	7.14	10408	4.28	152	22.7
Mining	RC031	17/6/2019	31.52	7.23	6337	6.01	105.9	24.4
Reference (Eastern)	RC57	18/6/2019	28.39	7.39	8322	0.67	-159.8	23.7
Reference (Eastern)	RC59	18/6/2019	28.15	7.52	3151	4.33	83.5	23.3
Reference (Northern)	RC64	18/6/2019	23.33	7.32	3730	3.67	219.5	23.2
Mining	RC100	18/6/2019	19.61	7.56	3758	6.71	213.7	22.1
Mining	RC122 (P021)	17/6/2019	29.69	7.1	9084	5.13	119.9	23.9
Mining	RC282	17/6/2019	13.36	6.4	150.7	1.39	-30.1	21.4

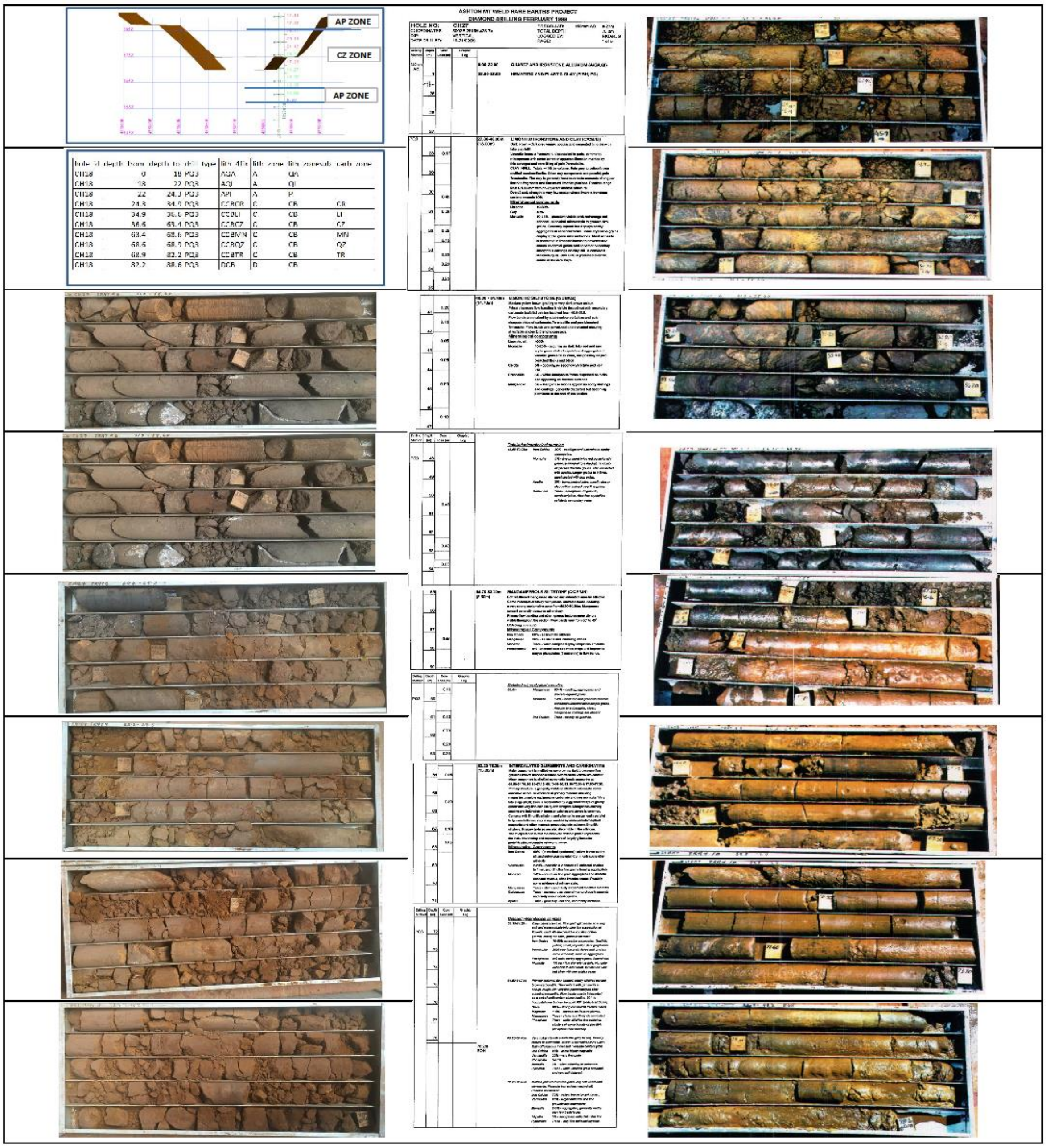
Appendix E Diamond Drill Core Images

hole_id	depth_from	depth_to	drill_type	lith_4fix	lith_zone	lith_zonesub	carb_zone
CH29	0	24	6A	AQA	A	QA	
CH29	24	28	6A	BBH	B	BH	
CH29	28	38.9	PQ3	BPC	B	PC	
CH29	38.9	40.1	PQ3	BCS	B	CS	
CH29	40.1	42.4	PQ3	CCBLI	C	CB	LI
CH29	42.4	51.4	PQ3	CCBCZ	C	CB	CZ
CH29	51.4	57.6	PQ3	CCBMN	C	CB	MN
CH29	57.6	63.4	PQ3	CCBQZ	C	CB	QZ
CH29	63.4	74.4	PQ3	CCBTR	C	CB	TR
CH29	74.4	80.2	PQ3	CCBQZ	C	CB	QZ
CH29	80.2	97.5	PQ3	CCBTR	C	CB	TR
CH29	97.5	101.2	PQ3	DCB	D	CB	



Core Photos taken 5/11/2015

Core Photos taken 28/02/1999



hole id	depth from	depth to	drill type	lith 4ls	lith zone	lith zonesub	carb zone
CH18	0	18	PQ3	AQA	A	QA	
CH18	18	22	PQ3	AQI	A	QI	
CH18	22	24.3	PQ3	API	A	P	
CH18	24.3	34.9	PQ3	CCBCB	C	CB	CB
CH18	34.9	36.6	PQ3	CCBLI	C	CB	LI
CH18	36.6	63.4	PQ3	CCBCZ	C	CB	CZ
CH18	63.4	68.6	PQ3	CCBMN	C	CB	MN
CH18	68.6	68.9	PQ3	CCBQZ	C	CB	QZ
CH18	68.9	82.2	PQ3	CCBTR	C	CB	TR
CH18	82.2	88.6	PQ3	DCB	D	CB	

Appendix F Troglofauna Survey Results

Area	Bore Code	Sample Start Date	Sample End Date	Taxon	Abundance	Status	Collection Method
Mining	CH11	18/6/2019	7/8/2019	*Paraplatyarthrus crebesconicus*	2	Non-troglofauna	Litter Trap
