Vecco Critical Mineral Project- stygofauna survey

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1.1. Background

The Vecco Critical Minerals Project (Project) is being developed to meet the growing demand for vanadium, High Purity Alumina (HPA) and Rare Earth Elements (REE).

Vanadium is recognised as a ‘critical mineral’ by both the Queensland Government and the Commonwealth Government. In addition to its traditional uses, vanadium is used in the manufacture of vanadium redox flow batteries, which will be critical to the development of renewable energy generation and the global shift to decarbonisation. These large-scale batteries can store energy from solar panels and wind turbines to use at night-time or when the wind is not blowing. Vanadium does not degrade over a 25-year battery life making it a truly green energy storage solution and part of the circular economy. As a result, vanadium demand is growing rapidly. Queensland’s vanadium deposits, including the Vecco deposit, offer an in-demand product in the decarbonising movement.

HPA and REE are also recognised as ‘critical minerals’ by both the Queensland Government and the Commonwealth Government. Their uses include batteries and other renewable energy technology, such as wind turbines and solar panels.

The development of these resources in Queensland provides a unique regional employment opportunity with significant economic benefits for local communities such as Julia Creek and Townsville. The Project will also provide significant benefits to the State, in respect of both royalties payable and contributions toward Queensland’s renewable energy target. In addition to supporting local demand, the Project will contribute to Queensland's growing vanadium export industry.

1.2. Proponent

The proponent of the Vecco Critical Minerals Project (Project) is Vecco Industrial Pty Ltd ACN 158 805 497 (Vecco), a wholly owned subsidiary of Vecco Group Pty Ltd ACN 162 084 424.

Vecco is a private Australian-based company developing local vanadium, HPA and REE resources and manufacturing downstream products, such as vanadium electrolyte, for use in batteries and renewable energy generation. Vecco is currently developing Australia’s first vanadium electrolyte manufacturing facility in Townsville which will integrate with the production of vanadium from the Vecco Critical Minerals Project to provide a secure supply chain for batteries in Australia.

The Executive Team and Board of Vecco Group have over 100 years’ experience in the development and operation of mining assets in Queensland.

1.3. Location

The Project is located approximately 70 km north of Julia Creek township and approximately 515 km west of Townsville in north-west Queensland (Figure 1). The townships of Cloncurry and Richmond are located approximately 125 km west and 145 km east of the Project, respectively.

The land within and surrounding the Vecco Project area is designated as ‘Rural’ zone under the *McKinlay Shire Planning Scheme 2019*. Existing land use of the Vecco project area is low intensity cattle grazing.

1.4. Project Description

Vecco is seeking to develop the Project to mine and process the world class Vecco vanadium deposit. The Project will primarily target vanadium pentoxide (V_2O_5) and HPA, with minor quantities of other REEs also produced. The life of mine (LOM) is expected to be approximately 36 years, including construction, operation, and rehabilitation.

The Project is a proposed greenfield operation that will consist of a shallow, open-cut mine that will process up to 1.9 Mtpa ROM feed to produce up to approximately 5,500 tpa V_2O_5 and 4,000 tpa HPA over an operational life of approximately 26 years. Minor quantities of other REE may present opportunities for saleable biproducts of the process. Ore will be mined to an approximate depth of up to 35 m. Processing will occur following on-site crushing and screening of the ore. Mineral products will be packed in containers and transported by truck or rail to Townsville, for secondary processing into battery electrolyte or export from the Port of Townsville to international markets.

Key components of the Project include:

- open cut mining of up to 1.9 Mtpa ROM ore over a period of approximately 26 years;
- development of a mine infrastructure area (MIA), including, administration buildings, bathhouse, crib rooms, storage warehouse, workshop, fuel storage, refuelling facilities, wash bay, laydown area, and a helipad;
- development of mine areas (open cut pits) and out-of-pit waste rock emplacements. This includes vegetation and soil stripping;
- development of out-of-pit waste rock emplacements;
- construction and operation of a Mineral Processing Plant (MPP) and ore handling facilities adjacent to the MIA (including ROM ore and product stockpiles and rejects);
- construction of an access road from Punchbowl Road to the MIA;
- construction of an airstrip to provide access for the Royal Flying Doctors Service;
- construction of a 10 MW solar farm and associated energy storage system;
- installation of a raw water supply pumping system and pipeline to connect the MIA to the Saxby River for water harvesting;
- construction of an on-site workers village and associated facilities, including an adjacent sewage treatment plant (STP);
- other associated minor infrastructure, plant, equipment and activities;
- progressive establishment of soil stockpiles, laydown area and borrow pits (for road base and civil works). Material will be sourced from local quarries where required;
- open-cut mining operations using conventional surface mining equipment (excavators, front end loaders, rear dump trucks, dozers);
- strategic disposal of neutralised process rejects within the backfilled mining void;
- continued exploration and resource definition drilling on the MLAs;
- progressive development of internal roads and haul roads including a causeway over the Saxby River (designed for minimum impact on flow events) to enable access and product haulage;
- development of water storage dams and sediment dams, and the installation of pumps, pipelines, and other water management equipment and structures including temporary levees, diversions and drains; and

- progressive rehabilitation occurring at defined milestones through the operational life. All voids will be backfilled to natural surface, ensuring all rehabilitated landforms achieve a sustainable post-mining land use on closure.

Existing regional infrastructure, facilities and services may be used to support Project activities. These include the Townsville Port, the rail networks, electricity networks, local roads and the Flinders Highway.

