Bennelongia Environmental Consultants

Tronox Mining – Osprey Extension – Subterranean Fauna Desktop Assessment

Prepared for:

Tronox Management Pty Ltd

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Short-Range Endemics I Subterranean Fauna

Waterbirds I Wetlands

Tronox Mining – Osprey Extension – Subterranean Fauna Desktop Assessment

Bennelongia Pty Ltd
5 Bishop Street
Jolimont WA 6014

P: (08) 9285 8722
F: (08) 9285 8811
E: info@bennelongia.com.au

ABN: 55 124 110 167

Report Number: 706

Report Version	Prepared by	Reviewed by	Submitted to Client	
			Method	Date
Draft	Oscar Garswood	Stuart Halse	email	17 April 2025
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EXECUTIVE SUMMARY

Tronox Management Pty Ltd (Tronox) is looking to expand their current operations at Cooljarloo, 30 kilometres west from Cervantes in the Shire of Dandaragan. A Subterranean fauna assessment was undertaken in 2013 and is being updated to include the Osprey Expansion. The desktop assessment will be used to review the current knowledge of subterranean fauna in the region and characterise the local habitat within a regional context; and identify the potential threats to subterranean fauna species and assess the threat of loss of subterranean fauna species as a result of Project development. Subterranean fauna consist of air-breathing troglofaunal that live between the water table and ground surface and aquatic stygofauna that live in groundwater.

The Cooljarloo mine sits on the northern Swan Coastal Plain in the Perth Basin. The Project area comprises coastal dunes, marine shoreline deposits and some areas of limestone. There is a surficial aquifer in the marine shoreline deposits and underlying Bassendean Sand, with a more confined Yarragadee aquifer below. An analysis of geology and, more particularly, known occurrence of subterranean fauna in south-west Western Australia, suggest the dune and shoreline deposits have low prospectivity for troglofaunal. While limestone areas are potentially more prospective, there is no evidence of the necessary weathering to create the necessary caves and karst. The lack of stygofauna records from a survey at Cooljarloo, together with few records on the northern Swan Coastal Plain suggests stygofauna species are unlikely to occur at Cooljarloo.

More detailed documentation of subterranean fauna species records in the databases of the Western Australian Museum and Bennelongia confirmed the lack of prospectivity for subterranean fauna at the Osprey extension. There is a moderate number of possible troglofauna records from caves in a 100 x 100 km search area on the northern coastal plain, some of which are probably surface species and all of which probably have widespread distributions. There are no records of troglofaunal from sand in the search area. There are only five records of stygofauna identified to species of genus in the search area and the only one potentially occurring in regional surficial aquifer was well east of the coastal plain. Any stygofauna community in the Osprey Expansion will be depauperate. Development of the Osprey Expansion is unlikely to impact subterranean fauna conservation values.

CONTENTS

Executive Summary iii
1. Introduction 1
2. Subterranean Fauna Framework 1
2.1.1. Stygofauna 1
2.1.2. Troglofauna 1
2.1.3. Conservation Legislation 3
3. Environment 3
3.1. Biogeography 3
3.2. Geology 3
3.3. Hydrogeology 7
3.4. Subterranean Fauna Habitats 7
3.4.1. Fauna habitats at Project 7
4. Desktop Fauna Searches 9
4.1. Methods 9
4.1.1. Troglofauna 9
4.1.2. Stygofauna 10
5. Discussion 11
6. References 11

LIST OF FIGURES

Figure 1: Project Location 2
Figure 2: Bedrock Geology 4
Figure 3: Surface Geology 6
Figure 4: Desktop Survey Records 8

LIST OF TABLES

Table 1. Bedrock codes 5
Table 2. Surface geology codes. 5
Table 3. Described troglofauna species collected from caves in search area. 9
Table 4. Other potential troglofauna species in search area. 10
Table 5. Stygofauna species collected from caves in search area. 11

1. INTRODUCTION

Tronox is looking to expand their current operations at Cooljarloo, 30 km west of Cervantes in the Shire of Dandaragan (Figure 1). A Subterranean fauna assessment was undertaken in 2013 and is being updated to include the Osprey Expansion. The desktop assessment will be used to review the current knowledge of subterranean fauna in the sub-region around the mine and characterise the local habitat within a regional context, identify the potential threats to subterranean fauna species, and assess the threat of loss of subterranean fauna species as a result of the mine expansion.

2. SUBTERRANEAN FAUNA FRAMEWORK

The term subterranean fauna is applied to animals that inhabit underground habitats. These subterranean habitats include caves but in Western Australia the smaller caverns and small voids extending out from caves or found more widely across the landscape usually contain far more more species than caves do. Subterranean fauna is broadly split into two groups: stygofauna and troglofauna. Stygofauna species inhabit underwater subterranean habitats, such as the small underground matrices within groundwater aquifers that particularly form within porous rock. Troglofauna species are air-breathing animals that occupy spaces in the matrix above the water table but nevertheless require a high level of humidity (Gibson *et al.* 2019)..

