

# NORTON GOLD FIELDS

*Binduli Operations*

## Supporting Document Native Vegetation Clearing Permit

**Apache Project**

**December 22**

Prepared by  
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## Document Control

Version No.	Date Prepared	Description	Prepared By	Approved By
1	21/09/2022	Document prepared	C Woods	-
1.1	22/12/2022	Updates made	B Ovens	A Lally



22 December 2022  
Department of Mines, Industry Regulation and Safety  
Mineral House  
100 Plain Street  
East Perth WA 6004

To Whom It May Concern,

**Native Vegetation Clearing Permit Application for the Apache Project - Various Tenements**

Norton Gold Fields Pty Ltd (Norton) has developed this submission regarding the proposal to clear native vegetation to enable development of the Apache Project (Project). This Project will be subject to a forthcoming Mining Proposal (MP), involving the extraction of ore from a new pit to support Norton's Binduli Operations. The Native Vegetation Clearing Permit Application therefore seeks approval to clear up to 310ha within the 378.28ha footprint for open pit mining, waste rock landform construction, the run-of-mine pad and other supporting infrastructure.

The area covered by this application lies within the following leases all of which are held by Bellamel Mining Pty Ltd, a subsidiary of Norton:

- M 26/115
- M 26/243
- M 26/430
- M 26/474

This document has been prepared to support the application for a Native Vegetation Clearing Permit (NVCP) pursuant to Section 51E of the *Environmental Protection Act 1986* (EP Act) required to undertake the proposed clearing activities. Norton are seeking to secure a Purpose Permit for this work. The clearing permit application area ('the Project Area') subject to this NVCP is an area sufficient to accommodate the current mine design and a range of minor changes that may be made to the mine design and footprint as the MP is developed and submitted.

Sincerely,



Brandon Ovens  
Senior Environmental Advisor

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## 1. Introduction

### 1.1 Proposed Works

The Apache Project is located approximately 10km west of the centre of the City of Kalgoorlie-Boulder to the south of Great Eastern Highway, in the Binduli South mining area (Figure 1.1). To carry out the proposed works, clearing of native vegetation is required. This clearing will facilitate the construction of the following features:

- Transportation and service infrastructure corridors;
- Open pit;
- Waste Rock Landform;
- Run-of-mine pad;
- Monitoring bores (possible); and
- Topsoil stockpile areas.

The proposed clearing will include up to 310ha of native vegetation within the clearing permit application area as shown in Figure 1.2.



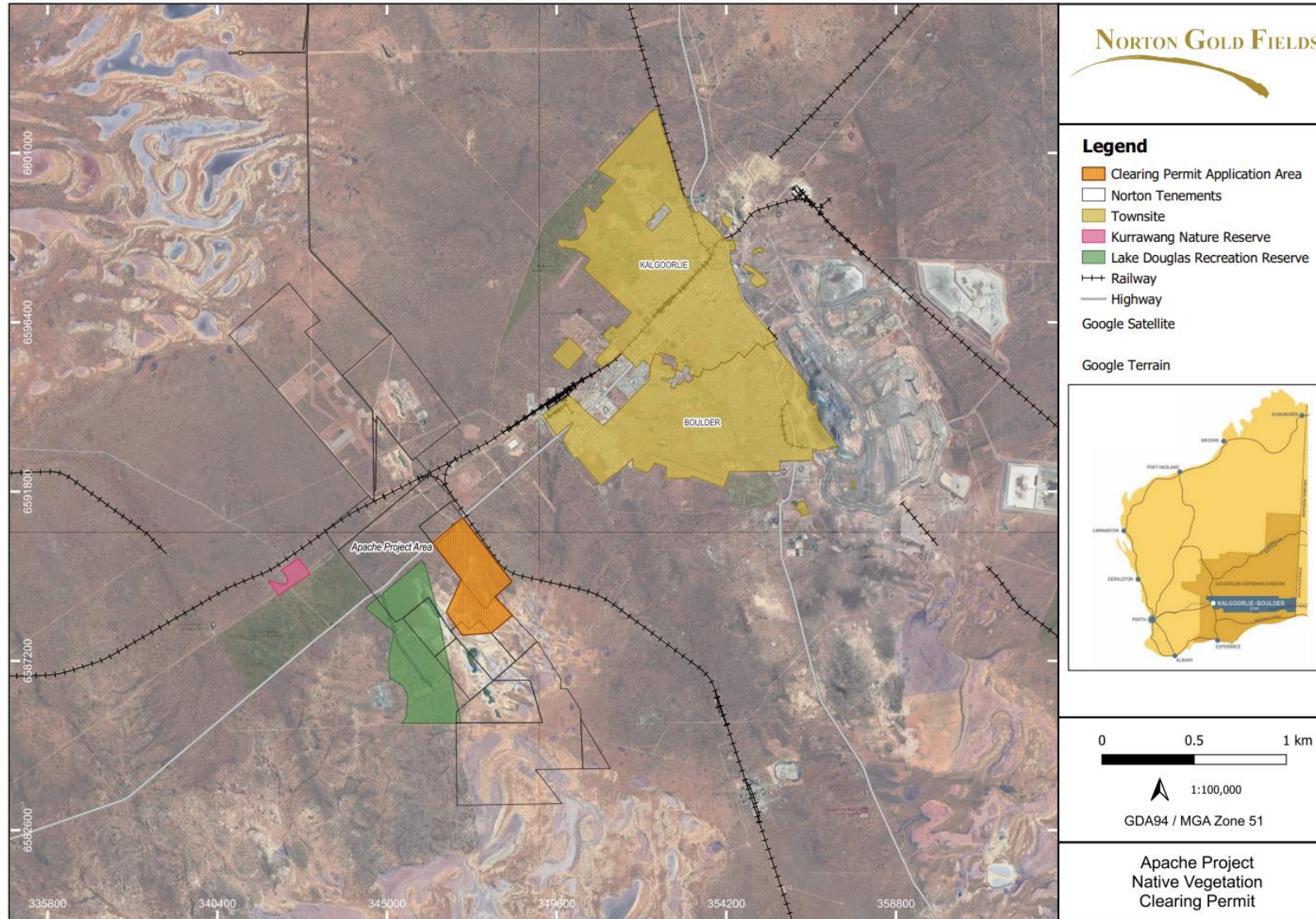


Figure 1.1 Locality context of Apache Project area



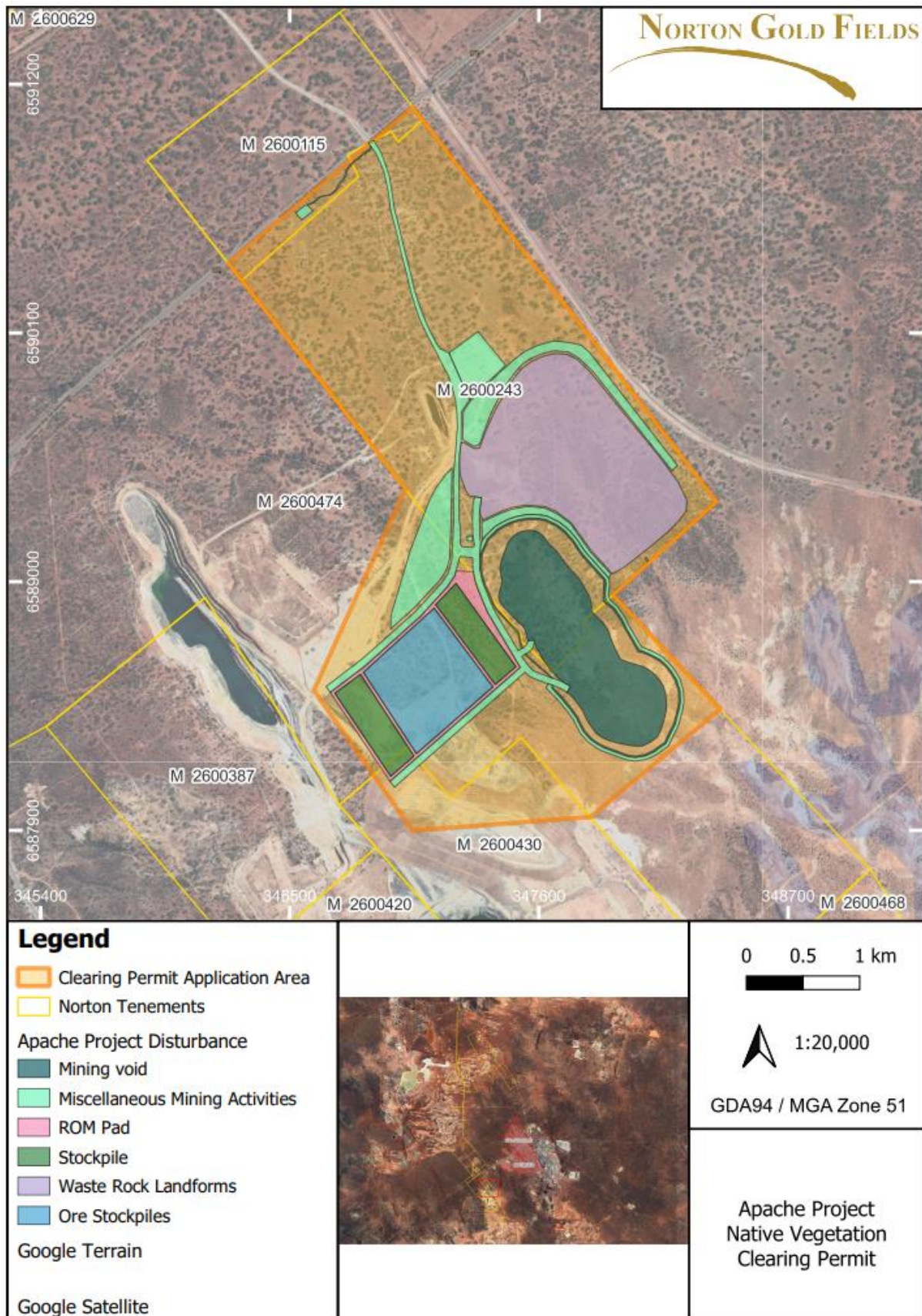


Figure 1.2 Apache Project disturbance footprint

## 2. Existing Environment

### 2.1 Biogeography

The Project area lies within the Eastern Goldfields subregion (COO3) of the Eremaean Province of Western Australia, as defined by the Interim Biogeographical Regionalisation of Australia (IBRA) classification system (Thackway and Cresswell, 1995). The subregion is characterised by ridges of Archaean greenstone belts and Proterozoic granulate, containing rich mineralised deposits. The underlying geology consists of highly weathered gneisses and granites, covered with calcareous loamy soils and scattered bedrock. Remnants of an ancient major drainage line exist throughout the region, evident through the presence of large playa lake systems (Cowan, 2001).

The region exhibits vast sandplains rich with endemic Proteaceae, Acacia, Mallee and shrub heath. Eucalypt woodlands dominate areas such as salt lakes, ranges and in valleys. Salk lake systems also support dwarf samphire shrubland communities (Cowan, 2001). The Project area is not located within the vicinity of any conservation parks, forestry reserves, or Environmentally Sensitive Areas (ESAs). The closest reserve to the Project is the Kurrawang Nature Reserve, located approximately 5km west of the Project area.

### 2.2 Climate

The Project area is in the Goldfields region which experiences arid to semi-arid climate, usually hot, dry summers, and cool, wet winters (Cowan, 2001). The area experiences average maximum temperatures between 33.6°C and 18.3°C in January, and average minimum temperatures between 16.8°C and 5.1°C in July. The area experiences approximately 264.9mm of rainfall per year, and an average of 39.4 days of rain per year. Rainfall is highest in February at 32.4mm and lowest in September at 13.4mm (BoM, 2022). Mean rainfall and temperature are shown in Figure 2.1.

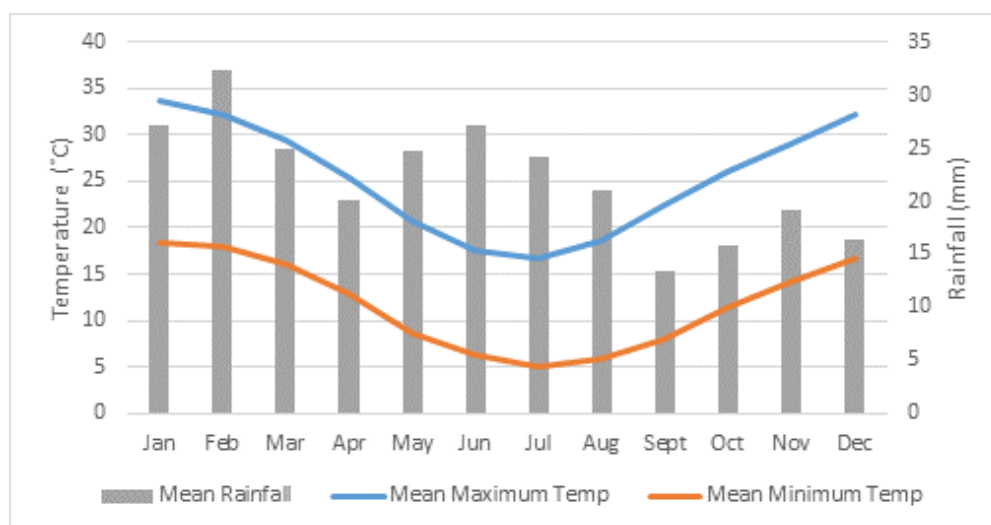


Figure 2.1 Mean Monthly Maximum and Minimum Temperatures, and Rainfall 1939-2021 – Kalgoorlie Boulder Airport (BoM, 2022)

Across the year, on average, morning (9:00) humidity levels are highest in June with an average of 74%, dropping to an average of 43% in December. Afternoon humidity levels (15:00) are highest in June at an average of 48%, with the months of December and January experiencing the lowest afternoon humidity levels at 24% (BOM, 2022). Average daily evaporation rates in the region range from 12.5mm in January and 2.6mm in June (BoM, 2022).

Morning (9:00am) wind conditions are predominantly between 12km/hr in June and 17.5km/hr in February. Afternoon (3:00pm) wind conditions are typically between 18.1km/hr in September and 13.5km/hr in March (BoM, 2022).

## 2.3 Geology

The Apache Project area lies within the Kalgoorlie Terrane of the Norseman-Wiluna greenstone belt. This belt trends north south and comprises of Archaean rocks within the Eastern Goldfields Province. Bedrock within the Project area consists of volcanoclastic and sedimentary rocks, and felsic porphyry intrusive.

Within the Binduli Domain, one of the four major domains that form part of the Kalgoorlie Terrain, Black Flag beds are dominated by steep, intermediate to felsic volcanoclastics with numerous porphyry intrusions. In the Kurrawang Syncline lie epiclastic sediments, conformable with the overlying conglomerates within the area. Regolith within the Project area is expected to consist of exposed rock, saprolite and saprock (Landloch, 2021).

## 2.4 Soils

The Atlas of Australian Soils provides a broad description of soil and land systems across Australia. The Project area overlies the MX43 land systems and the SV15 land systems which are characterised by gently undulating valley plains and pediments and some outcrop of rock. The soils of the MX43 land system consist predominately of alkaline red earth with limestone and limestone nodules at shallow depth on gently sloping slightly concave plains with low gentle rises. The soils in the SV15 land systems consist of gypseous and saline loams, with gypseous and saline soil on the lake beds. Associated soil types include sandy red earths on lunettes, soils on plains, soil on eroded plains and small areas of soil on clay pans (Mine Earth, 2016).

Mine Earth (2016) identified four (4) soil units within the Project area. These include undulating upper plains, undulating plains, alluvial plains, with drainage channels, surrounding salt flats, and gentle slopes. The soil units found within the Project area and their descriptions are provided in Table 2.1 and Figure 2.2. The full report is provided in Appendix A.



*Table 2.1 Description of soil units within the Project area*

Soil Unit	Horizon	Key Soil Characteristics	Dispersion	Chemistry
<b>C. Undulating upper plain</b> Moderately deep, brown, sandy clay loam with many gravels and cobbles in the subsoil.	Topsoil	0-10/15 cm reddish brown, sandy loam, weak subangular block or single grain, 5-30% gravels.	Non-dispersive	Mild to moderately alkaline, non to slightly saline, non-sodic, low nutrient and metal concentrations.
	Subsoil	10-50 cm brown, sandy clay loam, 50-80% gravels and cobbles (sometimes this horizon does not exist, and soil directly overlies substrate).	Non-dispersive	Strongly alkaline, non to extremely saline, non to strongly sodic, low nutrient and metal concentrations.
<b>D. Undulating plain</b> Shallow, brown, sandy loam/sandy clay loam with many gravels and cobbles throughout.	Topsoil	0-15/20 cm brown, sandy loam, weak subangular blocky, 5-30% gravels and cobbles.	Partially dispersive	Very strongly acidic, non-saline, strongly sodic, low nutrient and metal concentrations.
	Subsoil	15-25 cm brown, sandy loam/sandy clay loam, massive 50-70% gravels and cobbles.	Non-dispersive	Very strongly acidic, non-saline, marginally sodic, low nutrient and metal concentrations.
<b>F. Alluvial plain</b> Shallow, salty, reddish brown sandy soil over blueish grey clay.	Topsoil	0-15/20 cm brownish red, sand/sandy loam, single grain, weak, 0% gravels. 15-35/40 cm dark reddish brown, sandy loam, massive, weak, 0% gravels.	Partially dispersive	Neutral, extremely saline, strongly sodic, low nutrient and metal concentrations.
	Subsoil	35-85+ cm blueish grey, clay, massive, sticky, 0% gravels.	Highly dispersive	Mildly alkaline, extremely saline, strongly sodic, low nutrient concentrations and slightly elevated metal concentrations.
<b>G. Gentle slope</b> Shallow yellowish red fine sandy loam over dark reddish-brown clay.	Topsoil	0-10 cm yellowish red fine sandy loam weak, single grained, 0% gravels.	Highly dispersive	Neutral, non-saline, marginally sodic, low nutrient and metal concentrations.
	Subsoil	10-55 cm dark reddish-brown clay, strong angular and blocky, 0% gravels.	Non-dispersive	Strongly alkaline, highly saline, strongly sodic, low to moderate nutrient concentrations and low metal concentrations.

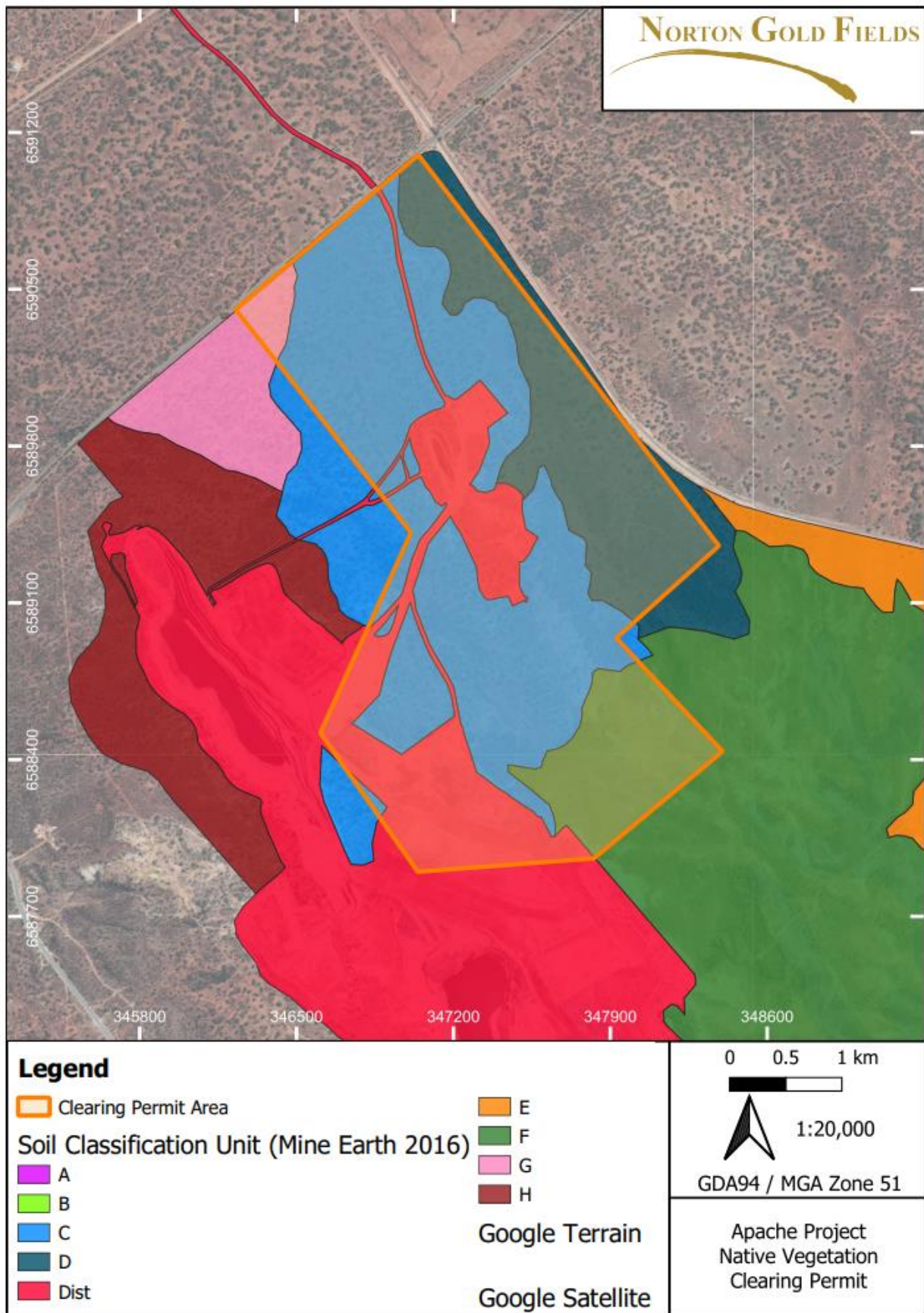


Figure 2.2 Apache Project area soil characterisation units

## 2.5 Hydrogeology

The occurrence of groundwater in the Project area is likely to be controlled by faulting, fracturing, and weathering. The weathered zone generally has low to moderate permeability in the clay-saprolite zone and can sometimes act as a confining layer locally. Permeability is likely to increase along the transitional zone to the fresh rock layer (Groundwater Resource Management, 2017).

Groundwater in the region tends to flow predominantly south-southeast and is generally hypersaline in nature. Water salinities typically exceed 100,000 mg/L Total Dissolved Solids (TDS) and have neutral to slightly alkaline pH levels. Dissolved metal concentrations are usually low, with some increase in sulphate concentrations, simultaneous with increasing TDS (Groundwater Resource Management, 2017).

Fractured bedrock aquifers comprise the main aquifer units of interest in the Project area, and possibly strike north-northwest (simultaneous with the Apache ore deposit trend) and extend south-southeast. These aquifers exhibit moderate to high hydraulic conductivity and moderate storage and are thought to be semi-confined to confined locally in the southern Binduli and Apache areas (Groundwater Resource Management, 2017).

GRM conducted investigation drilling which suggested that the fractured rock aquifers extend sub-vertically from around the base of weathered bedrock (clay saprolite). This saprolite layer exhibits low to moderate hydraulic conductivity and modest storage. The fractured rock aquifers are flanked by fresh crystalline basement rock which exhibit low to very low hydraulic conductivity and storage (Groundwater Resource Management, 2017).

## 2.6 Hydrology

AQ2 (2022) was commissioned to undertake a surface water assessment for the Binduli South Project. This report has been included in *Appendix B*. The Apache Project area is located within the DWER regional Salt Lake Basin, where streams and drainage lines drain to inland lakes. It sits just south of the regional catchment divide between the Raeside-Ponton catchment (draining to the north) and the Lake Lefroy catchment (draining to the south). These catchments contain a chain of salt lake basins which typically act as local terminal points for drainage but have the potential to overtop and become interconnected with each other. There are no significant streams or available streamflow monitoring data in the region around the Project (AQ2, 2022).

The project area lies within two local catchments already impacted by historic infrastructures and features. Surface water generally drains from north to south of the Project area predominantly as sheet flow or utilising the two minor non-perennial drainage lines (Figure 2.3). Drainage is directed south towards a series of small, interconnected salt basins which are connected to White/Douglas Lake at the (AQ2, 2022). Drainage within the Project area has been historically impacted by the rail (to the east), highway (to the north) and waste rock landforms and open pits (to the west).



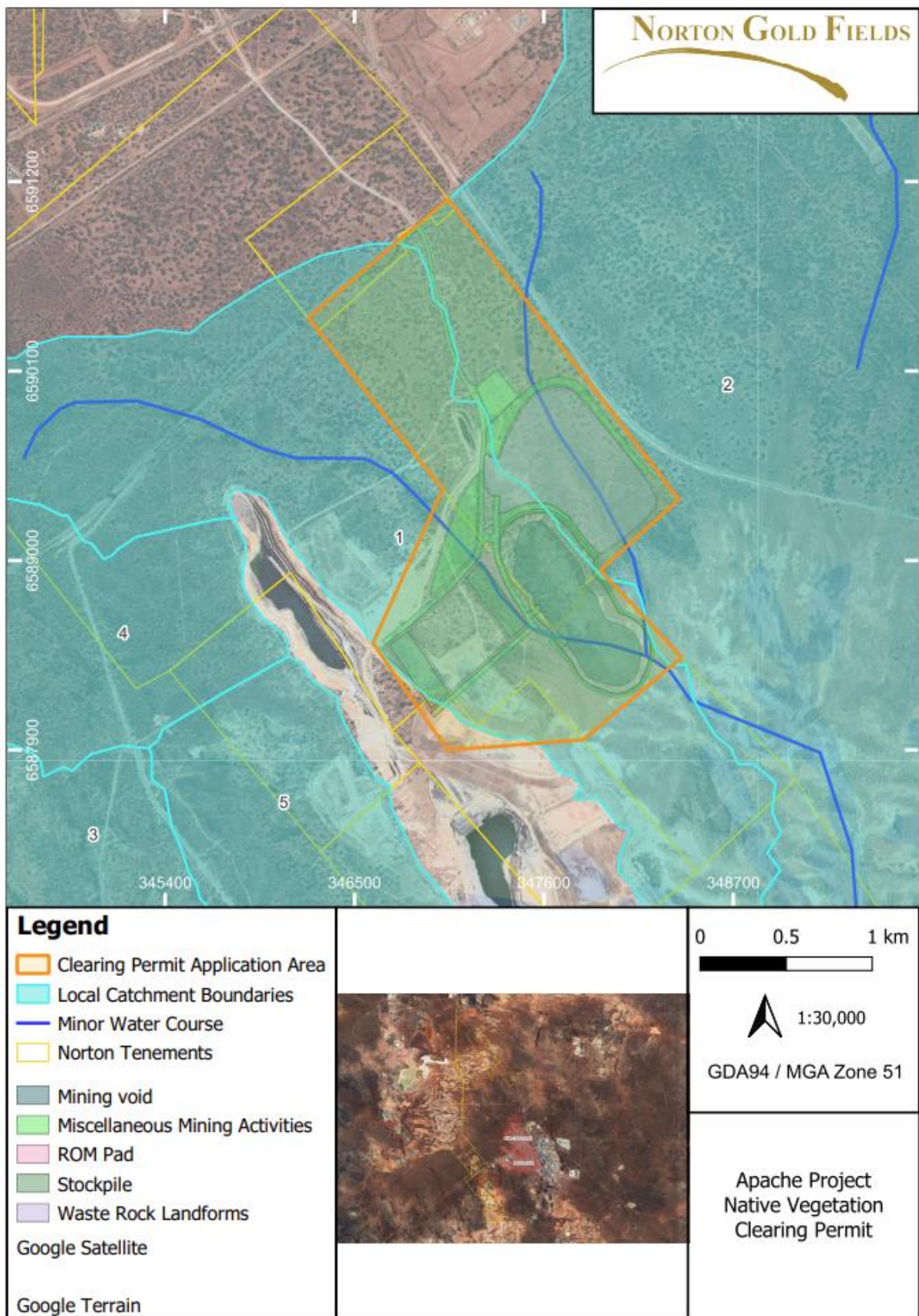


Figure 2.3 Apache Project hydrological features and surface water courses



## 2.7 Flora and Vegetation

The Project area has been well-surveyed historically, with a more recent survey of the broader Binduli South area undertaken by Spectrum Ecology in 2021. The findings from this assessment are summarised below and the report included in Appendix C.

### 2.7.1 Vegetation associations

The pre-European vegetation communities (Beard, Beeston, Harvey, Hopkins, & Shepherd, 2013) found within the Project area are sub-associations (SA) 9, 123.1, and 1294. SA123.1 is restricted to the Coolgardie IBRA region while SA9, is found within two IBRA regions: Coolgardie and Mallee. The remaining vegetation association is widespread across WA. Each sub-association has greater than 96% of its pre-European extent in WA remaining (Spectrum Ecology, 2022a). Table 2.2 describes the three Beard vegetation associations present within the Apache Project area.

Table 2.2 Description of vegetation associations within Apache Project area and their remaining extent

Vegetation association	Description	Remaining extent	Remaining extent within NVCP Area
SA 9	Eucalyptus woodland consisting of Upper layer: <i>Eucalyptus torquata</i> , <i>Eucalyptus lesouefii</i> and <i>Eucalyptus clelandii</i> Middle layer: <i>Eremophila scoparia</i> , <i>Eremophila glabra</i> and <i>Eremophila oldfieldii</i> .	235,162ha 98%	264.52ha 0.11%
SA 123.1	Atriplex mixed open chenopod shrubland consisting of: Upper layer: <i>Casuarina cristata</i> , <i>Myoporum platycarpum</i> , and <i>Callitris columellaris</i> Middle layer: <i>Eremophila miniata</i> and <i>Grevillea sarissa</i> . Ground Layer: <i>Atriplex hymenotheca</i> and <i>Maireana</i> sp.	8,902ha 98%	85.12ha 0.96%
SA 1294	Eucalyptus woodland consisting of <i>Eucalyptus torquata</i>	6,047ha 96%	28.64ha 0.47%

### 2.7.2 Vegetation communities

Spectrum Ecology (2022a) mapped six vegetation types within the Project area, which were recorded on undulating sandy-clay plains, sandy-clay floodplains, sandy plains, granitic hill slopes, drainage lines, and salt lakes and pans. Most of the Project area is characterised as mixed Eucalyptus woodlands which is dominated by *E. griffithsii*, *E. lesouefii* and *E. oleosa* subsp. *oleosa* species (P1). Descriptions of the vegetation communities present are shown in Table 2.3. None of the vegetation communities identified within the Project area are considered to be regionally or locally significant (Spectrum Ecology, 2022a).

Table 2.3 Vegetation Communities within Apache Project Area

Code	Vegetation Description	Landform
Plains		
P1	<i>Eucalyptus griffithsii</i> , <i>Eucalyptus lesouefii</i> , and <i>Eucalyptus oleosa</i> subsp. <i>oleosa</i> mid open woodland, over <i>Eremophila scoparia</i> , <i>Senna artemisioides</i> subsp. <i>filifolia</i> , and <i>Scaevola spinescens</i> mid to tall sparse shrubland, over <i>Atriplex vesicaria</i> and <i>Maireana sedifolia</i> low open shrubland.	Undulating plains. Red-orange, Sandy-clay.
P4	<i>Eremophila scoparia</i> and <i>Acacia densiflora</i> Mid to tall sparse shrubland, over <i>Cratystylis subspinescens</i> , <i>Scaevola spinescens</i> , and <i>Exocarpos aphyllus</i> low open shrubland.	Sandy-clay floodplains surrounding lake bed. Orange clay-loam.
P5	<i>Acacia masliniana</i> and <i>Eremophila miniata</i> tall open shrubland, over <i>Alyxia buxifolia</i> , <i>Scaevola spinescens</i> and <i>Cratystylis subspinescens</i> mid open shrubland, over <i>Frankenia fecunda</i> and <i>Eremophila glabra</i> subsp. <i>glabra</i> low sparse shrubland.	Sand plain between salt pans. Orange sand.
Slopes		
S1	<i>Acacia acuminata</i> (+/- <i>Melaleuca hamata</i> ) tall open shrubland, over <i>Eremophila granitica</i> , <i>Exocarpos aphyllus</i> , and <i>Scaevola spinescens</i> mid sparse shrubland.	Rocky granitic hill slopes. Large common granite stones. Red-orange sandyclay.
Drainage		
D1	<i>Eucalyptus salubris</i> and/or <i>Eucalyptus longissima</i> low open woodland, over <i>Acacia acuminata</i> , <i>Acacia tetragonophylla</i> , and <i>Alyxia buxifolia</i> tall shrubland, over <i>Dodonaea lobulata</i> and <i>Scaevola subspinescens</i> mid opens shrubland.	Drainage lines. Few scattered ironstone rocks. Red-orange sandy-clay loam.
D2/3	<i>Tecticornia indica</i> subsp. <i>bidens</i> and <i>Tecticornia disarticulata</i> (+/- <i>Atriplex vesicaria</i> ) low sparse chenopod shrubland. <i>Cratystylis subspinescens</i> , <i>Frankenia interioris</i> , and <i>Surreya diandra</i> low open shrubland.	Salt lake, salt pans. Brownorange clay. Margins of salt pans. Orange-cream clay.

### 2.7.3 Vegetation condition

The condition of vegetation within the Project area ranged from Very Good to Completely Degraded. Most of the intact vegetation was mapped as Very Good, with disturbances such as tracks and weeds. Weeds were found to exist in clumps of individuals around existing disturbance. Existing disturbance area was mapped as 'Completely Degraded', which included mining pits and infrastructure (Spectrum Ecology, 2022a).

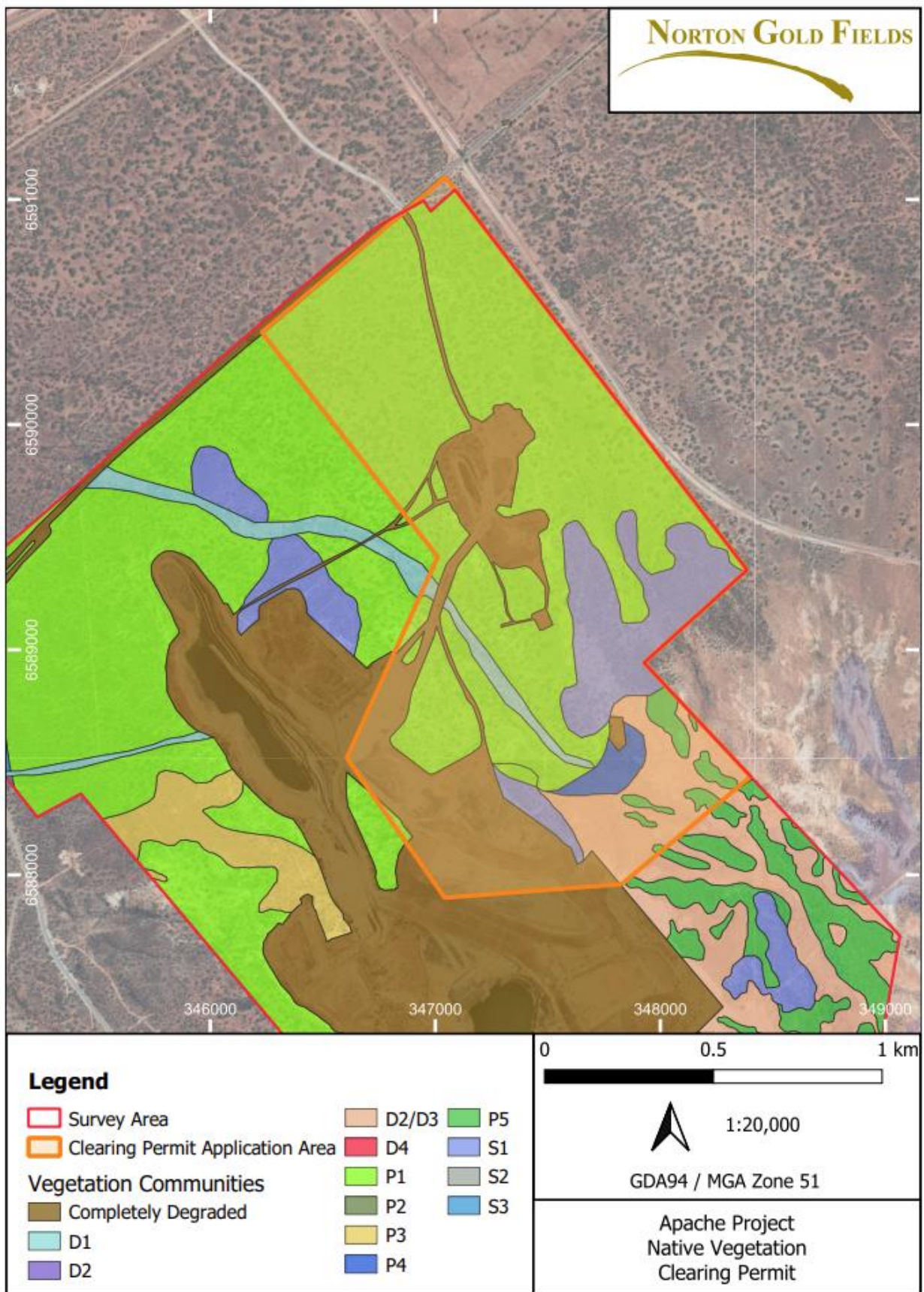


Figure 2.4 Vegetation Communities within Apache Project Area



## 2.7.4 Conservation Significant Flora and Vegetation

### TECS/PECS/ESA

The vegetation types present within the Project area do not represent Threatened Ecological Communities (TECs), Priority Ecological Communities (PECs), or Environmentally Sensitive Areas (ESAs) recognised by the Department of Biodiversity, Conservation and Attractions (DBCA). The closest listed community to the study area was the Priority 3 PEC Emu Land System, located approximately 40km to the north-east (Spectrum Ecology, 2022a).

### Threatened and Priority Flora

There were no Threatened species listed under the WA Biodiversity Conservation Act 2016 (BC Act) or the Commonwealth Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act) reported within the study area during the Spectrum Ecology (2022a) assessment. One Priority 3 flora species was recorded within the survey area, but not within the Project area: *Alyxia tetanifolia* (Figure 2.5). *Alyxia tetanifolia* is known from multiple locations in the local and regional area and is not considered to be locally or regionally significant.

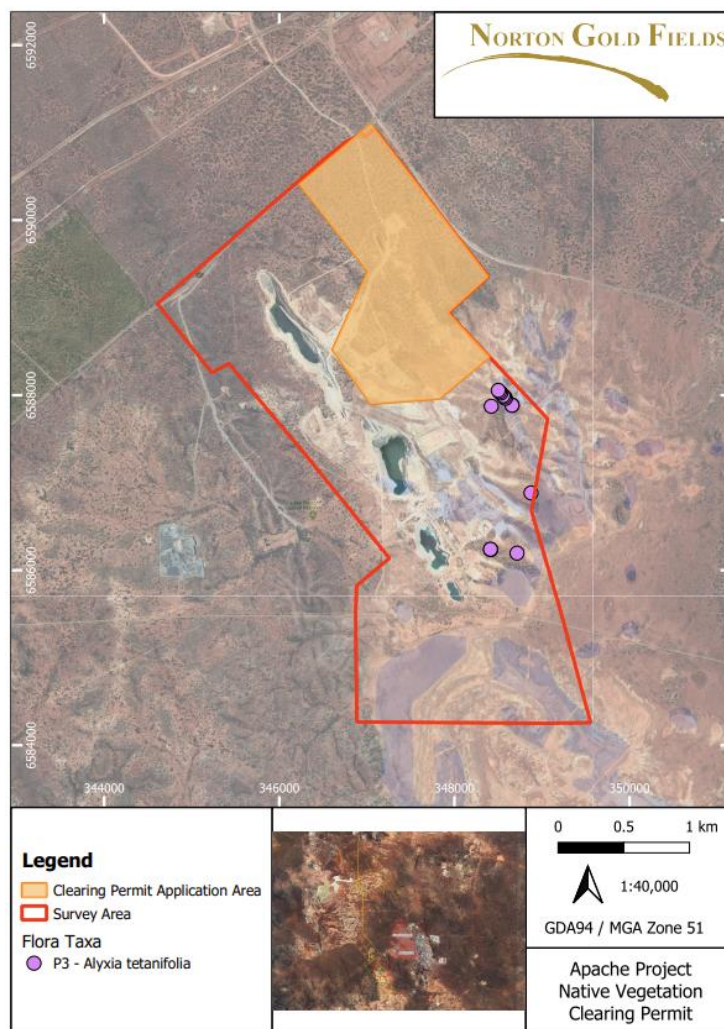


Figure 2.5 Conservation Significant Flora



## 2.8 Fauna

### 2.8.1 Fauna habitats

Spectrum Ecology (2022b) identified five major fauna habitat types within the Project area after conducting updated vegetation mapping from previous habitat mapping completed by Eco Logical Australia (2016). This report can be found in *Appendix D*. These fauna habitats fall into the vegetation communities characterised as P1, P4, P5, S1, D1, D2 and D3. The fauna habitats within the survey area are described in Table 2.4. The Mixed Eucalypt open woodland (FHab1) is the most widespread habitat in the Project Area.

Table 2.4 Fauna Habitats within the Apache Project Area

Fauna Habitat	Vegetation Community	Description
1	P1	Mixed Eucalypt open woodland over mixed shrubland on undulating plains on red-orange sandy clay soils
4	P4 & 5	Acacia and Eremophila shrubland on sandplains and floodplains on orange clay loam to sand
5	S1	Acacia shrubland on rocky granitic slopes
8	D1	Eucalypt woodland over mixed shrubland in drainage lines on red-orange sandy-clay-loam
9	D2, 3 & 4	Low sparse chenopod shrubland on salt lakes and salt pans

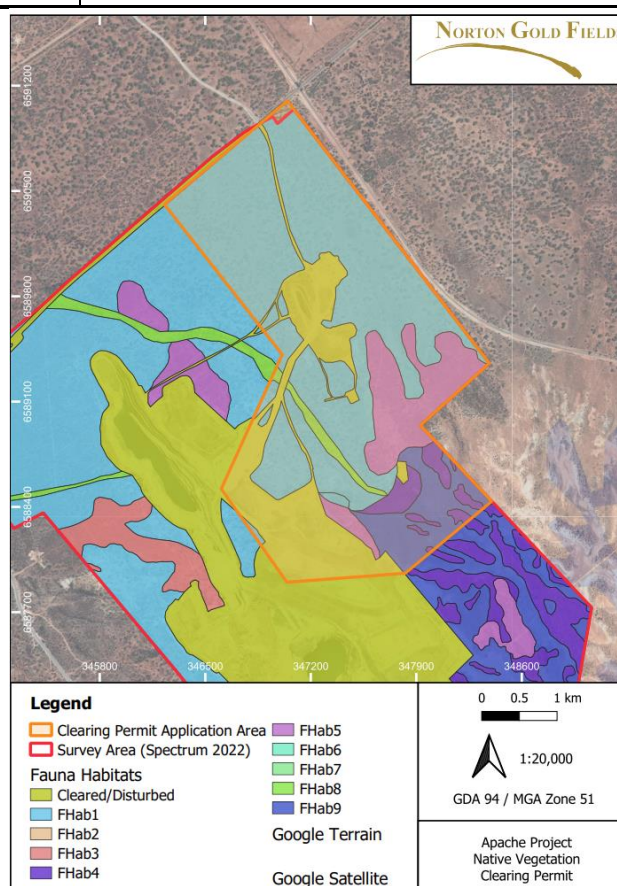


Figure 2.6 Fauna Habitats within the Apache Project Area

## 2.8.2 Conservation Significant Fauna

Twenty-nine conservation significant fauna species were identified during the desktop assessment with a potential to occur within the survey area (Spectrum Ecology, 2022b). Following the field assessment, 14 of those species were considered by Spectrum Ecology (2022b) to have a medium likelihood of occurring based on their known distributions and the habitats present within the survey area (Table 2.5).

Table 2.5 Conservation Significant Fauna with a Medium Likelihood of Occurring within the Apache Project Area

Species	Conservation Status			Reasoning (Spectrum Ecology, 2022b)
	EPBC Act	BC Act	DBCA	
BIRDS				
Malleefowl <i>Leipoa ocellata</i>	VU	VU	-	Multiple records in close proximity to the Survey Area, with previous survey within the Survey Area only recording old mound. Potential foraging habitat occurs in the Survey Area.
Curlew Sandpiper <i>Calidris ferruginea</i>	CR, MI	CR	-	The species has been recorded within 50 km of Survey Area within the last 20 years. The habitat present in the Survey Area is marginal for this species and would only be used occasionally when White Lake or the smaller salt lake/pans areas are inundated.
Carnaby's Cockatoo <i>Calyptrorhynchus latirostris</i>	EN	EN	-	Records of the species are recent and very close to the Survey Area. Some Salmon Gum are present in fauna habitat 1. Carnaby's Cockatoos use Salmon Gums for both breeding and night roosting.
Common Greenshank <i>Tringa nebularia</i>	MI	MI	-	Multiple recordings exist within 50 km of the Survey Area. Despite this, the habitat present in the Survey Area would only be used occasionally when White Lake (salt lake) or the smaller salt lake/pans areas are inundated.
Common Sandpiper <i>Tringa hypoleucos</i>	MI	MI	-	The species has been recorded within 50 km of the Survey Area within the last 20 years. The habitat present in the Survey Area would only be used occasionally when White Lake (salt lake) or the smaller salt lake/pans areas are inundated.
Fork-tailed Swift <i>Apus pacificus</i>	MI	MI	-	The species occupies diverse habitat and is generally associated with storm fronts therefore has the potential to occur in proximity to the Survey Area.
Oriental Plover <i>Charadius veredus</i>	MI	MI	-	This migratory species was recorded > 50 km away from Survey Area. The habitat in the Survey Area is marginal and would only be used occasionally.
Red-necked Stint <i>Calidris ruficollis</i>	MI	MI	-	Species recorded within last 20 years <50 km from Survey Area. Habitat present in the Survey Area would only be used occasionally when White Lake (salt lake) or the smaller salt lake/pans areas are inundated.

Species	Conservation Status			Reasoning (Spectrum Ecology, 2022b)
	EPBC Act	BC Act	DBCA	
Sharp-tailed Sandpiper <i>Calidris acuminata</i>	MI	MI	-	Species has been recorded in proximity to the Survey Area within the last 20 years. The habitat present in the Survey Area would only be used occasionally when White Lake (salt lake) or the smaller salt lake/pans areas are inundated.
Peregrine Falcon <i>Falco peregrinus</i>	-	OS	-	Although records are over 40 km away from Survey Area, the species occupies extremely diverse habitats and therefore could be recorded inside or in close proximity to the Survey Area. Nesting habitat is not present inside the Survey Area.
Hooded Plover <i>Thinornis rubricollis</i>	-	-	P4	Only one species records within 50 km of the Survey Area since 2001. This species seems rarely recorded from around Kalgoorlie. The habitat present in the Survey Area would only be used occasionally when White Lake (salt lake) or the smaller salt lake/pans areas are inundated.
Western Rosella <i>Platycercus icterotis xanthogenys</i>	-	-	P4	Species not recorded within 50 km of Survey Area; however, suitable habitat occurs within and in proximity to Survey Area.
INVERTEBRATES				
Arid Bronze Azure Butterfly <i>Ogyris subterrestris subsp. petrina</i>	CR	CR	-	All records are from over 20 years ago. Despite surveys in adjacent areas and the wider region, the species has not been recorded from this location since 1991. Suitable habitat occurs within and in close proximity to the Survey Area.
Inland Hairstreak Butterfly <i>Jalmenus aridus</i>	-	-	P1	There are five historical records between 1985 and 1997. Suitable habitat occurs within the Survey Area.

#### Malleefowl (*Leipoa ocellata*)

There have been several recordings of Malleefowl within 20km of the survey area which have been made within the last 5 years. No sightings, additional mounds, or secondary evidence of Malleefowl were observed during the survey. The only mound located within the area was revisited after a previous survey (Eco Logical Australia, 2016), and found to be eroded and likely a very old (100+ years). Overall, the fauna habitats recorded within the Survey Area would be considered very marginal. As a result, Malleefowl would likely only use the area for foraging (Spectrum Ecology, 2022b).

#### Carnaby's Cockatoo (*Calyptorhynchus latirostris*)

Carnaby's Cockatoo have been recorded within 8km of the survey area in the Kalgoorlie town centre in 2016, 2017, and 2018. However, the survey area occurs over 250 km outside of the current modelled distribution for this species, and the nearest previous records occur approximately 150 km south of Kalgoorlie (DBCA 2021). This

suggests that the recent records consist of individuals dispersing in an atypical manner. However, the species is thought to be expanding inland during recent years, most likely due to increasingly scarce foraging habitat (Spectrum Ecology and Spatial, 2022b).

No evidence or sightings of Carnaby's Cockatoo occurred during the survey. Some preferred breeding habitat is located within the survey area, within the mixed Eucalypt open woodland over mixed shrubland on undulating plains on red-orange sandy clay soils fauna habitat. This habitat type contains at least 34 Salmon Gum with a DBH of more than 300 mm. This species of Eucalypt is also used for night roosting. Therefore, this species may use the Eucalypt woodlands present in the survey area during periodic dispersal events further inland (Spectrum Ecology, 2022b).

*Fork-tailed Swift (Apus pacificus)*

The Fork-tailed Swift was stated in the EPBC Act Protected Matters Report as being likely to occur in proximity to the study area. The species has also been recorded 49 km south of the study area during a recent field survey. No fork-tailed Swift's were recorded during the survey. Their diverse habitat preferences as well as their almost entirely aerial lifestyle in Australia means there is potential for the species to fly over the survey area, but it is very unlikely to land there (Spectrum Ecology, 2022b).

*Hooded Plover (Thinornis cucullatus)*

There are three regional records of the Hooded Plover, which are all 30-47 km away from the survey area to the north and north-east. Two of these are historical records from 1980 and 1992, and one is from 2001. This species is rarely recorded from around the Kalgoorlie area. No records of this species have been made within the survey area despite the apparent suitable salt lake wetland habitat to the south (White Lake), and smaller salt lakes/pans to the east. However, it may occur occasionally during periods of inundation (Spectrum Ecology, 2022b).

*Peregrine Falcon (Falco peregrinus)*

The Peregrine Falcon was recorded in 2013 and 2014 at wetland habitat 65 km north-west of the Survey Area, suggesting they use this habitat for foraging. Foraging habitat may also be present in the survey area; however, it is unlikely the habitat available would be used for breeding. No Peregrine Falcon's were observed during the survey. This species typically occurs in low densities and is likely only to be observed infrequently (Spectrum Ecology, 2022b).

*Western Rosella (Platycercus icterotis xanthogenys)*

The species was recorded 59 km south-east of the Survey Area in 2008. There have been no further recordings despite suitable habitat within the region and Survey Area. This species may utilise the Survey Area sporadically (Spectrum Ecology, 2022b).

*Arid Bronze Azure Butterfly (Ogyris subterrestris petrina)*

The Survey Area is adjacent to Douglas Lake, which is one of only three known locations for the Arid Bronze Azure Butterfly (ABAB), the other two of which are 90 km apart and over 300 km away. Seventeen historical records of the species exist in the



DBCA database, near the survey area. These range from the first historical record in Kalgoorlie in 1911, with the rest occurring between 1982 and 1991. There were also two individuals observed in the area in 1993; however, none have been seen since then. Despite more recent surveys, no further observations of the species have been made (Spectrum and Ecology, 2022b).

No evidence of *Camponotus* sp. nr. *terebrans* colonies were recorded during recent surveys in 2016, 2020 and 2021. During this survey, four *Camponotus* sp. specimens were collected for identification. However, none of these specimens were identified as the target species. In addition, no ABAB individuals were sighted during the survey period. However, there is suitable habitat for this species within the survey area (Spectrum and Ecology, 2022b).

#### *Inland Hairstreak Butterfly (Jalmenus aridus)*

*Acacia tetragonophylla*, *Senna artemisioides* subsp. *artemisioides* and *Senna artemisioides* subsp. *filifolia* were recorded from several quadrats within the survey area during Eco Logical Australia's (2016) flora and vegetation assessment. These were in the mixed Eucalypt open woodland on red-brown loam plains habitat in the north-west and central east sections of the Study Area (Spectrum and Ecology, 2022b).

During this survey, *Senna artemisioides* subsp. *filifolia* and *Acacia tetragonophylla* were recorded from four fauna habitats: Eucalypt woodland over mixed shrubland on low rocky hills with ironstone and quartz over red-orange sandy-clay, mixed Eucalypt open woodland over mixed shrubland on undulating plains on red-orange sandy clay soils, *Allocasuarina* over mixed shrubland on rocky plains and rises, and *Acacia* shrubland on rocky granitic slopes (Spectrum and Ecology, 2022b).

No evidence of Froglet ant or Inland Hairstreak were recorded during the survey. However, some potential habitat for this species exists within the Survey Area (Spectrum and Ecology, 2022b).

### 2.8.3 Short Range Endemic species

Thirty-four invertebrate species, from 16 taxa, were collected by Spectrum Ecology (2022b) from dry pit fall traps, leaf litter samples, and active searches. Twelve taxa belonged to SRE target groups, and nine of these are considered potential SRE (one Araneomorph spider, one Mygalomorph spider, two Pseudoscorpions, one Geophilomorph centipede, one Scolopendromorph centipede, one Polydesmid millipede, one Symphyla pseudocentipede and one Eupulmonata snail) (Spectrum Ecology, 2022b).

The confirmed or potential SRE invertebrate taxa recorded are all widespread and proximate to the region and not expected to be restricted to the survey area (Spectrum Ecology, 2022b).

#### 2.8.4 Subterranean Fauna

Phoenix Environmental Sciences (2017) was commissioned to undertake a subterranean fauna assessment of the Binduli Expansion Project area, with the field component being completed in August 2016 (Appendix E).

A number of factors contribute to the likelihood of stygofauna to occur, including sediment texture (chiefly related to hydraulic conductivity and correlated with size of pore spaces suitable for biota), hydraulic conductivity (controlling food and oxygen supply), depth from surface, water regime (timing, frequency, duration, extent and depth, and variability), energy (food) flow (in form of dissolved organic matter (DOM)), salinity (accepted upper tolerance approximately 70,000 mg/L TDS), dissolved oxygen (DO) and redox status of the groundwater. With groundwater salinities generally well over 70,000 mg/L throughout much of the study area, it is extremely unlikely that stygofauna are present (Phoenix Environmental Sciences, 2017).

Shallow sediments present within the survey area are unlikely to maintain stable subterranean cavities capable of supporting troglafauna and are prone to strong surface dehydration with elevated surface temperatures and water inundation during high rainfall events. The Cainozoic soils in the study area are generally shallow which will not provide stable, sufficiently moist conditions required by troglafauna. The presence of troglafaunal in the survey area is not anticipated (Phoenix Environmental Sciences, 2017).

#### 2.8.5 Introduced Fauna

Two introduced mammal species were recorded during the Spectrum (2022b) survey. Rabbit and goat are commonly recorded in the area, along with wild dogs and cats. The Project area is near town and community spaces, such as Lake Douglas Reserve, which makes it highly likely that cats and dogs will continue to persist in the area.

### 2.9 Heritage

#### 2.9.1 Aboriginal Heritage

Aboriginal heritage surveys of the Project area were undertaken by R & E O'Connor Pty Ltd in July 2022, with members of the Maduwongga Group (MWG) and the Sambo Family Group (SFG); and by Tera Rosa Consultants in December 2022 with members of Marlinyu Goorhlie (MG).

Following the surveys, it was determined that there are no sacred, ritual, or ceremonial Aboriginal sites within the Project area. Likewise, there are no burial sites or former camping areas there. No Aboriginal artefact scatter sites were identified by the Aboriginal participants during the pedestrian inspections. Two areas of isolated finds were identified, which, in the opinion of the Aboriginal people involved in the surveys, do not constitute Aboriginal sites within the meaning of Section 5 of the *Aboriginal Heritage Act 1972*.

The heritage inspections included the proposed site for the relocation of the Pitman and Walsh Memorial. It was established there are no Aboriginal heritage issues that could be an impediment to that relocation.

#### 2.9.2 European

In the centre of the proposed Apache development is the Pitman and Walsh memorial site. The memorial was formally established in September 2015 by funding from Norton, to commemorate the lives of police detectives J. J. Walsh, and A. H. Pitman who were brutally murdered while investigating a gold theft in Kalgoorlie in 1926. Norton has taken an avoidance approach when designing the mine site layout to ensure no direct impact to Milers Find shaft, however, acknowledges due to the proximity some disturbance is potential. In addition, public access to the memorial will closed off for the duration of the project.

Norton has approached key stakeholders to gain support for the relocation of the memorial site and has commenced planning for the relocation.

### 3. Tenure

#### 3.1 Mining Tenure

The area covered by this application lies within the following leases all of which are held by Bellamel Mining Pty Ltd, a subsidiary of Norton:

- M 26/115
- M 26/243
- M 26/430
- M 26/474

Proof of ownership has been supplied in *Appendix F* along with Norton Gold Fields Company Extract showing relation between Norton and Bellamel.

#### 3.2 Underlying Land Tenure

Norton acknowledges Reserve 8787 underlies the mining lease M26/243 which has been vested to the City of Kalgoorlie-Boulder for recreational purposes. Norton have engaged with the City and gained support for the activity proposed within R8787. The letter provided by the City has been included in *Appendix G*.



## 4. Land Clearing Process

Clearing will be undertaken progressively using the following equipment and methodology.

### 4.1 Equipment

The equipment required to support and undertake clearing will include;

- Excavator;
- Dozer;
- Water Cart; and
- Service Vehicles.

### 4.2 Proposed Clearing Methodology

Prior to clearing, the area to be cleared will be demarcated using high visibility tape or equivalent where suitable to ensure operators undertake clearing within the Clearing Permit Application Area. A maximum of 310ha is required as part of the purpose permit. This includes areas associated with the infrastructure for the mining operations. Clearing will be undertaken using dozer or loader to remove vegetation, topsoil, and overburden. Any salvaged vegetation and topsoil will be stockpiled for rehabilitation purposes. A spotter will be present at all times to ensure all clearing and disturbance is undertaken within the proposed clearing boundaries.

## 5. Assessment against the Ten Clearing Principles

An assessment of the proposed clearing within the Clearing Permit Application Area against the ten clearing principles outlined in Schedule 5 of the EP Act is provided in Table 5.1 below. This assessment was undertaken utilising the information provided in the supporting studies.

This assessment demonstrates that the proposed clearing is not in variance with any of the ten clearing principles and where required, management measures will be established to mitigate any potential unacceptable detrimental environmental harm.

Table 5.1 Assessment against the Ten Clearing Principles

Principle	Assessment	Outcome
A) Native vegetation should not be cleared if it compromises a high level of biological diversity.	<p>There were 183 flora taxa from 37 families and 94 genera recorded from 50 quadrats (Spectrum Ecology, 2022a). The number of species recorded was comparable to previous surveys conducted within the vicinity of the study area. Proportion of flora collected was consistent with expectations for this type of survey. The vegetation identified at the study area is not considered to have a high level of biological diversity.</p> <p>The vertebrate fauna assemblage identified from the study area by Spectrum Ecology (2022b) is not considered unique or of high biological diversity. The SRE taxa recorded during the SRE survey is also consistent with other surveys in the surrounding region and does not constitute a high level of biodiversity.</p>	Not at variance with the clearing principle
B) Native vegetation should not be cleared if it comprises the whole or a part of, or is necessary for the maintenance of, a significant habitat for fauna indigenous to Western Australia.	Eucalypt woodland habitats identified within the Study Area occur extensively across the Coolgardie region and is not considered a significant habitat type. Small areas potentially suitable for the Malleefowl were recorded; however, these areas are too small to support a population/breeding pair. Other habitat or flora species suitable to support other conservation significant species were identified in the project area, however these are widespread and not specific to the Project area.	Not at variance with the clearing principle
C) Native vegetation should not be cleared if it includes, or is necessary for the continued existence of, rare flora.	<p>No Threatened flora were recorded from the survey area or is considered likely to occur in the survey area. Of the 94 Priority flora species returned in the database searches, six were considered to have some level of likelihood of occurrence in the Study Area: <i>Goodenia salina</i> (P2), <i>Alyxia tetanifolia</i> (P3), <i>Isolepis australiensis</i> (P3), <i>Eremophila praecox</i> (P2), <i>Lepidium fasciculatum</i> (P3), <i>Notisia intonsa</i> (P3). Both <i>Alyxia tetanifolia</i> and <i>Goodenia salina</i> are not considered to be locally significant. The four remaining flora taxa were assigned a Low likelihood of occurrence post survey.</p> <p>Vegetation at the study area is not necessary for the continued existence of these significant flora taxa (Spectrum Ecology, 2022a).</p>	Not at variance with the clearing principle



Principle	Assessment	Outcome
D) Native vegetation should not be cleared if it comprises the whole or a part of or is necessary for the maintenance of a Threatened Ecological Community (TEC).	No TEC or PECs were recorded within 40 km of the Study Area and no vegetation within the Project area resembles any known TEC/PEC communities.	Not at variance with the clearing principle
E) Native vegetation should not be cleared if it is significant as a remnant of native vegetation in an area that has extensively cleared.	Three Beard vegetation communities were mapped at the Apache Project area: 9, 123.1, and 1294. Each sub-association has greater than 90% of its pre-European extent remaining. The project area includes less than 1% or each of the sub-associations. No vegetation within the Project area is significant as a remnant of native vegetation in an area that has been extensively cleared.	Not at variance with the clearing principle
F) Native vegetation should not be cleared if it is growing in, or in association with, an environment associated with a watercourse or wetland.	There are a series of small, interconnected salt basins directly south of the project area, to the east of existing disturbance. Surface water flows predominantly as sheet flow or utilising minor non-perennial drainage lines to the south. These have been impacted by historical and existing activity in the area and Norton considers the proposed works will not cause further impact. There are no significant drainage channels, streams or available streamflow monitoring data in the region around the Project. With the existing disturbance and clearing within the area, the proposed clearing for Apache Project area will have an insignificant effect on drainage channels.	Not at variance with the clearing principle
G) Native vegetation should not be cleared if the clearing of the vegetation is likely to cause appreciable land degradation	Considering the small area to be cleared, the existing vegetation condition and the surrounding land uses, it is unlikely that the proposed clearing will cause appreciable land degradation. Further, existing high salinities and poor soil quality have limited vegetation within much of the Project area.	Not at variance with the clearing principle
H) Native vegetation should not be cleared if the clearing of the vegetation is likely to have an impact on the environmental values of any adjacent or nearby conservation area.	The closest conservation area is the Lake Douglas Recreational Reserve located south-west of the Project area. Clearing for the proposal is unlikely to have an impact on the environmental values of this Reserve.	Not at variance with the clearing principle

Principle	Assessment	Outcome
I) Native vegetation should not be cleared if the clearing of the vegetation is likely to cause deterioration in the quality of surface or underground water.	Considering the small area likely to be cleared, the proposed clearing of native vegetation at the Project area is not expected to cause deterioration in the quality of surface or underground water. Groundwater in the region has little use for activities other than mining given the high salinities. No permanent surface water bodies exist in the area.	Not at variance with the clearing principle
J) Native vegetation should not be cleared if clearing the vegetation is likely to cause, or exacerbate, the incidence of flooding.	Considering the small area likely to be cleared, the proposed clearing of native vegetation at the Study Area is not expected to cause or exacerbate the incidence of flooding. Surface water management infrastructure has been proposed within the mining proposal, perspective of the proposed infrastructure.	Not at variance of the clearing principle

## 6. Environmental Management

All potential environmental impacts will be managed in accordance with Norton's Environmental Management Plan. Key considerations have been summarised below.

### 6.1 Existing Environmental Approvals

The proposed activities will require approvals pursuant to the *Mining Act 1978* and *Environmental Protection Act 1986* (Works Approval and subsequent Licence). Applications for these instruments are being made in conjunction with this application. Norton recognises that there are statutory requirements associated with these approvals and that clearing associated with the Purpose Permit cannot be undertaken without those permits in place.

### 6.2 Threatened and Priority Flora

In the instance where the proposed works unexpectedly intercept Threatened or Priority flora, Norton will cease work and seek independent management advice.

### 6.3 Threatened and Priority Fauna

In the instance where the proposed works unexpectedly intercept Threatened or Priority fauna, Norton will cease work and seek independent management advice.

### 6.4 Weed Species

To avoid the introduction of weeds, all vehicles and machinery will be inspected where practicable prior to access to the site. In the event where any seeds or weeds are identified, they will be removed, contained, and disposed of in an appropriate manner.

### 6.5 Hydrocarbons Spills

Due to the utilisation of heavy machinery and vehicles during the proposed works, there is a potential for minor hydrocarbon spills to occur at the Project. Hydrocarbon storage, handling, disposal, and spillage response will be managed in accordance with Norton's existing hydrocarbon management procedures. Hydrocarbon spill kits will be available to manage any spills from machinery. Any contaminated material/rags etc. will be removed from site in a suitable container and disposed of appropriately.

### 6.6 Fugitive Dust

Due to exposure of the ground surface as a result of the proposed works, there is a potential for fugitive dust to be generated on site. Dust will be managed through the application of dust suppressing techniques including the application of saline water via the use of water carts. A water cart will be available for use as required.



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## 8. Appendices

Appendix A: Mine Earth (2016) Binduli Expansion Project, baseline soil assessment

Appendix B: AQ2 Pty Ltd (2022) Surface Water Management Plan Binduli South Project

Appendix C: Spectrum Ecology and Spatial (2022) Binduli South Project Flora and Vegetation Assessment

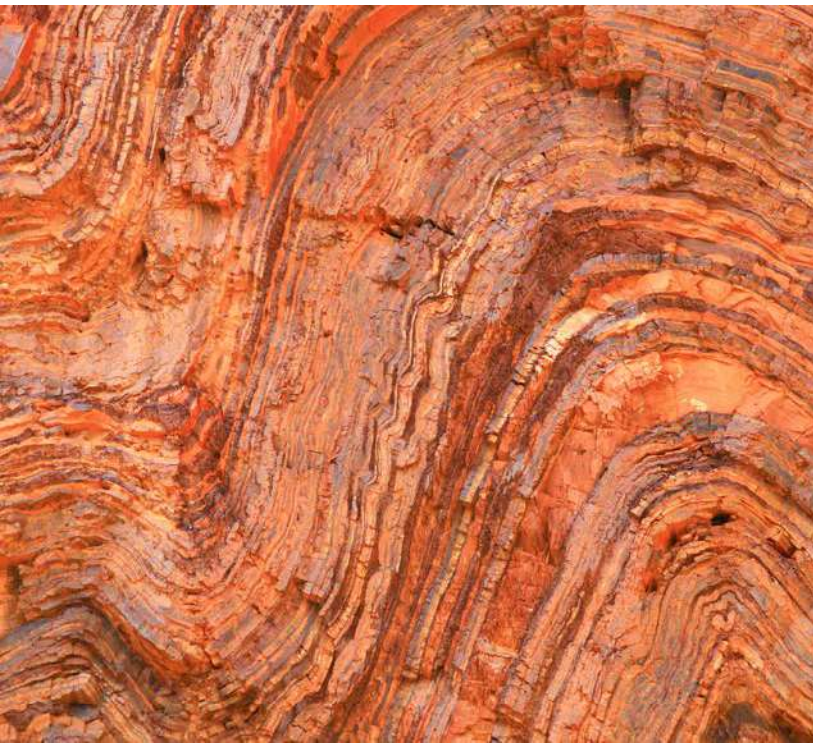
Appendix D: Spectrum Ecology and Spatial (2022) Binduli South Project Terrestrial Fauna and SRE Assessment

Appendix E: Phoenix Environmental Sciences (2017) Level 1 subterranean fauna assessment for the Binduli Expansion Project

## **Appendix A: Mine Earth (2016) Binduli Expansion Project, baseline soil assessment**



The leading mine closure planning consultancy



## **NORTON GOLD FIELDS LIMITED**

**Binduli Expansion Project,  
baseline soil assessment**

**JULY 2016**



# Norton Gold Fields Limited, Binduli Expansion Project

## Baseline soil assessment, July 2016

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## EXECUTIVE SUMMARY

The Binduli Project (the Project) is owned and managed by Norton Gold Fields Limited (Norton). The Project is located approximately 3 km west of the city of Kalgoorlie-Boulder in the Goldfields region of Western Australia. It consists of 23 mining tenements and is divided into northern and southern areas. Norton is currently considering an expansion to the Project which would involve extending and merging a number of historical pits, the creation of new open pit and the development of additional infrastructure.

Mine Earth was commissioned by Norton to undertake a baseline soil assessment for the Project, which included:

- A literature review and desk top study of soil and landform units.
- A field assessment, mapping and sampling program to develop an understanding of soil within the Project area.
- The assessment of the physical and chemical properties of soil samples.
- The preparation of a soil resource balance.
- The development of soil handling and management recommendations.

A program of soil mapping and sampling of the Project area was undertaken during February 2016 by Mine Earth. Soil samples were subjected to field testing and laboratory analyses with results summarised in Table ES1. Based on these results, a total of eight soil units were identified across the northern and southern Project areas.

It was recommended that topsoils from all soil units except soil unit F, and subsoil from soil units A, B, D and H should be retained for use during rehabilitation activities. Remaining soil units are not recommended for use during rehabilitation activities because of elevated salinity and sodicity. Due to the differing management requirements of the soil units, each unit should be stockpiled separately. Where it is recommended that topsoil and subsoil be collected from the same soil unit (soil units A, B, D and H), the topsoil and subsoil could be stored together.

A calculation of available rehabilitation resources was completed based on the recommendations above. It was estimated that approximately 1,445,024 m<sup>3</sup> of soil would be recovered from Project disturbance areas. It was estimated that approximately 1,566,468 m<sup>3</sup> of soil will be required for the rehabilitation of all Project disturbance areas. This equates to a topsoil deficit of 121,443 m<sup>3</sup>. Given the likely soil deficit it is recommended that other sources of rehabilitation resources are investigated during the operating phase of the Project.

## ES1 Summary of physical and chemical characteristics of soil units from the Project.

Soil unit	Horizon	Coarse PSD	Fine PSD	Dispersion	Hardsetting	pH	EC	Nutrients and OC	ESP	Total metals
A Flat sand plain	Topsoil	Dominated by less than 2 mm fraction	Sand to sandy loam	Partially to highly dispersive	Not likely	Slightly acid to mildly alkaline	Non-saline	Low	Non-sodic to marginally sodic	Low
	Subsoil	Dominated by less than 2 mm fraction	Sandy loam to sandy clay loam	Non-dispersive to highly dispersive	Not likely	Moderately to strongly alkaline	Non-saline to slightly saline	Low	Non-sodic to strongly sodic	Low
B Gravelly flat plain	Topsoil	Dominated by less than 2 mm fraction	Loamy sand	Partially dispersive	Not likely	Very strongly acid to moderately alkaline	Non-saline	Low	Non-sodic to strongly sodic	Low
	Subsoil	Dominated by less than 2 mm fraction	Sandy loam	Partially dispersive	Not likely	Very strongly acid to strongly alkaline	Slightly saline	Low	Non-sodic to marginally sodic	Low
C Undulating upper plain	Topsoil	Dominated by less than 2 mm fraction	Loamy sand and sandy loam	Non-dispersive	Not likely	Mildly alkaline to moderate alkaline	Non-saline to slightly saline	Low	Non-sodic	Low
	Subsoil	Dominated by the >4.75 mm fraction	Sandy loam	Non-dispersive	Not likely	Strongly alkaline	Non-saline to extremely saline	Low	Non-sodic to strongly sodic	Low
D Undulating plain	Topsoil	Dominated by less than 2 mm fraction	Loamy sand	Partially dispersive	Not likely	Very strongly acidic	Non-saline	Low	Strongly sodic	Low
	Subsoil	Dominated by less than 2 mm fraction	Sandy loam	Non-dispersive	Not likely	Very strongly acidic	Non-saline	Low	Marginally sodic	Low
E Dune	Topsoil	Dominated by less than 2 mm fraction	Sand	Partially dispersive	Not likely	Moderately acidic	Non-saline	Low	Marginally sodic	Low



Soil unit	Horizon	Coarse PSD	Fine PSD	Dispersion	Hardsetting	pH	EC	Nutrients and OC	ESP	Total metals
F Alluvial plain	Subsoil	Dominated by less than 2 mm fraction	Sandy loam	Highly dispersive	Not likely	Mildly alkaline	Moderately saline	Low	Strongly sodic	Low
	Topsoil	Dominated by less than 2 mm fraction	Loamy sand	Partially dispersive	Not likely	Neutral	Extremely saline	Low	Strongly sodic	Low
	Subsoil	Dominated by less than 2 mm fraction	Sandy loam	Highly dispersive	Not likely	Mildly alkaline	Extremely saline	Low	Strongly sodic	Slightly elevated
G Gentle dune	Topsoil	Dominated by less than 2 mm fraction	Sandy loam	Highly dispersive	Not likely	Neutral	Non-saline	Low	Marginally sodic	Low
	Subsoil	Dominated by the greater than 4.75 mm fraction	Sandy clay loam	Non-dispersive	Not likely	Strongly alkaline	Highly saline	Low to moderate	Strongly sodic	Low
H Flat plain	Topsoil	Dominated by less than 2 mm fraction	Sandy loam	Non-dispersive	Not likely	Very strongly acid	Non-saline	Low	Strongly sodic	Low
	Subsoil	Dominated by less than 2 mm fraction	Sandy loam	Non-dispersive	Not likely	Very strongly acid	Non-saline	Low	Marginally sodic	Low

In relation to the stripping and preservation of relevant soil units, Mine Earth recommends the following where feasible:

- Soil stockpiles should be paddock dumped or pushed up into windrows.
- Vegetation should be track rolled through the soil during recovery of these resources.

In terms of the soil resource at the Project, there are a number of factors that are likely to require management prior to its use in rehabilitation activities:

- Acidic soil may require treatment with lime.
- Salinity was moderate within some soil units. It is recommended that local provenance species are used in rehabilitation seed mixes for the soil units.
- Plant available N was low within all soil units, it is likely that a high nitrogen and low phosphorus slow release fertiliser will be required to increase concentrations of plant available N in stockpiled topsoil.
- Sodic soil units may require treatment with gypsum.

Topsoil stockpiles should be assessed prior to their use in rehabilitation activities as changes in soil structure and chemical and physical properties are likely as a result of stockpiling.

If feasible, rehabilitation trials assessing plant growth and germination versus soil treatments (addition of lime and fertiliser) are recommended. In addition, it is recommended that Norton implement a seed collection programme during operations to ensure that the provenance seed store for the Project is sufficient for rehabilitation activities.

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## Appendices

Appendix A	Sample site descriptions
Appendix B	Description and relevance of laboratory analysis
Appendix C	Laboratory results
Appendix D	Results of statistical analysis



## 1 INTRODUCTION

The Binduli Project (the Project) is owned and managed by Norton Goldfields Limited (Norton). The Project is located approximately 3 km west of the city of Kalgoorlie-Boulder in the Goldfields region of Western Australia (Figure 1); spanning both north and south sides of the Great Eastern Highway. It consists of 23 mining tenements and is divided into northern and southern expansion areas.