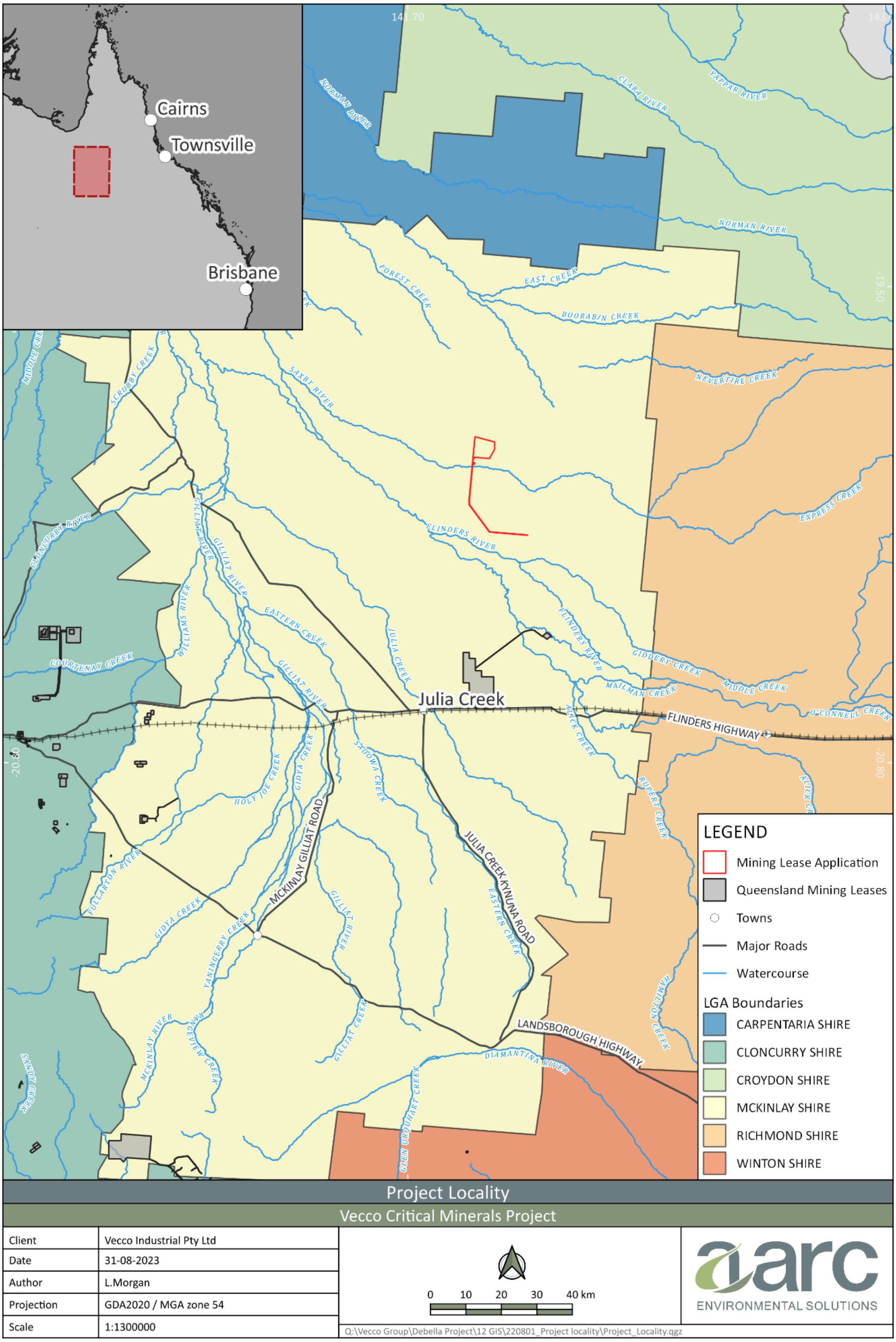

Figure 1: Location of mining lease north of Julia Creek

1.5. Scope of Works

Eco Logical Australia Pty Ltd (ELA) was engaged to conduct a pilot survey for stygofauna for the Vecco Critical Mineral Project. The aim of the survey was to determine the likelihood of stygofauna occurring in aquifers of the project area. Seven monitoring bores were available to sample.

2. Stygofauna ecological requirements

Stygofauna are generally small aquatic invertebrates that live in groundwater systems. They are typically crustaceans, although there are a few insect taxa and other non-crustacean invertebrates in the communities of the Hunter Valley. Estimates suggest there could be as many as 2,680 species in the western half of the Australian continent, although only approximately 12% of these have been described (Guzik et al. 2011).

Stygofauna have special adaptations to survive in the relatively resource-poor aquifers, where there is no light, space is limited, and food is scarce (Humphreys 2008). Adaptations include blindness, slow metabolism, reduced body size, elongation, and low reproduction rates (Coineau 2000). As there is no photosynthesis below ground, subterranean environments rely on inputs of organic matter from the surface to provide the basis of the food web (Schneider et al. 2011). Alluvial aquifers often have gradients in species diversity associated with distance from recharge areas, where dissolved or fine particulate organic matter enters the aquifer (Datry et al. 2005). Tree roots are also important sources of organic matter for groundwater food webs, and where they intersect the water table can have support diverse communities (Hancock and Boulton 2008, Jasinska et al. 1996).

Many ecosystem functions provide essential services to humans, saving both money and resources (Boulton et al. 2008). Despite their small size, the cumulative effect of some key stygofauna processes are likely to cause significant changes to groundwater quality. These processes are evident in alluvial aquifers where water moving though sediment particles is cleaned during transit, in much the same way as water moving through slow sand filters or trickle filters during water and sewage treatment (Hancock et al. 2005). It is likely that through their movement and grazing of sediment-bound microbes, stygofauna also help prevent alluvial aquifer sediments from clogging (Hancock et al. 2005).

Unlike many surface aquatic species, stygofauna have no aerial life stages, and are limited in their ability to disperse. Consequently, movement through aquifers is relatively slow and often restricted to convoluted passages between sediment grains or along fractures in rock. Usually, greater porosity corresponds to higher connectivity between interstitial spaces, meaning that stygofauna can move around in the aquifer with greater ease. Conversely, areas of low porosity can restrict the transfer of genetic material. Aquifers that are hydrologically disconnected from each other often have different stygofaunal compositions, although they may share some species if the aquifers were connected in the past or become connected occasionally during periods of high water level. The more frequent the aquifers are connected, the more similar the stygofauna communities are likely to be. However, with prolonged genetic isolation between adjacent aquifers or isolated sections of the same aquifer, species may begin to evolve, resulting eventually in the development of new species (Watts et al. 2007). Aquifers that have been isolated for long periods often contain several unique species of stygofauna with very limited distributions.

Aquifers are relatively stable compared to surface aquatic environments with little or no daily fluctuations in parameters such as temperature, water level, and electrical conductivity (EC). As such, many stygofauna taxa are sensitive to rapidly changing conditions (Hancock et al. 2005). Activities such as water table draw-down, the removal of aquifer material for mining or quarrying, or rapid changes to water quality can all have detrimental effects to stygofauna communities and possibly cause extinctions (Humphreys 2008).

