Bennelongia Environmental Consultants

Lake Wells Potash Project

Assessment of Short Range Endemic Invertebrate Values

Prepared for:

Australian Potash Limited

October 2018

Final Report

Short-Range Endemics | Subterranean Fauna

Waterbirds | Wetlands

Lake Wells Potash Project
Assessment of Short Range Endemic Invertebrate Values

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EXECUTIVE SUMMARY

Australian Potash Limited proposes to develop the Lake Wells Potash Project (the Project) at Lake Wells in the northeastern Yilgarn region of Western Australia. This will involve extracting groundwater brines underlying the Lake Wells salt lake system and subsequent concentration in solar evaporation ponds to produce sulphate of potash. This report provides the results of desktop and field surveys to determine the conservation values of short range endemic (SRE) invertebrates, as well as other conservation-listed terrestrial invertebrates, in the vicinity of the Project. An assessment is made of the potential impacts of the Project on SRE and listed terrestrial invertebrate species. An SRE species is 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 capability.

As a result of the lack of previous targeted survey for terrestrial invertebrates in the area a desktop search did not yield any records of SRE Group taxa or listed invertebrate species in the vicinity of the Project. There are no Priority Ecological Communities (PECs) or Threatened Ecological Communities (TECs) in the vicinity of the Project that are listed on a basis of terrestrial invertebrates. Four Threatened or Priority terrestrial invertebrate species – the Arid Bronze Azure Butterfly *Ogyris subterrestris petrina* (Critically Endangered), the Inland Hairstreak *Jalmenus aridus* (P1) and the trapdoor spiders *Kwonkan moriartii* (P2) and *Idiosoma castellum* (P4) – have the potential to occur at the Project, although the latter two species are unlikely to occur. The impact of the Project on these conservation-listed species will be negligible.

Seven habitat units for SREs were identified in the Project area based on the desktop review. Most habitats in the Project area are generally considered to have low prospectivity for SRE species but will probably prove to harbour species from SRE Groups (i.e. the groups of invertebrates recognised in environmental impact assessment as having high proportions of SRE species). Salt lake playa and gypsum dunes are considered moderately prospective for SRE species.

A single-phase survey targeting invertebrates from the SRE Groups was carried out in May 2018. Survey techniques were consistent with EPA guidelines. Habitats observed in the field were consistent with those identified in the desktop review. Field survey recorded a total of 38 species belonging to SRE Groups in and around the Project area including mygalomorphs, pseudoscorpions, scorpions, millipedes, centipedes, land snails, and at least one species each of isopod and wolf spider. When combined with results of previous survey, 47 species from SRE Groups are known from the Project area and close vicinity. Gypsum dunes comprise a habitat in the Project area that appears to host a considerable number of potential SRE species. No conservation listed invertebrate species were recorded.

No confirmed SRE species were recorded from the Project area or surrounds but nine potential SRE species are known only from within the Project development envelope, including three species - *Idiosoma* sp. B45, Cheiridiidae sp. B02 and Chernetidae sp. B15 – known only from the Project footprint. However, the extent of the habitats from which these species were collected, and their respective life histories, suggest all nine species are likely to have ranges extending beyond the Project development envelope, so that their conservation status will not be threatened.

Although a large proportion of playa habitat within the Project area will be developed, it equates to a very small proportion of the total area of playa throughout the Lake Wells system.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

Australian Potash Limited proposes to develop the Lake Wells Potash Project (the Project) at Lake Wells, approximately 160 km northeast of Laverton, in the northeastern Yilgarn region of Western Australia (Figure 1). The Project will involve extracting potassium-rich groundwater brines underlying the Lake Wells salt lake system and subsequent concentration of this groundwater in solar evaporation ponds to produce sulphate of potash. Additional infrastructure will include salt harvesting and treatment facilities, roads, an airstrip, accommodation, administration facilities, drainage and borefields. The site layout of the Project is shown in Figure 2.

This report provides the results of desktop and field surveys to determine the conservation values of short range endemic (SRE) invertebrates, as well as other conservation-listed terrestrial invertebrates, that may occur in the vicinity of the Project. An assessment is made of the potential impacts of the Project on SRE or listed terrestrial invertebrate species.

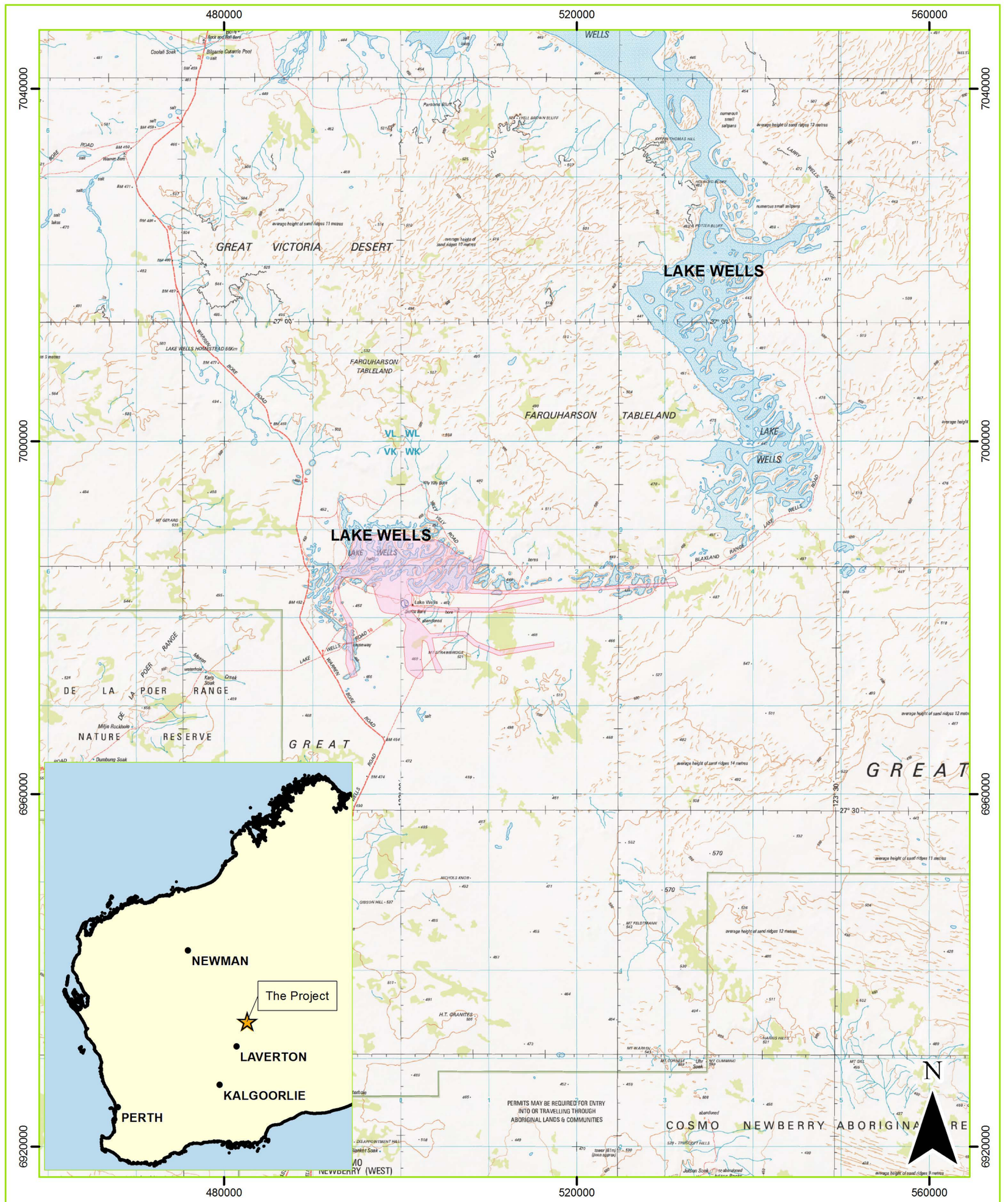
For the purposes of the current work the 'Project area' refers to a development envelope of 14,340.9 ha surrounding planned developments. Planned developments are collectively referred to as the 'Project footprint'. The Project area also contains non-disturbance areas. The Project footprint is smaller than the total Project area at approximately 3,220 ha (Figure 2).

2. SRE FRAMEWORK

An SRE species are defined as having an overall range of less than 10,000 km^2 (Harvey 2002). 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, as prescribed by the Environmental Protection Authority (EPA 2016a, b), typically focuses on a number of taxonomic groups (the SRE Groups) that are known to contain high proportions of SRE species. These include land snails (Gastropoda); millipedes (Diplopoda); centipedes (Chilopoda); pseudoscorpions (Pseudoscorpiones); scorpions (Scorpiones); spiders [Araneae, mainly Mygalomorphae (trapdoor spiders), but also some modern spider families such as Lycosidae]; slaters (Isopoda) and harvestmen (Opiliones). Some other groups, such as velvet worms (Onychophora) and earthworms (Oligochaeta), contain SRE species but are restricted to mesic environments.

Species with restricted ranges also occur in groups containing species that are mostly widespread due to high vagility, ecological plasticity or xeric adaptation (Framenau *et al.* 2008; Rix *et al.* 2015) and, conversely, many species belonging to SRE Groups are in fact widespread. Determining whether or not a species belonging to an SRE Group actually has a significantly restricted range (notionally <10,000 km^2) is often difficult. However, the distribution of an SRE Group species is likely to reflect 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. Most SRE species occur in habitats that have patchy occurrences. An addition constraint is that in some groups there may be some species turnover, often linked to climatic gradients, in widespread habitats that results in a species occupying only part of a widespread habitat and, therefore, being an SRE (Rix *et al.* 2015).

