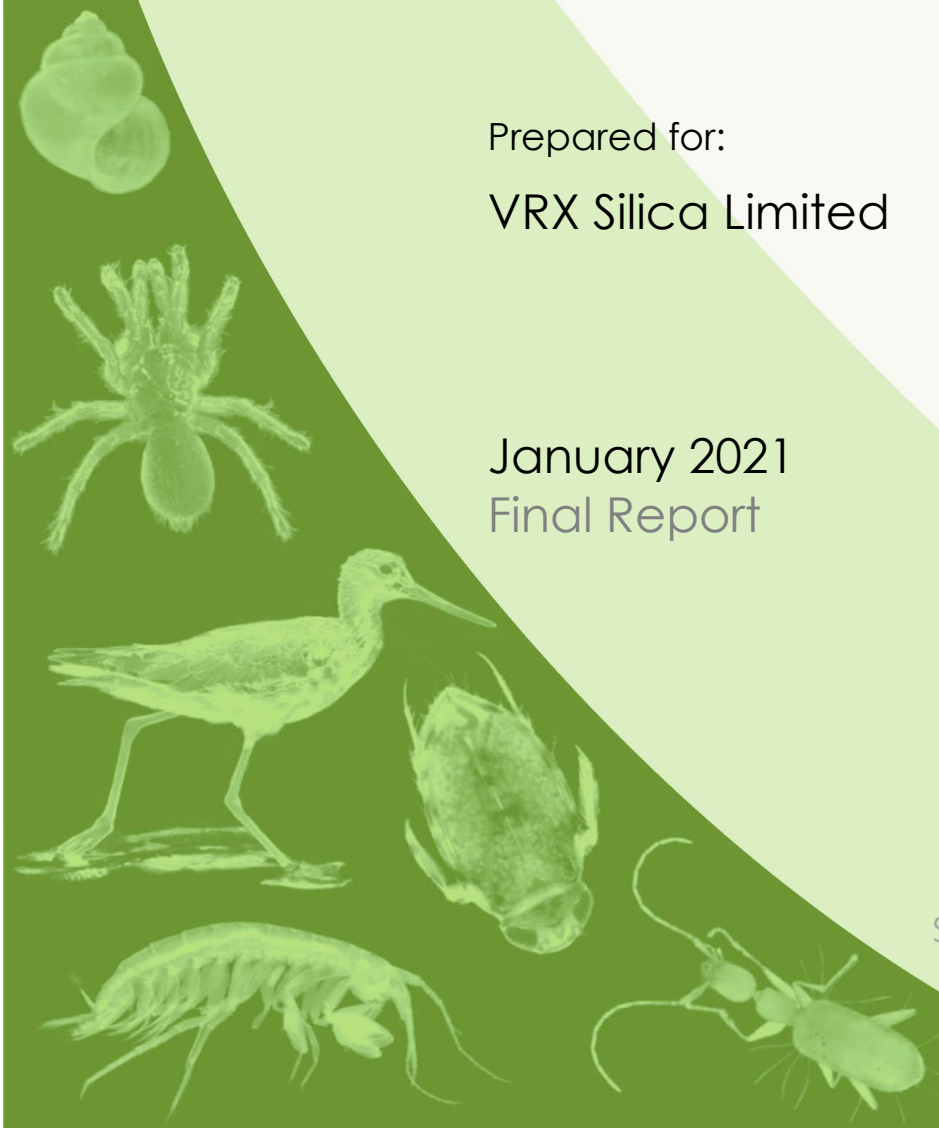
Bennelongia Environmental Consultants

Arrowsmith North Project SRE Invertebrate Desktop Assessment

Prepared for:

VRX Silica Limited

January 2021
Final Report



Short-Range Endemics I Subterranean Fauna

Waterbirds I Wetlands

Arrowsmith North Project SRE Invertebrate Desktop Assessment

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EXECUTIVE SUMMARY

VRX Silica Limited is proposing to develop the Arrowsmith North Silica Sand Project (the Project), located in the Geraldton Sands bioregion of Western Australia, approximately 40 km north of Eneabba. The Project aims to mine high-grade silica sand via extraction and mechanical upgrading.

Preston Consulting, on behalf of VRX Silica Limited, has engaged Bennelongia Environmental Consultants to undertake a desktop assessment to determine the likelihood of conservation significant and short-range endemic (SRE) invertebrate fauna occurring in the Project area. SRE invertebrate species are defined as having an overall range of less than 10,000 km^2. They tend to exhibit patchy distributions within their range, slow growth, low fecundity and poor dispersal capabilities. The assessment of SRE invertebrates in Western Australia typically focuses on a selection of ground-dwelling invertebrate groups that contain a high proportion of range-restricted species (SRE Groups).

The purpose of this desktop assessment is to determine the likelihood of conservation significant and SRE invertebrate fauna occurring in the Project area. The assessment is based on the habitat types present at the Project, as well as previous records of terrestrial invertebrates within a search area around the Project (50km north, south and east, and west to the Indian Ocean).

The Project area features a range of habitat types, largely *Banksia* heath/shrubs with diverse understoreys and isolated pockets of *Eucalyptus* woodland, typical of coastal Kwongan vegetation. These vegetation types could contain a range of microhabitats prospective for SRE species; indeed, despite relatively little sampling in the region, similar habitats on the Geraldton Sandplains have yielded SREs from groups including mygalomorph spiders, scorpions, pseudoscorpions, isopods, millipedes and snails. In addition to the potential microhabitats for ground-dwelling invertebrates, the heath vegetation at the project includes several flowering species that are known to be hosts for listed and range-restricted bees.

The desktop assessment identified three Priority listed terrestrial invertebrate species within the search area, the land snail *Bothriembryon perobesus,* the trapdoor spider *Idiosoma kwongan* and the bee *Hylaeus globuliferus*. *B. perobesus* has been collected from *Banksia* woodlands and low shrubland on white sandy soils in multiple locations surrounding the Project and is likely to also occur within the Project area. *I. kwongan* and *H. globuliferus* have been collected at locations between 20 and 50 km south of the Project, again in Kwongan habitats similar to the Project area. *H. globuliferus* is a specialist of Proteaceae flowers and is considered to have a moderate likelihood of occurring at the Project. The record of *I. kwongan*, however, is at the northern edge of its known range and the species is considered to have a lower probability of extending as far north as the Project.

The assessment also identified a moderate diversity of potential SRE species within the search area, with 25 species from SRE Groups that have potentially restricted ranges, including modern and trapdoor spiders, pseudoscorpions, scorpions, centipedes, millipedes and slaters, along with 15 insect species from non-SRE Groups that have potentially restricted ranges. While many of these represent undescribed species that are difficult to assess due to data deficiency, there are also a range of described species known only from the Geraldton Sandplains in habitats similar to those at the Project. In particular, jumping spiders (family Salticidae), the trapdoor spiders *Bungulla banksia* and *Euoplos mcmillani*, and millipedes in the genus *Antichiropus* are likely to occur within the Project area and have limited ranges. Additionally, several of the range-restricted bees in the genera *Euhesma, Leioproctus* and *Trichocolletes* feed on plants that are known to occur at the Project.

There are several challenges to identifying full impacts of the Project developments on SRE invertebrates. First, the species recorded within the search area provide an indication of the type of community likely to occur in the vicinity, but desktop assessment cannot identify the species actually occurring in an unsurveyed area such as the Project. As noted above, many of the species identified within the search

area have a moderate-high likelihood of occurring at the Project but for these species impacts from the Project will usually be minor, as they are already known to occur outside of the Project. However, given that SRE species are by definition restricted to small areas and many of the reported groups (e.g. mygalomorph spiders and *Antichiropus* millipedes) tend to have high species turnover across landscapes, it is also possible that different species within these groups will occur more locally at the Project.

Secondly, for many of the invertebrate groups only a broad understanding of habitat prospectivity can be gleaned from vegetation mapping and previous collections of SRE species. The groups that can be most confidently assessed in terms of habitat distribution include flying insects such as bees, whose ranges are mainly restricted by their host feeding plants. Many of the conservation significant and range-restricted bees identified in this report feed on plant species within heath communities that extend outside of the Project development envelopes. Therefore, if these species do occur at the Project, the most likely impacts may be minor reductions of habitat rather than complete loss. On the other hand, ground-dwelling groups such as trapdoor spiders, jumping spiders and millipedes are more dependent upon microhabitats within vegetation communities than on the community composition. Therefore, the actual distribution on SREs species in such groups will depend on the spatial extent of features such as leaf litter beds, soil humus, large debris and south-facing slopes, which can be patchy even within widespread vegetation types.

In conclusion, this desktop assessment indicates that a moderate community of SRE invertebrates is likely to occur at the Project, including trapdoor spiders, jumping spiders, millipedes and native bees; although the exact species that will be found at the Project cannot be identified without survey within the area. In addition, some listed Priority species could occur at the Project, in particular the snail *Bothriembryon perobesus*. The level of threat posed to terrestrial invertebrates by the proposed developments could range from low to moderate, depending on the particular species that occur in the Project area, and whether these species are dependent upon restricted microhabitats within the area.

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1. INTRODUCTION

VRX Silica Limited is proposing to develop the Arrowsmith North Silica Sand Project (the Project), located in the Geraldton Sands bioregion of Western Australia, approximately 40 km north of Eneabba (Figure 1). The Project aims to mine high-grade silica sand via extraction and mechanical upgrading. Proposed activities include the sequential block mining of silica sand, development of a mine feed plant, moveable surface conveyor, pipeline, processing plant, freshwater supply bore, access corridor, laydown, administration, water storage and associated infrastructure including a gas fired power station, communications equipment, offices, workshop and laydown areas.

Mining will be conducted over a total area of no more than 412.2 ha. This includes clearing of land for mine access, sand processing and mine development itself. Clearing of native vegetation has the potential to detrimentally impact terrestrial Short-Range Endemic (SRE) invertebrate fauna that inhabit or rely on surface soils or associated vegetation. This is particularly the case with traditional mining practices where surface soils are cleared, and topsoil stockpiled for later re-spreading during mine rehabilitation.