Norton is currently considering changes to the existing Project which would involve:

- The expansion of the Janet Ivy open pit.
- The merging and expansion of the Centurion, Navajo Chief and Ben Hur 1 and 2 pits.
- The creation of the new Apache open pit.
- The development of a heap leach facility, tailings storage facility and associated processing infrastructure.

Historic disturbance at the Project includes a total of nine pits, eight Waste Rock Dumps (WRD), and associated infrastructure such as run of mine pads (ROM), roads and pipelines (Figure 2). The Project area was largely disturbed as a result of historic mining operations throughout the 1990's. Norton's operations recommenced at Janet Ivy and Navajo Chief in the late 2000's, however operations at Navajo Chief have ceased and Janet Ivy is on a program of Care and Maintenance. The mining of Fort Scott commenced in 2015.

Mine Earth was commissioned by Norton to undertake a baseline soil assessment for the Project. The scope of the assessment includes:

- A literature review and desktop study of soil and landform units.
- A field assessment, mapping and sampling program to develop an understanding of soil within the project area.
- Assessment of the physical and chemical properties of soil samples.
- The preparation of a soil resource balance.
- The development of soil handling and management recommendations.





Date: 28/06/2016  
Author: Elis Smedley

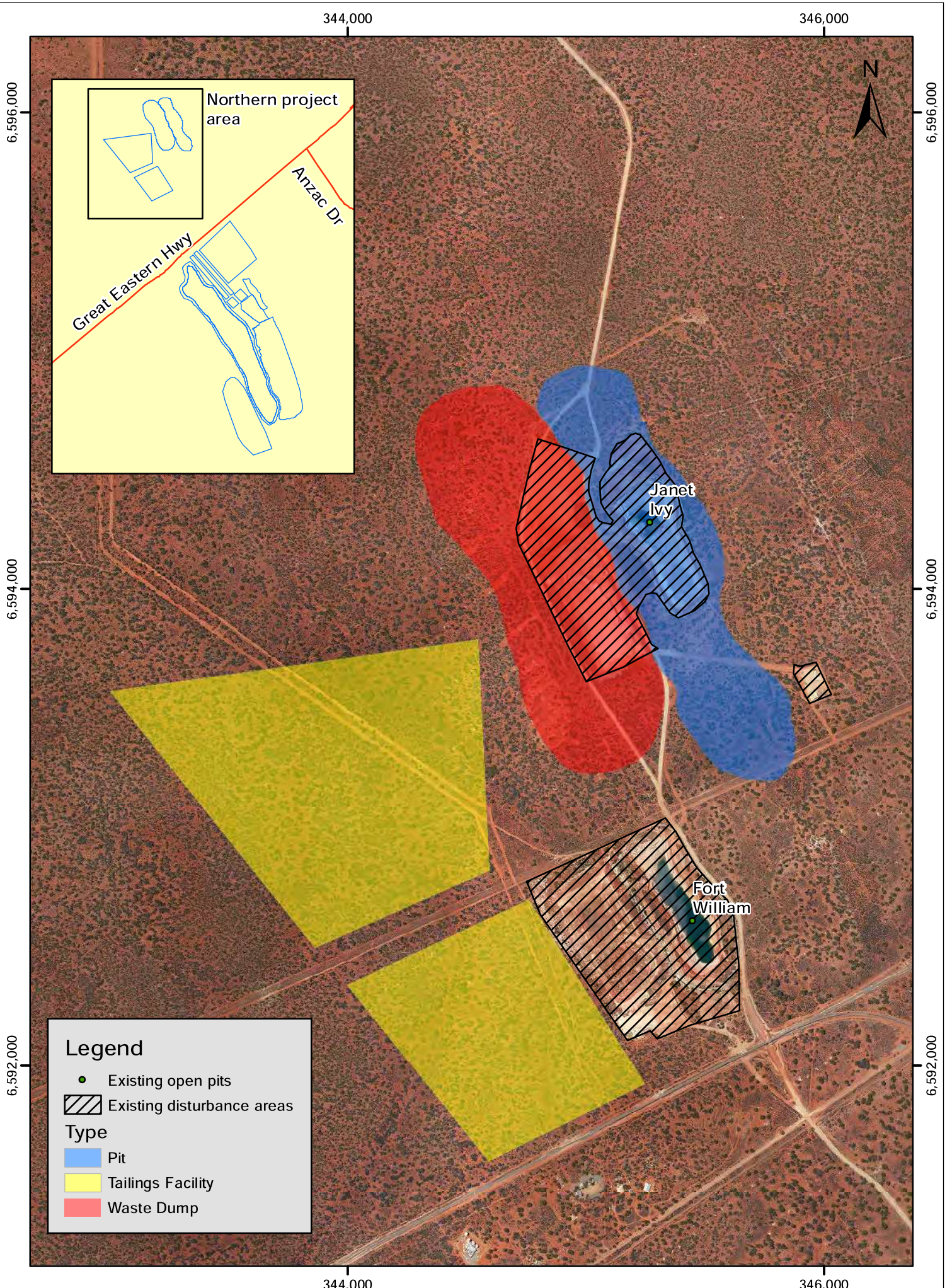
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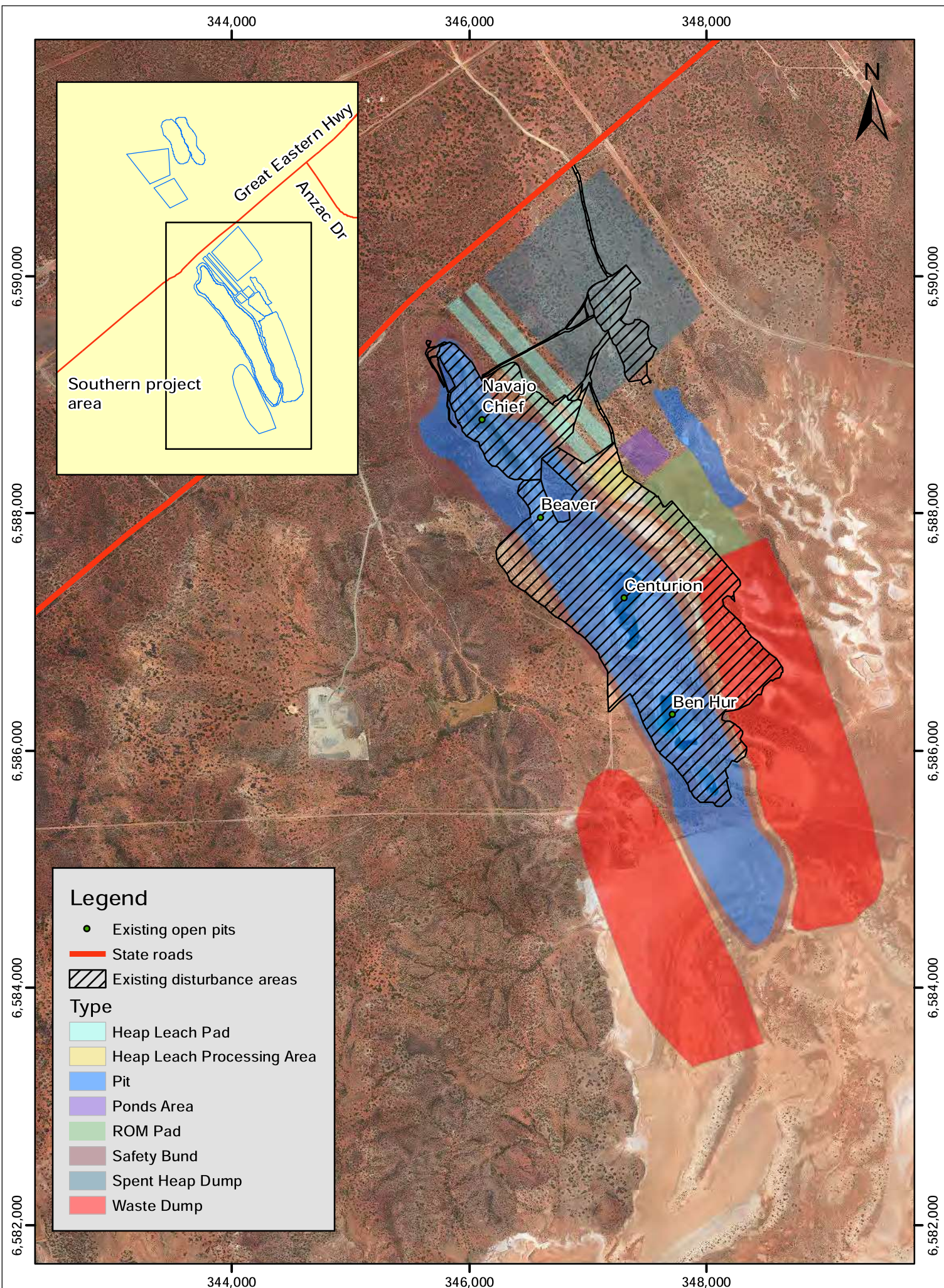
Regional location

Figure  
1











## **2 BACKGROUND**

### **2.1 Local environment**

The Project is situated in the Eastern Goldfields subregion of the Coolgardie bioregion as defined by the Interim Biogeographic Regionalisation for Australia. Vegetation in this sub region consists broadly of Mallees, Acacia thickets and shrub heath on sandplains (Cowen, 2001).

The climate of the Coolgardie bioregion is classified as arid to semi-arid. The nearby Kalgoorlie-Boulder airport weather station has recorded a long term annual rainfall average of 266 mm. The majority of the rainfall falls in the first six months of the year.

### **2.2 Local Geology**

As described by Witt (2011), the Janet Ivy deposit in the north of the Project area is located on the western margin of a north northwest-striking feldspar porphyry intrusion where it contacts with metasedimentary rocks via a steep, contact-parallel fault (the Western Fault – defined by a strong foliation and muscovite alteration). Muscovite alteration overprints more extensive areas of the potassic (in the form of pyrite and disseminated and veinlet biotite) and carbonate alteration (replacing primary ferromagnesian minerals such as pyroxene, amphibole and biotite). Dusty hematite imparts a red/pink colour to the porphyry in these alteration zones.

As described in Norton Gold Fields Ltd (2015), the geology of the southern half of the Project area (Centurion, Navajo Chief, Ben Hur, Apache) is dominated structurally by three major mineralised trends:

- Centurion-Ben Hur Trend.
- Beaver-Navajo Trend.
- Pitman-Fort William Trend.

The Centurion-Ben Hur and Beaver-Navajo trends are both situated along the Centurion Shear, a northwest trending, east-dipping structure that acts as a major lithological divide in the area. To the east of this shear lie Black Flag beds that are dominated by steep, easterly-dipping intermediate to felsic volcanoclastics with numerous porphyry intrusions and domes that increase in abundance with increasing proximity to the Centurion Shear. West of the shear lie west-dipping epiclastic sediments, conformable with the overlying conglomerates of the Kurrawang Syncline.

The Beaver-Navajo trend is located 300 m west of the Centurion-Ben Hur trend, with deposits forming in west-dipping conjugates of the Centurion Shear and hosted by carbonate-altered coarse grained arenites.

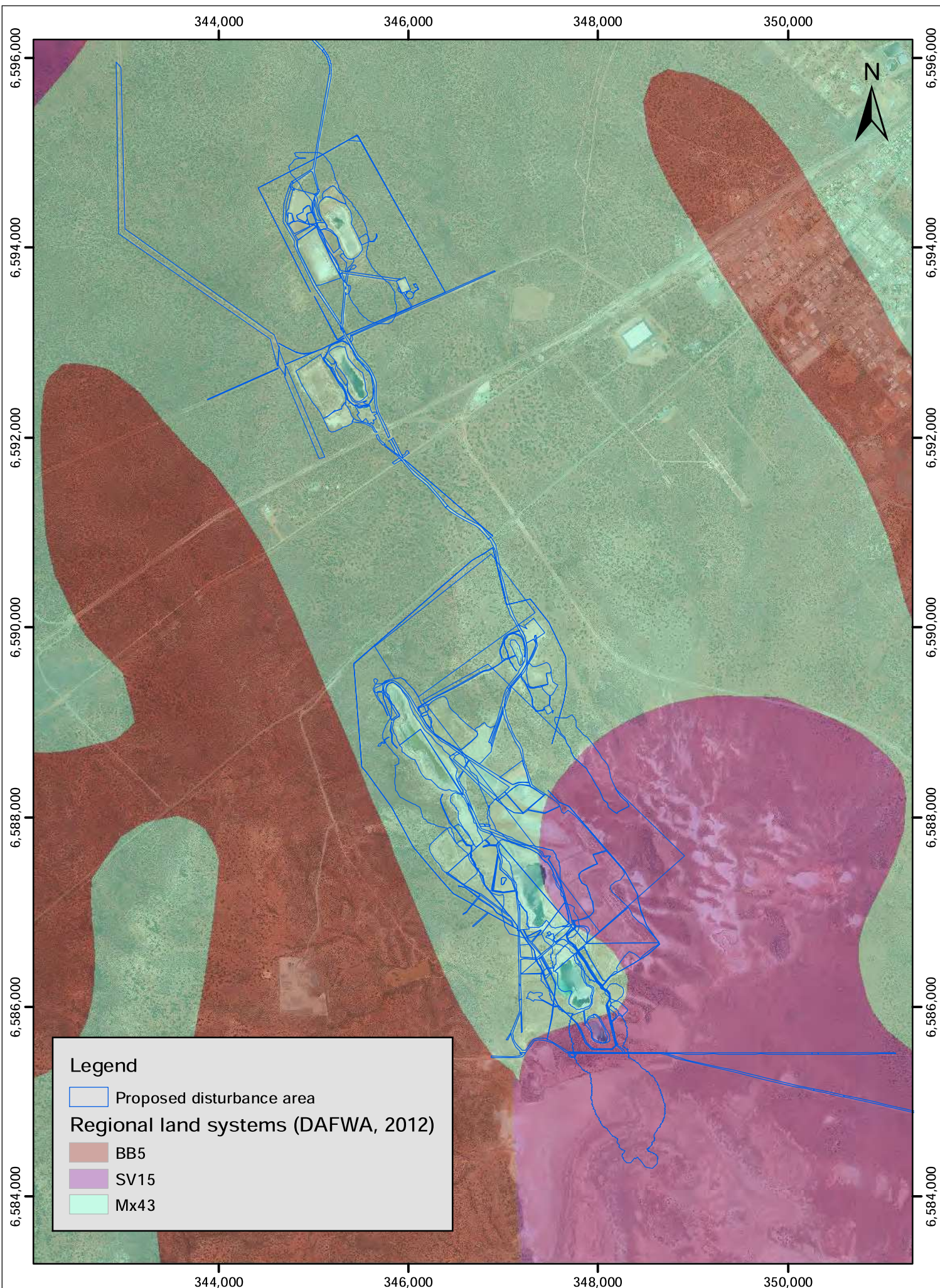
The Pitman-Fort William trend is located 1 km east of the Centurion-Ben Hur line along a northwest trending, east-dipping thrust fault system. The host unit for the deposit is a thin, strain-attenuated porphyry within carbonate-altered andesite breccias.

## **2.3 Land systems**

The Atlas of Australian Soils provides a broad description of soil and land systems across Australia. The northern Project area overlies the MX43 land system as defined by the Atlas of Australian Soils (Figure 4). The MX43 land system is characterised by gently undulating valley plains and pediments and some outcrop of rock. Soil consists predominately of alkaline red earth with limestone and limestone nodules at shallow depth on gently sloping slightly concave plains with low gentle rises.

The southern Project area covers both MX43 and SV15 land systems (Figure 4). Within the SV15 land system common soil types include gypseous and saline loams, with gypseous and saline soil on the lake beds. Associated soil types include sandy red earths on lunettes, soil on plains, soil on eroded plains and small areas of soil on clay pans.







### 3 METHODS

A program of soil mapping and sampling of the Project area was undertaken during February 2016 by Mine Earth. Soil samples were subjected to field testing and laboratory analyses to assess their physical and geochemical attributes, with statistical analysis undertaken on the laboratory results.

#### 3.1 Desktop assessment

Available aerial imagery, topography, geology and vegetation data was reviewed along with online and published regional and local soil data to stratify the Project area broadly into land systems (Figure 4) prior to the field assessment. This information was then used to develop a field assessment and sampling plan.

#### 3.2 Field assessment and sampling

The proposed disturbance area for the Project was traversed to verify the occurrence and extent of local soil units, and to identify representative soil sample sites. Forty soil sample sites were subsequently selected (Figure 5). Soil pits were dug using shovel and mattock to refusal, or in some locations using a bobcat digger, with samples taken from both topsoil and subsoil horizons. A total of 79 soil samples were collected (Table 1). The measurements recorded for each horizon included horizon depth, matrix colour, texture, rock fragment percentage, rock fragment size, structure type, consistence and general comments on any other relevant features (Appendix A). Photographs were taken of the soil profile and soil surface at each location (Appendix A). Soil units were then mapped across the Project area based on the field and desktop assessment.

#### 3.3 Laboratory assessment

Each topsoil and subsoil sample was dry sieved to separate the <2 mm, 2 mm-4.75 mm and >4.75 mm fractions and the relative proportions of each were recorded. The <2 mm portion of the 79 samples was analysed for pH and EC by CSBP. The samples were then bulked together based on the pH and EC, field characteristics and soil units to form 20 representative bulk samples for analysis (Table 1). The 20 bulk samples were sent to Intertek, CSBP and Graeme Campbell and Associates (GCA) for analysis as per Table 2. Those samples ending in the prefix A were topsoil samples, while those ending in B were subsoil samples. Appendix B describes the laboratory analyses undertaken and outlines their relevance. The laboratory analysis focussed on assessing the suitability of soils for supporting revegetation and providing adequate surface stability.

**Table 1 Composition of bulk samples, horizon and corresponding soil unit**

Bulk sample	Soil sample sites	Soil Unit	Horizon
BINB1A	DU27A, DU28A	A	Topsoil
BINB1B	DU27B, DU28B	A	Subsoil
BINB2A	DU29A, DU30A, DU31A, DU32A	A	Topsoil
BINB2B	DU29B, DU30B, DU31B, DU32B	A	Subsoil
BINB3A	DU33A, DU34A, DU35A	B	Topsoil
BINB3B	DU33B, DU34B, DU35B	B	Subsoil
BINB4A	DU10A, DU11A, DU12A	C	Topsoil

Bulk sample	Soil sample sites	Soil Unit	Horizon
BINB4B	DU10B, DU11B, DU12B	C	Subsoil
BINB5A	DU24A, DU37A, DU38A	C	Topsoil
BINB5B	DU24B, DU37B, DU38B	C	Subsoil
BINB6A	DU7A, DU8A	D	Topsoil
BINB6B	DU7B, DU8B	D	Subsoil
BINB7A	DU2A, DU3A	E	Topsoil
BINB7B	DU2B, DU3B	E	Subsoil
BINB8A	DU4A, DU39A, DU40A	F	Topsoil
BINB8B	DU4B, DU39B, DU40B	F	Subsoil
BINB9A	DU13A, DU15A	G	Topsoil
BINB9B	DU13B, DU15B	G	Subsoil
BINB10A	DU14A, DU18A	H	Topsoil
BINB10B	DU14B, DU18B	H	Subsoil

**Table 2 Sample testwork program**

Parameters	No. of samples assessed
Chemical	pH (1:5 water and 1:5 CaCl <sub>2</sub> )
	Electrical conductivity (1:5 water)
	Organic-C (Walkley-Black); Colwell-P and -K; Sulphur-KCl; Nitrate-N and Ammonium-N
	Exchangeable cations (Ca <sup>2+</sup> , Mg <sup>2+</sup> , Na <sup>+</sup> , K) and exchangeable-sodium percentage
	Plant available metals (Cu, Zn, Mn and Fe)
	Total metals (As, Cd, Cr, Cu, Ni, Pb and Zn)
Physical	Particle size distribution
	Coarse particle sieving
	Emerson dispersion test (EDT)
	Modulus of rupture

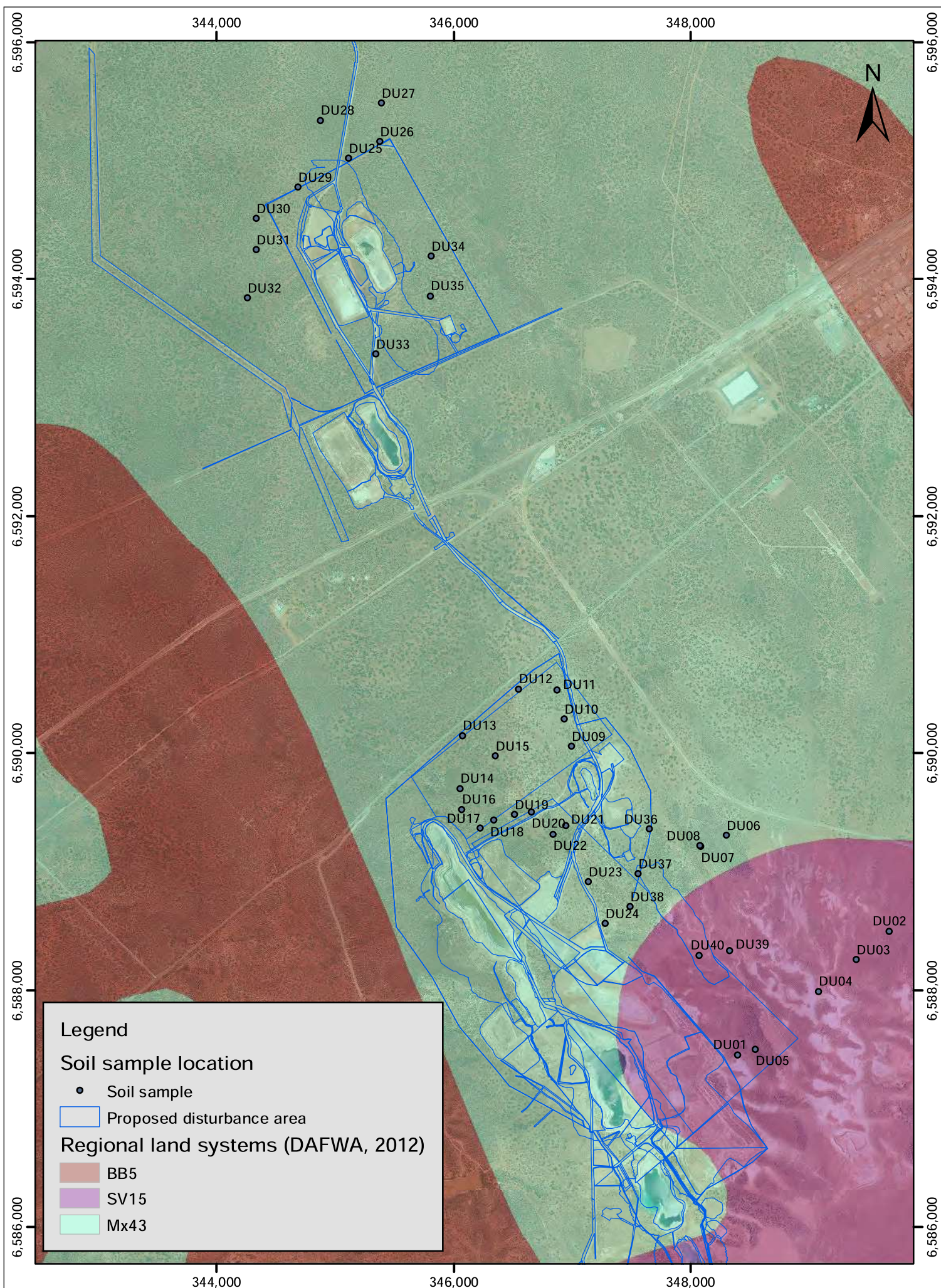
### 3.4 Statistical analysis

Statistical analysis of selected results was undertaken using Principal Components Analysis (PCA). This involved tabulating the results in Excel spreadsheets and then analysing the results using the PRIMER (Version 6) software package. Ordination of the data was performed using PCA to assess similarities between the samples and the soil units. PCA produces a plot on which sites with similar characteristics are located close together, while those with different characteristics are located further apart. Vectors on the plot represent the influence of the different parameters on the data set; the longer the vectors, the greater the influence on the data set. The strength of the PCA results is explained in



terms of percentage variation, a value that should exceed 60% over the first two axes, in order to adequately represent the data set (Clarke & Gorley, 2007).

Minitab was used to perform a One-way Analysis of Variance (ANOVA) on data to determine if selected parameters were significantly different between topsoil and subsoil samples (p values of  $<0.05$  were considered significant, at a confidence interval of  $\alpha = 0.05$ ).





## 4 RESULTS AND DISCUSSION

The results from the mapping and sampling program, the laboratory analyses (physical and chemical) (Appendix C, bulk samples only) and the statistical analysis (Appendix D), are presented in this section.

### 4.1 Soil units and descriptions

Based on field observation of the landscape, imagery, and the soil field and laboratory data information it was determined that there were eight main soil units within the study area (Table 3). The main soil units identified at the Project included flat sand plains, gravelly flat sand plains, undulating upper plains, undulating plain, shallow dunes and alluvial plains with drainage channels

A map of soil units within the Project area was developed for the northern and southern Project areas and are presented in Figure 6 and Figure 7. Two soil units (A and B) dominated the northern Project area. In contrast a number of different soil units occurred within the southern Project area, with the majority of the southern Project area being dominated by soil unit F.

**Table 3 Description of soil units within the Project.**

Soil unit	Description	Key soil characteristics	Bulk sample ID.*	% of proposed disturbance area
A Flat sand plain (Plate 1)	0-10 cm, dark reddish brown, loamy sand/sandy loam, 0% gravels. 10-50/70 cm red, sandy clay loam/clay loam, 0% gravels, carbonate coatings at depth.	Deep, red loamy soil with no gravels.	BINB1A, BINB1B, BINB2A, BINB2B	23%
B Gravelly flat plain (Plate 2)	0-10/20 cm, red, loamy sand, single grain, loose, 0% gravels. 10-40 cm, red, sandy loam/sandy clay loam, massive, firm, 0% gravels. 40-50 cm, red, sandy clay loam, massive, 50% gravels, carbonate coats on gravels.	Moderately deep, red, loam soil with gravels in the lower subsoil.	BINB3A, BINB3B,	4%
C Undulating upper plain (Plate 3)	0-10/15 cm reddish brown, sandy loam, weak subangular block or single grain, 5-30% gravels. 10- 50 cm brown, sandy clay loam, 50-80% gravels and cobbles (sometimes this horizon does not exist and soil directly overlies substrate).	Moderately deep, brown, sandy clay loam with many gravels and cobbles in the subsoil.	BINB4A, BINB4B, BINB5A, BINB5B	13%
D Undulating plain (Plate 7)	0-15/20 cm brown, sandy loam, weak subangular blocky, 5-30% gravels and cobbles. 15-25 cm brown, sandy loam/sandy clay loam, massive 50-70% gravels and cobbles.	Shallow, brown, sandy loam/sandy clay loam with many gravels and cobbles throughout.	BINB6A, BINB6B	3%
E Dune (Plate 4)	0-15/20 cm brownish red, sand, single grain, very weak, 0% gravels. 15-45 cm reddish brown, sandy clay loam, massive, very firm, 0% gravels.	Shallow, reddish brown sand over sandy clay loam with no gravels.	BINB7A, BINB7B	0% (this unit did not intercept the proposed

Soil unit	Description	Key soil characteristics	Bulk sample ID.*	% of proposed disturbance area
				disturbance area)
F Alluvial plain (Plate 5)	Alluvial plain, with drainage channels (DU01, DU04) and surrounding salt flats (DU39, DU40), and in some areas islands of isolated remnant low rises (DU05).  0-15/20 cm brownish red, sand/sandy loam, single grain, weak, 0% gravels. 15-35/40 cm dark reddish brown, sandy loam, massive, weak, 0% gravels. 35-85+ cm blueish grey, clay, massive, sticky, 0% gravels.	Shallow, salty, reddish brown sandy soil over blueish grey clay.	BINB8A, BINB8B	49%
G Gentle slope (Plate 6)	0-10 cm yellowish red fine sandy loam weak, single grained, 0% gravels. 10-55 cm dark reddish brown clay, strong angular and blocky, 0% gravels.	Shallow yellowish red fine sandy loam over dark reddish brown clay.	BIN9A, BIN9B	1%
H Flat plain (Plate 8)	0-10 cm red sandy loam, weak, sub-angular blocky, firm, 10% gravels. 10-30 cm red sandy loam, single grained, 40% gravels.	Shallow red sandy loam over gravelly sandy loam.	BIN10A, BIN10B	6%

\* A = topsoil sample, B = subsoil sample



**Plate 1** Soil pit from Soil unit A (DU28)



**Plate 2** Soil pit from Soil unit B (DU35)





**Plate 3** Soil pit from Soil unit C (DU10)



**Plate 4** Soil pit from Soil unit E (DU02)



**Plate 5** Soil pit from Soil unit F (DU40)



**Plate 6** Soil pit from soil unit G (DU15)



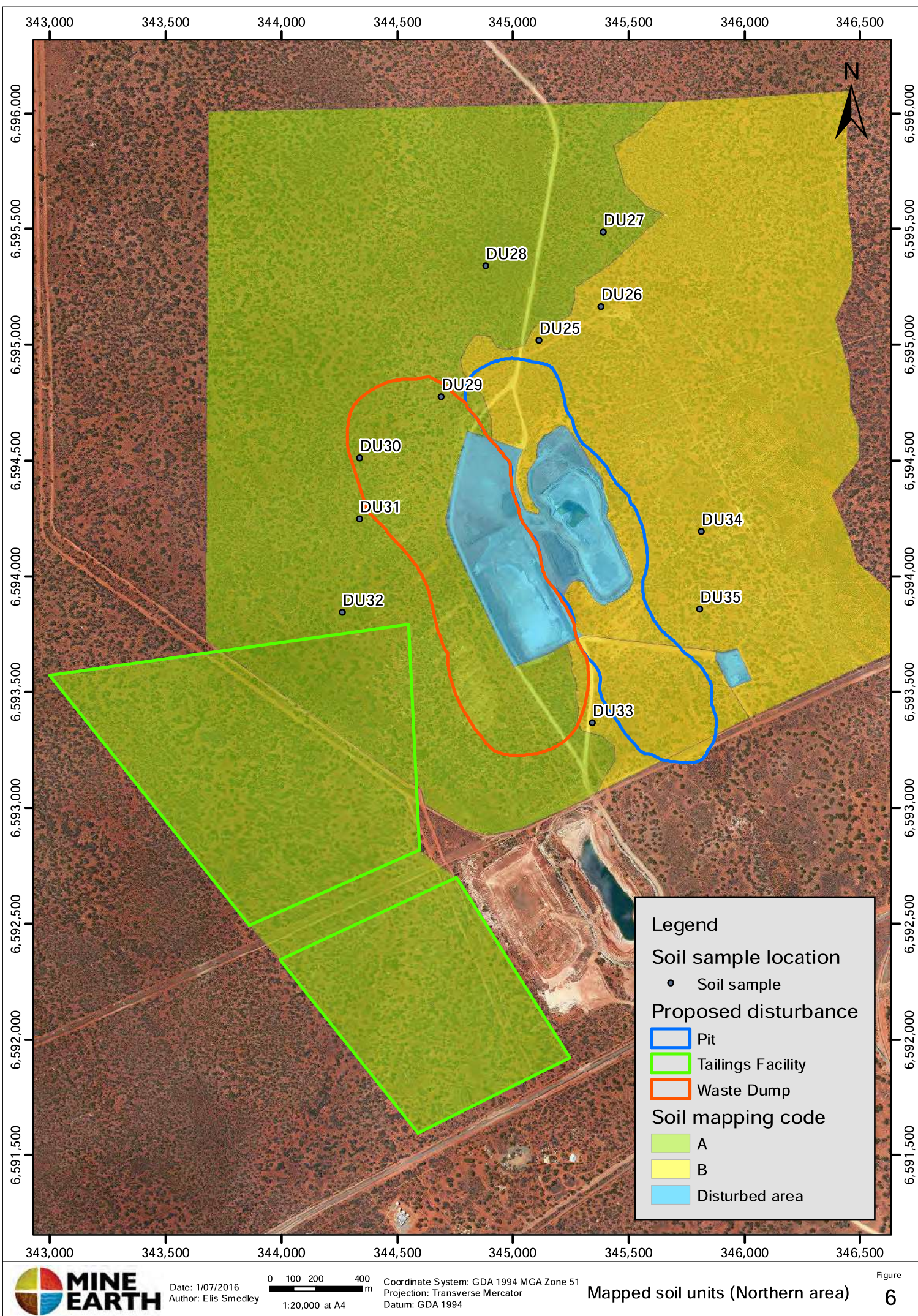


**Plate 7 Soil pit from Soil unit D (DU08)**

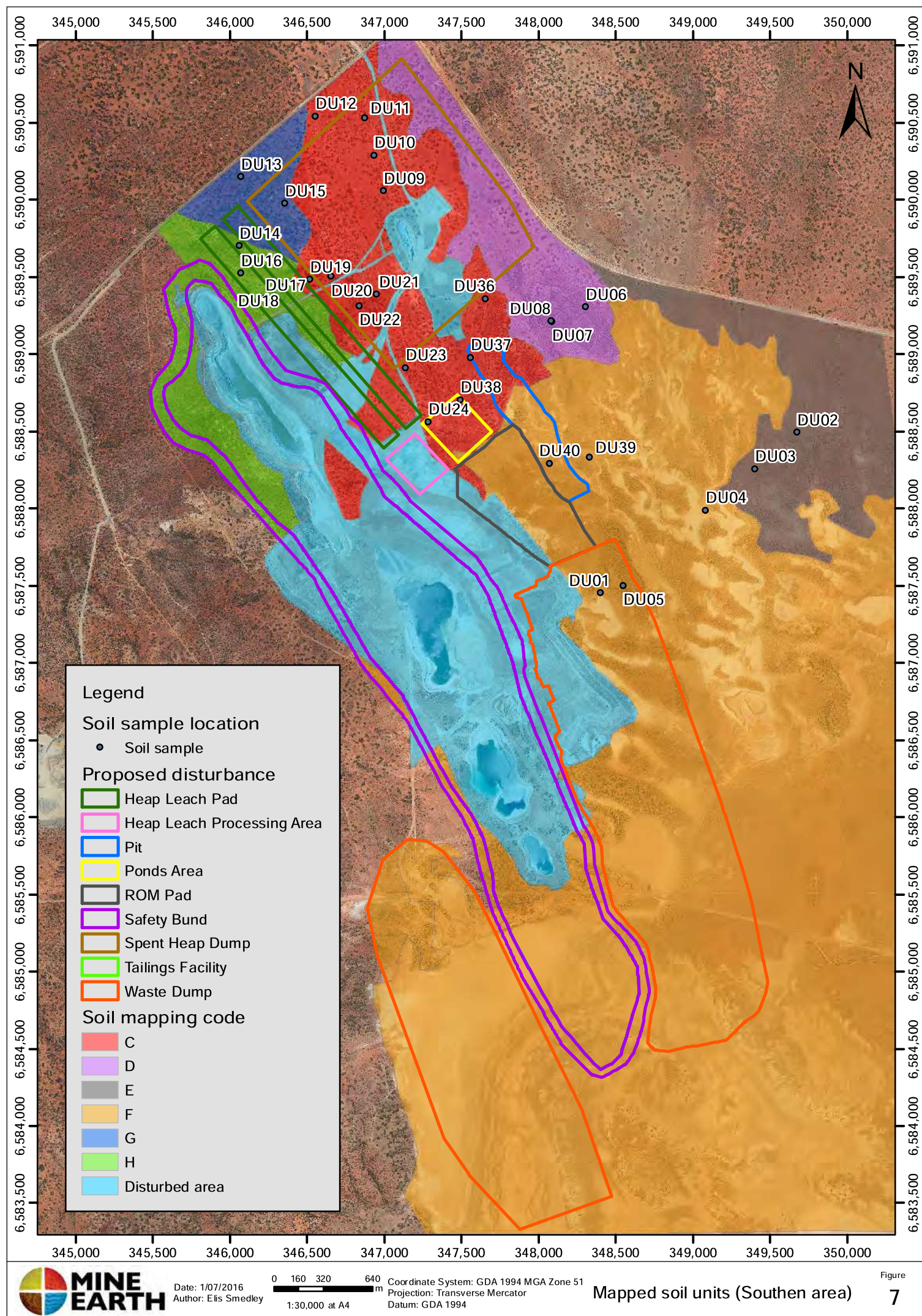


**Plate 8 Soil pit from Soil unit H (DU14)**







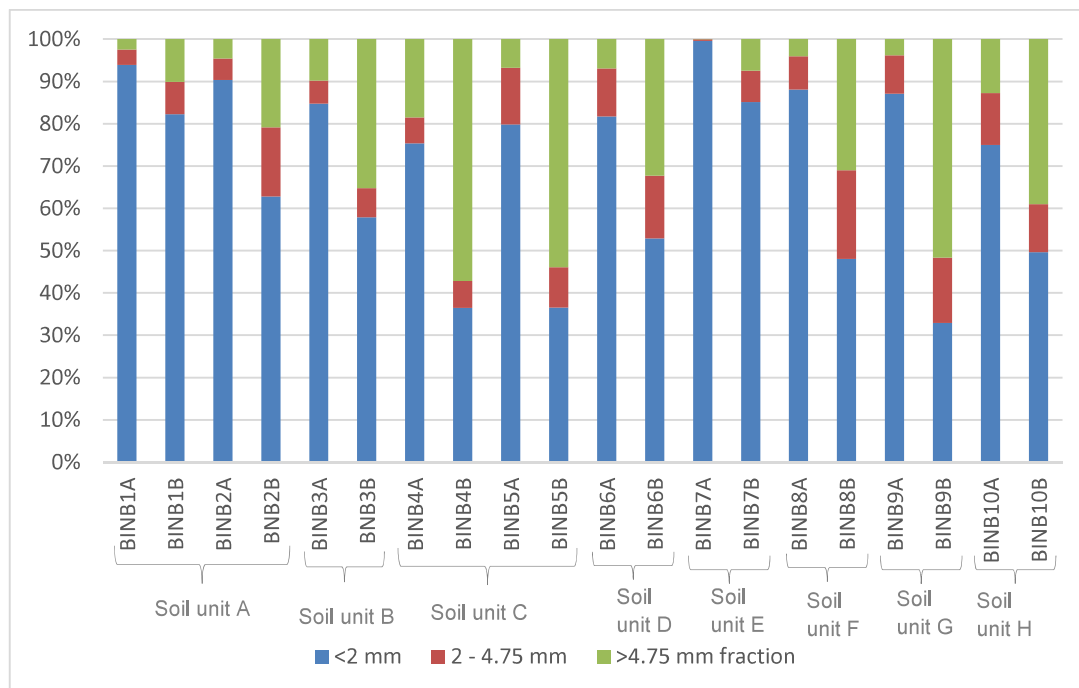




## 4.2 Physical characteristics

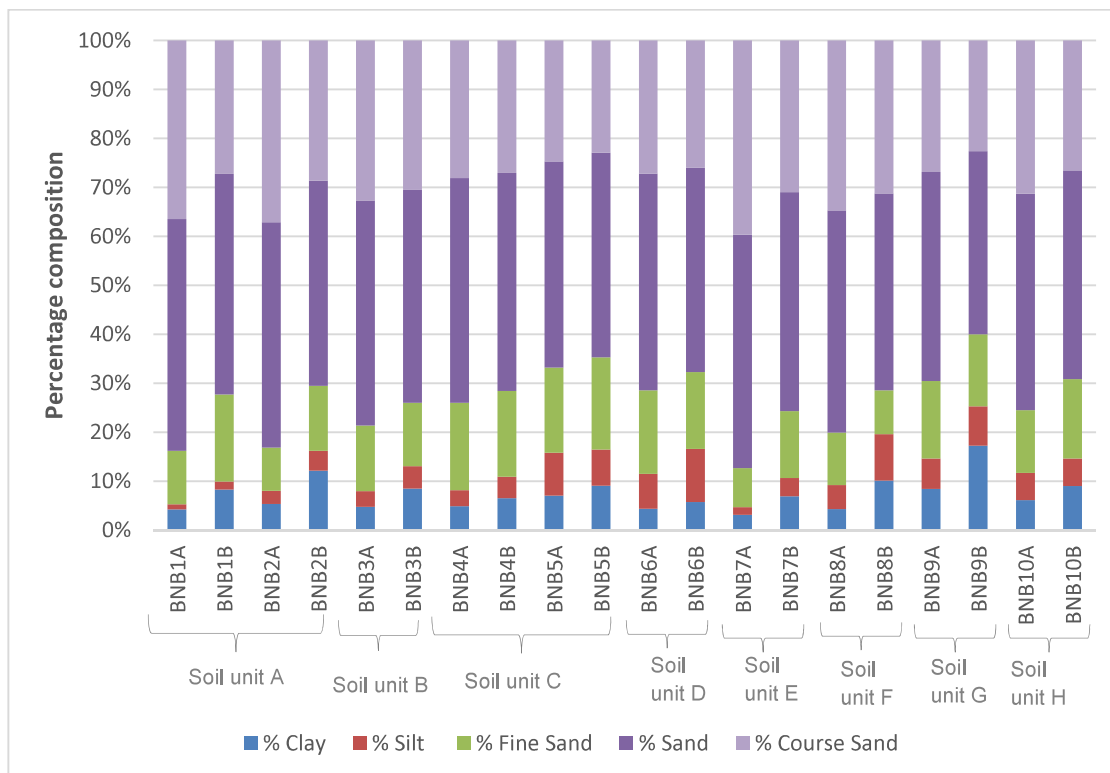
### 4.2.1 Particle size distribution

Most samples were dominated by the <2 mm fraction of soil (Figure 8). Throughout and within the soil units there was variation in regards to coarse particle size distribution. Soil unit E was dominated by the <2 mm fraction with minimal proportions of coarser material. Other soil units such as C, G and H typically contained a greater proportion of >4.75 mm and 2-4.75 mm soil fraction, particularly in the subsoil samples. Across all samples, subsoils contained a greater proportion of coarse fragments, and there were significant differences (i.e.  $p < 0.05$ ) in coarse PSD between topsoil and subsoil samples (Appendix D).



**Figure 8 Particle size distribution for the whole soil sample, showing the <2mm, 2 - 4.75 mm and >4.75 mm fractions, and grouped by soil units.**

The percentages of clay, silt and sand in the <2 mm fraction as measured by CSBP laboratories (Figure 9) (Appendix C) were used to determine soil texture on a soil texture triangle. Of the topsoil samples, BNB1A (soil unit A) and BNB7A (soil unit E) were classed as sand, with the remaining samples being either loamy sand or sandy loam. Of the subsoil samples, BNB2B and BNB9B (both from soil unit A) were classed as sandy clay loam whilst the remaining samples were sandy loam. All <2 mm fraction samples analysed were dominated by the coarse sand fraction. The topsoil samples contained significantly lower concentrations of clay and greater concentrations of coarse sand and sand in comparison to the subsoil samples.



**Figure 9 Particle size distribution of the <2 mm fraction, grouped by soil units**

#### 4.2.2 Emerson dispersion test

The Emerson dispersion test measures the slaking potential and dispersive properties of soil aggregates to determine potential erodibility. All of the samples tested displayed a degree of slaking (Table 4).

A wide degree of variability in dispersion existed between the samples. Samples from soil unit A (BNB2), soil unit E (BNB7 subsoil), soil unit F (BNB8 subsoil) and soil unit G (BNB9 topsoil) were highly dispersive. This dispersion indicates that all of these samples have the potential to be structurally unstable (Hazelton & Murphy, 2007). Partially dispersive samples were reported from soil unit A (topsoil sample BNB1), soil unit B (BNB3) and soil unit E (topsoil sample BNB7A). Non-dispersive soils were recorded from soil unit A (subsoil sample BNB1), soil unit C (all samples), soil unit D (subsoil sample BNB6), soil unit G (subsoil sample BNB9) and soil unit H (subsoil sample BNB10). There were no clear trends between soil units or between topsoil and subsoil layers.

Although the subsoil sample of soil unit F was classed as highly dispersive (Table 4), the <2mm fraction of this sample accounted for less than 50% of the sample. Given that this sample contained a considerable proportion of the 2 – 4.75 mm and >4.75 mm fraction (Figure 8), dispersion is less likely to be an issue in soil from this soil unit.

The “fizz” rating indicates the likely presence of carbonates (Appendix C) (Table 4). The subsoil samples tended to display a stronger fizz in comparison to the topsoil samples. Subsoil samples from soil unit A (BNB1 and BNB2), soil unit B (BNB3), soil unit C (BNB4) and soil unit G (BNB9) all had a very strong reaction, indicating the likely presence of carbonates in the samples. Carbonates tend to act as a cementing agent, and can restrict dispersion somewhat. However, stockpiling of soil can result in the leaching of carbonates and therefore result in soil structural decline (Barre, Biggs, & Sharp, 2004).



**Table 4 EDT results and inferred structural stability**

Unit	Sample ID	Topsoil			Sub soil		
		Emerson class	Inferred structural stability	'Fizz' rating	Emerson class	Inferred structural stability	'Fizz' rating
A Flat sand plain	BNB1	3a/3b	Slaking, partially dispersive	Weak	4	Slaking, non-dispersive	Very strong
	BNB2	3a	Slaking, highly dispersive	Weak	3a	Slaking, highly dispersive	Very strong
B Gravelly flat plain	BNB3	3a/3b	Slaking, partially dispersive	Moderate	3a/3b	Slaking, partially dispersive	Very strong
C Undulating upper plain	BNB4	4	Slaking, non-dispersive	Moderate	4	Slaking, non-dispersive	Very strong
	BNB5	4	Slaking, non-dispersive	Weak-moderate	4	Slaking, non-dispersive	Very strong
D Undulating plain	BNB6	3a	Slaking, partially dispersive	Absent	5	Slaking, non-dispersive	Absent
E Dune	BNB7	3a/3b	Slaking, partially dispersive	Absent	3a	Slaking, highly dispersive	Absent
F Alluvial plain	BNB8	3a	Slaking, Partially dispersive	Absent	3a	Slaking, highly dispersive	Absent
G Gentle slope	BNB9	3a	Slaking, highly dispersive	Absent	4	Slaking, non-dispersive	Very strong
H Flat plain	BNB10	5	Slaking, non-dispersive	Absent	5	Slaking, non-dispersive	Absent

### 4.2.3 Modulus of rupture

The modulus of rupture of each sample was assessed to determine the potential for soil hard-setting. A value >60 kPa has been identified as critical to the identification of soil that would hard-set and restrict root penetration (Cochrane & Aylmore, 2002) if the soil undergoes repeated wetting and drying cycles. None of the samples tested were likely to be prone to hard-setting (Table 5).

**Table 5 Soil strength measured as modulus of rupture**

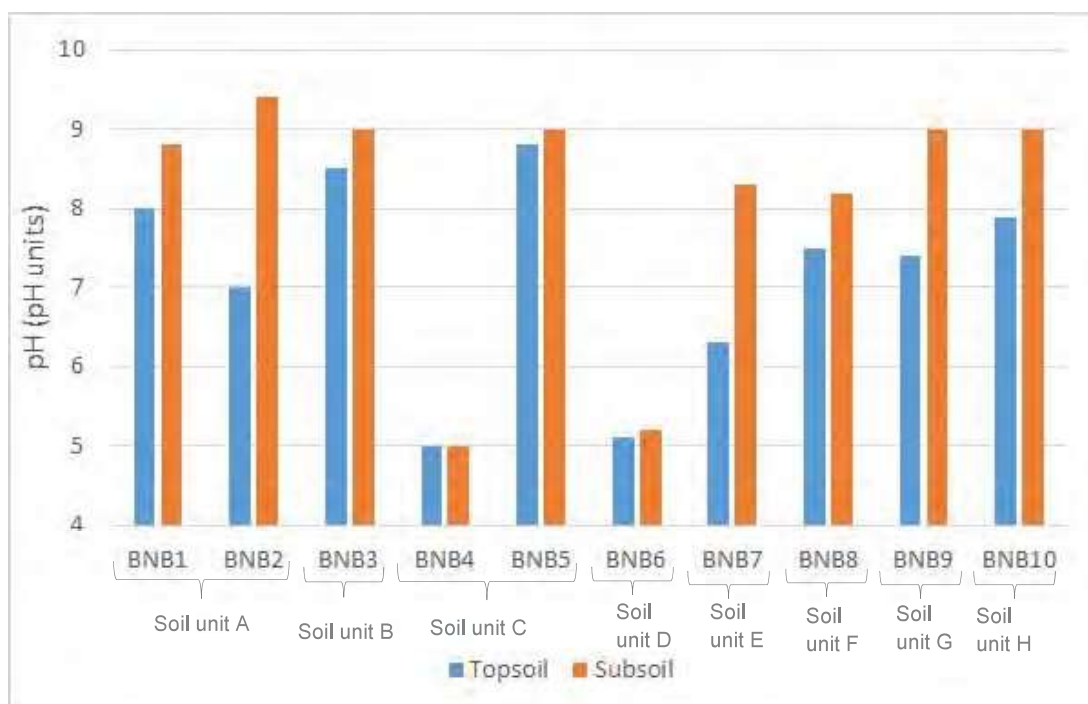
Soil unit	Sample ID	Modulus of rupture (kpa)	
		Topsoil	Subsoil
A Flat sand plain	BNB1	<10	<10
	BNB2	<10	<10 to 10
B Gravelly flat plain	BNB3	<10	<10
C Undulating upper plain	BNB4	<10	<10
	BNB5	<10	<10
D Undulating plain	BNB6	<10	10 to 25
E Dune	BNB7	<10	<10
F Alluvial plain	BNB8	<10	10 to 25
G Gentle slope	BNB9	<10	<10
H Flat plain	BNB10	<10	<10

## 4.3 Chemical characteristics

### 4.3.1 Soil pH

Soil pH was variable throughout the Project area (Figure 10) ranging from very strongly acid (<5) within soil unit C to very strongly alkaline (>9) within soil unit A.

Within all soil units the soil pH was significantly higher in the subsoil samples in comparison to the topsoil samples (Appendix D). An increase in pH throughout the soil profile is common in West Australian soils (Moore, Dolling, Porter, & Leonard, 2004)

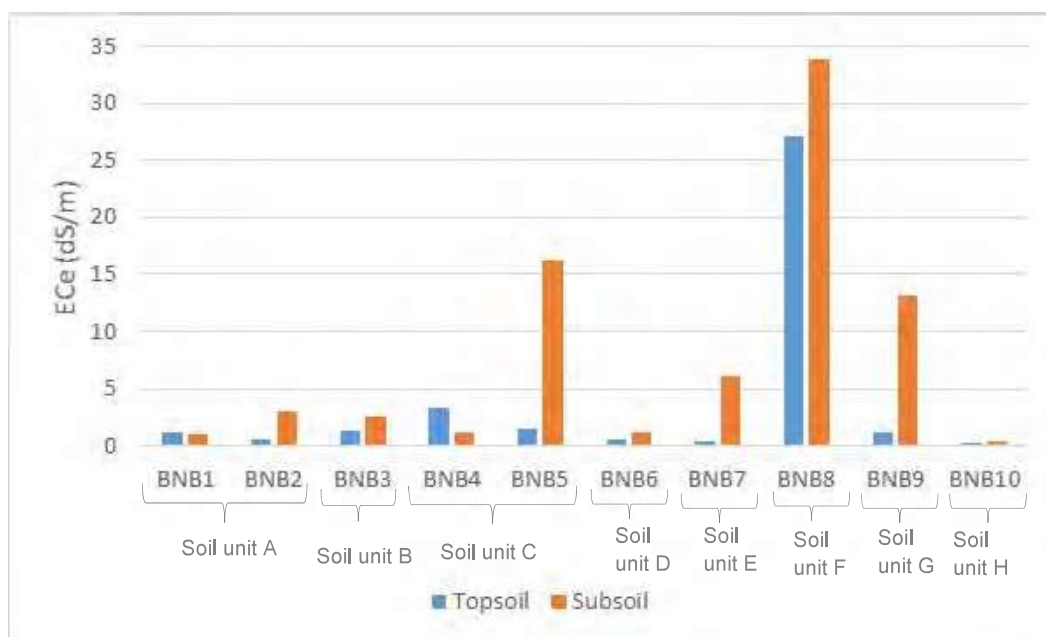


**Figure 10 Soil pH (1:5 soil:water)**

#### 4.3.2 Electrical conductivity

The electrical conductivity (EC) as measured in the laboratory was converted to ECe (EC of a saturated soil extract) using a multiplier factor for each sample based on soil texture (Hazelton and Murphy, 2007) (Figure 11). This measurement was preferred because it approximates the field water content of the soil, producing a measurement that equates more closely to a plant's response (Moore, 2004). All of the topsoil samples were considered non-saline ( $EC_e < 2$  dS/m), with the exception of topsoil for one sample in soil unit C which was considered slightly saline and one topsoil sample within soil unit F that was extremely saline ( $EC_e > 16$  dS/m). All subsoils, except one sample from soil unit C, were significantly higher in salinity in comparison to the corresponding topsoil sample.





**Figure 11 Soil salinity (measured in E<sub>Ce</sub> (dS/m))**

### 4.3.3 Exchangeable cations

Exchangeable cations ( $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Na}^+$ ,  $\text{K}^+$ ), effective cation exchange capacity (eCEC) and exchangeable sodium percentage (ESP) were assessed for each sample (Table 6).

The eCEC reflects the total capacity of the soil to hold and exchange cations, influencing the soil's ability to retain nutrients and provide a buffer against soil acidification (Hazelton and Murphy, 2007). The eCEC for all samples ranged from very low ( $<2 \text{ cmol}(+)/\text{kg}$ ) to moderate ( $12\text{--}25 \text{ cmol}(+)/\text{kg}$ ) (Table 6). This indicates that the soil is likely to lose essential cations via changes in soil chemistry that may occur through movement of the soil. Soil with an eCEC less than three, such as BNB10A, are often low in fertility and susceptible to soil acidification (Hazelton & Murphy, 2007). The eCEC of subsoil samples was significantly higher in comparison to the topsoil samples indicating that the subsoil samples are more likely to retain and exchange cations and be more resistant to soil structural changes (Appendix D).

Proportions of most exchangeable cations fell within the normal ranges for Australian soils (Moore, 2004). Proportions of K exceeded normal ranges (i.e. 3 – 10%) within the majority of samples from soil units (Table 6). Although most of the samples were dominated by Ca, a topsoil sample from soil unit H (BNB10A) was dominated by K, with proportions of Ca considered low in comparison to the other samples.

ESP values are important as this identifies soil which is sodic and therefore prone to structural decline, dispersion and erosion (Hazelton and Murphy, 2007). Samples from soil unit C (BNB5B), soil unit D (BNB6A), soil unit E (BNB7B), soil unit F (BNB8A and BNB8B), soil unit G (BNB9B) and soil unit H (BNB10A) reported an ESP which exceeds 14% and were therefore considered strongly sodic (Table 6). These soils are likely to be prone to severe surface crusting, low infiltration and hydraulic conductivity, severe gully erosion and are also likely to be susceptible to tunnel erosion. Marginally sodic soil was reported at soil unit D (BNB6B), soil unit E (BNB7A), soil unit G (BNB9A) and soil unit H (BNB10B). The remaining samples were classified as non-sodic.

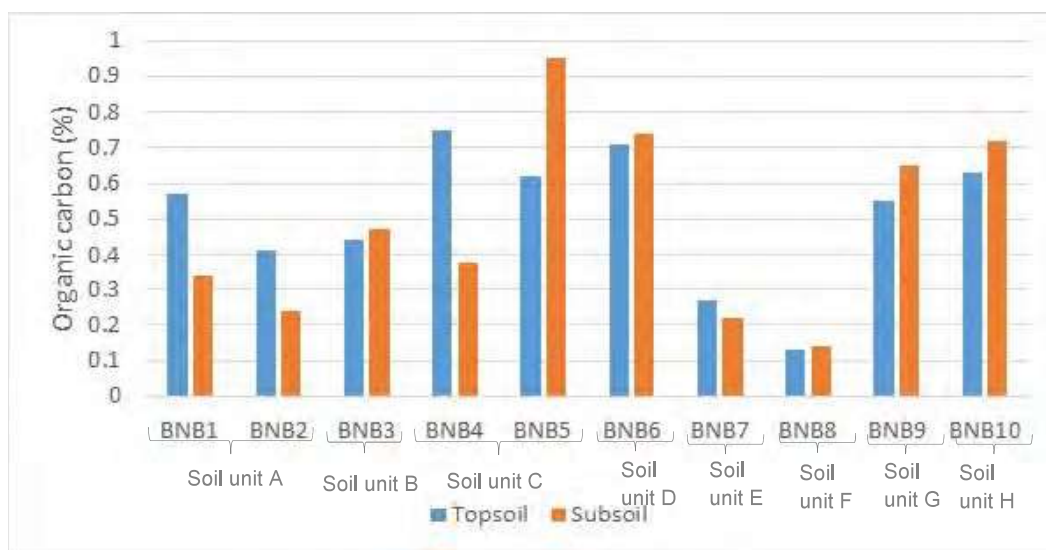
There were no clear differences in terms of ESP and exchangeable cations between topsoil and subsoil samples.

**Table 6 Exchangeable cations and eCEC values for sampled soils**

Soil-landform association	Horizon	Sample ID	Ca <sup>2+</sup>	K <sup>+</sup>	Mg <sup>2+</sup>	ESP	eCEC
				%			cmol(+)/kg
A Flat plain	Topsoil	BNB1A	75.4	8.8	14.7	1.0	10.4
	Subsoil	BNB1B	64.7	11.1	22.3	1.9	17.7
	Topsoil	BNB2A	60	12.3	26	1.7	8
	Subsoil	BNB2B	50.1	11	28.1	10.7	22.3
B Flat plain	Topsoil	BNB3A	70.1	10.3	18.2	1.5	12.1
	Subsoil	BNB3B	61.1	9.4	24.9	4.6	18.9
C Undulating upper plain	Topsoil	BNB4A	68.7	12.1	17.7	1.5	13.6
	Subsoil	BNB4B	56.8	10.4	29.6	3.3	16.8
	Topsoil	BNB5A	51.2	11.1	33.9	3.8	17.5
	Subsoil	BNB5B	44.9	6	33.4	15.8	25
D Undulating plain	Topsoil	BNB6A	36	31.3	16.8	15.9	3.7
	Subsoil	BNB6B	61.4	12.4	16.4	9.8	8.5
E Dune	Topsoil	BNB7A	39.9	23.6	29.5	7.1	3.1
	Subsoil	BNB7B	18.1	11.1	41.3	29.4	19.5
F Alluvial plain	Topsoil	BNB8A	27.5	10.1	40.7	21.7	8.7
	Subsoil	BNB8B	12.8	9.8	50.7	26.7	16.9
G Gentle slope	Topsoil	BNB9A	42.3	14.3	34	9.4	13.3
	Subsoil	BNB9B	41	6.9	33.9	18.2	29
H Flat plain	Topsoil	BNB10A	20.8	45.3	18.1	15.7	2.2
	Subsoil	BNB10B	52	20.3	16.5	11.1	5.4

#### 4.3.4 Organic carbon

Throughout the Project area, organic carbon ranged from low (0.6 to 1.00%) to very low (<0.60%) in both topsoil and subsoil samples (Figure 12). Topsoil and subsoil from soil units E and F were particularly devoid of organic carbon, in comparison to other soil units within the Project area.



**Figure 12 Organic carbon content of the <2 mm soil fraction.**

#### 4.3.5 Soil nutrients and trace elements

Soil nutrient and trace element concentrations were assessed for all samples (Table 7). Results indicated the following:

- In terms of P, concentrations less than 5 mg/kg are considered very low and are common in West Australian soils (Bolland, 2004). The majority of samples tested contained concentrations of P less than 5 mg/kg. Concentrations of P in topsoil samples from BNB4A (soil unit C), BNB7A (soil unit E) and BNB9A (soil unit G) were slightly higher than 5 mg/kg, however were still considered low. Concentrations of P were significantly higher in topsoil samples in comparison to subsoil samples (Appendix D).
- Concentrations of K were medium (70 – 200 mg/kg) (Hazelton & Murphy, 2007) for most samples. Samples from soil unit B (BNB3B), soil unit C (BNB4A, BNB4B, BNB5A) and soil unit E (BNB7B) were considered high.
- Concentrations of S were highly variable throughout the Project; however, S was significantly higher in the subsoil samples in comparison to the topsoil samples (Table 7, Appendix D). Concentrations of S in soil are typically correlated with seasonal conditions and concentrations of organic matter present.
- Plant available nitrogen ( $\text{NO}_3\text{-N}$ ) ranged from <1 mg/kg to 36 mg/kg, however the majority of samples recorded concentrations of  $\text{NO}_3\text{-N}$  that were less than 4 mg/kg. Two subsoil samples from soil unit A (BNB2B) and soil unit G (BNB9B), recorded elevated concentrations of  $\text{NO}_3\text{-N}$ , with respective values of 17 mg/kg and 36 mg/kg.
- Concentrations of trace elements (Cu, Zn, Mn and Fe) were variable throughout the Project. There were no significant differences between concentrations of these trace elements between topsoil and subsoil samples. Unusually high concentrations of Mn were recorded with samples from soil unit C (BNB5A), soil unit E (BNB7B) and soil unit G (BNB9A), however concentrations were below Ecological Investigation Levels (EIL's).



**Table 7 Nutrient and trace element values (available NO<sub>3</sub>-N, NH<sub>4</sub>-N, P, K, and total S) and available metal concentrations (Cu, Zn, Mn, and Fe) in mg/kg**

Soil unit	Horizon	Sample ID	P	K	S	NO <sub>3</sub> -N	NH <sub>4</sub> -N	Cu	Zn	Mn	Fe
A Flat sand plain	Topsoil	BNB1A	3	127	2.3	1	<1	1.4	0.9	60.5	36.3
	Subsoil	BNB1B	<2	142	1.9	1	<1	1.2	0.2	3.5	5.0
	Topsoil	BNB2A	3	149	2.0	<1	1	1.7	0.7	58.9	24.4
	Subsoil	BNB2B	<2	208	28.3	17	<1	1.9	0.2	5.4	5.4
B Gravelly flat plain	Topsoil	BNB3A	3	158	1.6	<1	<1	2.0	0.8	71.5	20.4
	Subsoil	BNB3B	<2	216	10.2	8	<1	1.9	0.3	7.8	4.5
C Undulating upper plain	Topsoil	BNB4A	8	307	47.1	4	2	1.3	0.7	17.9	7.1
	Subsoil	BNB4B	<2	224	7.0	1	<1	1.9	0.5	4.0	3.5
	Topsoil	BNB5A	5	263	5.3	1	<1	3.1	1.0	165.8	24.0
	Subsoil	BNB5B	3	162	107.2	1	<1	2.1	0.3	4.7	3.8
D Undulating plain	Topsoil	BNB6A	3	126	8.8	3	3	0.9	0.5	6.6	17.9
	Subsoil	BNB6B	2	76	46.0	2	4	0.8	0.4	7.2	26.4
E Dune	Topsoil	BNB7A	7	109	2.5	<1	<1	1.2	1.9	107.	22.7
	Subsoil	BNB7B	<2	206	40.1	<1	<1	3.3	2.0	247.8	31.0
F Alluvial plain	Topsoil	BNB8A	4	120	83.1	<1	<1	1.4	1.1	80.4	22.8
	Subsoil	BNB8B	2	134	260.1	<1	<1	1.8	2.1	86.1	27.2
G Gentle slope	Topsoil	BNB9A	7	279	2.5	4	2	2.4	1.3	140.1	25.7
	Subsoil	BNB9B	2	189	225.0	36	<1	1.8	0.4	6.7	5.8
H Flat plain	Topsoil	BNB10A	<2	92	8.5	2	2	1.4	0.5	2.4	17.1
	Subsoil	BNB10B	2	80	12.8	1	2	1.1	0.8	6.4	31.0

#### 4.3.6 Total metals

Total metals were measured to provide baseline concentrations in samples prior to mining (Table 8). Concentrations of Pb, Zn and As were highest in the subsoil sample from soil unit F (BNB8B). Concentrations of most total metals were below EIL's. However, concentrations of Ni within some samples, exceeded the EIL of Ni (60 ppm), but this was likely to be representative of natural conditions within the Project area.

**Table 8 Total metal concentrations (As, Cd, Cr, Cu, Ni, Pb ad Zn) in ppm**

Soil unit	Horizon	Sample ID	As	Cd	Cr	Cu	Ni	Pb	Zn
A Flat sand plain	Topsoil	BNB1A	15.5	0.03	455	16.6	55.5	7.9	22
	Subsoil	BNB1B	8.3	0.03	412	19	53.6	7.6	23
	Topsoil	BNB2A	12	<0.02	462	14.6	54	8.1	22
	Subsoil	BNB2B	7.4	<0.02	358	25.6	69.3	9.7	29
B Gravelly flat plain	Topsoil	BNB3A	12.4	0.02	549	17.1	<b>64.2</b>	10.6	29
	Subsoil	BNB3B	7.1	0.03	365	22.2	<b>62.3</b>	9.7	32
C Undulating upper plain	Topsoil	BNB4A	10.1	0.04	538	20.5	<b>61.9</b>	11.6	35
	Subsoil	BNB4B	6.7	0.04	390	26	55.3	10.9	31
	Topsoil	BNB5A	10.9	0.08	409	29	59.5	16.8	46
	Subsoil	BNB5B	8.9	0.07	250	41.1	54.1	14.9	42
D Undulating plain	Topsoil	BNB6A	7.7	0.02	300	16.6	46.9	12.1	35
	Subsoil	BNB6B	5.4	<0.02	138	13.7	36.7	11.7	32
E Dune	Topsoil	BNB7A	10.2	0.04	372	14.5	44.6	7.4	33
	Subsoil	BNB7B	9.1	0.09	301	34.7	<b>77</b>	11.9	62
F Alluvial plain	Topsoil	BNB8A	16.4	0.07	510	19.1	42.1	13	34
	Subsoil	BNB8B	23	0.04	370	32.5	51.2	24.8	73
G Gentle slope	Topsoil	BNB9A	12.3	0.07	533	22.1	<b>77.9</b>	13.2	37
	Subsoil	BNB9B	11.1	0.05	408	28.9	<b>79.6</b>	13.1	42
H Flat plain	Topsoil	BNB10A	12.4	0.02	448	19	50.4	16.4	27
	Subsoil	BNB10B	9.8	<0.02	301	17.9	49.1	18.9	30

#### 4.4 Summary of results

A summary of the characteristics of each of the soil units is provided in (Table 9). The results of the statistical analysis is also discussed in this section.

**Table 9 Summary of the physical and chemical properties of soil units**

Soil unit	Horizon	Coarse PSD	Fine PSD	Dispersion	Hardsetting	pH	EC	Nutrients and OC	ESP	Total metals
A Flat sand plain	Topsoil	Dominated by less than 2 mm fraction	Sand to sandy loam	Partially to highly dispersive	Not likely	Slightly acid to mildly alkaline	Non-saline	Low	Non-sodic to marginally sodic	Low
	Subsoil	Dominated by less than 2 mm fraction	Sandy loam to sandy clay loam	Non-dispersive to highly dispersive	Not likely	Moderately to strongly alkaline	Non-saline to slightly saline	Low	Non-sodic to strongly sodic	Low
B Gravelly flat plain	Topsoil	Dominated by less than 2 mm fraction	Loamy sand	Partially dispersive	Not likely	Very strongly acid to moderately alkaline	Non-saline	Low	Non-sodic to strongly sodic	Low
	Subsoil	Dominated by less than 2 mm fraction	Sandy loam	Partially dispersive	Not likely	Very strongly acid to strongly alkaline	Slightly saline	Low	Non-sodic to marginally sodic	Low
C Undulating upper plain	Topsoil	Dominated by less than 2 mm fraction	Loamy sand and sandy loam	Non-dispersive	Not likely	Mildly alkaline to moderate alkaline	Non-saline to slightly saline	Low	Non-sodic	Low
	Subsoil	Dominated by the >4.75 mm fraction	Sandy loam	Non-dispersive	Not likely	Strongly alkaline	Non-saline to extremely saline	Low	Non-sodic to strongly sodic	Low
D Undulating plain	Topsoil	Dominated by less than 2 mm fraction	Loamy sand	Partially dispersive	Not likely	Very strongly acid	Non-saline	Low	Strongly sodic	Low
	Subsoil	Dominated by less than 2 mm fraction	Sandy loam	Non-dispersive	Not likely	Very strongly acid	Non-saline	Low	Marginally sodic	Low
E Dune	Topsoil	Dominated by less than 2 mm fraction	Sand	Partially dispersive	Not likely	Moderately acidic	Non-saline	Low	Marginally sodic	Low



Soil unit	Horizon	Coarse PSD	Fine PSD	Dispersion	Hardsetting	pH	EC	Nutrients and OC	ESP	Total metals
F Alluvial plain	Subsoil	Dominated by less than 2 mm fraction	Sandy loam	Highly dispersive	Not likely	Mildly alkaline	Moderately saline	Low	Strongly sodic	Low
	Topsoil	Dominated by less than 2 mm fraction	Loamy sand	Partially dispersive	Not likely	Neutral	Extremely saline	Low	Strongly sodic	Low
	Subsoil	Dominated by less than 2 mm fraction	Sandy loam	Highly dispersive	Not likely	Mildly alkaline	Extremely saline	Low	Strongly sodic	Slightly elevated
G Gentle dune	Topsoil	Dominated by less than 2 mm fraction	Sandy loam	Highly dispersive	Not likely	Neutral	Non-saline	Low	Marginally sodic	Low
	Subsoil	Dominated by the greater than 4.75 mm fraction	Sandy clay loam	Non-dispersive	Not likely	Strongly alkaline	Highly saline	Low to moderate	Strongly sodic	Low
H Flat plain	Topsoil	Dominated by less than 2 mm fraction	Sandy loam	Non-dispersive	Not likely	Very strongly acid	Non-saline	Low	Strongly sodic	Low
	Subsoil	Dominated by less than 2 mm fraction	Sandy loam	Non-dispersive	Not likely	Very strongly acid	Non-saline	Low	Marginally sodic	Low

#### 4.4.1 Comparison between topsoil and subsoil

Principal components analysis (PCA) was completed on laboratory data for pH, EC, concentrations of nutrients, and metals (Figure 13). With the exception of two samples (one from soil unit H [BNB10A] and one from soil unit D [BNB6A]), the topsoil and subsoil samples were typically distinct from each other and they may have separate management requirements:

- Subsoil samples typically reported greater concentrations of Ca, NO<sub>2</sub>-N and a more alkaline pH in comparison to topsoil samples.
- There was also greater variation between the subsoil samples in comparison to the topsoil samples as depicted by the spread of subsoil samples across the plot.

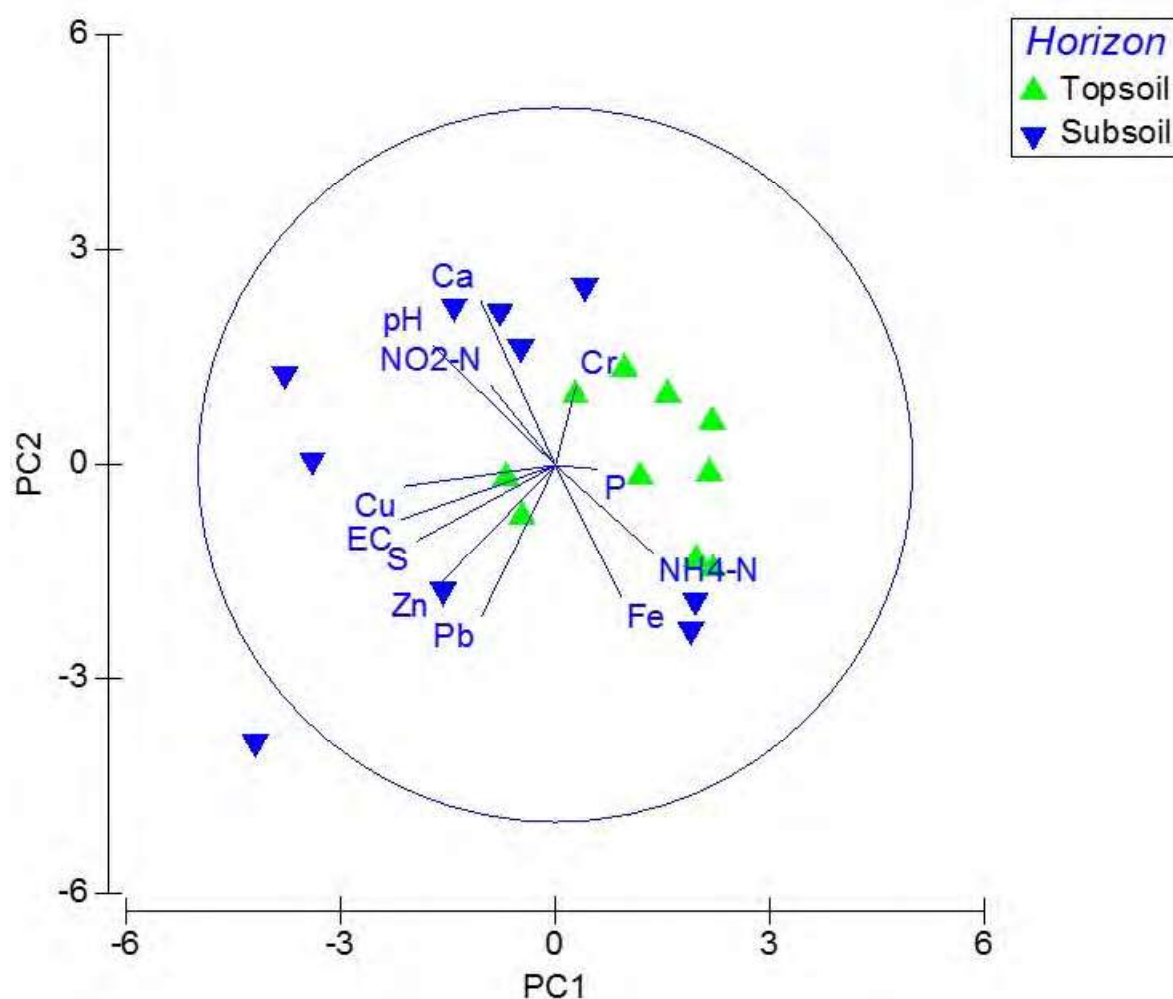
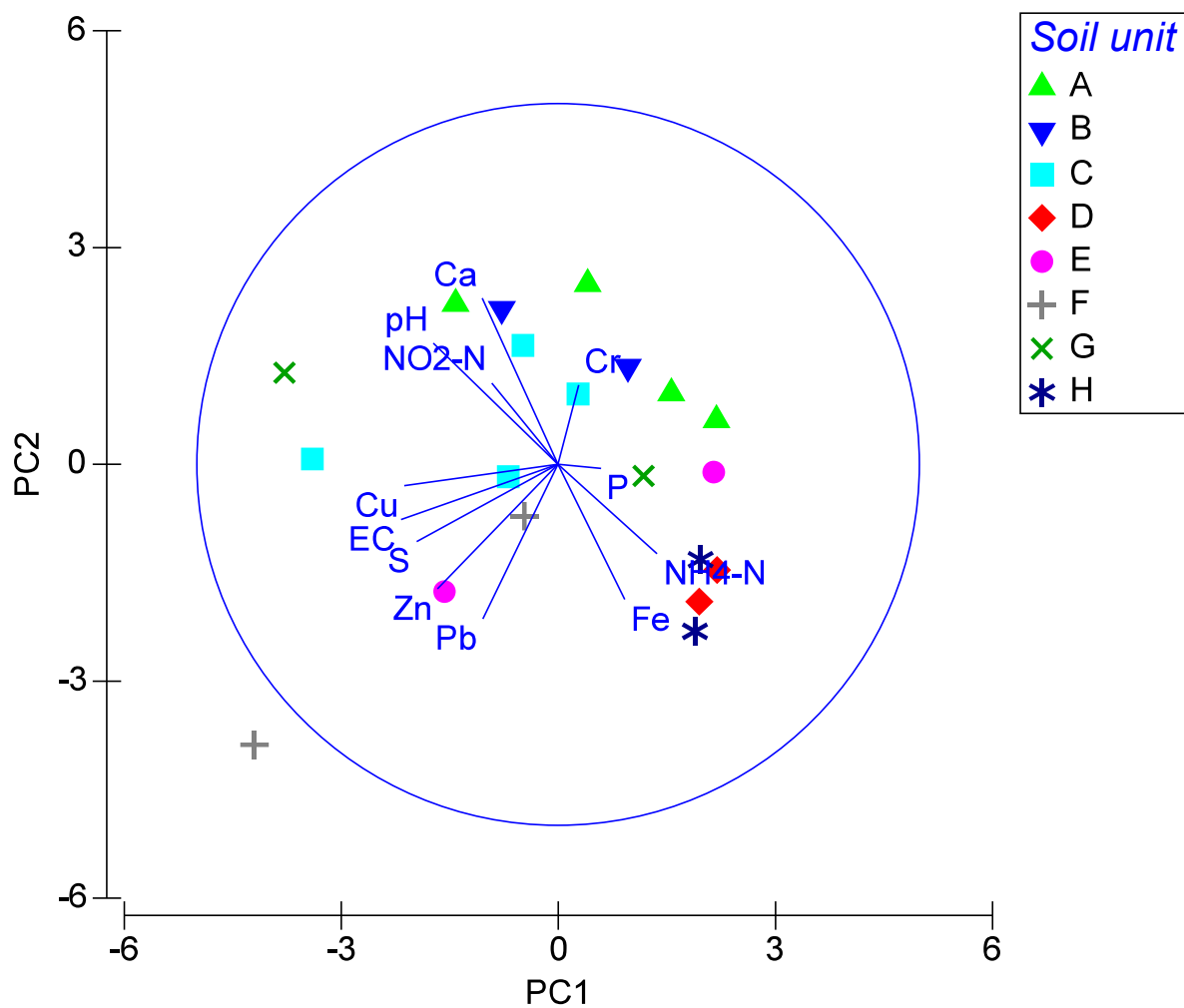


Figure 13 PCA plot of selected parameters groups according to the soil horizon

#### 4.4.2 Comparison between soil units

There were no clear trends in terms of similarities between soil units apparent from the PCA (Figure 14). However, soil units D and H were similar and typically had higher concentrations of Fe and NH<sub>4</sub>-N in comparison to the other soil units. There was considerable variation both within and between all other

soil units. This may be due in part to the distinct differences between soil horizon as depicted in Figure 13.