It is a combination of the features outlined above that have driven concerns for the potential loss of stygofauna biodiversity, particularly in areas subjected to rapid and extensive anthropogenic changes. The key attributes of stygofauna that may place them at risk are:

- The adaptation to relatively stable conditions and vulnerability to rapid or excessive changes in water level, temperature, and salinity;
- Their slow rate of reproduction and slow growth rate;
- The limited ability to disperse through aquifers, and intuitively recolonise following disturbance; and
- The high degree of endemism, with entire species restricted to only small geographic areas.

Concerns over the impact of mining and other large development projects, and concerns for State responsibility to maintain biodiversity, prompted the Queensland Government to develop guidelines for stygofauna assessments (DSITI 2015).

2.1. Background - Factors influencing biological distribution in aquifers

As with all fauna, stygofauna require favourable conditions to inhabit an aquifer, but with the large number of species occurring in aquifers, there is a broad range of variability in ecological requirements. Not all aquifers are naturally suitable for stygofauna and those that are suitable, may become unsuitable as a result of human activities or natural changes. The biological distribution of stygofauna in groundwater is influenced by historical, geological, hydrological, physico-chemical, and biological properties (Strayer 1994, Hancock et al. 2005). There is still a lot to learn about stygofauna ecology, particularly in the eastern states where there have been relatively few surveys when compared to Western Australia. Nevertheless, it is possible to briefly summarise what is already known about the aquifer conditions that are likely to influence the distribution of stygofauna.

1.1.1 Aquifer type

Stygofauna have been collected from many aquifer types, including fractured basalt, fractured sandstone, and pesolithic aquifers, but are most common in karstic and alluvial aquifers. Critical aquifer characteristics are the hydraulic conductivity, depth to water table, and porosity.

Generally, stygofauna occur more frequently in alluvial and karst aquifers than in other geological formations (Hancock et al. 2005, Humphreys 2008). Alluvial aquifers occur beneath floodplains, which often provide the following favourable conditions to stygofauna:

- Water table is shallow, so there is recharge of infiltrating rainwater and organic matter, and the water table is accessible to floodplain tree roots.
- There is often some degree of hydrological connectivity with surface rivers. This is particularly influential in regulated rivers where artificial flow releases from upstream dams may provide aquifer recharge of organic matter and oxygen in periods where natural surface flow would be absent.
- Compared to deeper aquifers, water in alluvial aquifers is young, has a rapid flux, and can have a lower salinity.

1.1.2 Hydraulic conductivity

Hydraulic conductivity indicates how rapidly water flows through an aquifer. This is important to stygofauna communities because the flux of water through an aquifer often influences how rapidly organic matter and oxygen concentrations can be replenished.

1.1.3 Depth of water table

Depth to water table influences the amount of organic matter and oxygen that are available to aquifer food webs. With increasing depth below the land surface, the concentration of organic matter dissolved in infiltrating rainwater diminishes as it is absorbed in transit by soil bacteria and plant roots. Shallow water tables of less than 15 m have been found to favour high diversity in alluvial aquifers in the Hunter Valley and other parts of eastern Australia (Hancock and Boulton 2008).

Another source of organic matter to aquifer invertebrates is the presence of phreatophytic roots (Jasinska et al. 1996). Root density is likely to be higher in shallower aquifers, and the resultant increased availability of organic matter provides food to diverse stygofauna communities (Hancock and Boulton 2008).

1.1.4 Connectivity to recharge areas

A large proportion of the organic matter that fuels aquifer food webs has its origin at the surface and enters groundwater in particulate or dissolved forms. Therefore, sections of aquifers that are nearer to recharge areas are likely to have higher diversity and abundance than those that are further away since the transfer of organic matter and oxygen is greater at these sites (Datry et al. 2005).