Determination of the SRE status of the species listed in this desktop review is based on the SRE classification system of the Western Australian Museum (WAM; Appendix 1), modified in some cases to compensate for limited data. For example, detailed habitat information is not always available for species in WAM databases, so habitat information cannot always be used to predict distributions. The factors considered when evaluating the SRE status of each species in this report were the known range of the species; habitat(s) at the collection location(s) and the spatial extent and connectivity of these habitats; and distribution patterns of phylogenetically related surrogate species (which are ideally members of the same genus).



Legend

Project development envelope

0 15 30

kilometres

Bennelongia Environmental Consultants

GDA_1994_MGA_Zone_51
Author: A. Mittra
Date: 08-06-2018

Figure 1. Location of the Project

500000 510000 520000 530000

6990000

6980000

6970000

Concentrator and Crystalliser Ponds

Fractured borefield north

Harvest Ponds

Brine borefield

Processing Plant

Bitterns Pond

Brine borefield

Fractured borefield south

Aistrip

Access Road

Fractured borefield south

Accommodation Village

Landfill

N

Legend

- Development envelope
- Access Roads and Tracks
- Accommodation Village
- Airstrip
- Bitterns Pond
- Brine Borefield
- Concentrator and Crystalliser Ponds
- Fractured Borefield North
- Fractured Borefield South
- Harvest Ponds
- Landfill
- Processing Plant
- Playas/claypans

0 5 10

kilometres

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Figure 2. Layout of site developments at the Project

Species are considered 'widespread' if their known, or likely range, exceeds 10,000 km^2. However, even restricted species may be locally widespread around a project area. Thus, identifying SRE species is only the first part of a filtering process used to determine whether species may be threatened by a development. The actual level of threat to an SRE species depends on its range relative to the development footprint rather than SRE status alone. Determining the likely level of threat to a species requires consideration of the extent of the species' preferred habitat, both locally and regionally, as well as the area of disturbance.

3. DESKTOP REVIEW

The desktop component of this work reviewed previous records of terrestrial invertebrates and habitat information, including geology, hydrogeology and vegetation mapping, to examine the possibility of SRE or conservation listed invertebrate species occurring in the vicinity of the Project and to assess the requirement for field survey.

3.1. Previous records

Previous records of terrestrial invertebrates, specifically SRE Groups but also conservation listed species, in the vicinity of the Project were collated by searching available databases (Bennelongia, WAM, NatureMap) and relevant literature within an area of approximately 10,000 km^2 (defined by 26.604°S, 122.489°E and 27.624°S, 123.57°E).

Besides collections of a small number of invertebrate specimens made during a survey of vertebrate fauna in the Project area (Harewood 2017, discussed below) the desktop search did not yield any records of SRE Group taxa or listed invertebrate species within the search area. This is interpreted as a consequence of the lack of previous targeted survey for terrestrial invertebrates in the area.

3.1.1. Previous Survey at the Project

Harewood (2017) collected 46 individual terrestrial invertebrate specimens belonging to at least 10 species in pitfall traps during a targeted two-phase survey of vertebrate fauna in the Project area in September 2016 and April 2017. The specimens were identified by Erich Volschenk of Alacran Environmental Science and Simon Judd (isopod identifications). SRE Groups recorded were scorpions, centipedes, mygalomorph spiders, isopods and millipedes (Table 1). A single potential SRE species, the isopod *Buddelundia* `10ld`, was recorded in the Project development envelope outside the Project footprint from gypsum dune habitat. In addition, some indeterminate identifications were classed as possibly representing potential SRE species.

Table 1. Species from SRE Groups recorded in the Project area during vertebrate fauna survey.

SRE Group	Lowest Identification	No. of sites	Location	SRE status*
Trapdoor spiders				
Idiopidae	Idiopidae sp. indet.	1	Outside envelope	Potential
	Idiosoma `LW1`	1	Outside envelope	Potential
Nemesiidae	*Aname* `MYG251`	1	Outside envelope	Widespread
Slaters				
Armadillidae	*Buddelundia* `10ld`	1	Development envelope	Potential
	Buddelundia `27dv`	3	Outside envelope	Potential
Millipedes				
Paradoxosomatidae	Paradoxosomatidae `LW`	1	Outside envelope	Potential
Polyzoniidae	`*Megalosiphon* LW`	1	Outside envelope	Potential
Centipedes	*Scolopendra morsitans*	1	Outside envelope	Widespread
Scorpions				
Buthidae	*Lychas* `adonis`	3	Outside envelope	Widespread
	Lychas `LW2`	2	Outside envelope	Potential
Urodacidae	*Urodacus* sp. indet.	3	Outside envelope	Potential

*As designated by Erich Volschenk (Harewood 2017).

3.1.2. Listed Invertebrate Species at the Search Area

There are no Priority Ecological Communities (PECs) or Threatened Ecological Communities (TECs) in the vicinity of the search area listed on a basis of terrestrial SRE taxa. Priority species listed by DBCA that have the potential to occur in the vicinity of the Project include the Arid Bronze Azure Butterfly *Ogyris subterrestris petrina* (Critically Endangered), the Inland Hairstreak *Jalmenus aridus* (Priority 1) and the trapdoor spiders *Kwonkan moriartii* (Priority 2) and *Idiosoma castellum* (Priority 4).

The critically endangered butterfly *Ogyris subterrestris petrina* is known from two sites near Kalgoorlie (ALA 2018) and occurs in mallee-dominated woodland. This species depends on the sugar ant (*Camponotus terebrans*), with the butterfly depositing its eggs at the entrances of sugar ant nests that abut the base of living trees and shrubs of various species. The host ant species is widespread across Australia. There are no records of this butterfly species (either historical or recent) in the search area. Its primary habitat is woodlands where the host ant constructs nests and this habitat type is present in the search area and survey area. The Project will have a minimal impact on this habitat.

The Priority 1 butterfly *Jalmenus aridus* is known from a handful of records near Kalgoorlie and Ngaanyatjarraku in the Northern Yilgarn, indicating that it may be rare but widespread in the Yilgarn. The species is not commonly collected and is poorly represented in Australian research collections. The larvae of this butterfly feed on the leaves and flowers of *Senna* spp. and *Acacia tetragonophylla* (Graham and Moulds 1988). Both host plants occur widely in the Yilgarn and are generalist species that do not occur on specific geologies or soils, so this butterfly may be widespread but poorly sampled. Both *Senna* spp. and *Acacia tetragonophylla* are likely to occur in the Project area, although the impact to habitats containing these plant species will be regionally negligible, and the conservation status of the butterfly is unlikely to be impacted.

The Priority 2 wishbone spider *Kwonkan moriartii* is known only from the male holotype collected at Kathleen Valley Station, north of Leonora (Main 1983) and the range of this species is unclear (ALA 2018). There are no records of this species in the search area surrounding the Proposal. Many *Kwonkan* species have very short ranges and are confined to specific soil types or geological features, with field data suggesting that some species prefer open plain habitats whilst others are confined to BIF habitats (Bennelongia, unpublished data). Given the short-ranges of most *Kwonkan* species and the absence of records from elsewhere in the Yilgarn (despite many SRE surveys in the southern Yilgarn over the last decade) it is reasonable to assume that the species is restricted to the area surrounding Kathleen Valley Gold Mine and will not be affected by the Project.

The Priority 4 tree stem trapdoor spider *Idiosoma castellum* (formerly *Aganippe castellum*) has been recorded throughout the Wheatbelt and western Goldfields, although records do not extend east of Mt Manning. The habitat for the species consists of flood-prone depressions and flats with myrtaceous shrubland (especially Broombush *Melaleuca uncinata* and Sheoak) on sandy-loam soil. The distributions of known occurrences of the species, combined with the absence of favoured habitat, suggest that *Idiosoma castellum* is unlikely to occur at the Project.

3.2. Regional Setting

The Project lis within the Shield subregion (GVD01) of the wider Great Victoria Desert bioregion (Interim Biogeographic Regionalisation of Australia). The subregion is characterised by salt lakes and major valley floors with lake-derived dunes, sandplains with patches of seif dunes with outcropping and silcrete-capped mesas and plateaus. Characteristic vegetation includes spinifex (*Triodia*) and mallee (*Eucalyptus kingsmilli* and *Eucalyptus youngiana*) over hummock grassland dominated by *Triodia basedowii* on aeolian sandplain; scattered marble gum (*Eucalyptus gongylocarpa*) and native pine (*Callitris*) on deeper sands; mulga and other *Acacia* woodlands on colluvial and residual soils; and salt bush (*Atriplex*), bluebush (*Maireana*) and samphire (*Tecticornia*) fringing salt lakes and saline drainage areas. The climate of the region is semi-arid to arid with hot, dry summers and mild winters.

Median annual rainfall at Delita Station (65 km northwest of the Project) since 1992 was 365 mm with the majority of rainfall received between January and April.