**Figure 14** PCA plot of selected soil parameters grouped according to soil unit



## 5 SOIL RESOURCES INVENTORY

This section discusses the suitability of soil resources and the requirements for topsoil for use in rehabilitation activities.

### 5.1 Suitability of soil resources

The suitability of each soil unit for use as a rehabilitation resource based on the physical and chemical properties of the unit is discussed in Table 10. This is also presented in Figure 15.

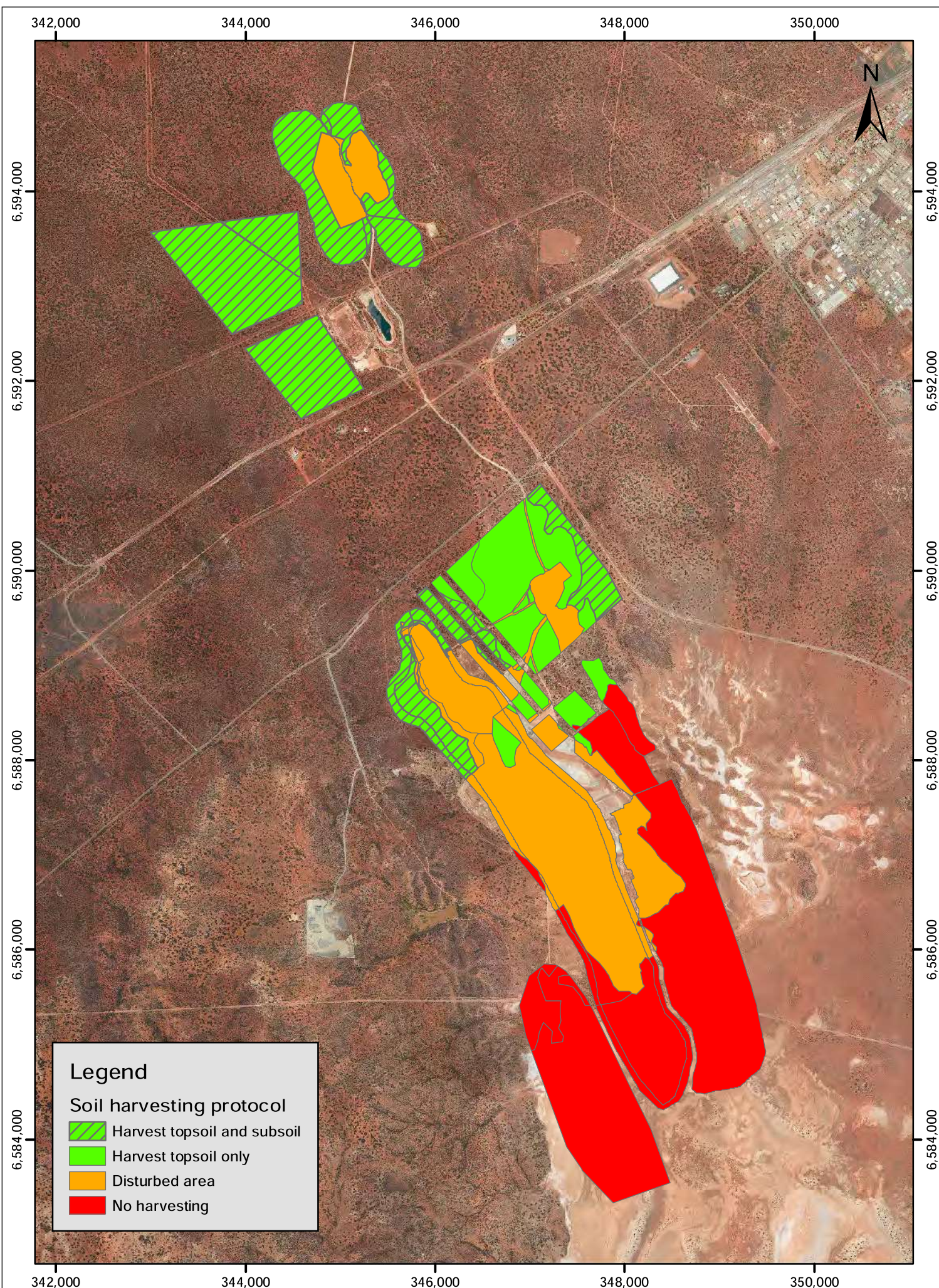
**Table 10 Suitability of soil for use in rehabilitation activities**

Soil unit	Horizon	Suitable for rehabilitation activities (Y/N)	Comment
A Flat sand plain	Topsoil	Y	Dispersion was an issue in some samples.
	Subsoil	Y	
B Gravelly flat plain	Topsoil	Y	Samples were sodic and had an acidic pH.
	Subsoil	Y	
C Undulating upper plain	Topsoil	Y	Mildly alkaline and slightly saline.
	Subsoil	N	Samples very saline and sodic.
D Undulating plain	Topsoil	Y	Samples were partially dispersive, acidic and sodic.
	Subsoil	Y	
E Dune	Topsoil	Y	Sandy, acidic and marginally sodic
	Subsoil	N	Highly dispersive, moderately saline, strongly sodic
F Alluvial plain	Topsoil	N	Highly dispersive, extremely saline and strongly sodic
	Subsoil	N	
G Gentle Dune	Topsoil	Y	Samples were highly dispersive and marginally sodic.
	Subsoil	N	Samples were highly saline
H Flat plain	Topsoil	Y	Samples were sodic and had an acidic pH.
	Subsoil	Y	

It is recommended that subsoil from soil units C, E, and G and topsoil and subsoil from soil unit F should not be preserved for rehabilitation activities, due mainly to elevated salinity.

Due to the differing management requirements of the soil units they should be stockpiled separately. Where it is recommended that subsoil (soil unit A, B D and H) be collected, these could be stockpiled with the associated topsoil.







## 5.2 Soil resource balance

A soil resources inventory for the Project was calculated based on current projected disturbance areas, an estimate of potential topsoil recovery and recommendations for soil usage as described in Section 5.1. These calculations were based on a number of assumptions:

- No topsoil will be placed between the open pit and abandonment bund.
- All disturbed areas are to have topsoil applied to a depth of 150 mm.
- Topsoil can be recovered to a depth of 150 mm except for soil units A, B, D and H. For these units it is recommended that subsoil is also collected. The subsoil depths for each unit were 300 mm, 400 mm, 250 mm and 400 mm respectively.
- There will be no topsoil recovery from areas identified as existing disturbance (i.e. major disturbance areas as inferred from aerial photography).
- There will be no topsoil collected from soil unit F as it is unsuitable for use in rehabilitation activities.
- A recovery loss of 10% has been applied to account for erosion, handling losses, access restrictions and soil recovery restrictions.

Based on these assumptions it was estimated that:

- Approximately 1,445,024 m<sup>3</sup> of soil would be recovered from Project disturbance areas.
- Approximately 1,566,468 m<sup>3</sup> of soil will be required for rehabilitation of all Project disturbance areas.
- This equates to a topsoil deficit of 121,443 m<sup>3</sup>.

## 6 SOIL HANDLING AND MANAGEMENT RECOMMENDATIONS

Effective soil handling and management practices are critical for revegetation success. Recommendations for harvesting, storing and managing Project soil resources are provided below.

### 6.1 Harvesting topsoil

Topsoil should be stripped to a maximum depth of 150 mm as the native species seed bank and most of the biological activity occurs in the top 100 mm of the soil profile (Van Gorp & Erskine, 2011). Given the likely topsoil deficit, additional volumes may be able to be harvested from areas where the soil extends deeper than 150 mm.

With the exceptions of subsoil from soil units A (up to 300 mm), B (up to 400 mm), D (up to 250 mm) and H, (up to 400 mm) subsoils should not be retained for rehabilitation activities.

To preserve the integrity of soil as much as practicable, topsoil should only be stripped and moved during dry conditions (Golos & Dixon, 2014).

### 6.2 Soil storage

Direct placement of topsoil on rehabilitated areas is the most effective in terms of maximising rehabilitation success (Van Etten, McCullough, & Lund, 2012). Stockpiling of topsoil can result in increased bulk density, decreased water holding capacity, chemical changes, reduced nutrient cycling, reduced microbial activity, and loss or reduction of viable plant remnants (Ngugi, et al., 2015). The seed bank of topsoil stockpiles is also diminished by storage due to anaerobic conditions within the stockpile resulting from increased moisture and decomposing vegetation (Golos & Dixon, 2014).

The duration of soil storage can also be a factor to revegetation success. Recent studies have shown that the seed bank decline is minimal after one year, but significant after two years (i.e. a 50% decline in the seed bank viability was reported between year one and two). This is particularly apparent for grass species such *Eriachne* (Golos & Dixon, 2014). This study also reported that dry storage of topsoil can result in an approximately 3.5 times larger germinable seed bank.

The Mine Closure Plan guidelines (DMP and EPA, 2015) recommend the following in relation to soil storage:

- Use stockpiled topsoil as soon as feasible, to reduce the time the topsoil is stored.
- Cover topsoil (e.g. through the use of tarpaulins, erosion control matting or geotextiles) to maintain topsoil in a dry state.
- Design stockpiles that have a height greater than 2 m (to reduce the amount of moisture in the stockpile).
- Design stockpiles to optimise run-off from the stockpiles.

These recommendations may not be suitable for the Project and Mine Earth recommend the following where feasible:

- Topsoil stockpiles should be paddocked dumped or pushed up into windrows.
- Vegetation removed during clearing should be track rolled through the soil.
- Provenance native seed should be applied to topsoil stockpile if possible.



### **6.3 Amelioration of stockpiled soil**

In terms of the topsoil resource at the Project, there are a number of factors that may require management prior to its use in rehabilitation activities. The low pH of soils may impact the ability of vegetation to germinate as a pH range of 5.5 to 7.0 is typically required for germination. Stockpiling of topsoils may contribute to an increase in pH (Golos & Dixon, 2014), but acidic soils are still likely to prevail. Acidity may be managed with the addition of lime.

Given the low plant available nitrogen within the soil samples, it is likely that a high nitrogen and low phosphorus slow release fertiliser will be required to increase concentrations of plant available N in stockpiled topsoil.

It is recommended that the topsoil stockpiles are assessed to determine their pH status prior to their use for rehabilitation activities. This will allow for the assessment of whether the addition of lime is required. During this time, the nutrient status should also be assessed to determine the fertiliser requirements of the stockpiled topsoil.

Sodicity is likely to be a problem for a number of soil units across the Project area. Sodicity can be amended by the use of gypsum.

If feasible, rehabilitation trials assessing plant growth and germination versus soil treatments (addition of lime and fertiliser) are recommended. In addition, it is recommended that Norton implement a seed collection programme to ensure that the provenance seed store for the Project is sufficient for rehabilitation activities. It is likely that the seed collection program will need to be implemented over numerous seasons to collect sufficient quantities of seed.

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## APPENDIX A

### **Sample site descriptions**



Sample ID	Date Collected	Easting	Northing	Horizon	Sample Depth (top - bottom)	Matrix Colour	Texture	Rock Fragments (%)	Rock Fragment size	Structure grade	Structure type	Consistence	Comments
DU01	24/2/16	348402	6587454	C1	0-20cm	Dark reddish brown	Sand	0	n/a		Single grained	Very weak	Moist salt crusting on surface, salt bush vegetation. Edge of dune adjacent to lake
DU01	24/2/16			C2	20-40cm	Dark reddish brown	Clay	0	n/a		Single grained	Weak	Sticky
DU01	24/2/16			2C	40-85cm	Blueish white	Clay	0	n/a		Massive	Weak	
DU02	24/2/16	349680	6588495	A1	0-15cm	Brownish red	Sand	0	n/a	Weak	Subangular blocky	Very weak	No gravel, shrubs and small trees, surface dune
DU02	24/2/16			C	15-40cm	Brownish red	Sand	0	n/a		Single grained	Loose	
DU02	24/2/16			2C	40-45cm	Darkish brown	Sandy clay loam	0	n/a		Massive	Very firm	Not sampled
DU03	24/2/16	349404	6588258	A1	0-18cm	Red	Sand	0	n/a		Single grained	Weak	Dune, shrubs. 5mm surface crust, no surface gravel
DU03	24/2/16			2C	18-25cm	Reddish brown	Sandy clay loam	0	n/a		Massive	Very firm	As per layer 3 on DU02

Sample ID	Date Collected	Easting	Northing	Horizon	Sample Depth (top - bottom)	Matrix Colour	Texture	Rock Fragments (%)	Rock Fragment size	Structure grade	Structure type	Consistence	Comments
DU04	24/2/16	349082	6587989	C1	0-20cm	Reddish brown	Sand	0	n/a		Single grained	Weak	Salty drainage area, foot of dunes. Patches of salt bush. Salt efflorescences
DU04	24/2/16			C2	20-30cm	Dark reddish brown	Sandy clay loam	0	n/a		Massive	Firm	
DU04	24/2/16			2C	30-35+ cm	Blueish grey	Light clay	0	n/a		Massive	Very firm	Distinct yellow mottles
DU05	24/2/16	348551	6587499	A1	0-20cm	Brownish red	Sand	0	n/a		Single grained	Loose	Shoulder of dune. Small-medium trees (Acacia and mallees). Gravel and cobbles on surface. Surface partially sealed.
DU05	24/2/16			C	20-35cm	Red	Sand	65	2-60mm and 60-200mm		Single grained	N/a	Many cobbles. Towards crest cobbles become shallower - exposed on crest
DU06	24/2/16	348307	6589306	A1	0-10cm	Brown	Loamy sand	30	2-60mm and 60-200mm		Subangular blocky to single grained	Firm	Boulders, stones and cobbles on ??? Shrubs, few roots. Rocky ridgeline. Skeletal soils.

Sample ID	Date Collected	Easting	Northing	Horizon	Sample Depth (top - bottom)	Matrix Colour	Texture	Rock Fragments (%)	Rock Fragment size	Structure grade	Structure type	Consistence	Comments
DU06	24/2/16	348088	6589212	C	10- 20cm	Brown	Loamy sand	65	2- 60mm, 60- 200mm and 200- 600mm		Single grained	N/a	Mostly stones (200- 600mm) on top. NOT SAMPLED
DU07	24/2/16	348088	6589212	A2	0-15cm	Brown	Sandy loam	25	2-60- mm	Moderat e	Subangular blocky	Firm	Small trees and shrubs. Sealed surface crust. Rocky ridge
DU07	24/2/16			B	15- 22cm	Reddish brown	Sandy clay loam	10	2- 60mm and 60- 200mm		Single grained	N/a	
DU08	24/2/16	348084	6589215	A1	0-18cm	Reddish brown	Sandy loam	10	2- 60mm	Weak	Subangular blocky	Firm	Smal trees and shrubs, sealed surface. Shoulder to midslope of rocky ridge
DU08	24/2/16			B	18- 25cm	Brown	Sandy loam	60	2- 60mm and 60- 200mm		Single grained	N/a	
DU09	25/2/16	346999	6590058	A1	0-15cm	Reddish brown	Sandy loam	5	2- 60mm	Weak	Subangular blocky	Weak	Shrubs, small trees, roots to 100mm. 15% gravel on

Sample ID	Date Collected	Easting	Northing	Horizon	Sample Depth (top - bottom)	Matrix Colour	Texture	Rock Fragments (%)	Rock Fragment size	Structure grade	Structure type	Consistence	Comments
DU09	25/2/16			B	15- 50cm	Dark reddish brown	Sandy clay loam	40	2- 60mm and 60- 200mm		Single grained	Weak	surface, sealed, some trash.
DU10	25/2/16	346938	6590288	A1	0-20cm	Brown	Sandy loam	30	2- 60mm		Single grained	Weak	Surface gravel and cobble 15%. Low ris 1.5% slope. Moss coverage on surface. Fine roots to 25cm. Thin surface crust.
DU10	25/2/16			B	20- 50cm	Reddish brown	Sandy clay loam	60	2- 60mm and 60- 200mm		Single grained	N/a	
DU11	25/2/16	346877	6590529	A1	0-15cm	Red	Loamy sand	5	2- 60mm		Single grained	Very weak	Low hill, some trees. 60% gravel at surface
DU11	25/2/16			C	15- 30cm	Red	Loamy sand	70			Single grained	N/a	platy sedimentary rock
DU12	25/2/16	346555	6590542	A1	0-15cm	Reddish brown	Sandy loam	20	2- 60mm		Single grained	Firm	Shrubs and grasses. 5% surface gravel. Moss coverage. Mid-upper slope
DU12	25/2/16			B	15- 40cm	Brown	Sandy loam	80	2- 60mm		Single grained	N/a	



Sample ID	Date Collected	Easting	Northing	Horizon	Sample Depth (top - bottom)	Matrix Colour	Texture	Rock Fragments (%)	Rock Fragment size	Structure grade	Structure type	Consistence	Comments
DU13	25/2/16	346075	6590148	A1	0-10cm	Yellowish Red	Fine loam	0	n/a		Single grained	Weak	No surface gravel. Partial moss coverage. Shrubs and trees. Gentle slope
DU13	25/2/16			B	10-55cm	Dark reddish brown	Clay	0	2-60mm	Strong	Angular blocky	Strong	
DU14	25/2/16	346060	6589701	A1	0-10cm	Red	Sandy loam	10	2-60mm	Weak	Subangular blocky to single grained	Firm	Flat plain. Gravel, cobbles and stones ~60%. Weak thin crust. Tall shrubs
DU14	25/2/16			B	10-30cm	Red	Sandy loam	40	2-60mm and 60-200mm		Single grained	N/a	Rock fragments increase with depth to stones
DU15	25/2/16	346358	6589976	A1	0-10cm	Yellowish Red	Loamy sand	0	n/a		Single grained	Weak	Patches of fine gravel on surface ~15%. Gentle slope
DU15	25/2/16			B1	10-25cm	Reddish dark brown	Sandy loam	0	n/a	Structure -less	Angular blocky	Very firm	

Sample ID	Date Collected	Easting	Northing	Horizon	Sample Depth (top - bottom)	Matrix Colour	Texture	Rock Fragments (%)	Rock Fragment size	Structure grade	Structure type	Consistence	Comments
DU15	25/2/16			B2	25-50cm	Dark reddish brown	Clay	0	n/a	Structure -less	Subangular blocky	Strong	
DU16	25/2/16	346073	6589524	A1	0-10cm	Reddish brown	Fine loam	0	n/a	Weak	Single grained	Very weak	Minimal gravel on surface. Small shrubs. Medium roots to 100mm. Flat plain - flood out area. Small patches of moss on surface.
DU16	25/2/16			B	10-40cm	Brown	Loamy sand	80	2-60mm and 60-200mm		Single grained	N/a	
DU17	25/2/16	346228	6589364	A1	0-10cm	Yellowish Red		0	n/a	Weak	Subangular blocky	Weak	Sealed surface, no gravel. Medium trees, shrubs. Flat plain.
DU17	25/2/16			B1	10-45cm	Reddish brown	Sandy loam	5	2-60mm		Massive	Very firm	
DU17	25/2/16			B2	45-50cm	Reddish brown	Sandy loam	40	2-60mm		Massive	Very firm	

Sample ID	Date Collected	Easting	Northing	Horizon	Sample Depth (top - bottom)	Matrix Colour	Texture	Rock Fragments (%)	Rock Fragment size	Structure grade	Structure type	Consistence	Comments
DU18	25/2/16	346341	6589433	A1	0-6cm	Reddish brown	Sandy loam	5	2-60mm		Massive to single grained	Firm	
DU18	25/2/16			B/C	6-30cm	Reddish brown	Loamy sand	75	2-60mm, 60-200mm and 200-600mm	Structure -less	n/a	n/a	
DU19	25/2/16	346521	6589483	A1	0-10cm	Brown	Sandy loam	5		Moderate	Angular blocky to single grained	Firm	Surface gravel and cobbles ~20%, small shrubs and medium trees. Lower slope.
DU19	25/2/16			C	10-30cm	Brown	Sandy loam	80	2-60mm, 60-200mm and 200-600mm		Single grained	N/a	Platy sedimentary cobbles and stones

Sample ID	Date Collected	Easting	Northing	Horizon	Sample Depth (top - bottom)	Matrix Colour	Texture	Rock Fragments (%)	Rock Fragment size	Structure grade	Structure type	Consistence	Comments
DU20	25/2/16	346657	6589504	A1	0-10cm	Yellowish red???	Sandy clay loam	0	2-60mm	Moderate	Subangular blocky	Firm	Drainage line. Surface crust with cracking in places.
DU20	25/2/16			B	10-50cm	Red	Sandy clay loam	0	n/a		Single grained	Firm	Sealed surface. Med roots to 200mm. Small trees and shrubs.
DU21	25/2/16	346949	6589390	A1	0-12cm	Reddish brown	Fine sandy loam	0	n/a		Single grained	Firm	
DU21	25/2/16			B2	12-45cm	Dark reddish brown	Sandy loam	0	n/a	Moderate	Subangular blocky	Very firm	
DU21	25/2/16			C	45-60cm	Dark reddish brown	Light clay	0	n/a				Underlying sedimentary rock
DU22	25/2/16	346840	6589312	A1	0-18cm	Brown	Sandy loam	0	n/a		Single grained	Firm	Medium trees, shrubs. Sealed to crusted surface. Lower plain.
DU22	25/2/16			B	18-40cm	Dark reddish brown	Light clay	0	n/a	Structure less	Angular blocky	Very firm	Carbonate segregations?



Sample ID	Date Collected	Easting	Northing	Horizon	Sample Depth (top - bottom)	Matrix Colour	Texture	Rock Fragments (%)	Rock Fragment size	Structure grade	Structure type	Consistence	Comments
DU22	25/2/16			C	40- 50cm			0	n/a	Structure less - weak			Platy sedimentary rock
DU23	25/2/16	347138	6588913	A1	0-18cm	Brown	Loam	10	2- 60mm		Subangular blocky to single grained	Firm	Drainage washout. Slight surface crust, some lichen
DU23	25/2/16			B	18- 40cm	Brown	Sandy loam	10	2- 60mm	Structure less	Massive to single grained	Firm	
DU23	25/2/16			C									Platy sedimentary rock
DU24	25/2/16	347286	6588562	A1	0-18cm	Brown	Sandy loam	5	2- 60mm		Single grained	Weak	Drainage washout, surface crusting. Mallee, medium trees and shrubs. Fine roots to 200mm
DU24	25/2/16			B/C	18- 50cm	Brown	Sandy loam	80	2- 60mm and 60- 200mm		Single grained		Crumbles away, stony at depth

Sample ID	Date Collected	Easting	Northing	Horizon	Sample Depth (top - bottom)	Matrix Colour	Texture	Rock Fragments (%)	Rock Fragment size	Structure grade	Structure type	Consistence	Comments
<b>DU24</b>	25/2/16				50- 60cm								Platy sedimentary rock
<b>DU25</b>	25/2/16	345115	6595019	A1	0-10cm	Red	Loamy sand	0	n/a		Single grained	Weak	Spinifex, small-medium trees, fine roots, flat plain
<b>DU25</b>	25/2/16			B2-1	10- 40cm	Red	Fine sandy loam	0	n/a		Massive to single grained	Firm	
<b>DU25</b>	25/2/16			B2-2	40- 50cm	Red	Sandy loam	50	2- 60mm and 60- 200mm		Single grained		Apparent carbonate coating of gravel
<b>DU26</b>	25/2/16	345383	6595163	A1	0-20cm	Red	Fine sandy loam	0	n/a		Single grained	Weak	Low rise. Spinifex, small trees. Thin weak crust. Abundant very fine roots
<b>DU26</b>	25/2/16			B2	20- 45cm	Red	Sandy clay loam	0	n/a		Massive	Strong	
<b>DU26</b>	25/2/16			B2-2	45- 50cm	Red	Sandy clay loam	50	2- 60mm			Strong	Gravels

Sample ID	Date Collected	Easting	Northing	Horizon	Sample Depth (top - bottom)	Matrix Colour	Texture	Rock Fragments (%)	Rock Fragment size	Structure grade	Structure type	Consistence	Comments
DU27	25/2/16	345393	6595486	A1	0-10cm	Red	Loamy sand	0	n/a	Weak	Subangular blocky to single grained	Weak	Surface crusting. Spinifex, small-medium trees, plain.
DU27	25/2/16			B2-1	10-55cm	Red	Sandy clay loam	0	n/a		Massive single grained	Firm	
DU27	25/2/16			B2-2	55-70cm	Dark reddish brown	Clay	0	n/a		massive	Rigid	
DU27	25/2/16			B/C	70+cm								Gravelly sand
DU28	25/2/16	344883	6595340	A1	0-18cm	Red	Loamy sand	0	n/a		Single grained	Loose	Spinifex, shrubs, medium trees. Loose surface, smooth. Plain
DU28	25/2/16			B2-1	19-50cm	Red	Sandy loam	0	n/a		Single grained	Strong	
DU28	25/2/16			B2-2	50-70cm	Red	Sandy clay loam	0	n/a		Massive single grained	Rigid	10% carbonate segregations

Sample ID	Date Collected	Easting	Northing	Horizon	Sample Depth (top - bottom)	Matrix Colour	Texture	Rock Fragments (%)	Rock Fragment size	Structure grade	Structure type	Consistence	Comments
DU29	25/2/16	344690	6594775	A1	0-15cm	Red	Loamy fine sand	0	n/a		Single grained	Very weak	Plain. Firm, thin crust. Shrubs. Smooth surface
DU29	25/2/16			B2-1	15-50cm	Red	Sandy loam	0	n/a		Massive	Very firm	
DU29	25/2/16			B2-2	50-60cm	Dark red	Sandy clay loam	0	n/a		Massive	Rigid	10% carbonate nodules
DU30	25/2/16	344341	6594509	A1	0-15cm	Red	Loamy sand	0	n/a		Single grained	Very weak	Roots to 100mm
DU30	25/2/16			B2-1	15-50cm	Red	Sandy clay loam	0	n/a		Massive	Very firm	Plain. Thin crust, smooth surface. Small-medium trees, spinifex.
DU30	25/2/16			B2-2	50-65cm	Reddish brown	Clay	0	n/a		Massive	Very strong	Minor carbonate assemblage
DU31	25/2/16	344340	6594247	A1	0-15cm	Dark reddish brown	Fine loamy sand	0	n/a		Single grained	Very weak	Small-medium trees, spinifex, weak crust on surface, smooth. Increased litter on ground. Shallow slope
DU31	25/2/16			B2-1	15-55cm	Red	Sandy clay loam	0	n/a		Massive	Very strong	



Sample ID	Date Collected	Easting	Northing	Horizon	Sample Depth (top - bottom)	Matrix Colour	Texture	Rock Fragments (%)	Rock Fragment size	Structure grade	Structure type	Consistence	Comments
DU32	25/2/16	344265	6593843	A1	0-15cm	Dark reddish brown	Sandy loam	0	n/a	Weak	Subangular blocky	Firm	Medium trees. Smooth surface with leaf and twig litter. Medium roots to 150mm.
DU32	25/2/16			B2-1	15-70cm	Dark reddish brown	Sandy loam	0	n/a		Massive	Very strong	Minor carbonates at depth
DU33	25/2/16	345346	6593365	A1	0-12cm	Reddish brown	Sandy loam	0	n/a	Weak	Subangular to blocky single grained	Weak	Small-medium trees, sealed, firm surface, gentle slope
DU33	25/2/16			B2-1	12-30cm	Reddish brown	Sandy loam	0	2-60mm		Single grained	na	Carbonate coatings
DU34	25/2/16	345816	6594193	A1	0-10cm	Reddish brown	Sandy loam	20	2-60mm and 60-200mm		Single grained	Very weak	Cobbles and stones on surface ~35%. Small bushes. Very few large roots. Low rise, top appears scalped off
DU34	25/2/16			B2	10-20cm	Reddish brown	Fine loamy sand	80	2-60mm, 60-200mm		Single grained	N/a	Gravels, cobbles and stones covered in carbonates.

Sample ID	Date Collected	Easting	Northing	Horizon	Sample Depth (top - bottom)	Matrix Colour	Texture	Rock Fragments (%)	Rock Fragment size	Structure grade	Structure type	Consistence	Comments
and 200- 600mm													
DU35	25/2/16	345810	6593858	A1	0-10cm	Reddish brown	Loamy sand	0	n/a		Single grained	Weak	Medium trees. Leaf, bark and twig litter. Gentle slope.
DU35	25/2/16			B2-1	10- 40cm	Reddish brown	Sandy clay loam	0	n/a	Weak	Subangular blocky	Firm	
DU36	26/2/16	347656	6589360	B2-1	0-18cm	Brown	Sandyloam	20	2- 60mm and 60- 200mm	Moderate	Subangular blocky	Firm	Small-medium shrubs, sealed surface (almost hardset). Gravel and cobbles 25%. Shoulder of a low rise
DU36	26/2/16			B2	18- 35cm	Greyish brown	Sandy clay loam	50			Single grained	Firm	Carbonate coating on the gravels
DU37	26/2/16	347558	6588978	A1	0-15cm	Brown	Sandy clay loam	15	2- 60mm	Moderate	Subangular blocky	Very firm	Small shrubs. Hard surface, sealed, almost hardsetting. Quartz gravel 10%, patchy. Step on a broader slope
DU37	26/2/16			B2	15- 35cm	Greyish brown	Loam	60	2- 60mm		Single grained	N/a	Gravels and cobbles covered by carbonate

Sample ID	Date Collected	Easting	Northing	Horizon	Sample Depth (top - bottom)	Matrix Colour	Texture	Rock Fragments (%)	Rock Fragment size	Structure grade	Structure type	Consistence	Comments
													and 60-200mm
DU38	26/2/16	347496	6588704	A1	0-15cm	Reddish brown	Sandy loam	10	2-60mm	Weak	Subangular blocky	Very firm	Lower slope, coarse sand/fine gravel on surface. Small shrubs, occasional tree. Softer than DU36 and 37.
DU38	26/2/16			B2	15-25cm	Dark reddish brown	Light clay	40	2-60mm and 60-200mm		Single grained	N/a	
DU39	26/2/16	348334	6588330	A1	0-15cm	Greyish brown	Sandy loam	0	n/a		Massive to single grained	Firm	Drainage line, salt bush. Salt efflorescences. Superficial cracking on surface. Lots of water channels. Cracking clays in troughs. Mounds accumulated around vegetation - Napka
DU39	26/2/16			B	15-40cm	Dark reddish brown	Light clay	0	n/a	Weak	Subangular blocky	Very firm	
DU39	26/2/16			C	40+cm	Dark reddish brown		50	2-60mm				Nearby stream channel indicates likely to be top of rock.
DU40	26/2/16	348073	6588292	A1	0-10cm	Yellowish brown	Loamy sand	0	n/a		Single grained	Firm	Salt flats. Salt bush. Cracking clays on surface -

Sample ID	Date Collected	Easting	Northing	Horizon	Sample Depth (top - bottom)	Matrix Colour	Texture	Rock Fragments (%)	Rock Fragment size	Structure grade	Structure type	Consistence	Comments
DU40	26/2/16			B	10- 30cm	Dark reddish brown	Sandy clay loam	0	n/a	Weak	Subangular blocky	Very firm	skin only. Napka around vegetation. <1% quartz gravel on surface



## APPENDIX B

### **Description and relevance of laboratory analyses**

## Soil laboratory analysis and methods

Soil parameter	Method
Coarse fragment screening (>2 mm fraction)	Dry sieve
Particle size distribution (clay, silt, fine sand, coarse sand)	Indorante <i>et al.</i> , 1990
Emerson test (Soil slaking and dispersion) , including presence of carbonates	Emerson, 2002
Modulus of rupture	Aylmore and Sills, 1982; Harper and Gilkes, 1994
pH 1:5 soil:water	Method 4A1 in Rayment and Lyons, 2011
pH 1:5 soil:CaCl <sub>2</sub>	Method 4B1 in Rayment and Lyons, 2011
EC 1:5 soil:water	Method 3A1 in Rayment and Lyons, 2011
Exchangeable cations (Ca <sup>2+</sup> , Mg <sup>2+</sup> , Na <sup>+</sup> , K <sup>+</sup> ) and eCEC	Method 15B2 in Rayment and Lyons, 2011
Organic carbon (Walkley Black)	Method 6A1 in Rayment and Lyons, 2011
Available phosphorous (Colwell-P)	Method 9B in Rayment and Lyons, 2011
Available potassium (K)	Method 18A1 in Rayment and Lyons, 2011
Available sulphur (S)	Method 10D1 in Rayment and Lyons, 2011
Available nitrate (NO <sub>3</sub> ) and ammonium (NH <sub>4</sub> -N)	Method 7C2b in Rayment and Lyons, 2011
Available metals (Cu, Zn, Mn, Fe)	Method 12A1 in Rayment and Lyons, 2011

### Coarse fragment screening (>2 mm fraction)

The coarse fragment screening determines the relative proportion of soil fraction as opposed to rock. The soil fraction is important as it provides a growth media for vegetation and improves the water holding capacity of the topsoil. The coarse fraction can enhance stability of the topsoil.

### Particle size distribution

Particle size distribution provides information on the proportion of sand, silt, clay and coarse fragments in a soil sample. The nature and proportion of particles can influence soil properties and how the soil behaves in terms of transmitting water, holding water, storing and releasing nutrients, soil stability and susceptibility to erosion.

### Emerson test

Structural stability was determined using the Emerson test to measure the slaking potential and dispersive properties of soil aggregates under a worst case scenario. Soil aggregates that slake and disperse can indicate that the soil aggregate structure is weak and may easily degrade. Soils were divided into eight classes (1 to 8) on the basis of their coherence in water, with class 3 further subdivided (3a and 3b) according to the degree of dispersion of the remoulded soil.

### Modulus of rupture (Soil strength)

Soil strength was assessed by determining the modulus of rupture conducted on reconstructed soil disc samples that had been saturated and then dried. Pressure was then applied to the soil disc and the greater the pressure required the stronger the soil strength indicating hard-set features. The test results provide a measure of pressure in kPa, and a value >60 kPa has been identified as critical to the

identification of soils that would hard-set and restrict root penetration (Cochrane and Aylmore, 1997) if the soil undergoes repeated wetting and drying cycles.

### **Soil pH**

Soil pH value indicates the level of acidity in the soil which in turn influences soil conditions and plant growth. It is measured on a scale of 1 to 14 with pH 7 being neutral, pH <7 being acidic and pH >7 being alkaline. Soil pH provides an insight into soil chemistry; it affects solubility and activity of various biologically important elements and chemical processes. For plants it determines whether nutrients will be readily available or limiting (ideal range is pH 5.0 to 7.5 for agricultural crops), and whether metals released become toxic (e.g. at pH <4.5, aluminium becomes toxic).

Soil pH can be measured in water and in 0.01 M calcium chloride (CaCl<sub>2</sub>). Calcium chloride is used because it is considered to be a measurement more like the soil solution which is taken by plants. The pH differences vary and a dilute salt solution such as 0.01 M calcium chloride would be expected to have a lower pH compared to the same soil measured in water.

### **Electrical conductivity**

Electrical conductivity is used to estimate the concentration of soluble salts in a soil suspension. High electrical conductivity values correspond with high concentrations of soluble salts in the soil and this is not ideal for most plants.

### **Exchangeable cations**

Exchangeable cations are used in assessments of soil fertility and as part of the determination of effective cation exchange capacity (eCEC). Cation exchange capacity (CEC) is a measure of the soils ability to retain cations. The amount and balance of individual exchangeable cations present will influence soil physical and chemical properties, e.g. if exchangeable sodium is >6% the soil is considered to be sodic which implies poor physical properties and susceptibility to degradation and erosion from slaking and dispersing in clayey soils.

### **Organic carbon**

Organic carbon (OC) is used to assess the amount of soil organic matter in the soil. Soil organic carbon can generally be converted to soil organic matter by multiplying by a factor of 1.72. Soil organic matter influences a number of soil functions including providing nutrients and nutrient retention capacity, energy for biological processes, binds soil particles improving structure stability, and enhance water holding capacity.

### **Soil nutrients**

Soils provide nutrients for plant roots to absorb, enabling plants to grow. An arbitrary division is made between macro-nutrients (such as carbon, nitrogen, phosphorus, sulphur and potassium) and micro-nutrients (such as copper, zinc, manganese and iron). If plant nutrients are limiting, plant growth will not be optimal and in some cases excess nutrients can be toxic to plants (e.g. manganese toxicity in acidic soils).

There is limited knowledge about nutrient requirements for native species. Assessment ratings for agricultural soils are commonly used as an indicative guide to the soil's ability to supply nutrients to agricultural plants and these have been used for discussion purposes only.

## APPENDIX C

### **Laboratory results**



Lab No	RFS16042	RFS16043	RFS16044	RFS16045	RFS16046	RFS16047	RFS16048	RFS16049
Name	DU01	DU01	DU02	DU02	DU03	DU03	DU04	DU04
Code	A	B	A	B	A	B	A	B
Customer	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory
Depth	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10
Conductivity	0.036	0.064	0.421	0.028	0.053	0.036	0.890	4.379
pH Level (CaCl2)	6.7	7.0	5.9	6.0	5.7	5.8	7.2	7.7
pH Level (H2O)	7.2	7.4	6.7	7.0	6.7	6.6	8.4	8.1

## ANALYSIS REPORT

Lab No	RFS16050	RFS16051	RFS16052	RFS16053	RFS16054	RFS16055	RFS16056	RFS16057
Name	DU05	DU05	DU06	DU07	DU07	DU08	DU08	DU09
Code	A	B	A	A	B	A	B	A
Customer	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory
Depth	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10
Conductivity	0.015	0.124	0.016	0.030	0.035	0.028	0.209	1.630
pH Level (CaCl2)	5.0	5.7	4.1	4.1	4.2	4.4	4.2	7.7
pH Level (H2O)	6.0	6.4	4.9	5.0	5.2	5.4	4.8	8.6

## ANALYSIS REPORT

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Lab No	RFS16058	RFS16059	RFS16060	RFS16061	RFS16062	RFS16063	RFS16064	RFS16065
Name	DU09	DU10	DU10	DU11	DU11	DU12	DU12	DU13
Code	B	A	B	A	B	A	B	A
Customer	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory
Depth	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10
Conductivity	3.220	0.102	0.123	0.257	0.099	0.074	0.079	0.025
pH Level (CaCl2)	7.9	7.6	7.9	6.7	7.8	7.5	7.8	6.5
pH Level (H2O)	8.5	8.8	9.2	7.4	8.8	8.8	9.0	7.8



ANALYSIS REPORT

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Lab No	RFS16066	RFS16068	RFS16069	RFS16070	RFS16071	RFS16072	RFS16073	RFS16074
Name	DU13	DU14	DU14	DU15	DU15	DU16	DU16	DU17
Code	B	A	B	A	B	A	B	A
Customer	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory
Depth	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10
Conductivity	1.022	0.027	0.025	0.183	2.111	0.040	0.769	0.055
pH Level (CaCl2)	7.9	4.0	3.9	5.9	7.9	6.4	7.7	7.0
pH Level (H2O)	8.9	4.9	4.8	6.9	8.8	7.5	8.5	8.0





ANALYSIS REPORT

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Lab No	RFS16075	RFS16076	RFS16077	RFS16078	RFS16079	RFS16080	RFS16081	RFS16082
Name	DU17	DU18	DU18	DU19	DU19	DU20	DU20	DU21
Code	B	A	B	A	B	A	B	A
Customer	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory
Depth	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10
Conductivity	0.975	0.012	0.026	0.088	1.210	0.337	0.157	0.146
pH Level (CaCl2)	8.0	4.3	4.3	7.0	7.6	6.8	7.5	6.7
pH Level (H2O)	9.2	5.2	5.2	8.0	8.4	7.3	8.1	8.0

ANALYSIS REPORT

Lab No	RFS16083	RFS16084	RFS16085	RFS16086	RFS16087	RFS16088	RFS16089	RFS16090
Name	DU21	DU22	DU22	DU23	DU23	DU24	DU24	DU25
Code	B	A	B	A	B	A	B	A
Customer	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory
Depth	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10
Conductivity	2.382	0.056	0.827	0.125	0.282	0.192	2.400	0.061
pH Level (CaCl2)	8.0	7.2	7.9	7.3	8.1	7.2	7.8	6.1
pH Level (H2O)	9.3	8.1	8.8	8.3	9.2	7.8	8.3	7.0

# ANALYSIS REPORT

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Lab No	RFS16091	RFS16092	RFS16093	RFS16094	RFS16095	RFS16096	RFS16103	RFS16104
Name	DU25	DU26	DU26	DU27	DU27	DU28	DU28	DU29
Code	B	A	B	A	B	A	B	A
Customer	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory
Depth	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10
Conductivity	0.041	0.043	0.153	0.036	0.076	0.045	0.084	0.026
pH Level (CaCl2)	7.1	7.1	7.7	7.1	7.7	7.3	7.5	6.5
pH Level (H2O)	7.8	8.0	9.0	7.9	8.8	8.2	8.3	7.8



ANALYSIS REPORT

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Lab No	RFS16105	RFS16106	RFS16107	RFS16108	RFS16109	RFS16110	RFS16111	RFS16112
Name	DU29	DU30	DU30	DU31	DU31	DU32	DU32	DU33
Code	B	A	B	A	B	A	B	A
Customer	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory
Depth	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10
Conductivity	0.091	0.016	0.686	0.027	0.106	0.059	0.665	0.068
pH Level (CaCl2)	7.3	6.0	8.0	6.6	7.8	6.9	8.0	7.8
pH Level (H2O)	8.1	7.2	9.0	7.7	8.7	7.9	8.9	8.6



# ANALYSIS REPORT

Lab No	RFS16113	RFS16114	RFS16115	RFS16116	RFS16117	RFS16118	RFS16119	RFS16120
Name	DU33	DU34	DU34	DU35	DU35	DU36	DU36	DU37
Code	B	A	B	A	B	A	B	A
Customer	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory
Depth	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10
Conductivity	dS/m	0.409	0.037	0.105	0.060	0.092	0.079	0.099
pH Level (CaCl2)	pH	7.9	7.0	7.7	7.3	7.8	7.7	7.7
pH Level (H2O)	pH	8.9	8.1	8.4	8.0	8.6	8.6	8.5



ANALYSIS REPORT

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Lab No	RFS16121	RFS16122	RFS16123	RFS16124	RFS16125	RFS16126	RFS16127
Name	DU37	DU38	DU38	DU39	DU39	DU40	DU40
Code	B	A	B	A	B	A	B
Customer	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory
Depth	0-10	0-10	0-10	0-10	0-10	0-10	0-10
Conductivity	1.382	0.092	1.169	1.215	2.537	0.879	3.349
pH Level (CaCl2)	7.9	7.7	8.2	7.9	7.8	7.1	7.7
pH Level (H2O)	8.4	8.5	9.1	8.5	8.2	7.7	8.2

**ANALYSIS REPORT**

Lab No	SRS16012	SRS16013	SRS16014	SRS16015	SRS16016	SRS16017	SRS16018	SRS16019
Name	BNB1	BNB1	BNB2	BNB2	BNB3	BNB3	BNB4	BNB4
Code	A	B	A	B	A	B	A	B
Customer	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory
Depth	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10
Colour	BROR	BROR	BROR	BRRD	BR	BR	BRGR	BR
Gravel	0	0	0	0	0	0	0	0
Texture	2.5	3.0	3.0	3.0	3.0	3.0	2.5	2.5
Ammonium Nitrogen	< 1	< 1	1	< 1	< 1	< 1	2	< 1
Nitrate Nitrogen	1	1	< 1	17	< 1	8	4	1
Phosphorus Colwell	3	< 2	3	< 2	3	< 2	8	< 2
Potassium Colwell	127	142	149	208	158	216	307	224
Sulphur	2.3	1.9	2.0	28.3	1.6	10.2	47.1	7.0
Organic Carbon	0.57	0.34	0.41	0.24	0.44	0.47	0.75	0.38
Conductivity	0.049	0.068	0.026	0.321	0.056	0.181	0.147	0.086
pH Level (CaCl2)	7.3	7.8	6.2	8.2	7.5	8.0	7.2	8.0
pH Level (H2O)	8.0	8.8	7.0	9.4	8.5	9.0	7.9	9.0
% Clay	7.97	15.06	9.86	20.85	8.84	15.02	9.01	11.74
% Course Sand	69.28	49.57	68.81	49.28	60.49	54.06	51.96	48.78
% Fine Sand	20.74	32.35	16.38	22.90	24.75	22.88	32.99	31.61
% Sand	90.02	81.92	85.18	72.18	85.24	76.94	84.95	80.40
% Silt	2.01	3.02	4.96	6.97	5.92	8.04	6.04	7.86
EDTA Copper	1.44	1.19	1.73	1.94	1.98	1.87	1.33	1.88
EDTA Iron	36.34	4.95	24.36	5.44	20.38	4.54	7.13	3.54
EDTA Manganese	60.51	3.46	58.89	5.38	71.47	7.75	17.92	3.98
EDTA Zinc	0.88	0.17	0.68	0.18	0.81	0.30	0.74	0.50



ANALYSIS REPORT

Lab No	SRS16020	SRS16021	SRS16022	SRS16023	SRS16024	SRS16025	SRS16026	SRS16027
Name	BNB5	BNB5	BNB6	BNB6	BNB7	BNB7	BNB8	BNB8
Code	A	B	A	B	A	B	A	B
Customer	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory
Depth	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10
Colour	LTBR	BRGR	BR	LTBR	DKBR	BRRD	LTBR	BRGR
Gravel	0	0	0	5	0	0	0	0
Texture	3.0	3.0	3.5	3.5	2.5	3.0	2.5	3.5
Ammonium Nitrogen	< 1	< 1	3	4	< 1	< 1	< 1	< 1
Nitrate Nitrogen	1	1	3	2	< 1	< 1	< 1	< 1
Phosphorus Colwell	5	3	3	2	7	< 2	4	2
Potassium Colwell	263	162	126	76	109	206	120	134
Sulphur	5.3	107.2	8.8	46.0	2.5	40.1	83.1	260.1
Organic Carbon	0.62	0.95	0.71	0.74	0.27	0.22	0.13	0.14
Conductivity	0.108	1.155	0.024	0.086	0.027	0.439	1.178	2.415
pH Level (CaCl2)	7.8	8.1	4.2	4.4	5.8	7.1	7.0	7.7
pH Level (H2O)	8.8	9.0	5.1	5.2	6.3	8.3	7.5	8.2
% Clay	12.10	15.54	7.80	9.78	5.93	12.49	7.88	16.87
% Course Sand	42.64	39.42	48.76	44.68	75.76	56.05	63.57	52.23
% Fine Sand	30.06	32.38	30.69	26.86	15.32	24.71	19.63	14.98
% Sand	72.70	71.79	79.46	71.54	91.08	80.76	83.20	67.20
% Silt	15.19	12.67	12.75	18.68	2.99	6.75	8.92	15.92
EDTA Copper	3.13	2.14	0.91	0.80	1.21	3.30	1.37	1.84
EDTA Iron	24.03	3.75	17.85	26.35	22.74	30.97	22.78	27.19
EDTA Manganese	165.82	4.67	6.58	7.18	107.02	247.76	80.35	86.06
EDTA Zinc	1.03	0.31	0.51	0.38	1.90	1.95	1.07	2.05





## ANALYSIS REPORT

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Lab No	SRS16028	SRS16029	SRS16030	SRS16031
Name	BNB9	BNB9	BNB10	BNB10
Code	A	B	A	B
Customer	Stacey Gregory	Stacey Gregory	Stacey Gregory	Stacey Gregory
Depth	0-10	0-10	0-10	0-10
Colour	DKBR	BRRD	BROR	BR
Gravel	0	0	0	0
Texture	3.0	3.0	3.0	3.0
Ammonium Nitrogen	2	< 1	2	2
Nitrate Nitrogen	4	36	2	1
Phosphorus Colwell	7	2	< 2	2
Potassium Colwell	279	189	92	80
Sulphur	2.5	225.0	8.5	12.8
Organic Carbon	0.55	0.65	0.63	0.72
Conductivity	0.088	1.391	0.014	0.028
pH Level (CaCl2)	6.7	8.1	4.1	4.0
pH Level (H2O)	7.4	9.0	5.0	5.0
% Clay	14.71	27.54	10.93	15.70
% Course Sand	46.86	36.12	56.12	46.26
% Fine Sand	27.60	23.53	22.97	28.20
% Sand	74.46	59.65	79.08	74.46
% Silt	10.82	12.81	9.99	9.84
EDTA Copper	2.37	1.84	1.37	1.06
EDTA Iron	25.69	5.80	17.12	31.02
EDTA Manganese	140.12	6.70	2.43	6.41
EDTA Zinc	1.33	0.43	0.54	0.81

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Testing Laboratory: Unit B, 15 Rose Street, Bridgetown, WA 6255

1606/1

COMPANY: Mine Earth Pty Ltd  
ATTENTION: Elis Smedley  
FROM: Graeme Campbell  
SUBJECT: Binduli Project: Hardsetting and Emerson-Dispersion  
Testing of Soil Samples

NO. PAGES (including this page): 19      DATE: 27th April 2016

---

Elis,

The following pages present the outcomes of the above testing.

Regards,

**Dr GD Campbell**  
**Director**



## 2.0 SOIL-STRENGTH TESTING FOR HARDSETTING ASSESSMENT

This testing is based on modified modulus of rupture testing for Western Australian [agricultural soils](#) by Harper and Gilkes (1994) and Aylmore and Sills (1982). Testing was performed on the -2 mm fraction.

The results of the hard-setting testwork are presented in the following Table.

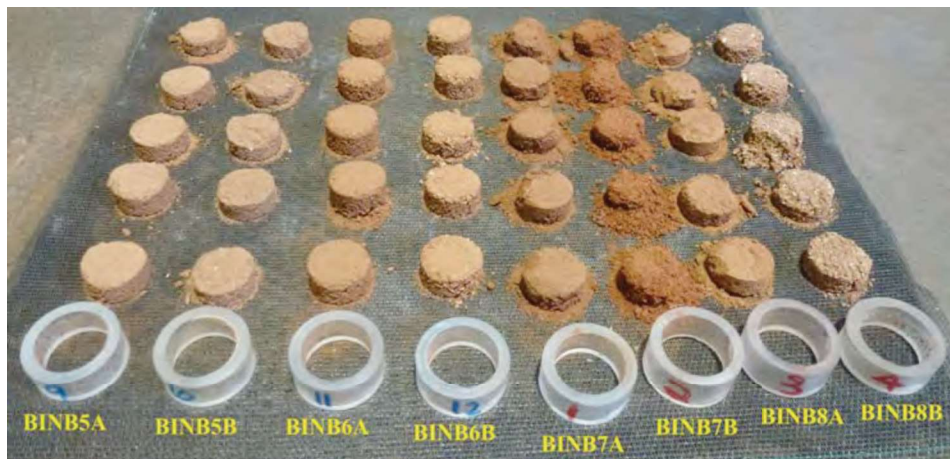
SAMPLE ID ID	MODULUS OF RUPTURE (kPa)	SAMPLE ID ID	MODULUS OF RUPTURE (kPa)
BINB1A	< 10	BINB6A	< 10
BINB1B	<10	BINB6B	10 to 25
BINB2A	< 10	BINB7A	< 10
BINB2B	< 10 to 10	BINB7B	< 10
BINB3A	< 10	BINB8A	< 10
BINB3B	< 10	BINB8B	10 to 25
BINB4A	< 10	BINB9A	< 10
BINB4B	< 10	BINB9B	< 10
BINB5A	<10	BINB10A	< 10
BINB5B	<10	BINB10B	< 10
	n = 5		n = 5

Aylmore and Sills (1982) cite [60 kPa](#) as a somewhat arbitrary choice of the [lower-limit](#) of hard-setting behaviour based on the experience of farmers within the Western Australian wheatbelts. It is a moot point as to how well this indicative threshold also applies to major impediment to shoot emergence during germination of rangeland plant species (cf. cereal crops and clover pastures, etc.). Also, the 'stony' nature of growth media – which include 'clast-rich' regoliths – employed in site-wide rehabilitation at mine-sites reduces hard-set risk, due to structural heterogeneity at the meso-scale (e.g. sub-metre-scale).

The photographs below show the oven-dried (overnight @ 45 °C) [soil-discs](#) prior to testing with a pocket penetrometer.

Note that some samples were so weak that the soil-discs collapsed upon lifting-off the acrylic-rings used for soil-disc preparation.







### 3.0 EMERSON DISPERSION TESTING

This testing is based on the 'soil-science' approach described by Emerson (2002) [cf. AS 1289.3.8.1-1997 as often employed in civil-engineering contexts).

#### 3.1 Pre-Wetting and Dewatering to **Field-Capacity**

The following shows initial wetting-up to a matric-suction of *ca.* 5 cm via a wicking-platform using blotting paper and deionised-water.



The following shows dewatering of the fully wetted-up soils to their 'field-capacity' as approximated by applying a matric-suction of 100 cm (= 0.1 bar or 10 kPa) over 1-2 days.



### 3.3 Testing for the Presence of **Reactive Carbonate-Minerals**

The following shows 'fizz' testing on the -2 mm fractions using *ca.* 3 M-HCl to determine presence of calcites, dolomites, etc.



The results of the 'fizz' testing are presented in the following Table.

SAMPLE ID	FIZZ RATING	SAMPLE ID	FIZZ RATING
BINB1A	1	BINB6A	0
BINB1B	<b>3</b>	BINB6B	0
BINB2A	1	BINB7A	0
BINB2B	<b>3</b>	BINB7B	0
BINB3A	2	BINB8A	0
BINB3B	<b>3</b>	BINB8B	0
BINB4A	2	BINB9A	0
BINB4B	<b>3</b>	BINB9B	<b>3</b>
BINB5A	1-2	BINB10A	0
BINB5B	<b>3</b>	BINB10B	0

Notes:

0 = zero reaction; 1 = weak reaction; 2 = moderate reaction; **3 = vigorous reaction**

There was a tendency for the 'A-series' samples to fizz less intensely, but for longer, compared with the 'B-series' samples for which reaction with HCl 'in-the-cold' was vigorous.

---

### 3.4 Natural Soil-Aggregates and Remoulded 'Soil-Balls' for Testing

The samples of unsieved were gently sieved using a -2 mm sieve, and [dry natural soil-aggregates](#) (cf. lithic fragments) up to several mm in sizing were removed for testing.

After bringing the -2 mm fractions to near field-capacity, [remoulded moist soil-balls](#) up to a few mm in diameter were prepared by hand. Some effort was expended in 'working-up' the soil-balls to ensure that bonding agents were broken down via mechanical means.

There was enough clay, sesquioxides and other binding agents (e.g. calcites) in a number of the '[B-series](#)' samples that sticky soil-balls could be worked-up with ease for testing.

However, this was invariably not the case for the '[A-series](#)' samples which were quite sandy – extra deionised-water had to be misted onto these samples to prepare the soil-balls, and these were soft and weak (e.g. rapid 'run-out' of very-fine silts often occurred upon immersion in deionised-water).

Note that the photographs shown below correspond to an 'ageing-time' of [ca. 24 hrs](#) for osmotic-stress from 'infinite-dilution' condition to be fully expressed in terms of '[colloid-cloud](#)' [development and expansion](#) via diffusion, etc.

Where 'haziness' is actually due to 'run-out' of fine-silts (e.g. 2-10  $\mu\text{m}$  in terms of the Australian 'soil-science' silt range [2-20  $\mu\text{m}$ ]) during slaking, this is flagged.

### 3.4 BINB1A

#### Dry Natural Soil-Aggregates



Slaking

#### Remoulded Moist Soil-Balls



Slaking; moderate 'colloid-cloud'.  
**Emerson Class 3a/3b**

### 3.5 BINB1B

#### Dry Natural Soil-Aggregates



Slaking

#### Remoulded Moist Soil-Balls



Slaking; no colloid-cloud and  
calcareous. **Emerson Class 4**  
(Haziness reflects initial run-out of  
fine-silts from soft soil-balls).



### 3.6 BINB2A

#### Dry Natural Soil-Aggregates



Slaking

#### Remoulded Moist Soil-Balls



Slaking; **extensive** colloid-cloud.  
**Emerson Class 3a**

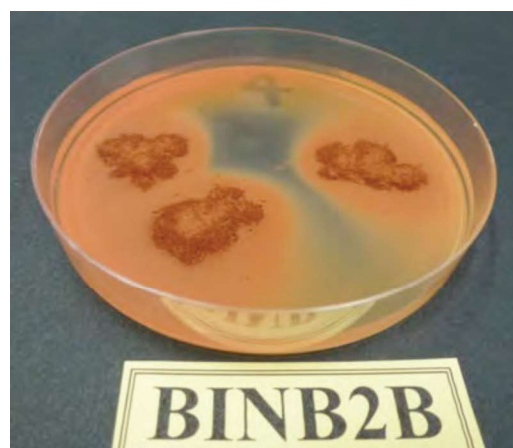
### 3.7 BINB2B

#### Dry Natural Soil-Aggregates



Slaking

#### Remoulded Moist Soil-Balls

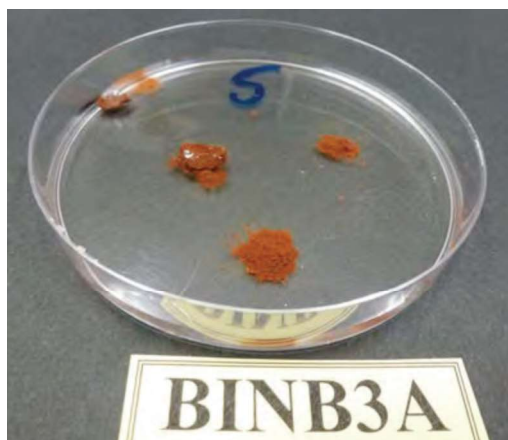


Slaking; **extensive** colloid-cloud.  
A major portion of the 'colloid-cloud-spread' occurred within the first 1-2 hrs.  
**Emerson Class 3a**



### 3.8 BINB3A

Dry Natural Soil-Aggregates



Slaking

Remoulded Moist Soil-Balls



Slaking; moderate colloid-cloud.  
**Emerson Class 3a/3b**

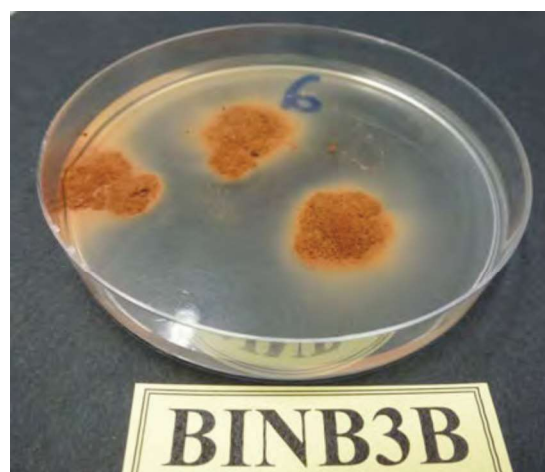
### 3.9 BINB3B

Dry Natural Soil-Aggregates



Slaking

Remoulded Moist Soil-Balls



Slaking; moderate colloid-cloud.  
**Emerson Class 3a/3b**

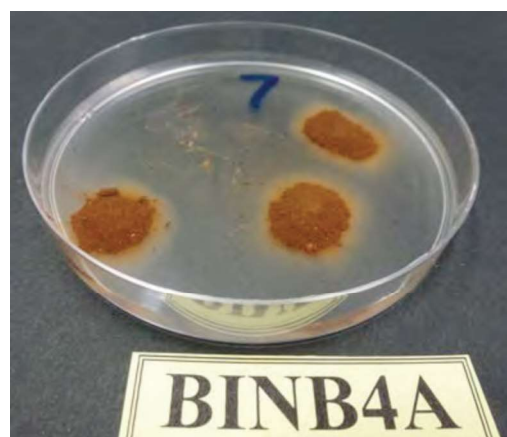
### 3.10 BINB4A

#### Dry Natural Soil-Aggregates



Slaking

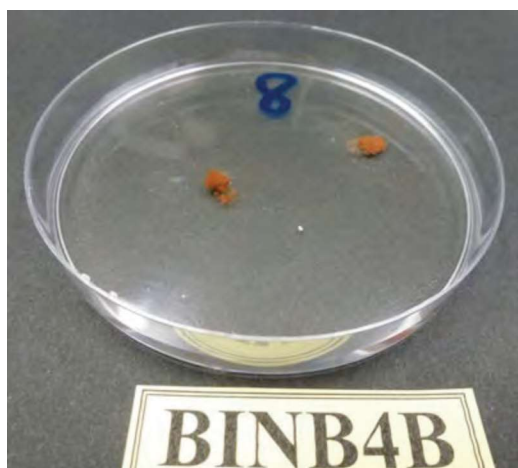
#### Remoulded Moist Soil-Balls



Slaking; no colloid-cloud and calcareous. **Emerson Class 4**  
(Haziness reflects initial run-out of fine-silts from soft soil-balls).

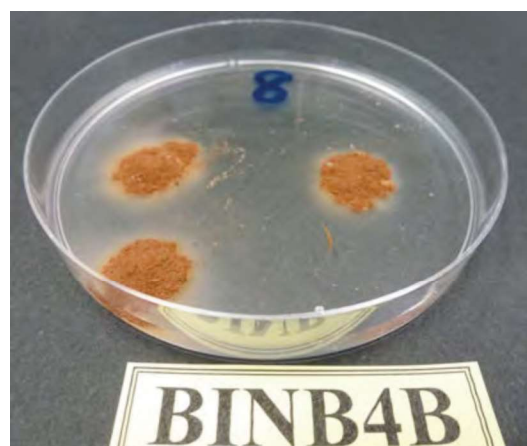
### 3.11 BINB4B

#### Dry Natural Soil-Aggregates



Slaking  
(True soil-aggregates rare)

#### Remoulded Moist Soil-Balls



Slaking; no colloid-cloud and calcareous. **Emerson Class 4**  
(Haziness reflects initial run-out of fine-silts from soft soil-balls).

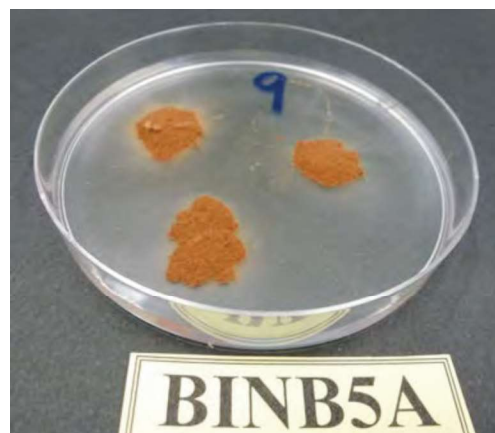
### 3.12 BINB5A

#### Dry Natural Soil-Aggregates



Slaking

#### Remoulded Moist Soil-Balls



Slaking; no colloid-cloud and calcareous. **Emerson Class 4**  
(Haziness reflects initial run-out of fine-silts from soft soil-balls).

### 3.13 BINB5B

#### Dry Natural Soil-Aggregates



Slaking

#### Remoulded Moist Soil-Balls



Slaking; no colloid-cloud and calcareous. **Emerson Class 4**  
(Haziness reflects initial run-out of fine-silts from soft soil-balls).



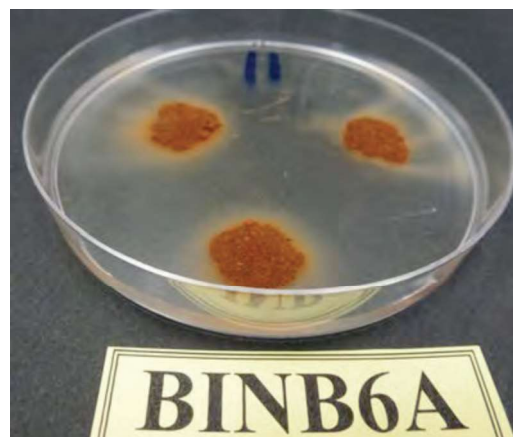
### 3.14 BINB6A

#### Dry Natural Soil-Aggregates



Slaking

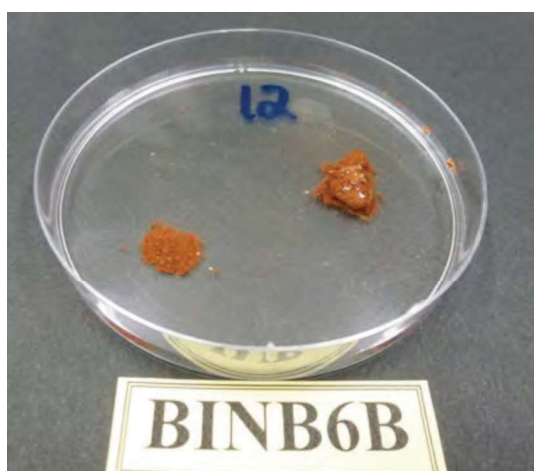
#### Remoulded Moist Soil-Balls



Slaking; expansive colloid-cloud with streaking overnight.  
**Emerson Class 3a**

### 3.15 BINB6B

#### Dry Natural Soil-Aggregates



Slaking

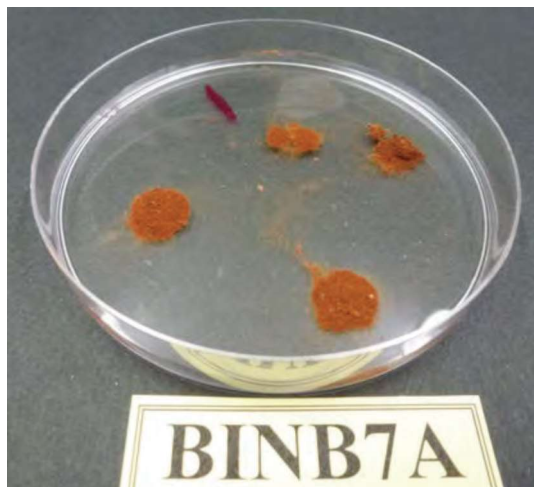
#### Remoulded Moist Soil-Balls



Slaking; no colloid-cloud and not calcareous. **Emerson Class 5** – see results of shaking at 1:5 (solid:water ratio, w/w) soil suspensions in Section 3.23. (Haziness reflects initial run-out of fine-silts; soil-balls quite sticky).

### 3.16 BINB7A

Dry Natural Soil-Aggregates



Slaking

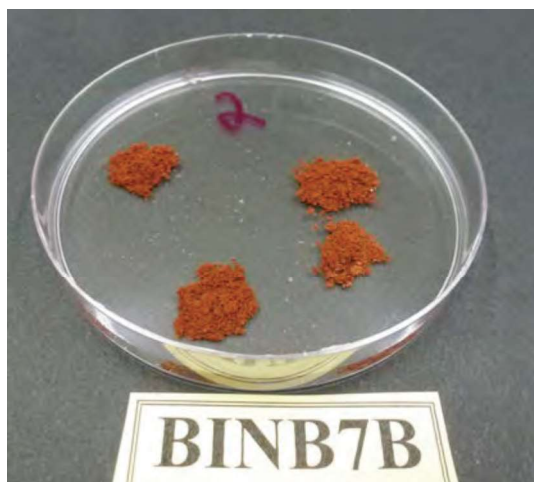
Remoulded Moist Soil-Balls



Slaking; moderate colloid-cloud.  
**Emerson Class 3a/3b**

### 3.17 BINB7B

Dry Natural Soil-Aggregates



Slaking

Remoulded Moist Soil-Balls

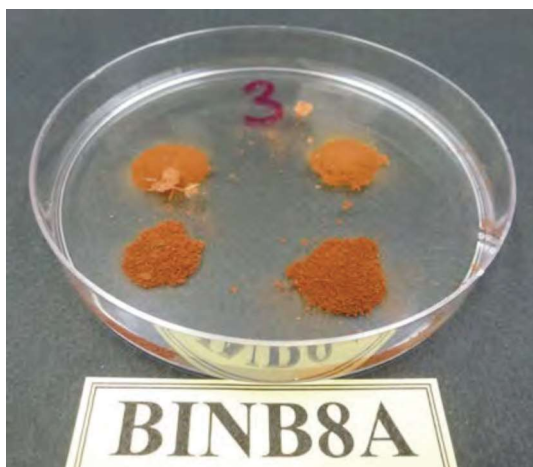


Slaking; **extensive** colloid-cloud.  
**Emerson Class 3a**



### 3.18 BINB8A

Dry Natural Soil-Aggregates



Slaking

Remoulded Moist Soil-Balls



Slaking; expansive colloid-cloud with streaking overnight.  
**Emerson Class 3a**

### 3.19 BINB8B

Dry Natural Soil-Aggregates



Slaking

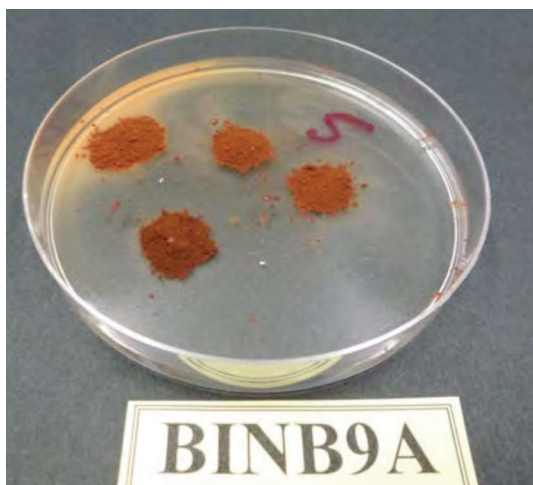
Remoulded Moist Soil-Balls



Slaking; **extensive** colloid-cloud.  
**Emerson Class 3a**  
A major portion of the 'colloid-cloud-spread' occurred within the first 1-2 hrs.

### 3.20 BINB9A

#### Dry Natural Soil-Aggregates



Slaking; partial colloid-cloud  
**Emerson Class 2 (?)**

#### Remoulded Moist Soil-Balls



Slaking; **extensive** colloid-cloud.  
A major portion of the 'colloid-cloud-spread' occurred within the first 1-2 hrs. **Emerson Class 3a**

### 3.21 BINB9B

#### Dry Natural Soil-Aggregates



Slaking

#### Remoulded Moist Soil-Balls



Slaking; no colloid-cloud and calcareous. **Emerson Class 4**  
(Haziness reflects initial run-out of fine-silts from very sticky soil-balls).

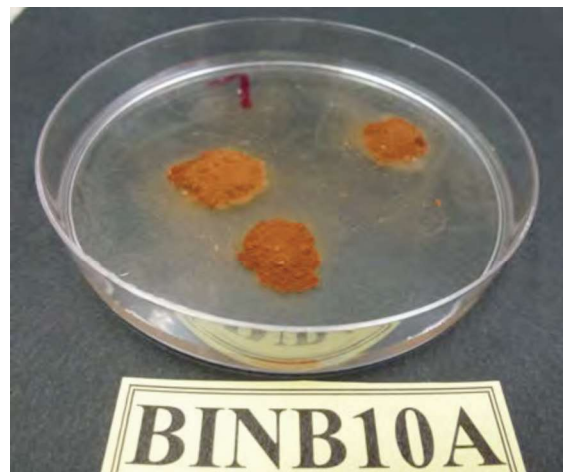
### 3.22 BINB10A

#### Dry Natural Soil-Aggregates



Slaking

#### Remoulded Moist Soil-Balls



Slaking; no colloid-cloud and not calcareous. **Emerson Class 5** – see results of shaking at 1:5 (solid:water ratio, w/w) soil suspensions in Section 3.23. (Haziness reflects initial run-out of fine-silts; soil-balls quite sticky).