VRX Silica Limited is aiming to minimise impacts and speed up ecological recovery by employing modern and innovative mining and rehabilitation techniques. Mining will be progressively rehabilitated using Vegetation Direct Transfer (VDT). VDT is the practice of salvaging and replacing intact sods of vegetation with the underlying soil still intact (Ross *et al*. 2000). This results in faster regeneration of the ecosystem (Mattiske 2019) and increased survival rates of sensitive plant species that are often missing in other rehabilitation methods (Mattiske 2019 and references within). This form of mining and rehabilitation has the potential to minimise disturbance to SRE species and allow establishment and/or recolonisation of invertebrates much faster than traditional methods, as has been shown in trials by Rodgers *et al.* (2011).

Preston Consulting, on behalf of VRX Silica Limited, has engaged Bennelongia Environmental Consultants to undertake a desktop assessment to determine the likelihood of conservation significant and short-range endemic (SRE) invertebrate fauna occurring in the Project area. The specific aims are to assess:

- The occurrence of potential SRE species from invertebrate records in the vicinity of the Project;
- The occurrences of any listed species from invertebrate records in the vicinity of the Project (Biodiversity Conservation Act 2016 or Environment Protection and Biodiversity Conservation Act 1999); and
- Determine the likelihood that SRE and listed invertebrate species occur in the Project area, based on the types of habitat present.

2. CONSERVATION FRAMEWORK

2.1. Listing of Threatened Terrestrial Invertebrates

The listing of species for special protection is governed at the federal level under the Environment Protection and Biodiversity Conservation Act 1999, and at the state level under the Biodiversity Conservation Act 2016. The state-level listing of Threatened species (Critically Endangered, Endangered and Vulnerable species; Appendix 1) is maintained by the Department of Biodiversity, Conservation and Attractions (DBCA); additionally, the DBCA maintains a list of Priority species that potentially require protection but do not currently meet survey or data requirements for formal Threatened status (see Appendix 1 for definitions of Priority Categories).

2.2. SRE Terrestrial Invertebrates

In addition to formal listing of Threatened and Priority fauna, the assessment of SRE invertebrates in Western Australia is prescribed by the Environmental Protection Authority (EPA 2016a, b). Under this framework, SRE species are broadly defined as having an overall range of less than 10,000 km^2, following Harvey (2002). They are usually characterised by patchy or fragmented distributions within their range,

slow growth, low fecundity and poor dispersal capabilities. Assessment of environmental impacts on SREs typically focuses on several taxonomic groups (the SRE Groups) that are known to contain high proportions of species with these characteristics. In southwestern Australia, these groups include land snails (Gastropoda); millipedes (Diplopoda); centipedes (Chilopoda); pseudoscorpions (Pseudoscorpiones); scorpions (Scorpiones); spiders [Araneae, mainly Mygalomorphae (trapdoor spiders), but also some modern spiders within Aranaeomorphae]; slaters (Isopoda), harvestmen (Opiliones), velvet worms (Onychophora) and earthworms (Oligochaeta).

The SRE Groups listed above provide a useful practical framework for identifying potential restricted species, however it is important to note two further points. First, SREs can also occur in groups where most other species are widespread, due to high vagility, ecological plasticity or xeric adaptation (Framenau *et al*. 2008; Rix *et al.* 2015). Second, and conversely, many species belonging to SRE Groups are in fact widespread. Therefore, determining whether a species has a significantly restricted range (notionally <10,000 km^2) is more difficult than simply identifying them as belonging to an SRE Group.

One guide to the distribution of an SRE Group species is that it is likely to be confined to the extent of its preferred or obligate habitat(s), so that species that are only found in restricted or patchy habitats usually have smaller ranges than those collected from extensive or common habitats. Nevertheless, in some groups there may be some species turnover in more widespread habitats (e.g. due to climatic gradients) that results in a species occupying only part of a widespread habitat and, therefore, being an SRE with a range that is much smaller than the extent of its apparently suitable habitat (Rix *et al.* 2015).

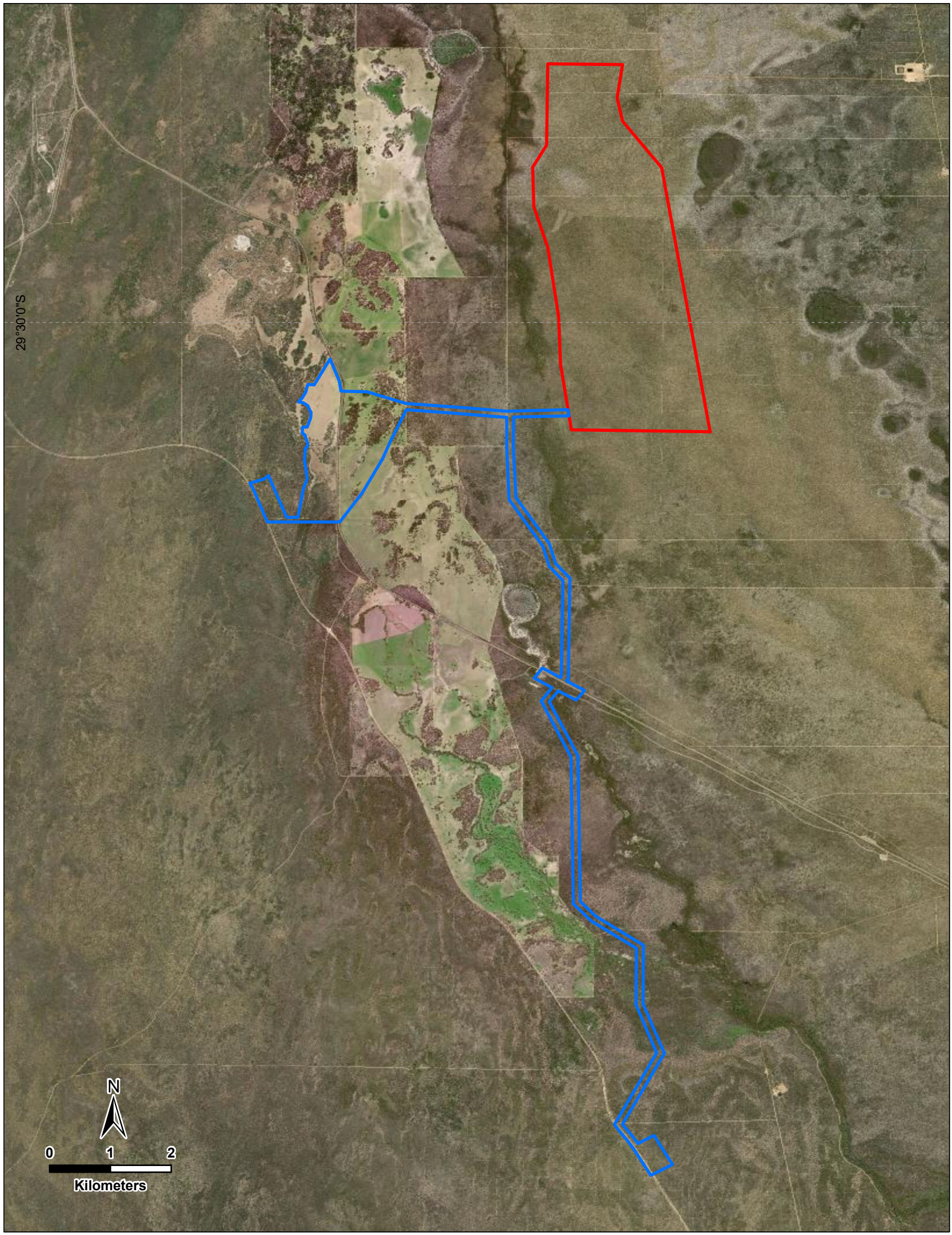
In this desktop assessment the SRE status of each species in the search area (see Section 4) was determined using a modified version of the Western Australian Museum's (WAM) SRE classification system (Appendix 2). The modifications used by Bennelongia aim to account for the fact that many recorded species have limited available data on their taxonomy, range, habitat preferences, and/or natural history.

First, species in the SRE Groups identified above were assigned to the following categories: *widespread (not an SRE), confirmed SRE*, *likely potential SRE,* or *unlikely potential SRE*. Species were considered *widespread* if they have a known distribution >10,000 km^2. If species have known distributions of <10,000 km^2 and have a well-known taxonomy from well represented collections, they were considered *confirmed SREs*. For species that have currently been recorded from areas <10,000 km^2, but are taxonomically uncertain, belong to groups that are not well represented in collections, and/or are associated with patchy sampling effort, we assign them as *likely* or *unlikely potential SREs* based on the following information (if available):

- Habitat indicators and degree of specialisation (e.g. occur in one or multiple habitats);
- Research and expertise (expert information of the biology and ecology of related species); and/or
- Molecular evidence regarding the genetic variability within sampling areas.

If species are data deficient in all these areas, the precautionary approach was taken of assigning them *likely potential SREs*; although we highlight these species in our results and note the lack of available data.

Second, potentially range-restricted species from non-SRE groups were assessed, i.e. groups where most species are widespread. For species in these groups that have currently recorded distributions <10,000 km^2, we apply the same criteria as above to determine whether any are *confirmed SREs, likely potential SREs*, or *unlikely potential SREs*.



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Date: 4/02/2021

Legend

- Access and Processing Development Envelope
- Mine Development Envelope

Figure 1. Development envelopes associated with the Project.