The characteristic morphological adaptations of subterranean species reflect living in an environment without light and with poor nutritional conditions and include the partial or total loss of eyes and skin pigmentation, vermiform body shape, exaggerated chemoreceptive sense organs and loss of wings. Such traits are not uniform across all subterranean species and vary with environment and phylogeny. The majority of subterranean species in Western Australia are invertebrates, although a subterranean fish (Whitley 1974) and reptiles (Aplin 1998) have also been recorded. The diversity in subterranean fauna in Western Australia is particularly rich, with estimates indicating at least 4,500 distinct species are present across the state, many of which remain undescribed (Guzik *et al.* 2011; Halse 2018a).

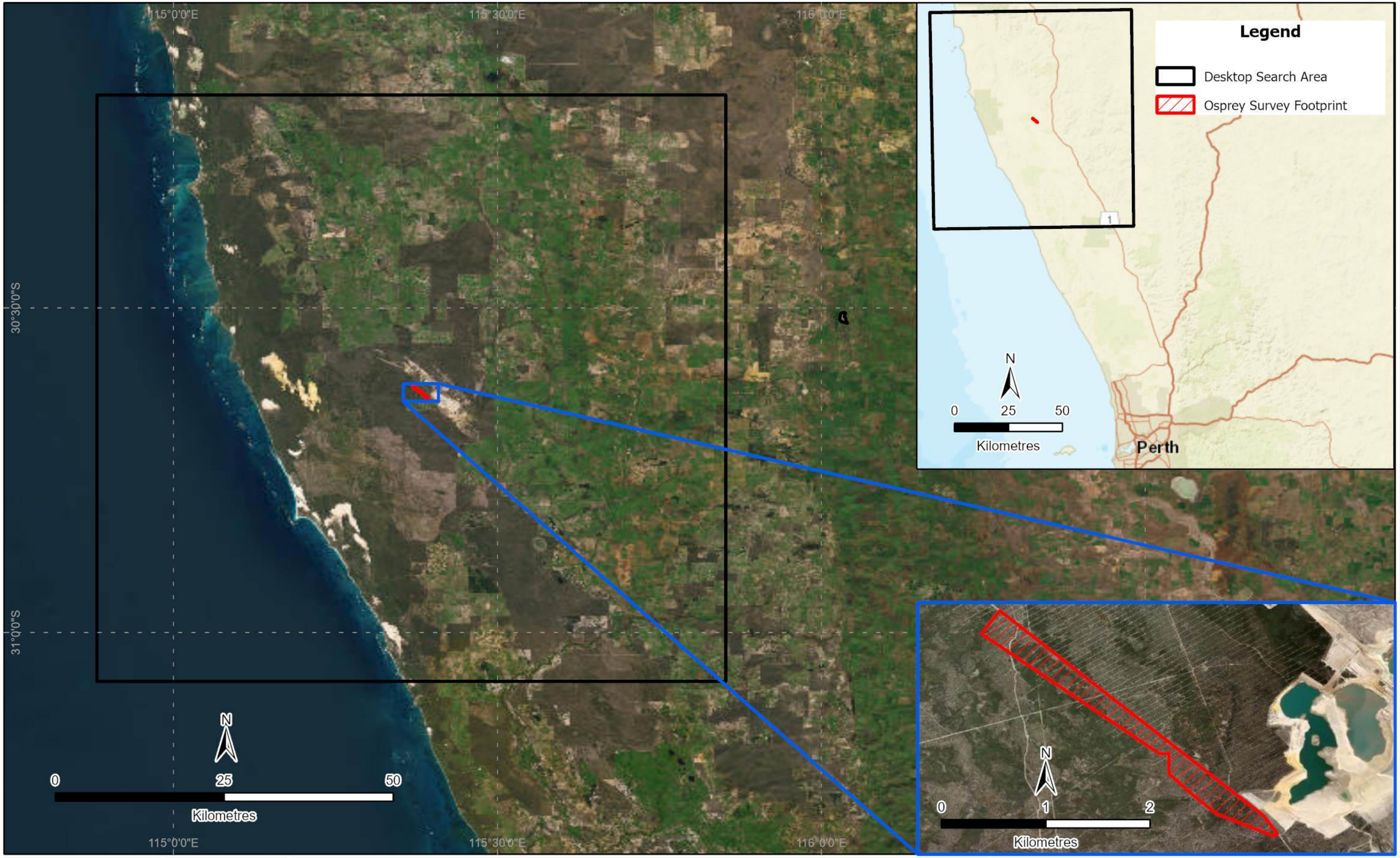
The ranges of subterranean species are often highly restricted, with most distributions satisfying the <10,000km^2 range area requirement for being classified as a short-range endemic as defined by (Harvey 2002). The distribution of subterranean animals is driven primarily by presence of spaces in the subterranean matrix and, most importantly, by the degree of three-dimensional inter-connectivity of these spaces. Connectivity on the lateral plane allows for organisms to disperse into a larger area, while vertical connectivity allows movement of nutrients from the surface to the network of subterranean species (Korbel and Hose 2011).