1.1.5 A space for living

Stygofauna can only live in aquifers that have enough space for them to move around in. Space is present in the solute cavities in karst, between pesolithic sediments in calcrete, and fractures in sandstone and basalt. In unconsolidated sedimentary aquifers, the size of pore space between particles often correlates to the size of the animals present, with larger species occurring in aquifers of coarser material (Strayer 1994). Also important when considering the space available for living is the connectivity between pores, cavities, and fractures. These act as migration pathways to allow fauna to move around in the aquifer and are likely to be important in recolonising following disturbance.

1.1.6 Evolutionary history

Most stygofauna evolved from ancestors that once lived in surface freshwater or marine environments. As a result, it is possible that they have retained some of the traits and environmental tolerances of their ancestry. As an example, in coastal areas where ancestral stygofauna species may have come from a marine origin, contemporary taxa may be tolerant of high salinity (Hancock and Steward 2004, Humphreys 2008). Conversely, taxa with a freshwater ancestry may prefer lower salinities (Hancock and Boulton 2008).

1.1.7 Food availability

Stygofauna have adapted to the resource-starved conditions in aquifers and can tolerate low concentrations of organic matter (Strayer 1994, Hahn 2006). Food is available to stygofauna as particulate organic matter, groundwater bacteria, or as roots of phreatic trees. In its dissolved or fine particulate form, organic matter enters aquifers with recharging water. Dissolved organic matter is taken up by groundwater bacteria, which are then imbibed by smaller stygofauna. Most stygofauna are opportunistic omnivores.

1.1.8 Water regime

Local or regional climate and river-flow regimes can influence aquifer recharge, and so affect the organic matter flux in the aquifer. Periods of high, steady rainfall can increase hydrological connectivity between the land surface and the aquifer and can reduce depth to water table. Exchange between rivers, the hyporheic zone, and aquifers can be an important source of nutrients to stygofauna communities (Dole-Olivier et al. 1994), so flow fluctuations that enhance hyporheic exchange can subsequently enrich stygofauna communities in deeper parts of the aquifer.

1.1.9 Salinity

Stygofauna in inland aquifers are generally restricted to fresh or partly brackish water. Hancock and Boulton (2008) suggest that most taxa collected from alluvial aquifers in NSW and Queensland prefer EC less than 5000 µS/cm. In surveys of coastal areas and near salt lakes in Western Australia, stygofauna were collected from aquifers with salinities at or exceeding sea water (50 000 µS/cm, Watts and Humphreys 2004). No stygofauna in NSW are known from aquifers where EC is this high, but there have been recent collections from an aquifer in the Condomine basin, Qld, where EC was between 36 000 and 56 000 µS/cm (Andrea Prior *pers comm.* Glanville et al. 2016).

1.1.10 Dissolved oxygen

Stygofauna can tolerate very low concentrations of dissolved oxygen when compared to surface aquatic invertebrates. Hahn (2006) observed a strong decrease in concentrations below 1.0 mg/L, but found some fauna in concentrations down to 0.5 mg/L. Some taxa can survive with virtually no oxygen for temporary periods of up to 6 months (Henry and Danielopol 1999, Malard and Hervant 1999).

3. Groundwater characteristics of the project area

Project geology and hydrogeology are descried in detail by JBT (2022), with relevant details discussed below. As the project will only impact on the surface layers and extend down to a depth of >40 m, only the upper strata are discussed below.

The surface geology of the project area consists primarily of the Wandoola Beds and of Quaternary sediments dominated by sand and alluvial plain deposits. The Wandoola Beds are Tertiary-Quaternary sediments consisting of unconsolidated sand, clay, and gravels up to 10 m thick.

Seven groundwater monitoring bores were installed for the project in November 2021 and April 2022. The construction logs for these bores indicate that Quaternary sediments of sand, soil, clays and pebbles extended to a depth of 2-3 m. This is underlain by the Wandoola Beds with sand and minor pebbles do a depth of 7-12 m for MB01-MB05, and further Quaternary sediments dominated by silt, minor sands and clays down to 9 m at MB06_S and MB06_DR. Beneath the Quaternary sediments at all bores is a layer of Allura Mudstone with a thickness of 6 to 15 m. This forms a confining layer above the Toolebuc Formation, preventing the direct infiltration of rainfall. The Toolebuc Formation is thought to be recharged approximately 10 km east of the Project Area, where it outcrops at the surface (JBT 2022).