3. HABITAT ASSESSMENT

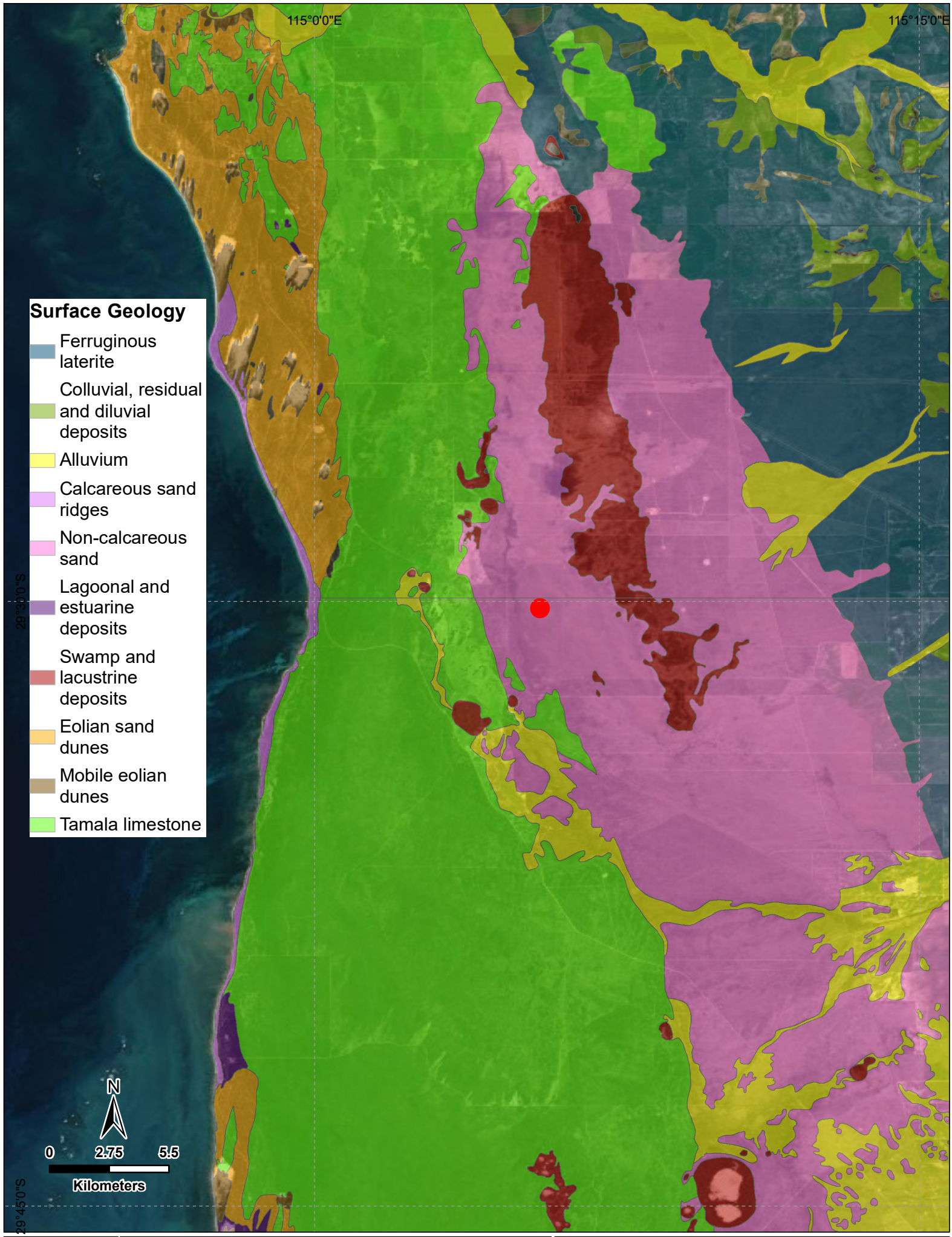
3.1. Regional Setting

The Project is located within the Lesueur Sandplains subregion, one of 419 Australian sub-regions recognised by the Interim Biogeographic Regionalisation of Australia (IBRA) [http://www.environment.gov.au/land/nrs/science/ibra/australias-bioregions-maps; accessed 11 December 2020]. The Lesueur Sandplains comprise the southern half of the Geraldton Sandplain Region, covering coastal areas south of Geraldton to Jurien Bay. The underlying geology of the subregion is characterised by Permian to Cretaceous sedimentary basins, with extensive undulating sandplains at the surface that include limestones, siltstones, sandstones and drainage-associated alluvials (Figure 2; Desmond and Chant 2002). The region has a dry, warm Mediterranean climate, with the majority of precipitation falling in the winter months. Flora communities of the Lesueur Sandplains are mainly proteaceous scrub-heath of *Banksia*, *Melaleuca*, *Eucalyptus* and *Acacia*, characteristic of the Kwongan vegetation type of south-western Australia (Mucina *et al.* 2014). The sub-region is notable by both national and international standards for its high levels of floristic species richness and endemism (Desmond and Chant 2002).

3.2. Local Habitat in the Project Area

Vegetation communities in the Project area were mapped by Mattiske (2020a, 2020b), including the Arrowsmith North proposed mine site and the proposed Western and Southern transport corridors. Eight vegetation communities were identified within the Arrowsmith North survey area, with an additional nine communities in the proposed transport corridors (Table 1; community H1 was present in both the Arrowsmith North mine and transport corridor survey areas). These were predominantly heath and scrub communities, particularly in the Arrowsmith North mine survey area, where community H4 (open heath) dominates the northern section and communities H1-H3 (open-closed heaths) comprise most of the southern section (Figure 3). *Banksia attenuata, B. hookeriana, Melaleuca leuropoma* and *Conospermum triplinervium* are typical throughout these heaths, with the sedge *Mesomelaena pseudostygia* a common understorey species (Table 1). Shrubs and thickets are mostly restricted to the western border of the mine survey area, with a few isolated pockets of *Banksia* woodland in the northern section (Figure 3). Vegetation condition within the mine site survey area was considered excellent-pristine (Figure 5)

Within the transport corridors, taller vegetation communities are more common than in the mine survey area, with *Eucalyptus erythrocorys* woodland (W4) and thickets of *Acacia blakelyi* and *Macrozamia fraseri* (T6) covering the largest areas within the corridors (Figure 4). The long, narrow Southern transport corridor traverses many different vegetation communities, although the total area covered by the corridor is relatively small (Figure 4). Vegetation within the Southern transport corridor was excellent-pristine, while the Western corridor includes good-pristine vegetation as well as currently cleared land (Figure 5).



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Legend

The Project

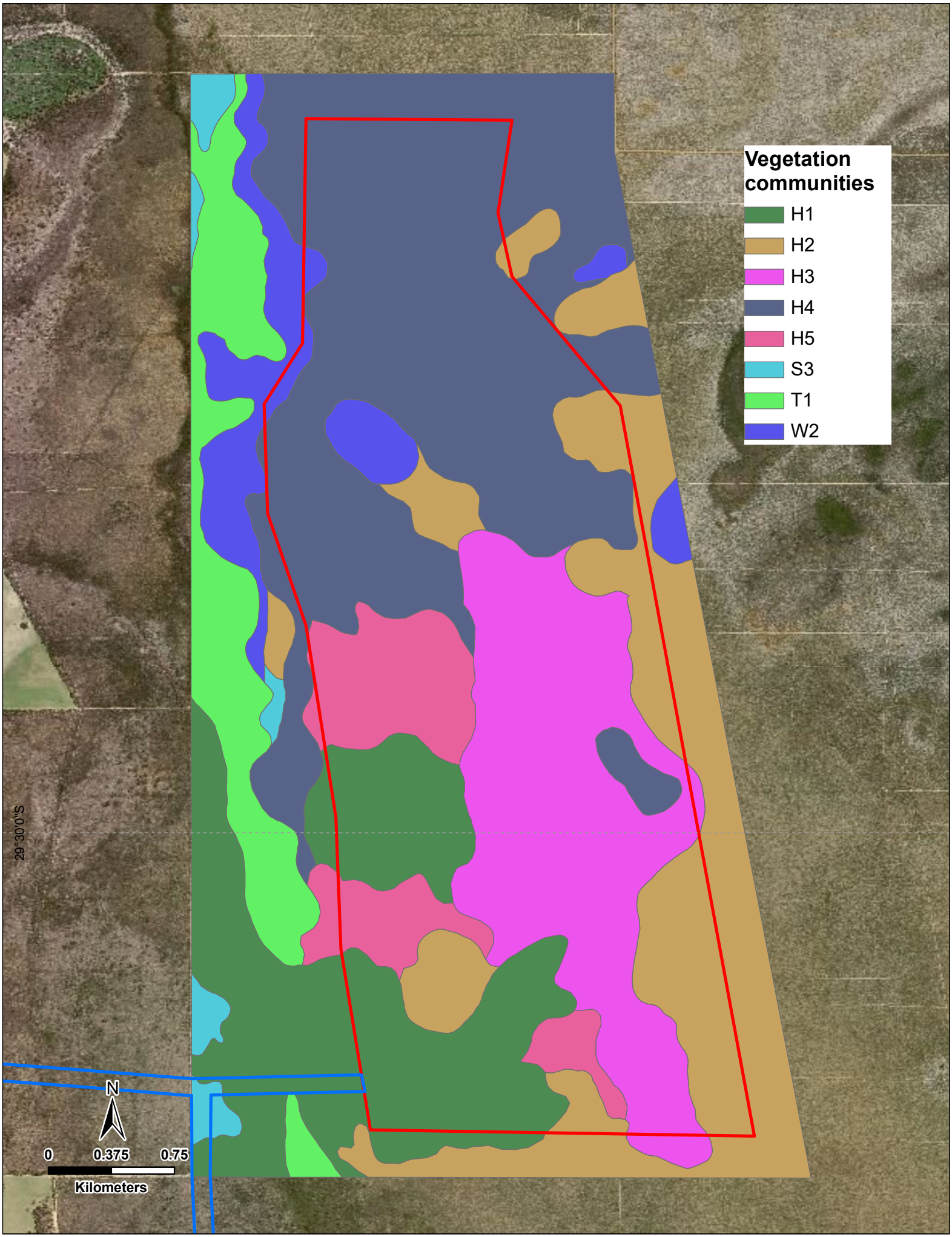
Figure 2. Surface geology in the vicinity of the Project as per the Western Australia Geological Survey 1:100,000 series.

The vegetation communities within the Project area have the potential to harbour SRE species, particularly in microhabitats that have higher local moisture content than surrounding areas, such as bark, leaf litter beds, soil humus, large debris and south-facing slopes. Such microhabitats within remnant vegetation on the Geraldton Sandplains are likely to have provided refuges for many relictual invertebrate taxa, as the region has undergone long-term aridification and historical clearing for pastoral land use (ecologia 2010). It is possible that the taller and/or thicker vegetation communities, such as woodlands, shrubs and closed heaths, are likely to contain a higher proportion of prospective microhabitats than more open communities within the Project. However, such microhabitats could be found within any of the Project area vegetation communities. Despite a lack of dedicated sampling effort in the Geraldton Sandplains, species from numerous SRE Groups have been recorded from habitats in the bioregion that resemble the Project area, including mygalomorph spiders, scorpions, pseudoscorpions, isopods, millipedes and snails (Harvey *et al*. 2000; ecologia 2010). Mygalomorph spiders are particularly well-known to inhabit coastal sandplains of the bioregion; for example, many species of the family Idiopidae are endemic to the Geraldton Sandplains (Rix *et al.* 2018a; Rix *et al.* 2018b; Rix *et al.* 2019).

Table 1: Vegetation communities at the Arrowsmith North Project identified by Mattiske (2020a, b).