2.1.1. Stygofauna

The majority of stygofauna species in Western Australia are crustaceans, although beetles, worms and snails, as well as some more primitive invertebrates, also occur. A significant predictor for the presence of stygofauna is aquifer transmissivity. Stygofauna communities are most frequently found in shallow aquifers (water table <30 mbgl) in calcretes/karstic limestone, alluvium and colluvium, particularly in palaeovalleys (Halse 2018c; Hyde *et al.* 2018). They can also occur in fractured rock aquifers, detrital iron, sandstone and greenstone terrane, usually at lower abundance. Stygofauna are most frequently encountered in fresh or hyposaline water, although there are also species that are tolerant of high salinity (Halse *et al.* 2014).

2.1.2. Troglofauna

Troglofauna species are mostly arthropods such as insects, isopods, myriapods, spiders and pseudoscorpions (Halse and Pearson 2014). Geologies that frequently host troglofauna communities include weathered iron formations and karstic calcretes and limestone. Troglofauna also occur in some weathered mafic and ultramafic rocks, sandstone, colluvium and alluvium (Halse 2018b).



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GCS GDA 1994
Author: ogarswood
Date: 26/03/2025

Legend

Osprey Survey Footprint

Desktop Search Area

Figure 1. Location of Ospre with th Desktop Search area overlaid

Troglofauna can be divided into three groups. These are:

- Troglobites spend their entire lifecycle in a dark, high humidity subterranean environment and have adaptations to this environment, such as a lack of pigment and reduced eyes (Moulds 2007).
- Troglophiles in Western Australian non-cave subterranean environments are characterised by living underground in the dark but having a component of their life cycle (usually mating at night after rain) above ground; troglophile species in caves usually occupy the twilight zone rather than full darkness in deeper sections of caves.
- Trogloxenes are facultative users of the subterranean environment. It is often difficult to distinguish troglophiles and trogloxenes when only recorded in a few subterranean samples.

2.1.3. Conservation Legislation

Native flora and fauna in Western Australia are protected at both State and Commonwealth levels. At the state level, the *Biodiversity Conservation Act 2016* (BC Act) provides a legal framework for protection of species, particularly for species listed by the Minister for the Environment as threatened. In addition to the formal list of threatened species under the BC Act, the Department of Biodiversity, Conservation and Attractions (DBCA) also maintains a list of priority fauna species that are of conservation importance but, for various reasons, do not meet the criteria for listing as threatened. At the national level, the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) provides a legal framework to protect and manage nationally and internationally important flora, fauna and ecological communities. Both the EPBC and BC Acts provide frameworks for the protection of threatened ecological communities (TECs). Within Western Australia, DBCA also informally recognises communities of potential conservation concern, but for which there is little information, as priority ecological communities (PECs). The list of subterranean fauna-based TECs recognised under the BC Act is larger than the EPBC Act list. Most listed Western Australian subterranean fauna communities are PECs rather than TECs.