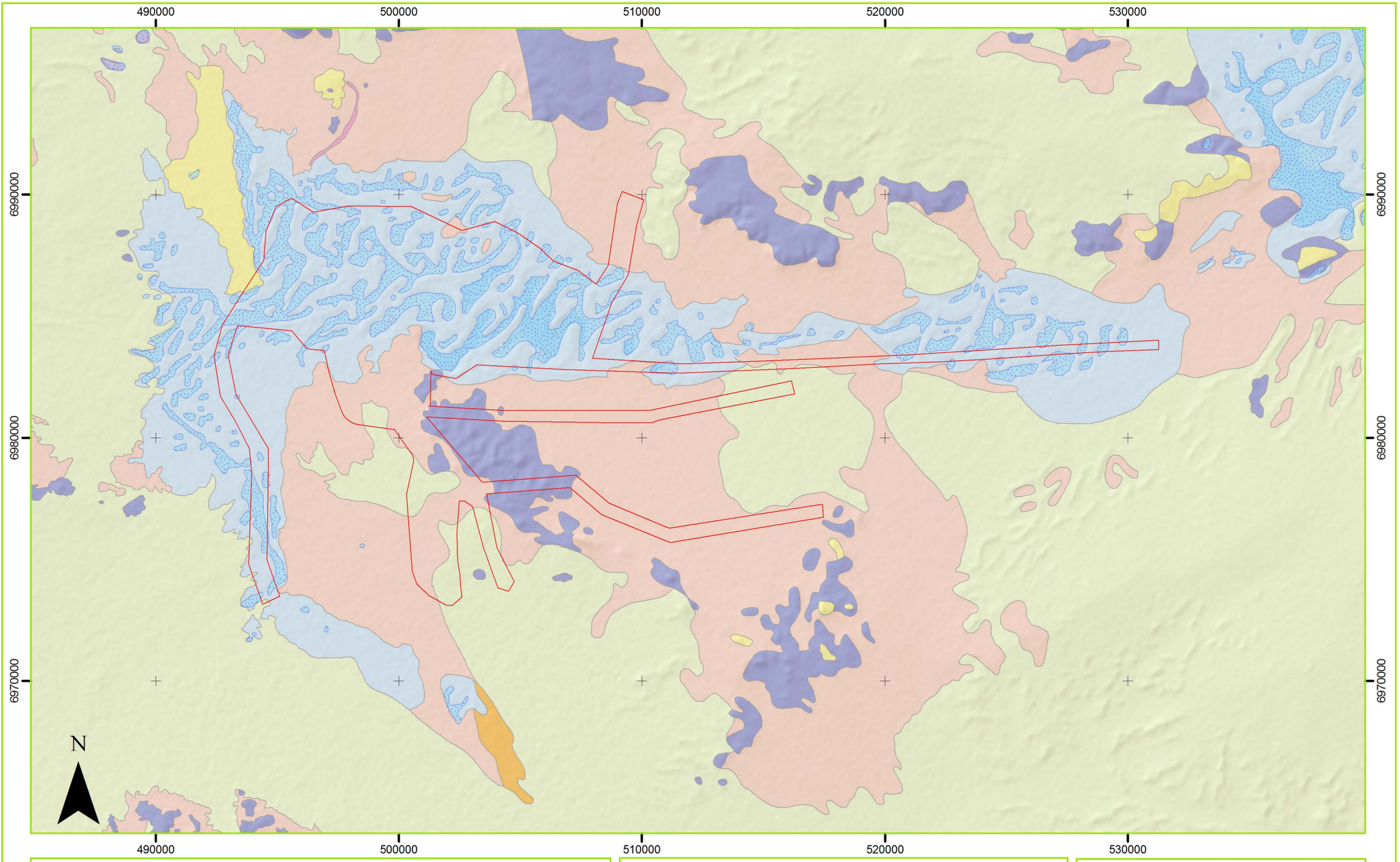
3.3. Habitat Prospectivity

Five criteria were used to identify habitat units in the Project area and predict their prospectivity for SRE species (as opposed to SRE Groups): moisture retention and exposure; soil structure; geology; vegetation; and extent and connectivity. Emphasis is usually placed on identifying relict, isolated, sheltered or moist habitats but 'specialist' habitats such as rock outcrops and ranges may also harbour SRE species. Isolated or patchy habitats are generally considered to be more prospective for SRE species. It is also now recognised that inland salt lakes in Western Australia may host a variety of specialist invertebrate taxa, including wolf spiders, tiger beetles and crickets that are halotolerant and highly restricted, although there has been relatively little documentation of such species and communities (but see Durrant and Guthrie 2004; Framenau and Hudson 2017).

Vegetation mapping at both local (Botanica Consulting 2017) and regional (1:3,000,000; Beard *et al.* 2013) scales and geological mapping at the 1:500,000 scale (Marnham and Morris 2003) were reviewed to gauge habitat prospectivity for SRE species. Beard *et al.* (2013) vegetation mapping classifies some 900 vegetation associations into 50 major vegetation types and 20 vegetation mosaics across Australia based on structure, physiognomy, floristics and ecological and regional attributes. The digital 1:500,000 regolith map of WA (Marnham and Morris 2003) is a compilation of finer-scale (1:250,000 and 1:100,000) geological maps and simplifies prevailing surficial geologies into nine subdivisions, including areas of outcrop, residual or relict units, and seven depositional regolith units. Fauna habitat mapping at the Project (Harewood 2017) was also reviewed. When combined, these resources provide a reasonable indication of SRE habitats, but classification of microhabitats within larger habitat units is not necessarily practicable without field survey. This is a limitation of desktop survey because many SRE species are distributed at the microhabitat scale.

The Project area is diverse in terms of both vegetation and geology; for example, Botanica Consulting (2017) identified 17 vegetation types from five major vegetation groups occurring across nine different landform types (Appendix 2), while mapped geology indicates seven surficial units in and around the development area (Figure 3). SRE habitats are likely to comprise fewer than the 17 vegetation types due to the similarity between some vegetation types in terms of the microhabitats provided to SRE species. For instance, the vegetation group 'Chenopod shrublands, samphire shrublands and forblands (MVG 22)' contains three vegetation types that are considered to present similar habitat for SRE invertebrates, while there is also likely to be substantial overlap between the seven vegetation types representing '*Acacia* forests and woodlands (MVG 6)' (Appendix 2) in terms of habitat provision.

Using the above information, seven habitat units for SREs were identified in the Project area (Table 2; Figure 4). While no moist habitats are likely to be present, some outcrops may be present to the north and south of the main playa network among the rocky hills and slopes and may provide specialist habitat for a range of species including burrowing *Urodacus* scorpions, trapdoor spiders and rock-specialist pseudoscorpions. This will depend on local situation and microhabitats. Following rainfall events, these rocky areas may to some degree retain moisture in drainage lines and soil deposits between rocks embedded on slopes. Rocky hills and slopes will be minimally impacted by the Project. As alluded to above, salt lake playas at Lake Wells (and possibly fringing shrublands) may also host specialised halotolerant taxa. Other habitats in the Project area are generally considered to have low prospectivity for SRE species but will probably prove to harbour species from SRE Groups.



Legend

- Development envelope
- Playas/claypans

Regolith

- Alluvium
- Colluvium
- Calcrete
- Lacustrine
- Ferruginous, siliceous and calcareous duricrust
- Sandplain
- Exposed rock

0 8 16

Kilometres

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Date: 09-07-2018

Figure 3. Mapped surficial geology in and around the Project

Regolith is mapped at the 1:500,000 scale (Marnham & Morris 2003).

Table 2. Potential habitat units for SRE species identified through desktop review.

Habitat No.	Landform	Vegetation/description	Moisture retention/Exposure	Soil/geology	Extent/Connectivity	Prospectivity	Comments
1	**Closed depressions and playa fringes**	Chenopod, samphire and saltbush shrublands in closed depressions and fringing plays	Highly exposed; low-to-moderate moisture retention (high evaporation of surface water, but high water table may provide moisture for burrowing species)	Sandy-loams and clays, cracking clays in some ephemeral water holes	Extensive and somewhat interconnected in association with the Lake Wells system, although regionally isolated	Low-moderate	Patchy, but extensive outside dev. envelope. May be utilised by salt lake specialists.
2	**Kopi (gypsum) dunes**	*Casuarina* and *Eucalyptus* woodland over shrubland on kopi dunes and islands adjacent to playas and depressions	Highly exposed; low moisture retention	Fine weathered gypsum	Moderately common in association with the Lake Wells system, although regionally isolated.	Moderate	Patchy and regionally isolated, but extensive outside dev. envelope. Some SRE Groups may be present in leaf litter around *Casuarina*, or in burrows.
3	**Rocky hills and slopes**	*Acacia* woodland and shrubland with grasses and herbs on rocky slopes and outcrops	Moderately-to-highly exposed; moisture retention generally low, possibly greater depending on local situation	Exposed granites, quartz and other rocks with sandy loams and clays	Regionally common but somewhat patchy	Low-moderate	Generally low prospectivity and may mirror surrounding plains in terms of microhabitat, although larger hills may be more prospective and could harbour specialist taxa.
4	**Clay-loam plains, low slopes and minor drainage lines**	*Acacia* woodland, mallee and shrubland over tussock grasses and herbs	Moderately-to-highly exposed; low-to-moderate moisture retention	Red sandy loams	Regionally common and interconnected	Low	Widespread, including outside development envelope and not considered prospective for SRE species, although SRE Groups probably present.
5	**Sand-loam plains**	Open *Acacia* woodland over shrubland, hummock/tussock grasses and herbs	Highly exposed; generally low moisture retention with moderate retention in soil at depth	Red sand and sandy loams	Regionally common and interconnected	Low	Widespread, including outside development envelope. Not considered prospective for SRE species although SRE Groups probably present.
6	**Sandplains, dunes**	Open mallee and *Eucalyptus* woodland, shrublands and hummock grassland	Highly exposed; low moisture retention	Red sand, minimal organic content	Regionally common and interconnected	Low	Widespread, including outside development envelope and unlikely to contain SRE species, although scorpions and mygalomorphs likely to be present (and possibly other groups).
7	**Salt lake playa**	Unvegetated ephemeral salt lake	Low-moderate moisture retention – surface water rapidly evaporates, but high water table may provide moisture for burrowing species	Salt crust over lacustrine sands and muds	Extensive and somewhat interconnected in association with the Lake Wells system, although regionally isolated	Moderate	Occurs outside development envelope in northern arm of Lake Wells, although this system as a whole is considered regionally isolated. May harbour specialised halotolerant taxa including SRE species.