### 3.23 BINB10B

#### Dry Natural Soil-Aggregates



Slaking

#### Remoulded Moist Soil-Balls

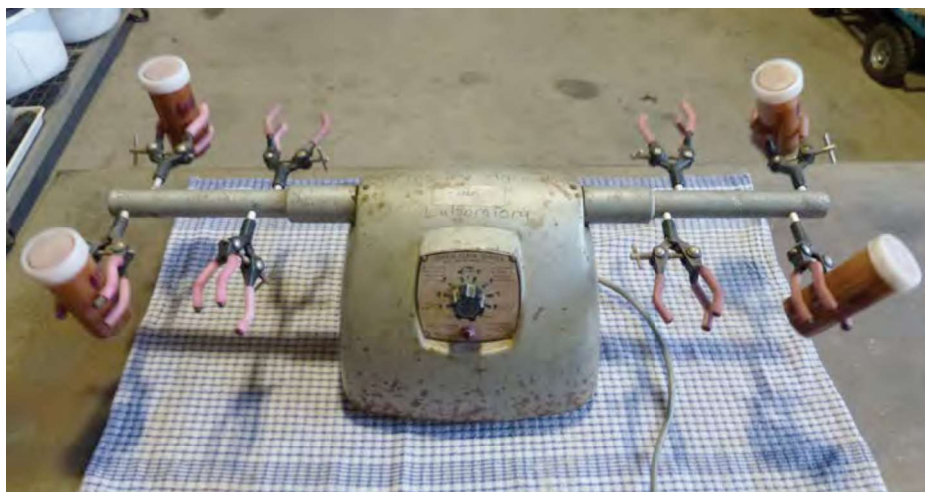


Slaking; no colloid-cloud and not calcareous. **Emerson Class 5** – see results of shaking at 1:5 (solid:w ratio, w/w) soil suspensions in Section 3.23. (Haziness reflects initial run-out of fine-silts; soil-balls quite sticky).



### 3.23 Shaking and Settling Testwork

The following shows the agitation of 1:5 (w/w) soil:water slurries for samples BINB6A, BINB6B, BINB10A and BINB10B. Vigorous wrist-action shaking undertaken for 10 minutes before being left to stand. The soil-slurries had pH values of 4.7-5.1.



The following shows the degree of 'flocculation/dispersion' upon standing to determine classifying into either Emerson Class 5 (dispersed), or Class 6 (flocculated).

After Standing for 10 minutes



After Standing Overnight





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## 4.0 REFERENCES

- AS 1289.3.81, 1997, "Methods of Testing Soils for Engineering Purposes. Method 3.8.1 – Soil Classification Tests – Dispersion – Determination of Emerson Class Number of a Soil", Australian Standards Association.
- Aylmore LAG and Sills ID, 1982, "Characterization of Soil Structure and Stability Using Modulus of Rupture – Exchangeable Sodium Percentage Relationships", *Australian Journal of Soil Research*, 20:213-224
- Emerson WW, 2002, "Emerson Dispersion Test", Chapter 13 in McKenzie N, Coughlan K and Cresswell H (eds), *"Soil Physical Measurement and Interpretation for Land Evaluation"*, CSIRO Publishing, Collingwood
- Harper RJ and Gilkes RJ, 1994, "Hardsetting in the Surface Horizons of Sandy Soils and its Implications for Soil Classification and Management", *Australian Journal of Soil Research*, 32:603-619

# ANALYTICAL REPORT

**MINE EARTH PTY LTD**  
PO Box 404  
FREMANTLE, W.A. 6959  
AUSTRALIA

## JOB INFORMATION

JOB CODE : 1960.0/1604664  
No. of SAMPLES : 20  
No. of ELEMENTS : 16  
CLIENT O/N : BIN-1512 (Job 1 of 0)  
SAMPLE SUBMISSION No. : BIN-1512  
PROJECT : BINDULI  
STATE : Soil  
DATE RECEIVED : 08/04/2016  
DATE COMPLETED : 19/05/2016  
DATE PRINTED : 19/05/2016  
ANALYSING LABORATORY : Intertek Genalysis Perth

## LEGEND

X = Less than Detection Limit  
N/R = Sample Not Received  
\* = Result Checked  
( ) = Result still to come  
I/S = Insufficient Sample for Analysis  
E6 = Result X 1,000,000  
UA = Unable to Assay  
> = Value beyond Limit of Method  
OV = Value over-range for Package

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## SAMPLE DETAILS

### **DISCLAIMER**

Intertek Genalysis wishes to make the following disclaimer pertaining to the accompanying analytical results.

**All work is performed in accordance with the Intertek Minerals Standard Terms and Conditions of work <http://www.intertek.com/terms/>**

This report relates specifically to the sample(s) that were drawn and/or provided by the client or their nominated third party. The reported result(s) provide no warranty or verification on the sample(s) representing any specific goods and/or shipment and only relate to the sample(s) as received and tested. This report was prepared solely for the use of the client named in this report. Intertek accepts no responsibility for any loss, damage or liability suffered by a third party as a result of any reliance upon or use of this report.

**The results provided are not intended for commercial settlement purposes.**

### **SIGNIFICANT FIGURES**

It is common practice to report data derived from analytical instrumentation to a maximum of two or three significant figures. Some data reported herein may show more figures than this. The reporting of more than two or three figures in no way implies that the third, fourth and subsequent figures may be real or significant.

Intertek Genalysis accepts no responsibility whatsoever for any interpretation by any party of any data where more than two or three significant figures have been reported.

## SAMPLE STORAGE DETAILS

### **GENERAL CONDITIONS**

#### **SAMPLE STORAGE OF SOLIDS**

Bulk Residues and Pulps will be stored for 60 DAYS without charge. After this time all Bulk Residues and Pulps will be stored at a rate of \$4.00 per cubic metre per day until your written advice regarding collection or disposal is received. Expenses related to the return or disposal of samples will be charged to you at cost. Current disposal cost is charged at \$150.00 per cubic metre.

#### **SAMPLE STORAGE OF SOLUTIONS**

Samples received as liquids, waters or solutions will be held for 60 DAYS free of charge then disposed of, unless written advice for return or collection is received.

# ANALYSIS

ELEMENTS	As	Ca	Cd	Cr	Cr	Cu	K	Mg	Ca Exch	eCEC
UNITS	ppm	mg/l	ppm	ppm	ppm	ppm	mg/l	mg/l	%mol(+)/kg	
DETECTION LIMIT	0.5	10	0.02	5	1	0.5	20	20	0.1	0.1
DIGEST	4A/	AmCl/	4A/	4A/	4A/	4A/	AmCl/	AmCl/		
ANALYTICAL FINISH	MS	OE	MS	OE	MS	MS	OE	OE	/CALC	/CALC
SAMPLE NUMBERS										
0001 BINB1A	15.5	1574	0.03	455	423	16.6	361	187	75.4	10.4
0002 BINB1B	8.3	2293	0.03	412	380	19.0	772	480	64.7	17.7
0003 BINB2A	12.0	961	X	462	431	14.6	384	253	60.0	8.0
0004 BINB2B	7.4	2240	X	358	331	25.6	965	764	50.1	22.3
0005 BINB3A	12.4	1700	0.02	549	526	17.1	487	268	70.1	12.1
0006 BINB3B	7.1	2316	0.03	365	340	22.2	699	573	61.1	18.9
0007 BINB4A	10.1	1865	0.04	538	512	20.5	643	292	68.7	13.6
0008 BINB4B	6.7	1903	0.04	390	352	26.0	679	603	56.8	16.8
0009 BINB5A	10.9	1797	0.08	409	392	29.0	758	723	51.2	17.5
0010 BINB5B	8.9	2242	0.07	250	236	41.1	583	1013	44.9	25.0
0011 BINB6A	7.7	267	0.02	300	285	16.6	454	76	36.0	3.7
0012 BINB6B	5.4	1049	X	138	135	13.7	415	170	61.4	8.5
0013 BINB7A	10.2	245	0.04	372	351	14.5	283	110	39.9	3.1
0014 BINB7B	9.1	709	0.09	301	296	34.7	851	982	18.1	19.5
0015 BINB8A	16.4	481	0.07	510	481	19.1	345	433	27.5	8.7
0016 BINB8B	23.0	432	0.04	370	354	32.5	647	1042	12.8	16.9
0017 BINB9A	12.3	1123	0.07	533	519	22.1	740	549	42.3	13.3
0018 BINB9B	11.1	2377	0.05	408	395	28.9	781	1194	41.0	29.0
0019 BINB10A	12.4	94	0.02	448	434	19.0	387	48	20.8	2.2
0020 BINB10B	9.8	564	X	301	289	17.9	431	109	52.0	5.4
CHECKS										
0001 BINB3A	12.7	1662	X	534	512	16.8	461	259		
STANDARDS										
0001 ASS1511-2									56.4	22.6
0002 OREAS 45e	16.3		0.04	922	904	757.3				
BLANKS										
0001 Control Blank	X	X	X	6	X	X	X	X		



**ANALYSIS**

ELEMENTS	ESP	K Exch	Mg Exch	Na	Ni	Pb	Zn
UNITS	%	%	%	mg/l	ppm	ppm	ppm
DETECTION LIMIT	0.01	0.1	0.1	10	0.5	0.5	1
DIGEST				AmCl/	4A/	4A/	4A/
ANALYTICAL FINISH	/CALC	/CALC	/CALC	OE	MS	MS	MS
SAMPLE NUMBERS							
0001 BINB1A	1.04	8.8	14.7	25	55.5	7.9	22
0002 BINB1B	1.87	11.1	22.3	76	53.6	7.6	23
0003 BINB2A	1.74	12.3	26.0	32	54.0	8.1	22
0004 BINB2B	10.69	11.0	28.1	549	69.3	9.7	29
0005 BINB3A	1.47	10.3	18.2	41	64.2	10.6	29
0006 BINB3B	4.59	9.4	24.9	200	62.3	9.7	32
0007 BINB4A	1.54	12.1	17.7	48	61.9	11.6	35
0008 BINB4B	3.29	10.4	29.6	127	55.3	10.9	31
0009 BINB5A	3.84	11.1	33.9	155	59.5	16.8	46
0010 BINB5B	15.76	6.0	33.4	905	54.1	14.9	42
0011 BINB6A	15.93	31.3	16.8	136	46.9	12.1	35
0012 BINB6B	9.82	12.4	16.4	193	36.7	11.7	32
0013 BINB7A	7.08	23.6	29.5	50	44.6	7.4	33
0014 BINB7B	29.36	11.1	41.3	1319	77.0	11.9	62
0015 BINB8A	21.72	10.1	40.7	437	42.1	13.0	34
0016 BINB8B	26.69	9.8	50.7	1037	51.2	24.8	73
0017 BINB9A	9.37	14.3	34.0	286	77.9	13.2	37
0018 BINB9B	18.23	6.9	33.9	1215	79.6	13.1	42
0019 BINB10A	15.73	45.3	18.1	79	50.4	16.4	27
0020 BINB10B	11.07	20.3	16.5	138	49.1	18.9	30
CHECKS							
0001 BINB3A				31	64.2	10.5	30
STANDARDS							
0001 ASS1511-2	3.28	1.6	38.7				
0002 OREAS 45e					459.8	17.0	45
BLANKS							
0001 Control Blank				13	X	X	X

METHOD CODE DESCRIPTION

<u>Method Code</u>	<u>Analysing Laboratory</u> <b>NATA Laboratory Accreditation</b>	<u>NATA Scope of Accreditation</u>
<b>/CALC</b>	Intertek Genalysis Perth <b>3244 3237</b>	
No digestion or other pre-treatment undertaken. Results Determined by calculation from other reported data.		
<b>4A/MS</b>	Intertek Genalysis Perth <b>3244 3237</b>	<b>4A/ : MPL_W002, MS : ICP_W003</b>
Multi-acid digest including Hydrofluoric, Nitric, Perchloric and Hydrochloric acids in Teflon Tubes. Analysed by Inductively Coupled Plasma Mass Spectrometry.		
<b>4A/OE</b>	Intertek Genalysis Perth <b>3244 3237</b>	<b>4A/ : MPL_W002, OE : ICP_W004</b>
Multi-acid digest including Hydrofluoric, Nitric, Perchloric and Hydrochloric acids in Teflon Tubes. Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.		
<b>AmCl/OE</b>	Intertek Genalysis Perth <b>3244 3237</b>	
Extraction with 1M NH4Cl according to standard ASPAC soil analysis techniques. Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.		

## APPENDIX D

### **Results of statistical analysis**

## Differences between soil horizon

**One-way ANOVA: Ammonium Nitrogen versus Horizon**

Source	DF	SS	MS	F	P
Horizon	1	0.31	0.31	0.29	0.599
Error	18	19.63	1.09		
Total	19	19.94			

S = 1.044    R-Sq = 1.57%    R-Sq(adj) = 0.00%

Individual 95% CIs For Mean Based on Pooled StDev

Level	N	Mean	StDev
A	10	1.250	0.920
B	10	1.000	1.155

0.50    1.00    1.50    2.00

Pooled StDev = 1.044

**One-way ANOVA: Nitrate Nitrogen versus Horizon**

Source	DF	SS	MS	F	P
Horizon	1	130.0	130.0	1.93	0.182
Error	18	1214.2	67.5		
Total	19	1344.2			

S = 8.213    R-Sq = 9.67%    R-Sq(adj) = 4.66%

Individual 95% CIs For Mean Based on Pooled StDev

Level	N	Mean	StDev
A	10	1.700	1.457
B	10	6.800	11.523

0.0    5.0    10.0    15.0

Pooled StDev = 8.213

**One-way ANOVA: Phosphorus Colwell versus Horizon**

Source	DF	SS	MS	F	P
Horizon	1	39.20	39.20	13.89	0.002
Error	18	50.80	2.82		
Total	19	90.00			

S = 1.680    R-Sq = 43.56%    R-Sq(adj) = 40.42%

Individual 95% CIs For Mean Based on Pooled StDev

Level	N	Mean	StDev
A	10	4.400	2.271
B	10	1.600	0.699

1.5    3.0    4.5    6.0

Pooled StDev = 1.680

### One-way ANOVA: Potassium Colwell versus Horizon

Source	DF	SS	MS	F	P
Horizon	1	432	432	0.09	0.763
Error	18	82700	4594		
Total	19	83133			

S = 67.78    R-Sq = 0.52%    R-Sq(adj) = 0.00%

Individual 95% CIs For Mean Based on Pooled StDev

Level	N	Mean	StDev
A	10	173.00	78.80
B	10	163.70	54.59

-----+-----+-----+-----+-----  
 (-----\*-----)  
 (-----\*-----)  
 -----+-----+-----+-----+-----  
 125                  150                  175                  200

Pooled StDev = 67.78

### One-way ANOVA: Sulphur versus Horizon

Source	DF	SS	MS	F	P
Horizon	1	16526	16526	3.43	0.080
Error	18	86708	4817		
Total	19	103233			

S = 69.41    R-Sq = 16.01%    R-Sq(adj) = 11.34%

Individual 95% CIs For Mean Based on Pooled StDev

Level	N	Mean	StDev
A	10	16.37	27.18
B	10	73.86	94.32

-----+-----+-----+-----+-----  
 (-----\*-----)  
 (-----\*-----)  
 -----+-----+-----+-----+-----  
 0                  40                  80                  120

Pooled StDev = 69.41

### One-way ANOVA: T-S versus Horizon

Source	DF	SS	MS	F	P
Horizon	1	4.928	4.928	5.81	0.027
Error	18	15.273	0.849		
Total	19	20.201			

S = 0.9212    R-Sq = 24.39%    R-Sq(adj) = 20.19%

Individual 95% CIs For Mean Based on Pooled StDev

Level	N	Mean	StDev
A	10	-0.6118	0.8999
B	10	0.3810	0.9419

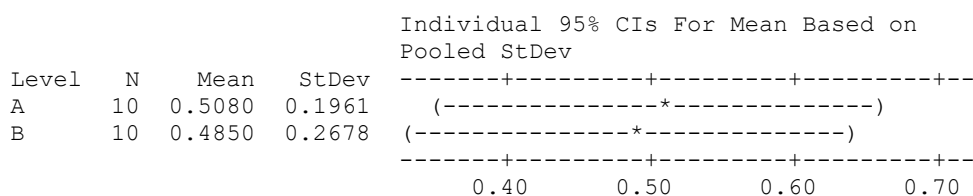
+-----+-----+-----+-----+-----  
 (-----\*-----)  
 (-----\*-----)  
 +-----+-----+-----+-----+-----  
 -1.20                  -0.60                  0.00                  0.60

Pooled StDev = 0.9212



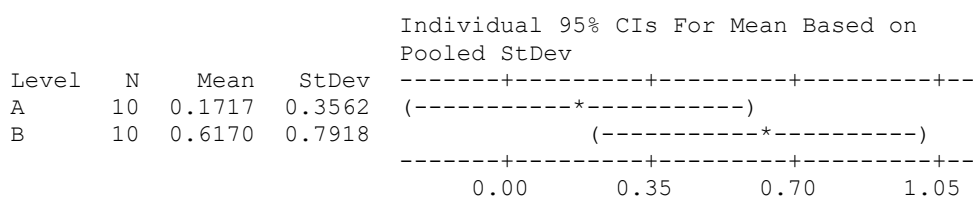
Source	DF	SS	MS	F	P
Horizon	1	0.0026	0.0026	0.05	0.829
Error	18	0.9914	0.0551		
Total	19	0.9941			

S = 0.2347      R-Sq = 0.27%      R-Sq(adj) = 0.00%



Pooled StDev = 0.2347

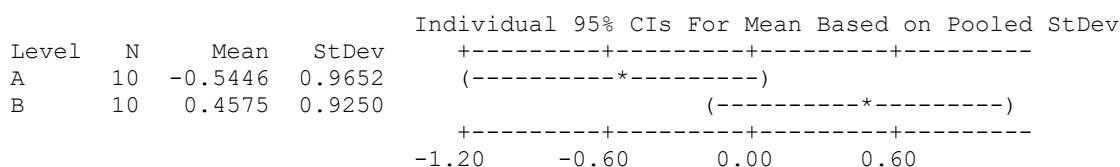
Source	DF	SS	MS	F	P
Horizon	1	0.991	0.991	2.63	0.122
Error	18	6.785	0.377		
Total	19	7.776			

$$S = 0.6139 \quad R\text{-Sq} = 12.75\% \quad R\text{-Sq}(\text{adj}) = 7.90\%$$


Pooled StDev = 0.6139

Source	DF	SS	MS	F	P
Horizon	1	5.021	5.021	5.62	0.029
Error	18	16.085	0.894		
Total	19	21.106			

S = 0.9453      R-Sq = 23.79%      R-Sq(adj) = 19.56%



Pooled StDev = 0.9453

### One-way ANOVA: pH Level (CaCl<sub>2</sub>) versus Horizon

Source	DF	SS	MS	F	P
Horizon	1	2.89	2.89	1.36	0.258
Error	18	38.16	2.12		
Total	19	41.05			

S = 1.456    R-Sq = 7.04%    R-Sq(adj) = 1.87%

				Individual 95% CIs For Mean Based on Pooled StDev			
Level	N	Mean	StDev	-----+-----+-----+-----			
A	10	6.380	1.316	(------*-----)			
B	10	7.140	1.583	(------*-----)			
				-----+-----+-----+-----			
				5.60          6.30          7.00          7.70			

Pooled StDev = 1.456

### One-way ANOVA: t-ph ca versus Horizon

Source	DF	SS	MS	F	P
Horizon	1	4.26	4.26	4.09	0.058
Error	18	18.77	1.04		
Total	19	23.03			

S = 1.021    R-Sq = 18.50%    R-Sq(adj) = 13.98%

				Individual 95% CIs For Mean Based on Pooled StDev			
Level	N	Mean	StDev	-----+-----+-----+-----			
A	10	-0.453	0.704	(------*-----)			
B	10	0.471	1.261	(------*-----)			
				-----+-----+-----+-----			
				-0.60          0.00          0.60          1.20			

Pooled StDev = 1.021

### One-way ANOVA: pH Level (H2O) versus Horizon

Source	DF	SS	MS	F	P
Horizon	1	4.42	4.42	2.04	0.171
Error	18	39.07	2.17		
Total	19	43.49			

S = 1.473    R-Sq = 10.16%    R-Sq(adj) = 5.17%

				Individual 95% CIs For Mean Based on Pooled StDev			
Level	N	Mean	StDev	-----+-----+-----+-----			
A	10	7.150	1.316	(------*-----)			
B	10	8.090	1.616	(------*-----)			
				-----+-----+-----+-----			
				6.40          7.20          8.00          8.80			

Pooled StDev = 1.473

### One-way ANOVA: T ph versus Horizon

Source	DF	SS	MS	F	P
--------	----	----	----	---	---

Horizon	1	3.367	3.367	5.37	0.033
Error	18	11.292	0.627		
Total	19	14.659			

S = 0.7921    R-Sq = 22.97%    R-Sq(adj) = 18.69%

Level	N	Mean	StDev	Individual 95% CIs For Mean Based on Pooled StDev
A	10	-0.3218	0.5384	(-----*-----)
B	10	0.4987	0.9823	(-----*-----)

-0.50      0.00      0.50      1.00

Pooled StDev = 0.7921

### One-way ANOVA: % Clay versus Horizon

Source	DF	SS	MS	F	P
Horizon	1	214.9	214.9	13.52	0.002
Error	18	286.1	15.9		
Total	19	501.0			

S = 3.987    R-Sq = 42.90%    R-Sq(adj) = 39.72%

Level	N	Mean	StDev	Individual 95% CIs For Mean Based on Pooled StDev
A	10	9.503	2.524	(-----*-----)
B	10	16.059	5.041	(-----*-----)

9.0      12.0      15.0      18.0

Pooled StDev = 3.987

### One-way ANOVA: % Silt versus Horizon

Source	DF	SS	MS	F	P
Horizon	1	26.4	26.4	1.29	0.270
Error	18	367.1	20.4		
Total	19	393.4			

S = 4.516    R-Sq = 6.71%    R-Sq(adj) = 1.52%

Level	N	Mean	StDev	Individual 95% CIs For Mean Based on Pooled StDev
A	10	7.959	4.287	(-----*-----)
B	10	10.256	4.734	(-----*-----)

5.0      7.5      10.0      12.5

Pooled StDev = 4.516

### One-way ANOVA: % Fine Sand versus Horizon

Source	DF	SS	MS	F	P
Horizon	1	18.6	18.6	0.55	0.467
Error	18	606.5	33.7		
Total	19	625.1			

S = 5.805    R-Sq = 2.97%    R-Sq(adj) = 0.00%

				Individual 95% CIs For Mean Based on Pooled StDev			
Level	N	Mean	StDev	-----+-----+-----+-----+			
A	10	24.113	6.145	(-----*-----)			
B	10	26.040	5.443	(-----*-----)			
				-----+-----+-----+-----+			
				22.5	25.0	27.5	30.0

Pooled StDev = 5.805

### One-way ANOVA: % Sand versus Horizon

Source	DF	SS	MS	F	P
Horizon	1	391.9	391.9	9.32	0.007
Error	18	756.6	42.0		
Total	19	1148.5			

S = 6.483    R-Sq = 34.12%    R-Sq(adj) = 30.46%

				Individual 95% CIs For Mean Based on Pooled StDev			
Level	N	Mean	StDev	-+-----+-----+-----+-----			
A	10	82.537	6.082	(-----*-----)			
B	10	73.684	6.861	(-----*-----)			
				-+-----+-----+-----+-----			
				70.0	75.0	80.0	85.0

Pooled StDev = 6.483

### One-way ANOVA: % Course Sand versus Horizon

Source	DF	SS	MS	F	P
Horizon	1	581.0	581.0	7.30	0.015
Error	18	1432.0	79.6		
Total	19	2013.1			

S = 8.919    R-Sq = 28.86%    R-Sq(adj) = 24.91%

				Individual 95% CIs For Mean Based on Pooled StDev			
Level	N	Mean	StDev	+-----+-----+-----+-----			
A	10	58.425	10.956	(-----*-----)			
B	10	47.645	6.251	(-----*-----)			
				+-----+-----+-----+-----			
				42.0	48.0	54.0	60.0

Pooled StDev = 8.919

### One-way ANOVA: EDTA Copper versus Horizon

Source	DF	SS	MS	F	P
Horizon	1	0.052	0.052	0.11	0.739
Error	18	8.174	0.454		
Total	19	8.226			

S = 0.6739    R-Sq = 0.63%    R-Sq(adj) = 0.00%

				Individual 95% CIs For Mean Based on Pooled StDev			
Level	N	Mean	StDev	-+-----+-----+-----+-----			
A	10	1.6840	0.6546	(------*-----)			
B	10	1.7860	0.6926	(-----*-----)			
				-+-----+-----+-----+-----			
				1.25	1.50	1.75	2.00

Pooled StDev = 0.6739

### One-way ANOVA: EDTA Iron versus Horizon

Source	DF	SS	MS	F	P
Horizon	1	280	280	2.62	0.123
Error	18	1924	107		
Total	19	2204			

S = 10.34 R-Sq = 12.72% R-Sq(adj) = 7.87%

				Individual 95% CIs For Mean Based on Pooled StDev			
Level	N	Mean	StDev	-----+-----+-----+-----+			
A	10	21.84	7.41	(------*-----)			
B	10	14.36	12.60	(-----*-----)			
				-----+-----+-----+-----+			
				12.0	18.0	24.0	30.0

Pooled StDev = 10.34

### One-way ANOVA: EDTA Manganese versus Horizon

Source	DF	SS	MS	F	P
Horizon	1	5503	5503	1.21	0.286
Error	18	81756	4542		
Total	19	87259			

S = 67.39 R-Sq = 6.31% R-Sq(adj) = 1.10%

				Individual 95% CIs For Mean Based on Pooled StDev			
Level	N	Mean	StDev	--+-----+-----+-----+-----			
A	10	71.11	54.85	(------*-----)			
B	10	37.94	77.94	(-----*-----)			
				--+-----+-----+-----+-----			
				0	35	70	105

Pooled StDev = 67.39

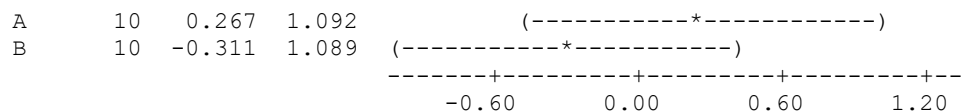
### One-way ANOVA: T-mn versus Horizon

Source	DF	SS	MS	F	P
Horizon	1	1.67	1.67	1.40	0.252
Error	18	21.42	1.19		
Total	19	23.09			

S = 1.091 R-Sq = 7.23% R-Sq(adj) = 2.08%

				Individual 95% CIs For Mean Based on Pooled StDev			
Level	N	Mean	StDev	-----+-----+-----+-----+			



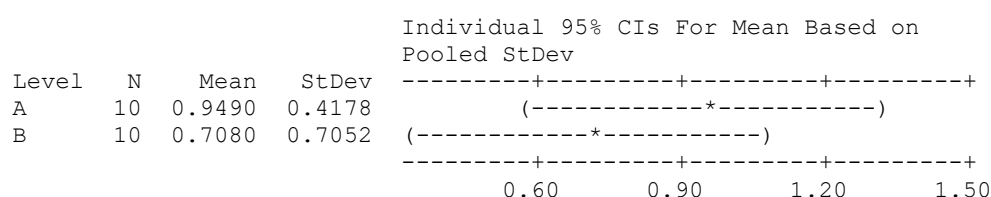


Pooled StDev = 1.091

### One-way ANOVA: EDTA Zinc versus Horizon

Source	DF	SS	MS	F	P
Horizon	1	0.290	0.290	0.86	0.365
Error	18	6.046	0.336		
Total	19	6.336			

S = 0.5796 R-Sq = 4.58% R-Sq(adj) = 0.00%

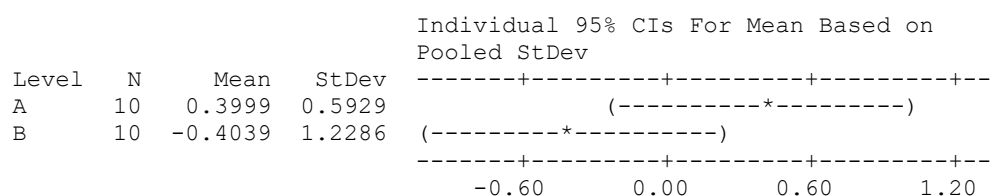


Pooled StDev = 0.5796

### One-way ANOVA: T zn versus Horizon

Source	DF	SS	MS	F	P
Horizon	1	3.230	3.230	3.47	0.079
Error	18	16.748	0.930		
Total	19	19.979			

S = 0.9646 R-Sq = 16.17% R-Sq(adj) = 11.51%

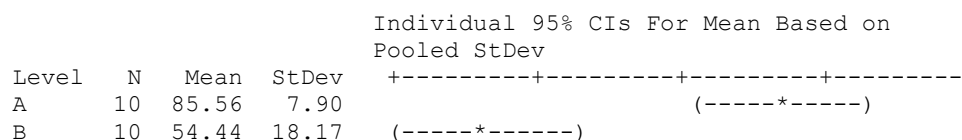


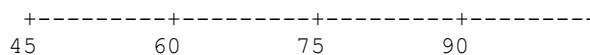
Pooled StDev = 0.9646

### One-way ANOVA: <2 mm versus Horizon

Source	DF	SS	MS	F	P
Horizon	1	4842	4842	24.67	0.000
Error	18	3534	196		
Total	19	8376			

S = 14.01 R-Sq = 57.81% R-Sq(adj) = 55.47%



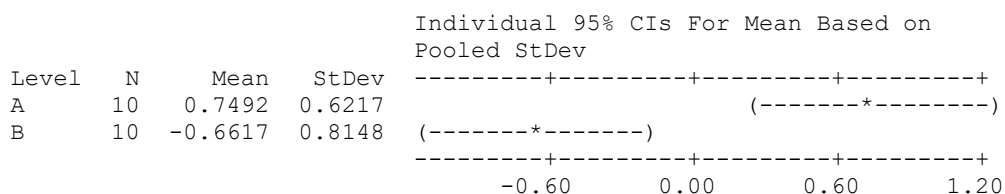


Pooled StDev = 14.01

### One-way ANOVA: T < 2 versus Horizon

Source	DF	SS	MS	F	P
Horizon	1	9.953	9.953	18.95	0.000
Error	18	9.453	0.525		
Total	19	19.407			

S = 0.7247 R-Sq = 51.29% R-Sq(adj) = 48.58%

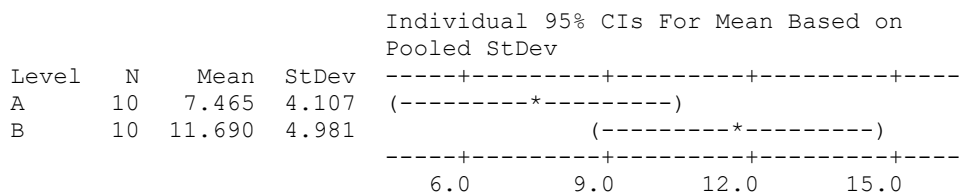


Pooled StDev = 0.7247

### One-way ANOVA: 2 - 4.75 mm versus Horizon

Source	DF	SS	MS	F	P
Horizon	1	89.2	89.2	4.28	0.053
Error	18	375.1	20.8		
Total	19	464.3			

S = 4.565 R-Sq = 19.22% R-Sq(adj) = 14.73%

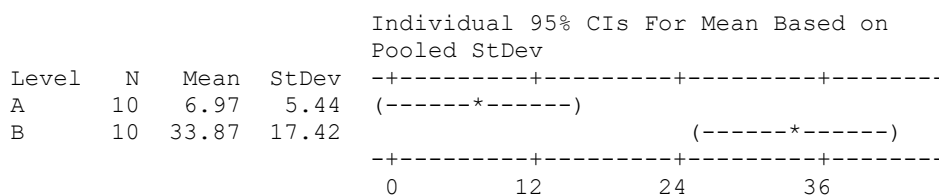


Pooled StDev = 4.565

### One-way ANOVA: >4.75 mm fraction versus Horizon

Source	DF	SS	MS	F	P
Horizon	1	3617	3617	21.71	0.000
Error	18	2998	167		
Total	19	6615			

S = 12.91 R-Sq = 54.67% R-Sq(adj) = 52.15%





**Appendix B: AQ2 Pty Ltd (2022) Surface Water Management Plan Binduli  
South Project**

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**SURFACE WATER MANAGEMENT PLAN**  
**BINDULI SOUTH PROJECT**

**Prepared for**  
**TALIS CONSULTANTS**

**March 2022**

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## Document Status

Version	Purpose of Document	Author	Reviewed By	Review Date
a	Draft for review	NH	MN	21 Feb 2022
b	Final	NH	MN	18 Mar 2022

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Date:	18 March 2022		

## EXECUTIVE SUMMARY

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Norton Gold Fields Pty Ltd (Norton) currently holds a range of tenements associated with the Binduli Project, located both north and south of Great Eastern Highway (GEH), approximately ten kilometres (km) west of Kalgoorlie in Western Australia (WA). Binduli is divided by the highway into Binduli North (BN) and Binduli South (BS), both of which have additional resources which Norton wishes to exploit.

Norton has secured the necessary approvals to progress operations at BN through the construction of a processing plant and heap leach operation and similar approvals are required for the BS Project. At this stage, the BS Project will not include any processing. Instead, the ore will be transported (by truck or conveyor) to BN for processing.

This report details the baseline hydrological conditions and potential environmental receptors associated with the project, including the results of 2D hydrological modelling. Subsequently, hydrological risk identification for the project was completed in accordance with DMIRS guidelines and inherent risk levels determined. Measures to mitigate these risks were proposed and the residual risk levels assessed.

A Hydrological Risk Assessment has been completed for the project and several medium to high-inherent (unmitigated) risks to the hydrological environment were identified based on a review of Baseline Flood Mapping. The main project specific risks were as follows:

- Construction of a waste rock dump and associated topsoil stockpile within a salt lake causing disrupted connectivity of flowpaths within the salt lake system and a risk to the geotechnical stability of the structure due to adjacent ponding.
- Construction of an open cut pit adjacent to the salt lake presenting a risk of flooding to the pit.

Mitigation measures have been proposed to reduce the hydrological risks of the project to acceptable (low) levels and are presented in Figure 5.1. Measures have included:

- Diversion of flows around mining infrastructure (where possible) to reduce ponding and return surface water flows to drainage lines downstream.
- Construction of bunding around Ben Hur pit to prevent flooding from the salt lake.
- Construction of culverts or flood ways along the access road that surrounds the site to allow the continuity of the existing hydrological flow regime.
- Construction of containment bunding and sediment basins at the downstream locations of all sediment generating disturbance areas (i.e., waste dump, pit, stockpiles, and ROM) will mitigate sediment generation and transport.

These proposed conceptual mitigation measures were incorporated within a LOM 2D flood model to prepare LOM Flood Maps. Based on the LOM Flood Map results, the identified inherent risks were re-assessed to quantify the residual risks of the project. The Residual Risk Matrix (also shown in Appendix A) indicates that these management measures reduce all residual risks to a Low rating.

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Although low risk, there are areas of ponding that it has not been reasonably possible to manage, particularly to the west and southeast of the project.

If practical, Norton should consider the feasibility of reshaping the footprint of WRD3 to reduce the incursion of the WRD into the channel that connects the chain of salt lakes and results in subsequent blockage of downstream flows. This would reduce the need for proposed Diversion 3.

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## Appendix

Appendix A:	Surface Water Risk Matrix
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## 1 BACKGROUND

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Norton Gold Fields Pty Ltd (Norton) currently holds a range of tenements associated with the Binduli Project, located both north and south of Great Eastern Highway (GEH), approximately ten kilometres (km) west of Kalgoorlie in Western Australia (WA) (see Figure 1.1). Binduli is divided by the highway into Binduli North (BN) and Binduli South (BS), both of which have additional resources which Norton wishes to exploit.

Norton has secured the necessary approvals to progress operations at BN through the construction of a processing plant and heap leach operation and similar approvals are required for the BS Project. At this stage, the BS Project will not include any processing. Instead, the ore will be transported (by truck or conveyor) to BN for processing.

Based on Norton's experience with BN, it is likely that similar approvals for BS will be required, including a referral pursuant to Part IV of the *Environmental Protection Act 1986* (EP Act) to the Environmental Protection Authority (EPA) and a Native Vegetation Clearing Permit (NVCP) pursuant to Part V of the EP Act. In addition, a Mining Proposal (MP)/Mine Closure Plan (MCP) (through the Department of Mines, Industry Regulation and Safety (DMIRS)) and Works Approval (through the Department of Water and Environmental Regulation (DWER)) will also be required.

## 2 ACTIVITY DETAILS

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### 2.1 Proposed Mining Activities and Disturbances

This assessment has been based on layouts of proposed mine pits and site infrastructure which have been provided by Norton. The BS Project is a redevelopment and expansion of existing gold mining operations at the site and is not a greenfield development. The proposed Project includes the following proposed activities:

- Open cut mining, resulting in a number of open cut pits.
- Transport of or to BN, resulting in the requirement for the development of a transport corridor (road and/or conveyor) between the Project and Great Eastern Highway, connecting to an existing road on the north side of Great Eastern Highway.
- Storage of waste rock material, resulting in the creation of a number of Waste Rock Landforms (WRL).
- Storage of topsoil for closure/rehabilitation, resulting in the creation of a number of top soil stockpiles.

The layout of these activities is shown in Figure 2.1. The Life of Mine for the project is expected to be approximately 20 years in conjunction with BN.

### 2.2 Proposed Infrastructure Footprint

The operating footprint areas of proposed infrastructure for BS are shown in Table 2.1 and are based on the maximum extent of infrastructure as provided by Norton.

### 2.3 Site Plan

A layout plan for the proposed Life-of-Mine (LOM) site disturbance areas is shown in Figure 2.1 and consists of the following:

- Five open-cut mine pits (of which four are expansions of existing pits and one is a new pit).
- Six waste rock dumps surrounding the pits (of which four are significant expansions of existing waste rock dumps and two are new dumps).
- Six topsoil stockpiles adjacent to the waste rock dumps.
- A ROM pad/crusher located in the centre of the pits and waste rock dumps.
- A conveyor heading north from the ROM pad towards Binduli North.
- Offices to the north of the pits and waste rock dumps.
- Haul and access roads within the perimeter of the proposed development and heading north towards Binduli North.

**Table 2.1: Proposed Operational Footprints**

<b>Infrastructure</b>	<b>Footprint (km<sup>2</sup>)</b>
Open-cut pits	2.0
Run of Mine (ROM) Pad	0.1
Waste rock dumps	5.8
Topsoil stockpiles	0.4
Offices	0.1
Roads	0.5
<b>Total</b>	<b>8.9</b>

### 3 BASELINE ENVIRONMENTAL DATA

#### 3.1 Climate

The climate of the region is arid, with hot summers and cool winters. Temperatures can range from below 0° C in winter, to over 45° C in summer.

#### 3.2 Rainfall

In Kalgoorlie, approximately 10 km north-east, a weather station has measured rainfall data since 1939, providing over 80 years of rainfall data. The mining area of Gindalbie is also relatively close to the site (66 km to the north east), where a further long-term rainfall gauge exists with data since 1918 providing 100 years of rainfall data. Details for these rain gauges are presented in Table 3.1.

**Table 3.1: Nearby BoM Rainfall Gauges**

Site Name	BoM Site Number	Commencement Date	Latitude	Longitude	Operational Status
Kalgoorlie-Boulder Airport	012038	1939	30.79° S	122.45° E	Open
Gindalbie	012247	1918	30.28° S	121.76° E	Open

Kalgoorlie has an average rainfall of 265 mm per annum from 82 years of data (Bureau of Meteorology (BoM) Site 012038, 2021). The rainfall is highly variable with the larger rainfall events typically as a result of rainfall from ex-tropical lows during late summer. Temperature and rainfall statistics are displayed in Table 3.2 and Figure 3.1.

**Table 3.2: Climate Conditions at Kalgoorlie (BoM site 012038)**

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean max temp (°C)	33.6	32.1	29.5	25.3	20.7	17.6	16.8	18.7	22.4	26.0	29.1	32.1	25.3
Mean min temp (°C)	18.3	17.9	16.1	12.8	8.7	6.3	5.1	5.8	8.1	11.3	14.2	16.7	11.8
Mean rainfall (mm)	27.2	32.4	25.0	20.0	24.8	27.1	24.2	21.0	13.4	15.8	19.1	16.3	264.9

Pan evaporation data for the Mine site was extracted from the BoM gridded datasets (BoM, 2019), with annual pan evaporation total of 2,614 mm. Average monthly evaporation rates exceed average rainfall rates throughout the year (Figure 3.1).

##### 3.2.1 Probability Terminology

Australian Rainfall and Runoff (ARR) (Ball, et. al, 2019) recommends the use of Annual Exceedance Probability (AEP) when defining flood probability, so has been adopted throughout this report. AEP is defined as the probability or likelihood of an event occurring or being exceeded within any given year, usually expressed as a percentage. This new terminology supersedes the Annual Recurrence

Interval (ARI) terminology adopted in the earlier revision of ARR (Institution of Engineers, Australia, 1987). The relationship between ARI and AEP is defined below.

$$AEP = 1 - \exp\left(\frac{-1}{ARI}\right)$$

For example, a 1 in 100 ARI event would occur on average once every 100 years, and has a 1% chance of occurring in any particular year (i.e. 1% AEP), while a 1 in 50 ARI event has a 2% chance of occurring (2% AEP).

### 3.2.2 Rainfall IFD and PMP Data

Intensity-Frequency-Duration (IFD) data was extracted from the BoM website for the Project site, from the 2016 datasets. The 2016 IFD data is presented in Figure 3.2.

Closure of mines requires contemplation of rare storm events that could occur in time undefined after closure. In this regard, DMIRS has suggested the use of the Probable Maximum Precipitation (PMP), which is an estimate of the upper physical bound to the precipitation that the atmosphere can produce.

The BoM has developed the following methods for estimating PMP rainfall depths depending on storm duration for the Project region:

- GSDM – Generalised Short Duration Method, implemented for storm durations up to 6 hours.
- GSAM - Generalised Southeast Australia Storm Method.
- GTSMR – Generalised Tropical Storm Method Revised, developed for storm durations greater than or equal to twenty-four hours.

The Project sits within the WA Transition Zone, requiring both the GSAM and GTSMR to be calculated and the highest values adopted, which in this case were the GSDM and GTSMR. Results from the adopted PMP estimation methods (GSDM and GTSMR) for the Project location are shown in Table 3.3, along with other rare IFDs sourced from the BoM (2021c) for context.

**Table 3.3: PMP and Rare Event IFD Data for Aphrodite Project**

Duration / AEP (1 in X)	1hr Rainfall (mm)	3hr Rainfall (mm)	12hr Rainfall (mm)	24hr Rainfall (mm)	48hr Rainfall (mm)	72hr Rainfall (mm)
1,000	84	119	198	258	323	366
2,000	97	138	229	299	375	429
PMP	320	460	610	730	1050	1310

### 3.3 Landscape/Topography

The topography of the Mine development ranges from 335-400mRL. The ridgelines that serve as catchment boundaries for the study area extend up to 400mRL and the ultimate receptor of drainage from the Mine catchment, White Lake and/or Douglas Lake, sits at approximately 335mRL.



Hydrological assessments were carried out using the following datasets:

- Digital Elevation Model (DEM) provided by Norton (DSM\_Binduli\_South\_GeoTIFF\_GDA94z51.tif).
- SRTM Worldwide Elevation Data (1-arc-second Resolution, SRTM Plus V3).

Local detailed elevation data was provided by Norton to cover the majority of the overall Project Area (refer Figure 3.3). The local elevation data was predominantly used for two-dimensional (2D) surface water modelling and was supplemented with SRTM (Shuttle Radar Topography Mission) data where the data didn't cover catchment extents.

### **3.4 Hydrology**

The following sections characterise the hydrology of the Project area itself as well as the surrounding areas that may be impacted by, or impact on, the Project.

#### **3.4.1 Regional Hydrology**

The Project area and its immediate surroundings are located within the DWER regional Salt Lake Basin, where streams and drainage lines drain to inland lakes. It sits just south of the regional catchment divide between the Raeside-Ponton catchment (draining to the north) and the Lake Lefroy catchment (draining to the south). These catchments contain a chain of salt lake basins which typically act as local terminal points for drainage but have the potential to overtop and become interconnected with each other. There are no significant streams or available streamflow monitoring data in the region around the Project.

#### **3.4.2 Potential Environmental Receptors**

White Lake and/or Douglas Lake is located immediately downstream of the Project. White Lake is a part of a large interconnected lake system formed of three main lakes known as Brown Lake, Red Lake and White Lake. White Lake itself consists of two major lobes and is variously mapped as White Lake and/or Lake Douglas (Essential Environmental, 2016). Characteristics of the lake system are presented in Essential Environmental (2016) however limited historic information or background studies are available. It is considered to be representative of other salt lake systems in the region and does not have high environmental significance.

The catchments of the lake system in the vicinity of the Project area are shown on Figure 3.4. Additional catchments not shown, largely to the south and west of the lakes, make up the total catchment area of approximately 2,463 km<sup>2</sup>. The remainder of the Lake Lefroy catchment extends to the south of the subject lakes and interaction with the broader catchment is considered highly unlikely (Essential Environmental, 2016). Essential Environmental (2016) completed two-dimensional (2D) flood modelling of the catchment to predict the peak stored volumes, top water levels, and extents of inundation in the White Lake system.

#### **3.4.3 Project Hydrology**

The hydrology of the Project area and local catchments are shown on Figure 3.5. Surface water generally drains from north to south towards White/Douglas Lake. Two small catchments flow towards the western boundary of the existing mine disturbance area and pond against it or are

directed to flow south along its western edge. Drainage from an upstream catchment to the west of the existing disturbance area is directed towards a local dam that can be seen on the aerial imagery. There are a series of small interconnected salt basins to the east of the existing disturbance that drain to the south and are connected to White/Douglas Lake at the southern end of the existing disturbance area. Surface water flows in this area are likely to be predominantly sheetflow or in flat undefined flow channels.

The Regional Flood Frequency Procedure (RFFP) developed by Flavell (Flavell, 2012) for the Goldfields was used to estimate peak flows for the larger catchments draining towards the Project area. The characteristics of each of these catchments were determined from the topographic data and peak flow rates were estimated using the RFFP for the 1%, 2%, and 5% AEP rainfall events. The results are summarised in Table 3.5 for the catchments shown on Figure 3.5.

**Table 3.5: RFFP Design Peak Flows (m<sup>3</sup>/s)**

Catchment	Catchment Area (km <sup>2</sup> )	5% AEP	2% AEP	1% AEP
1	9.5	13	20	28
2	42.3	48	69	97
3	8.2	14	20	28
4	2.1	5	8	11
5	2.1	2	4	5

It should be noted that there is significant uncertainty in the RFFP methods given it is based on limited runoff data which is available in the Goldfields region. Runoff data which was used to develop the RFFP assessment was for larger catchments than those assessed for this project. The salt lakes and dams within the catchments also provide additional storage and attenuate peak flows, reducing the design flows expected compared with those calculated using the RFFP method. As such, the values in Table 3.5 should be considered as indicative of the order of magnitude of flows which could be generated by the catchments in the study area.

#### **3.4.3.1 Flood Modelling – Baseline Conditions**

The Baseline flood characteristics of the Project area have been mapped for this SWMP by creating a 2D flood model using HEC-RAS.

#### **3.4.3.2 2D Model Set-Up**

The 2D model was developed using a DEM that represents existing topographical conditions to predict inundation extents resulting from the 1% AEP estimated design event. Detailed DEM coverage was provided for the Project area but did not extend across the full extent of surrounding surface water catchments. The 2D model extent was limited to that area for which the DEM is available and an inflow hydrograph was required to the model boundary for the catchment that extended out further from the DEM extents.

The general model build details are as follows (refer to Figure 3.6):

- A 40m x 40m grid applied across the model with a refined grid of 10m x 10m applied across the extent of the existing disturbance area.
- Manning's 'n' value of 0.1 applied across the complete domain.
- An inflow from the upgradient catchment of 50 m<sup>3</sup>/s (calculated using RFFP) was applied at the upstream model boundary at a constant rate to simulate a 1% AEP design runoff flow rate.
- Rain-on-Grid hydrology was applied across the model using nested frequency storms to represent a 12-hour rainfall event.

It should be noted that the modelling approach adopted is focused on providing baseline hydrological flood characteristics from local catchments immediately surrounding the proposed development but does not represent flooding within the salt lakes to the south for the following reasons:

- The critical duration storm to cause flooding of the salt lakes/basins is likely to be different to that being modelled for flooding of the local small catchments.
- The model doesn't cover the full catchment area of the lakes.
- The hydraulic connection of the other lake chains during a flood event is not simulated (model allows outflow along the downstream boundary).
- A constant inflow rate of 50m<sup>3</sup>/s over the model run time is applied as the upstream boundary condition, such that the runoff volume from the modelled catchment area will likely be over-estimated.
- No initial storage of water in the salt lakes has been accounted for.
- Evaporative or infiltration losses within the lake body have not been allowed for.

This is consistent with the modelling approach adopted by Essential Environmental (2016).

### 3.4.3.3 Pre-Development Baseline Results

The baseline 1% AEP event flood depth and velocity predictions using the existing terrain surface from the 2D hydraulic model are shown on Figures 3.7 and 3.8 respectively. Note that flood mapping is screened to only show areas where flow depths exceeding 0.1m occur.

Key observations from the 1% AEP flood predictions for baseline conditions are:

- There a number of flowpaths draining north-south to the east of the existing infrastructure including from the external inflow to the model. These flow into the salt pan area and cause interconnecting pools to form.
- A number of flowpaths draining from the west of the existing disturbance have had their natural drainage lines interrupted by the existing mining areas and either pond adjacent to the existing landform or flow south along the western edge.
- A dam exists to the west of the existing disturbance area. This retains some upstream flow but does appear to overtop and release flows downstream during a 1% AEP event.

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- Outside of areas where flood water ponds (salt pans, open cut pits, trapped drainage lines etc.), the flood depths are predicted to be less than 1m deep.
  - Velocity of runoff is typically low (less than 0.75m/s), reflecting the flat nature of the topography.
  - The southern end of the existing disturbance area is predicted to be impacted by flooding from the salt pans at its downstream end, noting, as discussed in the limitations above, that the model has not been constructed with the purpose of accurately representing the flood levels in the salt lakes.

## 4 HYDROLOGICAL IMPACT IDENTIFICATION

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Potential hydrological impacts of the project are identified in the section below. The identification of potential impacts from the project on the hydrological environment was completed by comparing the proposed infrastructure layout to the existing catchments and baseline flood modelling results. The potential impacts are also summarised in the left hand side of the Hydrological Risk Matrix presented in Appendix A (and documented further in the following sections).

### 4.1 Impacts of Mining Operations on the Hydrological Regime

Mining operations in general have the potential to impact on the environmental values and hydrological behaviour of the surrounding areas. The greatest threats to the hydrological environment fall into the following categories:

- Modification of the existing hydrological regime, by increasing or reducing water availability within the environment.
- Modification of the physical water quality (i.e. suspended sediments) in the downstream environment, which may be due to erosion of disturbed areas relating to construction, stockpiles, laydowns and waste dumps (among others).
- Modification of the chemical water quality (for example hydrocarbon pollution).

These impacts and their implications for environmental quality are discussed further below.

#### 4.1.1 Modification of the Existing Hydrological Regime

Generally, construction of mine pits, waste dumps, haul roads and other associated infrastructure for proposed mines potentially could affect existing surface water drainage features, including creek lines, pools and flood plains. Modification of the existing catchments and drainage channels can reduce the volume and distribution of runoff to some areas, creating water shadows and increasing flows and periods of ponding in others. This disturbance has the potential to adversely impact downstream vegetation due to water starvation, drowning and/or sedimentation.

Haul roads located in relatively flat areas of the floodplain or across shallow drainage areas have the potential to impede flow and create water shadows on the downstream side of the road. The dynamic loads imposed by heavy traffic loads potentially can result in compaction of the subgrade and therefore decreasing permeability. The development of mine pits adjacent to or within major drainage channels poses significant flood risk to the mine pits and potential for water starvation downstream. Runoff from waste dumps and cleared or disturbed areas may increase the volume of runoff and adversely impact water quality.

The proposed project development may have the following impacts to the hydrological regime if no surface water management infrastructure is implemented (noting that mitigation measures are discussed in Section 5):

- The proposed waste rock dump and topsoil stockpile footprints may reduce the total runoff volume discharging through the Project area as they could result in ponding along their upstream boundaries and potential water shadows downstream of infrastructure. In some



areas, they may also cause flows to be directed downslope along their boundary and discharge in a different location.

- The southeast corner of the proposed footprint for WRD3 and a proposed topsoil stockpile to the south extend into the salt lake and would disrupt the natural surface water hydraulic connectivity with other downstream sections of the salt lake drainage system (refer Figure 4.1). Less runoff will therefore report to the White lake system downstream of the blockage, including Red Lake and Brown Lake. This blockage of the natural flowpaths also has the potential to increase the flooding caused upstream by ponding and impact on mining operations. In addition, water will pond against the southeastern boundary of WRD 3 and the topsoil stockpile following a flood event.
- The open cut pit, waste dump and topsoil stockpile footprints have the potential to contain rainfall falling across these footprints, thereby reducing the effective catchment area to downstream receptors.
- A number of roads are proposed to be constructed across drainage lines, which (if unmanaged) is likely to result in either ponding upstream or redirection of surface water flows along the road alignments.

#### **4.1.2 Sediment Generation**

Mining operations will inherently cause ground disturbance related to mining and construction of ancillary infrastructure, such as ROM pads and crushers, and waste landforms. The impacts of this ground disturbance can be significant, depending on several factors, including the location of the deposit, mine planning, and the terrain of the area, among others. These activities tend to increase sediment loads transported in runoff and could result in sedimentation of vegetated and other sensitive ecological areas.

The potential sources of sediment from the site are as follows:

- External runoff washing sediment from the ROM pad footprint.
- Runoff from the waste rock dumps and topsoil stockpiles carrying sediment-laden water downstream.
- External runoff eroding the toe of the waste rock dumps.

#### **4.1.3 Chemical Water Quality**

Mine development has potential for adverse impacts to surface and groundwater quality due to:

- Spillage of hydrocarbons and chemicals stored, handled or transported on site;
- Runoff from the mine pit, stockpiles, ROM pad and waste dump areas containing metals or other elements; and
- Discharge of water used for dust suppression.

Contaminated discharges have the potential to impact on vegetated areas, pools and other sensitive ecological areas downstream if allowed to enter nearby waterways. The management of hydrocarbons and other chemicals are typically dependent on implemented management practices.

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## **4.2 Impacts to Operations from the Hydrological Regime**

As well as impacting on local hydrology, mining operations can also be impacted by flooding. In this case, flooding of the development has potential to damage waste rock dumps or topsoil stockpiles due to upstream catchments or from the salt lake. There may also be some impact on roads crossing surface water flowpaths. Flooding of the open cut pits from upstream catchments is unlikely to be significant however there is a potential risk of flooding from the salt lake, particularly to Ben Hur pit at the southern end of the Project.

## 5 HYDROLOGICAL RISK ASSESSMENT

### 5.1 Introduction

The previous section identified the potential impacts of the proposed mining project on the hydrological and environmental values of the surrounding area in the absence of any mitigation measures. This section assesses the inherent risk of these impacts and the residual risk remaining following the application of mitigation measures.

DMIRS suggests the evaluation of risks associated with mine development be conducted through considering the objectives for different Environmental Factors shown in the excerpt below (Table 5.1), of which, the Water Resources and Rehabilitation and Mine Closure factors are the most relevant for this report.

**Table 5.1: DMIRS Environmental Factors**

Factor	Objective
Biodiversity	To maintain representation, diversity, viability and ecological function at the species, population and community level.
Water Resources	To maintain the hydrological regimes, quality and quantity of groundwater and surface water to the extent that existing and potential uses, including ecosystem maintenance, are protected.
Land and Soils	To maintain the quality of land and soils so that environmental values are protected.
Rehabilitation and Mine Closure	Mining activities are rehabilitated and closed in a manner to make them physically safe to humans and animals, geo-technically stable, geo-chemically non-polluting/non-contaminating, and capable of sustaining an agreed post-mining land use, and without unacceptable liability to the State.

The hydrological risk assessment has been completed using the qualitative risk matrix template shown in Appendix A, which is based on templates provided in DMIRS 2020. Application of the matrix involves rating each impact on the following:

- Most credible consequence of the impact resulting from the mining operation.
- Likelihood of the adverse impact occurring.

DMIRS 2020 provides general Descriptors for rating each of the Consequence and Likelihood aspects of the risk assessment, which have been adapted for this study (refer Appendix A). Consequences focuses on both the magnitude and duration of impact, ranging from insignificant to severe. The Likelihood of an impact occurring due to the mining operations is focused on the frequency/probability of different scale rain events (i.e. Annual Exceedance Probability) in relation to the expected life of the project.

The likelihood of a flood event exceeding an AEP design criteria over the operational lifetime of the mine (approximately 20 years) was calculated. The exceedance probability is computed using the following equation (as per ARR) and is presented in Table 5.2 for a range of events and design lives:

$$p = 1 - \exp\left(-\frac{L}{Y}\right)$$

Where:

Y = the return period of a given flood event (ARI)

L = the design life in years

p = the exceedance probability during the design life

**Table 5.2: Exceedance Probability**

Mine Life (years)	Probability of Exceedance (%) for AEP					
	39.4% (2yr ARI)	18.1% (5yr ARI)	10% (10yr ARI)	5% (20yr ARI)	2% (50yr ARI)	1% (100yr ARI)
20	100%	98%	86%	63%	33%	18%

With respect to surface water assessments, the likelihood of an event occurring is directly related to the probability that a certain size rain event (% AEP) will occur.

## 5.2 Inherent Unmitigated Hydrological Risks

An inherent risk assessment was completed and includes a combined risk rating for each of the identified potential impacts, which accounts for both the consequence and likelihood of the impact event. The impacts shown in Appendix A as a result of the unwanted events represent the 'worst case scenarios' of that impact type under a no-management scenario.

From the inherent risk matrix (Appendix A), several potential impacts to the environment have a medium to high risk of short to medium-term impact to the hydrological environment of the area.

The most significant issue relates to the development of a waste rock landform (WRD3) and its associated topsoil stockpile within the salt lakes, disrupting the natural flowpath as discussed in Section 4.1.1 and creating a risk of erosion of the waste rock dump toe due to ponding of floodwaters. Related to this is the location of Ben Hur pit adjacent to the salt lake and the potential for flooding of the open pit.

Other risks are related to the development of infrastructure footprints within drainage lines, with the resultant ponding upstream and surface water shadowing downstream. A number of the identified impacts pose a risk in the form of sediment or hydrocarbons being washed away from the Project to impact on downstream receptors.

### 5.3 Mitigation Measures

Following identification of inherent risks associated with the Project, the following process was completed and is outlined subsequently:

- Assess which unmitigated risks are acceptable.
- Propose risk treatments (in the form of Surface Water Management Infrastructure) that can be used to reduce the Residual Risk to an acceptable rating.
- Outline any risks which can't be reduced to acceptable levels through mitigation measures.

Storm water runoff around the mine area and associated infrastructure must be managed to limit the environmental impacts of the mine operations on the surface water regime and reduce the impacts of flooding on the mine operations. From a risk management perspective, surface water management infrastructure should reduce the total risk of an unwanted event occurring such that it can be appropriately managed to an acceptable level of risk. As such, the general management objectives for the Project relating to surface water are as follows:

- Maintain the existing hydrological regime as much as is practicable.
- Mitigate impacts on surface water quality from construction and operations and contain or treat any contaminated water on-site.
- Ensure the quality of the water released from the site will not lead to significant deterioration of the water resources and environment downstream.

Generally, treatment measures should meet the above objectives and design philosophies (where possible):

- Clean water should be diverted around the disturbance footprints to the downstream environment to prevent contamination of clean water catchments.
- Dirty water should be captured and treated close to the source of dirty water (i.e., close to the disturbance area) to reduce the volume of water that needs to be treated. Where possible, treated water should be returned to the downstream environment.
- Surface water management infrastructure must incorporate measures to avoid excessive scour, erosion and sediment transport.
- Drainage around operational areas should be designed to prevent prolonged ponding following rainfall events.
- Flood mitigation measures are required to prevent flood ingress to open pits and mine infrastructure areas.

Based on the guidance outlined by DMIRS (2020), surface water impacts with a High unmitigated risk rating are not acceptable and require treatment to reduce their risk rating. Where possible, mitigation measures should also be considered for events with a rating of medium.



### 5.3.1 Proposed Surface Water Management Infrastructure (Operations)

The proposed management of surface water for the site during mining operations is summarised as follows:

- Where possible, external catchments will be diverted around the development footprint to reduce the volume of water flowing through the site, with the potential to become contaminated by the mining operations.
- Runoff from disturbance areas within the site will either be captured or treated prior to discharge downstream as detailed below.

#### 5.3.1.1 Flow Diversions

Flow diversions are proposed in the following locations, as shown on Figure 5.1:

1. Diversion 1 – Around the northern perimeter of the proposed mine disturbance area, a diversion drain is recommended to capture and divert flows from the catchment to the north around WD1 and WD2 and direct it towards the salt lakes.
2. Diversion 2 – Flowing north-south to the west of WD5 and WD6 a diversion drain is recommended to capture flows from the western catchment and direct them towards the salt lakes to the south. A bund is also recommended adjacent to this diversion through low points to contain water within the drain. The drain alignment is generally downslope, such that a low depth of cut should be required.
3. Diversion 3 – A drain is recommended to be constructed around the south-eastern corner of the topsoil stockpile associated with WD3 to restore the connection between the salt lakes and allow water to flow towards the southwest.

#### 5.3.1.2 Life-of-Mine 2D Model Scenario

A Life-of-Mine (LOM) scenario flood model has been prepared using the diversions proposed in Figure 5.2. A 40m grid was used across the model extent and the pit, waste rock dump and topsoil stockpile footprints were excluded from generating runoff to the surrounding environment as it is assumed that surface water from these areas will be captured and retained. The elevation of the ROM Pad has been raised based on the design information provided by Norton. The flood depth and velocity predictions, including a flood level difference map to the Baseline scenario, are presented in Figures 5.3-5.5.

Figure 5.4 indicates that there is an increase in flood depths within the salt pan upstream of WRD3 as a result of the proposed Project development, despite the inclusion of diversion 3. Figure 5.6 zooms in on this area and shows that the modelled diversion 3 is not sufficient to restore the natural surface water connectivity within the salt lake system and the blockage caused by the Project footprint continues to trap flows upstream. A reduction in the area of the salt lake is also shown by the reduced flood depths within the footprint of WRD3. Figure 5.4 does however indicate that there is minimal change in flood depths downstream of the Project area.

Diversions 1 and 2 (in the north and west of the Project area) function to divert upstream surface water flows and return them to the environment downstream of the infrastructure. There is still however a reduction in flood depths within flowpaths that drain to the east of the Project into the

salt lakes. An increase in the depth of ponding to the west of WRD5 is also shown, as no diversion has been proposed in this location.

#### **5.3.1.3 Road Crossings**

The design and implementation of works should incorporate management features to minimise or mitigate the adverse changes to existing flow regimes, flood characteristics, scour, siltation and erosion of the drainage channels, inundation of areas upstream and water starvation of areas downstream of the construction.

Maintenance of the existing flow regimes should be considered when designing drainage structures. Where linear infrastructure (such as the haul roads) cross flow paths or floodways, any culverts should be maintained to allow continuity of the existing flooding characteristics of the floodplain. Floodways may also be required along the haul road alignment.

Minor waterway crossings should be installed, where required, to ensure areas upstream of the crossings are not unduly inundated, and that waterways at crossings are protected from erosion. Structures should be designed to impede flood flows as little as possible. Each crossing and its release zone should be designed to minimize erosion and potential head cutting of the stream bed.

#### **5.3.1.4 Sediment Control**

Where runoff from waste dumps, pits and stockpile areas can discharge to the environment, capture bunding will be installed to collect runoff and direct it to sedimentation traps which will be located at key positions on the downstream sides of the mine disturbance areas to treat the surface water runoff prior to discharge to the natural watercourse. Proposed nominal locations of sediment basins for the project area are shown in Figure 5.1, along with areas from which dirty flows can be diverted into the pits.

Waste rock dump batter faces should be designed to minimise runoff erosion, and runoff captured from the waste rock dump and other sediment-yielding infrastructure such as stockpile areas and ROM pad will be diverted through sedimentation traps prior to release to the natural watercourse. In general, "dirty" runoff should be treated close to the source disturbance area to reduce the volume of runoff requiring treatment and be kept separate from clean runoff and external catchment areas.

#### **5.3.1.5 Water Quality**

##### **Hydrocarbons**

Hydrocarbons should be managed to avoid leaks and spills. Fuel handling areas should be bunded to capture any spills for remediation and be located outside of floodplains or appropriately elevated to avoid the risk of flood inundation.

Stormwater runoff from workshop pavements, fuel unloading and storage areas and from vehicle washdown areas shall be directed to grit and oil interceptors to remove pollutants prior to discharge of the water. Accidental spills outside controlled areas must be remediated to avoid contamination of groundwater or surface water.

### **Acid Sulfate Soils (ASS)**

At some mine sites, lowering of the water table during mine dewatering can generate ASS in nearby wetlands and pools. If exposed to air, ASS has the potential to cause acidification of these surface waters (low pH) which may impact on flora and fauna.

### **Dust Suppression Water**

Dust suppression water has the potential to impact surrounding vegetation if not managed appropriately. Dust suppression activities need to avoid overspray. Dust suppression will be sourced from local groundwater supplies, which are likely to be fresh and therefore the risk of excessive dust suppression causing runoff that impacts vegetation health is minimal. However, dust suppression water should still be applied to avoid excess water running off to the environment.

### **5.3.2 Pit Surface Water Management**

The pit cells are generally within the shadow of other infrastructure and with no upstream external catchments. No diversions are therefore proposed for surface water management of the pits. However, it is proposed that rainfall collected within the pit footprint and be pumped out as required.

As discussed previously, Ben Hur pit is at risk of flooding from the salt lakes and it is recommended that bunding is installed sufficient to retain the 1% AEP event. The modelling completed by Essential Environmental (2016) produced a peak water elevation of 335.73mRL for a 1% AEP event in White Lake close the Project.

### **5.3.3 Design Standards**

The following nominal design standards for flood mitigation and surface water management measures that were proposed for the Binduli North development (AQ2, 2021) are deemed appropriate for this extension to the development (where relevant):

- Minimum 10% AEP for the design of drainage channels, haul road culverts/floodways, sedimentation traps and diversion drains;
- Abandonment bunds to be constructed above the nominal 1% AEP flood level to prevent external runoff from entering the pit footprint;
- Allowance for a minimum of 0.5m freeboard in all drainage channels and diversion bunding to account for uncertainties, debris and rough construction; and
- Where required, sedimentation traps are to be designed to drop sediment particles greater than or equal to 75 µm out of suspension prior to discharge into the environment during a 10% AEP flood event. The sedimentation traps will also be able to capture the runoff during the first flushing event. A nominal 0.5m storage depth will be allowed for sediment accumulation before clean-out is required.

## **5.4 Closure**

Surface water management measures at closure generally aim to protect the hydrological environment and remaining landforms from flood events including the PMP event (refer Section 3.2.2). A closure scenario PMP flood model was developed, based on the following assumptions of surface water management for the Project at closure which can be revised if required:

- The pit voids will remain in place, with abandonment bunding along the perimeters. Where abandonment bunding is required to divert surface water, it shall be constructed in line with flood bund construction requirements.
- Final waste rock dump surfaces have been assumed to be shaped to reduce runoff velocities and the potential for erosion from the face. Rainfall will be contained on the top of the waste rock dumps by the construction of crest containment bunding to reduce the runoff on the batter slopes. Batter slopes will be contour ripped and sloped to prevent erosion of the waste dump faces.
- Runoff from the face of the waste rock dumps will be diverted to adjacent pits for containment where possible, or allowed to flow to the surrounding environment. Where required, the toes of the waste rock dumps will be protected from the erosive velocities of floodwater from extreme events.
- Removal and rehabilitation of stockpiles, the ROM pad, offices and road alignments.
- Diversion bunds and drains will remain in place to provide continued protection of the rehabilitated landforms in the immediate post-closure phase, plus continuation of flow around the landforms.

The closure scenario for the 2D modelling was developed by simulating the assumed terrain for the waste rock dumps using the top heights provided by Norton and 3% side slopes. Pit abandonment bunding were included as glass walls. The results for the Probable Maximum Flood (PMF) based on the calculated PMP for a 12 hour event are presented in Figures 5.7 and 5.8. The 12 hour event was adopted as it produced greater flood depths than a 3 hour event and was assumed to be representative of the peak event for the catchments surrounding the Project area.

The figures show that extensive flooding is likely to be experienced during a PMF event, including ponding adjacent to waste rock dumps in the north and west of the Project and between infrastructure footprints. Figure 5.9 also demonstrates that diverting the flows around WRD still results in a blockage of flows during the PMF.

## 5.5 Mitigated Risk Analysis and Evaluation

The left-hand part of the Risk Matrix in Appendix A shows the calculated risk rating of potential unwanted events during mine operation without the implementation of any surface water management infrastructure. The hydrological impacts to and from the project were re-assessed (assuming implementation of the treatment measures described above) to quantify the Residual Risks (right hand side of the table in Appendix A).

The resulting Residual Risks are all rated as Low following the application of the proposed management measures, including the following:

- R2 – Construction of waste rock dump 3 within the salt pan resulting in disrupted connectivity of flowpaths within the salt lakes.

It is however recommended that, if possible, a redesign of the footprint of WRD3 and its associated stockpile is considered to reduce the impact on surface water flows within the salt lakes and restore the connectivity to downstream areas.

## 6 SUMMARY AND CONCLUSIONS

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Proposed mining activities associated with the BS Project include open-cut mining, construction of waste rock dumps and topsoil stockpiles and ancillary infrastructure.

Norton's proposed BS open cut pits and associated infrastructure are located immediately upstream of White Lake and/or Douglas Lake, which is part of a large interconnected salt lake system. Surface water flows in this area are likely to be predominantly characterised as sheetflow or in flat undefined flow channels.

A Hydrological Risk Assessment has been completed for the project and several medium to high-inherent (unmitigated) risks to the hydrological environment were identified based on a review of Baseline Flood Mapping. The main project specific risks were as follows:

- Construction of a waste rock dump and associated topsoil stockpile within a salt lake causing disrupted connectivity of flowpaths within the salt lake system and a risk to the geotechnical stability of the structure due to adjacent ponding.
- Construction of an open cut pit adjacent to the salt lake presenting a risk of flooding to the pit.

Mitigation measures have been proposed to reduce the hydrological risks of the project to acceptable (low) levels and are presented in Figure 5.1. Measures have included:

- Diversion of flows around mining infrastructure (where possible) to reduce ponding and return surface water flows to drainage lines downstream.
- Construction of bunding around Ben Hur pit to prevent flooding from the salt lake.
- Construction of culverts or flood ways along the access road that surrounds the site to allow the continuity of the existing hydrological flow regime.
- Construction of containment bunding and sediment basins at the downstream locations of all sediment generating disturbance areas (i.e., waste dump, pit, stockpiles, and ROM) will mitigate sediment generation and transport.

These proposed conceptual mitigation measures were incorporated within a LOM 2D flood model to prepare LOM Flood Maps. Based on the LOM Flood Map results, the identified inherent risks were re-assessed to quantify the residual risks of the project. The Residual Risk Matrix (also shown in Appendix A) indicates that these management measures reduce all residual risks to a Low rating. Although low risk, there are areas of ponding that it has not been reasonably possible to manage, particularly to the west and southeast of the project.

If practical, Norton should consider the feasibility of reshaping the footprint of WRD3 to reduce the incursion of the WRD into the channel that connects the chain of salt lakes and results in subsequent blockage of downstream flows. This would reduce the need for proposed Diversion 3.