The seven bores sample groundwater in the Toolebuc Formation and Wallumilla Formation. MB06_S is screened in the Quaternary Alluvium and Allura Mudstone (Table 1, Figure 2).

Hydraulic conductivity of the Toolebuc Formation is relatively low, ranging from 0.001 to 0.031 m/day in MB02, MB03 and MB04, and 0.006 m/day in MB05 (JBT2022). Hydraulic conductivity is higher in MB01 (0.93 m/day) and MB06_DR (1.55 m/day), which are screened in oil shale. This higher conductivity is potentially due to localised fracturing at these bores and the hydraulic conductivity of this stratum should generally be considered as low (JBT 2022).

No data was available for groundwater of the project area. JY 2022 includes a brief account of the underlying Great Artesian Basin aquifer from Queensland Government bores, noting water has an electrical conductivity of 475 µS/cm. This aquifer is disconnected from the project aquifers so is not likely to influence stygofauna occurrence.

The Saxby River is the nearest large ephemeral watercourse to the project. The alluvium of Saxby River is thought to be less than 20 m, and is likely to be dry for much of its extent, except following recharge events (JBT 2022). Water level in the bore nearest the Saxby Alluvium (MB06_DR) indicates that the regional groundwater level of the Toolebuc Formation is below the base of the Saxby Alluvium, and the two aquifers are disconnected (JBT 2022).

Table 1.Groundwater monitoring bores at Vecco, and a summary of the strata they sample

Bore	Sampled depth (mbgl)	Water level during construction	Strata sampled	Description
MB01	26-29	17.8	Toolebuc Formation	Shale, weathered, dark brown black, sparse carbonate, becoming fresh to base

Bore	Sampled depth (mbgl)	Water level during construction	Strata sampled	Description
MB02	27-35	18.1	Toolebuc Formation	Shale, weathered, dark brown black, sparse carbonate, becoming fresh to base/ Mudstone, fresh, dark blue grey.
			Wallumbilla Formation	Mudstone, fresh, dark blue grey.
MB03	27-35	18.4	Toolebuc Formation	Shale, weathered, dark brown black, sparse carbonate, becoming fresh to base.
			Wallumbilla Formation	Mudstone, fresh, dark blue grey.
MB04	28-36	19.8	Toolebuc Formation.	Shale, weathered, dark brown black, sparse carbonate, becoming fresh to base.
			Wallumbilla Formation	Mudstone, fresh, dark blue grey.
MB05	24-30	21.1	Toolebuc Formation	Limestone, coquina, fresh, light, off-white cream. Shale bands in part
			Toolebuc Formation	Shale, fresh, dark brown black, minor carbonate bands.
MB06_S	6-10	Dry	Quaternary	Silt, minor sands, clay, light orange-brown.
			Allura Mudstone	Unconsolidated, cohesive, soft
MB06_DR	30-35	21.17	Toolebuc Formation	Limestone, coquina, fresh, light, off-white cream. Shale bands in part
			Toolebuc Formation	Shale, fresh, dark brown black, minor carbonate bands

4. Methods

This stygofauna assessment follows the *Guidelines for Environmental Assessment of Subterranean Aquatic Fauna* (DSITI 2015), which provides advice on the minimum requirements for stygofauna assessments in Queensland.

A desktop review was conducted that included a description of aquifers in the project area, and an assessment of their suitability as stygofauna habitat. Any stygofauna assessments from nearby aquifers were also reviewed.

Principal Groundwater Ecologist Dr Peter Hancock collected stygofauna samples from Vecco on 9 and 10 May 2023. Seven bores were visited (Figure 2), although MB06_S was dry.

Prior to the collection of stygofauna samples, groundwater temperature, electrical conductivity (EC), pH, and dissolved oxygen (DO) were measured using a Horiba U-50 multi-parameter meter. Six litres of water were collected from each bore using a bailer. The meter was calibrated in the laboratory prior to the field survey, and dissolved oxygen probe was calibrated at the start of each survey day.