3. ENVIRONMENT

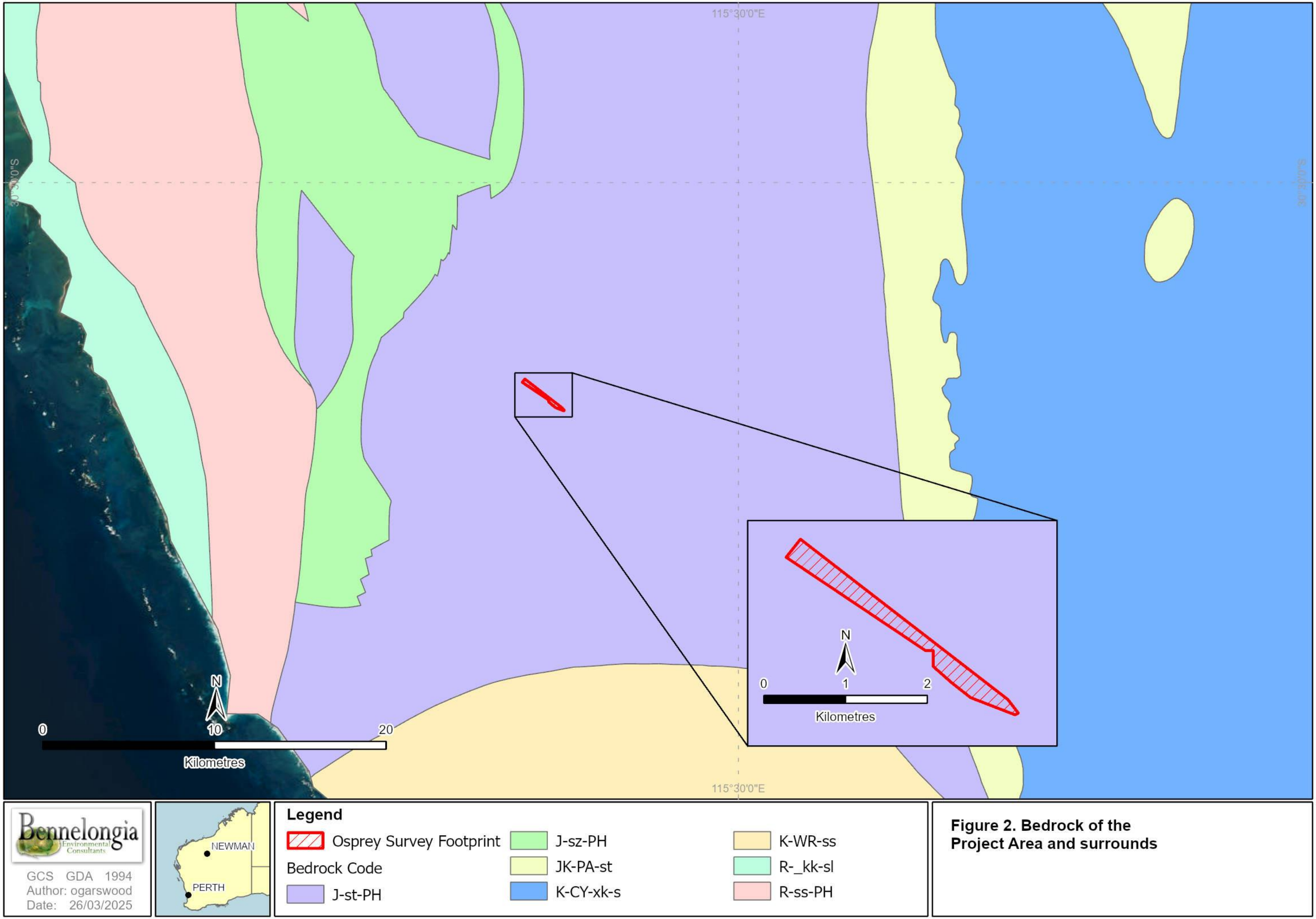
3.1. Biogeography

The Project is located within the Perth subregion of the Swan Coastal Plain bioregion (SWA2) as outlined in the Interim Biogeographic Regionalisation of Australia 7 (Thackway and Cresswell 1995). Rainfall ranges between 600 and 1000 mm annually and the climate is Mediterranean (Mitchell *et al.* 2002). There are TECs in this bioregion that host subterranean fauna, such as the "Aquatic root mat community number 1 of caves of the Swan Coastal Plain" which hosts the critically endangered Crystal Cave Crangonyctoid (*Hurleya* sp., WAM642-97) (DEC 2003).

3.2. Geology

The Project lies in the Perth Basin, a deep trough nearly 1,000 km long that averages about 65 km in width, filled with sedimentary rocks (McPherson and Jones 2005). The coastal part of the Perth Basin is covered by the Swan Coastal Plain, a low-lying, gently undulating plain with Quaternary coastal dunes and numerous wetlands over extensive marine shoreline deposits and some areas of limestone, below which is the Yarragadee formation which consist of clayey sands and siltstone (Worley Parsons 2012) (Figures 2 and 3). The 40 km-wide plain is bound by the Indian Ocean to the west and Gingin Scarp to the east (Department of Water 2017).

There are four areas on the Swan Coastal Plain north of Perth where clusters of moderately large caves occur: Yanchep, Cervantes/Nambung, Jurien and Eneabba (DEC 2003; Moulds 2007). Minor caves occur elsewhere on the coastal plain and much of the limestone karstic.



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Date: 26/03/2025

Figure 2. Bedrock of the Project Area and surrounds

Table 1. Bedrock codes.

Code	Description
J-st-PH	Middle and Upper Jurassic sedimentary rocks, Perth Basin; Sandstone and siltstone, lesser limestone
J-sz-PH	Lower and Middle Jurassic sedimentary rocks, Perth Basin; Sandstone, minor siltstone and conglomerate; limestone in upper part; dominantly fluvial with marine transgression at top
JK-PA-st	Warnbro Group; Interbedded sandstone, siltstone, and shale; minor conglomerate
K-CY-xk-s	Coolyena Group; Chalk, greensand, glauconitic sandstone, siltstone, marl; characteristically glauconitic
K-WR-ss	Warnbro Group; Interbedded sandstone, siltstone, and shale; minor conglomerate
R-_kk-sl	Kockatea Shale; Shale; minor siltstone and sandstone; in places calcareous; sandstone members at base
R-ss-PH	Middle to Upper Triassic sandstone and siltstone, Perth Basin; Sandstone, minor siltstone

Table 2. Surface geology codes.