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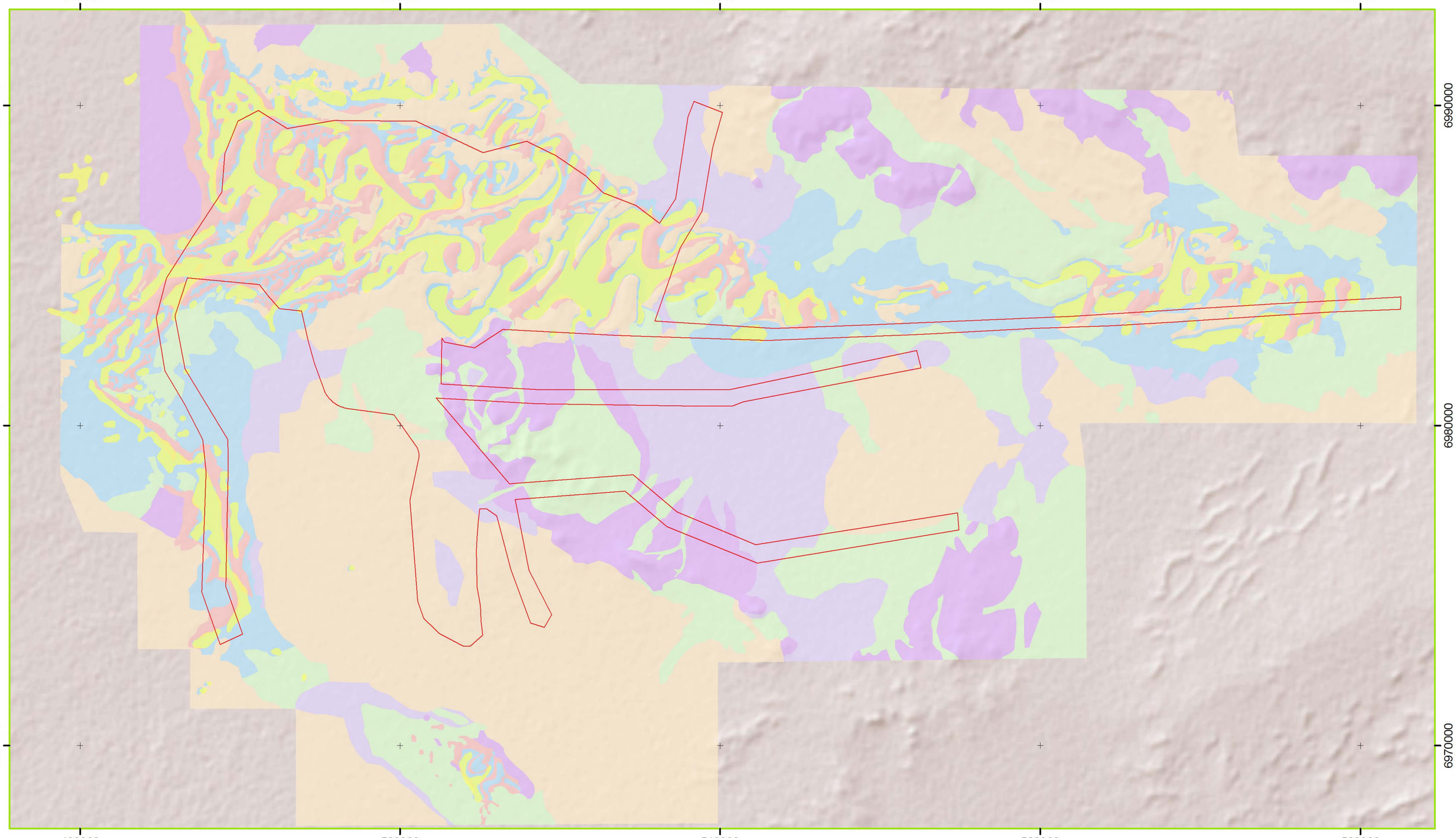
6980000

6970000



490000 500000 510000 520000 530000

Legend

Development envelope

SRE Habitats

1
2
3
4
5
6
7

0 5 10
kilometres

N

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Author: A. Mittra
Date: 13-06-2018

Figure 4. Inidicative habitat units for SRE invertebrates at Lake Wells identified through desktop review

Habitat numbers correspond to those given in Table 2.

4. FIELD SURVEY

Results of the desktop review, in particular the previous collections of potential SRE species but also the presence of moderately prospective SRE habitats, led to the conclusion that a targeted field survey for terrestrial SRE invertebrates was required. A single-phase survey targeting invertebrates belonging to the SRE Groups was carried out over four days in May 2018. Field survey was conducted by Michael Curran and Anton Mittra. Species identifications were completed by Jane McRae and Michael Curran.

Survey design and methods were based on *Technical Guidance: Sampling of short range endemic invertebrate fauna* (EPA 2016a) and aimed to collect species from recognised SRE Groups from the suite of habitat types encompassed by the indicative development envelope at the Project and reference areas in corresponding habitats. Specimens were collected both from exhaustively-searched sites chosen due to habitat, as well as at opportunist sites at which a limited range of methods were employed. Sampling methods also varied at each site according to habitat, knowledge of the biology of specific taxa and visual observations of burrows or other tell-tale signs of target species.

Sampling techniques included active hand foraging, cup traps, turning over and breaking apart logs and dead wood, turning over rocks, sieving leaf litter and other detritus, using a leaf blower to remove leaf litter and reveal burrows, excavating burrows with hand trowels, peeling bark, spotlighting (including ultraviolet torches to target scorpions), and opportunistic use of butterfly nets. At several sites it was impractical to excavate all burrows because of high abundance, so burrows were assigned to species based on their morphology and location, particularly for *Urodacus* scorpions and *Aname* trapdoor spiders.

Collected specimens were placed in 100% ethanol and transported to the laboratory for identification. In addition to the specimens collected in the field, leaf litter samples (approximately 1 L per site) were placed in calico bags, transported to the laboratory and placed in Tullgren funnels to collect invertebrates.

4.1. Laboratory Methods

Specimens collected in the field were identified under dissecting and compound microscopes using appropriate taxonomic resources and in-house expertise. Every effort was made to align specimens with known species or other specimens previously collected in the vicinity. This included comparing specimens with those lodged at WAM and those collected by Harewood (2017).

4.2. Rainfall

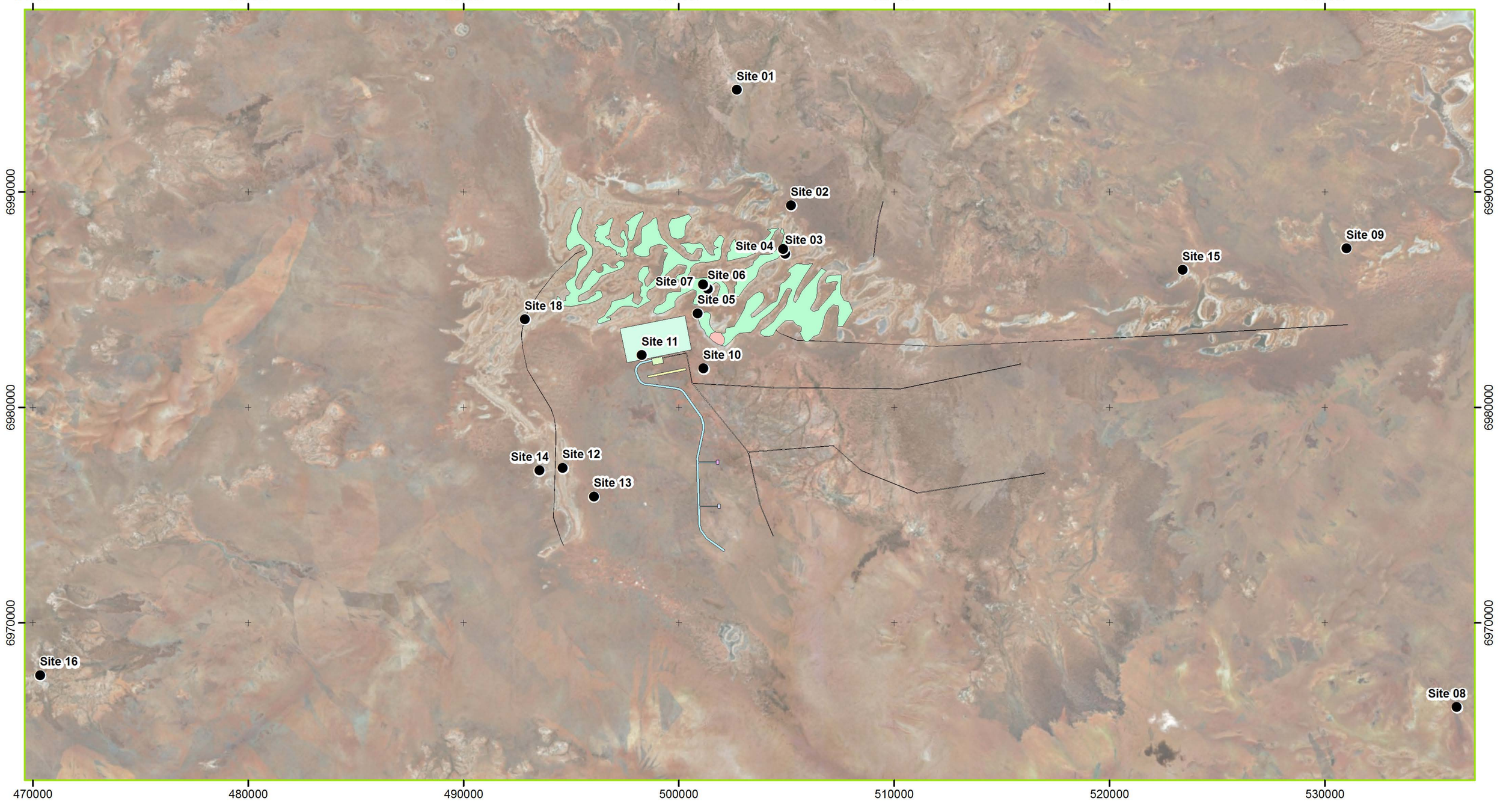
Many SRE species are particularly active after rainfall (Harvey 2002) and recommended survey periods reflect this (EPA 2016a); however, no rainfall was received at Delita Station (BOM station no. 13035) in the month prior to survey. Minor rainfall was received during survey but was not sufficient to induce high levels of invertebrate activity.