Type	Description
H1	Open Heath to Closed Heath of *Hakea polyanthema*, *Calothamnus blepharospermus, Conospermum triplinervium, Petrophile macrostachya* and *Melaleuca leuropoma* with emergent *Banksia attenuata* over *Acanthocarpus preissii* and *Ecdeiocolea monostachya* on cream and white surface sands.
H2	Open Heath to Closed Heath of *Banksia hookeriana, B. attenuata* with occasional *B. menziesii* over *Melaleuca leuropoma, Eremaea beaufortioides* var. *beaufortioides, Scholtzia laxiflora, Conospermum triplinervium, E. violacea* subsp. *violacea* over *Mesomelaena pseudostygia* on white sands on plains.
H3	Open Heath of *Melaleuca leuropoma, Leptospermum oligandrum, Hakea polyanthema, Conospermum triplinervium, Beaufortia elegans* and *Pileanthus filifolius*, with isolated trees of *Banksia attenuata* and *Xylomelum angustifolium* over *Mesomelaena pseudostygia* and *Ecdeiocolea monostachya* on cream/grey sand on plains.
H4	Open Heath of *Conospermum triplinervium, Banksia attenuata, B. hookeriana, Melaleuca leuropoma, Daviesia divaricata* subsp. *divaricata* and *Eremaea beaufortioides* var. *beaufortioides* over *Mesomelaena pseudostygia* and *Dampiera spicigera* on yellow-cream/white sand on flats.
H5	Open Heath to Closed Heath of *Banksia shuttleworthiana, B. attenuata* with occasional *B. menziesii* over *Melaleuca leuropoma, Eremaea beaufortioides* var. *beaufortioides, Conospermum triplinervium, Scholtzia laxiflora* and *Verticordia grandis* over *Mesomelaena pseudostygia, Ecdeiocolea monostachya* and *Lepidobolus preissianus* subsp. *preissianus* on pale yellow sandy flats.
H7	Open Heath to Closed Heath of *Banksia leptophylla* var. *melletica, Melaleuca leuropoma* and *Hakea trifurcata* over *Ecdeiocolea monostachya, Lepidobolus preissianus* and *Stenanthemum notiale* subsp. *notiale* on cream sand on lower slopes.
S3	Scrub of *Banksia attenuata, B. leptophylla* var. *melletica, Hakea polyanthema* and *Melaleuca leuropoma* over *Scholtzia laxiflora, Petrophila macrostachya, P. drummondii, Allocasuarina humilis, H. costata* and *Acacia spathulifolia* over *Scaevola repens* subsp. Northern Sandplains and *Mesomelaena pseudostygia* on white-yellow sand on flats and slopes.
S6	Open shrubland of *Acacia blakelyi* and *Allocasuarina campestris*, over *Ecdeiocolea monostachya, Jacksonia hakeoides* and *Lepidobolus preissianus* on cream/grey sand on flats to lower slopes.
T1	Thicket to Scrub of *Allocasuarina campestris, Grevillea leucopteris, Guichenotia ledifolia, Acacia ?lineolata, Calothamnus quadrifidus* subsp. *quadrifidus* with occasional *Eucalyptus*

Type	Description
	todtiana and *Banksia attenuata* over *Dianella revoluta* and *Ecdeiocolea monostachya* on grey/cream/orange/red sand on flats and slopes.
T3	Thicket of *Allocasuarina campestris, Acacia spathulifolia, Melaleuca ?systena, Callitris arenaria* over *Ecdeiocolea monostachya, Lechenaultia linarioides* and *Acanthocarpus preissii* on cream sand on flats.
T4	Thicket to Scrub of *Acacia blakelyi* and *A. rostellifera* over *Lepidosperma aff. apricola, Scholtzia laxiflora, Hakea lissocarpha* and *Verticordia densiflora* on grey sand on flats.
T5	Thicket of *Acacia blakelyi*, *A. saligna* and *Macrozamia fraseri* over *Waitzia acuminata* and *Poaceae* sp. on sandy loam/clay on low lying flats.
T6	Thicket of *Acacia blakelyi* and *Macrozamia fraseri* with occasional *Grevillea leucopteris* over *Conostylis candicans, Waitzia acuminata* and *Aira caryophyllea* on cream/grey sand on flats.
W2	Low Open Woodland of *Banksia attenuata* and *B. menziesii* over open shrubland of *Melaleuca leuropoma, Eremaea beaufortioides var. beaufortioides, Daviesia triflora, Styphelia xerophylla, Pileanthus filifolius* and *Stirlingia latifolia* over *Alexgeorgea nitens, Lyginia imberbis* and *Stylidium crossocephalum* on cream to white sands on plains.
W3	Open mallee woodland of *Eucalyptus drummondii*, over shrubland of *Acacia saligna*, over isolated *Solanum ?lasiophyllum* and *Poaceae* sp. on grey clay loam on flats.
W4	Woodland to isolated trees of *Eucalyptus erythrocorys*, over sparse to closed shrubland of *Acacia spathulifolia* and *A. rostellifera*, over *Melaleuca leuropoma*, *Conostylis ?candicans* subsp. *procumbens*, and *Ecdeiocolea monostachya* on cream sand with limestone outcropping on slopes.
W5	Isolated trees of *Eucalyptus erythrocorys*, over open shrubland of *Melaleuca ?systena, Banksia sessilis* and *Labichea cassioides*, over *Hibbertia hypericoides* subsp. *hypericoides* and *Desmocladus asper* on grey/brown sand with limestone outcropping on flats and slopes.



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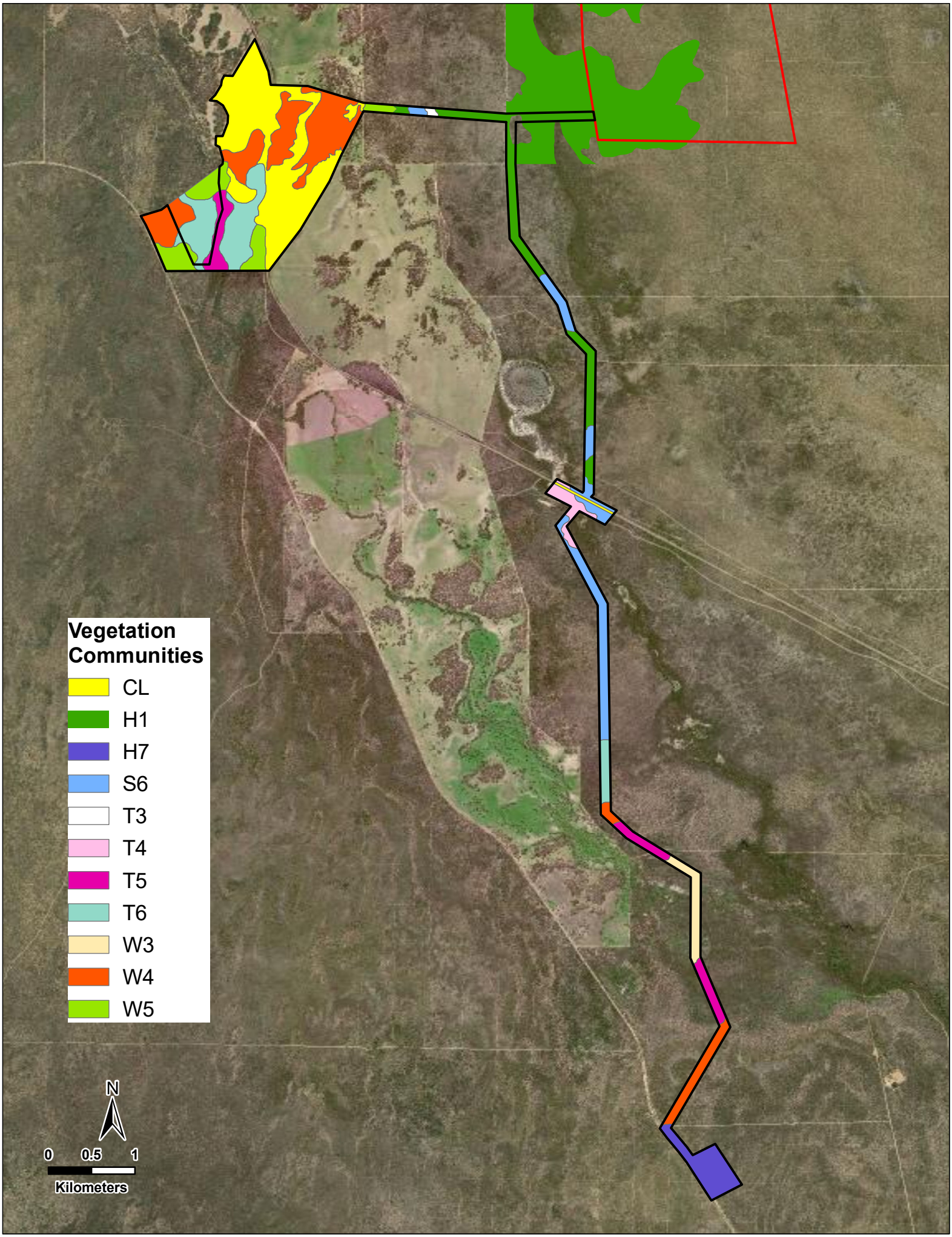
Legend

- Access corridors
- Mine envelope
- Project Area

Figure 3. Vegetation communities in the Project survey area, as per Mattiske (2020a,b).