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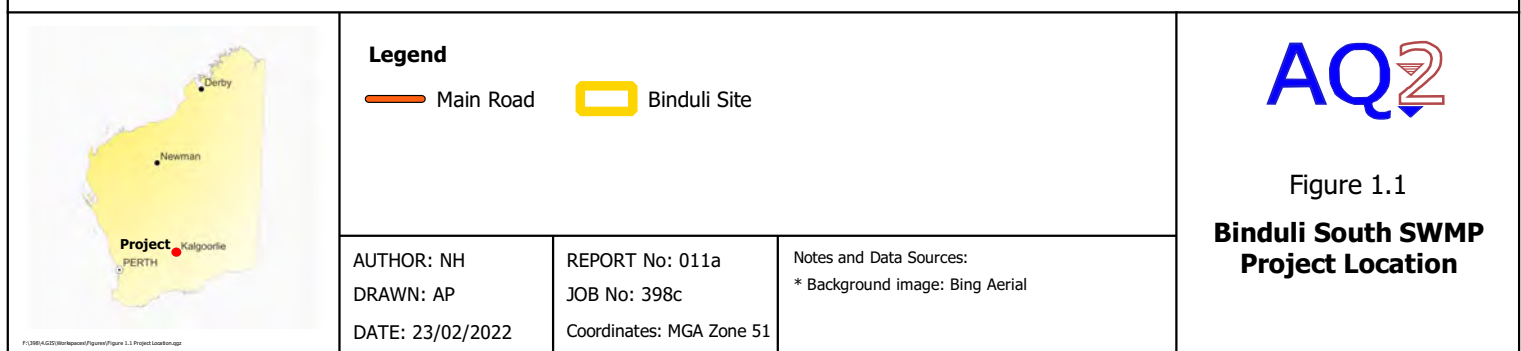
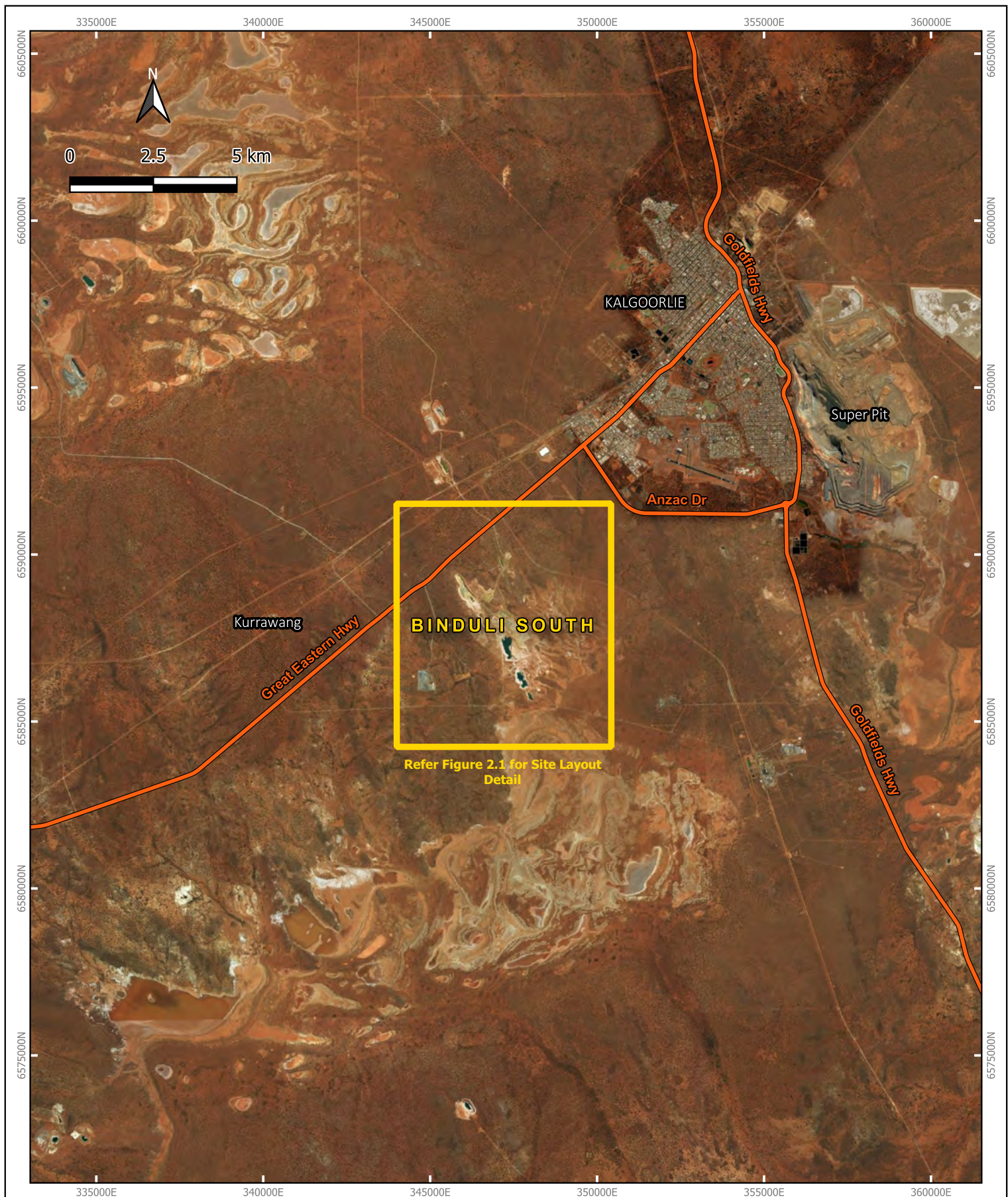
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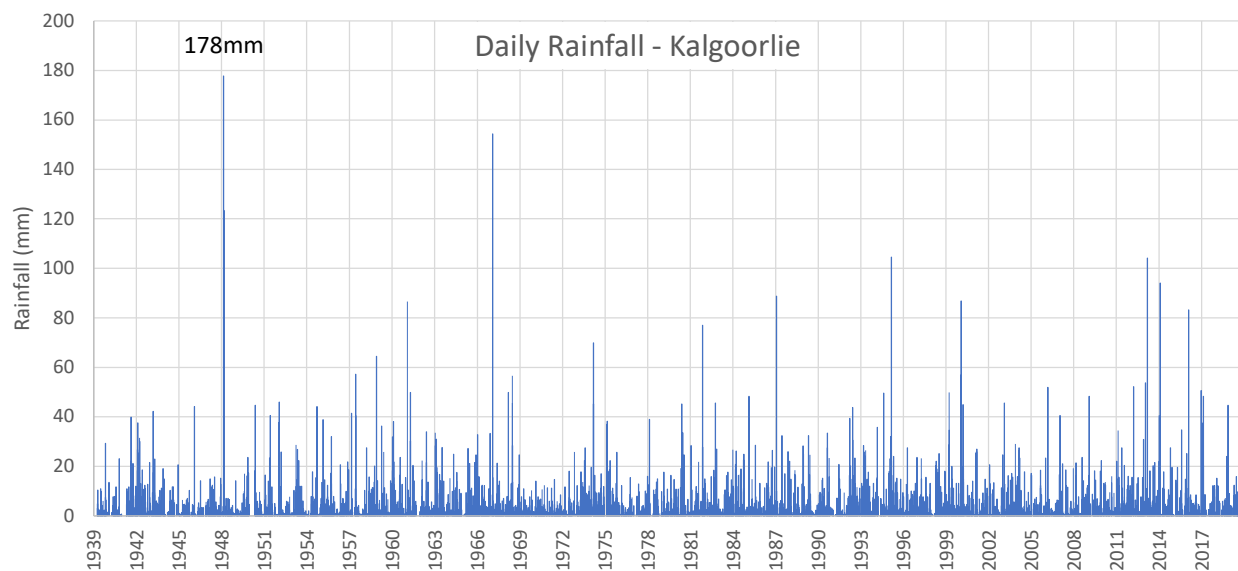
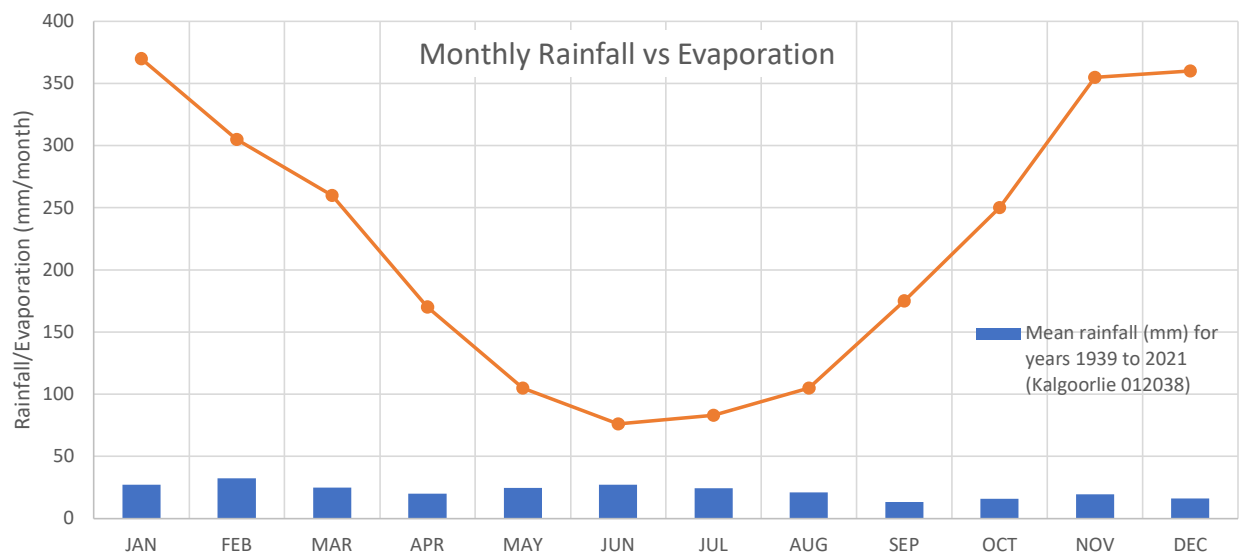
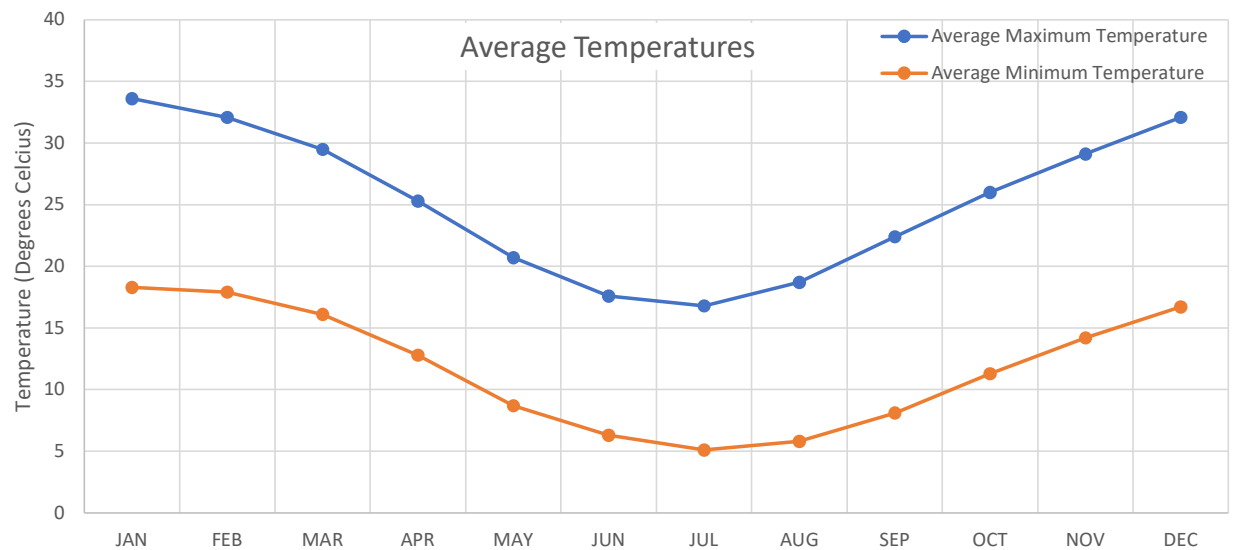
## FIGURES













## IFD Design Rainfall Depth (mm)

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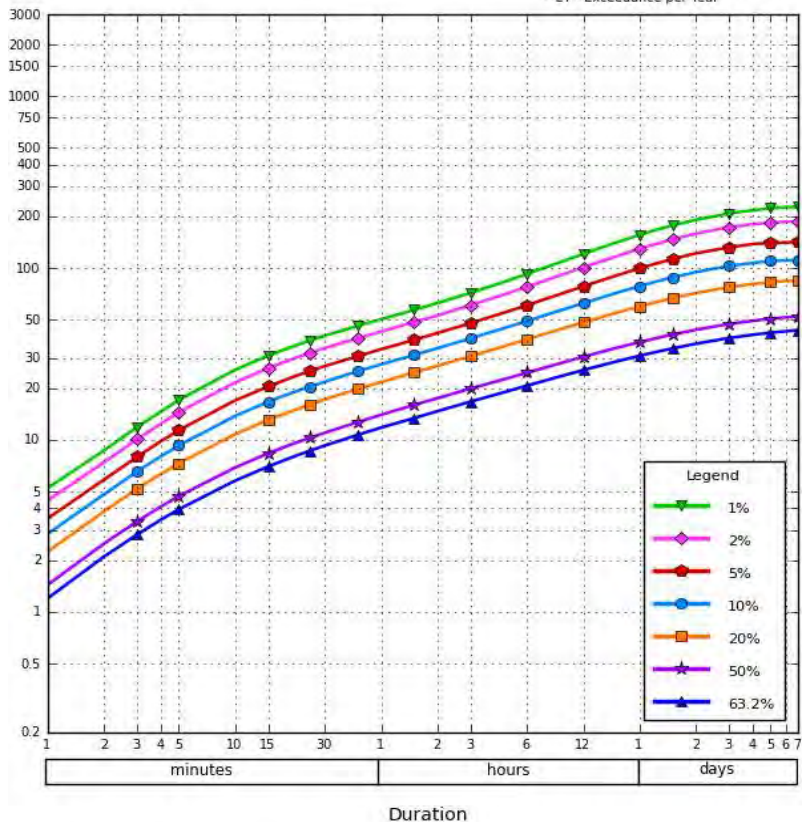
### IFD Design Rainfall Depth (mm)

Issued: 15 December 2021

Rainfall depth in millimetres for Durations, Exceedance per Year (EY), and Annual Exceedance Probabilities (AEP).

Depth  
(mm)

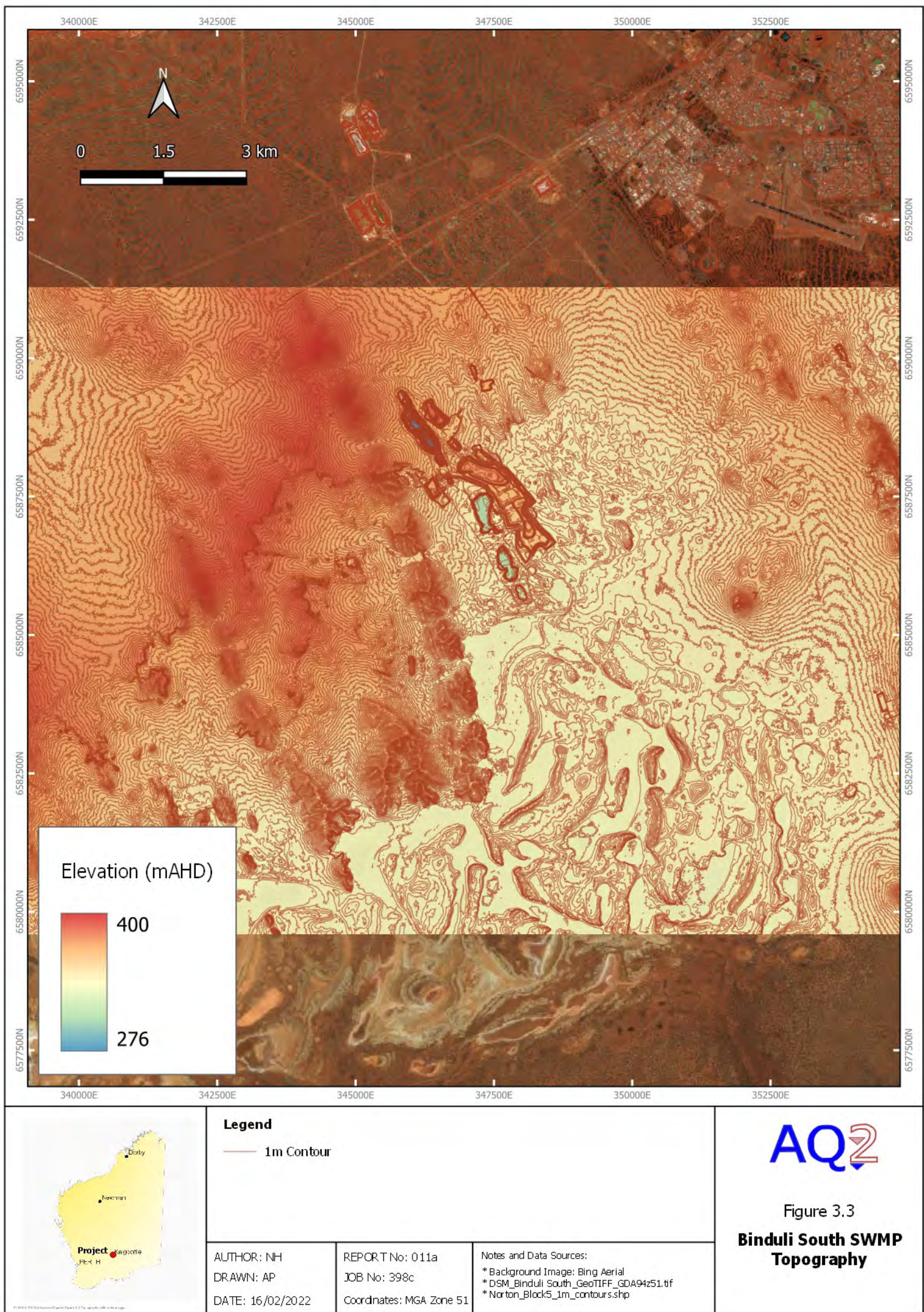
\*AEP - Annual Exceedance Probability  
 \*\*EY - Exceedance per Year



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	Annual Exceedance Probability (AEP)						
Duration	63.2%	50%#	20%*	10%	5%	2%	1%
1 min	1.20	1.44	2.24	2.85	3.50	4.46	5.26
2 min	2.10	2.50	3.85	4.84	5.89	7.43	8.71
3 min	2.82	3.36	5.19	6.56	7.99	10.1	11.9
4 min	3.43	4.09	6.33	8.02	9.81	12.4	14.6
5 min	3.95	4.71	7.32	9.29	11.4	14.5	17.1
10 min	5.80	6.92	10.8	13.8	17.0	21.6	25.6
15 min	7.01	8.36	13.1	16.7	20.5	26.2	31.0
20 min	7.92	9.44	14.7	18.8	23.1	29.5	34.8
25 min	8.65	10.3	16.1	20.4	25.2	32.0	37.9
30 min	9.27	11.0	17.2	21.8	26.9	34.2	40.4
45 min	10.7	12.7	19.8	25.1	30.7	39.1	46.1
1 hour	11.8	14.0	21.7	27.5	33.7	42.7	50.4
1.5 hour	13.4	16.0	24.7	31.2	38.2	48.5	57.1
2 hour	14.7	17.5	27.0	34.2	41.9	53.1	62.6
3 hour	16.7	19.9	30.7	39.0	47.8	60.8	71.7
4.5 hour	18.9	22.5	35.0	44.6	54.9	70.0	82.9
6 hour	20.7	24.6	38.5	49.2	60.8	77.8	92.4
9 hour	23.4	27.9	44.0	56.6	70.5	90.6	108
12 hour	25.5	30.5	48.3	62.5	78.3	101	121
18 hour	28.6	34.3	54.9	71.7	90.5	117	141
24 hour	30.9	37.1	59.9	78.5	99.8	130	156
30 hour	32.7	39.3	63.7	84.0	107	139	168
36 hour	34.1	41.1	66.9	88.3	113	147	177
48 hour	36.3	43.8	71.6	94.9	122	159	191
72 hour	39.2	47.3	77.5	103	132	173	208
96 hour	40.9	49.3	80.8	107	138	180	217
120 hour	42.1	50.7	82.8	110	140	184	223
144 hour	42.9	51.7	84.0	111	141	186	226
168 hour	43.5	52.3	84.7	111	142	187	227

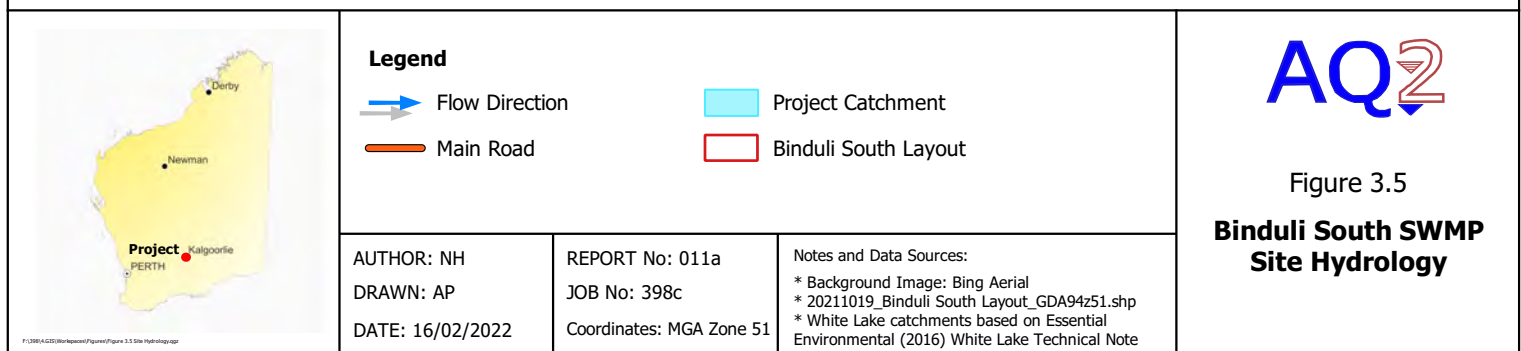
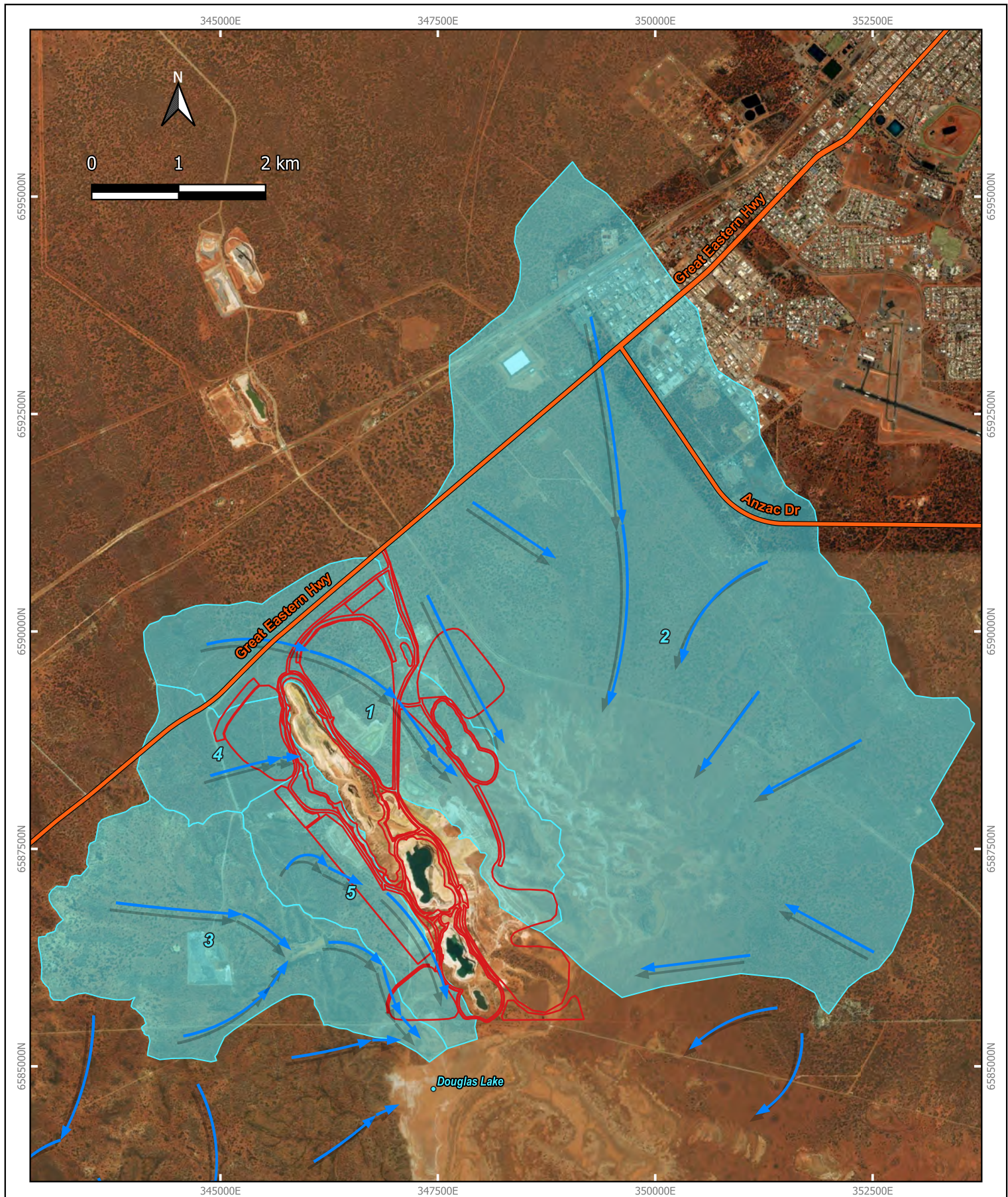




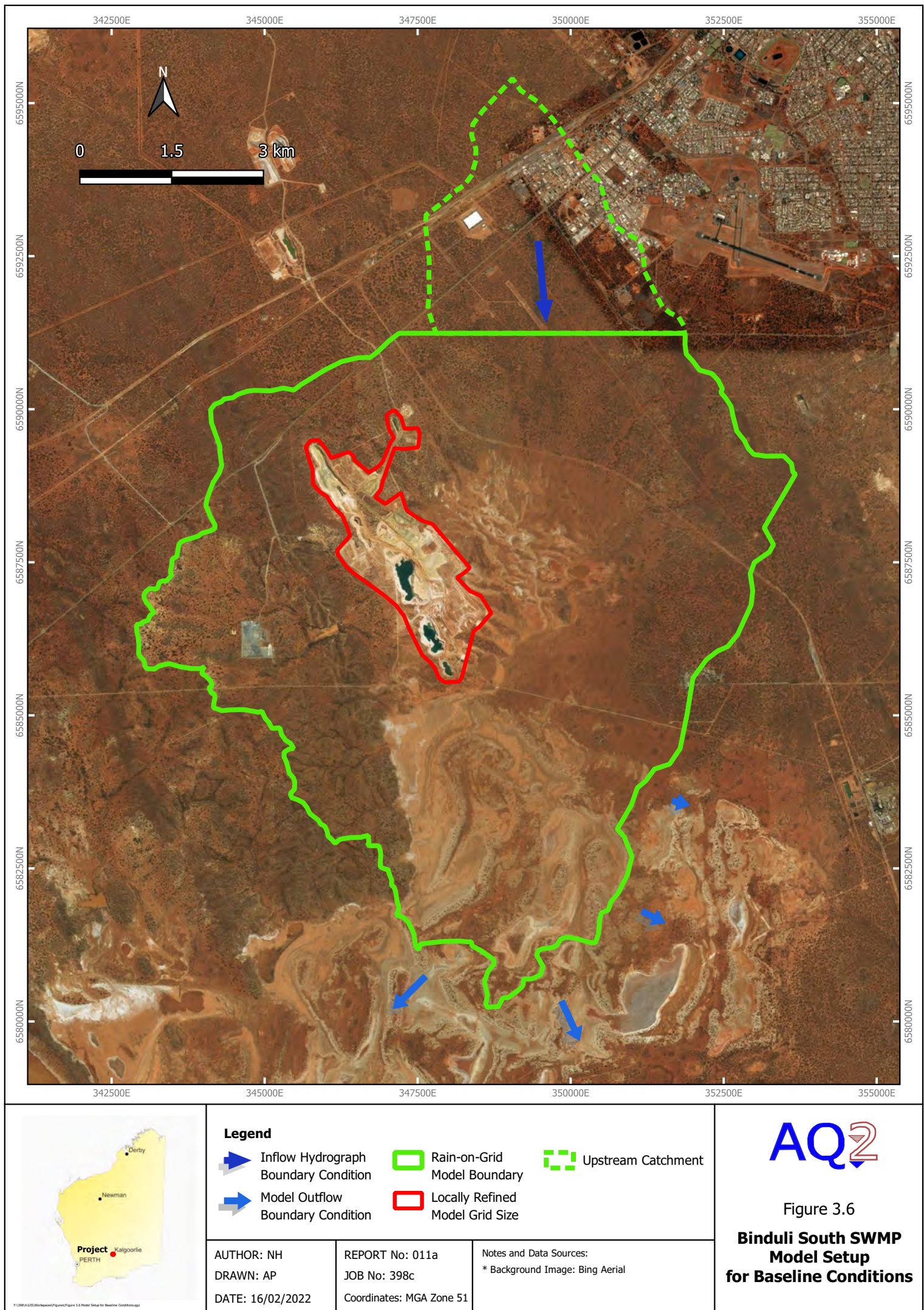




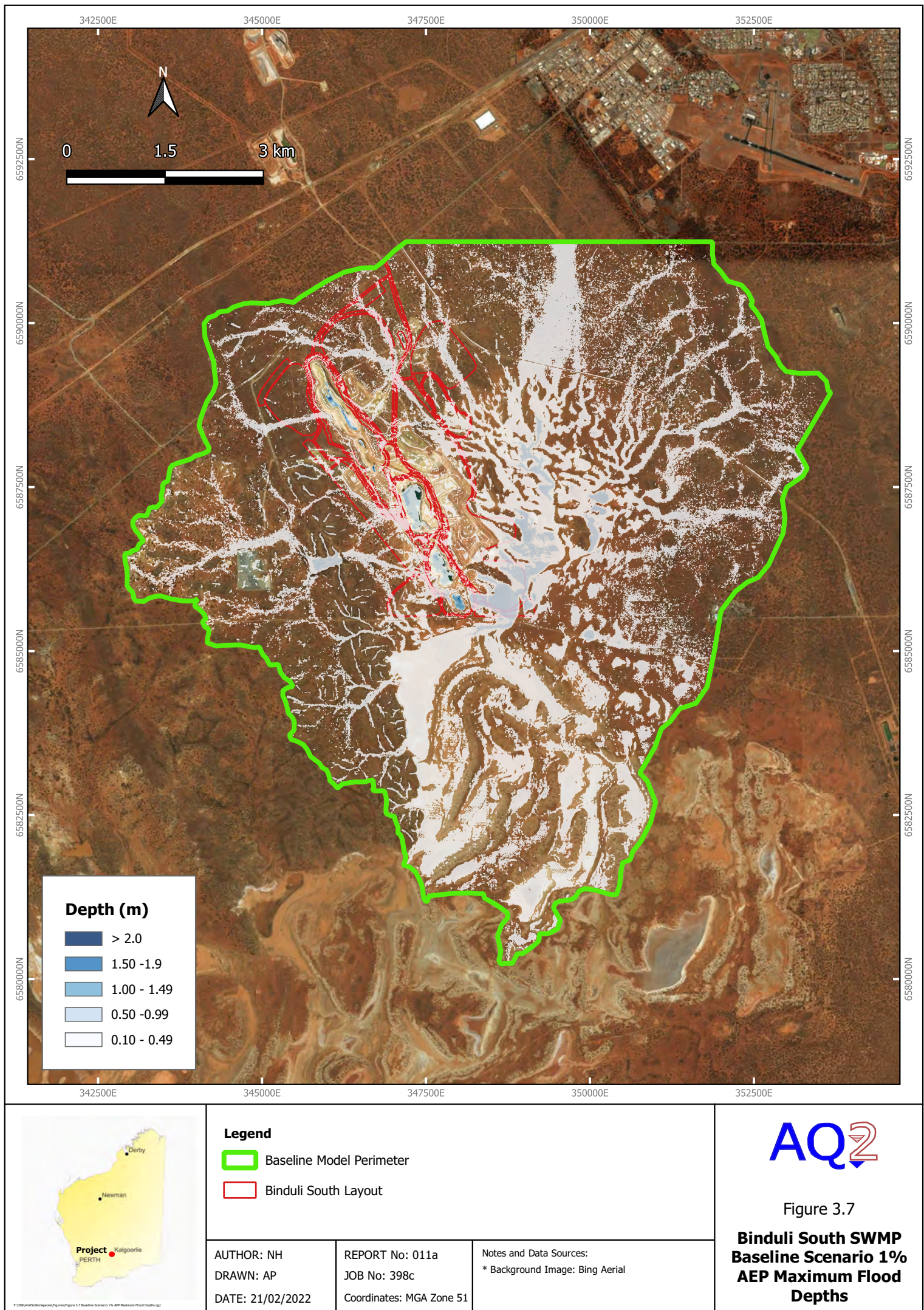




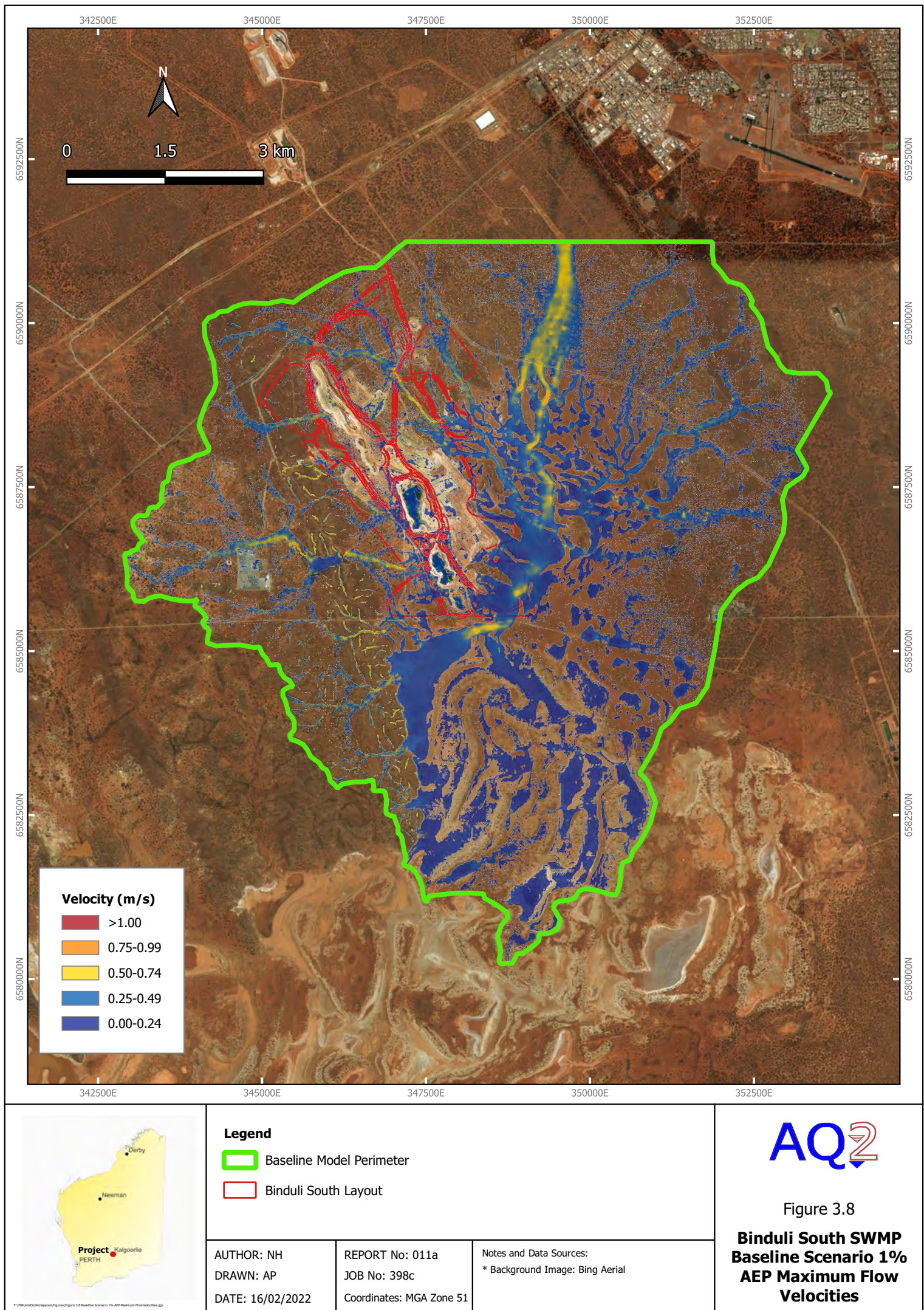




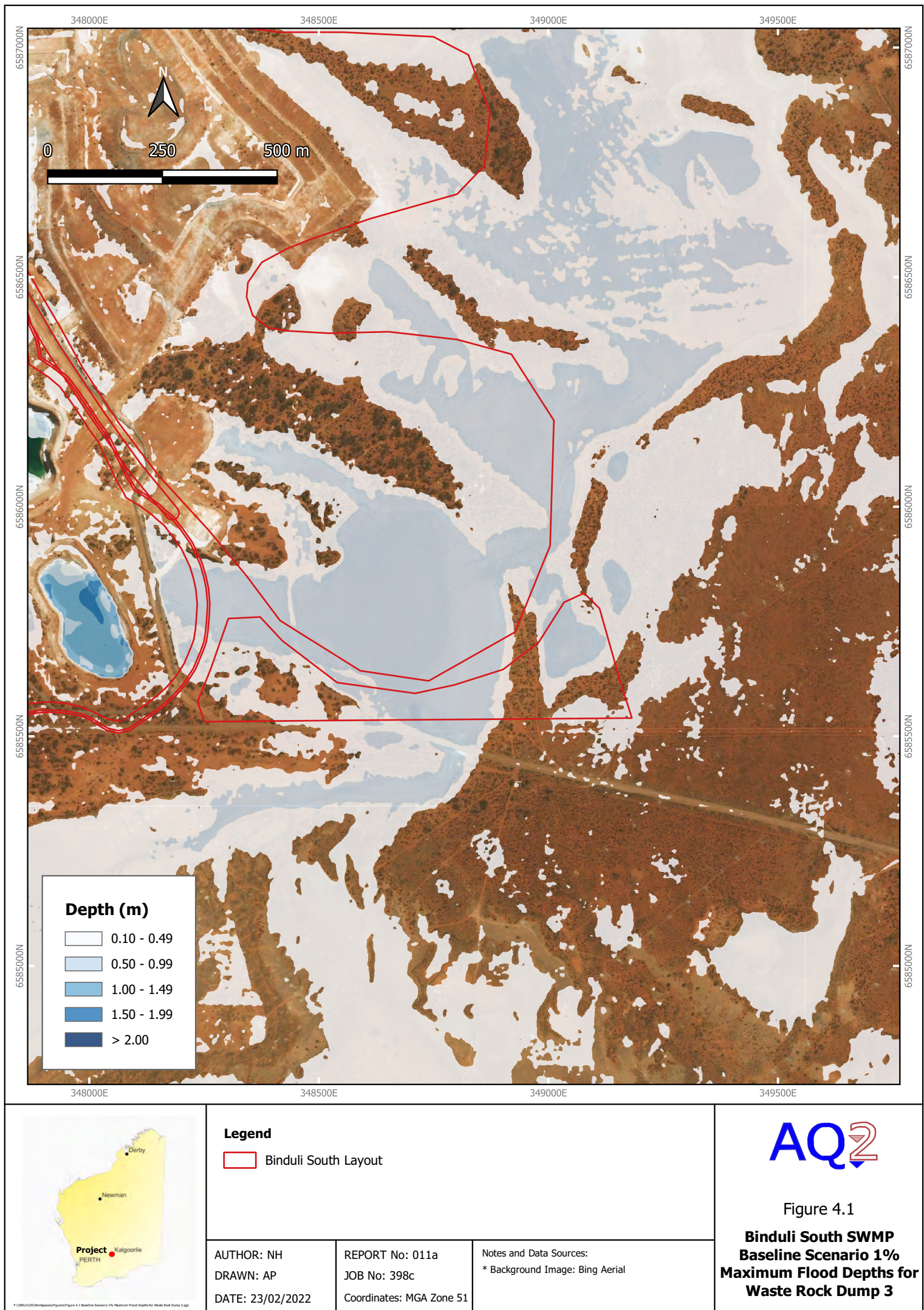




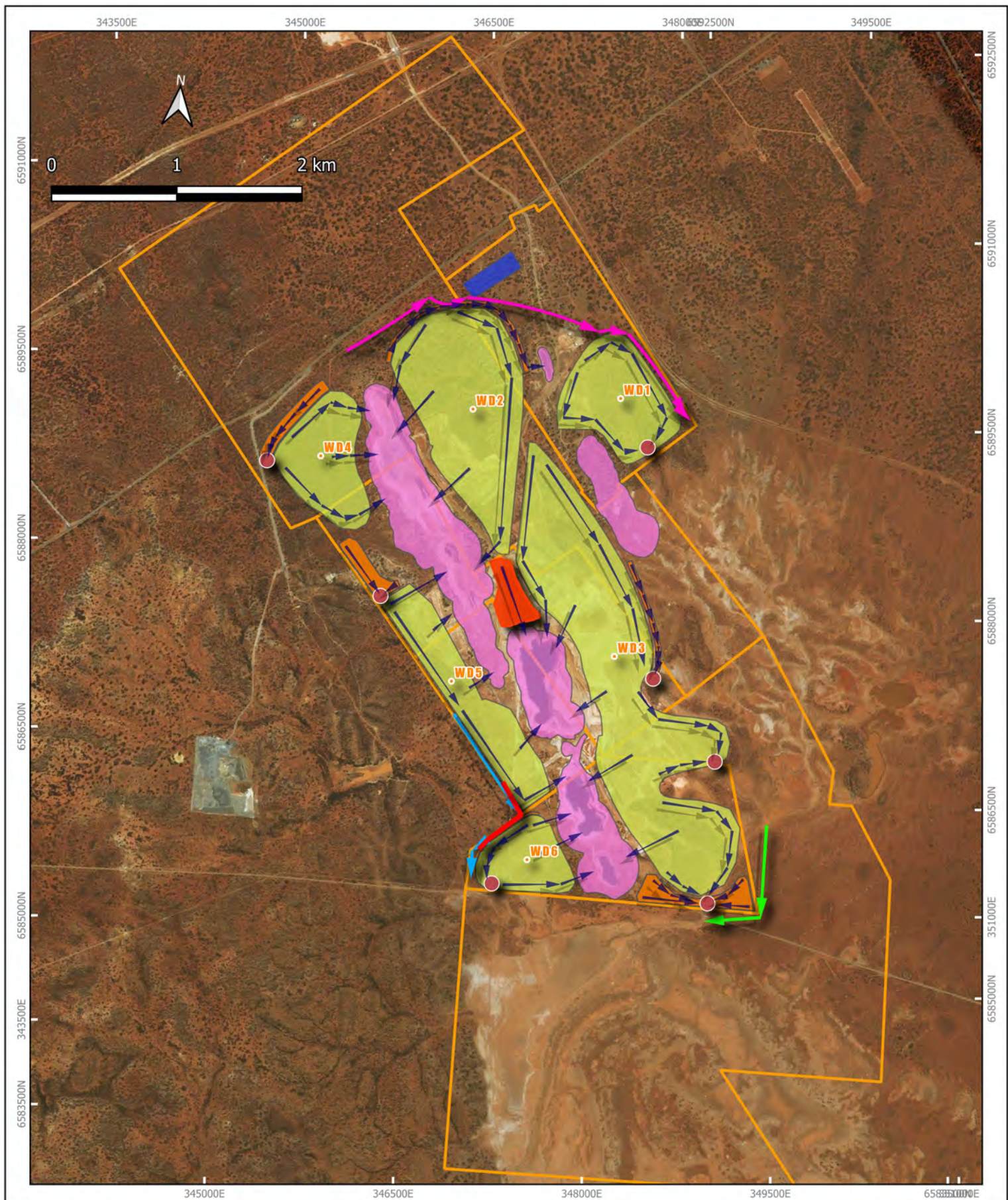












#### Legend

- Proposed Sediment Basins
- ➔ Diverted dirty flows
- Bund 1
- ➔ Diversion 1
- ➔ Diversion 2
- ➔ Diversion 3
- Offices
- Open Pit
- ROM / Crusher
- Topsoil Stockpile
- Waste Rock Landform
- RoM modification
- BS Tenure

AUTHOR: NH

DRAWN: AP

DATE: 24/02/2022

REPORT No: 011a

JOB No: 398c

Coordinates: MGA Zone 51

Notes and Data Sources:

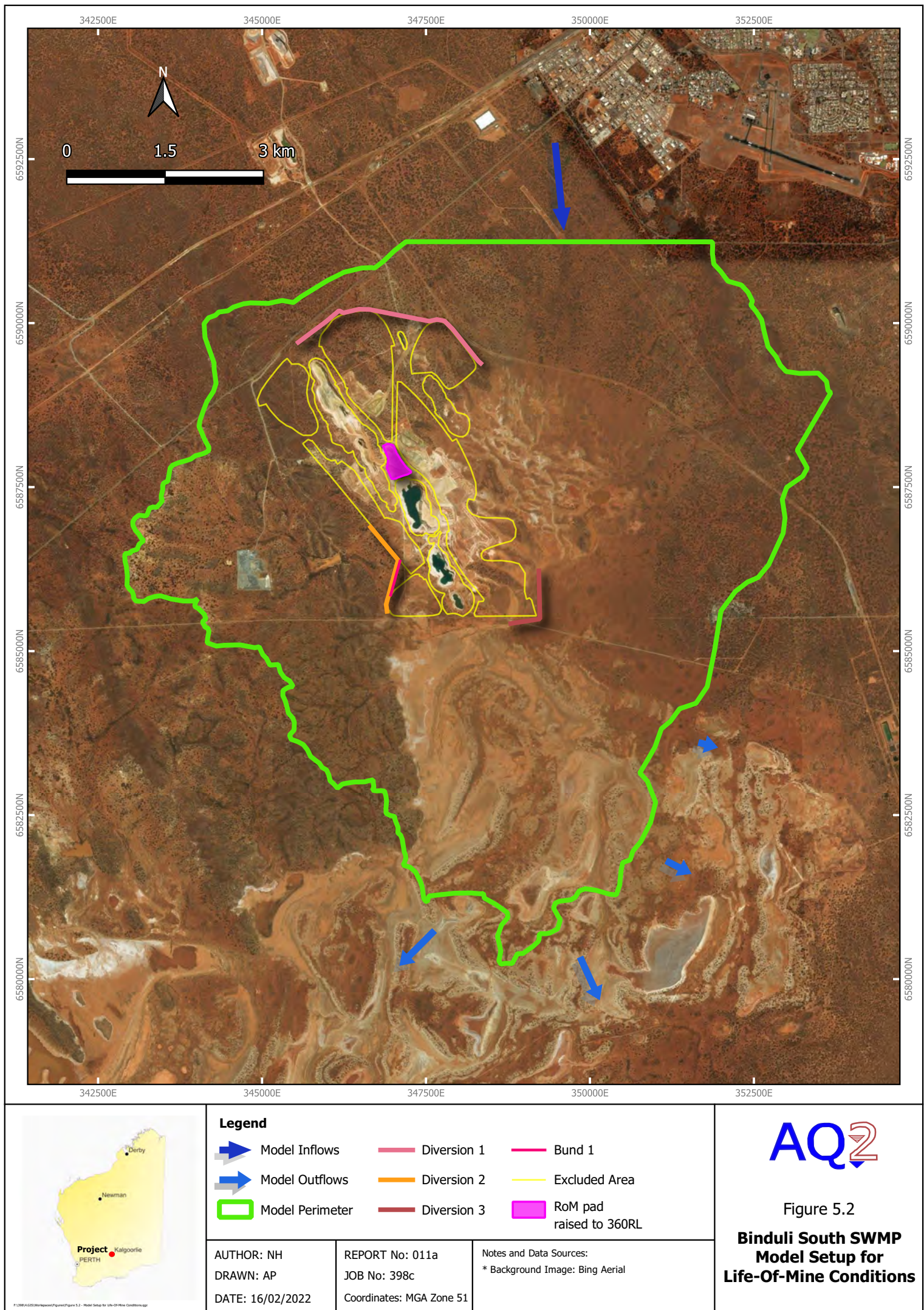
\* Background Image: Bing Aerial

**AQ2**

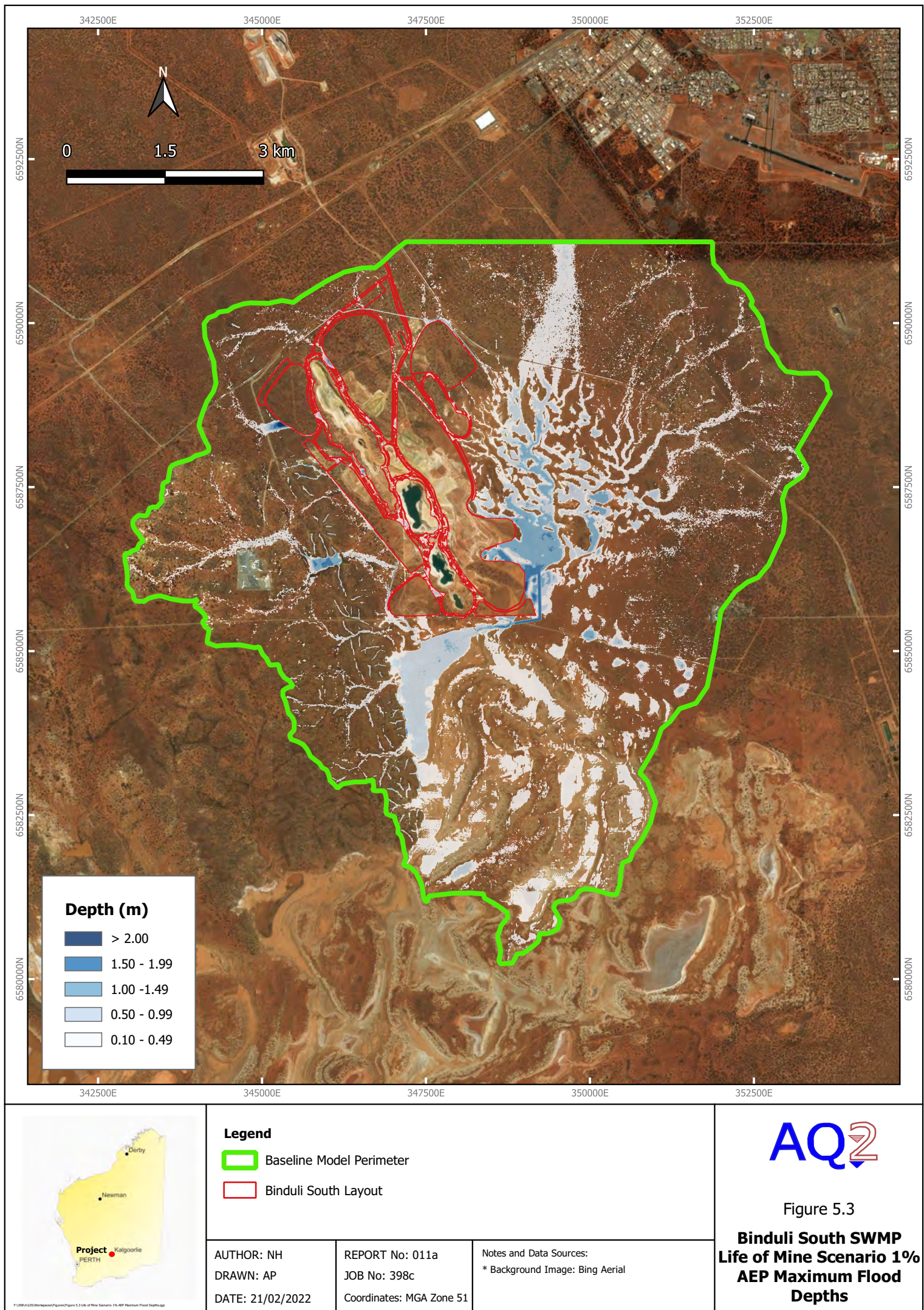
Figure 5.1

**Binduli South SWMP  
Proposed Surface Water  
Mitigation (Operations)**

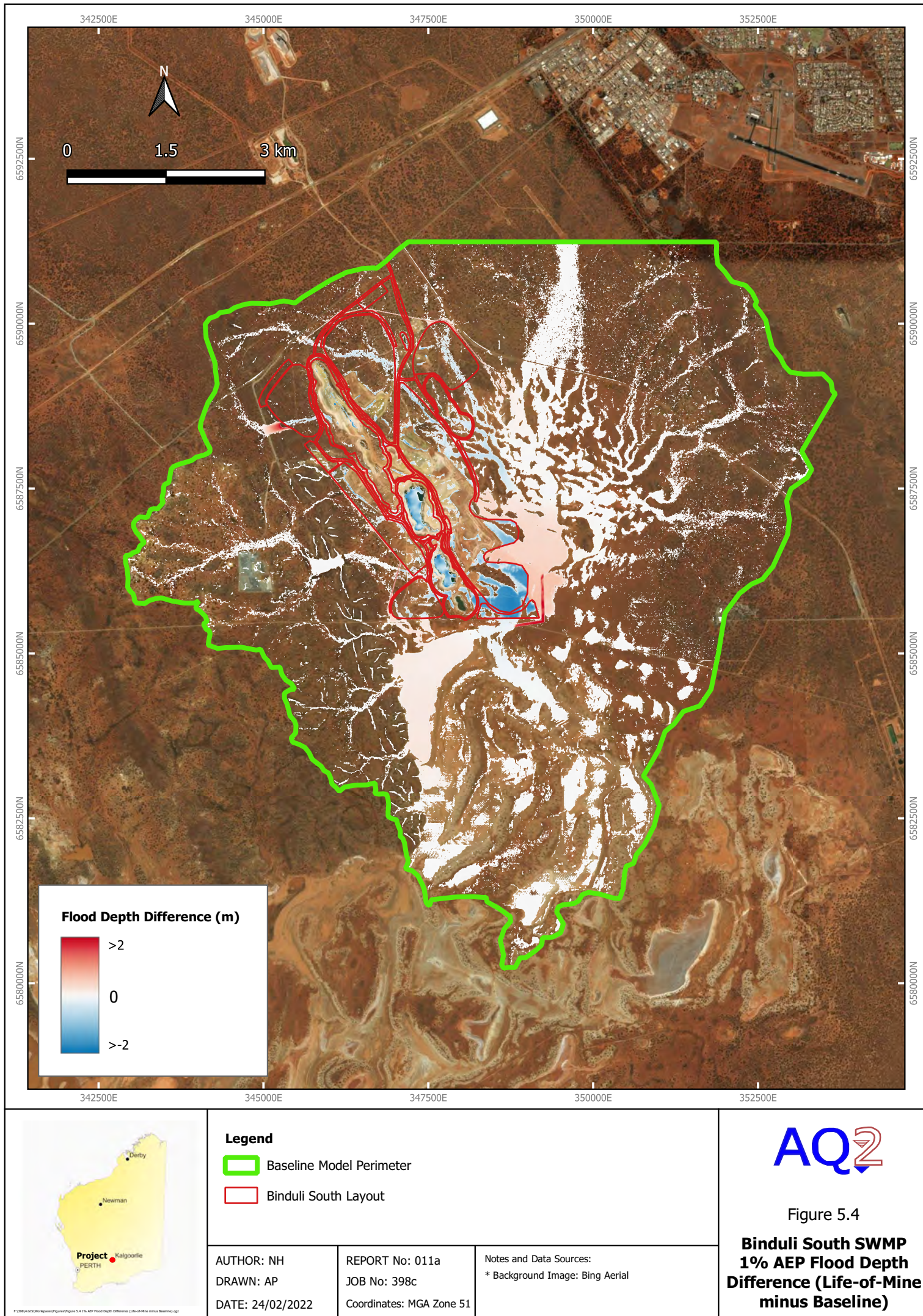




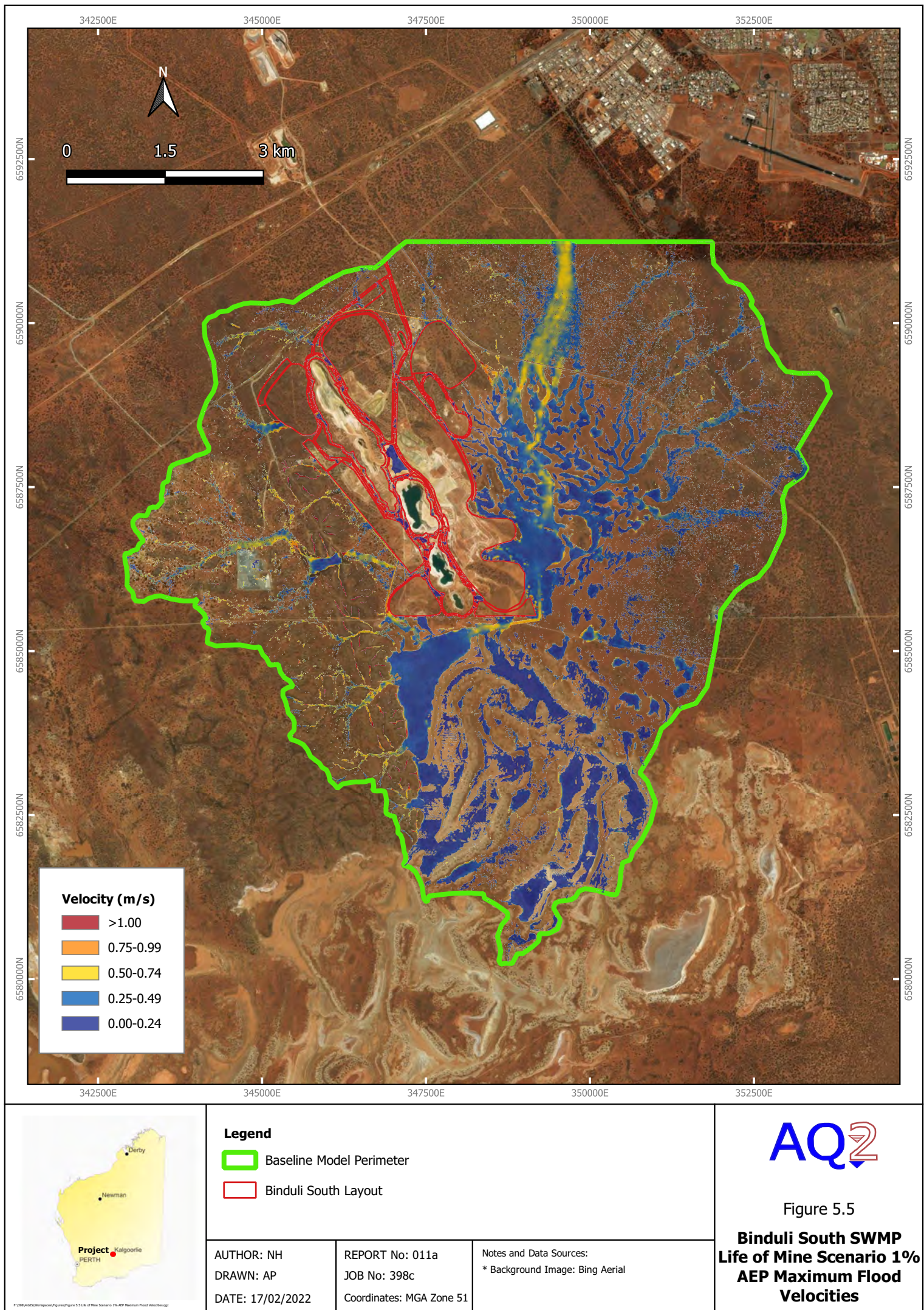




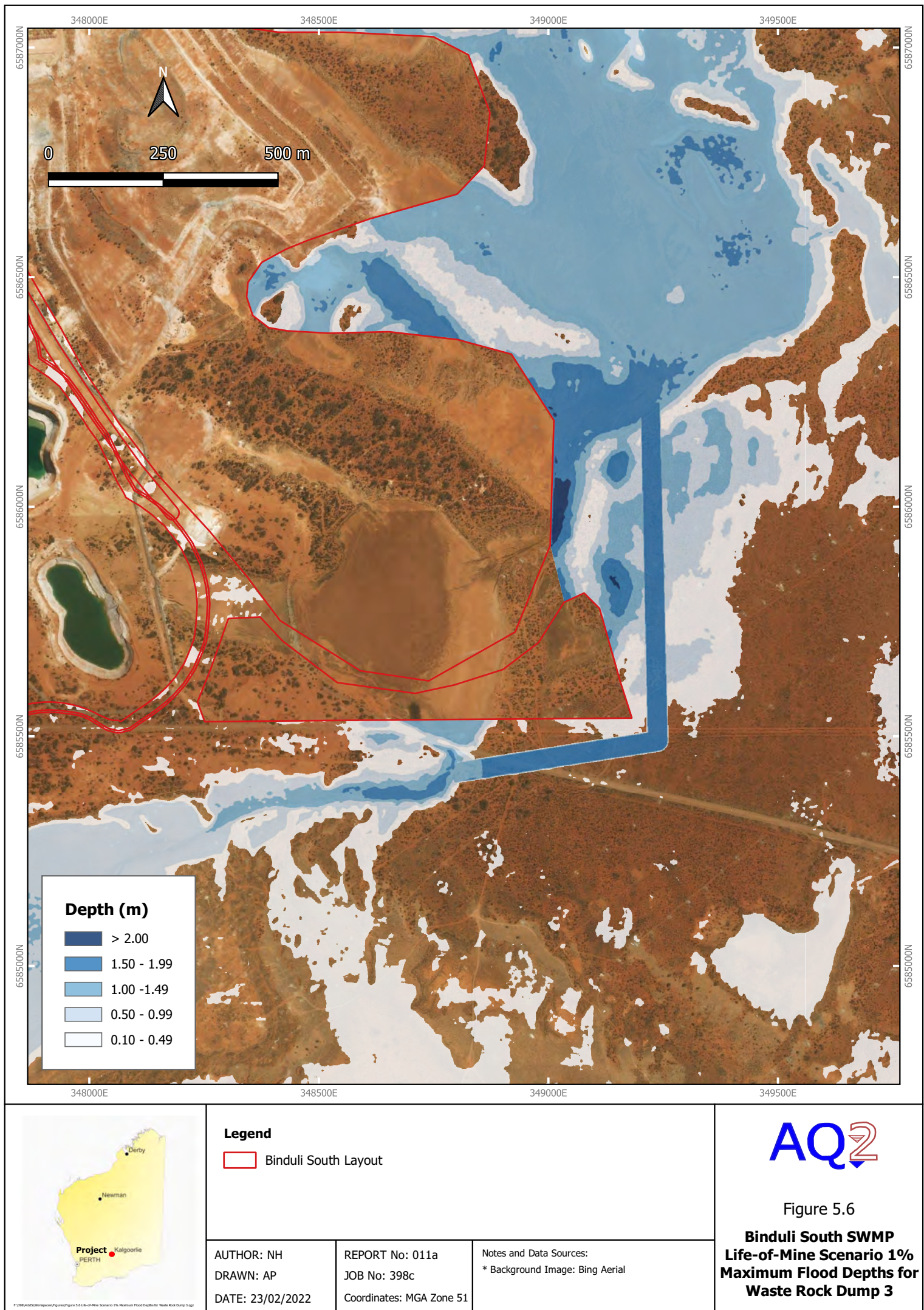




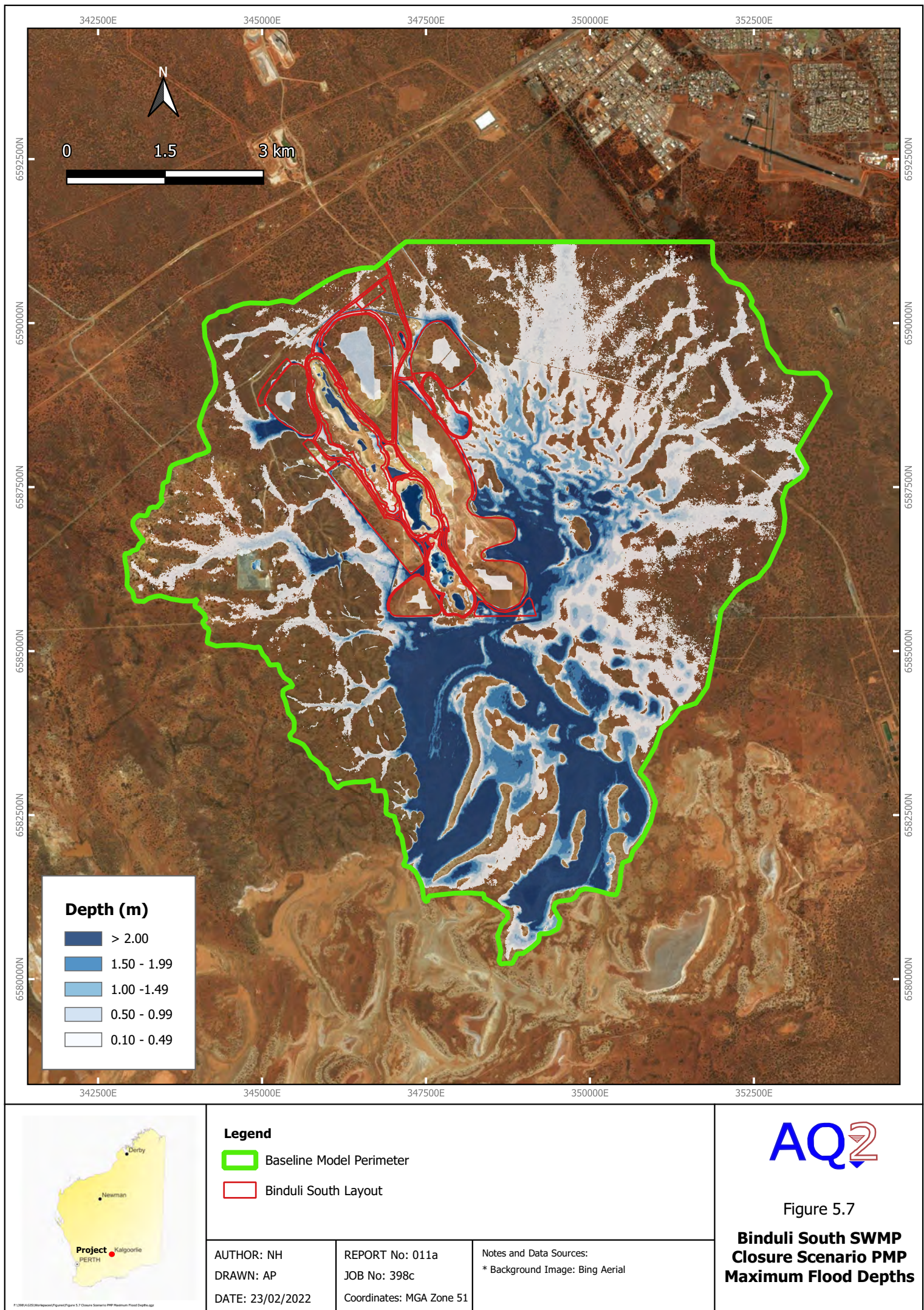




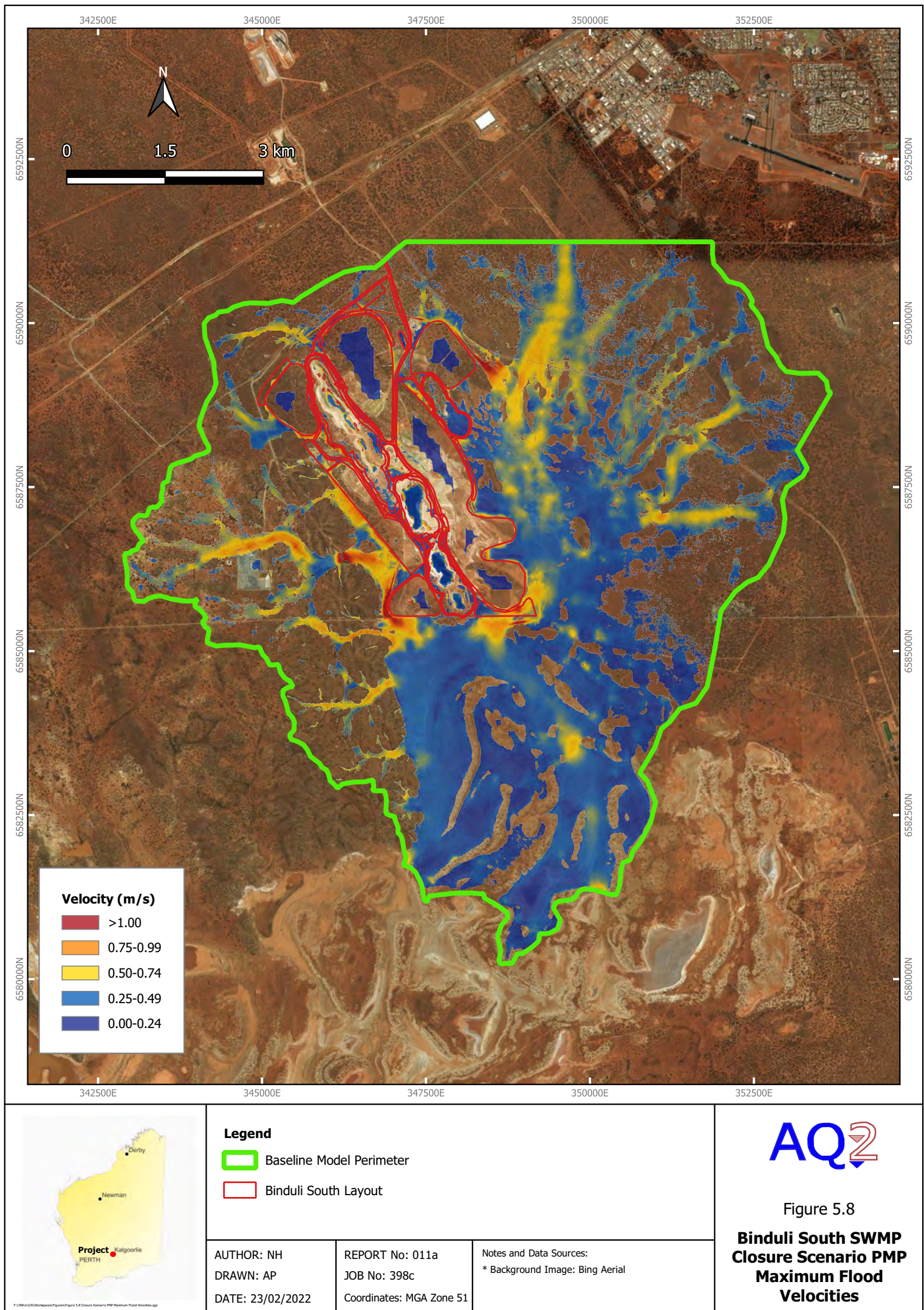




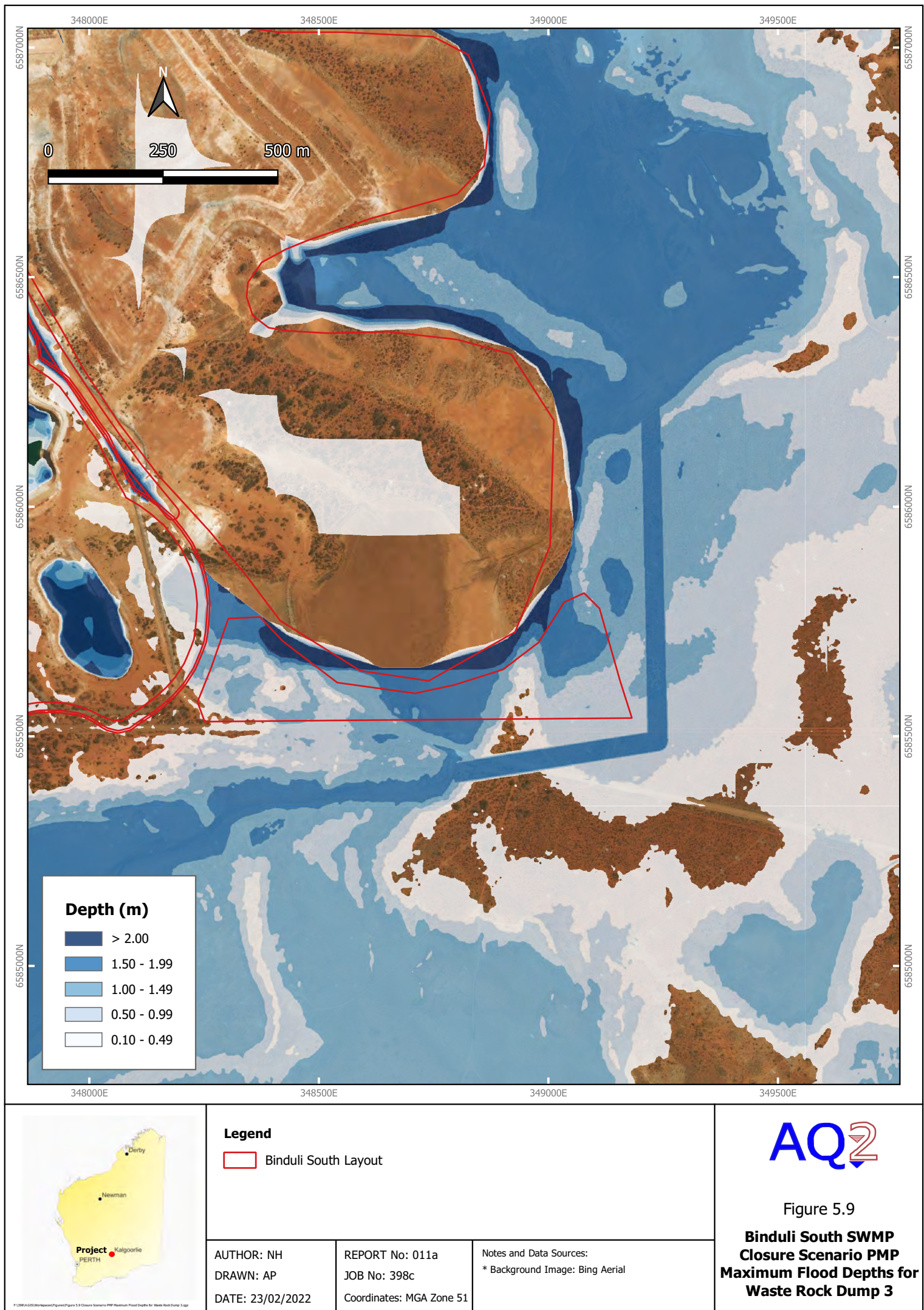












**APPENDIX A**  
**Surface Water Risk Matrix**

		Inherent (Unmitigated)					Residual (Mitigated)				
	Risk ID	Risk Pathway/Unwanted Event	Description of Impact	Phase(s)	Consequence	Likelihood	Risk Rating	Risk Treatment / Mitigation Measure	Consequence	Likelihood	Risk Rating
Modification of Hydrological Regime	R1	Construction of waste rock dumps and topsoil stockpiles in the path of drainage lines	Water shadow on the downstream side of waste rock dumps and topsoil stockpiles and reduction of downstream flow. Ponding on the upstream side of waste rock dumps and topsoil stockpiles.	Operations/Closure	Moderate	Possible	M-13	Where feasible, divert flows around waste rock dumps and topsoil stockpiles as shown on Figure 5.1.	Insignificant	Rare	L-1
	R2	Construction of waste rock dump 3 within the salt pan across a drainage outlet to downstream salt pans	Disrupted connectivity of flowpaths within the salt pan/lake, increased flood depths upstream	Operations/Closure	Major	Possible	H-18	Divert flows around the perimeter of waste rock dump 3 to restore the natural connectivity of surface water flows within the salt lakes/pans.	Minor	Unlikely	L-5
	R3	Removal of catchment area due to pit development	Reduction of flow to the salt pans Pit footprints represent less than 0.1% reduction of the lake system catchment	Construction/ Operations/Closure	Insignificant	Possible	L-4	N/A	N/A	N/A	N/A
	R4	Removal of catchment area due to waste rock dump and topsoil stockpile development	Waste rock dump and topsoil stockpile footprints represent less than 0.1% reduction of the lake system catchment	Construction/ Operations	Insignificant	Possible	L-4	N/A	N/A	N/A	N/A
	R5	Flooding of Ben Hur pit from ponding in the salt lake	Capture of salt pan water within pit void	Closure	Major	Rare	M-10	Construct bunding around the pit to prevent flooding from entering the pit during a PMP event.	Minor	Unlikely	L-5
	R6	Construction of Haul/Access Roads in path of drainage line	Water shadow downstream of roads and ponding on upstream side. Potential redirection of surface water flows along roads	Construction/ Operations	Minor	Possible	M-8	Construct waterway crossings (i.e. culvert, floodway) at appropriate locations	Insignificant	Rare	L-1
Sediment Generation	R7	Erosion of waste rock dump toe	Baseline modelling indicates that low velocity flows will generally be experienced across the Project. Some inundation against the WRD toe will occur following flood events.	Operations/Closure	Moderate	Unlikely	M-9	Rock armour toe at closure and design WRD to withstand adjacent ponding. Some diversions are proposed for environmental reasons that will assist in keeping flows away from some waste rock dumps.	Minor	Unlikely	L-5
	R8	Sediment-laden runoff from face of waste rock dumps or topsoil stockpiles	Ongoing sediment release to downstream environment from frequent rainfall events impacting downstream water quality	Operations	Moderate	Likely	H-17	Construction of containment bunding and sediment basins to remove particles greater than 75um from a 10% AEP event prior to discharge downstream	Minor	Unlikely	L-5
	R9	Sediment-laden runoff from face of waste rock dumps or topsoil stockpiles	Sediment release to downstream environment from large, rare rain events impacting downstream water quality	Construction/ Operations	Moderate	Rare	L-6	Sediment basins from R7 act to remove some sediment. There will be a natural high sediment load in the surface water environment following a large rainfall event. Site discharge contained in downstream salt pans.	Minor	Rare	L-3
	R10	Runoff through the ROM Pad footprint washing sediment downstream	Potential to mobilise sediment from the ROM pad and impact downstream water quality	Operations	Minor	Unlikely	L-5	ROM pad runoff will report to adjacent pit	Insignificant	Rare	L-1
Water Quality	R11	Runoff from disturbance areas containing metals or other chemicals	Pollution of downstream environment leading to environmental damage	Operations	Moderate	Likely	H-17	Runoff from wash bays and fuel storage/handling areas to be directed to grit and oil separators prior to discharge to downstream environment. Runoff from mine pits will be contained within the pits. Sediment basins from R7 will retain runoff from stockpiles and waste rock dumps for settlement/treatment prior to discharge to the environment.	Moderate	Rare	L-6
	R12	Dust suppression water to runoff to environment	Vegetation adversely affected by runoff water	Construction/ Operations	Minor	Possible	M-8	Roads not to be overwatered	Minor	Unlikely	L-5
Impact to Operations	R13	Capture of upstream catchment runoff	Flooding of pit impacting operations	Operations	Minor	Unlikely	L-5	N/A	N/A	N/A	N/A
	R14	Construction of roads across drainage lines	Flooding of roads restricting serviceability	Construction/ Operations	Minor	Possible	M-8	Construct waterway crossings (i.e. culvert, floodway) at appropriate locations along impacted alignments to allow continuity of the existing flow regime.	Minor	Unlikely	L-5
	R15	Flooding of Ben Hur pit from ponding in the salt lake	Flooding of pit impacting operations	Operations	Moderate	Unlikely	M-9	Construct bunding around the pit to prevent flooding from entering the pit during a 1% AEP event (minimum).	Minor	Unlikely	L-5



## **Appendix C: Spectrum Ecology and Spatial (2022) Binduli South Project Flora and Vegetation Assessment**

# BINDULI SOUTH PROJECT FLORA & VEGETATION ASSESSMENT

PREPARED FOR: TALIS CONSULTING |  
NORTON GOLD FIELDS



**Spectrum**  
ECOLOGY & SPATIAL



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Report Details			
Project Description:		Binduli South Project Flora & Vegetation Assessment	
Prepared For:		Talis Consulting   Norton Gold Fields	
Project ID:		2015	
Version History	Authors	Reviewer	Date of Issue
V1	M. Hay	M. Hay	21-Dec-2021
V2	M. Hay	M. Hay	13-Jan-2022

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## EXECUTIVE SUMMARY

Norton Gold Fields Limited (Norton) is exploring the potential for further development at its Binduli South (BS) Gold operations immediately west of Kalgoorlie. Norton have recently secured approvals for its Binduli North (BN) operations which is positioned to the north of the Great Eastern Highway and are now considering future options.