Code	Description
Qrw	Swamp and Lacustrine deposits - sand, clay, diatomite - Recent
Qrs	Safety Bay Sand: calcerous eolian and beach sand, in places weakly lithified - Recent
Qrsm	Safety Bay Sand forming mobile dunes - Recent
Qpe	Eolian sand - quartz sand derived from ephemeral lakes and swamps - Pleistocene and Recent
Qpa	Alluvium - sand, silt and clay - Pleistocene
Qpck	Coastal Limestone: eolian limestone and kankar - Pleistocene
Qpcs	Coastal Limestone covered by residual quartz sand - Pleistocene
Qpb	Bassendean Sand: Quartz sand forming ancient coastal dunes - Pleistocene
Qpo	Colluvium - Quartz Sand - Pleistocene and Recent
Czl	Laterite - ferrugenous laterite - Upper Cainozoic
Jky	Yarragadee Formation: Sandstone, siltstone, shale - Jurassic to Cretaceous
Jm	Champion Bay Group: sandstone, limestone - Middle lower Jurassic

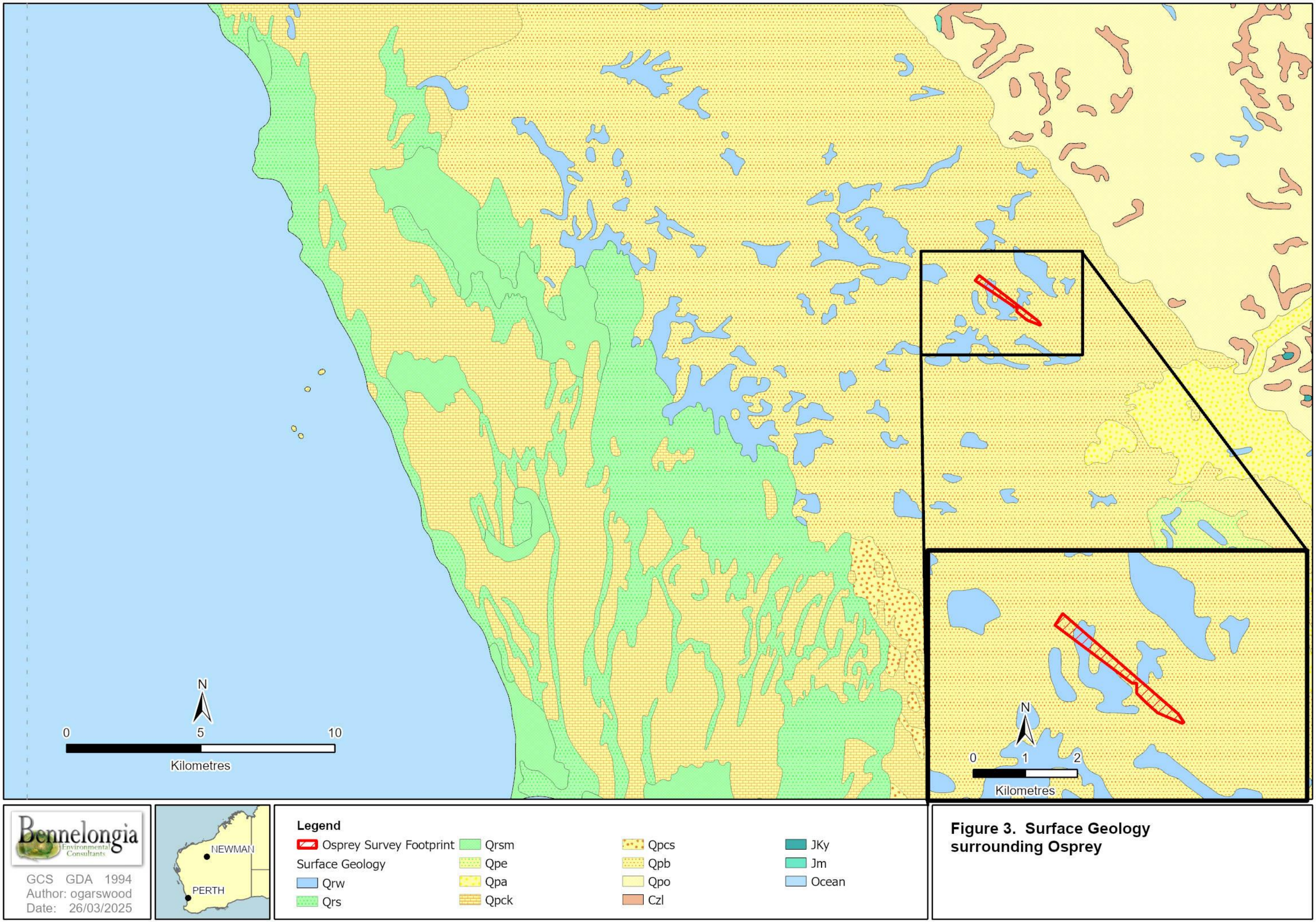


Figure 3. Surface Geology surrounding Osprey

3.3. Hydrogeology

There are two regional aquifer systems in the vicinity of the Project. These are surficial aquifer and the Yarragadee aquifer. The surficial aquifer lies in the marine shorelines and Bassesdean Sand and is comprised of beds of sand and clay in alternate layers forming a semi-confined to unconfined anisotropic groundwater predominantly flows westward to the Indian Ocean. Near the surface, clays sometimes confine the underlying aquifer and support seasonal perched aquifers (Worley Parsons 2012). The surficial aquifer extends to depths of up to 50 m below ground.