Reference (Western)	MWEX10268	19/6/2019	8/8/2019		0		Litter Trap
Reference (Western)	MWEX10268	19/6/2019	19/6/2019		0		Scrape
Reference (Western)	PROP001	19/6/2019	8/8/2019		0		Litter Trap
Reference (Western)	PROP003	19/6/2019	8/8/2019		0		Litter Trap
Reference (Western)	PROP005	19/6/2019	8/8/2019	*Paraplatyarthrus* nr *pallidus* OES26	1	Potential Troglofauna	Litter Trap
Reference (Western)	PROP006	19/6/2019	8/8/2019		0		Litter Trap
Mining	RC031	17/6/2019	7/8/2019		0		Litter Trap
Mining	RC031	17/6/2019	17/6/2019		0		Scrape
Mining	RC30	18/6/2019	7/8/2019		0		Litter Trap
Reference (Eastern)	RC49	18/6/2019	7/8/2019		0		Litter Trap
Reference (Eastern)	RC57	18/6/2019	7/8/2019		0		Litter Trap
Reference (Eastern)	RC57	18/6/2019	18/6/2019		0		Scrape
Reference (Eastern)	RC59	18/6/2019	7/8/2019		0		Litter Trap
Reference (Eastern)	RC59	18/6/2019	18/6/2019		0		Scrape
Reference (Northern)	RC64	18/6/2019	7/8/2019		0		Litter Trap
Reference (Northern)	RC64	18/6/2019	18/6/2019		0		Scrape
Mining	RC72	18/6/2019	18/6/2019		0		Scrape
Mining	RC72	18/6/2019	7/8/2019		0		Litter Trap
Mining	RC76	18/6/2019	7/8/2019		0		Litter Trap
Mining	RC100	18/6/2019	7/8/2019		0		Litter Trap
Mining	RC100	18/6/2019	18/6/2019		0		Scrape
Mining	RC121	18/6/2019	7/8/2019	*Paraplatyarthrus crebesconicus*	9	Non-troglofauna	Litter Trap
Mining	RC122 (P021)	17/6/2019	7/8/2019	*Paraplatyarthrus crebesconicus*	1	Non-troglofauna	Litter Trap
Mining	RC122 (P021)	17/6/2019	17/6/2019		0		Scrape
Mining	RCSTAN01	17/6/2019	7/8/2019	*Paraplatyarthrus crebesconicus*	1	Non-troglofauna	Litter Trap
Mining	RCSTAN01	17/6/2019	17/6/2019		0		Scrape
Mining	Stan02	18/6/2019	7/8/2019		0		Litter Trap

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