A desktop review was undertaken by Spectrum Ecology & Spatial Pty Ltd (Spectrum) to determine future field efforts for flora within the Study Area (3,556 ha). Following this assessment, Spectrum undertook a detailed, one-phase reconnaissance flora and vegetation assessment and targeted significant flora survey within the Survey Area (1,652 ha). The Survey Area is approximately half the size of the Study Area, and results were used to verify and update the Ecological (2016) detailed flora and vegetation assessment.

The current assessment was undertaken by Spectrum and completed by one botanist over a five-day period. (25–29 October 2021). Spectrum surveyed 26 relevés and 55 km of targeted traverses and the data collected from both relevés, and mapping notes were used to update the vegetation mapping and vegetation condition assessment undertaken by Ecological (2016). Ecological (2016) undertook a detailed level survey in the Study Area from 23 to 30 May 2016. Two botanists surveyed 50 quadrats in the Study Area, of which 18 were conducted within the Survey Area.

A total of 183 taxa from 37 families and 94 genera were recorded within the Study Area. The most species rich family were Asteraceae and Chenopodiaceae with 23 species each, followed by Fabaceae with 22 species. The most species rich genera were *Eucalyptus* and *Acacia* with 13 species, followed by *Eremophila* with 12 species.

One significant flora taxon was recorded in the Survey Area: *Alyxia tetanophylla* (P3) and one was recorded in the Study Area and has potential to occur in the Survey Area: *Goodenia salina* (P2). *Alyxia tetanophylla* (P3) was recorded commonly on the sandy plains close to salt pans in vegetation type P2 and P5. *Alyxia tetanifolia* is known from multiple locations in the local and regional area and is not considered to be locally or regionally significant. *Goodenia salina* (P2) has potential to occur on the low gypseous, Kopi dunes, on vegetation type S2. There are multiple locations of *Goodenia salina* in the local area and it is not considered to have local significance, however as this is the only population in the Coolgardie region (the remaining are in Esperance Plains, approx. 1,000 km south-west) it is considered to have regional significance at the Survey Area.

Of the 183 taxa recorded, 12 (6.6%) were introduced flora taxa which included: \**Asphodelus fistulosus* (Onion Weed), \**Centaurea melitensis* (Maltese Cockspur), \**Cuscuta epithymum* (Lesser Dodder), \**Dittrichia graveolens* (Stinkwort), \**Lactuca serriola* forma *serriola* (Prickly Lettuce), \**Nicotiana glauca* (Tree Tobacco), \**Rumex vesicarius* (Ruby Dock), \**Sonchus oleraceus* (Common Sowthistle), \**Tamarix aphylla* (Athel Pine) in the Survey Area and \**Cenchrus ciliaris* (Buffel Grass), \**Chloris virgata* (Feathertop Rhodes Grass), and \**Salvia verbenaca* (Wild Sage) in the Study Area only. Of these weeds, \*\**Tamarix aphylla* (Athel Pine) is a Weed of National Significance, and a Declared Pest.

A total of 12 vegetation types were described from the Survey Area, which were recorded on clay plains, sandy plains, rocky plains, granitic hillslopes, Gypseous dunes, drainage lines, salt lakes and salt pans. The most common vegetation type was dominated by mixed *Eucalyptus* species woodlands which were widespread in the northern half of the Survey Area and various Chenopod shrublands dominated the remainder.

No TEC or PEC communities occur or are likely to occur within the Study Area and none of the vegetation communities resemble any known TEC or PEC communities.

Of the 12 vegetation types in the Survey Area, one is locally and regionally significant: S2: *Callitris columellaris* (+/-*Eucalyptus griffithsii*) low open woodland, over *Dodonaea viscosa* subsp. *angustissima* mid sparse shrubland, over *Lawrenia helmsii*, *Scaevola spinescens*, and *Rhagodia drummondii* low sparse shrubland on Gypseous (Kopi) dunes. S2 is restricted to small areas associated with the Gypseous dunes in between salt lakes which are likely to be locally and regionally restricted. It is associated with locally and regionally restricted Beard sub-association 123.1.

The vegetation condition within the Survey Area were mapped by Ecological 2016 and ranged from Very Good (68.5%) to Completely Degraded (27.2%). The majority of the intact vegetation was mapped as Very Good, with disturbances including exploration tracks and scattered weeds.



# 1. INTRODUCTION

## 1.1. Project Background

Norton Gold Fields Limited (Norton) is exploring the potential for further development at its Binduli South (BS) Gold operations immediately west of Kalgoorlie (Map 1.1). Binduli South (the Study Area) consists of open pits and Waste Rock Landforms (WRLs) from previous mining activities (with ore being transported to their Paddington operations to the north of Kalgoorlie).

Norton have recently secured approvals for its Binduli North (BN) operations, which are positioned to the north of the Great Eastern Highway and are now considering future options. The Binduli South project will require detailed biological survey information to support the approvals process.

## 1.2. Project Scope

A desktop review was undertaken in order to determine future field effort covering appropriate surveys for both flora and fauna, short range endemic (SRE) species, salt-lake invertebrates, and subterranean fauna (as required) within the Study Area.

A detailed flora and vegetation assessment was undertaken by Ecological (2016) across the Study Area (3,556 ha). Following the desktop assessment, it was determined that an additional targeted survey would be required along with a site visit to verify the results of the Ecological (2016) assessment.

Spectrum undertook a detailed flora and vegetation assessment on the Survey Area (1,652 ha), an area half the size of the Study Area. This report presents the flora and vegetation values at the Survey Area, including the updated results of the Ecological (2016) detailed assessment, and the current targeted and verification survey.

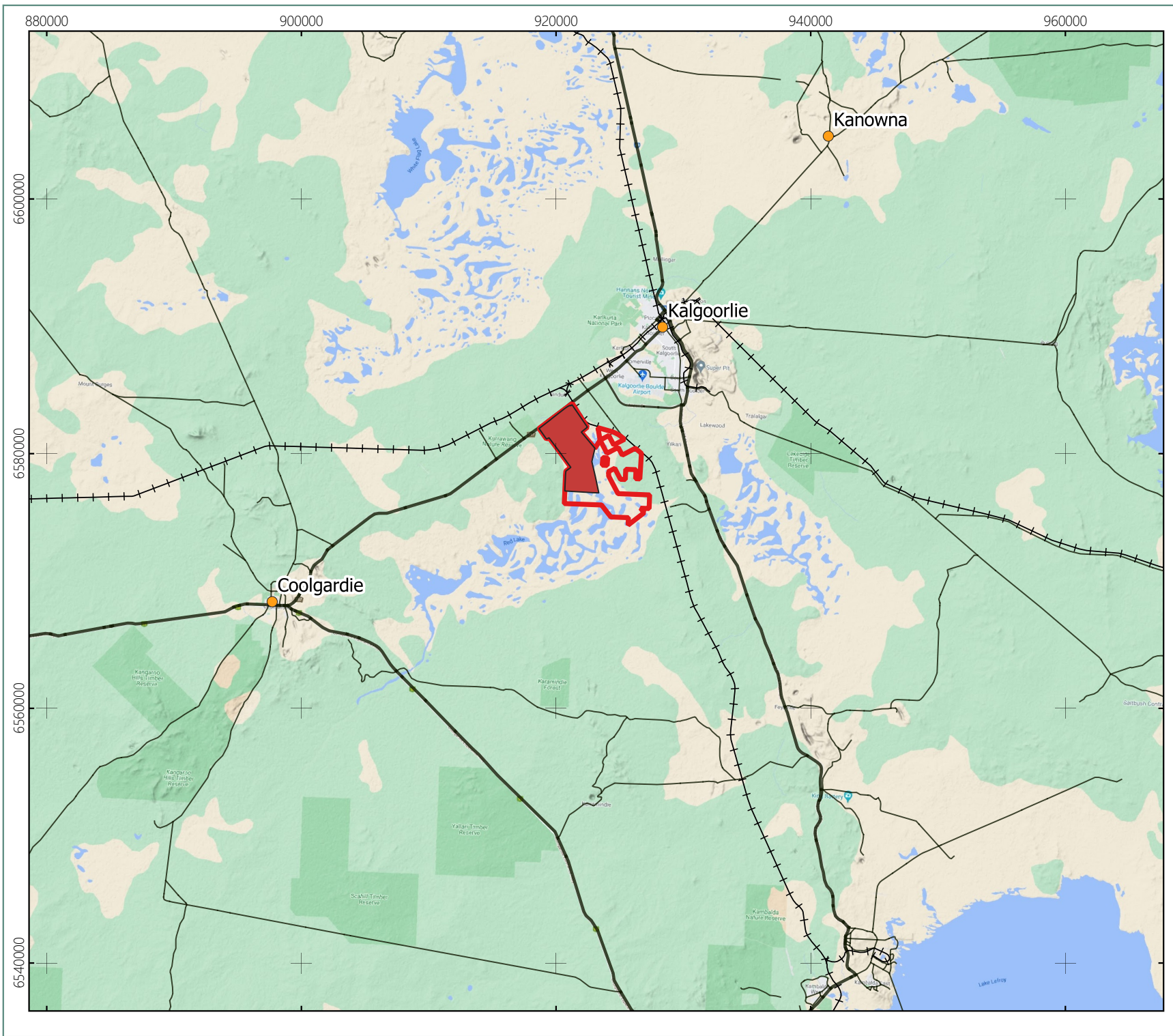
## 1.3. Legislation & Guidelines

Flora and fauna in Western Australia are protected by various legislation, including:

- *Biodiversity Conservation Act 2016* (BC Act, WA Gov, 2016);
- *Environmental Protection Act 1986* (EP Act, WA Gov, 1986); and
- *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act, DoEE, 2016b).

This assessment is compliant with the appropriate guidelines as outlined in:

- EPA Technical Guidance: Flora and Vegetation Surveys for Environmental Impact Assessment (Environmental Protection Authority, 2016c);
- EPA Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection (Environmental Protection Authority, 2002);
- EPA Environmental Factor Guideline: Flora and Vegetation (Environmental Protection Authority, 2016b);
- DBCA Threatened and Priority Flora Report Form – Field Manual (Department of Biodiversity Conservation and Attractions, 2017); and
- National Vegetation Information System (NVIS) Australian Vegetation Attribute Manual (ESCAVI, 2003).




### Legend

- Study Area
- Survey Area
- Australian\_Cities\_Towns

#### Roads


- Dual Carriageway
- Minor Road
- Principal Road
- Secondary Road
- Track
- Railways



0 5 10 15 km

Scale 1:405000

Coordinate System: GDA 1994 MGA Zone 51  
Projection: Universal Transverse Mercator  
Units: Metre

Spectrum  
ECOLOGY • SPATIAL

Author: JH

Date: 12-01-2022

## Location of the Binduli South Study Area

### Binduli Expansion Project

Prepared for  
Talis Consultants | Norton

MAP  
1.1

## 1.4. Bioregion

The Interim Biogeographic Regionalisation for Australia (IBRA) classified Australia into regions based on the dominant landscape, climate, lithology, geology, landform, and vegetation (Thackway and Cresswell, 1995).

The Study Area is situated in the Coolgardie IBRA region, which is made up of three sub-regions: Eastern Goldfields, Mardabilla, and Southern Cross. The Coolgardie IBRA region is characterised by low greenstone hills, granite outcrops, laterite uplands, broad plains, and salt lakes. Aboriginal land, pastoral lease, gold and nickel mines, and national parks and reserves make up the land tenure (McKenzie, May and McKenna, 2003).

The Study Area lies in the north-west of the Eastern Goldfields IBRA subregion (Figure 1.1). This subregion is characterised by gently undulating plains interrupted by low hills and ridges of Archaean greenstones, and by a horst of Proterozoic basic granulite. The substrate is dominated by calcareous earths which cover much of the plains and greenstone areas (McKenzie, May and McKenna, 2003).

A series of large playa lakes in the western half are the remnants of an ancient major drainage line. The vegetation is generally dominated by Mallees, Acacia shrublands and sandplains with heath, while the ranges, valleys and salt lake surrounds are dominated by diverse Eucalyptus woodlands. Samphire habitats can also be found at the numerous salt lakes. A high level of endemism occurs with the Acacia species of the Eastern Goldfields subregion (McKenzie, May and McKenna, 2003).

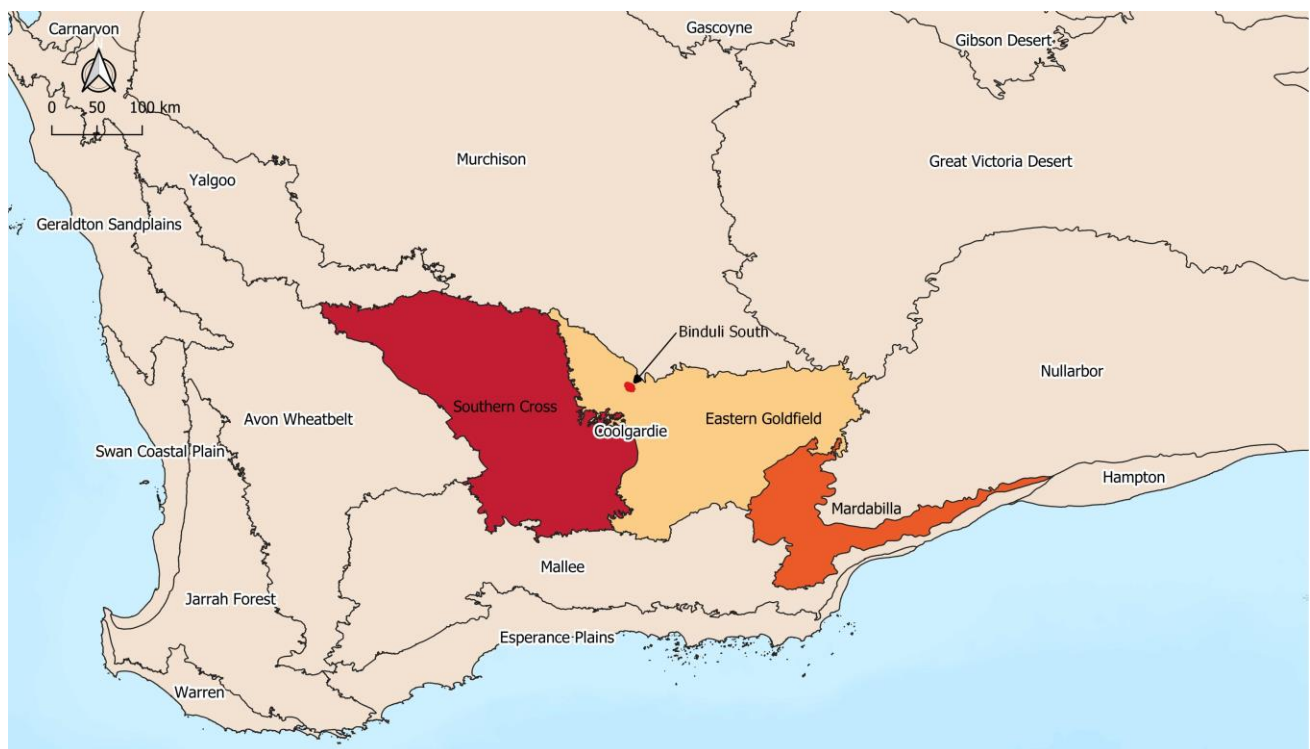


Figure 1.1: IBRA Classification of the Survey Area



## 1.5. Disturbance History

The Eastern Goldfields subregion consists mainly of Unallocated Crown Land (UCL) which includes low impact recreational disturbance, pastoral leases (disturbance from grazing by cattle and sheep), as well as mining leases (Cowan, 2001). Logging for fuel and mineshafts was previously conducted in the region from 1890 to 1950 but these are now regenerating (Cowan, 2001). The main threatening processes affecting fauna are feral predators, grazing (by stock and rabbits), fragmentation and changed fire regimes (McKenzie, May and McKenna, 2003).

## 1.6. Geology

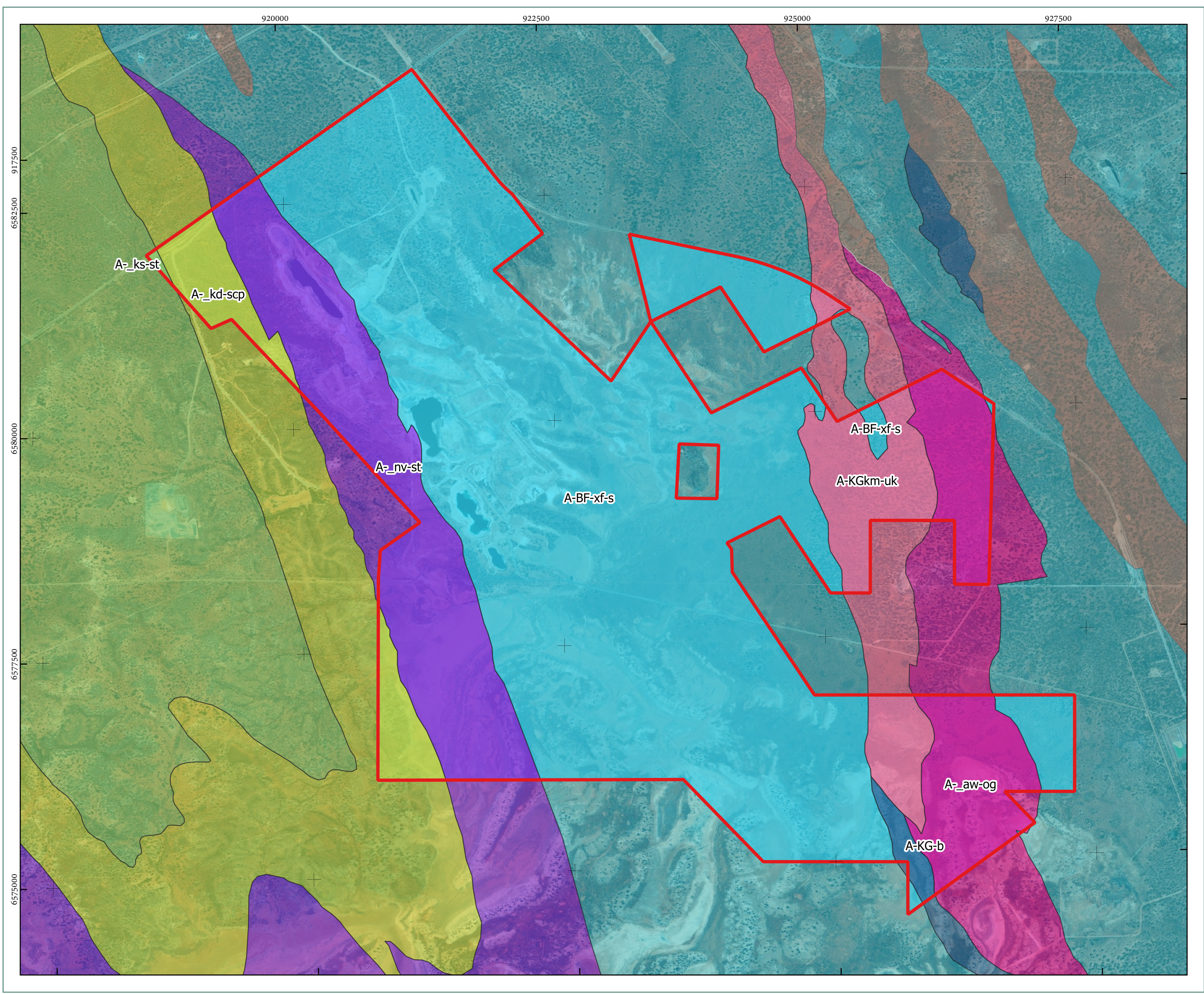
The geology of Western Australia has been mapped at a scale of 1:500,000 (DMIRS 2020), which is the finest-scale digital mapping available for the area mapped to the state extent. Seven units have been mapped within the Study Area and these are listed in Table 1.1 and mapped on Map 1.2.

The Black Flag Group has the largest occurrence within the Study Area, covering a total of 65.6%, which comprises 0.4% of the wider Coolgardie bioregion. The Abattoir West Gabbro geological unit is relatively very small and is also restricted to the Coolgardie bioregion, with 44.8% of its total extent occurring within the Study Area. The Navajo Sandstone unit is also both relatively small and restricted to Coolgardie, with 19.8% of its total extent occurring in the Study Area. The remaining five geological units all have less than 2% of their total extents within the Study Area.

**Table 1.1: Geological Units of the Study Area**

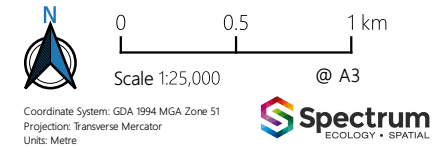
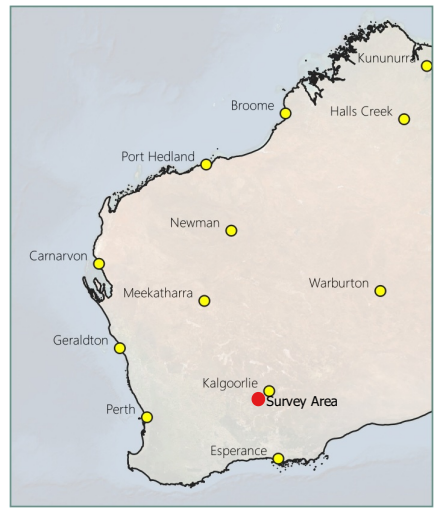
Unit Name	Unit Code	Description	Area in Study Area (ha)	% of Study Area	Total WA Extent (ha)	Total Coolgardie Extent (ha)	% of Coolgardie Extent Within Study Area
Abattoir West Gabbro	A-_aw-og	Gabbro; differentiated; metamorphosed	298.7	8.4	666.1	666.1	44.8
Black Flag Group	A-BF-xf-s	Felsic volcanoclastic and siliciclastic rocks; includes subordinate felsic and mafic volcanic rocks; metamorphosed	2,334.3	65.6	593,091.6	578,457.8	0.4
Kalgoorlie Group	A-KG-b	Mafic volcanic rock dominant; metamorphosed	25.6	0.7	171,485.6	136,016.5	<0.1
Kambalda Komatiite	A-KGkm-uk	Komatiite; basal pyroxenite; peridotite and picrite; minor sedimentary rock; metamorphosed	234.8	6.6	30,747.6	30,747.6	0.8
Lake Douglas Conglomerate Member	A-_kd-scp	Conglomerate, sandy conglomerate, and pebbly sandstone; metamorphosed	141.9	4.0	9516.2	9516.2	1.5
Navajo Sandstone	A-_nv-st	Quartz-rich sandstone with subordinate cobble-pebble conglomerate; tabular to trough cross-bedding; local clast-supported conglomerate; metamorphosed	518.0	14.6	2,620.4	2620.4	19.8
Seven Mile Sandstone Member	A-_ks-st	Quartz-rich sandstone; massive to planar bedded; rare pebbly sandstone; rare cross-bedding; metamorphosed	2.7	0.1	17,067.1	17,067.1	<0.1





Legend

- Study Area
- Geological Units**
  - A-aw-og
  - A-kd-scp
  - A-ks-st
  - A-nv-st
  - A-BF-xf-s
  - A-KG-b
  - A-KGkm-uk
  - Not in Study Area



Author: JH    Approved: AH    Date: 16-12-2021

Geology of the Study Area (1:500,000)

Binduli South

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MAP

1.2



## 1.7. Pre-European Beard Vegetation Mapping

Pre-European vegetation mapping was originally undertaken by Beard at various scales across the state and has since been updated to be consistent with the National Vegetation Information System (NVIS) descriptions at a scale of 1:250,000 (Department of Primary Industry and Regional Development, 2019). State-wide vegetation statistics are available from 2018 for these associations which lists pre-European extent, current extent, area in DBCA managed lands and is a useful tool to determine if a vegetation association is rare or otherwise significant (Government of Western Australia, 2019).

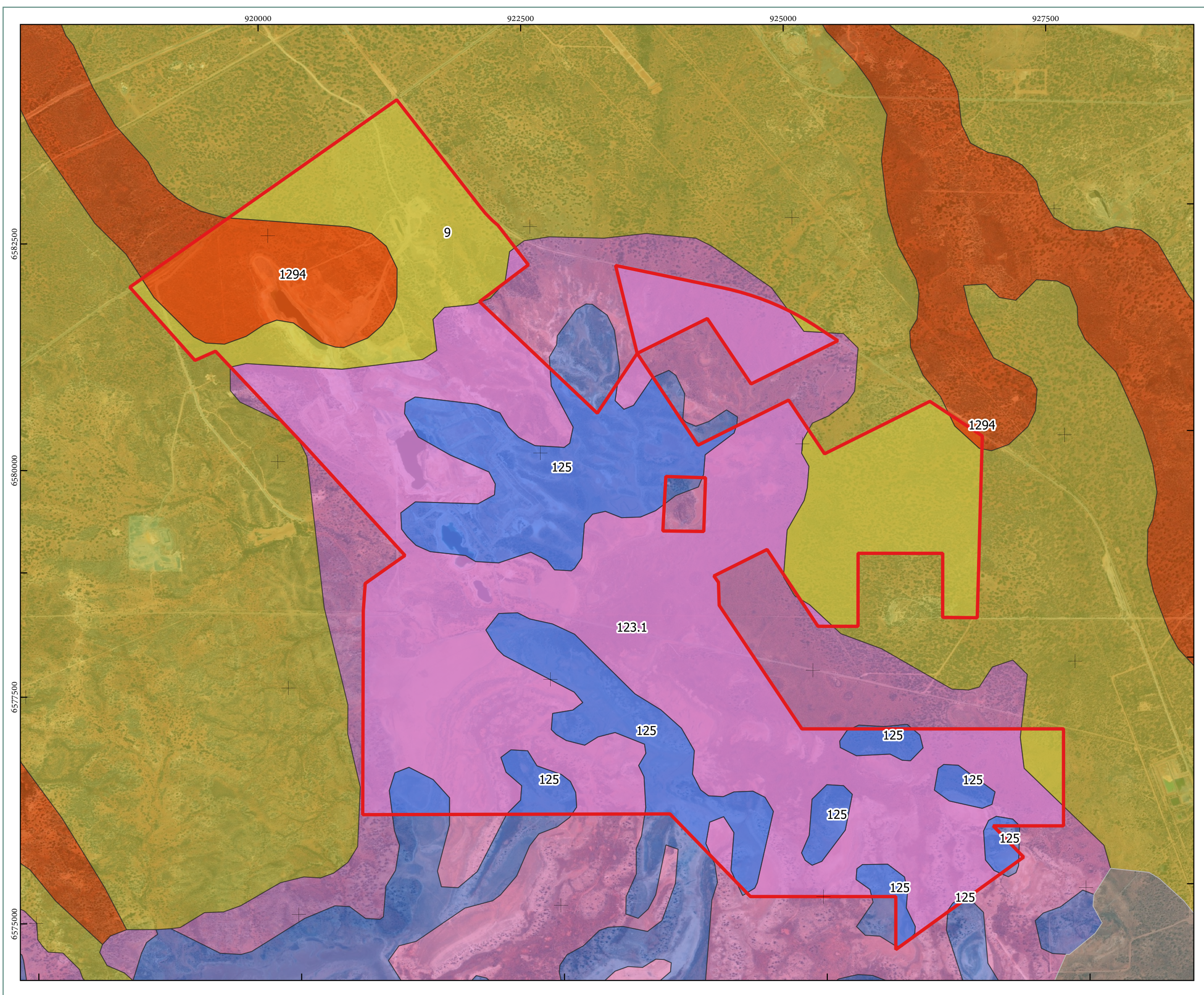
Four vegetation sub-associations (SA) were located within the Study Area: SA9, SA123.1, SA125 and SA1294. These SAs are listed in Table 1.2 and shown on Map 1.3.

Two units, SA123.1 and SA125, are restricted to the Coolgardie IBRA region. One unit, SA9, is found within two IBRA regions: Coolgardie and Mallee. The remaining vegetation association, salt lakes and samphire shrubland (SA125) is widespread across WA. All four have more than 90% of their pre-European extent remaining and have not been extensively cleared (Table 1.2).

**Table 1.2: Beard Vegetation Sub-Associations**

SA	NVIS Description	Area in Study Area (ha)	% of Study Area	Pre-European Extent WA	Current Extent WA (ha)	% Remaining	% of Current Extent in Study Area	% Current Extent in DBCA Lands
9	<i>Eucalyptus</i> woodland consisting of: Upper layer: <i>Eucalyptus torquata</i> , <i>Eucalyptus lesouefii</i> and <i>Eucalyptus clelandii</i> Middle layer: <i>Eremophila scoparia</i> , <i>Eremophila glabra</i> and <i>Eremophila oldfieldii</i> .	705	53	240,509	235,162	98	0.3	8
123.1	<i>Atriplex</i> mixed open chenopod shrubland consisting of: Upper layer: <i>Casuarina cristata</i> , <i>Myoporum platycarpum</i> , and <i>Callitris columellaris</i> Middle layer: <i>Eremophila miniata</i> and <i>Grevillea sarissa</i> . Ground Layer: <i>Atriplex hymenotheca</i> and <i>Maireana</i> sp.	1,891	19	9,090	8,902	98	21.2	0
125	Salt lakes (bare areas) and open Samphire shrubland consisting of: Ground layer: <i>Tecticornia halocnemoides</i> , <i>Arthrocnemum leiostachyum</i> , <i>Sesuvium portulacastrum</i>	702	7	3,485,785	3,146,487	90	<0.1	8
1294	<i>Eucalyptus</i> woodland consisting of: Upper layer: <i>Eucalyptus torquata</i>	258	20	6,296	6,047	96	4.3	2





### Legend

Study Area

**Vegetation Associations**

- 9.0
- 123.1
- 125.0
- 1294.0
- Not in Study Area

0 0.5 1 km  
Scale 1:25,000 @ A3

Coordinate System: GDA 1994 MGA Zone 51  
Projection: Transverse Mercator  
Units: Metre

Author: JH    Approved: AH    Date: 16-12-2021

## Beard Vegetation of the Study Area

Binduli South

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**MAP**  
**1.3**



## 1.8. Significant Lands

Several significant lands are located in the vicinity of the Study Area. These are listed in Table 1.3 and mapped on Map 1.4 and are described in the following sections.

**Table 1.3: Environmentally Significant Areas within 100 km of the Survey Area**

Reserve Name (Protected Area ID)	Distance from Study Area	Size (ha)
<b>Conservation Estates</b>		
Rowles Lagoon (WA04274)	65 km NW	404.7
Goldfields Woodlands (WA46127)	54 km SW	34,408.7
Victoria Rock (WA08480)	64 km SW	259.0
Yallari Timber Reserve (WA19212)	22 km SSW	6,077.1
Bullock Holes Timber Reserve (WA19825)	41 km NE	13,230.3
Kangaroo Hills Timber Reserve (WA19211)	33 km SW	3,120.9
Lakeside Timber Reserve (WA19214)	10 km E	2,390.9
Scahill Timber Reserve (WA19621)	29 km SW	6,915.0
Kalgoorlie Arboretum (WA23840)	9 km N	26.5
Credo (N7121)	60km NW	202,111.8
Clear And Muddy Lakes (WA07634)	65km NW	1,926.2
Kambalda (WA33300)	29km SSW	3,705.3
Kurrawang (WA35453)	<1km W	635.4
Dordie Rocks (WA03211)	78 km S	119.8
Binaronca (WA32552)	93 km S	186.0
Unnamed WA17804	88 km WSW	202.0
Wallaroo Rock (WA27655)	83 km W	1,214.0
Burra (WA07038)	63 km WSW	791.0
<b>TECs</b>		
Emu Land System (Priority 3)	38 km NE	395.4
<b>Wetlands</b>		
Rowles Lagoon System	63°km NW	32.0
Lake Marmion	100°km N	46.0

### 1.8.1. Conservation Estate

The Western Australian conservation estate includes land and waters vested in the Conservation and Parks Commission under the Conservation and Land Management Act (1984). The conservation estate is generally managed by the Department of Biodiversity, Conservation and Attractions (DBCA) to protect Western Australia's biodiversity and includes National Parks, Nature Reserves, Conservation Reserves, and other areas managed primarily for biodiversity conservation (Department of the Environment and Energy, 2016a). A total of 18 Conservation Reserves occur within 100 km of the Study Area, including five Conservation Parks, six Reserves, six Nature Reserves and one Nature Reserve in progress (Table 1.2).

### 1.8.2. Environmentally Sensitive Areas

Environmentally Sensitive Areas (ESA) are defined by the Department of Water and Environmental Regulation (Department of Water and Environmental Regulation, 2019) as:

- A defined wetland and the area within 50 m of a wetland;



- The area covered by vegetation within 50 m of Threatened flora, to the extent to which the vegetation is continuous with the vegetation in which the Threatened flora is located;
- The area covered by a Threatened Ecological Community (TEC);
- A Bush Forever site;
- Areas covered by the Gngangara Mound Crown Land Policy and Western Swamp Tortoise Policy; and
- Areas covered by lakes, wetlands, and fringing vegetation of the Swan Coastal Plain Lakes Policy, including South-west Agricultural Zone Wetlands Policy and Swan and Canning Rivers Policy.

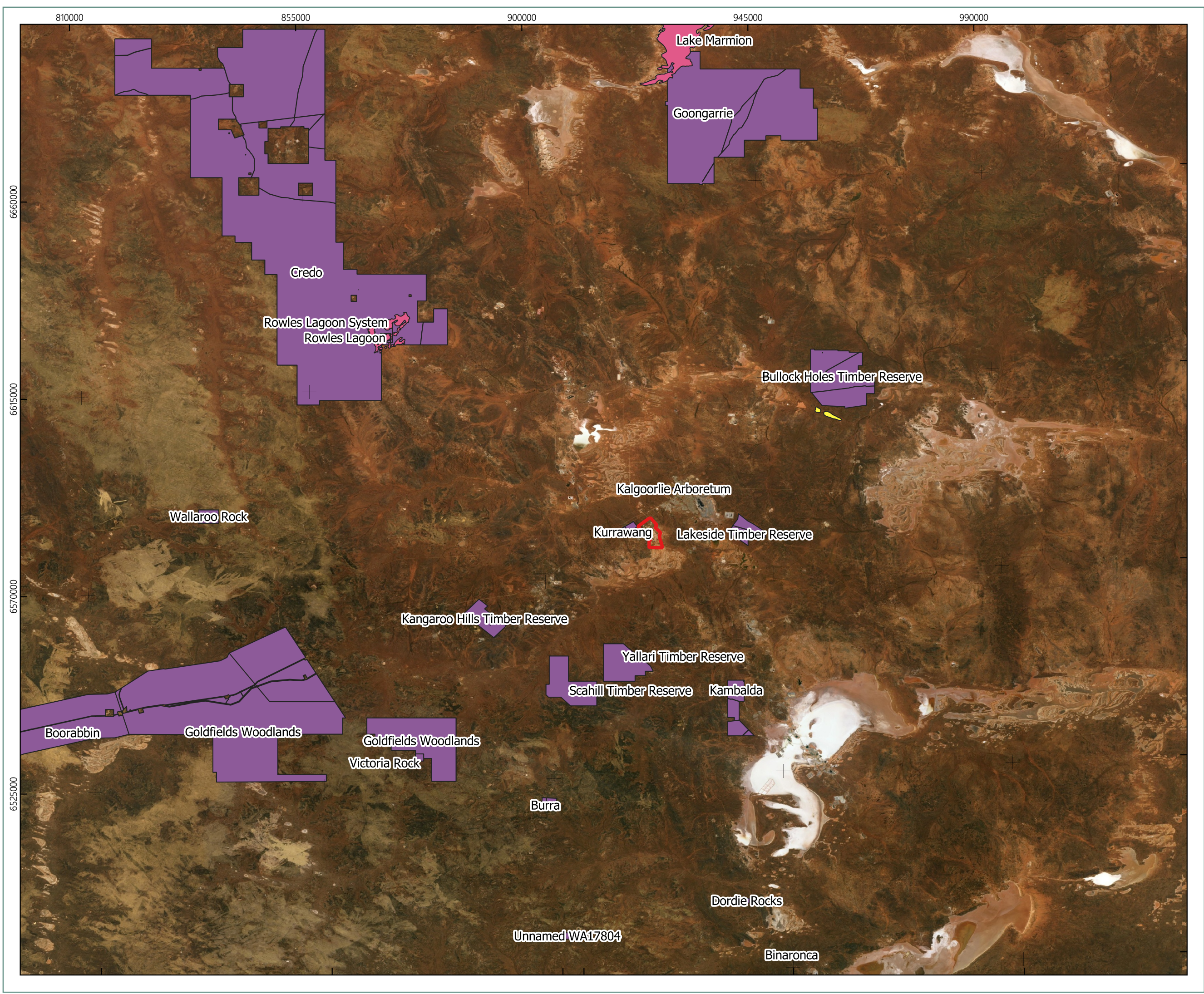
There is one ESA located within 40 km of the Study Area. The Emu Land System Threatened Ecological Community (TEC) is listed as a Priority 3 system (Table 1.2; Map 1.4). The major threat to this system is over grazing (DBCA 2020b).

### **1.8.3. Australian Wetlands Database**





The Australian Wetlands Database includes nationally significant wetlands (as listed in the directory of important wetlands), wetlands listed under the Ramsar convention, wetlands that are representative, rare, or unique, or wetlands that are considered of international importance (DotEE 2019).

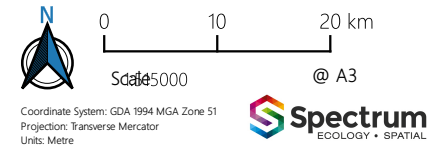
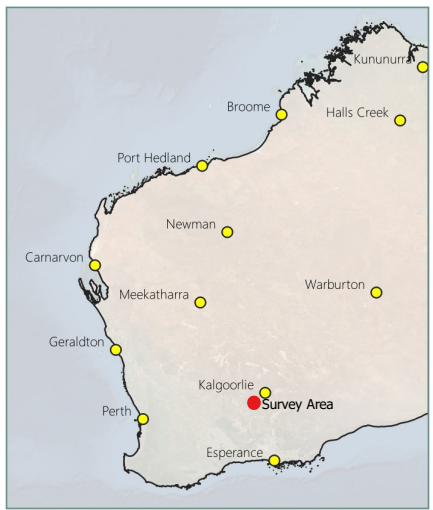
No nationally significant wetlands, including Ramsar wetlands, were mapped within the Study Area. The closest wetland of national significance is the Rowles Lagoon System which is located 63 km to the north-west (Table 1.3; Map 1.4).





Legend

-  Survey Area
-  Conservation Estates
-  Important Wetlands
-  Emu Land System (Priority 3)



Author: JH    Approved: AH    Date: 12-01-2022

Significant Lands in the  
Region

Binduli South



## 2. METHODS

### 2.1. Desktop Assessment

A desktop review of all relevant and available biological data sources was undertaken prior to the field survey to assess the flora, vegetation, and fauna likely to occur across the Study Area and to determine the required field surveys.

#### 2.1.1. Biological Database Searches

The following databases were searched and incorporated into the desktop assessment (Table 2.1).

**Table 2.1: Summary of Database Searches**

Data Source	Custodian	Details
Commonwealth Protected Matters Search Tool (PMST)	Department of the Environment and Energy (DoEE)	Buffer: 40 km Centre Point: - 30.84986 121.42327
NatureMap	Department of Parks and Wildlife / Western Australian Museum (WAM)	Buffer: 40 km Centre Point: 121° 25' 23" E, 30° 51' 01" S
DBCA Threatened & Priority Flora Databases (TPFL / WA Herbarium)	Department of Biodiversity Conservation and Attraction (DBCA)	Buffer: 90 km Reference: 50-0721FL
DBCA Communities Database	DBCA	Buffer: 60 km Reference: 21_0721EC
Index of Biodiversity Surveys and Assessments (IBSA) Database	Department of Water and Environmental Regulation (DWER)	Buffer: 70 km

#### 2.1.2. Literature Review

Previously conducted assessments within 80 km of the Study Area were reviewed for significant flora and fauna. Reports were incorporated if they were provided by Norton Mining, or if they were publicly available. The 17 reports incorporated into the desktop assessment are listed in Table 2.2 and the approximate locations of the surveys, where possible, are shown on Map 2.1.

**Table 2.2: Previously Conducted Biological Assessments**

Reference	Survey Level	Title	Client	Distance to Study Area
Ivey (1993)	Flora – Level 1	Memo re: Binduli NOI Flora & Fauna	Centurion	0 km
GEM (1993)	Flora – Level 1	Vegetation, Flora and Soils of a Proposed Mine near Binduli, WA	Croesus Mining	0 km
Marianna Partners (1996a)	Flora – Level 2 Fauna – Level 1	Binduli Project Area, Panel 3 and Tailings Dam Proposal, Pre-mining Environmental Survey	Croesus Mining	0 km
Marianna Partners (1996b)	Flora – Level 2 Fauna – Level 1	Binduli Project Area Open Pit Proposal, Pre-mining Environmental Survey, Survey Area 2 incorporating part of the Lake Douglas Recreation Reserve	Croesus Mining	0 km
GHD (2005)	Flora – Level 2 Fauna – Level 1	Coolgardie- Esperance Highway Emu Rocks and Spargoville Gravel Pit, Preliminary Environmental Impact Assessment and Biological Survey Assessment and Biological Survey	Main Roads	50 km
Jim's Seeds Weeds & Trees (2005)	Flora – Level 1	Vegetation Survey of the Janet Ivy Area (M26/447, M26/446, P26/2574, P26/2484, M26/629 & P26/2485)	Paddington Gold	3 km
ATA (2006)	Flora/Fauna – Level 1	Fauna Assessment, Proposed Clearing around the Janet Ivy Site	Placer Dome Australia	3 km
Botanica Consulting (2008)	Flora – Level 2	Binduli Flora and Vegetation Survey	Norton Gold Fields	0 km
GHD (2009)	Fauna – Level 1	Report for Navajo Chief, Development Activities, Level 1 Fauna Assessment	Paddington Gold	0 km

Reference	Survey Level	Title	Client	Distance to Study Area
Phoenix (2016)	Fauna – Desktop	Subterranean fauna desktop review for the Binduli Expansion Project	Norton Gold Fields	0 km
Eco Logical (2016c)	Flora – Desktop	Flora, Vegetation and Fauna Desktop Assessment Binduli Expansion Project	Norton Gold Fields	0 km
Eco Logical (2016b)	Fauna – Level 1, Targeted & Level 2 SRE	Biological Assessment – Binduli Expansion Project Level 1 Vertebrate Fauna and Short-range Endemic Invertebrate Survey	Norton Gold Fields	0 km
Eco Logical (Eco Logical Australia, 2016a)	Flora – Level 2	Biological Assessment – Binduli Expansion Project Flora and Vegetation	Norton Gold Fields	0 km
Phoenix (2018)	Fauna – Level 1 Vertebrate & Level 2 SRE	Terrestrial fauna survey for the St Ives Gold Mine Beyond 2018 Project	St Ives Gold Mining Company	55 km
NVS (2020)	Flora – Level 1	Reconnaissance Flora and Vegetation Survey of the Jaurdi Gold Project (M16/529)- May 2020	Beacon Minerals Limited	40 km
Spectrum Ecology (2020)	Flora and Fauna – Desktop	Binduli North Expansion Project, Desktop Report Review	Norton Gold Fields	0 km
Onshore (2021)	Fauna – Detailed & Targeted	Detailed and Targeted Fauna Survey, By-product Storage Site	Lynas Kalgoorlie Pty Ltd	15 km

### 2.1.3. Likelihood of Occurrence

An assessment of each significant species or community identified in the desktop assessment was completed with the following information provided:

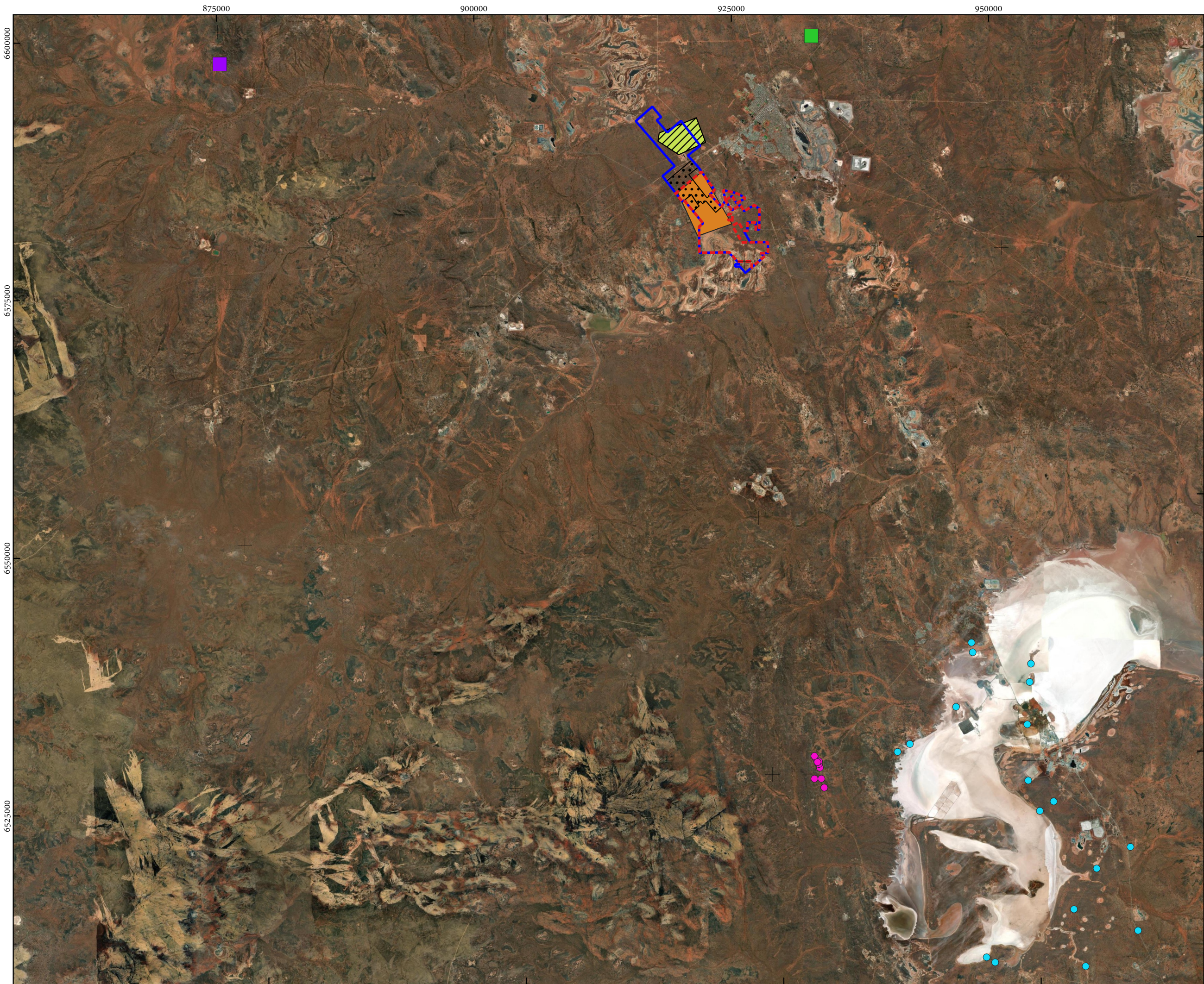
- Conservation status (EPBC Act, WC Act, DBCA listing);
- Description of species habitat requirements and presence of this habitat within the Survey Area;
- Description of species and flowering period;
- Summary of relevant records including source of record (DBCA, previous report etc.) and accuracy of the record location; and
- Likelihood of occurrence criteria assigned and justification of likelihood of occurrence that considers known habitats, survey effort etc. The likelihood of occurrence will be determined based on the criteria outlined in Table 2.3.

A likelihood of occurrence assessment was then conducted using the criteria listed in Table 2.3. This involved assessing the distance of the record from the tenements (historical database records considered not accurate were excluded if required), and the presence of appropriate habitats (using land systems, geology, vegetation mapping, and/or aerial imagery).











**Table 2.3: Likelihood of Occurrence Criteria – Flora & Vegetation**

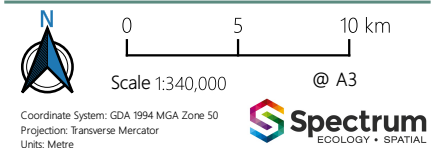
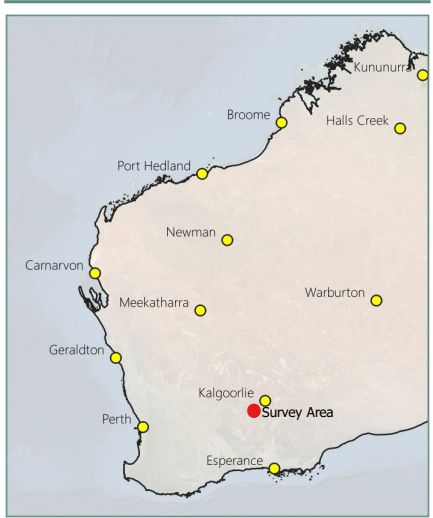
Likelihood	Flora & Vegetation
<b>Recorded</b>	Species or vegetation community accurately recorded within the Survey or Survey Area.
<b>High</b>	Species or vegetation community recorded near the Survey or Survey Area, and suitable habitat does, or is likely, to occur.
<b>Medium</b>	Species or vegetation community recorded outside the Survey or Survey Area but within 20 km and suitable habitat may occur.
<b>Low</b>	Species or vegetation community rarely or not recorded within 20 km of the Survey or Survey Area and suitable habitat is not likely to occur within the Survey Area.
<b>Very Low</b>	N/A





## Legend

-  Study Area
- Previous Survey Boundaries**
  -  Jim's Seeds, Weeds and Trees (2005)
  -  ATA Environmental (2006)
  -  Botanica Consulting (2008)
  -  GHD (2009)
  -  Eco Logical (2016a, b, c)
- Previous Survey Points**
  -  GHD (2005) Survey Sites
  -  Phoenix (2018) Survey Sites
  -  NVS (2020)
  -  Onshore (2021)



Author: JH    Approved: AH    Date: 16-12-2021

## Previous Flora & Fauna Assessments in the Region

Binduli South



## 2.2. Survey Timing

The assessment was undertaken over five days from the 25 to the 29 of October 2021. Rainfall preceding a field survey influences the number and type of flora species recorded. Monthly rainfall was sourced from the nearest Bureau of Meteorology (BOM) station with complete data (Kalgoorlie-Boulder #12038), located approximately 6 km north-east of the Study Area (Bureau of Meteorology, 2021). Rainfall recorded 12 months prior to the survey and median monthly rainfall are presented in Figure 2.1.

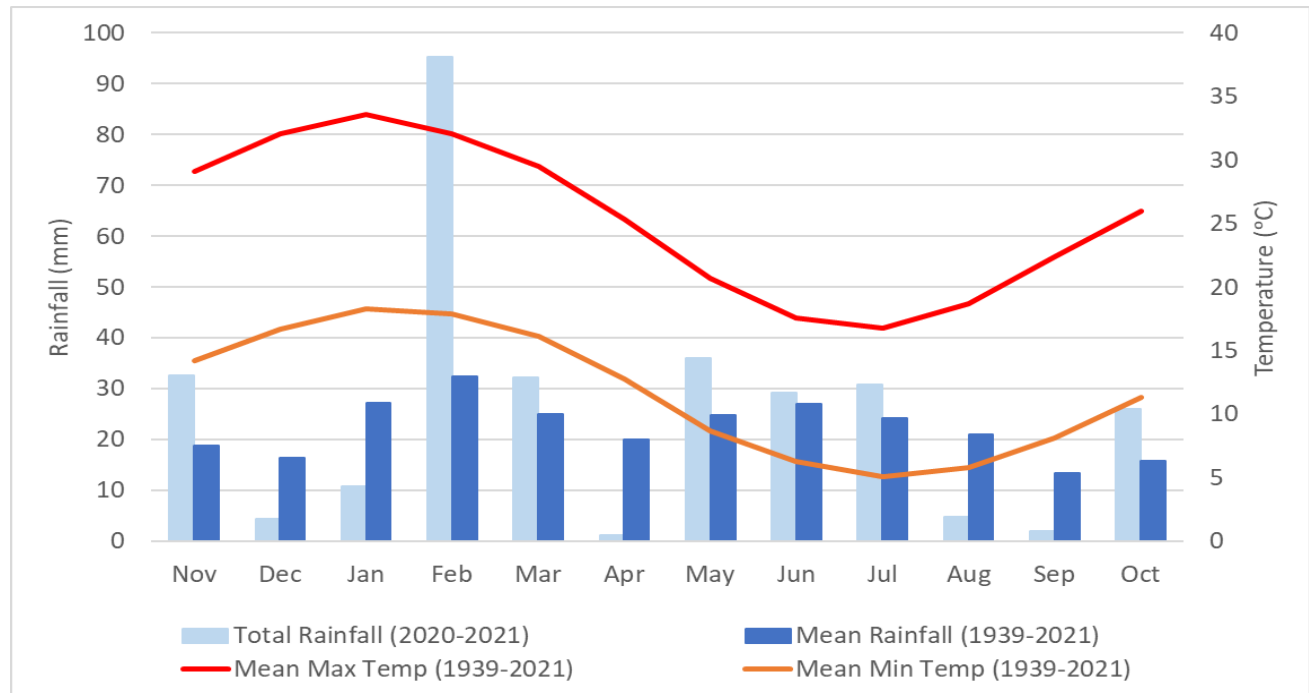


Figure 2.1: Climate Data Associated with the Survey Area

The following rainfall was recorded at Kalgoorlie prior to the survey:

- The 12 months preceding the field survey (November 2020 to October 2021) recorded 305.2 mm of rainfall, 39.2 mm higher than the sum of the long-term annual median of 266.0 mm; and
- The three-months preceding the field survey (August - October 2021) recorded 32.8 mm of rainfall, 17.4 mm lower than the sum of the long-term annual median for the same three months (50.2 mm).

The Coolgardie bioregion is considered part of the Interzone Botanical province and recommendations are to conduct flora and vegetation surveys after Autumn rains, in Spring from September – November (Environmental Protection Authority, 2016c). The field survey timing was conducted in accordance with EPA recommended timing following a period of slightly than lower median rainfall for the region.

## 2.3. Project Team & Licences

Spectrum personnel involved with this assessment are listed in Table 2.4, along with their role and years of experience. The fauna survey was conducted under licence number BA27000523.

Table 2.4: Project Team & Licences

Staff	Role	Project Tasks	Years of Experience	Flora Licence
Melissa Hay	Principal Botanist	Field survey, reporting, report review, plant identification	15	FB62000006-2 TFL 130-2021

Staff	Role	Project Tasks	Years of Experience	Flora Licence
Raymond Orifici	Senior Botanist	Plant identification	15	-
Emily Crowther	Botanist	Reporting, plant identification	2	FB62000330
Astrid Heidrich	Principal Zoologist	Reporting, report review	13	BA27000512 TFA 2021-0108
Erica MacIntyre	Senior Zoologist	Field survey, reporting	10	-
Jesse Harper	Senior Zoologist	Reporting, report review	8	BA27000512 TFA 2021-0108
Louise Ridgeway	Zoologist	Field survey, reporting	2	-

## 2.4. Field Methods & Sampling Effort

Spectrum conducted a one-phase reconnaissance flora and vegetation assessment and targeted significant flora survey used to verify and update the Ecological (2016) detailed flora and vegetation assessment. The survey undertaken by Spectrum was completed by one botanist over a five-day period. Ecological (2016) conducted a detailed survey of the Study Area by two botanists over an eight-day period.

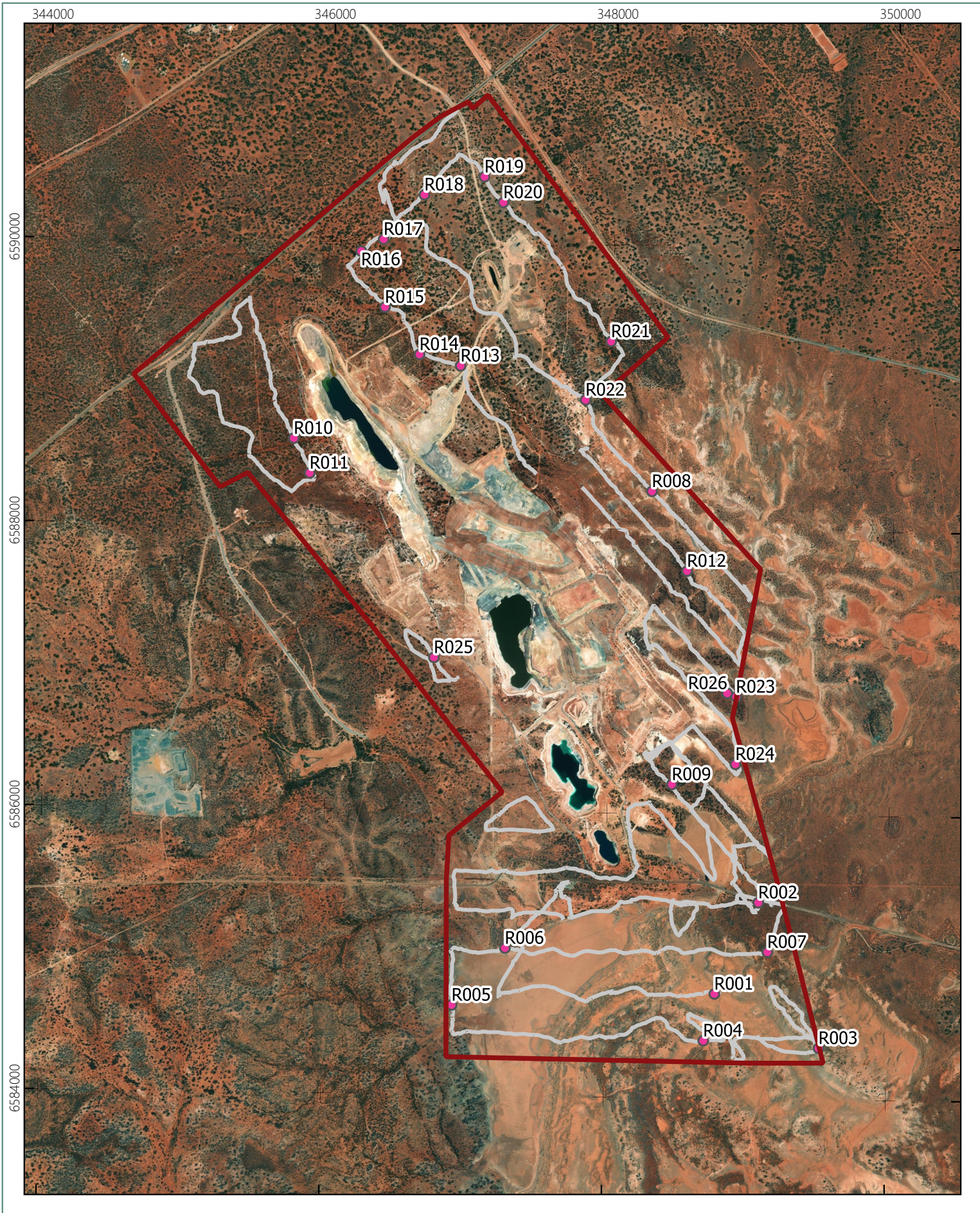
Spectrum sampled 26 relevés and 55 km of targeted traverses. This was considered appropriate for a reconnaissance level survey as stipulated in the technical guidance (Environmental Protection Authority, 2016c); these techniques are described in Table 2.5. Comprehensive relevé data collection information is included in Appendix A.

Ecological (2016) sampled 50 quadrats within the Study Area, of which 18 were within the Survey Area. No specific targeted survey effort was reported. The Sampling Effort is mapped in Map 2.2.

**Table 2.5: Reconnaissance Flora & Vegetation Survey Technique**

Survey Technique	Application & Purpose
<b>Relevés</b>	Relevés are a survey technique for gathering information for low-intensity reconnaissance flora and vegetation surveys. Information collected at each relevé includes: <ul style="list-style-type: none"> <li>• Site code, date, location, botanist;</li> <li>• A photograph;</li> <li>• Vegetation condition and disturbances (including fire);</li> <li>• Landform including; slope, soil, rock type, aspect;</li> <li>• Flora and vegetation information including; dominant species cover and structure; and</li> <li>• Significant and introduced flora species and counts.</li> </ul>
<b>Mapping Notes</b>	Note taken with the location and vegetation community present. Can include photographs or descriptions.
<b>Opportunistic Sampling</b>	Flora species not recorded through other sampling methods was opportunistically sampled as encountered in the Survey Area. Opportunistic sampling also included recording locations of significant, introduced (weed) and unknown species.
<b>Targeted Sampling</b>	Areas likely to support significant flora or vegetation were targeted during the survey. Including areas with existing records of significant flora (salt lake habitat types, Gypsum dunes, and sandy plains close to the salt lakes). Areas were selected based on existing records from previous surveys, database searches, geology, vegetation mapping and known ESAs. Where possible, unusual, and restricted geological features within the Survey Area were sampled. When potentially significant flora taxa were encountered during the survey, sufficient information was recorded to complete a Threatened and Priority Flora Report Form (TPRF).





#### Legend

- The Survey Area
- Flora Sites**
- Releve
- Traverse



0 0.4 0.8 1.2 km

Scale 1:40000

@ A4

Coordinate System: GDA 1994 MGA Zone 51  
Projection: Transverse Mercator  
Units: Meter



Author: MH

Date: 20-12-2021

Sampling Effort – Flora

Binduli South

Prepared for Talis  
Consultants/Norton

Map  
**2.2**



## 2.5. Vegetation Mapping

Data was collected from relevés and opportunistic collections, as well as general field notes and observations to update the vegetation mapping undertaken by Ecological (2016) across the Survey Area. Vegetation was originally classified by Ecological (2016) using quadrat data and floristic analysis, but was undertaken at a very broad scale to accurately map the vegetation communities present, and have therefore been updated structurally based on the dominant species recorded by Ecological and Spectrum at a finer scale. The vegetation classification is consistent with NVIS Level V – association vegetation descriptions (referred to as a ‘vegetation type’ for the local scale in this report). This level of description provides information on the dominant growth form, height and cover for up to three species for each of the upper, mid and ground strata (ESCAVI, 2003).

## 2.6. Vegetation Condition

Vegetation condition was recorded at relevés and where other areas of different vegetation condition were observed. The vegetation condition was updated during the current survey using the scale recommended for the Interzone Botanical Province as shown in Table 2.6 (Environmental Protection Authority, 2016c).

**Table 2.6: Vegetation Condition Scale & Criteria**

Vegetation Condition	Disturbance Criteria
<b>Pristine</b>	Pristine or nearly so, no obvious signs of disturbance or damage caused by human activities since European settlement.
<b>Excellent</b>	Vegetation structure intact, disturbance affecting individual species. Damage to trees caused by fire, the presence of non-aggressive weeds and occasional vehicle tracks.
<b>Very Good</b>	Vegetation structure altered with obvious signs of disturbance. Disturbance to vegetation structure caused by repeated fires, the presence of some more aggressive weeds, dieback logging and/or grazing.
<b>Good</b>	Vegetation structure significantly altered by obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it. Disturbance to vegetation structure caused by very frequent fires, the presence of very aggressive weeds, partial clearing, dieback and grazing.
<b>Degraded</b>	Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. Disturbance to vegetation structure caused by very frequent fires, the presence of very aggressive weeds at high density, partial clearing, dieback and grazing.
<b>Completely Degraded</b>	The structure of the vegetation is no longer intact, that the area is completely or almost completely without native species. These areas are often described as “parkland cleared” with the flora comprising weed or crop species with isolated native trees and shrubs.

## 2.7. Data for the Index of Biodiversity Survey's for Assessment (IBSA)

The Environmental Protection Authority has given instruction that all biological surveys collecting data on biodiversity will submit the report and associated raw data to IBSA as an IBSA data package. All survey data collected at the Survey Area has been provided electronically to comply with IBSA data standards.

## 2.8. Specimen Identification & Lodgement

Flora specimens were collected of any suspected or known significant flora and to confirm species recorded during the relevés for vegetation mapping. Specimens were identified using the appropriate taxonomic keys and where required, relevant taxonomic experts at the Western Australian Herbarium. Specimens are vouchered with the Western Australian Herbarium as per guidance; when they represent new populations

of Threatened or Priority Flora, new occurrences of TECs or PECs, individuals that have atypical characteristics, or bioregional range extensions.

## 2.9. Nomenclature

### 2.9.1. Flora

Flora nomenclature used in this report is consistent with the DBCA Census of Western Australian Plants database, provided through FloraBase (Western Australian Herbarium, 2021). Ecological 2016 species have been updated and are current at the time of report preparation (December 2021).

### 2.9.2. Significant Flora, Vegetation & Fauna Definitions

Significant flora can include (Environmental Protection Authority, 2016b):

- Being identified as Threatened: Critically Endangered, Endangered, or Vulnerable (state listed BC Act and/or nationally listed EPBC Act);
- Being identified as Priority Flora species: Priority 1 to 4, provided in Appendix B (Department of Biodiversity Conservation and Attractions, 2019);
- Locally endemic or association with a restricted habitat type (e.g., surface water or groundwater dependent ecosystems);
- New species or anomalous features that indicate a potential new species;
- Representative of the range of a species (particularly, at the extremes of range, recently discovered range extensions, or isolated outliers of the main range);
- Unusual species, including restricted subspecies, varieties or naturally occurring hybrids; or
- Relictual status, being representative of taxonomic groups that no longer occur widely in the broader landscape.

Significant vegetation can include (Environmental Protection Authority, 2016b):

- Threatened Ecological Community (TEC): Critically Endangered, Endangered or Vulnerable (state listed BC Act and/or nationally listed EPBC Act);
- Priority Ecological Community (PEC): Priority 1 to 5 (Department of Biodiversity Conservation and Attractions, 2020d);
- Restricted distribution;
- Degree of historical impact from threatening processes;
- A role as a refuge; or
- Providing an important function required to maintain ecological integrity of a significant ecosystem.

### 2.9.3. Introduced Flora & Declared Plant Categories

The Department of Primary Industries and Regional Development (DPIRD) keeps a database of organisms that are Declared Pests in Western Australia. This database is regulated under the Biosecurity and Agricultural Management Act (Government of Western Australia, 2007). The legal status and control requirements for these environmentally significant pests are provided in Appendix B.

## 2.10. Limitations & Constraints

Survey specific limitations and constraints for the flora and vegetation assessment at the Survey Area are discussed in Table 2.7.

**Table 2.7: Survey Limitations & Constraints**

Limitation	Constraint	Comment
Availability of contextual information at a regional and local scale.	No	Background information about the region was available and sufficient. There were numerous surveys undertaken within the vicinity of the Survey Area (2.1.2) which were incorporated into the desktop assessment. Database searches supplied information on significant flora and vegetation occurring in the vicinity of the Survey Area. Ecological 2016 undertook a thorough detailed flora and vegetation survey of the Study Area, which included the Survey Area and was used to map the flora and vegetation for this assessment.
Competency/ experience of the team carrying out the survey, including experience in the bioregion surveyed.	No	The field botanist, Melissa Hay (Principal Botanist) has 15 years' experience in conducting botanical surveys throughout Western Australia and has vast experience in the Mid-west and Goldfields regions in Western Australia.
Proportion of flora recorded and/or collected, any identification issues.	No	Only suspected significant, introduced, or flora that was part of vegetation communities were collected for this assessment. Specimens were identified by Raimond Orifici and Melissa Hay who both have botanical and taxonomic experience throughout Western Australia and the Goldfields. Specialist taxonomists from WAH were consulted to confirm <i>Calandrinia</i> species.
Survey effort and extent.	No	Relevés were selected to represent the diversity of vegetation and geology present at the Survey Area. The 26 relevés recorded from the Survey Area were sufficient to map and re-classify the vegetation to a fine scale. The 55 km of traverses were conducted across all habitat types that had potential to host significant flora species.
Access restrictions within the survey area.	No	No access constraints.
Survey timing, rainfall, season of survey.	No	The field survey was conducted during the optimal timing for a flora survey in the Coolgardie region and Interzone Botanical Province (October 2021, Spring). Seasonal conditions were average, with rainfall slightly under the long-term median rainfall. Annuals and short-lived perennials were present at the time of the survey.
Disturbance that may have affected the results of survey such as fire, flood or clearing.	No	No disturbances such as fire, flood or clearing were present that affected the results of the survey.



### 3. RESULTS & DISCUSSION

#### 3.1. Flora

##### 3.1.1. General Flora

A total of 183 taxa from 37 families and 94 genera were recorded within the Study Area and are listed in Appendix C. The most species rich family were Asteraceae and Chenopodiaceae with 23 species each, followed by Fabaceae with 22 species. The most species rich genera were *Eucalyptus* and *Acacia* with 13 species, followed by *Eremophila* with 12 species. Of the 183 taxa recorded, 12 (6.6%) were introduced flora taxa and one was a significant flora taxon.

#### 3.2. Significant Flora

##### 3.2.1. Desktop Assessment

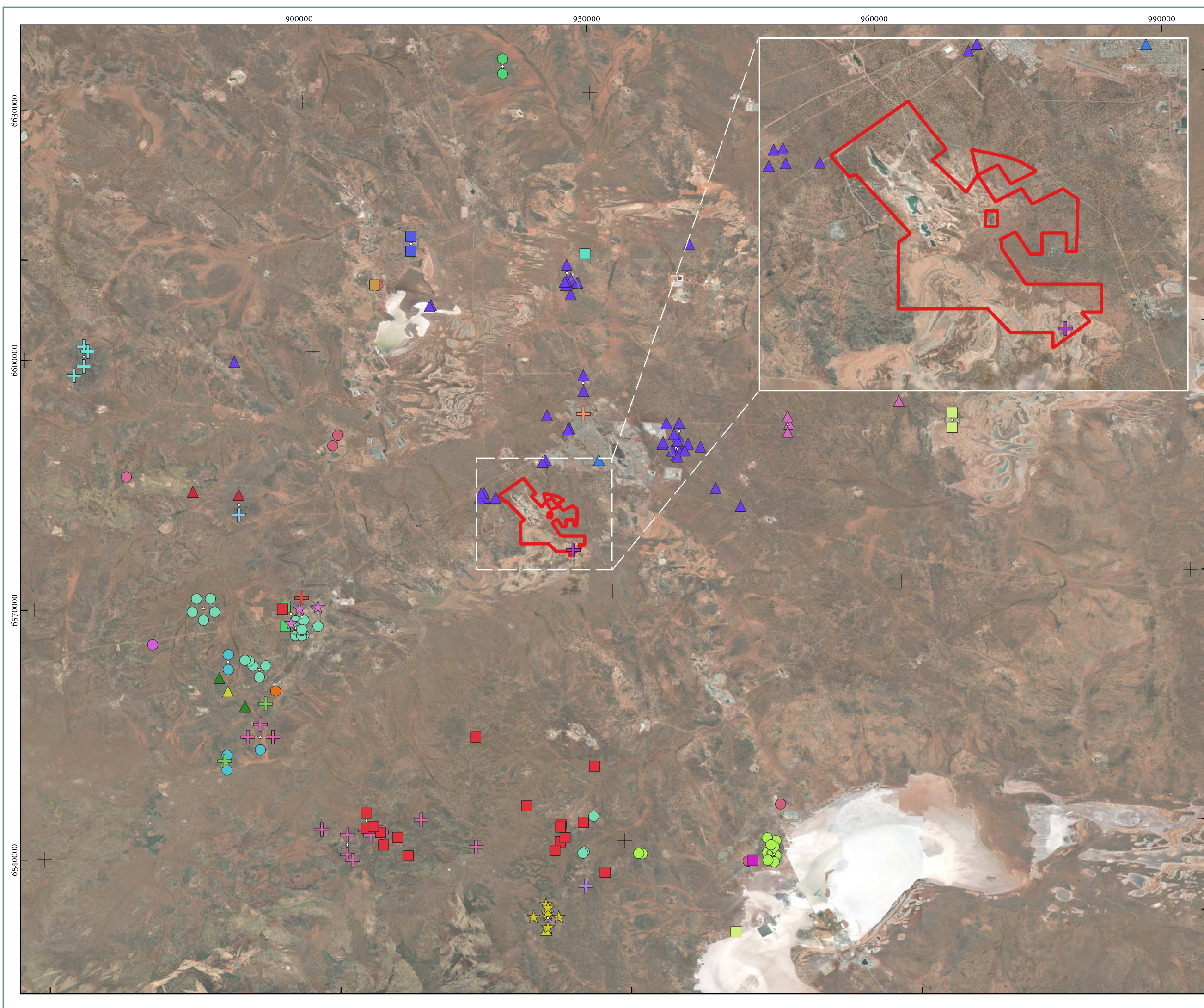
No Threatened flora species were reported from within the Binduli South Study Area during the desktop assessment. Three potential Threatened species were identified during the database searches and were assigned a low likelihood of occurrence in the Study Area (Appendix D).