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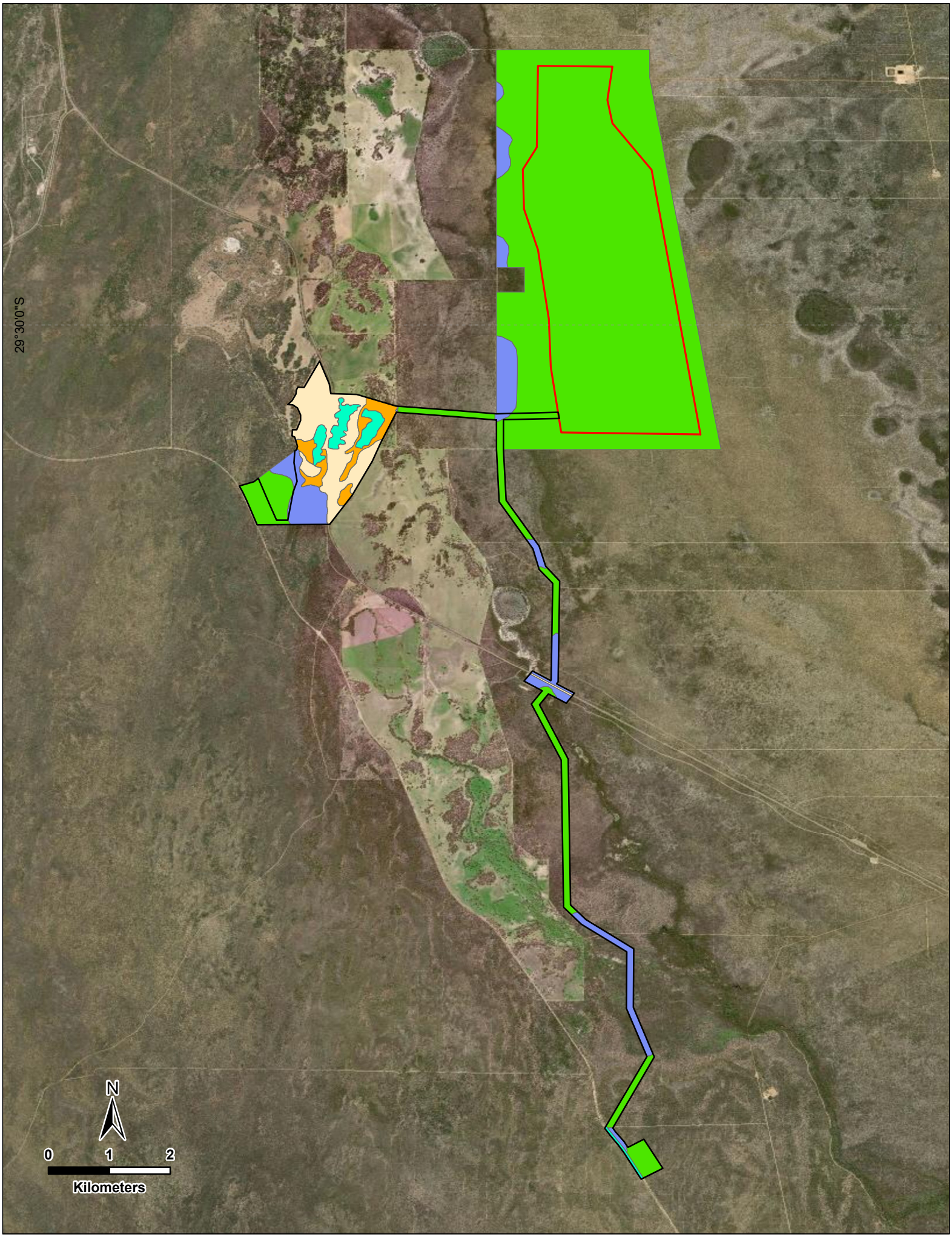
Legend

- Access corridors
- Mine envelope
- Project Area

Figure 4. Vegetation communities in the Project access corridors, as per Mattiske (2020a,b).



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Legend

- Access corridors
- Mine envelope
- Project Area

Vegetation Condition

- Completely Degraded
- Excellent
- Good
- Pristine
- Very Good

Figure 5. Vegetation condition in the Project survey area and access corridors, as per Mattiske (2020a,b).

4. DESKTOP SURVEY

4.1. Methods

Previous records of terrestrial invertebrate species were collated from Bennelongia and Western Australian Museum (WAM) databases, along with published taxonomic literature, from a search area that extended 50 km north, east and south of the Project, bordered on the west by the Indian Ocean (decimal degrees search area, top left: -29.0°S:114.8°E, bottom right -30.0°S:115.6°E). We first determined whether any invertebrates recorded in the search area were listed as Threatened or Priority species. For the remaining species, we applied the criteria outlined above (Section 2.2) to identify *confirmed* or *potential SREs*, separately for SRE Group and non-SRE Group species. Many of the records were higher order identifications for which the species had not been determined; these were retained in the final list only if there were no other species-level identifications within the same taxonomic group.

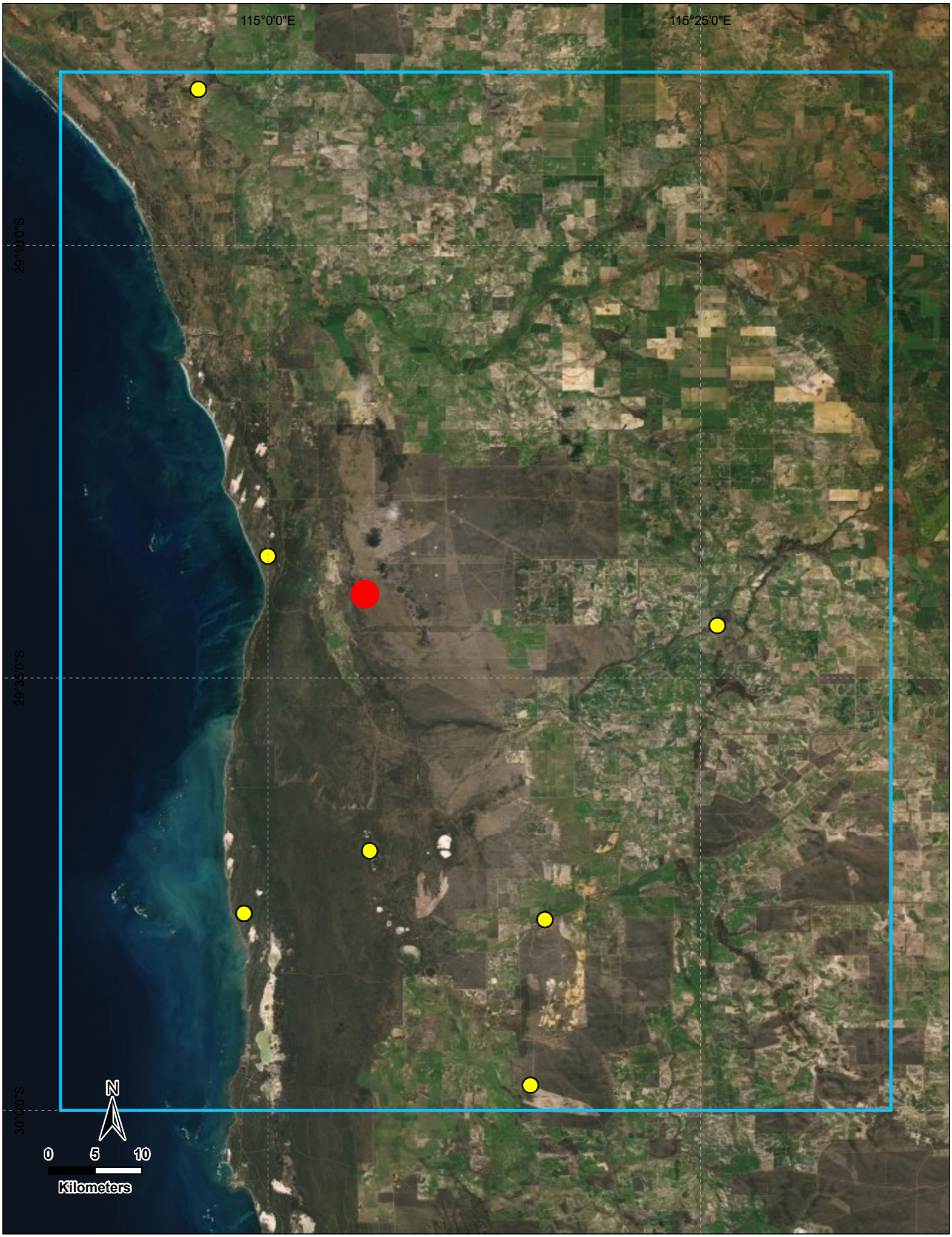
4.2. Results

4.2.1. Listed Threatened Invertebrates in the Search Area

The desktop search identified three listed invertebrate species within the search area (Table 2; Figures 6, 7); the Priority land snail *Bothriembryon perobesus,* the Priority trapdoor spider *Idiosoma kwongan* and the Priority bee *Hylaeus globuliferus*. The most commonly recorded of these species within the search area was *B. perobesus*, which has been collected from several locations surrounding the Project (Figure 6). The other species were collected from locations between 20 and 50 km south-east of the Project, with *I. kwongan* collected from one location and *H. globuliferus* collected from three locations in the search area (Figure 7). Below, we outline these previous collections and known habitats for each species, with comments on the likelihood of occurrence at the Project.

Table 2: Listed Threatened and Priority terrestrial invertebrates in the search area.

Higher Classification	Lowest Identification	BCA (2016) Status	EPBC (1999) Status	Presence of habitat at the Project	Likelihood of occurrence at the Project
Mollusca					
Gastropoda					
Stylommatophora					
Bothriembryontidae	*Bothriembryon perobesus*	P1	-	Yes	High
Arthropoda					
Chelicerata					
Arachnida					
Araneae					
Mygalomorphae					
Idiopidae	*Idiosoma kwongan*	P1	-	Yes	Low-Moderate
Hexapoda					
Insecta					
Hymenoptera					
Colletidae	*Hylaeus globuliferus*	P3	-	Yes	Moderate