The Yarragadee aquifer, which begins approximately 50m below ground, is the deepest and most extensive aquifer system in the northern Perth Basin. The Yarragadee aquifer is unconfined west of the Dandaragan Scarp and recharge is via infiltration of rainfall from overlying sediments (Worley Parsons 2012).

3.4. Subterranean Fauna Habitats

Troglofauna occupy air-filled subterranean spaces, such as alluvial interstices, voids and fissures, while stygofauna inhabit groundwater held by such structures. Stygofauna occur mostly in regional aquifers, although a small suite of stygofauna species sometimes occur in the hyporheic zone (the confluence of groundwater and surface-water habitats) of drainage lines and in groundwater-fed springs.

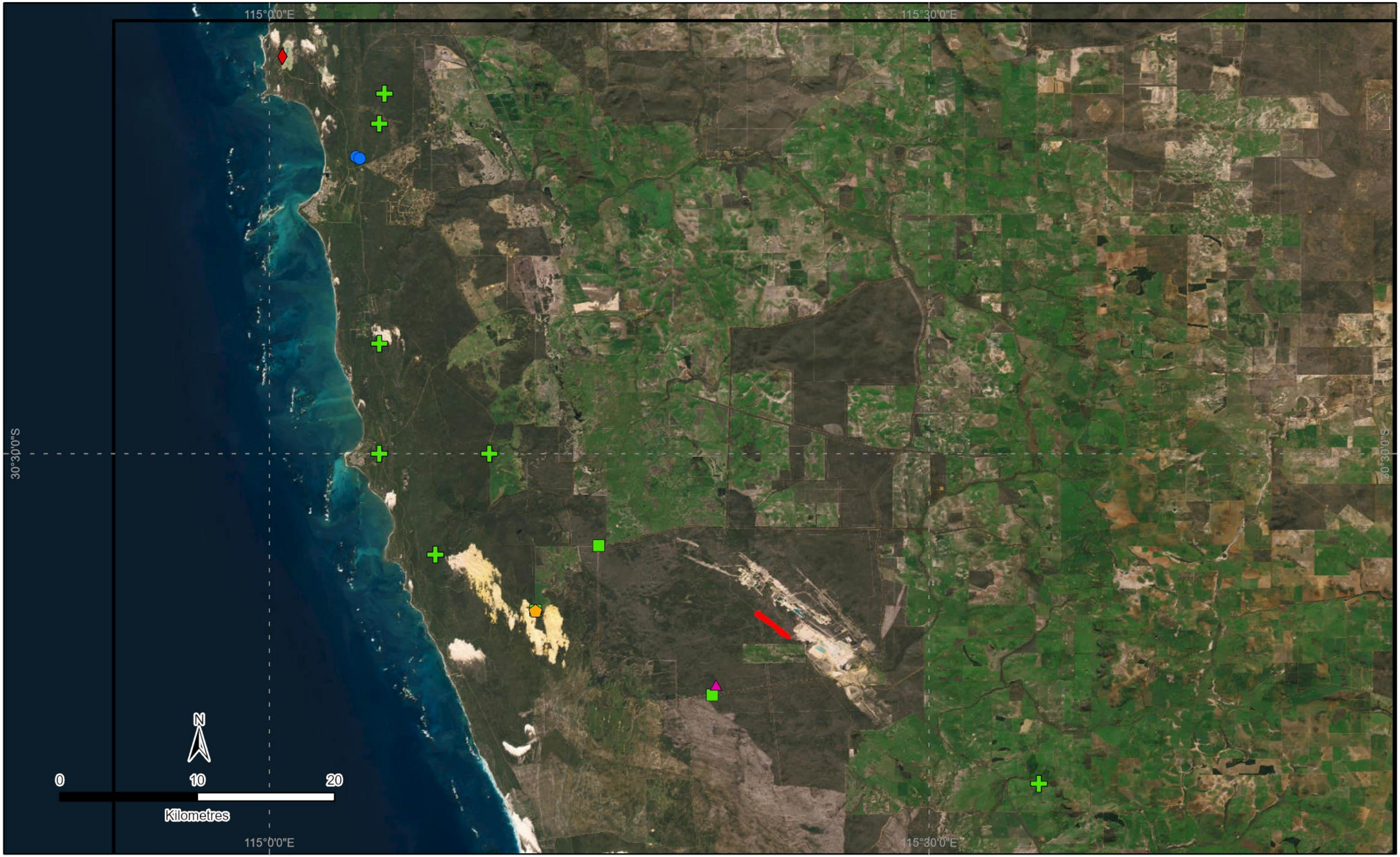
The most productive aquifers for stygofauna are alluvial and calcrete aquifers associated with palaeochannel deposits. Aquifers in weathered rock can also be productive and aquifers in some iron formations (especially channel iron formation) may contain moderately abundant stygofauna (Halse *et al.* 2014). Apart from salinity, the physiochemical tolerances of stygofauna have not been well defined. Most stygofauna assemblages have been recorded in aquifers with fresh to brackish water, although they have been reported in salinities of up to 50,000 mg/L TDS (78,000 µS/cm) or more (Bennelongia 2016; Reeves *et al.* 2007; Watts and Humphreys 2006).