One Priority 2 (*Goodenia salina*) and two Priority 3 species (*Alyxia tetanifolia*, *Isolepis australiensis*) have previously been recorded in the Study Area of which *Alyxia tetanifolia* was previously recorded in the Survey Area (Ecological 2016). A total of 92 further Priority flora taxa were also identified, three of which are considered to have a 'High' likelihood (*Eremophila praecox*, *Lepidium fasciculatum* and *Notisia intonsa*) and 13 a 'Medium' likelihood of occurrence within the Study Area (Table 3.1). The remaining 76 taxa have been assigned a 'Low' likelihood of occurrence (Appendix D).

Table 3.1: Desktop Significant Flora – Recorded, High & Medium Likelihood of Occurrence

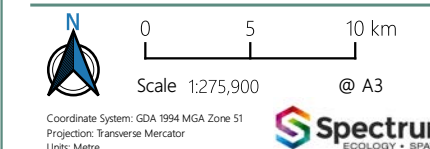
Likelihood	Status	Taxa	Longevity	Flowering Period
Recorded	P2	<i>Goodenia salina</i> (recorded in the Study Area only)	Annual	Aug-Nov.
	P3	<i>Alyxia tetanifolia</i>	Perennial	May-June, Nov.
	P3	<i>Isolepis australiensis</i> (recorded in the Study Area only)	Annual	Jun or Sept.
High	P2	<i>Eremophila praecox</i>	Perennial	Oct or Dec.
	P3	<i>Lepidium fasciculatum</i>	Annual	Sept-Nov.
	P3	<i>Notisia intonsa</i>	Annual	Sept-Oct.
Medium	P1	<i>Acacia websteri</i>	Perennial	-
	P1	<i>Calandrinia lefroyensis</i>	Perennial	-
	P1	<i>Ptilotus procumbens</i>	Annual	Nov.
	P1	<i>Ptilotus rigidus</i>	Perennial	-
	P1	<i>Ptilotus</i> sp. Kalgoorlie (J. Jackson & B. Moyle 260)	-	-
	P1	<i>Thryptomene planiflora</i>	Perennial	-
	P1	<i>Thryptomene</i> sp. Londonderry (R.H. Kuchel 1763)	Perennial	-
	P2	<i>Elachanthus pusillus</i>	Annual	Aug-Oct.
	P3	<i>Angianthus prostratus</i>	Annual	Jul-Sep.
	P3	<i>Austrostipa</i> sp. Carlingup Road (S. Kern & R. Jasper LCH 18459)	Perennial	-
	P3	<i>Phlegmatospermum eremaeum</i>	Annual	Jun or Aug-Oct.
	P4	<i>Eremophila caerulea</i> subsp. <i>merrallii</i>	Perennial	Oct-Dec.
	P4	<i>Eucalyptus jutsonii</i> subsp. <i>jutsonii</i>	Perennial	-





## Legend

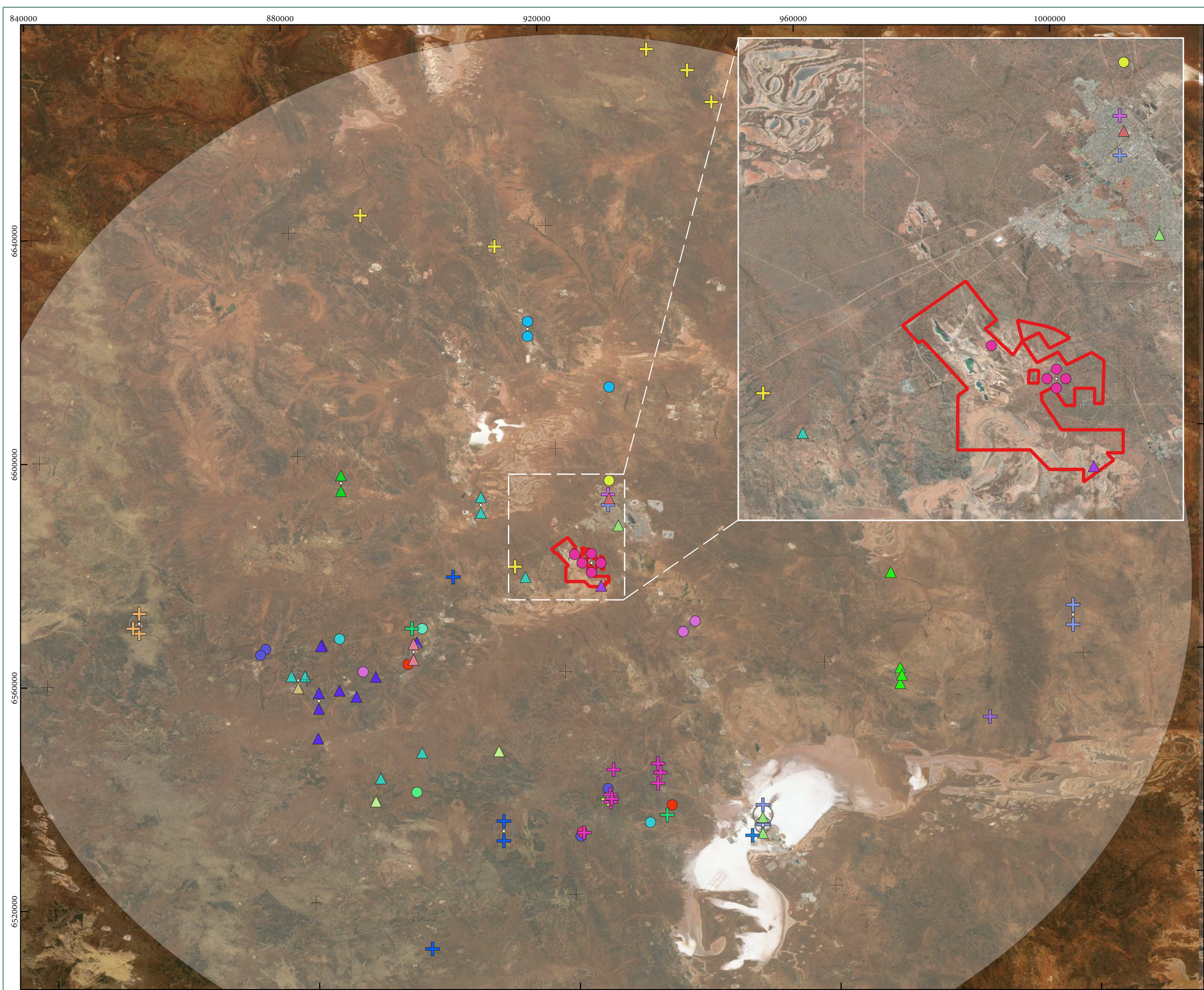
- Study Area (with 90 km buffer)
- Significant Flora**
- T-Gastrolobium graniticum
  - T-Tetradlea spenceri
  - T-Thelymitra stellata
  - P1-Acacia coatesii
  - P1-Acacia epedunculata
  - P1-Acacia sclerophylla var. teretiuscula
  - P1-Acacia websteri
  - P1-Calandrinia lefroyensis
  - P1-Chamaecrista sp. Parker Range
  - P1-Cyathostemon divaricatus
  - P1-Dampiera plumosa
  - P1-Eremophila praecox
  - P1-Eremophila xantholaema
  - P1-Eucalyptus websteriana subsp. norsemanica
  - P1-Grevillea phillipsiana
  - P1-Lepidosperma sp. Parker Range
  - P1-Phebalium appressum
  - P1-Ptilotus chortophytus
  - P1-Ptilotus procumbens
  - P1-Ptilotus rigidus
  - P1-Ptilotus sp. Kalgoorlie
  - P1-Rhodanthe uniflora
  - P1-Ricnocarpos digynus
  - P1-Tecticornia flabelliformis
  - P1-Thryptomene planiflora
  - P1-Thryptomene sp. Coolgardie
  - P1-Thryptomene sp. Londonderry
  - P2-Acacia kerryana
  - P2-Austrostipa sp. Dowerin
  - P2-Elachanthus pusillus
  - P2-Eucalyptus educta
  - P2-Goodenia salina
  - P2-Hakea rigida
  - P2-Lepidium merrallii
  - P2-Phebalium clavatum



Author: CS Approved: AH Date: 26-08-2021

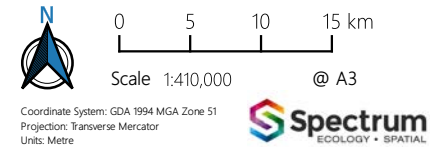
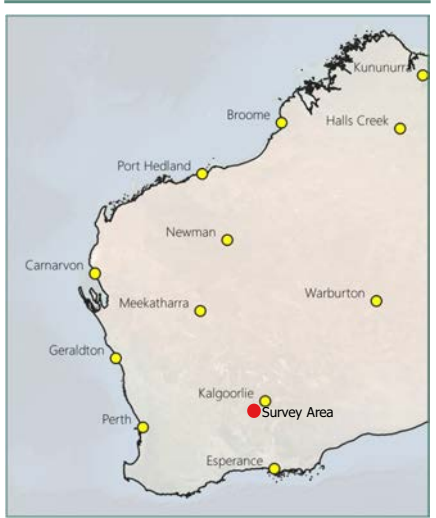
## Desktop Significant Flora Within 90 km - Threatened, P1 & P2 Binduli South





Legend

- Study Area (with 90 km buffer)
- Significant Flora**
- P3-Acacia crenulata
  - P3-Allocasuarina eriochlamys subsp. grossa
  - P3-Alyxia tetanifolia
  - P3-Angianthus prostratus
  - P3-Austrostipa blackii
  - P3-Austrostipa sp. Carlingup Road
  - P3-Bossiaea celata
  - P3-Chrysocephalum apiculatum subsp. norsemanens
  - P3-Cratystylis centralis
  - P3-Cyathostemon verrucosus
  - P3-Diocirea acutifolia
  - P3-Eremophila arachnoides subsp. tenera
  - P3-Eremophila microphylla
  - P3-Eremophila veronica
  - P3-Gompholobium cinereum
  - P3-Grevillea georgeana
  - P3-Isolepis australiensis
  - P3-Lepidium fasciculatum
  - P3-Melaleuca coccinea
  - P3-Notisia intonsa
  - P3-Phlegmatospermum eremaeum
  - P3-Stylidium choreanthum
  - P3-Styphelia rectiloba
  - P4-Eremophila caerulea subsp. merrallii
  - P4-Eucalyptus jutsonii subsp. jutsonii
  - P4-Eucalyptus kruseana
  - P4-Eucalyptus x brachyphylla
  - P4-Frankenia glomerata
  - P4-Myriophyllum petraeum
  - P4-Sowerbaea multicaulis



Author: CS    Approved: AH    Date: 26-08-2021

Desktop Significant Flora  
Within 90 km - P3 & P4

Binduli South



### 3.2.2. Current Assessment

No Threatened flora taxa were recorded during the desktop or current assessment or is considered likely to occur in the Survey Area.

One Priority 3 flora species was recorded within the Survey Area: *Alyxia tetanifolia* (Table 3.3, Map 3.3). This was recorded on vegetation types P2 and P5, which are sandy plains that occur between salt pans in the south and east of the Survey Area. There were 94 individuals recorded in the Survey Area (from the Ecological and Spectrum survey, with duplicates accounted for in the field) and an additional two were recorded in the Study Area by Ecological. *Alyxia tetanifolia* is known from multiple locations in the local and regional area and is not considered to be locally or regionally significant.

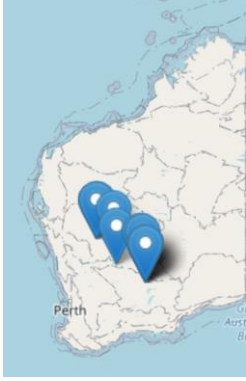

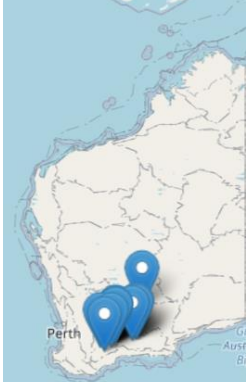

One Priority 2 flora species was recorded within the Study Area and following the field survey has potential to occur in the Survey Area: *Goodenia salina*. There were 45 individuals of *Goodenia salina* recorded by Ecological 2016 in the Study Area (Table 3.3, Map 3.3). This was recorded exclusively on vegetation type S2, on the low gypseous dunes near the salt pans in the south-east of the Study Area. No individuals were recorded within the Survey Area during the current assessment, however there is potential for them to occur here, as previous locations were visited and not found, suggesting that the species would not be present at the time of the survey. There are multiple locations of *Goodenia salina* in the local area and it is not considered to have local significance, however as this is the only population in the Coolgardie region (the remaining are in Esperance Plains, approx. 1,000 km south-west) it is considered to have regional significance at the Survey Area. Coordinates of all significant flora taxa have been provided electronically with this report.

No other significant flora taxa (as listed in the desktop assessment, section 2.9.2) were recorded at the Survey Area during the field assessment. The four significant flora taxa assigned High likelihood of occurrence (*Eremophila praecox* – P2, *Lepidium fasciculatum* – P3, and *Notisia intonsa* – P3) or Recorded (*Isolepis australiensis* – P3, previously recorded in the Study Area) prior to the survey, were assigned a Low likelihood of occurrence post survey (Table 3.2).

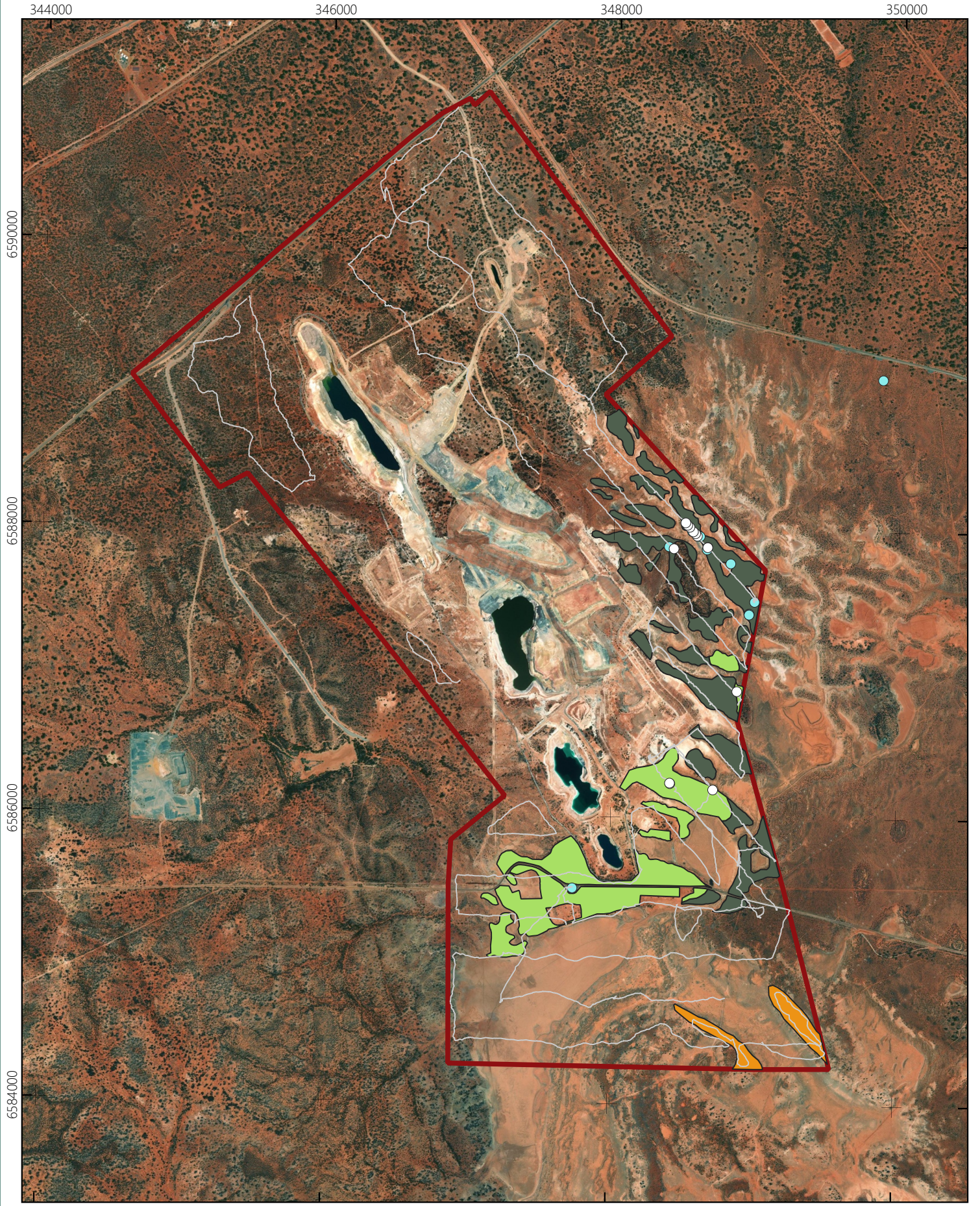
**Table 3.2: Desktop Significant Flora – Recorded & High Pre-survey Likelihood of Occurrence**

Pre-survey Likelihood	Post-survey Likelihood	Status	Taxa	Longevity	Flowering Period	Post-survey Likelihood
Recorded (Study Area)	High	P2	<i>Goodenia salina</i>	Annual	Aug-Nov.	Previous surveys visited, not recorded likely not present at the time of the survey.
	Recorded	P3	<i>Alyxia tetanifolia</i>	Perennial	May-June, Nov.	Previous locations visited and species recorded in the Survey Area.
	Low	P3	<i>Isolepis australiensis</i>	Annual	Jun or Sept.	Not visited as outside of Survey Area. Low post-survey likelihood of occurrence in the Survey Area as no habitat present.
High	Low	P2	<i>Eremophila praecox</i>	Perennial	Oct or Dec.	Previous location in vicinity of Survey Area visited and not found, likely a location error. Not found during the traverses through potential habitat. Low post-survey likelihood of occurrence.
	Low	P3	<i>Lepidium fasciculatum</i>	Annual	Sept-Nov.	Low post likelihood of occurrence. Not recorded during the traverses and flowering period indicates it should be present at the time of the survey.
	Low	P3	<i>Notisia intonsa</i>	Annual	Sept-Oct.	Low post likelihood of occurrence. Not recorded during the traverses and flowering period indicates it should be present at the time of the survey.

Table 3.3: Priority Flora Recorded or with Potential to Occur in the Survey Area

Description	Landform	Vegetation & Occurrence	# of individuals	Regional Distribution	Photograph	Local Distribution	Regional Distribution
<b><i>Alyxia tetanifolia</i> (Priority 3)</b>							
Erect, rigid shrub 1-2 m high. Flowers white, occurring during the survey.	Recorded on the sandy plains and rises in between saline salt pans.	Recorded on vegetation types P2 and P5 in the sandy plains between salt lakes in the south and east of the Survey Area. Likely present in between the traverse lines in these vegetation types – P2 and P5.	Within Survey Area Ecological – 56 Within Survey Area Spectrum – 38 Within Study Area – 2 <b>Total in Survey Area – 94</b>			Known from many locations in the local area, including in the Survey and Study Area.	Known from many scattered locations throughout Western Australia: Coolgardie, Murchison IBRA regions.
<b><i>Goodenia salina</i> (Priority 2)</b>							
Annual herb, 0.2 m high. Flowers yellow.	Recorded on the low gypseous dunes near salt pans of the Study Area.	Recorded on vegetation type V3 (Ecological 2016). Not recorded in the Survey Area by Ecological or Spectrum, but High potential to occur on S2 within the south-eastern area.	Within Survey Area – 0 Within Study Area – 45 <b>Total in Survey Area – 0</b>			Known from multiple records in the local area, predominantly in the Study Area.	Known from many scattered locations from a 1000 km range across Western Australia: Coolgardie and Mallee IBRA regions. Only one location in the Coolgardie region.





- Legend**
- The Survey Area
  - Significant Flora Traverses
  - Significant Flora - Spectrum**
    - Alyxia tetanifolia (P3)
  - Significant Flora - Ecological**
    - Alyxia tetanifolia (P3)

- Vegetation Mapping - Spectrum**
- P2 - Alyxia tetanifolia habitat
  - P5 - Alyxia tetanifolia habitat
  - S2 - Goodenia salina habitat

0 0.4 0.8 1.2 km  
Scale 1:40000 @ A4  
Coordinate System: GDA 1994 MGA Zone 51  
Projection: Transverse Mercator  
Units: Meter

**Spectrum**  
EDICOLOGY & SPATIAL

Author: MH Date: 21-12-2021

Priority Flora

Binduli South

Prepared for Talis Consultants/Norton

Map  
3.3



### 3.3. Introduced Flora

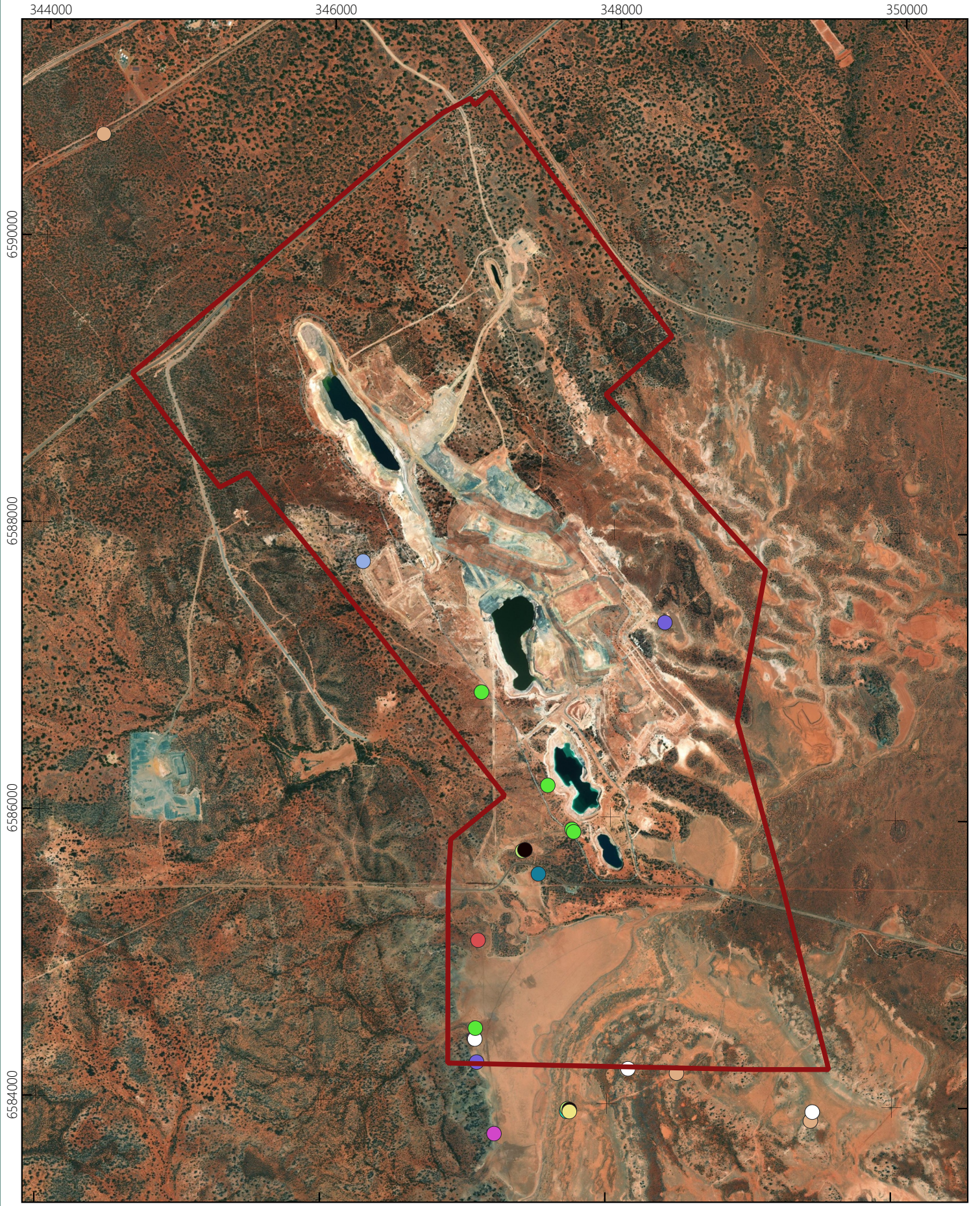
Nine introduced flora species were recorded at the Survey Area by Ecological 2016 of which one is a Declared Pest and Weed of National Significance (WoNS): *\*Tamarix aphylla* (Athel Pine). *\*Tamarix aphylla* is exempt from restricted keeping categories and has not been assigned required control measures. Three additional were recorded in the wider Study Area.

Introduced flora species were recorded often only as scattered clumps of individuals and did not form dominant components of the vegetation communities at the Survey Area. All introduced flora species are listed in Table 3.4. Locations have been provided on Map 3.4 and electronically with the report.

**Table 3.4: Introduced Flora Recorded at the Study Area**

Species	Number of Locations & Individuals in the Survey Area	Environmental Significance
<i>*Asphodelus fistulosus</i> (Onion weed)	1 location, 100 individuals.	Permitted - s11
<i>*Cenchrus ciliaris</i> (Buffel Grass)	Study Area only.	Permitted - s11
<i>*Centaurea melitensis</i> (Maltese Cockspur)	5 locations, 66 individuals.	Permitted - s11
<i>*Chloris virgata</i> (Feathertop Rhodes Grass)	Study Area only.	Permitted - s11
<i>*Cuscuta epithymum</i> (Lesser Dodder)	1 location, 5 individuals.	Permitted - s11
<i>*Dittrichia graveolens</i> (Stinkwort)	1 location, 5 individuals.	Permitted - s11
<i>*Lactuca serriola</i> forma <i>serriola</i> (Prickly Lettuce)	1 location, 5 individuals.	Permitted - s11
<i>*Nicotiana glauca</i> (Tree Tobacco)	2 locations, 2 individuals.	Permitted - s11
<i>*Rumex vesicarius</i> (Ruby Dock)	1 location, 1 individual.	Permitted - s11
<i>*Salvia verbenaca</i> (Wild Sage)	Study Area only.	Permitted - s11
<i>*Sonchus oleraceus</i> (Common Sowthistle)	1 location, 1 individual.	Permitted - s11
<i>*Tamarix aphylla</i> (Athel Pine)	1 location, 5 individuals.	Weed of National Significance (WoNS), Declared Pest - s22(2) (Exempt)

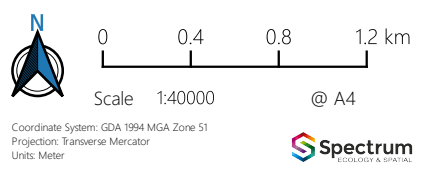




**Legend**

**Introduced Flora**

- \*Asphodelus fistulosus (Onion weed)
- \*Cenchrus ciliaris (Buffel Grass)
- \*Centaurea melitensis (Maltese Cockspur)
- \*Chloris virgata (Feathertop Rhodes Grass)
- \*Cuscuta epithymum (Lesser Dodder)
- \*Dittrichia graveolens (Stinkwort)
- \*Lactuca serriola forma serriola
- \*Nicotiana glauca (Tree Tobacco)
- \*Rumex vesicarius (Ruby Dock)
- \*Salvia verbenaca (Wild Sage)
- \*Sonchus oleraceus (Common Sowthistle)
- \*Tamarix aphylla (Athel Tree)



Author: MH Date: 20-12-2021



Introduced Flora

Binduli South

Prepared for Talis Consultants/Norton

Map  
3.4



### 3.4. Vegetation

#### 3.4.1. Desktop Assessment

##### 3.4.1.1. Threatened & Priority Ecological Communities

No TEC or PECs were identified within the Binduli South Study Area during the desktop assessment. The closest listed community to the Study Area was the Priority 3 PEC Emu Land System, located 40 km to the north-east (Map 1.4). This land system is characterised by fresh or brackish ephemeral lakes and swamps with Cane Grass, Lignum, and Paperbark shrublands and is assigned a 'Low' likelihood of occurrence in the Study and Survey Areas.

##### 3.4.1.2. Ecological 2016 Vegetation Associations

Six vegetation communities were described and mapped as occurring at the Study Area by Ecological (2016). Of these four (V1, V2, V3, V4) occur within the Survey Area (Table 3.5; Map 3.5). Vegetation association V3 in the south of the Study Area was determined by Ecological 2016 to be of significance as it provides habitat for the Priority 2 species *Goodenia salina* and contains regionally and locally restricted vegetation. Vegetation association V5 provides habitat for *Isolepis australiensis* (Table 3.5).

**Table 3.5: Ecological 2016 Vegetation Associations**

Type	Description	Significance	Landform	Area (ha) Mapped in Survey Area	Area (ha) Mapped in Study Area
V1	<i>Cratystylis subspinescens</i> , <i>Frankenia fecunda</i> and <i>Scaevola spinescens</i> sparse shrubland over <i>Sclerolaena gardneri</i> , <i>Surreya diandra</i> and <i>Maireana triptera</i> sparse chenopod shrubland over <i>Austrostipa elegantissima</i> and <i>Eragrostis pergracilis</i> isolated grasses over <i>Disphyma crassifolium</i>	-	Red sand-loam plains & rises	133.1	853.6
V2	Mixed <i>Eucalyptus</i> spp. woodland comprising predominantly <i>E. griffithsii</i> , <i>E. horistes</i> and <i>E. lesouefii</i> open woodland over <i>Eremophila scoparia</i> , <i>Exocarpos aphyllus</i> and <i>Senna artemisioides</i> subsp. <i>filifolia</i> sparse shrubland over <i>Atriplex vesicaria</i> , <i>Enchylaena tomentosa</i> var. <i>tomentosa</i> and <i>Sclerolaena gardneri</i> sparse chenopod shrubland over <i>Austrostipa elegantissima</i> isolated grasses. This community occasionally grades into pockets dominated by <i>E. salmonophloia</i> .	-	Red-brown loam plains and rises	671.2	3,093.4
V3	<i>Eucalyptus griffithsii</i> and <i>Callitris columellaris</i> open woodland over <i>Dodonaea viscosa</i> subsp. <i>angustissima</i> , <i>Lawrencia helmsii</i> and <i>Scaevola spinescens</i> sparse shrubland over <i>Rhagodia drummondii</i> , <i>Sclerolaena ?eurotioides</i> isolated chenopod shrubs over <i>Goodenia salina</i> (P2) and <i>Zygophyllum aurantiacum</i> subsp. <i>aurantiacum</i> isolated forbs.	Locally and regionally restricted. Habitat for <i>Goodenia salina</i> . Associated with Beard unit 123.	Gypseous dunes (Kopi)	11.1	215.0
V4	<i>Tecticornia indica</i> subsp. <i>bidens</i> , <i>Tecticornia disarticulata</i> and <i>Maireana appressa</i> sparse chenopod shrubland over <i>Eragrostis pergracilis</i> , <i>Enteropogon ramosus</i> and <i>Enneapogon polyphyllus</i> isolated grasses over <i>Disphyma crassifolium</i> subsp. <i>clavellatum</i> , <i>Brachyscome ciliaris</i> and <i>Senecio lacustrinus</i> sparse forbland.	-	Brown sandy clay flats and salt flats	386.4	1,077.6
V5	<i>Melaleuca lateriflora</i> open shrubland over <i>Eragrostis pergracilis</i> isolated grasses over <i>Cyperus rigidellus</i> isolated rushes over <i>Dianella revoluta</i> and <i>Marsilea drummondii</i> isolated forbs.	Habitat for <i>Isolepis australiensis</i> (P2)	Seasonally wet clay pans	-	44.1
V6	<i>Acacia acuminata</i> and <i>Eremophila granitica</i> open shrubland over <i>Austrostipa elegantissima</i> isolated grasses over <i>Cheilanthes sieberi</i> subsp. <i>sieberi</i> isolated ferns.	-	Shallow brown loam with granite outcropping	-	45.3



344000

348000

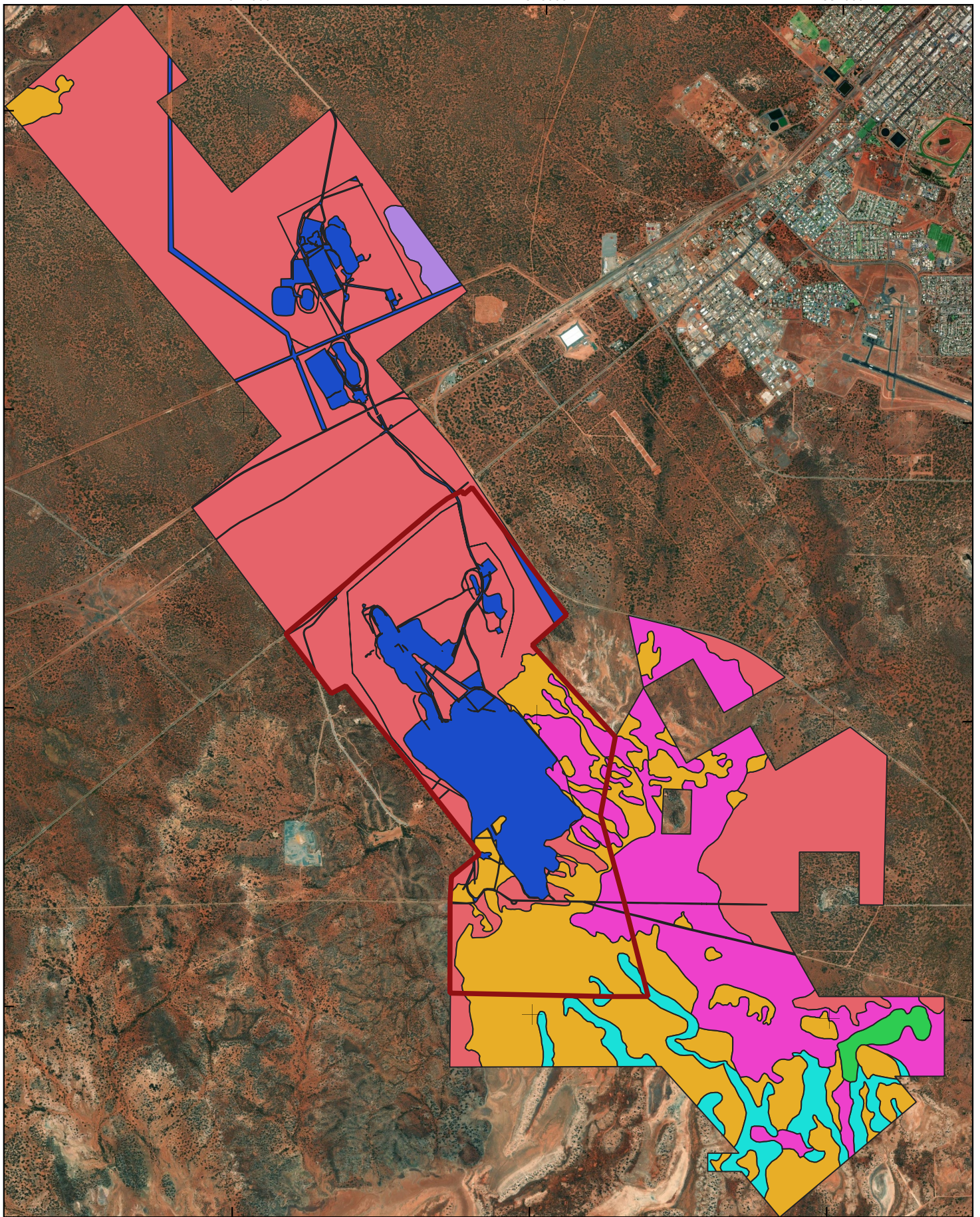
352000

6596000

6592000

6588000

6584000



### Legend

  The Survey Area

### Vegetation Communities

  1

  2

  3

  4

  5

  6

  Infrastructure



0 0.4 0.8 1.2 1.6 2 2.4 km

Scale 1:78733

@ A4

Coordinate System: GDA 1994 MGA Zone 51  
Projection: Transverse Mercator  
Units: Meter

**Spectrum**  
ECOLOGICAL & SPATIAL

Author: MH

Date: 21-12-2021

## Vegetation Mapping of the Study Area (Ecological 2016)

Binduli South

Prepared for Talis  
Consultants/Norton

Map

3.5



### 3.4.2. Current Assessment – Vegetation Types




A total of 12 vegetation types were described from the Survey Area, which were recorded on clay plains, sandy plains, rocky plains, granitic hillslopes, Gypseous dunes, drainage lines, salt lakes and salt pans (Table 3.6; Map 3.6).

The plains were characterised by mixed *Eucalyptus* species woodlands which were widespread in the northern half of the Survey Area (P1) and were dominated by mixed *Eucalyptus* species, over *Eremophila* and *Senna* mid shrublands, and mixed low chenopod shrubs. Ecological 2016 mapped the *Eucalyptus* woodland vegetation (V2) as the only vegetation type in the northern area, however this has been mapped at a finer scale to include hill slopes (S1), drainage lines (D1), and other plain vegetation types (P3), dominated by *Allocasuarina* low woodlands.




The salt pans and lakes were dominated by mixed *Tecticornia* species, which was widespread in the south and south-east of the Survey Area (D2). Ecological mapped the entire salt lake bed as *Tecticornia* low shrubland, but it has been refined to include sections of other chenopod low shrublands, including *Atriplex* and *Sclerolaena* (D4). Salt pans in the east of the Survey Area were mapped as a mosaic with a fringing vegetation type (D3) as it is difficult to distinguish the boundary on the aerial mapping from the *Tecticornia* shrublands (D2). This fringing vegetation type (D3) was dominated by *Cratystylis* and *Frankenia* spp. low shrublands. Sandy plains formed islands between the salt lakes and were dominated by *Acacia masliniana* and *Eremophila miniata* tall open shrublands (P5), sometimes with a *Eucalyptus* overstorey and *Triodia* hummock grassland (P2).



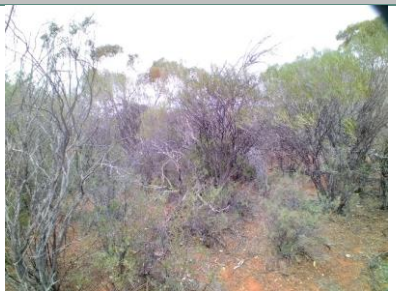
Small areas of granitic hillslopes were mapped across the Survey Area and were characterised by *Acacia acuminata* tall shrublands (S1). The western edge of the Survey Area included hillslopes dominated by *Eucalyptus griffithsii* over mixed *Eremophila* species, sometimes with *Acacia acuminata* (S3). Small areas of Gypseous dunes were present in the south-east and were dominated by *Callitris columellaris* low open woodlands (S2).




Table 3.6: Vegetation Types Recorded at the Survey Area

Code	Vegetation Description (NVIS Lvl 5)	Associated Species	Landform & Location	Sites 2021	Sites 2016	Area (ha) & % of Survey Area	Representative Photo
<b>Plains</b>							
P1	<i>Eucalyptus griffithsii</i> , <i>Eucalyptus lesouefii</i> , and <i>Eucalyptus oleosa</i> subsp. <i>oleosa</i> mid open woodland, over <i>Eremophila scoparia</i> , <i>Senna artemisioides</i> subsp. <i>filifolia</i> , and <i>Scaevola spinescens</i> mid to tall sparse shrubland, over <i>Atriplex vesicaria</i> and <i>Maireana sedifolia</i> low open shrubland.	<i>Eucalyptus horistes</i> <i>Exocarpos aphyllus</i> <i>Enchylaena tomentosa</i> <i>Sclerolaena gardneri</i> <i>Olearia muelleri</i> <i>Ptilotus obovatus</i> <i>Westringia rigida</i> <i>Tecticornia</i> spp. (close to salt lakes)	Undulating plains. Red-orange, Sandy-clay.  Widespread throughout northern area of Survey Area. Mapped as Ecological V1. Many minor VTs were mapped as this broad community.	R013, R016, R017, R018, R019, R020, R025	ELA12, ELA13, ELA16, ELA17, ELA18, ELA19, ELA20, ELA21, ELA22, ELA23, ELA27, ELA28, ELA30, ELA33, ELA34, ELA35, ELA36, ELA46, ELA47, ELA48.	466.9 ha 28.2%	
P2	<i>Eucalyptus flocktoniae</i> subsp. <i>flocktoniae</i> and <i>Eucalyptus cylindrocarpa</i> low woodland, over <i>Acacia hemiteles</i> , <i>Grevillea sarissa</i> subsp. <i>bicolor</i> , +/- <i>Melaleuca hamata</i> , tall sparse shrubland, over <i>Triodia scariosa</i> low open hummock grassland.	<i>Eucalyptus gracilis</i> <i>Eremophila parvifolia</i> subsp. <i>auricampa</i> <i>Halgania andromedifolia</i> <i>Santalum acuminatum</i> <i>Lomandra effusa</i> <i>Melaleuca eleuterostachya</i> <i>Alyxia tetanifolia</i> (P3)	Sandplains. Orange sand.  In some sections in the centre of the Survey Area, near the salt lakes. VT not defined by Ecological, grouped with general Eucalyptus woodland (V2).	R006, R009, R023	ELA10, ELA11.	67.8 ha 4.1%	
P3	<i>Allocasuarina corniculata</i> low isolated trees, over <i>Acacia tetragonophylla</i> , <i>Dodonaea lobulata</i> and <i>Eremophila oldfieldii</i> subsp. <i>angustifolia</i> tall open shrubland, over <i>Scaevola spinescences</i> and <i>Senna artemisioides</i> subsp. <i>filifolia</i> and <i>Ptilotus obovatus</i> low sparse shrubland.	-	Rocky plains and rises. Abundant ironstone rocks and red-orange sandy-clay. In one small section in the west of the Survey Area. VT not defined by Ecological, only small area with no quadrat sampled.	R011	-	24.6 ha 1.5%	

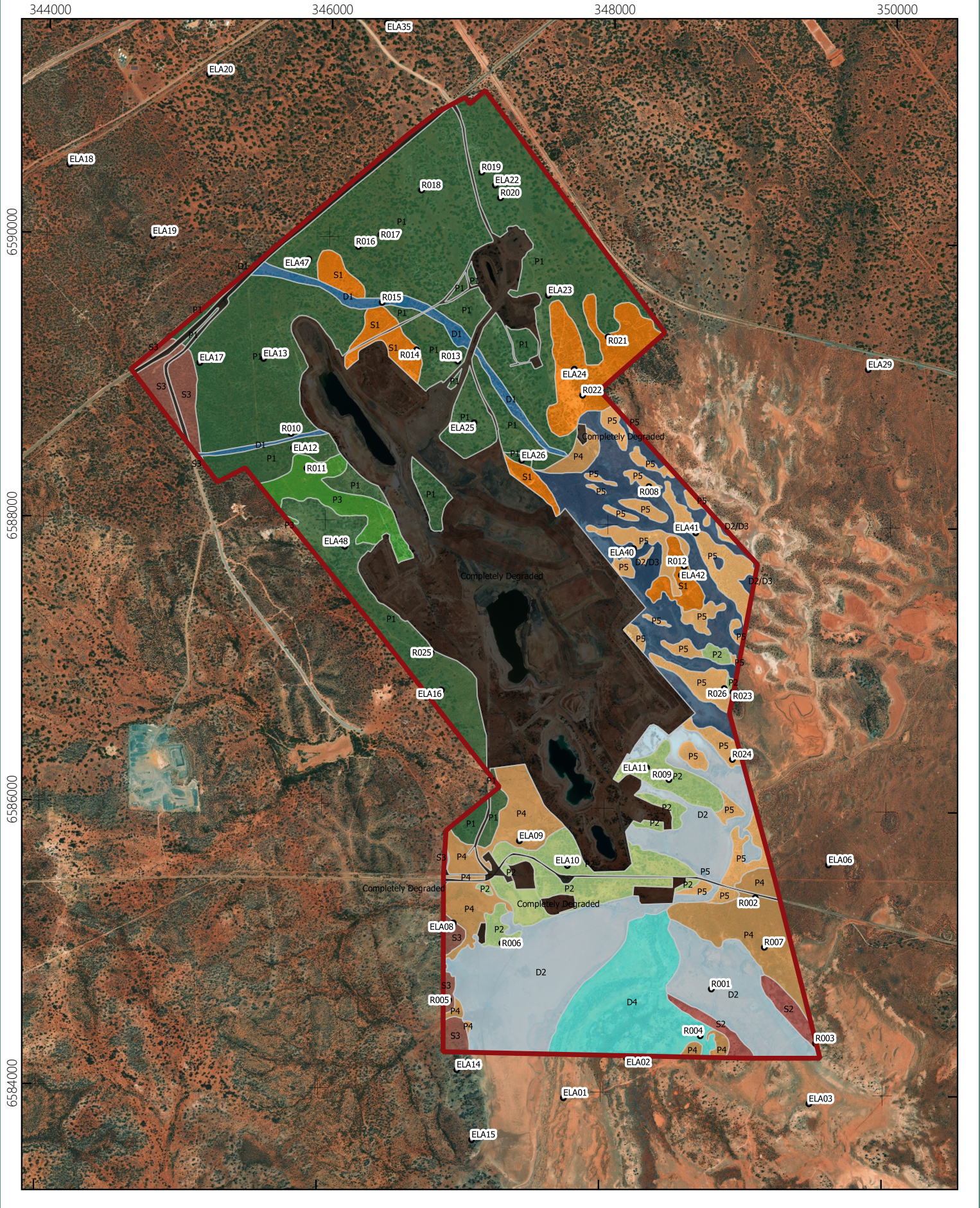


Code	Vegetation Description (NVIS Lvl 5)	Associated Species	Landform & Location	Sites 2021	Sites 2016	Area (ha) & % of Survey Area	Representative Photo
P4	<i>Eremophila scoparia</i> and <i>Acacia densiflora</i> Mid to tall sparse shrubland, over <i>Cratystylis subspinescens</i> , <i>Scaevola spinescens</i> , and <i>Exocarpos aphyllus</i> low open shrubland.	<i>Surreya diandra</i> <i>Acacia masliniana</i> <i>Rhagodia drummondii</i> <i>Cratystylis microphylla</i> <i>Maireana triptera</i> <i>Frankenia fecunda</i> <i>Maireana appressa</i> <i>Dodonaea viscosa</i> subsp. <i>angustissima</i>	Sandy-clay floodplains surrounding lake bed. Orange clay-loam.  In the southern areas of the Survey Area surrounding the salt lake. Mapped by Ecological as V1 but combined with Spectrum veg type D3.	R002, R007	ELA05, ELA06, ELA07, ELA29	83.2 ha 5.0%	
P5	<i>Acacia masliniana</i> and <i>Eremophila miniata</i> tall open shrubland, over <i>Alyxia buxifolia</i> , <i>Scaevola spinescens</i> and <i>Cratystylis subspinescens</i> mid open shrubland, over <i>Frankenia fecunda</i> and <i>Eremophila glabra</i> subsp. <i>glabra</i> low sparse shrubland.	<i>Dodonaea viscosa</i> subsp. <i>angustissima</i> <i>Santalum acuminatum</i> <i>Alyxia tetanifolia</i> (P3) <i>Jacksonia arida</i> <i>Atriplex vesicaria</i> <i>Enchylaena tomentosa</i> var. <i>tomentosa</i> <i>Enneapogon polyphyllus</i> <i>Dianella revoluta</i>	Sand plain between salt pans. Orange sand. In areas to the south-east of the Survey Area in between the salt pans. Mapped with Ecological V1. Not separated as different VT but is separate in the dendrogram.	R008	ELA41	76.7 ha 4.6%	
<b>Slopes</b>							
S1	<i>Acacia acuminata</i> (+/- <i>Melaleuca hamata</i> ) tall open shrubland, over <i>Eremophila granitica</i> , <i>Exocarpos aphyllus</i> , and <i>Scaevola spinescens</i> mid sparse shrubland.	<i>Austrostipa elegantissima</i> <i>Cheilanthes sieberi</i> subsp. <i>sieberi</i> <i>Prostanthera grylloana</i> <i>Prostanthera althoferi</i>	Rocky granitic hill slopes. Large common granite stones. Red-orange sandy-clay. Few scattered locations through the Survey Area. Mapped as Ecological vegetation type V6. Was mapped in small section outside of the Survey Area.	R012, R014, R021, R022	ELA37, ELA38, ELA39, ELA42	69.6 ha 4.2%	

Code	Vegetation Description (NVIS Lvl 5)	Associated Species	Landform & Location	Sites 2021	Sites 2016	Area (ha) & % of Survey Area	Representative Photo
S2	<i>Callitris columellaris</i> (+/- <i>Eucalyptus griffithsii</i> ) low open woodland, over <i>Dodonaea viscosa</i> subsp. <i>angustissima</i> mid sparse shrubland, over <i>Lawrenia helmsii</i> , <i>Scaevola spinescens</i> , and <i>Rhagodia drummondii</i> low sparse shrubland.	<i>Goodenia salina</i> <i>Roepera aurantiacum</i> <i>Kippistia suaedifolia</i> <i>Cratystylis conocephala</i> <i>Exocarpos aphyllus</i> <i>Roepera glaucum</i>	Kopi dunes. Gypseous dunes.  Two small dunes located in the south-east of the Survey Area. Mapped as Ecological vegetation type V3.	R003	ELA04, ELA43, ELA44.	12.0 ha 0.7%	
S3	<i>Eucalyptus griffithsii</i> low open woodland, over <i>Eremophila oldfieldii</i> subsp. <i>angustifolia</i> , <i>Eremophila maculata</i> subsp. <i>brevifolia</i> and <i>Senna artemisioides</i> subsp. <i>filifolia</i> mid to tall open shrubland, over <i>Atriplex vesicaria</i> , <i>Scaevola spinescens</i> and <i>Ptilotus obovatus</i> low sparse shrubland.	<i>Exocarpos aphyllus</i> <i>Dodonaea lobulata</i> <i>Allocasuarina acutivalvis</i> <i>Lycium australe</i> <i>Atriplex vesicaria</i> <i>Rhagodia drummondii</i> <i>Maireana sedifolia</i> <i>Olearia muelleri</i> <i>Solanum nummularium</i>	Low rocky hills. Ironstone and quartz abundant stones. Red-orange sandy-clay.  Located in small sections along the west of the Survey Area. VT not defined by Ecological, grouped with general <i>Eucalyptus</i> woodland (V2).	R005	ELA08, ELA14, ELA15	26.9 ha 1.6%	
<b>Drainage</b>							
D1	<i>Eucalyptus salubris</i> and/or <i>Eucalyptus longissima</i> low open woodland, over <i>Acacia acuminata</i> , <i>Acacia tetragonophylla</i> , and <i>Alyxia buxifolia</i> tall shrubland, over <i>Dodonaea lobulata</i> and <i>Scaevola subspinescens</i> mid opens shrubland.	<i>Ptilotus obovatus</i>	Drainage lines. Few scattered ironstone rocks. Red-orange sandy-clay loam.  Scattered drainage lines through the Survey Area. No quadrats sampled in drainage lines by Ecological.	R010, R015	-	18.7 ha 1.1%	


Code	Vegetation Description (NVIS Lvl 5)	Associated Species	Landform & Location	Sites 2021	Sites 2016	Area (ha) & % of Survey Area	Representative Photo
D2	<i>Tecticornia indica</i> subsp. <i>bidens</i> and <i>Tecticornia disarticulata</i> (+/- <i>Atriplex vesicaria</i> ) low sparse chenopod shrubland.	<i>Maireana appressa</i> <i>Eragrostis pergracilis</i> <i>Enteropogon ramosus</i> <i>Enneapogon polyphyllus</i> <i>Disphyma crassifolium</i> subsp. <i>clavellatum</i> <i>Brachyscome ciliaris</i> <i>Senecio lacustrinus</i> <i>Frankenia desertorum</i>	Salt lake, salt pans. Brown-orange clay. A large area in the south of the Study Area. Some smaller clay pans in the south-west. Mapped as Ecological vegetation type V4.	R015	ELA01, ELA02, ELA03, ELA09.	177.2 ha 10.7%	
D3	<i>Cratystylis subspinescens</i> , <i>Frankenia interioris</i> , and <i>Surreya diandra</i> low open shrubland.	<i>Lawrenia squamata</i> <i>Maireana glomerifolia</i> <i>Tecticornia undulata</i> <i>Atriplex vesicaria</i> <i>Maireana amoena</i> <i>Maireana appressa</i> <i>Frankenia fecunda</i> <i>Minuria cunninghamii</i> <i>Gunniopsis quadrifida</i>	Margins of salt pans. Orange-cream clay. Interzone between D2 ( <i>Tecticornia</i> shrubland) and P5 (sand plains). Mapped as a mosaic with D2 in salt pan area to the south-west. Originally mapped with Ecological V1. Is similar to this unit, but the overstorey is not present.	R024, R026	ELA40	90 ha 5.4% (mosaic area with D2)	
D4	<i>Atriplex vesicaria</i> , <i>Atriplex holocarpa</i> , <i>Olearia exiguifolia</i> low sparse shrubland.	<i>Disphyma crassifolium</i> subsp. <i>clavellatum</i> <i>Dodonaea viscosa</i> subsp. <i>angustissima</i> <i>Lawrenia helmsii</i> <i>Tecticornia</i> spp.	Salt lake. Orange sandy-clay. Located in the salt lake in areas where there is no to minimal <i>Tecticornia</i> present, and where there is more sand present. Not mapped or sampled by Ecological.	R004	-	66.4 ha 4.0%	





**Legend**


- The Survey Area
- Ecological 2016 Flora Sites
- Spectrum 2021 Flora Sites
- Vegetation Mapping**
- Completely Degraded
- D1
- D2
- D2/D3
- D4
- P1
- P2
- P3
- P4
- P5
- S1
- S2
- S3



00.40.81.2 km

Scale 1:40000 @ A4

Coordinate System: GDA 1994 MGA Zone 51  
Projection: Transverse Mercator  
Units: Meter



Author: MHDate: 21-12-2021

**Vegetation Types**



### 3.4.3. Significant Vegetation

The significance of vegetation types at the Survey Area based on the definitions listed in Section 2.9.2 (EPA 2016a) are listed and discussed in Table 3.7. One unit is locally and regionally significant: S2: *Callitris columellaris* (+/-*Eucalyptus griffithsii*) low open woodland, over *Dodonaea viscosa* subsp. *angustissima* mid sparse shrubland, over *Lawrenia helmsii*, *Scaevola spinescens*, and *Rhagodia drummondii* low sparse shrubland on Gypseous (Kopi) dunes.

Table 3.7: Significant Vegetation Discussion

Significant Vegetation Definition	Vegetation Type	Description
Threatened Ecological Community (TEC)	-	-
Priority Ecological Community (PEC)	-	-
Restricted distribution	P3	<b>Not significant</b> – restricted distribution in Survey Area as it is only recorded on the edges and the landform widespread through the local area. Associated with Beard SA9 which is widespread through local and regional area.
	S2	<b>Significant</b> – restricted to small areas associated with the Gypseous dunes in between salt lakes which are common landforms in the local area, but likely to be regionally restricted. Associated with locally and regionally restricted Beard SA123.1.
	S3	<b>Not significant</b> – restricted distribution in Survey Area as it is only recorded on the edges and the landform widespread through the local area. Associated with Beard SA9 which is widespread through local and regional area.
	D1	<b>Not significant</b> – drainage landforms are always restricted in area, but are widespread locally and regionally. Not associated with Beard unit, as a small feature.
Degree of historical impact from threatening processes	-	-
A role as a refuge	S2	<b>Significant</b> – provides habitat for P2 taxon <i>Goodenia salina</i> , which has high regional significance. All other Priority flora do not have a high local or regional significance.
Providing an important function required to maintain ecological integrity of a significant ecosystem	-	-

### 3.5. Vegetation Condition

The vegetation condition within the Survey Area were mapped by Ecological 2016 and ranged from Very Good (68.5%) to Completely Degraded (27.2%). The majority of the intact vegetation was mapped as Very Good, with disturbances including exploration tracks and scattered weeds. Weeds were not common, often recorded as clumps of individuals only and mostly around existing disturbance. Existing disturbance areas, including mining pits and infrastructure were mapped as 27.2% of the Survey Area. Vegetation condition of the Survey Area is presented in Table 3.8 and mapped in Map 3.7.

**Table 3.8: Vegetation Condition Recorded at the Survey Area (Ecological 2016)**

Condition	Area (ha) & % of Survey Area	Disturbance Detail in Survey Area
Excellent	-	-
Very Good	1,131.8 ha, 68.5%	Exploration tracks, scattered weeds.
Good	54.2 ha, 3.3%	Some areas where some old clearing may have occurred.
Poor	15.9 ha, 1.0%	Disturbance from installing the mining pit wall affecting vegetation structure.
Degraded	-	-
Completely Degraded	449.6 ha, 27.2%	Existing mining infrastructure and tracks.





**Legend**  
 The Survey Area

**Ecological 2016 Vegetation Condition**  
 Very Good  
 Good  
 Poor  
 Completely Degraded



0 0.4 0.8 1.2 km

Scale 1:40000

@ A4

Coordinate System: GDA 1994 MGA Zone 51  
 Projection: Transverse Mercator  
 Units: Meter



Author: MH

Date: 21-12-2021

Vegetation Condition

Binduli South

Prepared for Talis  
 Consultants/Norton

Map  
 3.7



## 4. CONCLUSIONS

### 4.1. Flora

No Threatened flora taxa were recorded or considered likely to occur in the Survey Area. The three Threatened flora taxa identified during the desktop assessment were assigned a 'Low' likelihood of occurrence in the Study Area pre and post survey.

One Priority 3 flora species was recorded within the Survey Area: *Alyxia tetanifolia*. This taxon was recorded on vegetation types P2 and P5, which are sandy plains that occur between salt pans in the south and east of the Survey Area. There were 94 individuals recorded in the Survey Area. *Alyxia tetanifolia* is known from multiple locations in the local and regional area and is not considered to be locally or regionally significant.

One Priority 2 flora species was recorded within the Study Area and following the field survey has potential to occur in the Survey Area: *Goodenia salina*. There were 45 individuals of *Goodenia salina* recorded by Ecological 2016 in the Study Area only. This was recorded exclusively on vegetation type S2, on the low gypseous dunes near the salt pans in the south-east of the Study Area. No individuals were recorded within the Survey Area during the current assessment, however there is potential for them to occur here. There are multiple locations of *Goodenia salina* in the local area and it is not considered to have local significance, however as this is the only population in the Coolgardie region (the remaining are in Esperance Plains, approx. 1,000 km south-west) it is considered to have regional significance at the Survey Area.

The four significant flora taxa assigned 'High' likelihood of occurrence (*Eremophila praecox* – P2, *Lepidium fasciculatum* – P3, and *Notisia intonsa* – P3) or Recorded (*Isolepis australiensis* – P3, in the Study Area) prior to the survey, were assigned a 'Low' likelihood of occurrence post survey.

### 4.2. Vegetation

No TEC or PEC communities occur or are likely to occur within the Study Area and none of the vegetation communities resemble any known TEC or PEC communities.

Of the 12 vegetation types in the Survey Area, one is locally and regionally significant: S2: *Callitris columellaris* (+/-*Eucalyptus griffithsii*) low open woodland, over *Dodonaea viscosa* subsp. *angustissima* mid sparse shrubland, over *Lawrenia helmsii*, *Scaevola spinescens*, and *Rhagodia drummondii* low sparse shrubland on Gypseous (Kopi) dunes. S2 is restricted to small areas associated with the Gypseous dunes in between salt lakes which are common landforms in the local area, but likely to be regionally restricted. It is also associated with locally and regionally restricted Beard sub-association 123.1.

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CSIRO, pp. 362–378.

## Appendix A: Flora Site Information





Site: R001		Type: Releve		Size: N/A		Date: 25/10/2021		Botanist: Melissa Hay	
Landform:	Drainage,Salt pan								
Slope, aspect:	<1° - Level								
Soil:	Clay, Red-orange								
Rocks:	-								
Abundance:	No rocks								
Size:	-								
Fire:	> 5 yrs								
Condition:	Excellent								
Notes:	Grazing (Low)								
Veg Unit:	D2								
Location (NW):	348779 mE, 6584735 mS								
Species		Height	Cover	Species		Height	Cover		
Atriplex vesicaria		0.2	0.5						
Frankenia interioris		0.1	0.2						
Tecticornia indica subsp. bidens		0.3	5						


Site: R002		Type: Releve		Size: N/A		Date: 25/10/2021	Botanist: Melissa Hay	
Landform:	Flat, Plain							
Slope, aspect:	<1° - Level							
Soil:	Sandy clay, Red-orange							
Rocks:	-							
Abundance:	No rocks							
Size:	-							
Fire:	> 5 yrs							
Condition:	Excellent							
Notes:	None							
Veg Unit:	P4							
Location (NW):	349081 mE, 6585382 mS							
Species			Height	Cover	Species		Height	Cover
Cratystylis subspinescens			0.5	5				
Eremophila scoparia			1.8	15				
Ptilotus obovatus			0.3	1				


Site: R003		Type: Releve		Size: N/A		Date: 26/10/2021		Botanist: Melissa Hay	
Landform:	Hill,Slope, Simple dune								
Slope, aspect:	3° - Gentle, None								
Soil:	Sandy clay, Orange,White,Cream								
Rocks:	-								
Abundance:	No rocks								
Size:	-								
Fire:	> 5 yrs								
Condition:	Very Good								
Notes:	Grazing (Medium)								
Veg Unit:	S2								
Location (NW):	349522 mE, 6584362 mS								
Species		Height	Cover	Species		Height	Cover		
Callitris columellaris		6	3	Pittosporum angustifolium		4	0.5		
Dodonaea viscosa subsp. angustissima		1	0.5	Roepera aurantiaca subsp. aurantiaca		0.3	0.5		
Lawrenzia helmsii		0.3	0.5						




Site: R004		Type: Releve		Size: N/A		Date: 26/10/2021		Botanist: Melissa Hay	
Landform:	Drainage,Salt pan								
Slope, aspect:	<1° - Level								
Soil:	Clay,Sandy clay, Red-orange								
Rocks:	-								
Abundance:	No rocks								
Size:	-								
Fire:	> 5 yrs								
Condition:	Excellent								
Notes:	Grazing (Low)								
Veg Unit:	D4								
Location (NW):	348705 mE, 6584404 mS								
Species			Height	Cover	Species			Height	Cover
Atriplex holocarpa			2	0.2	Lawrenia helmsii			0.3	0.2
Disphyma crassifolium subsp. clavellatum			0.2	0.5	Olearia exiguiifolia			0.3	6
Dodonaea viscosa subsp. angustissima			0.5	0.3					


Site: R005		Type: Releve		Size: N/A		Date: 26/10/2021		Botanist: Melissa Hay	
Landform:	Hill,Slope,Simple								
Slope, aspect:	10° - Moderate E								
Soil:	Sandy clay loam, Brown								
Rocks:	Quartz Ironstone								
Abundance:	50-90% Abundant								
Size:	20-60 mm - Coarse gravel								
Fire:	2-5 yrs								
Condition:	Excellent								
Notes:	Grazing (Low)								
Veg Unit:	P1								
Location (NW):	346921 mE, 6584631 mS								
Species				Height	Cover	Species		Height	Cover
Eucalyptus griffithsii				6	10				
Ptilotus obovatus				0.3	0.5				
Santalum acuminatum				1	0.1				
Scaevola spinescens				1	0.5				


Site: R006		Type: Releve		Size: N/A		Date: 26/10/2021		Botanist: Melissa Hay	
Landform:	Hill,Slope,Simple dune								
Slope, aspect:	<1° - Level -								
Soil:	Sand, Red-orange								
Rocks:	- -								
Abundance:	No rocks								
Size:	-								
Fire:	> 5 yrs								
Condition:	Excellent								
Notes:	Grazing (Low)								
Veg Unit:	P2								
Location (NW):	347292 mE, 6585037 mS								
Species		Height	Cover	Species		Height	Cover		
Dianella revoluta var. divaricata		0.4	0.1						
Melaleuca hamata		4	10						
Melaleuca lateriflora		1.7	5						
Triodia scariosa		0.5	3						


Site: R007		Type: Releve		Size: N/A		Date: 26/10/2021		Botanist: Melissa Hay	
Landform:	Flat, Plain								
Slope, aspect:	<1° - Level -								
Soil:	Sandy clay, Red-orange								
Rocks:	- -								
Abundance:	No rocks								
Size:	-								
Fire:	> 5 yrs								
Condition:	Excellent								
Notes:	Grazing (Low)								
Veg Unit:	P4								
Location (NW):	349150 mE, 6585034 mS								
Species		Height	Cover	Species		Height	Cover		
Cratystylis subspinescens		0.5	2						
Eremophila scoparia		1.7	1						

Site: R008		Type: Releve		Size: N/A		Date: 26/10/2021		Botanist: Melissa Hay	
Landform:	Flat, Plain								
Slope, aspect:	<1° - Level -								
Soil:	Sand, Red-orange								
Rocks:	- -								
Abundance:	No rocks								
Size:	-								
Fire:	> 5 yrs								
Condition:	Excellent								
Notes:	Grazing (Low)								
Veg Unit:	P5								
Location (NW):	348287 mE, 6588268 mS								
Species		Height	Cover	Species		Height	Cover		
Acacia masliniana		3	4	Santalum acuminatum		2	0.5		
Dianella revoluta var. divaricata		0.3	0.1	Scaevola spinescens		1	5		
Eremophila miniata		3	10						


Site: R009		Type: Releve		Size: N/A		Date: 27/10/2021		Botanist: Melissa Hay	
Landform:	Flat, Plain								
Slope, aspect:	<1° - Level -								
Soil:	Sand, Red-orange								
Rocks:	- -								
Abundance:	No rocks								
Size:	-								
Fire:	> 5 yrs								
Condition:	Excellent								
Notes:	Grazing (Low)								
Veg Unit:	P2								
Location (NW):	348458 mE, 6586205 mS								
Species		Height	Cover	Species		Height	Cover		
Acacia ligulata		2	0.5	Lomandra effusa		0.3	0.1		
Eucalyptus flocktoniae subsp. flocktoniae		12	15	Triodia scariosa		0.5	15		
Grevillea sarissa subsp. bicolor		2.2	5						


Site: R010		Type: Releve		Size: N/A		Date: 27/10/2021		Botanist: Melissa Hay	
Landform:	Drainage, Drainage line on flat								
Slope, aspect:	<1° - Level -								
Soil:	Clay, Sandy clay, Red-orange								
Rocks:	Ironstone Quartz								
Abundance:	2-10% Few								
Size:	20-60 mm - Coarse gravel								
Fire:	> 5 yrs								
Condition:	Excellent								
Notes:	Grazing (Low)								
Veg Unit:	D1								
Location (NW):	345747 mE, 6588607 mS								
Species		Height	Cover	Species		Height	Cover		
Acacia acuminata		3	45	Eremophila granitica		1.3	25		
Acacia tetragonophylla		2.5	1	Eucalyptus longissima		5	3		
Alyxia buxifolia		2	0.5	Leichhardtia australis		1	0.1		
Dodonaea lobulata		1	15	Scaevola spinescens		1	0.5		

Site: R011		Type: Releve		Size: N/A		Date: 27/10/2021		Botanist: Melissa Hay	
Landform:	Flat, Plain								
Slope, aspect:	1° - Very Gentle None								
Soil:	Sandy clay, Red-orange, Red								
Rocks:	Ironstone -								
Abundance:	50-90% Abundant								
Size:	20-60 mm - Coarse gravel								
Fire:	> 5 yrs								
Condition:	Excellent								
Notes:	Grazing (Low)								
Veg Unit:	P3								
Location (NW):	345862 mE, 6588363 mS								
Species		Height	Cover	Species		Height	Cover		
Acacia tetragonophylla		1.5	5	Ptilotus obovatus		0.3	0.5		
Allocasuarina corniculata		7	5	Scaevola spinescens		1	5		
Dodonaea lobulata		1.3	5	Senna artemisioides subsp. filifolia		1.5	3		
Eremophila oldfieldii subsp. angustifolia		2	0.5						


Site: R012		Type: Releve		Size: N/A		Date: 27/10/2021		Botanist: Melissa Hay	
Landform:	Hill,Slope,Simple								
Slope, aspect:	1° - Very Gentle S								
Soil:	Sandy clay,Sand, Red-orange								
Rocks:	Granite -								
Abundance:	10 -20% Common								
Size:	60-200 mm - Cobbles								
Fire:	> 5 yrs								
Condition:	Excellent								
Notes:	Grazing (Low)								
Veg Unit:	S1								
Location (NW):	348544 mE, 6587710 mS								
Species			Height	Cover	Species		Height	Cover	
Acacia acuminata			3	35	Melaleuca hamata		3	15	
Eremophila granitica			1	1	Scaevola spinescens		0.5	3	
Eremophila scoparia			1.5	3	Senna artemisioides subsp. filifolia		1.3	15	
Exocarpos aphyllus			2	0.5					






Site: R013		Type: Releve		Size: N/A		Date: 28/10/2021		Botanist: Melissa Hay	
Landform:	Flat, Plain								
Slope, aspect:	<1° - Level -								
Soil:	Sandy clay, Red-orange, Cream								
Rocks:	Quartz -								
Abundance:	2-10% Few								
Size:	20-60 mm - Coarse gravel								
Fire:	> 5 yrs								
Condition:	Excellent								
Notes:	Grazing (Low), Mounds								
Veg Unit:	P1								
Location (NW):	346920 mE, 6589133 mS								
Species			Height	Cover	Species		Height	Cover	
Atriplex vesicaria			0.3	3	Eucalyptus lesouefii		8	5	
Disphyma crassifolium subsp. clavellatum			0.1	0.4	Maireana glomerifolia		0.3	3	
Fremophila scoparia			2.1	1	Tecticornia indica subsp. bidens		0.4	15	


Site: R014		Type: Releve		Size: N/A		Date: 28/10/2021		Botanist: Melissa Hay	
Landform:	Flat, Rocky Outcrop								
Slope, aspect:	<1° - Level -								
Soil:	Sandy clay, Red-orange								
Rocks:	Granite -								
Abundance:	50-90% Abundant								
Size:	200-600 mm - Stones								
Fire:	> 5 yrs								
Condition:	Excellent								
Notes:	Grazing (Low)								
Veg Unit:	S1								
Location (NW):	346628 mE, 6589209 mS								
Species		Height	Cover	Species		Height	Cover		
Acacia acuminata		3	45	Melaleuca hamata		2.5	3		
Eremophila granitica		1.2	5	Scaevola spinescens		1.2	3		
Exocarpos aphyllus		1	0.5						


Site: R015		Type: Releve		Size: N/A		Date: 28/10/2021		Botanist: Melissa Hay	
Landform:	Drainage, Drainage line on flat								
Slope, aspect:	<1° - Level -								
Soil:	Sandy clay loam, Red-orange								
Rocks:	- -								
Abundance:	No rocks								
Size:	-								
Fire:	> 5 yrs								
Condition:	Excellent								
Notes:	None								
Veg Unit:	D1								
Location (NW):	346379 mE, 6589540 mS								
Species			Height	Cover	Species		Height	Cover	
Acacia tetragonophylla			3	1	Eucalyptus salubris		8	20	
Alyxia buxifolia			3	15	Exocarpos aphyllus		3	2	
Dodonaea lobulata			3	15	Senna artemisioides subsp. filifolia		3	10	


Site: R016		Type: Releve		Size: N/A		Date: 28/10/2021		Botanist: Melissa Hay	
Landform:	Drainage, Drainage line on flat								
Slope, aspect:	<1° - Level -								
Soil:	Sandy clay loam, Red-orange								
Rocks:	- -								
Abundance:	No rocks								
Size:	-								
Fire:	> 5 yrs								
Condition:	Excellent								
Notes:	Grazing (Low), Litter								
Veg Unit:	P1								
Location (NW):	346205 mE, 6589931 mS								
Species			Height	Cover	Species		Height	Cover	
Eremophila ionantha			2	0.5					
Eucalyptus salubris			6	45					
Ptilotus obovatus			0.3	0.1					

Site: R017		Type: Releve		Size: N/A		Date: 28/10/2021		Botanist: Melissa Hay		
Landform:	Flat, Plain									
Slope, aspect:	<1° - Level -									
Soil:	Sandy clay, Sand, Red-orange									
Rocks:	Ironstone -									
Abundance:	10 -20% Common									
Size:	<6 mm - Fine gravel									
Fire:	> 5 yrs									
Condition:	Excellent									
Notes:	Grazing (Low), Litter, Mounds									
Veg Unit:	P1									
Location (NW):	346363 mE, 6590018 mS									
Species			Height				Cover	Species	Height	Cover
Eremophila ionantha			1				1	Maireana sedifolia	1	5
Eremophila scoparia			2.5				8	Scaevola spinescens	1	1
Eucalyptus salmonophloia			15				5	Senna artemisioides subsp. filifolia	1.5	5
Eucalyptus salubris			9				0.5			


Site: R018		Type: Releve		Size: N/A		Date: 28/10/2021		Botanist: Melissa Hay	
Landform:	Flat, Plain								
Slope, aspect:	<1° - Level -								
Soil:	Sandy clay, Red-orange								
Rocks:	Quartz -								
Abundance:	20-50% Many								
Size:	6-20 mm - Medium gravel								
Fire:	> 5 yrs								
Condition:	Excellent								
Notes:	Grazing (Low), Litter, Tracks								
Veg Unit:	P1								
Location (NW):	346647 mE, 6590335 mS								
Species			Height	Cover	Species		Height	Cover	
Atriplex vesicaria			0.3	0.4	Ptilotus obovatus		0.3	0.1	
Eucalyptus oleosa subsp. oleosa			7	15	Senna artemisioides subsp. filifolia		1	0.5	
Maireana sedifolia			1	15					


Site: R019		Type: Releve		Size: N/A		Date: 28/10/2021		Botanist: Melissa Hay	
Landform:	Flat, Plain								
Slope, aspect:	<1° - Level -								
Soil:	Sandy clay, Red-orange								
Rocks:	Quartz -								
Abundance:	<2% Very few								
Size:	20-60 mm - Coarse gravel								
Fire:	> 5 yrs								
Condition:	Very Good								
Notes:	Grazing (Low), Litter, Mounds, Tracks								
Veg Unit:	P1								
Location (NW):	347071 mE, 6590467 mS								
Species		Height	Cover	Species		Height	Cover		
Atriplex vesicaria		0.5	35						
Eucalyptus oleosa subsp. oleosa		8	10						
Exocarpos aphyllus		2	0.1						
Maireana sedifolia		1	2						


Site: R020		Type: Releve		Size: N/A		Date: 28/10/2021		Botanist: Melissa Hay	
Landform:	Flat,Plain								
Slope, aspect:	<1° - Level -								
Soil:	Sandy clay, Red-orange,Brown								
Rocks:	- -								
Abundance:	No rocks								
Size:	-								
Fire:	> 5 yrs								
Condition:	Excellent								
Notes:	Grazing (Low),Tracks								
Veg Unit:	P1								
Location (NW):	347207 mE, 6590289 mS								
Species		Height	Cover	Species		Height	Cover		
Atriplex vesicaria		0.5	45						
Eucalyptus longicornis		12	5						
Exocarpos aphyllus		1	0.1						


Site: R021		Type: Releve		Size: N/A		Date: 28/10/2021		Botanist: Melissa Hay	
Landform:	Flat, Plain								
Slope, aspect:	<1° - Level -								
Soil:	Sandy clay, Red-orange								
Rocks:	- -								
Abundance:	No rocks								
Size:	-								
Fire:	> 5 yrs								
Condition:	Excellent								
Notes:	None								
Veg Unit:	S1								
Location (NW):	347983 mE, 6589320 mS								
Species			Height	Cover	Species		Height	Cover	
Acacia ?minyura			2	15	Eremophila granitica		1	5	
Acacia acuminata			4	20	Melaleuca hamata		3	10	
Eremophila alternifolia			1	2	Scaevola spinescens		1	0.5	




Site: R022		Type: Releve		Size: N/A		Date: 28/10/2021		Botanist: Melissa Hay	
Landform:	Hill,Slope,Simple								
Slope, aspect:	3° - Gentle S								
Soil:	Sandy clay, Red-orange,Cream								
Rocks:	Granite -								
Abundance:	50-90% Abundant								
Size:	200-600 mm - Stones								
Fire:	> 5 yrs								
Condition:	Very Good								
Notes:	Mounds,Tracks								
Veg Unit:	S1								
Location (NW):	347808 mE, 6588906 mS								
Species			Height	Cover	Species			Height	Cover
Acacia acuminata			4	8	Melaleuca hamata			3	1
Eremophila granitica			1	1	Senna artemisioides subsp. filifolia			1	2
Eucalyptus griffithsii			5	10					

Site: R023		Type: Releve		Size: N/A		Date: 28/10/2021		Botanist: Melissa Hay	
Landform:	Flat, Plain								
Slope, aspect:	<1° - Level -								
Soil:	Sand, Red-orange								
Rocks:	Granite -								
Abundance:	2-10% Few								
Size:	60-200 mm - Cobbles								
Fire:	> 5 yrs								
Condition:	Excellent								
Notes:	Tracks								
Veg Unit:	P2								
Location (NW):	348902 mE, 6586829 mS								
Species			Height	Cover	Species		Height	Cover	
Dianella revoluta var. divaricata			0.5	0.1	Exocarpos aphyllus		1.5	0.5	
Dodonaea viscosa subsp. angustissima			1	2	Scaevola spinescens		1	3	
Eucalyptus cylindrocarpa			8	15	Triodia scariosa		0.5	15	

Site: R024		Type: Releve		Size: N/A		Date: 28/10/2021		Botanist: Melissa Hay	
Landform:	Drainage,Salt pan								
Slope, aspect:	<1° - Level -								
Soil:	Clay,Sandy clay, Red-orange								
Rocks:	- -								
Abundance:	No rocks								
Size:	-								
Fire:	> 5 yrs								
Condition:	Excellent								
Notes:	Grazing (Low)								
Veg Unit:	D3								
Location (NW):	348905 mE, 6586354 mS								
Species		Height	Cover	Species		Height	Cover		
Atriplex vesicaria		0.2	0.5	Frankenia interioris		0.5	15		
Calandrinia sculpta		0.2	0.1	Maireana amoena		0.3	4		
Cratystylis subspinescens		0.5	2	Maireana glomerifolia		0.3	4		
Disphyma crassifolium subsp. clavellatum		0.1	0.2						

Site: R025		Type: Releve		Size: N/A		Date: 29/10/2021		Botanist: Melissa Hay	
Landform:	Flat,Plain								
Slope, aspect:	1° - Very Gentle None								
Soil:	Sandy clay,Sand, Red-orange,Brown								
Rocks:	Quartz -								
Abundance:	10 -20% Common								
Size:	20-60 mm - Coarse gravel								
Fire:	> 5 yrs								
Condition:	Very Good								
Notes:	Grazing (Low),Mounds,Tracks								
Veg Unit:	P1								
Location (NW):	346761 mE, 6587077 mS								
Species		Height	Cover	Species		Height	Cover		
Atriplex vesicaria		0.5	10	Eucalyptus oleosa subsp. oleosa		8	5		
Eremophila scoparia		3	20	Maireana glomerifolia		0.3	0.5		
Eucalyptus lesouefii		5	10	Tecticornia indica subsp. bidens		0.5	1		

Site: R026		Type: Releve		Size: N/A		Date: 29/10/2021		Botanist: Melissa Hay	
Landform:	Drainage,Salt pan								
Slope, aspect:	<1° - Level -								
Soil:	Clay,Sandy clay, Red-orange								
Rocks:	- -								
Abundance:	No rocks								
Size:	-								
Fire:	> 5 yrs								
Condition:	Excellent								
Notes:	Tracks								
Veg Unit:	D3								
Location (NW):	348840 mE, 6586853 mS								
Species		Height	Cover	Species		Height	Cover		
Calandrinia sculpta		0.3	0.1						
Cratystylis subspinescens		0.5	15						
Frankenia interioris		0.5	7						
Maireana amoena		0.2	1						

## Appendix B: Conservation Codes





## Appendix A1: Definitions of Conservation Categories under the EPBC Act

Category	Definition
<b>Extinct</b>	A native species is eligible to be included in the extinct category at a particular time if, at that time, there is no reasonable doubt that the last member of the species has died.
<b>Extinct in the Wild</b>	A native species is eligible to be included in the extinct in the wild category at a particular time if, at that time: (a) it is known only to survive in cultivation, in captivity or as a naturalised population well outside its past range; or (b) it has not been recorded in its known and/or expected habitat, at appropriate seasons, anywhere in its past range, despite exhaustive surveys over a time frame appropriate to its life cycle and form.
<b>Critically Endangered</b>	A native species is eligible to be included in the critically endangered category at a particular time if, at that time, it is facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with the prescribed criteria.
<b>Endangered</b>	A native species is eligible to be included in the endangered category at a particular time if, at that time: (a) it is not critically endangered; and (b) it is facing a very high risk of extinction in the wild in the near future, as determined in accordance with the prescribed criteria.
<b>Vulnerable</b>	A native species is eligible to be included in the vulnerable category at a particular time if, at that time: (a) it is not critically endangered or endangered; and (b) it is facing a high risk of extinction in the wild in the medium-term future, as determined in accordance with the prescribed criteria.
<b>Conservation Dependent</b>	A native species is eligible to be included in the conservation dependent category at a particular time if, at that time: (a) the species is the focus of a specific conservation program the cessation of which would result in the species becoming vulnerable, endangered, or critically endangered; or (b) the following subparagraphs are satisfied: (i) the species is a species of fish; (ii) the species is the focus of a plan of management that provides for management actions necessary to stop the decline of, and support the recovery of, the species so that its chances of long-term survival in nature are maximised; (iii) the plan of management is in force under a law of the Commonwealth or of a State or Territory; (iv) cessation of the plan of management would adversely affect the conservation status of the species.