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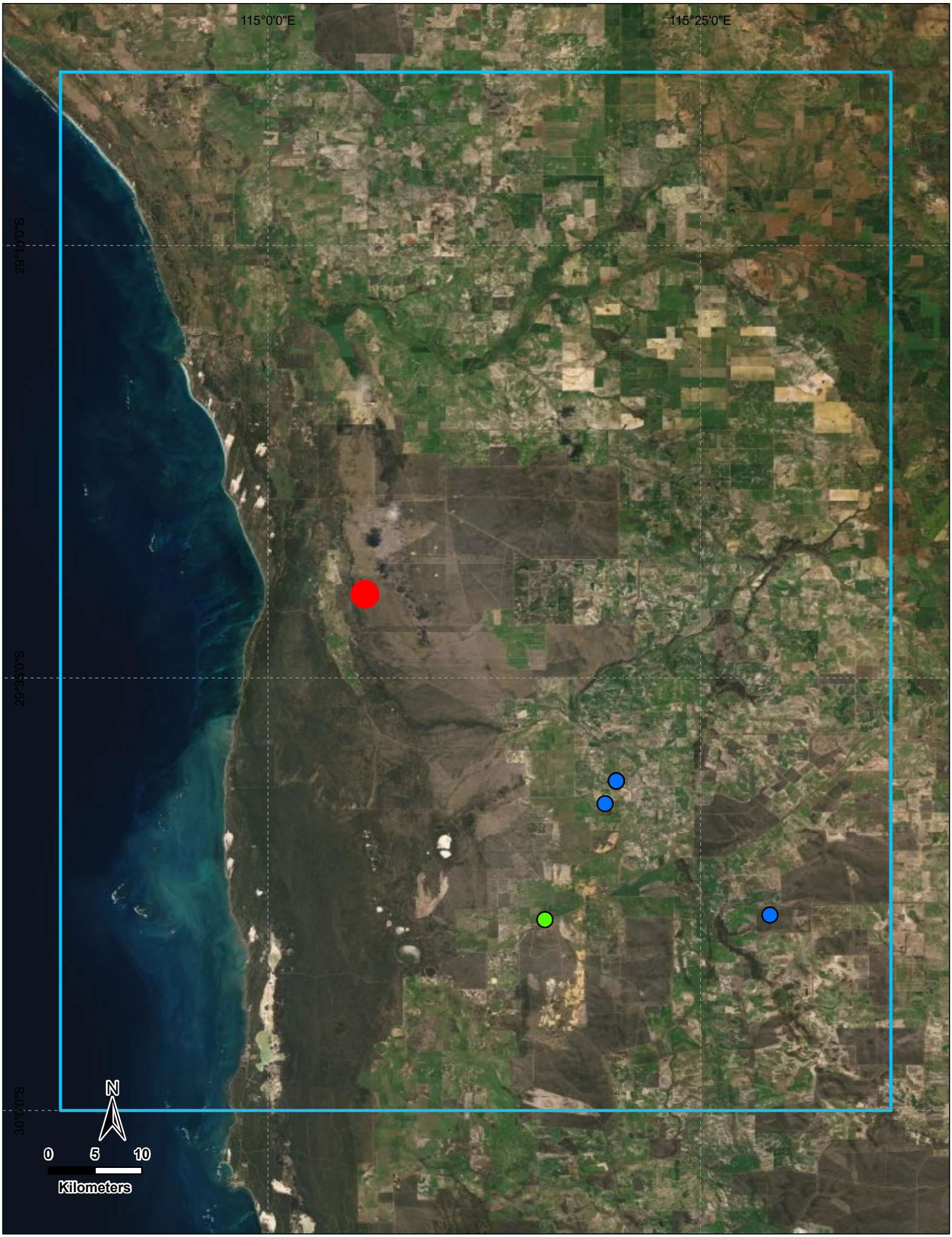
Legend

- The Project
- Survey Area
- Bothriembryon perobesus

Figure 6. Records of Bothriembryon perobesus within the search area.



Bennelongia Environmental Consultants

GCS GDA 1994
Author: VMarques
Date: 4/02/2021

Legend

- The Project
- Survey Area
- Idiosoma kwongan
- Hylaeus globuliferus

Figure 7. Records of other conservation significant species within the search area.

Bothriembryon perobesus

The Priority 1 snail *Bothriembryon perobesus* is listed as poorly known under the BCA (2016). It has currently been recorded as far south as Gingin (approximately 200 km south of the Project) and as far north as Geraldton (approximately 90 km north of the Project). Within the desktop search area, it has been collected from locations surrounding the Project, with the nearest collection approximately 5 km west on the coast (Figure 6). Many of the previous collections are associated with *Banksia* woodlands and low shrubland on white sandy soils, similar to the Project area vegetation (Whisson 2019). While most species in the genus are typically only collected among leaf litter, *B. perobesus* has been found on bare sand and the branches of shrubs (Whisson 2019). It is considered likely that *B. perobesus* will occur within the Project area.

Idiosoma kwongan

The Priority 1 shield-backed trapdoor spider, *Idiosoma kwongan*, is currently considered data deficient in terms of biology and ecology, but it appears to be restricted to the southern Geraldton Sandplains bioregion (i.e. the Lesueur Sandplains) (Rix *et al.* 2018a). The collection within the search area is among the most northerly known records of the species and is approximately 30 km south-east of the Project (Figure 7). However, the collection was from Kwongan vegetation at the Eneabba Mineral Sands mine site, which is similar to the Project area (Iluka 2012). It is therefore possible that the species might also occur in habitats at the Project.

Hylaeus globuliferus

The Priority 3 bee *Hylaeus globuliferus* occurs throughout southwestern Australia, with the records in the search area occurring in remnants vegetation near Eneabba, as well as in Kwongan vegetation of Tathra National Park (Figure 7). This species appears to be a Proteaceae specialist (Houston 2018) and the collections in the search area were all associated with flowers and foliage of the woollybush *Adenanthos cygnorum*. The vegetation mapping within the Project did not note *A. cygnorum* as a dominant species in any communities; however, *H. globuliferus* is also known to frequent flowers of other Proteaceae species such as *Banksia*, which do occur within the Project.

4.2.2. SRE Group Invertebrates in the Search Area

Using the WAM and Bennelongia databases, we recognised 25 species from SRE Groups (see Section 2.2) recorded within the search area that have known or potential ranges of <10,000 km^2 (Table 3). These species included modern and trapdoor spiders, pseudoscorpions, scorpions, centipedes, millipedes and slaters. None of the species had sufficient taxonomic certainty and representation in collections to categorise as *confirmed SREs*. However, based on available information regarding habitat specialisation, biology and ecology of the species or their close relatives, 14 of the species are considered *likely potential SREs*. A further 10 species were data deficient, and assigned as *likely potential SREs* by default (these species are marked with an asterisk in Table 3). One species with uncertain identification, the barychelid trapdoor spider *Synothele `howi*?' is considered an *unlikely potential SRE*. If this record represents *S. howi*, then a polygon around current records of the species extends slightly beyond 10,000 km^2. Below, we briefly outline the results for each group, with some comments on likely habitats in comparison to the Project area.

Araneomorph (modern) spiders

A total of 10 *potential SRE* species were recorded from various ground-dwelling groups of modern spiders. The most speciose group was Salticidae (jumping spiders, five species); other families included Lycosidae (wolf spiders, two species), Oonopidae (goblin spiders, one species), Sparassidae (huntsman spiders, one species) and Zodariidae (ant spiders, one species). The majority of these were undescribed species that are data deficient and considered *likely potential SREs* by default. However, three described species are known only from the Swan Coastal Plain and Geraldton sandplains: *Holoplatys dejongi, Maratus speciosus* and *Pentasteron securifer* (Atlas of Living Australia, https://bie.ala.org.au/, accessed 22/12/2020). Species of peacock jumping spider (the genus *Maratus* and the revised *Lycidas*) often prefer

low woodlands and shrublands (including *Banksia*) on coastal sandy soils, resembling the Project area (Richardson *et al*. 2006; Girard and Endler 2014).

Mygalomorph (trapdoor) spiders

Five species of trapdoor spiders in the search area were considered *potential SREs*, representing the families Actinopodidae (two species), Barychelidae (one species) and Idiopidae (two species). The two species within Actinopodidae were undescribed species of the mouse spider genus *Missulena*; species in this genus typically have restricted distributions (Miglio *et al*. 2012). The collections of these species were from heathland at a mineral sands mine south of Eneabba, similar to the Project area. The barychelid *Synothele* `*howi*?` is considered an *unlikely potential SRE*, as discussed above. The described species *Bungulla banksia* and *Euoplos mcmillani*, like many species in the family Idiopidae, are restricted to the Geraldton Sandplains region, where they prefer Kwongan heathland on sandy soils such as the habitat of the Project area (Rix *et al*. 2018b, 2019).

Pseudoscorpions

One pseudoscorpion in the search area was considered a *potential SRE*, the undescribed species *Beierolpium* `sp.`. While some pseudoscorpion species are considered potential SREs due to restricted ranges or habitat requirements (Harvey 2002), the taxonomy of this group is poorly defined and there has been no formal review of the genus *Beierolpium* in Western Australia. The species in the search is therefore considered data deficient and listed as a *likely potential SRE* by default.

Scorpions

As with pseudoscorpions, a single scorpion in the search area was considered a *potential SRE*, an undescribed species in the genus *Urodacus*. This genus is endemic to Australia and is likely to have a high diversity of undescribed species (Koch 1977; Volschenk *et al.* 2002; 2012). Similarly, the habitats and ecology of species within the genus are diverse; some species appear to prefer landscape features such as rock outcrops (Koch 1977), while others appear capable of burrowing in sandy substrates (Volschenk *et al.* 2012). The record in the search area is a collection near Mingenew, approximately 50 km north-east of the Project, from habitat that is likely to be quite different to the Project area.

Chilopods (centipedes)

One centipede species from the search area was considered a *potential SRE*, the undescribed species *Lamyctes* 'sp.' (family Henicopidae). *Lamyctes* is a highly diverse Gondwanan genus, with species from a range of temperate and tropical habitats in the Southern Hemisphere (Edgecombe and Giribet 2003). This genus has yet to receive detailed phylogenetic study. The species *Lamyctes* 'sp.' Is therefore considered data deficient and assigned as a *likely potential SRE* by default. The collection in the search area is from a mineral sands mine at Eneabba.

Diplopods (millipedes)

Six species of millipede in the search area were considered *potential SREs*. Five of these were polydesmids of the genus *Antichiropus*, including *A. sulcatus* and four other undescribed species, while the single remaining species was an undescribed spirostrepid of the genus *Podykipus*. Most known species in the genus *Antichirpous* have restricted ranges due to an inability to tolerate open, unvegetated areas away from protected microhabitats (Framenau *et al.* 2008; Car *et al.* 2013). *A. sulcatus* is likely restricted to the Lesueur Sandplains (Car *et al.* 2013), where it has been collected from mineral sand sites resembling the Project. *Podykipus* 'sp.' is considered data deficient; however, the genus is endemic to south-western Australia (Moir *et al.* 2009) and some collections within the search area were from Kwongan heath.

Isopods (slaters)

A single species of slater in the search area, *Buddelundia lateralis*, was considered a *likely potential SRE*. Several species in the genus *Buddelundia* have restricted distributions (Judd 2004), however, there is very little published information on *B. lateralis*, and it is considered data deficient. The records in the search area are from the Mingenew area, nearly 50 km from the Project and likely to be in very different habitat.

Table 3: Confirmed and potential SREs species from SRE Groups in the search area. *Species marked with an asterisk under the SRE category column were data deficient.