3.4.1. Fauna habitats at Project

The two potential habitats for subterranean fauna in the Project area are (1) the surficial aquifer in marine shoreline deposits and Bassendean Sand, and (2) limestone caves. These caves have several occurrences in the search area but there is no evidence that they occur in the Project area.

The relatively young geological age, and limited area, of karstic habitats on the Swan Coastal Plain suggest the majority of species in karst and caves are likely to be surface species, trogloxenes or troglophiles that have migrated in from elsewhere and retain strong surface dispersal abilities. There are a small number of records of troglofauna from shallow holes (wells etc) on the Swan Coastal Plain in sand habitats south of Perth (Biota 2003; Harvey and Mould 2006) but other surveys in these habitats south of Perth have not collected any troglofauna (Bennelongia 2009), suggesting coastal plain sand provides poor habitat for troglofauna. Thus, while information is currently limited, it may be summarized that sand in the Project area has low prospectivity for troglofauna and, while karst is prospective, there are no known caves or significantly karstic areas in the Project.

The surficial aquifer in the Project area is considered moderately prospective for stygofauna on the basis of geology and general stygofauna occurrence. For example, stygofauna have been recorded in Bassendean sand aquifers on the Swan Coastal Plain (Bennelongia 2015). However, Bennelongia (2013) recorded no stygofauna species in a survey at Cooljarloo, immediately west of the Project area and in the same aquifer, A survey south of Eneabba recorded only one species of syncarid crustacean (Bennelongia 2008). Thus, in summary, habitat in the Project area appears to have low prospectivity for stygofauna.



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GCS GDA 1994
Author: ogarswood
Date: 27/03/2025

Legend

- Osprey Survey Footprint
- GHD07 Desktop Search Area

Records

- Diacyclops `BCY100`
- Nematoda spp.
- Ostracoda sp. unident.
- Tubificinae sp.
- cf. Hydrobiidae `sp.`
- Troglofauna Sampling Locations

Figure 4: Distribution of Subterranean Fauna records in the search area

4. DESKTOP FAUNA SEARCHES

4.1. Methods

The desktop assessment combined four sources of information to document known occurrence of subterranean fauna at the Project and the surrounding sub-region, using a search area of 100 km x 100 km centred on the Project (vertices at 30.171965°S, 114.881973°E and 31.075444°S, 115.852672°E;). The information sources were

4.1.1. Troglofauna

Surveys in caves by Moulds (2007), combined with records from the WAM and Bennelongia databases provided a list of 10 formally described species collected in the desktop search area or in caves at Eneabba to the north of the search area. No troglobitic species occur in list, although the troglophilic pseudoscorpion *Protochelifer cavernarum*, centipede *Allothereua lesueri*, cockroach *Neotemnopterys* douglasi, and beetles *Speotarus lucifugus*, and *Brises acuticornis duboulayi* are present (Table 1).

There is some doubt around the status of the probable troglophiles in Table 1. Genetic work suggests that exact taxonomic status of *Protochelifer cavernarum* is uncertain and it may be a species complex (Moulds *et al*. 2007). Roth (1995) describes *Neotemnopterys douglasi* as cavernicolous, with some troglomorphies that probably make it more subterranean than most species in Table 1 but its status remains unclear in relation whether it would occur underground outside caves. The beetles must have surface dispersal, with *Speotarus lucifugus* widely distributed with, at least locally, no genetic structuring between cave populations (Moulds *et al*. 2007). *Brises acuticornis duboulayi* is also very widely distributed in caves in South Australia, central Australia and the Nullarbor (Moulds 2005).

Table 3. Described troglofauna species collected from caves in search area**.**

Higher Order	Species	Status
Arachnida		
Pseudoscorpiones		
Cheliferidae	*Protochelifer cavernarum*	Tp
Araneae		
Mimetidae	*Australomimetus djuka*	Tx
Myriapoda		
Scutigeridae	*Allothereua lesueri*	Tp
Crustacea		
Philosciidae	*Laevophiloscia richardsae*	Tx
Insecta		
Blattodea		
Ectobiidae	*Neotemnopteryx douglasi*	Tp
Coleoptera		
Carabidae	*Speotarus lucifugus*	Tp
Tenebrionidae	*Brises acuticornis duboulayi*	Tp
Ptinidae	*Ptinus exulans*	Tx
Lepidoptera		
Tineidae	*Monopis crocicapitella*	Tx
Zygentoma		
Nicoletiidae	*Trinemura novaehollandiae*	Tx/S