Stygofauna samples were collected using a specially designed net that was constructed of 53 µm mesh and had a diameter of 40 mm to allow sampling of 50 mm monitoring bores. The net was lowered to the bottom of each bore, raised, and lowered several times to agitate fauna resting on the bottom, and then retrieved. At the top of each retrieval, the net was emptied into a sieve. This process was repeated until the contents of six net hauls were in the sieve. These were then transferred to a sample jar and stored in 75% ethanol.

Stygofauna samples were returned to the laboratory for sorting under a Leica M80 dissecting microscope.

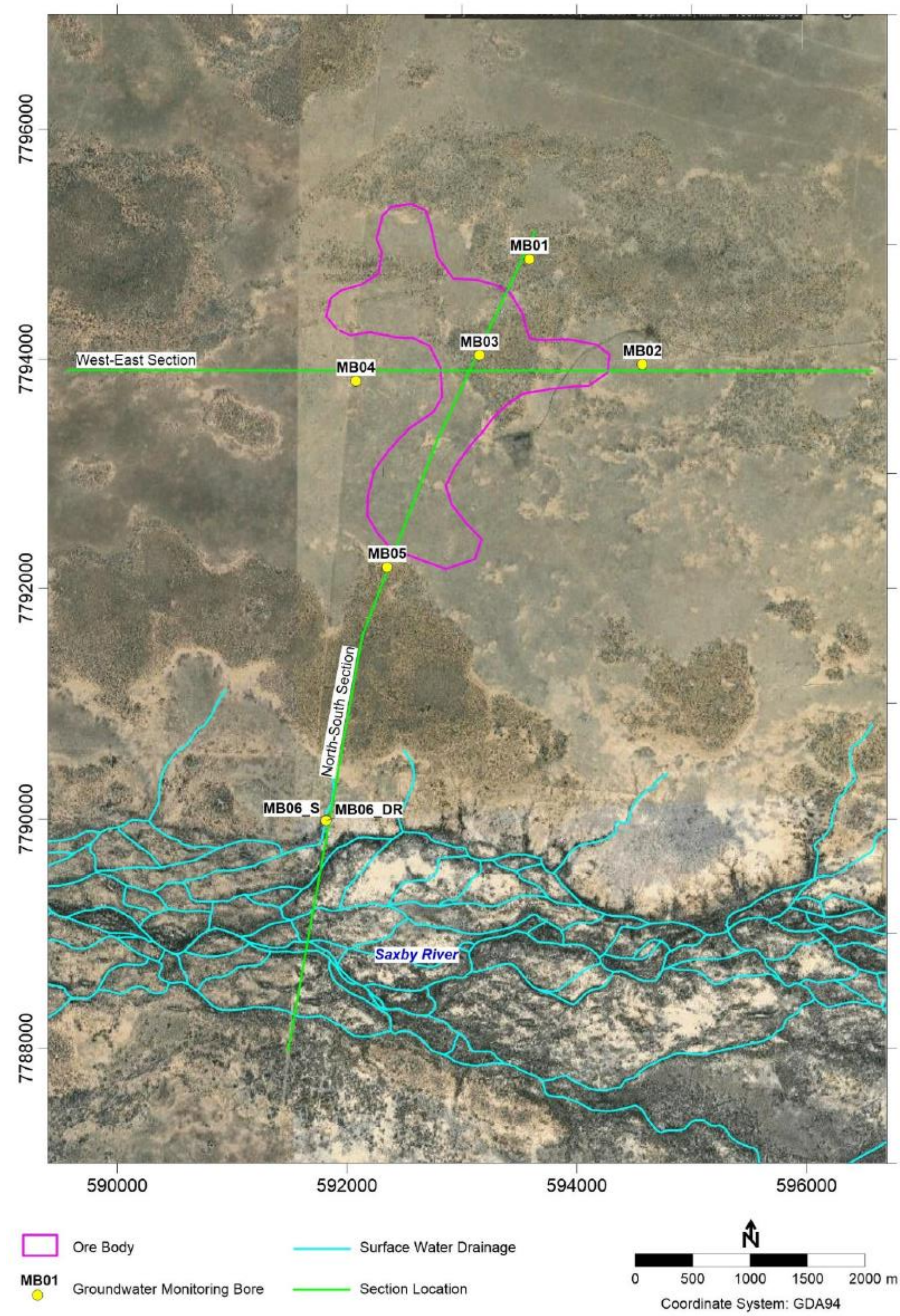

Figure 2: Location of monitoring bores sampled for stygofauna

5. Results

5.1. Desktop assessment

5.1.1. Suitability of aquifer

Based on the information reviewed, aquifers in the project area are unlikely to be suitable for stygofauna. The reasons for this include:

- Overlying Quaternary sediments are relatively thin, and although contain water following rain, they are likely to dry out during periods of no rain.
- Hydraulic conductivity in the Toolebuc Formation is likely to be too low to allow the interstitial spaces required for stygofauna movement and habitation.
- There is not direct hydrological connection to the surface. The Allura Mudstone acts as a confining layer, preventing the direct infiltration of groundwater to the underlying aquifers. This means that organic matter and nutrients are unlikely to be delivered in sufficient quantity to fuel groundwater foodwebs. Recharge location is approximately 10 km from the site, so any organic matter entrained in the water is likely to be not available for biological consumption by the time it reaches project aquifers
- The aquifers are disconnected from the Saxby River alluvium. Although there is no data to suggest the Saxby alluvium is inhabited by stygofauna (and this seems unlikely if the alluvium regularly goes dry), this is the nearest potential source for stygofauna colonisation of the project area.

5.1.2. Previous stygofauna assessments

frc environmental (2020) conducted a stygofauna assessment for the Saint Elmo Vanadium Project, which is located approximately 40 km south of the Vecco Critical Mineral Project. Geology of the Saint Elmo and Vecco Projects were similar, consisting of the Allaru Mudstone, Wallumbilla Formation and Toolebuc Formation in the upper strata. The desktop assessment for this work considered the geology to be unsuitable for stygofauna.

A pilot sampling program was planned, but was delayed due to the Covid-19 pandemic and no results from this are yet available.

5.2. Groundwater physico-chemistry

Groundwater level was between 17.67 and 23.15 mbgl across the six bores sampled (Figure 2, **Error! Reference source not found.**Table 2).

Physico-chemistry was generally suitable for stygofauna at most bores, although at MB04 pH was potentially too high. EC was between 193 and 5580 µS/cm, and pH between 7.32 and 9.23 (Table 2). Dissolved oxygen concentration was also suitable for stygofauna, with measurements between 1.35 and 2.71 % Saturation (Table 2).

Table 2. Physico-chemistry of groundwater at Vecco

	Units	MB02	MB03	MB04	MB06S	MB06-DR	MB05	MB01
Water table depth	mbgl	17.98	19.51	19.70		21.10	23.15	17.67
Temperature	°C	29.5	31.3	30.1		30.3	31.4	31.5
pH		8.59	7.79	9.23		7.89	8.45	7.32
Electrical Conductivity	µS/cm	2360	3370	802		2370	5580	193
DO mg/L	mg/L	1.58	1.41	1.35		2.25	2.71	2.20
DO %sat	% Saturation	20.3	14.1	13.8		30.1	35.1	26.2

5.3. Stygofauna community

No stygofauna were in the samples collected from the bores at Vecco during this survey.

6. Conclusion

Stygofauna generally prefer aquifers where the water table is shallow, electrical conductivity is less than 5000 µS/cm (Hancock and Boulton 2008), and dissolved oxygen concentration is aove 1 mg/L (Hahn 2006). Most of the bores at Vecco had water quality that was suitable for stygofauna. Water level at Vecco was also suitable for stygofauna. However, low hydraulic conductivity of the aquifers, their isolation from direct surface infiltration by the Allura Mudstone, the fact that the surface Quaternary sediments dry out, and the lack of connectivity to any potential colonising aquifer, make it very unlikely that stygofauna would occur in the aquifers affected by the Vecco Critical Mineral Project.

Six suitable groundwater monitoring bores were sampled during the pilot survey at Vecco. Bores were screened at from depths from 26 to 36 m, and sampled the Toolebuc Formation, Wallumbilla Formation, and Allura Mudstone. None of the samples contained stygofauna.

The lack of suitable habitat in the Vecco aquifers, and the absence of stygofauna from samples during the pilot survey, indicate that there are no stygofauna in the project area. Mining at Vecco will have no significant impact on stygofauna communities.

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