Higher Classification	Lowest Identification	SRE Category
Arthropoda		
Chelicerata		
Arachnida		
Araneae		
Araneomorphae		
Lycosidae	*Venator* `sp. (VWF119)`	Likely potential SRE*
	Venator `VWF sp. 140`	Likely potential SRE*
Oonopidae	*Gamasomorpha* `sp. 1`	Likely potential SRE*
Salticidae	*`Jotus`* `sp. 1`	Likely potential SRE*
	`Lycidas` `sp. 2`	Likely potential SRE
	`Lycidas` `sp. 3`	Likely potential SRE
	Holoplatys dejongi	Likely potential SRE
	Maratus speciosus	Likely potential SRE
Sparassidae	*Neosparassus* `sp. N23`	Likely potential SRE*
Zodariidae	*Pentasteron securifer*	Likely potential SRE
Mygalomorphae		
Actinopodidae	*Missulena* `Bisevac sp. 1`	Likely potential SRE
	Missulena `Bisevac sp. 2`	Likely potential SRE
Barychelidae	*Synothele `howi?`*	Unlikely potential SRE
Idiopidae	*Bungulla banksia*	Likely potential SRE
	Euoplos mcmillani	Likely potential SRE
Pseudoscorpiones		
Panctenata		
Olpiidae	*Beierolpium* `sp.`	Likely potential SRE*
Scorpiones		
Urodacidae	*Urodacus* `SCO016, Mingenew`	Likely potential SRE*
Myriapoda		
Chilopoda		
Lithobiida		
Henicopidae	*Lamyctes* `sp.`	Likely potential SRE*
Diplopoda		
Polydesmida		
Paradoxosomatidae	*Antichiropus* `DIP057, cooljarloo`	Likely potential SRE
	Antichiropus `DIP076, ensiculus`	Likely potential SRE
	Antichiropus `DIP076, houstoni`	Likely potential SRE
	Antichiropus `DIP078, Eneabba 1`	Likely potential SRE
	Antichiropus sulcatus	Likely potential SRE
Spirostreptida		
Iulomorphidae	*Podykipus* `sp.`	Likely potential SRE*
Crustacea		
Malacostraca		
Isopoda		
Ligiamorpha		
Armadillidae	*Buddelundia lateralis*	Likely potential SRE*

4.2.3. Non-SRE Group Invertebrates in the Search Area

Fifteen potentially range-restricted species from non-SRE Groups were recorded in the search area (Table 4). Of these, 14 were considered *likely potential SREs* (three species were assigned to this category by default due to data deficiency) and one was considered an *unlikely potential SRE*. The bulk of potential SRE species were beetles (five species) and bees (8 species), although there was also one scorpionfly and one pygmy mole cricket.

Table 4: Confirmed and potential SREs species from Non-SRE Groups in the search area. *Species marked with an asterisk under the SRE category column were data deficient

Higher Classification	Lowest Identification	SRE Category
Arthropoda		
Hexapoda		
Insecta		
Coleoptera		
Bolboceratidae	*Blackbolbus quinquecavus*	Likely potential SRE
Buprestidae	*Castiarina chlorota*	Likely potential SRE
	Synechocera parvipennis	Likely potential SRE
Erotylidae	*Xenocryptus* 'sp.'	Likely potential SRE*
Melyridae	Malachiinae 'sp.'	Likely potential SRE*
Hymenoptera		
Colletidae	*Dasyhesma argentea*	Likely potential SRE
	Euhesma semaphore	Likely potential SRE
	Euhesma undeneya	Likely potential SRE
	Euhesma undulata	Likely potential SRE
	Leioproctus sexmaculatus	Likely potential SRE
	Leioproctus tomentosus	Likely potential SRE
	Trichocolletes platyprosopis	Likely potential SRE
	Trichocolletes simus	Likely potential SRE
Mecoptera		
Meropeidae	*Austromerope* 'sp.'	Likely potential SRE*
Orthoptera		
Tridactylidae	*Dentridactylus* 'sp.'	Unlikely potential SRE

Three of the beetle species, *Blackbolbus quinquecavus*, *Castiarina chlorota* and *Synechocera parvipennis*, are only known from the Geraldton Sandplains, with *B. quinquecavus* only recorded from the Arrowsmith area and *S. parvipennis* only recorded at Eneabba (Bellamy 1987; Howden 1985). There has been little recent survey effort for any of these species. The collections of *S. parvipennis* were associated with host plants of the genus *Xanthorrhoea*, which were not noted in the vegetation mapping at the Project area (Mattiske 2020a, Mattiske 2020b). It might therefore be unlikely that this species occurs at the Project. The remaining two beetle species were the undescribed *Xenocryptus* 'sp.' and Malachiinae 'sp.'. The only described species of *Xenocryptus* in Australia is *X. tenebroides*, a pollinator of the plant *Macrozamia riedlei,* which occurs in the Project area (Mattiske 2020a, Mattiske 2020b). A search on florabase (Western Australian Herbarium 1998-) indicates that *M. riedlei* has a distribution throughout the south west of Western Australia, implying that *X. tenebroides* has a similar distribution. Since the record of *Xenocryptus* from the search area is a higher order identification (cannot be identified to species level), it is considered data deficient. Similarly, the subfamily Malachiinae contains some possibly restricted species, but inferences regarding the range of the record in the search area cannot be made without further identification.

The bee species categorised as *potential SREs* include several species of the genera *Euhesma* and *Leioproctus* that are endemic to coastal sandplains in south-western Australia (Houston 1989; Houston 1992; Exley 2002), along with two species of *Trichocolletes* and *Dasyhesma argentea* that are all restricted to the Geraldton Sandplains (Exley 2004; Batley and Houston 2012). Several of these species are known to pollinate plants that occur in the Project area, such as *Pileanthus filifolius, Conospermum* spp. and *Daviesia divaricata*; it is therefore likely that some of these species could occur at the Project.

The scorpionfly recorded in the search area is an unidentified member of the genus *Austromerope* 'sp.'; it is possible that this might represent the species *A. poultoni*, which occurs through south-western Australia and was recently removed from the Priority species list (BCA 2016) due to revision of its known range. If the collection represents a new species, it could have a restricted range similar to *A. poultoni*; however, the record is currently considered data deficient. The pygmy mole cricket *Dentridactylus* 'sp.' is included as a potential SRE due to the lack of information on the genus and the ground-dwelling habits of the group; however, known orthopterans typically do not meet the definition of SRE species, and *Dentridactylus* 'sp.' is therefore considered an *unlikely potential SRE*.

5. CONCLUSIONS AND ASSESSMENT OF POTENTIAL IMPACTS

The Project area features a range of habitat types, largely *Banksia* heath/shrubs with diverse understoreys and isolated pockets of *Eucalyptus* woodland, typical of coastal Kwongan vegetation. These vegetation types could contain a range of microhabitats prospective for SRE species; indeed, despite relatively little sampling in the region, similar habitats on the Geraldton Sandplains have yielded SREs from groups including mygalomorph spiders, scorpions, pseudoscorpions, isopods, millipedes and snails. In addition to the potential microhabitats for ground-dwelling invertebrates, the heath vegetation at the project includes several flowering species that are known to be hosts for listed and range-restricted bees.

The desktop assessment identified three Priority listed terrestrial invertebrate species within the search area, the land snail *Bothriembryon perobesus,* the trapdoor spider *Idiosoma kwongan* and the bee *Hylaeus globuliferus*. *B. perobesus* has been collected from *Banksia* woodlands and low shrubland on white sandy soils in multiple locations surrounding the Project and is likely to also occur within the Project area. *I. kwongan* and *H. globuliferus* were collected at locations between 20 and 50 km south of the Project, again in Kwongan habitats similar to the Project area. *H. globuliferus* is a specialist of Proteaceae flowers and is considered to have a moderate likelihood of occurring at the Project. The record of *I. kwongan*, however, is at the northern edge of its known range and the species is considered to have a lower probability of extending as far north as the Project.

The assessment also identified a moderate diversity of potential SRE species within the search area, with 25 species from SRE Groups that have potentially restricted ranges, including modern and trapdoor spiders, pseudoscorpions, scorpions, centipedes, millipedes and slaters, along with 15 insect species from non-SRE Groups that have potentially restricted ranges. While many of these represent undescribed species that are difficult to assess due to data deficiency, there are also a range of described species known only from the Geraldton Sandplains in habitats similar to those at the Project. In particular, jumping spiders (family Salticidae), the trapdoor spiders *Bungulla banksia* and *Euoplos mcmillani*, and millipedes in the genus *Antichiropus* are likely to occur within the Project area and have limited ranges. Additionally, several of the range-restricted bees in the genera *Euhesma, Leioproctus* and *Trichocolletes* feed on plants that are known to occur at the Project.

Two types of impacts on invertebrate faunal communities are typically associated with development projects: *primary impacts*, through activities (mainly land clearing) that result in complete loss of habitat; and *secondary impacts*, that result in degradation of habitat rather than complete loss, for example through vehicle movements (and associated vibrations and/or dust), weed encroachment, and clearing of small areas and infrastructure corridors (causing fragmentation and edge effects). Primary impacts

can either cause extinction of local populations, if all habitat within a local area is cleared, or species extinction if species have a range restricted to the development envelope. Secondary impacts are unlikely to cause extinction of either species or local populations, however they can cause reductions in population size.

It should be noted that VRX Silica Ltd is seeking to minimise habitat loss and maximise ecological recovery post mining by implementing an innovative mining and rehabilitation technique referred to as Vegetation Direct Transfer (VDT). VDT is the removal of intact sods of vegetation for relocation into previously mined pit voids (Ross *et al.* 2000). VRX Silica Ltd will translocate 3 X 3 m sods to a depth of 400 mm, from each 150 X 150 m mining void back to the previously mined area as rehabilitation. Advantages of VDT include recycling of plant and soil materials, faster re-vegetative process, restoration of the whole ecosystem, and erosion control, as well as retention of root stock, seed banks and soil micro-organisms (Ross *et al.* 2000).

Past research on VDT has demonstrated that this allows for the maintenance of sensitive plant species that would otherwise be lost during traditional rehabilitation methods (Rodgers *et al.* 2011) and preliminary assessments for some invertebrate species, including earth worms and snails, has also shown positive results (Rodgers *et al.* 2011). The survivorship of burrowing animals such as scorpions, millipedes and mygalomorph spiders after VDT has not been extensively studied however.