The likely trogloxenes in Table 1 also have uncertain status. The isopod *Laevophiloscia richardsae* (uncertain identification treated as troglophile by Moulds 2007) is described by Vander (1973) as a troglophile but has 18 ommatidia and is probably more correctly a trogloxene om the basis of these well-developed eyes. Despite being collected from the 'dark or 'deep' zone of species such as the spider *Australomimetus djuka* are often found in the entrance or twilight zone (as well as in forest sometimes) and has no troglomorphic adaptations (Harms and Harvey 2009). The beetle *Ptinus exulans* (treated as troglophile by Moulds 2007) co-occurs with some species found in many caves but Hickman (1974) described it as occurring under the bark of eucalypts in Tasmania, so it appears to be clearly a trogloxene. The moth *Monopis crocicapitella*, a tentative identification by Moulds (2007) and treated as a troglophile, is cosmopolitan and, like some other near cosmopolitan species found widely is subterranean habits, can be regarded as a trogloxene at most. Reasons for Moulds (2007) including *Trinemura novaehollandiae* as a troglophile are unclear. The identification was tentative but the species was originally described from surface habitat on the Darling Scarp Smith (1998).

Databases frequently contain records of surface species in caves, such as the cosmopolitan cellar spider *Pholcus phalangioides*, Australasian red-backed spider *Latrodectus hasselti* and grey platform spider *Baiami volucripes*. This, together with the paragraph above, highlights the difficulties of determining which species in an area are potential troglofauna that are reliant on subterranean habitat for persistence. For example, species of *Pholcus* can be troglobitic, although most are found only on the surface. Table 2 lists some other species collected from caves in the search area that may be troglofaunal. It is not a complete list and the part of cave occupied is sometimes unknown. With higher level identifications the degree of subterranean adaptation is usually unclear.

Table 4. Other potential troglofauna species in search area.

Higher Order	Species	Status
Arachnida		
Desidae	*Baiami volucripes*	Dark zone
Mysmenidae	*Trogloneta* sp.	Dark zone, likely troglophile
Oonopidae	*Opopaea* sp.	Maybe subterranean
Orsolobidae	*Tasmanoonops* 'fosteri'	May be troglophile
Theridiosomatidae	*Baalzebub* sp.	Likely troglophile
Symphyla		
Scutigeridae	*Allothereura* sp.	Dark zone, possible troglophile
Insecta		
Blattodea		
Nocticolidae	*Nocticola* `sp.`	Misidentification or troglophile?

4.1.2. Stygofauna

Examination of WAM and Bennelongia database records revealed few stygofauna records within the desktop search area, with only seven species found (Table 3). These include molluscs, worms and crustaceans.

The few species found were in caves, groundwater wells and streambeds. Survey elsewhere on the coastal plain has shown moderately extensive occurrence of copepods in coastal plain aquifer, with Tang and Knott (2009) documenting 15 copepod species occurring in the groundwater of the Gnangara Mound north of Perth. An overview of the stygofauna communities of the Swan Coastal Plain, and coastal areas of Australia more generally, is given in Table 1 of Sacco *et al*. (2022). With 23 species, the stygofauna community found in a Bassendean sand aquifer in Perth, to the south of the search area, consists of worms, copepods, ostracods and syncarid crustaceans (Bennelongia 2022). All of these animals are very small and can use very small interstitial spaces in groundwater.

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Table 5. Stygofauna species collected from caves in search area.

Higher Order	Species	Status
Mollusca		
Hydrobiidae	Hydrobiidae sp.	Uncertain
Annelida		
Naididae	Tubificinae sp.	Uncertain
Arthropoda		
Ostracoda		
Candonidae	*Acandona memoria*	Well on river terrace, stygophile
	Pseudocandona cf. *geratsi*	Well, stygobite?
Copepoda		
Cyclopidae	*Diacyclops* \`BCY100\`	Cave, stygophile
Amphipoda		
Paramelitidae	*Hurleya* sp.	Cave, stygophile/bite
Neoniphargidae	*Wesniphargus yanchepensis*	Cave, stygophile/bite

A previous survey for stygofauna at Tronox's Cooljarloo mineral sands mine to the east collected no stygofauna (Bennelongia 2013).

5. DISCUSSION

Habitat assessment in combination with a desktop search has provided a picture of the likelihood of subterranean fauna occurring in the Project area.

While a moderate number of potential troglofauna species have been collected from caves, no troglobitic species have been found. Cave species need to fit the troglobitic category to persist in the extreme 'deep cave' conditions that occur outside caves in the vadose zone between the water table and ground surface where most Western Australian troglofauna species occur. No cave habitat occurs in the Project area. No troglofauna species from other habitats are known to occur in the search area and few have been recorded from coastal plain habitat south of Perth (outside the search area).

The stygofauna species list for the search area is small. Of the five species identified to species or genus level, three are known only from caves and one was collected from a well on a river terrace (Karanovic 2003). The other species (*Pseudocandona* cf. *geratsi*) may be from a regional aquifer but it was collected a long way inland of the coastal plain in the upper Brockman River catchment. The lack of known stygofauna occurrences at Cooljarloo (Bennelongia 2013) strongly suggests the Project and surrounding coastal plain do not support a significant stygofauna community.

Project delopment is unlikely to impact subterranean fauna conservation values.

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