5. SURVEY RESULTS

Survey for specimens belonging to SRE Groups was conducted at a total of 18 sites in and around the Project area (Figure 5).

5.1. Habitat

A summary of habitat types at each collecting site is given in Table 3, while complete descriptions of habitat characteristics, methods and effort at each site are given in Appendix 3. Site photographs are presented in Appendix 4. Characteristics of the habitats observed in the field were more or less consistent with what was identified in the desktop review (Section 3.3; Table 2).



Legend

- Survey site
- Access Roads and Tracks
- Accommodation Village
- Airstrip
- Bitterns Pond
- Brine Borefield
- Concentrator and Crystalliser Ponds
- Fractured Borefield North
- Fractured Borefield South
- Harvest Ponds
- Landfill
- Processing Plant

0 5 10
kilometres

N

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Date: 31-08-2018

Figure 5. Sites surveyed for SRE invertebrates at the Project in May 2018

Table 3. Habitat units at each SRE survey site at Lake Wells in May 2018.

Habitat No.	Landform	Site																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Closed depressions and playa fringes		x		x	x	x					x				x			x
2	Kopi (gypsum) dunes			x				x					x		x	x		x	
3	Rocky hills and slopes s									x	x								
4	Clay-loam plains, low slopes and minor drainage lines	x									x			x					
5	Sand-loam plains		x			x						x			x		x		
6	Sandplains, dunes		x			x			x										
7	Salt lake playa				x		x												x

5.2. General Results

A total of 38 species belonging to SRE Groups were recorded in and around the Project area during field survey by Bennelongia in May 2018, including multiple species of mygalomorphs, pseudoscorpions, scorpions, millipedes, centipedes, land snails, and at least one species each of isopod and wolf spider (Table 4). Pseudoscorpions were particularly speciose with 15 species from seven families recorded. Mygalomorph spiders (seven species from four families) and scorpions (seven species, two families) were also moderately speciose.

At least nine other species were collected by Harewood (2017). The two *Idiosoma* species collected by Bennelongia and represented by female animals (*Idiosoma* sp. B43 and *Idiosmoa* sp. B44) are treated as different species from *Idiosoma* sp. 'LW1' collected by Harewood (2017) from site TS5.4, north of the development envelope, and represented by a male animal. In total, 47 species from SRE Groups have been collected from the Project area and surrounds (Tables 1 and 4).

Some specimens collected in May 2018 could not be identified to species level because they were immature, the wrong sex for identification or belonged to groups with insufficient taxonomic frameworks. These taxa were not included in counts of species richness unless they represented groups that would otherwise not have been recorded. No conservation listed invertebrate species were recorded.

Rainfall conditions before and during survey are considered to have potentially limited the numbers of terrestrial invertebrate species found, with animal activity likely to have been generally low due to dry conditions. Nevertheless, the survey revealed a moderately diverse suite of species from SRE Groups in and around the Project area.

5.3. Species Distributions

5.3.1. May 2018 survey

No confirmed SRE species were recorded from the Project area or surrounds. Six species recorded during survey in May 2018 are known from outside the survey area or are otherwise considered to be widespread (Table 4). These are the mygalomorph spiders *Cethegus ischnotheloides*, *Gaius* 'humphreysi' ms and *Aname* sp. B32; the centipede *Scolopendra laeta*; and the pupillid land snails *Pupoides adelaidae* and *Pupoides myoporinae*.

While 32 recorded species are nominally potential SREs, there is sufficient evidence to suggest that 15 of these are unlikely to have significantly restricted ranges (i.e. they are probably not SREs and are designated as '**unlikely'** in Table 4). The notional wider ranges of these species are supported by the wider occurrence of collection habitats both locally and regionally. Furthermore, 13 of the 15 'unlikely' SRE species were recorded outside the Project development envelope (Table 4).

Table 4. Terrestrial invertebrate species from SRE Groups recorded in and around the Project area at Lake Wells during field survey in May 2018.

Sites in red text are inside the Project footprint. 'x' denotes present but not collected.

Higher classification	Lowest identification	Site																	Comments on SRE status and known/likely range
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Arthropoda																				
Arachnida																				
Araneae																				
Araneomorphae																				
Lycosidae	Lycosidae sp. `LW1`				12		1												x	**Potential** SRE whose range is considered likely to extend outside the Project area throughout the Lake Wells system.
Mygalomorphae																				
Barychelidae	*Synothele* sp. B17 (*rastelloides* group)			2							2	2								Potential (data deficient) but **unlikely** SRE collected from three different habitats.
Dipluridae	*Cethegus ischnotheloides*		1	1											1					**Widespread**[1, 2].
Idiopidae	Idiopidae sp. indet*									x										Higher order identification (burrows).
	Gaius humphreysi ms	1												1						Potential SRE known from outside the Project area and may have a relatively large range throughout the Eastern Murchison, but poorly sampled (M. Rix, pers. comm.). Recorded outside the Project in common, extensive habitat. Considered **Widespread** for the purposes of this impact assessment.
	Idiosoma sp. B43										1									**Potential** SRE (data deficient) collected as a singleton.
	Idiosoma sp. B44	3							3			1			1					Potential (data deficient) but **unlikely** SRE collected over a moderately large area in several habitat types including outside the Project area.
	Idiosoma sp. B45											1								**Potential** SRE (data deficient) collected as a singleton.
Nemesiidae	*Aname* sp. B32		1			1			1			1			1					Moderately common, widespread species inhabiting sandy soil in a range of habitat types. **Widespread**.
Pseudoscorpiones																				
Atemnidae	Atemnidae sp. B07								2											Potential (deficient data) SRE collected as a singleton but **unlikely** to be restricted given extent and low prospectivity of collection habitat.
	Atemnidae sp. B08											6			2					Potential (data deficient) but **unlikely** SRE collected from eucalypt litter in two habitat units.
Cheiridiidae	Cheiridiidae sp. B02							1												**Potential** SRE (data deficient) collected as singleton from somewhat fragmented habitat.
Chernetidae	Chernetidae sp.*			12														1		Higher order identification.
	Chernetidae sp. B15							18												**Potential** SRE (data deficient) collected from a single site in somewhat fragmented habitat.
	Chernetidae sp. B16			10				1					1		7					**Potential** SRE (data deficient) collected from four sites in somewhat fragmented habitat. Recorded outside the Project area.
	Chernetidae sp. B17			7																**Potential** SRE (data deficient) collected from a single site in somewhat fragmented habitat.
Garypidae	Garypidae sp.														1					Higher order identification, **Potential** SRE (data deficient) collected outside the Project area from a somewhat fragmented habitat. Family contains both restricted and widespread species[6].
Garypinidae	Garypinidae sp.			1				1												Higher order identification considered to be a single species recorded from somewhat fragmented habitat. **Potential** SRE (deficient data).
Olpiidae	Olpiidae sp.*					1		1												Higher order identification.
	Beierolpium 8/4 sp. B19											1								Potential (deficient data) but **unlikely** SRE collected in a widespread habitat.
	Beierolpium 8/4 sp. B20	2																		Potential (data deficient) but **unlikely** SRE collected in a widespread habitat outside the Project area.

Higher classification	Lowest identification	Site																		Comments on SRE status and known/likely range
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
	Olpiidae sp. B03		1						1	1										Potential (data deficient) but **unlikely** SRE collected in a range of habitats including outside the Project area.
	Olpiidae sp. B04							1				1								Potential (data deficient) but **unlikely** SRE collected from under eucalypt bark in two habitat units.
Sternophoridae	Sternophoridae sp. B03								1											Potential (data deficient) but **unlikely** SRE collected outside the Project area in a widespread habitat.
	Sternophoridae sp. B04															1				**Potential** SRE (data deficient) collected as a singleton from a somewhat fragmented habitat outside the Project footprint.
	Sternophoridae sp. B05															1				**Potential** SRE (data deficient) collected as a singleton from a somewhat fragmented habitat outside the Project footprint.
Scorpiones																				
Buthidae	*Lychas* `*adonis*` ms		5									2								Part of the `*adonis*` species complex and range of collected species uncertain, although recorded in widespread habitat including outside the Project area. Potential (data deficient) but **unlikely** SRE.
	Lychas `annulatus complex`		1									1								Part of the `*annulatus*` species complex and range of collected species uncertain, although recorded in widespread habitat including outside the Project area. Potential (data deficient) but **unlikely** SRE.
Urodacidae	*Urodacus* sp. B14		1						2			1								Potential (data deficient) but **unlikely** SRE recorded in sandy soil in two extensive habitats types including outside the Project area.
	Urodacus sp. B15														4		1			**Potential** (data deficient) SRE recorded in fine, weathered soil including outside the Project area.
	Urodacus sp. B16		1																	Potential (data deficient) but **unlikely** SRE recorded in sandy soil in a widespread habitat outside the Project area.
	Urodacus sp. B17									1										**Potential** SRE (data deficient) recorded as a singleton from a fragmented habitat (rocky hill/outcrop) outside the Project area.
	Urodacus sp. B18														1					**Potential** SRE (data deficient) recorded as a singleton in fine, weathered soil outside the Project area.
Crustacea																				
Isopoda																				
Armadillidae	Armadillidae sp.*							1												Higher order identification
	Buddelundia sp. B80	2									21									Potential (data deficient) but **unlikely** SRE recorded from mesic refugia in two different habitat types, including outside the Project area. Also recorded as bycatch (subterranean fauna sampling) at hole LWFRP008.
Myriapoda																				
Chilopoda																				
Geophilida																				
Mecistocephalidae	*Mecistocephalus* sp.														1					**Potential** (data deficient) SRE with insufficient taxonomic framework for species-identification. Recorded outside the Project area in leaf litter on fine, weathered soil.
Scolopendrida																				
Cryptopidae	*Cryptops* sp.										4									**Potential** (data deficient) SRE with insufficient taxonomic framework for identification. Recorded leaf litter.
Scolopendridae	*Scolopendra laeta*	1		1																**Widespread**[3]
Diplopoda																				
Polyxenida																				
Polyxenidae	Polyxenidae sp.*								1											Higher order identification
	Unixenus sp.									1										**Potential** SRE (data deficient) collected from fragmented habitat. Genus appears to contain both widespread and restricted species[4].
Synxenidae	*Phryssonotus* sp.								1		1		1							Potential (data deficient) but **unlikely** SRE, although not identified

Higher classification	Lowest identification	Site																	Comments on SRE status and known/likely range
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
																				to species. Collected from a range of habitats including widespread habitats. Genus recently found to contain multiple Australian species[5].
Mollusca																				
Gastropoda																				
Pupillidae	*Pupoides adelaidae*										7									Both species **widespread**[6].
	Pupoides myoporinae												3							

*Higher order identifications not included in final counts of species richness.
[1]ALA 2018; [2]Raven 1985; [3]Koch 2008; [4]Short and Huynh 2013; [5]Huynh and Veenstra 2018; [6]Solem 1991.