Many SRE species inhabit leaf litter or habitats on or near the surface of the soil. Pseudoscorpions, slaters and centipedes for example, are known to inhabit surface environments such as leaf litter, beneath rocks and logs (Beier, 1965, Edgecombe and Giribet 2007, Judd 2004, Weygoldt 1969), while some pseudoscorpions are also found under the bark of both living and dead trees (Weygoldt 1969). Most modern spiders use surface environments, however some construct burrows of varying depths such as the wolf spiders (Vink 2002).

The majority of mygalomorph spiders construct burrows (Main 1984), often close to their maternal burrow due to their poor dispersal ability (Main 1984). Burrow morphology can by highly variable between species (Mason *et al.* 2012) and can consist of open holes (Castalanelli *et al.* 2020), or those covered with a trap door (Main 1985), and burrow depth can also be variable between species (Mason *et al.* 2012). Mason *et al.* (2012) reported variability in depth of trapdoor spider burrows from 300 mm to over 500 mm depth but, anecdotally, some species are able to build burrows in the vicinity of 1000 mm deep.

While the *Antichiropus* millipedes have recently received some attention (Car 2013), our knowledge of these animals is still very limited. It is believed that adults are only active at the surface after rain when conditions are right for mating (Harvey 2002). Subsequently, females burrow into the soil to lay their eggs (Harvey 2002). In the study conducted by Wojcieszek *et al.* (2010), *A variabilis* were housed in 80 mm deep containers and were successful in laying eggs that were able to hatch.

Scorpions of the genus *Urodacus* construct spiral shaped burrows to varying depths (Koch 1978). Scorpion burrows can range in depth from shallow to approximately 1000 mm deep (Koch 1978). Many species of scorpion spend over 90 % of their time in burrows (Polis 1990). Males are more vagrant during the mating season when they leave burrows in search of receptive females (Polis 1990). Burrows are used as a thermal retreat, for mating and rearing of young and as a place to await and ambush prey (Polis 1990).

The overall risk posed by development projects can be assessed through a combination of the likelihood of occurrence of significant species, their known ranges relative to project envelopes, and the likely consequences of potential impact types. However, there are several challenges to identifying full impacts on communities in a desktop search. First, the species recorded within the search area provide an indication of the type of community likely to occur in the Project area but do not provide a list of the

actual species that occur in this unsurveyed area. Nevertheless, many of the species identified within the search area have a moderate-high likelihood of occurring at the Project. For any of these species, impacts from the Project will usually be minor, as they are already known to occur outside of the Project. At the same time, SRE species are by definition restricted to small areas and many of the reported groups (e.g. mygalomorph spiders and *Antichiropus* millipedes) tend to have high species turnover across landscapes, so that is also possible that different species within these groups occur in the search area and, more locally, at the Project.

Secondly, for many of the invertebrate groups only a broad understanding of habitat prospectivity can be gleaned from vegetation mapping and previous collections of SRE species. The groups that can be most confidently assessed in terms of habitat distribution include flying insects such as bees, whose ranges are mainly restricted by their host feeding plants. Many of the conservation significant and range-restricted bees identified in this report feed on plant species within heath communities that extend outside of the Project development envelopes (Figures 3, 4). Therefore, if these species do occur at the Project, the most likely impacts may be minor reductions of habitat rather than complete loss. On the other hand, ground-dwelling groups such as trapdoor spiders, jumping spiders and millipedes are more dependent upon microhabitats within vegetation communities than on the community composition. Therefore, the actual distribution on SREs species in such groups will depend on the spatial extent of features such as leaf litter beds, soil humus, large debris and south-facing slopes, which can be patchy even within widespread vegetation types.

In conclusion, this desktop assessment indicates that a moderate community of SRE invertebrates is likely to occur at the Project, including trapdoor spiders, jumping spiders, millipedes and native bees; although the exact species that will be found at the Project cannot be identified without survey within the area. In addition, some listed Priority species could occur at the Project, in particular the snail *Bothriembryon perobesus*. The level of threat posed to terrestrial invertebrates by the proposed developments could range from low to moderate, depending on the particular species that occur in the Project area, and whether these species are dependent upon restricted microhabitats within the area.

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Appendix 1 – Threatened and Priority Species Categories

Western Australia – Biodiversity Conservation Act (2016)

The following is reproduced from:
Department of Biodiversity, Conservation and Attractions. *Conservation Codes for Western Australian Flora and Fauna*. Available at: https://www.dpaw.wa.gov.au/images/documents/plants-animals/threatened-species/Listings/Conservation%20code%20definitions.pdf (Accessed 14 October 2020).

Threatened species
Listed by order of the Minister as Threatened in the category of critically endangered, endangered or vulnerable under section 19(1), or is a rediscovered species to be regarded as threatened species under section 26(2) of the Biodiversity Conservation Act 2016 (BC Act). Threatened fauna is that subset of 'Specially Protected Fauna' listed under schedules 1 to 3 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018 for Threatened Fauna.

- CR, Critically Endangered: Threatened species considered to be "facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with criteria set out in the ministerial guidelines".
- EN, Endangered: Threatened species considered to be "facing a very high risk of extinction in the wild in the near future, as determined in accordance with criteria set out in the ministerial guidelines".
- VU, Vulnerable: Threatened species considered to be "facing a high risk of extinction in the wild in the medium-term future, as determined in accordance with criteria set out in the ministerial guidelines.

Priority species
Possibly threatened species that do not meet survey criteria, or are otherwise data deficient, are added to the Priority Fauna or Priority Flora Lists under Priorities 1, 2 or 3. These three categories are ranked in order of priority for survey and evaluation of conservation status so that consideration can be given to their declaration as threatened fauna or flora. Species that are adequately known, are rare but not threatened, or meet criteria for near threatened, or that have been recently removed from the threatened species or other specially protected fauna lists for other than taxonomic reasons, are placed in Priority 4. These species require regular monitoring.

- P1: Species that are known from one or a few locations (generally five or less) which are potentially at risk. All occurrences are either: very small; or on lands not managed for conservation, e.g. agricultural or pastoral lands, urban areas, road and rail reserves, gravel reserves and active mineral leases; or otherwise under threat of habitat destruction or degradation. Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under immediate threat from known threatening processes. Such species are in urgent need of further survey.
- P2: Species that are known from one or a few locations (generally five or less), some of which are on lands managed primarily for nature conservation, e.g. national parks, conservation parks, nature reserves and other lands with secure tenure being managed for conservation. Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under threat from known threatening processes. Such species are in urgent need of further survey.
- P3: Species that are known from several locations, and the species does not appear to be under imminent threat, or from few but widespread locations with either large population size or significant remaining areas of apparently suitable habitat, much of it not under imminent threat. Species may be included if they are comparatively well known from several locations

but do not meet adequacy of survey requirements and known threatening processes exist that could affect them. Such species are in need of further survey.

- P4: (a) Rare. Species that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently threatened or in need of special protection but could be if present circumstances change. These species are usually represented on conservation lands. (b) Near Threatened. Species that are considered to have been adequately surveyed and that are close to qualifying for vulnerable but are not listed as Conservation Dependent. (c) Species that have been removed from the list of threatened species during the past five years for reasons other than taxonomy.

Australia – Environmental Protection and Biodiversity Conservation Act 1999

Listing of species under the EPBCA 1999 is based on the IUCN Red List categories and criteria for threatened species listing. In addition to the categories Extinct (EX) and Extinct in the Wild (EW), these include:

- CR, Critically Endangered: Considered to be facing an extremely high risk of extinction in the wild
- EN, Endangered: Considered to be facing a very high risk of extinction in the wild.
- VU, Vulnerable: Considered to be facing a high risk of extinction in the wild.

These considerations are based on the criteria set out in:
IUCN (2000) *IUCN Red List and Criteria, V 3.1*. Available at http://s3.amazonaws.com/iucnredlist-newcms/staging/public/attachments/3097/redlist_cats_crit_en.pdf (Accessed 14 October 2020).

Additionally, under the EPBCA 1999 species in Australia can be listed under the category Conservation Dependent, if:

(a) the species is the focus of a specific conservation program the cessation of which would result in the species becoming Vulnerable, Endangered or Critically Endangered; or
(b) the following subparagraphs are satisfied: (i) the species is a species of fish; (ii) the species is the focus of a plan of management that provides for management actions necessary to stop the decline of, and support the recovery of, the species so that its chances of long term survival in nature are maximised; (iii) the plan of management is in force under a law of the Commonwealth or of a State or Territory; (iv) cessation of the plan of management would adversely affect the conservation status of the species.

For more information, see:
Threatened Species Scientific Committee (2014) *Guidelines for assessing the conservation status of a native species*. Available at https://www.environment.gov.au/system/files/pages/d72dfd1a-f0d8-4699-8d43-5d95bbb02428/files/tssc-guidelines-assessing-species-2020.pdf (Accessed 14 October 2020).

Appendix 2 – Western Australian Museum SRE Classification System

Confirmed SREs are species with well understood taxonomy that are well represented in collections or come from areas that have been well sampled and have a known distribution range <10,000 km2.
Potential SREs are species that belong to genus or other taxonomic grouping for which there are gaps in our knowledge, either because the taxon is not well represented in collections, taxonomic knowledge is incomplete, or species distributions are imperfectly understood because sampling has been patchy.
Widespread (not SRE) species have a known distribution range >10,000 km2. The taxonomy of the species is well understood and it is well represented in collections.

The WAM uses five further sub-categories if a species is determined to be a "Potential SRE". These relate to the reasons for treating a species as a Potential SRE:
1. Data deficient: This is a precautionary sub-category because classification because the species is treated as a Potential SRE because there are insufficient data available to determine SRE status, either because there is a lack of geographic and taxonomic information, or because the individuals sampled cannot be identified to species level (e.g. wrong sex, juvenile, damaged);

2. Habitat Indicators: Here and in the following sub-categories, there is some evidence available from which the likely SRE status of the species may be inferred. For example, habitat indicators may suggest a species is likely to be an SRE because of its association with a particular habitat;

3. Morphological Indicators: The likely SRE status of a species may be determined through its morphological characteristics;

4. Molecular Evidence: DNA sequence data reveal patterns congruent with the species being an SRE; and

5. Research & Expertise: Available research data and/or WAM expertise may provide the basis for considering a species likely to be an SRE.

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