Of the 17 potential SRE species that may have small ranges, eight species were collected only from inside the development envelope by Bennelongia, including three species from only within the Project footprint – *Idiosoma* sp. B45, Cheiridiidae sp. B02 and Chernetidae sp. B15 (Table 4). The ranges of these eight species, as well as the one species (*Buddelundia* `10ld`) collected only within the development envelope by Harewood (2017), are shown in Figure 6. More information about distributions of individual species is provided below.

5.3.2. Wolf spiders

Lycosidae sp. `LW1`

This wolf spider was observed and collected from playa and fringing chenopod shrubland (sites 4, 6 and 18) during active foraging at night using head torches at three sites within the Project development envelope. No adult specimens were collected, making comparisons with known species difficult without molecular work (although it was noted that larger individuals tended to be found on bare playa away from the shore, while numerous early-instar animals were collected or observed amongst fringing vegetation). The collection habitat and morphological characters including pale colouration and large eyes show that the collected specimens, which appear to belong to a single species, represent a specialised salt lake taxon. At least two and possibly three related genera occur in the region around Lake Wells and are difficult to separate morphologically due to convergence (V. Framenau, pers. comm.). Furthermore, there is strong evidence to suggest that there are SRE species among salt lake wolf spiders, although relatively few have been formally described despite significant recent work (Framenau and Hudson 2017). While the taxonomic affinity of the specimens from Lake Wells remains unknown, they are considered to represent a new species that may be an SRE restricted to the Lake Wells system. Although recorded from one site that is nominally outside the Project footprint, the development of brine concentrator and crystalliser ponds will cover a large proportion of the species' habitat within the Project area.

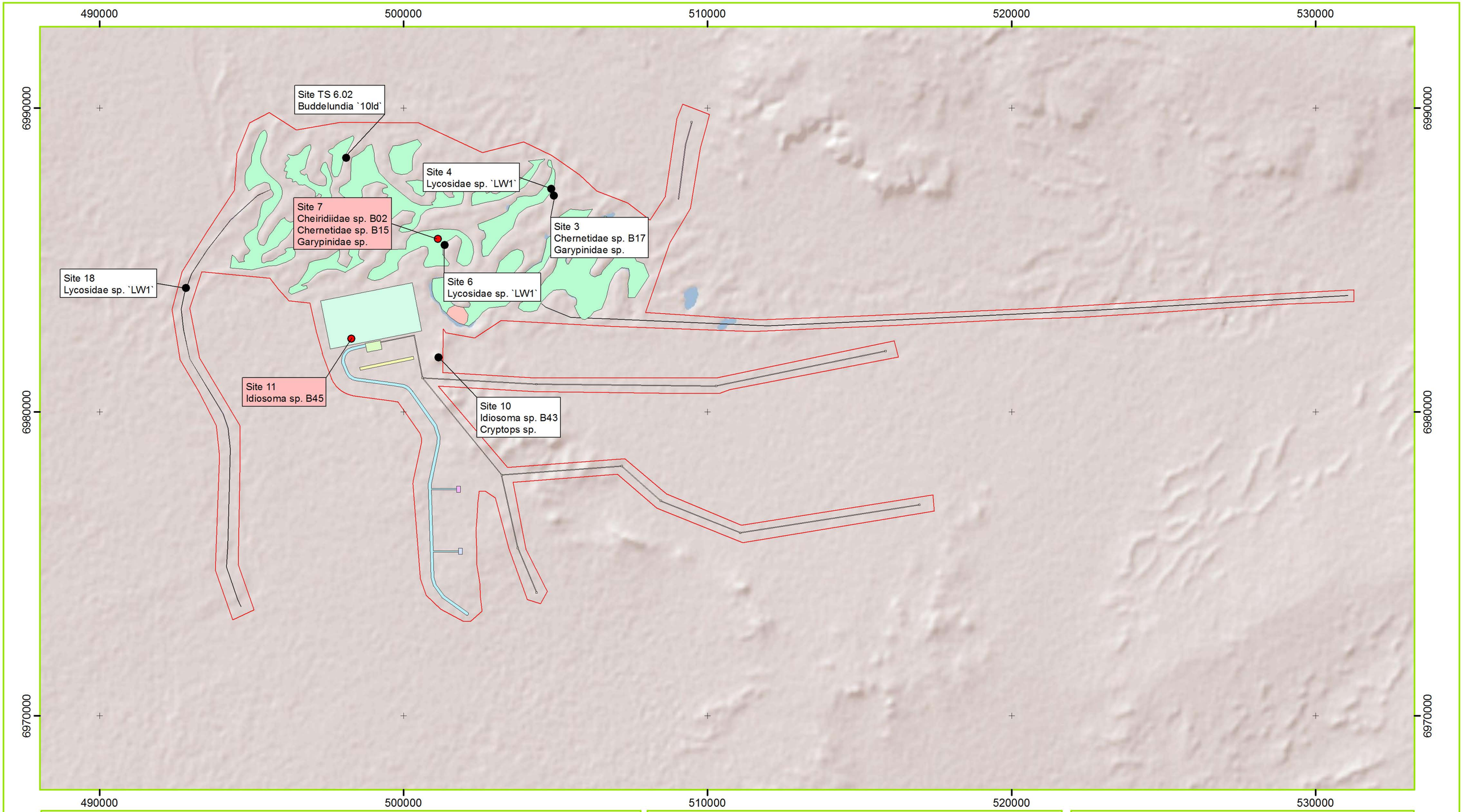
Salt lake lycosids burrow (Mendoza Belmontes *et al.* 2018) and forage on playa and fringing chenopod shrubland and appear not to utilise surrounding, more upland habitats. Given their habitat preference and possible reliance on the high water table for moisture (Framenau and Hudson 2017), there may be some degree of threat to local populations in the Project area following the construction of evaporation ponds and dewatering drawdown following brine extraction. However, given the extent of suitable habitat (particularly in the northern arm of the Lake Wells playa system), it is likely that the species' overall range extends beyond the Project area and the threat to persistence of the species is low.

5.3.3. Mygalomorphs

Two potential SRE trapdoor spider species were only recorded inside the development envelope and are discussed below. It is noted that morphological identifications based on female specimens and juvenile animals are problematic and molecular work would be required to elucidate the relationship between recorded morphospecies and described species known from the region. Collections of idiopid trapdoor spiders the Eastern Murchison have been patchy and specimens from Lake Wells may represent undescribed species.

***Idiosoma* sp. B43**

This morphospecies of trapdoor spider belongs to the highly diverse family Idiopidae whose species often have narrow geographic ranges (Rix *et al.* 2018a; Rix *et al.* 2018b). A singleton adult female was collected from a burrow on a small hill under *Acacia* litter in rocky, clay-rich soil (site 10, habitat 4) within the development envelope but outside the Project footprint. Observations in the field indicate that this site, while constituting a minor elevation feature, probably contains microhabitats analogous to the surrounding mulga woodland on sand-loam plains (habitat 5) and it is considered likely that *Idiosoma* sp. 43 utilises habitat 5 (which is widespread) and the reason for its collection at only one site in habitat 4 is that it is a moderately rare species that is difficult to locate and collect.



Legend

- Development envelope
- Access Roads and Tracks
- Accommodation Village
- Airstrip
- Bitterns Pond
- Brine Borefield
- Concentrator and Crystalliser Ponds
- Fractured Borefield North
- Fractured Borefield South
- Harvest Ponds
- Landfill
- Processing Plant

0 5 10
kilometres

N

Bennelongia Environmental Consultants

GDA_1994_MGA_Zone_51
Author: A. Mittra
Date: 10-08-2018

Figure 6. Collection locations of Potential SRE species known only from within the Project development envelope (black dots, white labels) or within the Project footprint (red dots, pink labels).

Note that Idiosoma sp. B45, Cheiridiidae sp. B02 and Chernetidae sp. B15 are only known from within the Project footprint.

Burrows likely belonging to an *Idiosoma* species were also observed in habitat 4 outside the development envelope at site 9, although attempts to collect these animals were unsuccessful. Although there is insufficient taxonomic and collection data to assign 'unlikely' SRE status to *Idiosoma* sp. B43, the inferred threat to from the Project is low because the species was recorded outside the Project footprint.

***Idiosoma* sp. B45**

A singleton female of this idiopid morphospecies was collected from a burrow in sandy loam soil under eucalypt leaf litter in habitat 5 at site 11 inside the footprint of the proposed harvest ponds. While this habitat is common and also occurs outside the development envelope, there is insufficient taxonomic and collection data to label *Idiosoma* sp. B45 as an 'unlikely' SRE. However, the inferred threat to *Idiosoma* sp. B45 is low because habitat 5 extends continuously west from site 11 outside the Project footprint and development envelope.

5.3.4. Pseudoscorpions

Epigean pseudoscorpions species are generally considered to have widespread distributions and it has been suggested that few species are SREs (Harvey 2002). Notably, however, some species with narrow ranges are restricted to specialist habitats including granite outcrops (Harvey 2010, 2012). While phoresy (dispersal by means of attachment to a host organism; White *et al.* 2017) has been documented for species from all the families recorded at Lake Wells (Harvey 2010; Jhasser Martínez *et al.* 2018; Judson 2003; Lira and Tizo-Pedroso 2017; Muchmore 1972) and probably contributes to few pseudoscorpion species having restricted distributions, pseudoscorpion taxonomy is poorly resolved at the species level. Many specimens recorded at Lake Wells may belong to undescribed species making range determination difficult.

Four pseudoscorpion morphospecies – Cheiridiidae sp. B02, Chernetidae sp. B15, Chernetidae sp. B17 and Garypinidae sp. – are potential SREs that are known only from within the Project development envelope on gypsum dunes (habitat 2), either under bark or in leaf litter of *Casuarina* or eucalypt trees. Gypsum dunes occur in association with salt lakes and in the study area appear to host a significant diversity of pseudoscorpions, as well as harbouring some other species from SRE Groups (Table 4). Despite being isolated on a regional scale, gypsum dunes are common in the Lake Wells palaeochannel and occur outside the Project area. The Project footprint encompasses some gypsum dunes, which are intended to be used as barriers around crystalliser ponds, depending on seepage analysis and the effectiveness of cut-off trench design and constructability. Thus, the dunes are not proposed to be directly impacted by clearing.

Taking into account the potential for phoresy and the occurrence and extent of gypsum dunes throughout the palaeochannel, Cheiridiidae sp. B02, Chernetidae sp. B15, Chernetidae sp. B17 and Garypinidae sp. are considered to have ranges that are likely to extend outside the Project area, so that they will not be threatened by proposed developments.

5.3.5. Myriapods

***Cryptops* sp.**

Species level taxonomy is poorly resolved for cryptopid centipedes, although the group is considered likely to contain species with narrow ranges. Four specimens belonging to the genus *Cryptops* were collected in *Acacia* leaf litter on a small hill (site 10) in habitat 4 outside the Project footprint. As noted for *Idiosoma* sp. B43 above, there is probably considerable overlap between habitat 4 (particularly at site 10) and habitat 5 in terms of the microhabitats they contain, with habitat 5 being widespread outside the development envelope. Despite potentially being an SRE species, it is considered likely that the species of *Cryptops* collected at site 10 also occurs outside the development envelope and, thus, its persistence will not be threatened by proposed developments.

5.3.6. Distributions of Previously Recorded Species

Leaving aside indeterminate mygalomorph and scorpion identifications, the potential SRE species recorded in previous fauna survey (Section 3.1.1) were, with the exception of the isopod *Buddelundia* `10ld`, collected outside the Project development envelope. *Buddelundia* `10ld` was collected in the northern part of the development envelope but outside the Project footprint (Figure 6).

It should be noted that the two millipede species collected by Harewood (2017) - Paradoxosomatidae `LW` and `Megalosiphon LW` - are likely to be SRE species. They were collected in habitat 4 outside the development envelope and are the only likely SRE species to be collected from the Project area and surrounds.

6. CONSERVATION IMPLICATIONS

Threats to the conservation of SRE species in the Project area are considered to be:

- *Clearing of native vegetation and landforms*. Clearing will remove microhabitats utilised by terrestrial invertebrates and is therefore considered a primary threat to SRE species in currently uncleared areas.

- *On-playa developments and dewatering drawdown under playa habitat from brine production*. This is considered a significant impact because of the potential for habitat removal. On-playa works may remove areas of available habitat for SRE species that forage on, or nest in, playa substrates. Substrate humidity levels may also be affected by drawdown as a result of the watertable dropping to a depth from which capillary action will not take water to the surface. This may reduce the survival of local populations of burrowing salt lake specialist species, such as halotolerant wolf spiders (Lycosidae), although the severity of this effect is not well-defined.

All potential SRE species recorded within the development envelope are considered likely to have ranges extending beyond the bounds of the Project area. In particular, *Idiosoma* sp. B45, Cheiridiidae sp. B02 and Chernetidae sp. B15, which are treated here as known only from the Project footprint, are likely to be occur beyond the development envelope as well as the Project footprint because of the continuity of the habitats in which they occur. In the case of pseudoscorpions, biological attributes also indicate wider distributions that collections confirm.

Based on available information, the species considered most likely to be impacted locally by proposed developments is the wolf spider Lycosidae sp. `LW1`. Much of the playa habitat within the development envelope will be lost through the construction of brine crystalliser ponds and the local population of the species may be impacted. However, the range of the species probably extends throughout the playas of the northern arm of Lake Wells (to the north-east of the Project), meaning that a large area of potential habitat for Lycosidae sp. `LW1` will remain unaffected.

One general point can also be made about the habitats at Lake Wells in relation to SRE Groups. Gypsum dunes appear to be important for many of these species, as demonstrated by the considerable diversity of pseudoscorpions recorded, as well as the presence of some other SRE Group species on the weathered, pale soils of gypsum landforms.

7. CONCLUSION

This assessment employed desktop and field survey to determine the conservation values of short-range endemic invertebrates, as well as other conservation-listed terrestrial invertebrates, in the vicinity of the Project.

Dry season survey revealed a moderate diversity of species from SRE Groups in the Project area, although no confirmed SRE species or conservation-listed species were recorded. All recorded species from SRE Groups are considered likely to have ranges extending beyond the Project footprint and surrounding development envelope. Overall, the Project is not considered to pose a significant threat to the persistence of any SRE species.

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9. APPENDICES

Appendix 1. Classification scheme of the Western Australian Museum for SRE invertebrates.

The scheme was modified for use in the current assessment as discussed in Section 2.

Categories:

- **Confirmed SRE:** species with a well surveyed range of less than 10,000 km^2.
- **Potential SRE:** species with imperfectly understood ranges because sampling has been patchy. In some cases, the uncertainty about range is compounded by an incomplete taxonomic framework.
- **Unlikely SRE:** includes potentially new species that do not possess the traits of a SRE species (i.e. biological or habitat factors). For example, this subcategory may include species recorded during a survey from one or more habitat types that have low prospectivity for SREs or species possessing very few morphological features typical of SREs.
- **Widespread:** known range of more than 10,000 km^2 or good evidence (multiple collections from different habitats) pointing towards a similarly-large range.
- **Unknown:** usually higher level identifications (possibly due to immature specimens) or identifications of species complexes where there have been recent revisions that make it unclear which species were originally collected.

The museum divides Potential SREs into five subcategories that provide some information about why the species is treated as a Potential SRE (definitions are paraphrased here). The subcategories are:

- Data deficient: There are insufficient data available to determine SRE status, because of few collecting records (and a belief sampling for the species has been geographically restricted) or uncertain identification;
- Habitat Indicators: The status of a species may be inferred using its association with a particular habitat;
- Morphological Indicators: The status of a species may be inferred using its morphological characteristics;
- Molecular Evidence: DNA sequence data may reveal patterns congruent or incongruent with SRE status for a species; and
- Research & Expertise: Available research data and/or WAM expertise may suggest the species is likely (or not) to be an SRE.

Appendix 2. Vegetation types in the Project area (Botanica Consulting 2017).

Landform	NVIS Vegetation Group	Vegetation Code	Vegetation Type	Area (ha)	Area (%)
Closed Depression	Chenopod Shrublands, Samphire Shrublands and Forblands (MVG 22)	CD-CSSSF1	Low samphire shrubland of *Tecticornia indica* subsp. *bidens*/ *Tecticornia* sp. Dennys Crossing (K.A. Shepherd & J. English KS522) in playa	6215	8.3
		CD-CSSSF2	Mid heathland of *Cratystylis subspinescens* over low open chenopod shrubland of *Atriplex vesicaria* and open forbland of *Frankenia* spp. on playa edge	4066	5.4
		CD-CSSSF3	Mid open shrubland of *Eremophila paisleyi*/ *Lawrencia squamata*/ *Lycium australis* over low open chenopod shrubland of *Atriplex* spp. and open forbland of *Frankenia* spp. on playa edge	4132	5.5
Clay-Loam Plain	Acacia Forests and Woodlands (MVG 6)	CLP-AFW1	Low open forest of *Acacia incurvaneura* over mid shrubland of *Eremophila margarethae* and low open tussock grassland of *Eriachne mucronata*/ *Eragrostis eriopoda* on clay loam plain	11350	15.2
	Acacia Forests and Woodlands (MVG 6)	CLP-AFW2	Low woodland of *Acacia caesaneura* over mid open shrubland of *A. burkittii* and mid chenopod shrubland of *Maireana pyramidata*/ low open hummock grassland of *Triodia desertorum* on clay loam plain	2017	2.7
Drainage Depression	Acacia Forests and Woodlands (MVG 6)	DD-AFW1	Low open forest of *Acacia caesaneura* over mid open shrubland of *Senna artemisioides* subsp. *filifolia* and low open tussock grassland of *Eragrostis eriopoda* in drainage depression	2023	2.7
Gypsum Dunefield	Casuarina Forests and Woodlands (MVG 8)	D-CFW1	Low open forest of *Casuarina pauper* over tall open shrubland of *Acacia burkittii* and low sparse chenopod shrubland of *Atriplex vesicaria* on gypsum dune	3510	4.7
	Mallee Woodlands and Shrublands MVG 14)	D-MWS1	Mid open mallee forest of *Eucalyptus gypsophila* over mid open shrubland of *Senna artemisioides*/ *Eremophila* spp. and low open chenopod shrubland of *Atriplex vesicaria* on gypsum dune	1440	1.9
Quartz/ Rocky Plain	Acacia Forests and Woodlands (MVG 6)	QRP-AFW1	Low open woodland of *Acacia caesaneura*/ *A. incurvaneura* over mid open shrubland of *A. burkittii*/ *Eremophila fraseri* and low open shrubland of *Ptilotus obovatus*/ sparse tussock grassland of *Eragrostis eriopoda* on quartz/rocky plain	2891	3.9
	Casuarina Forests and Woodlands (MVG 8)	QRP-CFW1	Low woodland of *Casuarina pauper* over mid shrubland of *Eremophila paisleyi* subsp. *paisleyi*/ *Senna artemisioides* subsp. *filifolia* and low open shrubland of *Ptilotus obovatus* on quartz/rocky plain	1328	1.8
Rocky Hillslope	Acacia Forests and Woodlands (MVG 6)	RH-AFW1	Low open forest of *Acacia quadrimarginea* over mid open shrubland of *Senna artemisioides* subsp. *filifolia*/ *Senna* sp. Meekatharra (E. Bailey 1-26) and low open shrubland of *Ptilotus obovatus* on rocky hillslope	829	1.1

Landform	NVIS Vegetation Group	Vegetation Code	Vegetation Type	Area (ha)	Area (%)
		RH-AFW2	Low woodland of *Acacia incurvaneura* over mid open shrubland of *Eremophila jucunda* and tussock grassland of *Eragrostis eriopoda/ Eriachne mucronata* on rocky hillslope	2468	3.3
Sand Dunefield	Acacia Forests and Woodlands (MVG 6)	SD-AFW1	Low woodland of *Acacia caesaneura/ A. incurvaneura* over tall open shrubland of *Eremophila* spp./ *Senna* spp./ *Melaleuca interioris* and low open hummock grassland of *Triodia basedowii/* low open tussock grassland of *Eragrostis eriopoda* in dunefield	3850	5.1
	Mallee Woodlands and Shrublands (MVG 14)	SD-MWS1	Mid mallee woodland of *Eucalyptus concinna* over low open shrubland of *Aluta maisonneuvei* subsp. *auriculata/ Dodonaea viscosa* and low closed hummock grassland of *Triodia desertorum* in dunefield	1790	2.4
Sand-Loam Plain	Acacia Forests and Woodlands/ Mallee Woodlands and Shrublands (MVG 6/ 14)	SLP-AFW/MWS1	Low open forest of *Acacia caesaneura/* mid mallee woodland of *Eucalyptus lucasii* over mid open shrubland of *Eremophila latrobei* subsp. *glabra* and low hummock grassland of *Triodia desertorum* on sand-loam plain	7630	10.2
Sandplain	Eucalypt Woodlands (MVG 5)	SP-EW1	Low woodland of *Eucalyptus gongylocarpa* over mid open shrubland of *Eremophila platythamnos* subsp. *exotrachys* and low hummock grassland of *Triodia desertorum* on sandplain	5971	8.0
	Mallee Woodlands and Shrublands (MVG 14)	SP-MWS1	Mid mallee shrubland of *Eucalyptus* spp. over mid open shrubland of *Acacia* spp. and low closed hummock grassland of *Triodia basedowii* on sandplain	13250	17.7
Total				74760	100

Appendix 3. Survey site characteristics and methods.

Characteristics

Site Code	Landform	Description	Slope angle	Aspect	Soil	Shade cover (%)	Leaf Litter Cover (%)			Habitat	
							<1 cm	1-5 cm	>5 cm	Logs	Rocks
Site 01	Tributary	Mulga tributary flanked by grassland and open plain	W & E	Gentle	Coarse+fine	40	89	7.5	3.5	Many	Many
Site 02	Sand dunes and steppe	Open Mulga woodland and samphire steppe	S	Gentle	Coarse	37.5	77.5	20	2.5	Many	Few
Site 03	Gypsum dunes	Scattered sheoak and *Acacia* shrubs over samphire and grass	-	Gentle	Fine	40	63.5	32.5	4	Many	Few
Site 04	Playa	Riparian samphire	SE	Gentle	Fine	27.5	24.5	75	0.5	None	None
Site 05	Sand dunes	Mulga woodland adjacent playa	SW	Gentle	Coarse	15	74	25	1	Many	Many
Site 06	Playa	Riparian samphire	S	Moderate	Fine	30	36	60	4	None	None
Site 07	Gypsum dunes	Scattered sheoak and *Acacia* shrubs over samphire and grass	ESE	Moderate	Fine	45	59.5	37.5	3	Many	Many
Site 08	Sand dunes	Open *Eucalyptus* woodland over spinifex and shrubs	-	Flat	Coarse	22.5	82	15	3	Many	Many
Site 09	Rocky outcrop	Mulga woodland over rocky outcrop	S	Gentle	Coarse	20	74	25	1	Many	Few
Site 10	Gentle hill	Exposed hill with open *Acacia* shrubland over herbs and grass	-	Flat	Coarse	25	63.5	35	1.5	Few	None
Site 11	Sand dunes and steppe	Open Mulga woodland adjacent to samphire steppe	-	Flat	Coarse	4	95.5	3.5	1	Few	Few
Site 12	Gypsum dunes	Scattered sheoak and *Acacia* shrubs over samphire and grass. Targeted site for pseudoscorpions.	S	Gentle	Fine	NA	NA	NA	NA	NA	NA
Site 13	Plains	Mulga woodland over mixed shrubs surrounded by hummock grassland on red soil	-	Flat	Coarse	15	95	5	0	Few	None
Site 14	Gypsum dunes, plains	Eucalyptus woodland over scattered *Senna* on gypsum sand and red sand-loam	-	Flat	Fine	10	91	7.5	1.5	Few	None
Site 15	Sand dunes	Scattered sheoak shrubs over spinifex and grass. Targeted site for pseudoscorpions.	-	Gentle	Coarse	NA	NA	NA	NA	NA	NA
Site 16	Open plain	Open herb plain	-	Flat	Fine	0	100	0	0	None	Few
Site 17	Gypsum dunes	Scattered sheoak shrubs over spinifex and grass. Targeted site for pseudoscorpions.	-	Flat	Fine	NA	NA	NA	NA	NA	NA
Site 18	Playa	Riparian samphire	-	Flat	Fine	27.5	24.5	75	0.5	None	None

Sampling methods

Effort Type	Field Code	Latitude	Longitude	Site Type	Visit Date	Cup Traps	Forage	Log Turn	Rock Turn	Litter Sieve	Leaf Blow	Spotlight	Soil & Litter Bags	UV (times)
Forage and litter	Site 01	-27.17009590	123.0270936	Reference	27/01/2018	-	✓	✓	✓	✓	✓		2	
Forage and litter	Site 02	-27.21854060	123.0524874	Reference	27/01/2018	-	✓	✓	✓	✓	✓		2	18:20–18:40
Forage and litter	Site 03	-27.23874630	123.0498519	Impact	27/01/2018	-	✓	✓	✓	✓	✓		2	18:45–19:05
Forage and litter	Site 04	-27.23675487	123.0489731	Impact	27/01/2018	2	✓	-	-			✓	0	19:05–19:15
Forage and litter	Site 05	-27.26372600	123.0088354	Impact	28/01/2018	4	✓	✓	✓		✓		2	
Forage and litter	Site 06	-27.25345710	123.0135537	Impact	28/01/2018	-	✓	-	-			✓	0	
Forage and litter	Site 07	-27.25158710	123.0113350	Impact	28/01/2018	-	✓	✓	✓	✓	✓		2	
Forage and litter	Site 08	-27.42836211	123.3652874	Reference	28/01/2018	-	✓	✓	✓	✓	✓		2	
Forage and litter	Site 09	-27.23615670	123.3130112	Reference	28/01/2018	-	✓	✓	✓	✓	✓		1	18:15–19:00
Forage and litter	Site 10	-27.28683800	123.0115592	Impact	29/01/2018	-	✓	✓	-	✓	✓		2	
Forage and litter	Site 11	-27.28121400	122.9825490	Impact	29/01/2018	-	✓	✓	✓	✓	✓		2	17:30–18:00

Effort Type	Field Code	Latitude	Longitude	Site Type	Visit Date	Cup Traps	Forage	Log Turn	Rock Turn	Litter Sieve	Leaf Blow	Spotlight	Soil & Litter Bags	UV (times)
Forage and litter	Site 12	-27.32846320	122.9452217	Impact	29/01/2018	-	✓	-	✓	✓			0	
Forage and litter	Site 13	-27.34042740	122.9602375	Reference	29/01/2018	-	✓	✓	-	✓	✓		1	
Forage and litter	Site 14	-27.32948970	122.9344320	Reference	29/01/2018	-	✓	✓	-	✓	✓		2	multiple events
Forage and litter	Site 15	-27.24530490	123.2361595	Reference	30/01/2018	-	✓	✓	✓	✓			0	
Forage and litter	Site 16	-27.41514000	122.6998900	Reference	30/01/2018	-	✓	-	✓				0	
Forage and litter	Site 17	-27.26548000	122.9264100	Reference	30/01/2018	-	✓	-	-	✓			0	
Forage and litter	Site 18	-27.26621000	122.9276400	Impact	30/01/2018	-	✓	-	-			✓	0	

Appendix 4. Photographs of SRE collection sites at Lake Wells in May 2018.

Site 1

Site 1

Site 2

Site 2

Site 3

Site 3

Site 4

Site 4

Site 5

Site 5

Site 6

Site 6

Site 7

Site 7

Site 8

Site 8

Site 9

Site 9

Site 10

Site 10

Site 11

Site 11

Site 12

Site 12

Site 13

Site 13

Site 14

Site 14

Site 15

Site 15

Foraged under single *Casuarina* (left)

Site 16

Site 17

No photos taken

Site 18

No photos taken