## Appendix A2: Definitions of Conservation Categories under the BC Act (DBCA 2019)

**Threatened Species:** Listed by order of the Minister as Threatened in the category of critically endangered, endangered, or vulnerable under section 19(1), or is a rediscovered species to be regarded as Threatened species under section 26(2) of the Biodiversity Conservation Act 2016 (BC Act).

*Threatened fauna* is that subset of 'Specially Protected Fauna' listed under schedules 1 to 3 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018 for Threatened Fauna.

Threatened flora is that subset of 'Rare Flora' listed under schedules 1 to 3 of the Wildlife Conservation (Rare Flora) Notice 2018 for Threatened Flora.

The assessment of the conservation status of these species is based on their national extent and ranked according to their level of threat using IUCN Red List categories and criteria as detailed below.

Category	Definition
CR	<p><b>Critically endangered species</b></p> <p>Threatened species considered to be "facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with criteria set out in the ministerial guidelines".</p> <p>Listed as critically endangered under section 19(1)(a) of the BC Act in accordance with the criteria set out in section 20 and the ministerial guidelines. Published under schedule 1 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018 for critically endangered fauna or the Wildlife Conservation (Rare Flora) Notice 2018 for critically endangered flora.</p>
EN	<p><b>Endangered species</b></p> <p>Threatened species considered to be "facing a very high risk of extinction in the wild in the near future, as determined in accordance with criteria set out in the ministerial guidelines".</p> <p>Listed as endangered under section 19(1)(b) of the BC Act in accordance with the criteria set out in section 21 and the ministerial guidelines. Published under schedule 2 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018 for endangered fauna or the Wildlife Conservation (Rare Flora) Notice 2018 for endangered flora.</p>
VU	<p><b>Vulnerable species</b></p> <p>Threatened species considered to be "facing a high risk of extinction in the wild in the medium-term future, as determined in accordance with criteria set out in the ministerial guidelines".</p> <p>Listed as vulnerable under section 19(1)(c) of the BC Act in accordance with the criteria set out in section 22 and the ministerial guidelines. Published under schedule 3 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018 for vulnerable fauna or the Wildlife Conservation (Rare Flora) Notice 2018 for vulnerable flora.</p>

**Extinct species:** Listed by order of the Minister as extinct under section 23(1) of the BC Act as extinct or extinct in the wild.

Category	Definition
EX	<p><b>Extinct species</b></p> <p>Species where "there is no reasonable doubt that the last member of the species has died", and listing is otherwise in accordance with the ministerial guidelines (section 24 of the BC Act).</p> <p>Published as presumed extinct under schedule 4 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018 for extinct fauna or the Wildlife Conservation (Rare Flora) Notice 2018 for extinct flora.</p>
EW	<p><b>Extinct in the wild species</b></p> <p>Species that "is known only to survive in cultivation, in captivity or as a naturalised population well outside its past range; and it has not been recorded in its known habitat or expected habitat, at appropriate seasons, anywhere in its past range, despite surveys over a time frame appropriate to its life cycle and form", and listing is otherwise in accordance with the ministerial guidelines (section 25 of the BC Act).</p> <p>Currently there are no Threatened fauna or Threatened flora species listed as extinct in the wild. If listing of a species as extinct in the wild occurs, then a schedule will be added to the applicable notice.</p>

**Specially protected species:** Listed by order of the Minister as specially protected under section 13(1) of the BC Act. Meeting one or more of the following categories: species of special conservation interest; migratory species; cetaceans; species subject to international agreement; or species otherwise in need of special protection.

Species that are listed as Threatened species (critically endangered, endangered, or vulnerable) or extinct species under the BC Act cannot also be listed as Specially Protected species.

MI	<p><b>Migratory species</b></p> <p>Fauna that periodically or occasionally visit Australia or an external Territory or the exclusive economic zone; or the species is subject of an international agreement that relates to the protection of migratory species and that binds the Commonwealth; and listing is otherwise in accordance with the ministerial guidelines (section 15 of the BC Act). Includes birds that are subject to an agreement between the government of Australia and the governments of Japan (JAMBA), China (CAMBA) and The Republic of Korea (ROKAMBA), and fauna subject to the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention), an environmental treaty under the United Nations Environment Program. Migratory species listed under the BC Act are a subset of the migratory animals, that are known to visit Western Australia, protected under the international agreements or treaties, excluding species that are listed as Threatened species.</p> <p>Published as migratory birds protected under an international agreement under <b>schedule 5</b> of the Wildlife Conservation (Specially Protected Fauna) Notice 2018.</p>
CD	<p><b>Species of special conservation interest (Conservation dependent fauna)</b></p> <p>Fauna of special conservation need being species dependent on ongoing conservation intervention to prevent it becoming eligible for listing as Threatened, and listing is otherwise in accordance with the ministerial guidelines (section 14 of the BC Act).</p> <p>Published as conservation dependent fauna under <b>schedule 6</b> of the Wildlife Conservation (Specially Protected Fauna) Notice 2018.</p>
OS	<p><b>Other specially protected species</b></p> <p>Fauna otherwise in need of special protection to ensure their conservation, and listing is otherwise in accordance with the ministerial guidelines (section 18 of the BC Act).</p> <p>Published as other specially protected fauna under <b>schedule 7</b> of the Wildlife Conservation (Specially Protected Fauna) Notice 2018.</p>
<p><sup>1</sup> The definition of flora includes algae, fungi, and lichens.</p> <p><sup>2</sup> Species includes all taxa (plural of taxon - a classificatory group of any taxonomic rank, e.g. a family, genus, species or any infraspecific category i.e. subspecies or variety, or a distinct population).</p>	



### Appendix A3: Definitions of Priority Species Classification (DBCA 2019)

**Priority species:** Possibly Threatened species that do not meet survey criteria, or are otherwise data deficient, are added to the Priority Fauna or Priority Flora Lists under Priorities 1, 2 or 3. These three categories are ranked in order of priority for survey and evaluation of conservation status so that consideration can be given to their declaration as Threatened fauna or flora.

Species that are adequately known, are rare but not Threatened, or meet criteria for near Threatened, or that have been recently removed from the Threatened species or other specially protected fauna lists for other than taxonomic reasons, are placed in Priority 4. These species require regular monitoring.

Assessment of Priority codes is based on the Western Australian distribution of the species, unless the distribution in WA is part of a contiguous population extending into adjacent States, as defined by the known spread of locations.

Category	Definition
P1	<b>Priority 1: Poorly-known species</b> Species that are known from one or a few locations (generally five or less) which are potentially at risk. All occurrences are either: very small; or on lands not managed for conservation, e.g. agricultural or pastoral lands, urban areas, road and rail reserves, gravel reserves and active mineral leases; or otherwise under threat of habitat destruction or degradation. Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under immediate threat from known threatening processes. Such species are in urgent need of further survey.
P2	<b>Priority 2: Poorly-known species</b> Species that are known from one or a few locations (generally five or less), some of which are on lands managed primarily for nature conservation, e.g. national parks, conservation parks, nature reserves and other lands with secure tenure being managed for conservation. Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under threat from known threatening processes. Such species are in urgent need of further survey.
P3	<b>Priority 3: Poorly-known species</b> Species that are known from several locations, and the species does not appear to be under imminent threat, or from few but widespread locations with either large population size or significant remaining areas of apparently suitable habitat, much of it not under imminent threat. Species may be included if they are comparatively well known from several locations but do not meet adequacy of survey requirements and known threatening processes exist that could affect them. Such species are in need of further survey.
P4	<b>Priority 4: Rare, Near Threatened and other species in need of monitoring</b> (a) Rare. Species that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently Threatened or in need of special protection but could be if present circumstances change. These species are usually represented on conservation lands. (b) Near Threatened. Species that are considered to have been adequately surveyed and that are close to qualifying for vulnerable but are not listed as Conservation Dependent. (c) Species that have been removed from the list of Threatened species during the past five years for reasons other than taxonomy

## Appendix A4: Legal Status Definition of Listed Plants in Western Australia

Legal Status	Definition
Declared Pest, Prohibited – s12	Prohibited organisms are declared pests by virtue of section 22(1) and may only be imported and kept subject to permits.
Declared Pest – s22(2)	Declared pests must satisfy any applicable import requirements when imported and may be subject to control keeping requirements.
Permitted – s11	Permitted organisms must satisfy applicable import requirements and import permits (where required).
Permitted, Requires Permit – r73	Regulation 73 permitted organisms may be subject to restriction under legislation other than the BAM Act (2007).
Unlisted	Unlisted organisms are prohibited in WA.
Control Categories	Definition
C1 Exclusion	Organisms should be excluded from parts or all of WA.
C2 Eradication	Organisms should be eradicated from all or parts of WA.
C3 Management	Organisms should have some form of management applied that will alleviate the harmful impact of the organism, reduce the numbers or distribution of the organism, or prevent or contain the spread of the organism.
Unassigned	Declared pest that are recognised as having a harmful impact under certain circumstances where their subsequent control requirements are determined by a plan or other legislative arrangements under the Act.
Keeping Categories	Definition
Prohibited keeping	Can only be kept under a permit for public display, education, or scientific purposes.
Restricted keeping	Kept under a permit by private individuals due to a low risk of becoming a problem for the environment.
Exempt keeping	No permit or conditions are required for keeping. Organism may be subject to restrictions under the Wildlife Conservation Act (WCA, 1950).

## Appendix C: Flora Species List





Family	Taxon Name	Significance	Ecological	Spectrum
Aizoaceae	<i>Disphyma crassifolium</i> subsp. <i>clavellatum</i>	-	x	x
Aizoaceae	<i>Gunniopsis quadrifida</i>	-	x	
Aizoaceae	<i>Gunniopsis septifraga</i>	-	x	
Amaranthaceae	<i>Ptilotus ?nobilis</i>	-	x	
Amaranthaceae	<i>Ptilotus helichrysoides</i>	-	x	
Amaranthaceae	<i>Ptilotus nobilis</i>	-	x	
Amaranthaceae	<i>Ptilotus obovatus</i>	-	x	x
Amaranthaceae	<i>Surreya diandra</i>	-	x	
Apocynaceae	<i>Alyxia buxifolia</i>	-	x	x
Apocynaceae	<i>Alyxia tetanifolia</i>	Priority 3	x	x
Apocynaceae	<i>Leichhardtia australis</i>	-	x	x
Asparagaceae	<i>Lomandra effusa</i>	-	x	x
Asparagaceae	* <i>Thysanotus ?manglesianus/patersonii</i>	-	x	
Asphodelaceae	<i>Asphodelus fistulosus</i>	Weed	x	
Asteraceae	<i>Asteridea chaetopoda</i>	-	x	
Asteraceae	<i>Brachyscome ciliaris</i>	-	x	
Asteraceae	<i>Brachyscome</i> sp.	-	x	
Asteraceae	<i>Calotis multicaulis</i>	-	x	
Asteraceae	* <i>Centaurea melitensis</i>	Weed	x	
Asteraceae	<i>Centipeda cunninghamii</i>	-	x	
Asteraceae	<i>Cratystylis conocephala</i>	-	x	
Asteraceae	<i>Cratystylis microphylla</i>	-	x	
Asteraceae	<i>Cratystylis subspinescens</i>	-	x	x
Asteraceae	* <i>Dittrichia graveolens</i>	Weed	x	
Asteraceae	<i>Gnephosis angianthoides</i>	-	x	
Asteraceae	<i>Kippistia suaedifolia</i>	-	x	
Asteraceae	* <i>Lactuca serriola</i> forma <i>serriola</i>	Weed	x	
Asteraceae	<i>Minuria cunninghamii</i>	-	x	
Asteraceae	<i>Olearia exiguiifolia</i>	-		x
Asteraceae	<i>Olearia muelleri</i>	-	x	
Asteraceae	<i>Olearia pimeleoides</i>	-	x	
Asteraceae	<i>Olearia</i> sp. <i>Eremicola</i> (Diels & Pritzel s.n. PERTH 00449628)	-	x	
Asteraceae	<i>Pseudognaphalium luteoalbum</i>	-	x	
Asteraceae	<i>Senecio lacustrinus</i>	-	x	
Asteraceae	<i>Senecio</i> sp.	-	x	
Asteraceae	<i>Siemssenia capillaris</i>	-	x	
Asteraceae	* <i>Sonchus oleraceus</i>	Weed	x	
Asteraceae	<i>Vittadinia humerata</i>	-	x	
Boraginaceae	<i>Halgania andromedifolia</i>	-	x	
Boraginaceae	<i>Heliotropium curassavicum</i>	-	x	
Casuarinaceae	<i>Allocasuarina acutivalvis</i> subsp. <i>acutivalvis</i>	-	x	
Casuarinaceae	<i>Allocasuarina corniculata</i>	-		x
Casuarinaceae	<i>Allocasuarina helmsii</i>	-	x	
Chenopodiaceae	<i>Atriplex holocarpa</i>	-		x

Family	Taxon Name	Significance	Ecological	Spectrum
Chenopodiaceae	<i>Atriplex lindleyi</i> subsp. <i>inflata</i>	-	x	
Chenopodiaceae	<i>Atriplex nana</i>	-	x	
Chenopodiaceae	<i>Atriplex nummularia</i> subsp. <i>spathulata</i>	-	x	
Chenopodiaceae	<i>Atriplex vesicaria</i>	-	x	x
Chenopodiaceae	<i>Enchylaena tomentosa</i> var. <i>tomentosa</i>	-	x	
Chenopodiaceae	<i>Maireana ?amoena</i>	-	x	
Chenopodiaceae	<i>Maireana amoena</i>	-	x	x
Chenopodiaceae	<i>Maireana appressa</i>	-	x	
Chenopodiaceae	<i>Maireana brevifolia</i>	-	x	
Chenopodiaceae	<i>Maireana glomerifolia</i>	-	x	x
Chenopodiaceae	<i>Maireana pentatropis</i>	-	x	
Chenopodiaceae	<i>Maireana sedifolia</i>	-	x	x
Chenopodiaceae	<i>Maireana triptera</i>	-	x	
Chenopodiaceae	<i>Rhagodia drummondii</i>	-	x	
Chenopodiaceae	<i>Salsola australis</i>	-	x	
Chenopodiaceae	<i>Sclerolaena ?eurotioides</i>	-	x	
Chenopodiaceae	<i>Sclerolaena ?gardneri</i>	-	x	
Chenopodiaceae	<i>Sclerolaena cuneata</i>	-	x	
Chenopodiaceae	<i>Sclerolaena gardneri</i>	-	x	
Chenopodiaceae	<i>Tecticornia disarticulata</i>	-	x	
Chenopodiaceae	<i>Tecticornia halocnemoides</i>	-	x	
Chenopodiaceae	<i>Tecticornia indica</i> subsp. <i>bidens</i>	-	x	x
Chenopodiaceae	<i>Tecticornia pergranulata</i>	-	x	
Chenopodiaceae	<i>Tecticornia undulata</i>	-	x	
Convolvulaceae	* <i>Cuscuta epithymum</i>	Weed	x	
Crassulaceae	<i>Crassula tetramera</i>	-	x	
Cupressaceae	<i>Callitris columellaris</i>	-	x	x
Cyperaceae	<i>Cyperus rigidellus</i>	-	x	
Cyperaceae	<i>Isolepis australiensis</i>	-	x	
Fabaceae	<i>Acacia ?minyura</i>	-		x
Fabaceae	<i>Acacia acuminata</i>	-	x	x
Fabaceae	<i>Acacia calcarata</i>	-	x	
Fabaceae	<i>Acacia densiflora</i>	-	x	
Fabaceae	<i>Acacia erinacea</i>	-	x	
Fabaceae	<i>Acacia hemiteles</i>	-	x	
Fabaceae	<i>Acacia jennerae</i>	-	x	
Fabaceae	<i>Acacia ligulata</i>	-	x	x
Fabaceae	<i>Acacia masliniana</i>	-	x	x
Fabaceae	<i>Acacia merrallii</i>	-	x	
Fabaceae	<i>Acacia nyssophylla</i>	-	x	
Fabaceae	<i>Acacia tetragonophylla</i>	-	x	x
Fabaceae	<i>Acacia xerophila</i> var. <i>brevior</i>	-	x	
Fabaceae	<i>Glycyrrhiza acanthocarpa</i>	-	x	
Fabaceae	<i>Jacksonia arida</i>	-	x	

Family	Taxon Name	Significance	Ecological	Spectrum
Fabaceae	<i>Senna aff. stowardii</i>	-	x	
Fabaceae	<i>Senna artemisioides subsp. ×artemisioides</i>	-	x	
Fabaceae	<i>Senna artemisioides subsp. filifolia</i>	-	x	x
Fabaceae	<i>Swainsona formosa</i>	-	x	
Fabaceae	<i>Swainsona purpurea</i>	-	x	
Fabaceae	<i>Templetonia incrassata</i>	-	x	
Fabaceae	<i>Tephrosia sp.</i>	-	x	
Frankeniaceae	<i>Frankenia desertorum</i>	-	x	
Frankeniaceae	<i>Frankenia fecunda</i>	-	x	
Frankeniaceae	<i>Frankenia interioris</i>	-		x
Goodeniaceae	<i>Dampiera tenuicaulis</i>	-	x	
Goodeniaceae	<i>Goodenia salina</i>	Priority 2	x	
Goodeniaceae	<i>Goodenia sp.</i>	-	x	
Goodeniaceae	<i>Scaevola spinescens</i>	-	x	x
Haloragaceae	<i>Haloragis trigonocarpa</i>	-	x	
Hemerocallidaceae	<i>Dianella revoluta var. divaricata</i>	-	x	x
Lamiaceae	<i>Prostanthera althoferi</i>	-	x	
Lamiaceae	<i>Prostanthera campbellii</i>	-	x	
Lamiaceae	<i>Prostanthera grylloana</i>	-	x	
Lamiaceae	* <i>Salvia verbenaca</i>	Weed	x	
Lamiaceae	<i>Westringia cephalantha</i>	-	x	
Lamiaceae	<i>Westringia rigida</i>	-	x	
Malvaceae	<i>Abutilon cryptopetalum</i>	-	x	
Malvaceae	<i>Lawrencia helmsii</i>	-	x	x
Malvaceae	<i>Lawrencia repens</i>	-	x	
Malvaceae	<i>Lawrencia squamata</i>	-	x	
Malvaceae	<i>Sida calyxhymenia</i>	-	x	
Marsileaceae	<i>Marsilea drummondii</i>	-	x	
Montiaceae	<i>Calandrinia eremaea</i>	-	x	
Montiaceae	<i>Calandrinia granulifera</i>	-	x	
Montiaceae	<i>Calandrinia sculpta</i>	-		x
Montiaceae	<i>Calandrinia sp.</i>	-	x	
Myrtaceae	<i>Eucalyptus campaspe</i>	-	x	
Myrtaceae	<i>Eucalyptus cylindrocarpa</i>	-	x	x
Myrtaceae	<i>Eucalyptus effusa subsp. effusa</i>	-	x	
Myrtaceae	<i>Eucalyptus flocktoniae subsp. flocktoniae</i>	-	x	x
Myrtaceae	<i>Eucalyptus gracilis</i>	-	x	
Myrtaceae	<i>Eucalyptus griffithsii</i>	-	x	x
Myrtaceae	<i>Eucalyptus horistes</i>	-	x	
Myrtaceae	<i>Eucalyptus lesouefii</i>	-	x	x
Myrtaceae	<i>Eucalyptus longicornis</i>	-		x
Myrtaceae	<i>Eucalyptus longissima</i>	-		x
Myrtaceae	<i>Eucalyptus oleosa subsp. oleosa</i>	-		x
Myrtaceae	<i>Eucalyptus salmonophloia</i>	-	x	x



Family	Taxon Name	Significance	Ecological	Spectrum
Myrtaceae	<i>Eucalyptus salubris</i>	-	x	x
Myrtaceae	<i>Melaleuca eleuterostachya</i>	-	x	
Myrtaceae	<i>Melaleuca hamata</i>	-	x	x
Myrtaceae	<i>Melaleuca lateriflora</i>	-	x	x
Myrtaceae	<i>Melaleuca sheathiana</i>	-	x	
Phrymaceae	<i>Peplidium</i> sp.	-	x	
Pittosporaceae	<i>Pittosporum angustifolium</i>	-	x	x
Poaceae	<i>Aristida contorta</i>	-	x	
Poaceae	<i>Austrostipa elegantissima</i>	-	x	x
Poaceae	* <i>Cenchrus ciliaris</i>	Weed	x	
Poaceae	* <i>Chloris virgata</i>	Weed	x	
Poaceae	<i>Enneapogon caerulescens</i>	-	x	
Poaceae	<i>Enneapogon polyphyllus</i>	-	x	
Poaceae	<i>Enteropogon ramosus</i>	-	x	
Poaceae	<i>Eragrostis falcata</i>	-	x	
Poaceae	<i>Eragrostis pergracilis</i>	-	x	
Poaceae	<i>Panicum ?decompositum</i>	-	x	
Poaceae	<i>Paspalidium constrictum</i>	-	x	
Poaceae	<i>Triodia scariosa</i>	-	x	x
Poaceae	<i>Tripogonella loliiformis</i>	-	x	
Polygonaceae	<i>Duma florulenta</i>	-	x	
Polygonaceae	* <i>Rumex vesicarius</i>	Weed	x	
Proteaceae	<i>Grevillea ?didymobotrya</i> subsp. <i>didymobotrya</i>	-	x	
Proteaceae	<i>Grevillea acuaria</i>	-	x	
Proteaceae	<i>Grevillea huegelii</i>	-	x	
Proteaceae	<i>Grevillea sarissa</i> subsp. <i>bicolor</i>	-	x	x
Pteridaceae	<i>Cheilanthes sieberi</i> subsp. <i>sieberi</i>	-	x	
Rhamnaceae	<i>Cryptandra aridicola</i>	-	x	
Rhamnaceae	<i>Pomaderris forrestiana</i>	-	x	
Santalaceae	<i>Exocarpos aphyllus</i>	-	x	x
Santalaceae	<i>Santalum acuminatum</i>	-	x	x
Santalaceae	<i>Santalum spicatum</i>	-	x	
Sapindaceae	<i>Dodonaea lobulata</i>	-	x	x
Sapindaceae	<i>Dodonaea stenozyga</i>	-	x	
Sapindaceae	<i>Dodonaea viscosa</i> subsp. <i>angustissima</i>	-	x	x
Scrophulariaceae	<i>Eremophila alternifolia</i>	-	x	x
Scrophulariaceae	<i>Eremophila caperata</i>	-	x	
Scrophulariaceae	<i>Eremophila decipiens</i> subsp. <i>decipiens</i>	-	x	
Scrophulariaceae	<i>Eremophila glabra</i> subsp. <i>glabra</i>	-	x	
Scrophulariaceae	<i>Eremophila granitica</i>	-	x	x
Scrophulariaceae	<i>Eremophila ionantha</i>	-	x	x
Scrophulariaceae	<i>Eremophila maculata</i> subsp. <i>brevifolia</i>	-	x	
Scrophulariaceae	<i>Eremophila miniata</i>	-	x	x
Scrophulariaceae	<i>Eremophila oldfieldii</i> subsp. <i>angustifolia</i>	-	x	x

Family	Taxon Name	Significance	Ecological	Spectrum
Scrophulariaceae	<i>Eremophila oppositifolia</i> subsp. <i>angustifolia</i>	-	x	
Scrophulariaceae	<i>Eremophila scoparia</i>	-	x	x
Scrophulariaceae	<i>Eremophila</i> sp.	-	x	
Scrophulariaceae	<i>Eremophila parvifolia</i> subsp. <i>auricampi</i>	-	x	
Scrophulariaceae	<i>Myoporum montanum</i>	-	x	
Solanaceae	<i>Lycium australe</i>	-	x	
Solanaceae	* <i>Nicotiana glauca</i>	Weed	x	
Solanaceae	<i>Solanum lasiophyllum</i>	-	x	
Solanaceae	<i>Solanum nummularium</i>	-	x	
Tamaricaceae	* <i>Tamarix aphylla</i>	Weed	x	
Thymelaeaceae	<i>Pimelea microcephala</i> subsp. <i>microcephala</i>	-	x	
Zygophyllaceae	<i>Roepera aurantiaca</i> subsp. <i>aurantiaca</i>	-	x	x
Zygophyllaceae	<i>Roepera glauca</i>	-	x	

## Appendix D: Significant Flora Likelihood of Occurrence





Status (EPBC/BC)	Taxon	Longevity	Lifeform	Description	Flowering	Habitat	Distance (km)	Likelihood
T (EN/EN)	<i>Thelymitra stellata</i>	Perennial	Herb	Tuberous, perennial, herb, 0.15-0.25 m high. Fl. yellow & brown.	Oct to Nov.	Sand, gravel, lateritic loam.	> 50	Low
T (VU/EN)	<i>Gastrolobium graniticum</i>	Perennial	Shrub	Erect, open shrub, to 2.5 m high. Fl. yellow & orange & red.	Aug to Sep.	Sand, sandy loam, granite. Margins of rock outcrops, along drainage lines.	24.3	Low
T (-/VU)	<i>Tetratea spenceri</i>	Perennial	Sub-shrub	Sub-shrub to 0.6 m high, 0.8 - 1 m wide. Stems from base, many stems, purple flower	Oct	Laterite outcrops, BIF	42.9	Low
P1	<i>Eremophila praecox</i>	Perennial	Shrub	Broom-like shrub, 1.5-3 m high. Fl. Purple.	Oct or Dec.	Red/brown sandy loam. Undulating plains.	0.4	High
P1	<i>Acacia websteri</i>	Perennial	Shrub	Shrub, 1.2-5 m high, bark fibrous. Fl. yellow.	-	Red sand, clay or loam. Low-lying areas, flats.	24.3	Medium
P1	<i>Calandrinia lefroyensis</i>	Perennial	Herb	-	-	-	18.2	Medium
P1	<i>Ptilotus procumbens</i>	Annual	Herb	Spreading procumbent annual, herb, ca 0.1 m high. Fl. pink-white.	Nov.	Red clay.	6.1	Medium
P1	<i>Ptilotus rigidus</i>	Perennial	Shrub	Shrubs, stems several, more or less prostrate	-	-	27.9	Medium
P1	<i>Ptilotus</i> sp. Kalgoorlie (J. Jackson & B. Moyle 260)	-	-	-	-	-	30.5	Medium
P1	<i>Thryptomene planiflora</i>	Perennial	Shrub	-	-	-	23.7	Medium
P1	<i>Thryptomene</i> sp. Londonderry (R.H. Kuchel 1763)	Perennial	Shrub	Spreading shrub to 1.5 m.	-	Brown stony to sandy loams. Yellow/orange sandplains.	> 50	Medium
P1	<i>Acacia coatesii</i>	Perennial	Shrub	Low-domed shrub <40 cm.	Sept-Oct.	Grows in shallow, red sandy clay on flat or gently sloping ground towards the base of a low greenstone ridge in open woodland dominated by Eucalyptus spp. over open shrubland.	33.4	Low
P1	<i>Acacia epedunculata</i>	Perennial	Shrub	Low spreading, becoming rounded, multi-stemmed shrub, 0.5-0.65 m high. Fl. yellow	Aug.	Yellow sand. Sandplains.	49.5	Low
P1	<i>Acacia sclerophylla</i> var. <i>teretiuscula</i>	Perennial	Shrub	Spreading, much-branched shrub, 0.25-2.5 m high. Fl. Yellow.	Sept-Oct.	Clay & loamy soils.	40.1	Low
P1	<i>Chamelaucium</i> sp. Parker Range (B.H. Smith 1255)	Perennial	Shrub	-	-	-	38.7	Low
P1	<i>Cyathostemon divaricatus</i>	Perennial	Shrub	-	-	-	36.4	Low
P1	<i>Dampiera plumosa</i>	Perennial	Herb	Erect perennial, herb, 0.15-0.2 m high. Fl. Blue.	Oct.	Red sandy soils.	30.9	Low
P1	<i>Eremophila perglandulosa</i>	Perennial	Shrub	Low, spreading, viscid shrub, ca 0.25 m high. Fl. blue-purple.	Jan	-	73.3	Low

Status (EPBC/BC)	Taxon	Longevity	Lifeform	Description	Flowering	Habitat	Distance (km)	Likelihood
P1	<i>Eremophila xantholaema</i>	Perennial	Shrub	Erect shrub to 1.2-3.0 m high. Flowers pink.	Sept-Oct.	Stony, brown loam soils in Eucalyptus-Casuarina woodland on the upper slopes of low rocky hills.	24.1	Low
P1	<i>Eucalyptus websteriana</i> subsp. <i>norsemanica</i>	Perennial	Tree	(Spreading mallee), to 3 m high, bark 'minni-ritchi'. Fl. yellow	Sept-Nov.	Rocky rises.	34.6	Low
P1	<i>Grevillea phillipsiana</i>	Perennial	Shrub	Prickly shrub, 0.8-1.5 m high. Fl. red/red & orange.	Jul-Sept	Red sand, stony loam. Granite hills.	79.6	Low
P1	<i>Lepidosperma</i> sp. Parker Range (N. Gibson & M. Lyons 2094)	Perennial	Sedge	Sedge.	-	Ridge/slope. Granite. Dry brown loam.	35.1	Low
P1	<i>Melichrus</i> sp. Coolgardie (K.R. Newbey 8698)	-	-	-	-	-	51.6	Low
P1	<i>Phebalium appressum</i>	Perennial	Shrub	Rounded shrub, ca 1 m high, leaves cordate-ovate, ca 2 mm long; flowers usually solitary; pedicels short, thick, ca 1 mm long. Flowers, white.	Jul.	Yellow sandplain.	27.0	Low
P1	<i>Philotheca apiculata</i>	Perennial	Shrub	Erect shrub, 0.5-1.5 m high. Fl. white-pink	-	Stony clay loam. Rocky outcrops, hillsides.	64.0	Low
P1	<i>Philotheca pachyphylla</i>	Perennial	Shrub	Erect shrub, 0.3-1.5 m high. Fl. White	May or Sept	Sand, red loam, clay loam. Sandplains, hill tops.	53.2	Low
P1	<i>Prostanthera splendens</i>	Perennial	Shrub	Erect, openly branched shrub, 0.2-1 m high. Fl. blue-purple	Aug-Oct.	Stony loam, shallow soils with ironstone pebbles. Breakaways.	67.6	Low
P1	<i>Pterostylis xerampelina</i>	-	Herb	Orchid	-	-	67.0	Low
P1	<i>Ptilotus chortophytus</i>	Perennial	Herb	Erect herb to 22 cm high, 10 cm wide, in bud. Succulent basal leaves.	Sep-Nov.	Quartz hillslopes or outcrops.	>50	Low
P1	<i>Rhodanthe uniflora</i>	Annual	Herb	Erect, woolly annual, herb, 0.02-0.1(-0.3) m high. Fl. Yellow.	Aug-Oct.	Brown earth. Open eucalyptus woodland.	27.7	Low
P1	<i>Ricinocarpos digynus</i>	Perennial	Shrub	-	-	-	41.1	Low
P1	<i>Tecticornia flabelliformis</i>	Perennial	Shrub	Erect shrub, to 0.2 m high.	Jan to May.	Clay. Saline flats.	40.6	Low
P1	<i>Tecticornia mellarium</i>	Perennial	Shrub	-	-	-	55.3	Low
P1	<i>Thryptomene</i> sp. Coolgardie (E. Kelso s.n. 1902)	Perennial	Shrub	Perennial shrub.	-	-	24.3	Low
P2	<i>Goodenia salina</i>	Annual	Herb	Annual, herb, 0.02-0.2 m high.	-	Well-drained, saline, grey or brown loamy clay. Low gypseous dunes near salt pans.	0.0	Recorded
P2	<i>Eremophila praecox</i>	Perennial	Shrub	Broom-like shrub, 1.5-3 m high. Fl. Purple.	Oct or Dec.	Red/brown sandy loam. Undulating plains.	0.4	High

Status (EPBC/BC)	Taxon	Longevity	Lifeform	Description	Flowering	Habitat	Distance (km)	Likelihood
P2	<i>Elachanthus pusillus</i>	Annual	Herb	Ascending or decumbent annual, herb, to 0.15 m high. Fl. yellow-green.	Aug-Oct.	In mallee, woodland, shrubland and coastal vegetation.	10.3	Medium
P2	<i>Acacia kerryana</i>	Perennial	Shrub	Low, spreading, domed shrub, 0.3-1 m high. Fl. Yellow.	Oct-Dec or Jan-Feb	Granitic loamy sand, stony clayey loam or clayey sand. Low stony ridges, undulating plains.	39.7	Low
P2	<i>Austrostipa</i> sp. Dowerin (G. Wiehl F 8004)	Perennial	Tussock	Tussock grass to 0.4 m.	-	Basalt crest or slopes.	32.6	Low
P2	<i>Bossiaea laxa</i>	Perennial	Shrub	Lax, open, spreading shrub, to 2 m high. Fl. yellow-green.	May	Brown loam over deep granite. Sheltered positions around outcrops.	60.5	Low
P2	<i>Eucalyptus educta</i>	Perennial	Tree	Mallee, 4 m tall, minirichi bark	Mar-April	Slopes, base of granite rocks, stoney rises, and low ironstone ridges.	46.0	Low
P2	<i>Goodenia corralina</i>	Perennial	Herb	Low spreading perennial, herb, 0.1-0.7 m high.	-	Brown loam, granite. Near large outcrop.	88.8	Low
P2	<i>Hakea rigida</i>	Perennial	Shrub	Shrub, 0.6-2.7 m high.	Sept-Oct.	Sandy soils, yellow sand.	27.0	Low
P2	<i>Lepidium merrallii</i>	Annual	Herb	Erect to spreading annual (possibly ephemeral), herb, 0.03-0.15 m high.	-	Clay loam.	24.3	Low
P2	<i>Phebalium clavatum</i>	Perennial	Shrub	Upright shrub, 0.5-1.5 m high. Fl. White.	Aug-Sept	Sandy soils.	34.7	Low
P2	<i>Phebalium</i> sp. Yerlgee Sandplain (J. Jackson 223)	Perennial	Shrub	-	-	-	79.1	Low
P2	<i>Rumex crystallinus</i>	Annual	Herb	Annual, herb, 0.06-0.4 m high.	-	Arid & semi-arid areas.	65.8	Low
P2	<i>Thryptomene eremaea</i>	Perennial	Shrub	Erect open shrub, 0.5-1.5 m high. Fl. pink/white,	Jul-Sep.	Red or yellow sand. Sandplains.	82.2	Low
P2	<i>Thysanotus</i> sp. Yellowdine (A.S. George 6040)	-	Herb	-	-	-	77.2	Low
P2	<i>Trachymene pyrophila</i>	Annual	Herb	Annual, herb, 0.1-0.5 m high, indumentum of patent glandular hairs. Fl. White	Nov-Dec or Jan-Mar	Yellow or orange sand. Sandplains; germinating after fire or other disturbances such as mining.	72.8	Low
P3	<i>Alyxia tetanifolia</i>	Perennial	Shrub	Erect, rigid, pungent shrub, 1-2 m high, to 2.5 m wide. Fl. white-cream	May-June, Nov.	Sandy clay, loam, concretionary gravel. Drainage lines, near lakes.	0.0	Recorded
P3	<i>Isolepis australiensis</i>	Annual	Herb	Annual, grass-like or herb (sedge), 0.03-0.055 m high.	Jun or Sept.	Silty sand, sandy clay. Lake margins, pools.	0.0	Recorded
P3	<i>Lepidium fasciculatum</i>	Annual	Herb	Erect annual, herb, (0.1-)0.3-0.6 m high.	-	-	9.6	High
P3	<i>Notisia intonsa</i>	Annual	Herb	Annual herb.	-	Moist red sand. Lake bank.	6.3	High
P3	<i>Angianthus prostratus</i>	Annual	Herb	Prostrate annual, herb. Fl. white-yellow	Jul-Sep.	Red clay or loamy soils. Saline depressions.	27.7	Medium



Status (EPBC/BC)	Taxon	Longevity	Lifeform	Description	Flowering	Habitat	Distance (km)	Likelihood
P3	<i>Austrostipa</i> sp. Carlingup Road (S. Kern & R. Jasper LCH 18459)	Perennial	Tussock	Tussock grass to 0.4 m.	-	Clay pan, basalt slopes.	14.5	Medium
P3	<i>Phlegmatospermum eremaeum</i>	Annual	Herb	Prostrate to spreading annual, herb, 0.02-0.1(-0.2) m high. Fl. white-cream	Jun or Aug-Oct.	Stony loam.	25.8	Medium
P3	<i>Acacia crenulata</i>	Perennial	Shrub	Bushy shrub or tree, 0.7-3 m high. Fl. yellow.	-	Clay, sandy clay, yellow sand. Rocky rises, granite outcrops, breakaways.	35.6	Low
P3	<i>Acacia cylindrica</i>	Perennial	Shrub	Spreading shrub, 1.5-3(-4) m high. Fl. Yellow.	Aug-Oct.	Yellow/brown sand, gravelly soils. Undulating plains, flats.	78.0	Low
P3	<i>Allocasuarina eriochlamys</i> subsp. <i>grossa</i>	Perennial	Shrub	Dioecious or monoecious shrub, 1-3 m high, bracteoles prominently exceeding cone.	-	Stony loam, laterite clay. Granite outcrops.	36.4	Low
P3	<i>Atriplex lindleyi</i> subsp. <i>conduplicata</i>	Annual / Perennial	Herb	Monoecious, short-lived annual or perennial, herb, ca 0.2 m high.	-	Crabhole plains.	65.3	Low
P3	<i>Austrostipa blackii</i>	Perennial	Tussock	Tufted perennial, grass-like or herb, 1 m high.	Fl. Sep to Nov.	West north-west facing gently inclined lower slope of basalt with red-brown deep sandy clay loam soils.	28.5	Low
P3	<i>Bossiaea celata</i>	Perennial	Shrub	Compact, intricately-branched shrub, to 0.8 m high. Fl. yellow-red-orange.	Sep-Oct	Deep sand. Open mallee.	44.1	Low
P3	<i>Calytrix creswellii</i>	Perennial	Shrub	Spreading shrub, 0.25-1 m high. Fl. White.	Sep-Dec	Yellow sand, sometimes with lateritic gravel. Sandplains.	83.0	Low
P3	<i>Chrysocephalum apiculatum</i> subsp. <i>norsemanense</i>	Perennial	Herb	Erect perennial herb c. 30-60 cm high.	-	Various soil types including yellow or red sand, yellow sandy clay, and calcareous soil.	23.7	Low
P3	<i>Cratystylis centralis</i>	Perennial	Shrub	Much-branched, brittle, greyish shrub, to 1 m high.	-	Red sandy loam with ironstone gravel. Flat plains, breakaway country.	43.4	Low
P3	<i>Cryptandra crispula</i>	Perennial	Shrub	Non-spinescent shrub, 0.25-0.9 m high.	-	Brown sandy clay, yellow loamy sand, red soil, pebbles. Dune ridges, hills, near salt lakes.	66.0	Low
P3	<i>Cyathostemon verrucosus</i>	Perennial	Shrub	Low spreading perennial shrub to 50-60 cm.	-	Yellow sand. Flat plains.	12.0	Low
P3	<i>Diocirea acutifolia</i>	Perennial	Shrub	Low, dense, rounded shrub, 0.3-0.8 m high. Fl. White.	Nov to Dec.	Clay loam, gravelly loam. Undulating flats.	32.0	Low
P3	<i>Eleocharis papillosa</i>	Annual	Sedge	Annual, herb. Fl. Brown	Nov	Red clay over granite, open clay flats. Claypans.	71.3	Low
P3	<i>Eremophila annosicaulis</i>	Perennial	Shrub	-	-	-	72.1	Low

Status (EPBC/BC)	Taxon	Longevity	Lifeform	Description	Flowering	Habitat	Distance (km)	Likelihood
P3	<i>Eremophila arachnoides</i> subsp. <i>tenera</i>	Perennial	Shrub	Broom-like shrub, to 3 m high, branches with tubercles often elongated & coalescing. Fl. white/blue-purple.	-	-	43.5	Low
P3	<i>Eremophila microphylla</i>	Perennial	Shrub	Rounded shrub, 0.45-0.9 m high, to 1 m wide. Fl.	Nov-Dec	Red-brown clay loam.	44.9	Low
P3	<i>Eremophila veronica</i>	Perennial	Shrub	Spreading, erect shrub, 0.5-1 m high. Fl. Purple.	Apr-May.	Stony clay, clay loam. Lateritic breakaways.	25.4	Low
P3	<i>Eucalyptus exigua</i>	Perennial	Tree	(Mallee), 2-5 m high, bark smooth. Fl. white-cream	Mar.	Sandy loam, white sand. Sandplains.	72.4	Low
P3	<i>Eucalyptus frenchiana</i>	Perennial	Tree	Mallee, 12 m tall, smooth bark	-	Gently rising ground, on sandy loam or clay loam soils	67.5	Low
P3	<i>Eutaxia actinophylla</i>	Perennial	Shrub	Shrub, to 0.5 m high. Fl. yellow/red	Sep-Oct	Red-brown clay loam, red clay loam over granite, gravel. Small depressions.	85.4	Low
P3	<i>Gompholobium cinereum</i>	Perennial	Shrub	Shrub, to 0.3 m high.	-	Yellow sand, clayey sand, brown loam, sandy gravel, laterite. Well-drained open sites, slopes, plains, roadsides.	34.6	Low
P3	<i>Grevillea georgeana</i>	Perennial	Shrub	Erect to widely spreading shrub, 1-3 m high, up to 4 m wide. Fl. red/red & pink & cream.	Jan, Mar, Sept to Nov.	Stony loam/clay. Ironstone hilltops & slopes.	26.6	Low
P3	<i>Grevillea petrophiloides</i> subsp. <i>remota</i>	Perennial	Shrub	Spreading shrub (with emergent flowering branches), 2.5-3 m high. Fl. pink,	Jun-Oct	Loamy sand, granite. Base of outcrops, crevices.	87.9	Low
P3	<i>Hibbertia pachyphylla</i>	Perennial	Shrub	Shrub, to 0.5 m high. Fl. Yellow.	Sep-Nov.	White to yellow sand, brown sandy gravel, gravelly loam, laterite, granite, quartz. Undulating plains, low rises, valley floors.	64.8	Low
P3	<i>Homalocalyx grandiflorus</i>	Perennial	Shrub	Spreading shrub, 0.2-0.5(-2) m high. Fl. purple-red-pink.	Oct-Dec	Yellow sand. Sandplains.	84.9	Low
P3	<i>Hysterobaeckea ochropetala</i> subsp. <i>cometes</i>	-	-	-	-	-	83.7	Low
P3	<i>Isoetes brevicula</i>	Perennial	Sedge	Cormous, perennial, herb or (fern ally), to 0.01 m high, stock 3-lobed; leaves 4-8 mm long; mature megaspores greyish white when dry.	-	Submerged in rock pools on granitic outcrops.	64.8	Low
P3	<i>Melaleuca coccinea</i>	Perennial	Shrub	Much branched shrub, 1.5-2.6 m high.	Sep-Nov, or Jan.	Sandy loam over granite. Granite outcrops, sandplain, river valleys.	6.1	Low
P3	<i>Melaleuca macronychia</i> subsp. <i>trygonoides</i>	Perennial	Shrub	Multi-stemmed, spreading shrub, 1-4 m high, leaves broadly elliptic. Fl. Red.	Feb or Jul	Sandy soils. Granite outcrops.	61.8	Low

Status (EPBC/BC)	Taxon	Longevity	Lifeform	Description	Flowering	Habitat	Distance (km)	Likelihood
P3	<i>Phebalium drummondii</i>	Perennial	Shrub	Upright shrub, 0.6-1.5 m high. Fl. Yellow.	Jul to Sep	Gravelly sandy or clayey soils. Flats, roadsides.	76.1	Low
P3	<i>Pityrodia scabra</i> subsp. <i>dendrotricha</i>	Perennial	Shrub	Shrub	-	-	71.0	Low
P3	<i>Rinzia triplex</i>	Perennial	Shrub	-	-	-	57.6	Low
P3	<i>Stylidium choreanthum</i>	Perennial	Herb	Creeping perennial, herb, 0.01-0.03 m high, to 0.3 m wide. Fl. pink/white	Sept-Nov.	White/yellow or red sand. Plains.	37.5	Low
P3	<i>Styphelia rectiloba</i>	Perennial	Shrub	Compact, erect shrub to 70 cm high.	-	Lateritic/granitic breakaways.	32.2	Low
P3	<i>Styphelia saxicola</i>	Perennial	Shrub	-	-	-	51.7	Low
P4	<i>Eremophila caerulea</i> subsp. <i>merrallii</i>	Perennial	Shrub	Spreading or sprawling shrub, to 0.35 m high, to 0.8 m wide. Fl. blue-purple.	Oct-Dec.	Sand, clay or loam. Undulating plains.	16.0	Medium
P4	<i>Eucalyptus jutsonii</i> subsp. <i>jutsonii</i>	Perennial	Tree	(Mallee), 4-7 m high, bark rough over most stems, grey to light grey-brown.	-	Red to pale orange deep sands. Undulating areas and on dunes.	6.4	Medium
P4	<i>Eucalyptus kruseana</i>	Perennial	Tree	(Straggly mallee), 2-3.5 m high, bark smooth. Fl. Yellow.	Jun-Sep	Sandy loam. Granite outcrops & hills.	63.5	Low
P4	<i>Eucalyptus x brachyphylla</i>	Perennial	Tree	(Mallee) or tree, to 4 m high, bark rough, flaky. Fl. white	Jun.	Sandy loam. Granite outcrops.	8.5	Low
P4	<i>Frankenia glomerata</i>	Perennial	Shrub	Prostrate shrub. Fl. pink-white.	Nov.	White sand.	10.3	Low
P4	<i>Myriophyllum petraeum</i>	Annual	Herb	Aquatic annual, herb, stems 0.15-0.3 m long. Fl. White	Aug-Dec	Strictly confined to ephemeral rock pools on granite outcrops.	65.0	Low
P4	<i>Sowerbaea multicaulis</i>	Perennial	Herb	Tufted perennial, herb, 0.075-0.25 m high. Fl. purple-violet	Oct-Jan	Yellow-brown sand.	49.9	Low



## **Appendix D: Spectrum Ecology and Spatial (2022) Binduli South Project Terrestrial Fauna and SRE Assessment**

# BINDULI SOUTH PROJECT

## TERRESTRIAL FAUNA AND SRE ASSESSMENT

PREPARED FOR: TALIS CONSULTING |  
NORTON GOLD FIELDS



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Report Details			
Project Description:		Binduli South Project Terrestrial Fauna and SRE Assessment	
Prepared For:		Talis Consulting   Norton Gold Fields	
Project ID:		2015	
Version History	Authors	Reviewers	Date of Issue
Version 1	E. MacIntyre, J. Harper, M. Henderson, Dr G. Beca	N. Palmer, J. Harper, D. Cancilla	04/03/2022
Final			11/03/2022

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## EXECUTIVE SUMMARY

Norton Gold Fields Limited (Norton) is exploring the potential for further development at its Binduli South (BS) Gold operations immediately west of Kalgoorlie. Norton have recently secured approvals for its Binduli North (BN) operations which is positioned to the north of the Great Eastern Highway and are now considering future options.

A desktop review was undertaken by Spectrum Ecology & Spatial Pty Ltd (Spectrum) to determine future field efforts for fauna within the Study Area (3,556 ha). Following this assessment, Spectrum undertook a basic and targeted vertebrate and SRE fauna assessment within the Survey Area (1,652 ha). The Survey Area is approximately half the size of the Study Area, and results were used to verify and update the Eco Logical (2016d) fauna and SRE report.

The current assessment was undertaken by Spectrum and completed by two zoologists over a five day period from 25 to 29 October 2021. A variety of survey techniques were employed during the survey period.

The literature review and database searches identified 16 non-volant native mammals, 11 introduced mammals, ten bats, 159 birds, 77 reptiles, six amphibians, and three non- SRE invertebrate species (two EPBC Act-listed species and one Priority species) previously recorded in the region. Of the species identified in the desktop assessment, 29 conservation significant fauna species were identified as potentially occurring within the Study Area; including three mammals, 22 birds, one reptile and three invertebrates. Of these, 15 species were considered to have a Medium to High likelihood of occurrence based on their known distributions and the habitats occurring within the Study Area.

The West Australian Museum invertebrate database searches identified 12 Arachnid (five mygalomorph, five araneomorph and two pseudoscorpion), five Polydesmid millipede, one Crustacean and two Mollusc taxa considered to be SRE fauna within 100 km of the Study Area. Other previous surveys in the region have identified an additional 18 Mygalomorph, seven Araneomorph, eight Pseudoscorpion, three Scorpion, three Polydesmid, two Crustacean, 15 Mollusc and two Carabid taxa of confirmed or potential SRE status.

A total of 10 major fauna habitat types were recorded during the survey, none of which are restricted to the Survey Area, these were:

- Mixed Eucalypt open woodland over mixed shrubland on undulating plains on red-orange sandy clay soils;
- Mixed Eucalypt low woodland with sparse shrubs over low hummock grassland on orange sandplains;
- *Allocasuarina* over mixed shrubland on rocky plains and rises;
- *Acacia* and *Eremophila* shrubland on sandplains and floodplains on orange clay loam to sand;
- *Acacia* shrubland on rocky granitic slopes;
- *Callitris* and Eucalypt woodland over sparse shrubland on Kopi and gypseous dunes;
- Eucalypt woodland over mixed shrubland on low rocky hills with ironstone and quartz over red-orange sandy-clay;
- Eucalypt woodland over mixed shrubland in drainage lines on red-orange sandy-clay-loam;
- Low sparse chenopod shrubland on salt lakes and salt pans; and
- Cleared areas.

No conservation significant fauna were recorded during the survey. After completion of the survey, 14 species of conservation significance were considered to have a Medium likelihood of occurrence in the Survey Area based on habitat preferences and regional records.

A total of nine potential SRE species were collected during the survey including: one Araneomorph spider, one Mygalomorph spider, two Pseudoscorpions, one Geophilomorph centipede, one Scolopendromorph centipede, one Polydesmid millipede, one Symphyla pseudocentipede and one Eupulmonata snail.

None of the habitats in which the potential SREs were recorded appear to be restricted to the Survey Area.

## 1. INTRODUCTION

### 1.1. Project Background

Norton Gold Fields Limited (Norton) is exploring the potential for further development at its Binduli South (BS) Gold operations immediately west of Kalgoorlie (Map 1.1). Binduli South (the Study Area) consists of open pits and Waste Rock Landforms (WRLs) from previous mining activities (with ore being transported to their Paddington operations to the north of Kalgoorlie). Norton have recently secured approvals for its Binduli North (BN) operations, which are positioned to the north of the Great Eastern Highway and are now considering future options. The Binduli South project will require detailed biological survey information to support the approvals process.

### 1.2. Scope of Works

A desktop review was undertaken in order to determine future field effort covering appropriate surveys for both flora and fauna, short range endemic (SRE) species, salt-lake invertebrates, and subterranean fauna (as required) within the Study Area. A Level 1 (basic) vertebrate fauna and a targeted Short-range Endemic (SRE) invertebrate survey was undertaken by (2016b) across the Study Area (3,556 ha). Following the desktop assessment, it was determined that an additional basic and targeted survey would be required to address particular fauna species. The targeted survey focused on conservation significant species including Malleefowl, Carnaby's Cockatoo, Curlew Sandpiper, Peregrine Falcon, Arid Bronze Azure Butterfly (ABAB), Migratory birds, a Fairy Shrimp, and three confirmed SRE taxa.

Spectrum completed a combined basic and targeted fauna assessment of the smaller Survey Area (1,652 ha), an area half the size within the Study Area (Map 1.1). The Study Area was used to inform the initial desktop review, whilst the current assessment focused on the Survey Area as it more accurately represents the future development envelope. This report presents the findings from this assessment of the Survey Area, including the updated results from the (2016b) report.

### 1.3. Legislation & Guidelines

Flora and fauna in Western Australia are protected by various legislation, including:

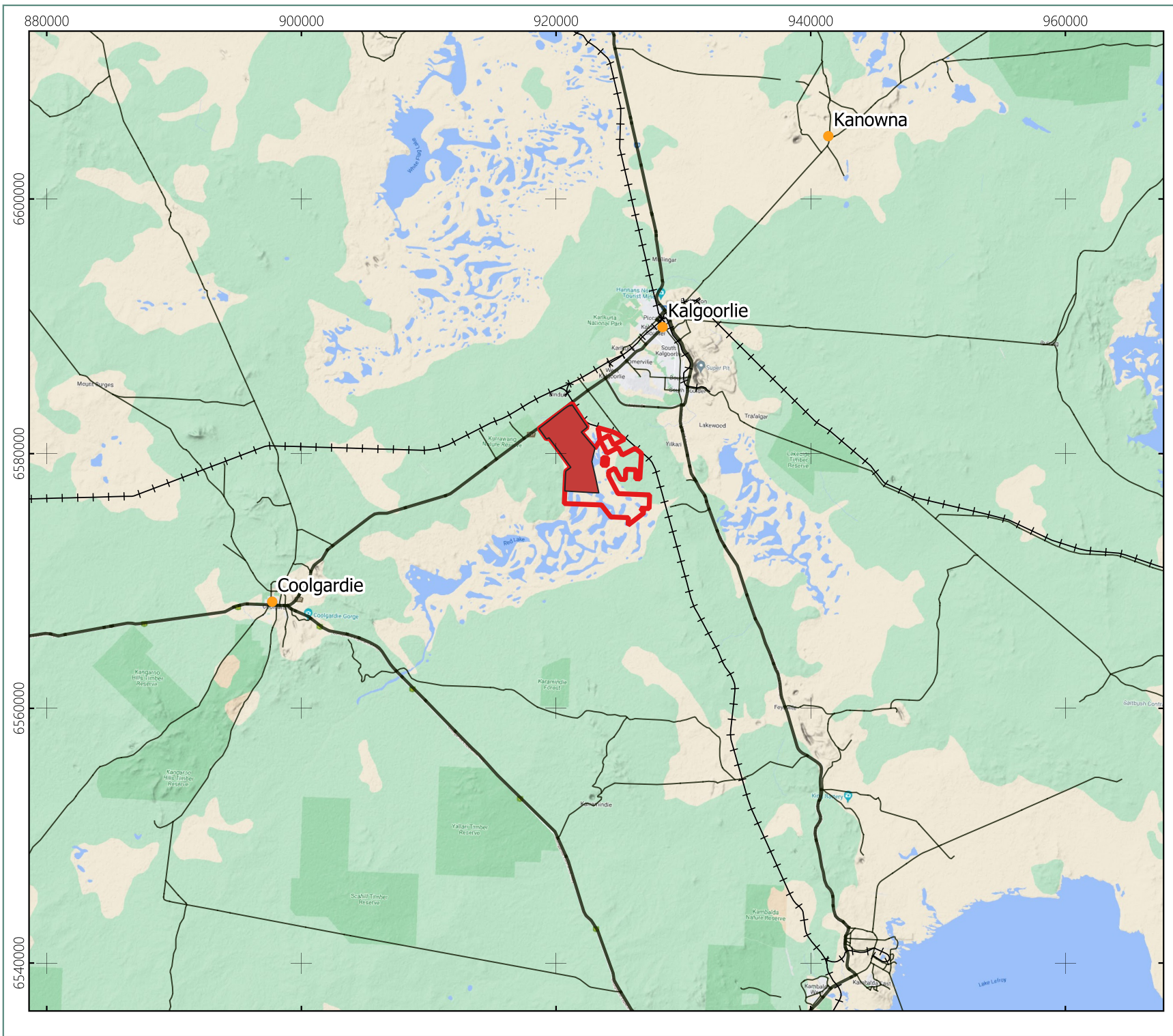
- *Biodiversity Conservation Act 2016* (BC Act);
- *Environmental Protection Act 1986* (EP Act); and
- *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act).

This assessment is compliant with the appropriate guidelines as outlined in:

- Technical Guidance: Terrestrial Vertebrate Fauna Surveys for Environmental Impact Assessment (EPA 2020)
- EPA Statement of Environmental Principles, Factors, and Objectives (EPA 2018);
- Environmental Protection Authority (EPA) Environmental Factor Guideline: Fauna (Environmental Protection Authority, 2016a);
- Technical Guidance: Sampling of Short Range Endemic Invertebrate Fauna (Environmental Protection Authority, 2016b);
- Technical Guidance: Terrestrial Vertebrate Fauna Surveys for Environmental Impact Assessment (Environmental Protection Authority, 2020);
- Survey Guidelines for Australia's Threatened Birds (DEWHA 2010); and

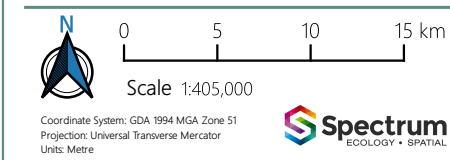


- Guideline for the Survey of Arid Bronze Azure Butterfly (ABAB) in Western Australia ((Department of Biodiversity Conservation and Attractions, 2020c).
- Revised draft referral guideline for three threatened black cockatoo species: Carnaby's Cockatoo, Baudin's Cockatoo and the Forest Red-tailed Black Cockatoo (Comm. of Aus., 2017).



# Legend

- Study Area
  - Survey Area
  - Cities and Towns
- Infrastructure
- Dual Carriageway
  - Minor Road
  - Principal Road
  - Secondary Road
  - Railways



Author: JH Date: 23-02-2022

## Location of the Binduli South Project Areas

### Binduli Expansion Project

## 1.4. Bioregion

The Interim Biogeographic Regionalisation for Australia (IBRA) classified Australia into regions based on the dominant landscape, climate, lithology, geology, landform, and vegetation (Thackway and Cresswell, 1995).

The Study Area is situated in the Coolgardie IBRA region, which is made up of three sub-regions: Eastern Goldfields, Mardabilla, and Southern Cross. The Coolgardie IBRA region is characterised by low greenstone hills, granite outcrops, laterite uplands, broad plains, and salt lakes. Aboriginal land, pastoral lease, gold and nickel mines, and national parks and reserves make up the land tenure (McKenzie, May and McKenna, 2003).

The Study Area lies in the north-west of the Eastern Goldfields IBRA subregion (Figure 1.1). This subregion is characterised by gently undulating plains interrupted by low hills and ridges of Archaean greenstones, and by a horst of Proterozoic basic granulite. The substrate is dominated by calcareous earths which cover much of the plains and greenstone areas (McKenzie, May and McKenna, 2003).

A series of large playa lakes in the western half are the remnants of an ancient major drainage line. The vegetation is generally dominated by Mallees, Acacia shrublands and sandplains with heath, while the ranges, valleys and salt lake surrounds are dominated by diverse Eucalyptus woodlands (McKenzie, May and McKenna, 2003). Samphire habitats can also be found at the numerous salt lakes. A high level of endemism occurs with the Acacia species of the Eastern Goldfields subregion (McKenzie, May and McKenna, 2003).

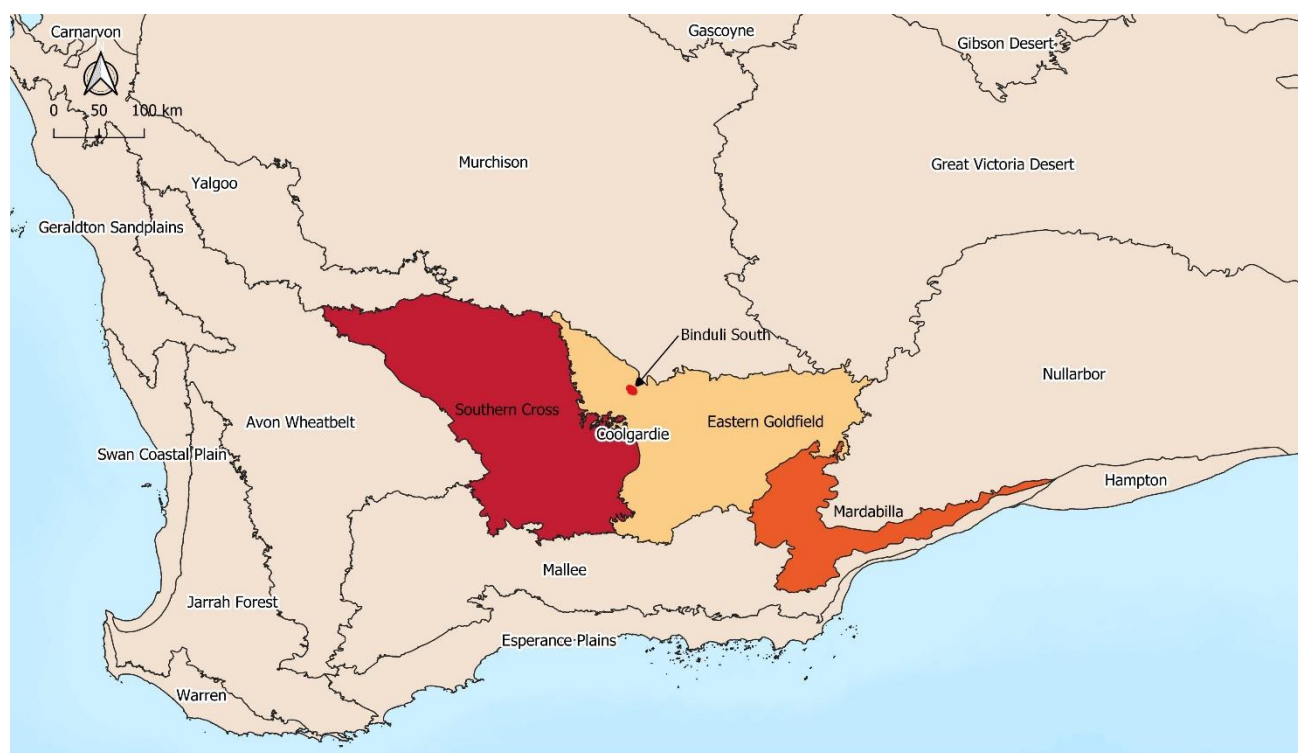


Figure 1.1: IBRA Classification of the Study Area



## 1.5. Climate

The climate associated with the Study Area is arid to semi-arid with an average annual rainfall of 200–300 mm, with rain occurring throughout the year although the majority falls in winter (Cowan, 2001). Temperature averages vary by approximately 15 degrees throughout the year, with typically warm summers and cool winters (Figure 1.2). The climate data shown below is from the nearest Bureau of Meteorology (BoM) station to the Survey Area, Kalgoorlie-Boulder Station (#12038; (BoM 2021). Rainfall that occurred during the months prior to the field survey was included in the below figure and discussed in Section 2.4.

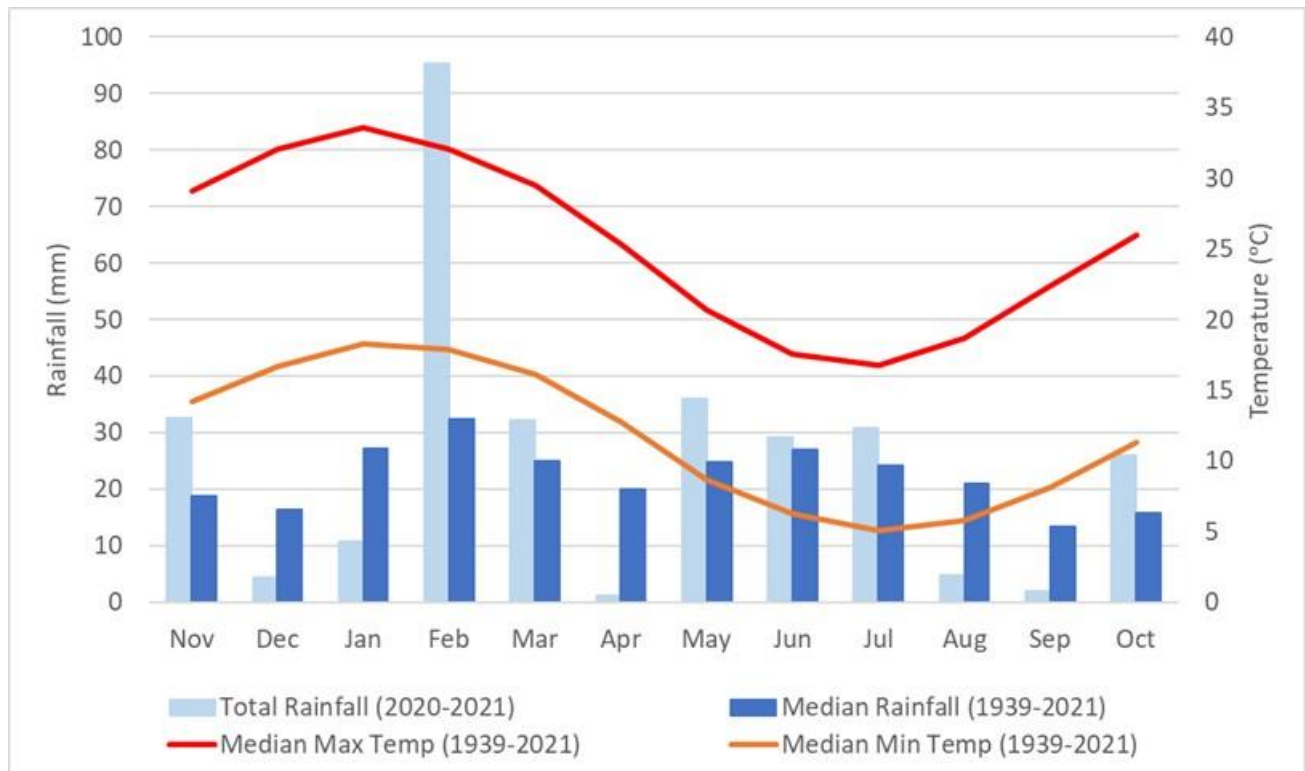


Figure 1.2: Mean Monthly Temperature and Rainfall in the Region (BoM 2021a)

## 1.6. Disturbance History

The Eastern Goldfields subregion consists mainly of Unallocated Crown Land (UCL) which includes low impact recreational disturbance, pastoral leases (disturbance from grazing by cattle and sheep), as well as mining leases (Cowan, 2001). Logging for fuel sources and material for the construction of mineshafts was previously conducted in the region from 1890 to 1950, but these woodland areas are now regenerating (Cowan, 2001). The main threatening processes affecting fauna are feral predators, grazing (by stock and rabbits), habitat fragmentation and changed fire regimes (McKenzie, May and McKenna, 2003).

## 1.7. Geology

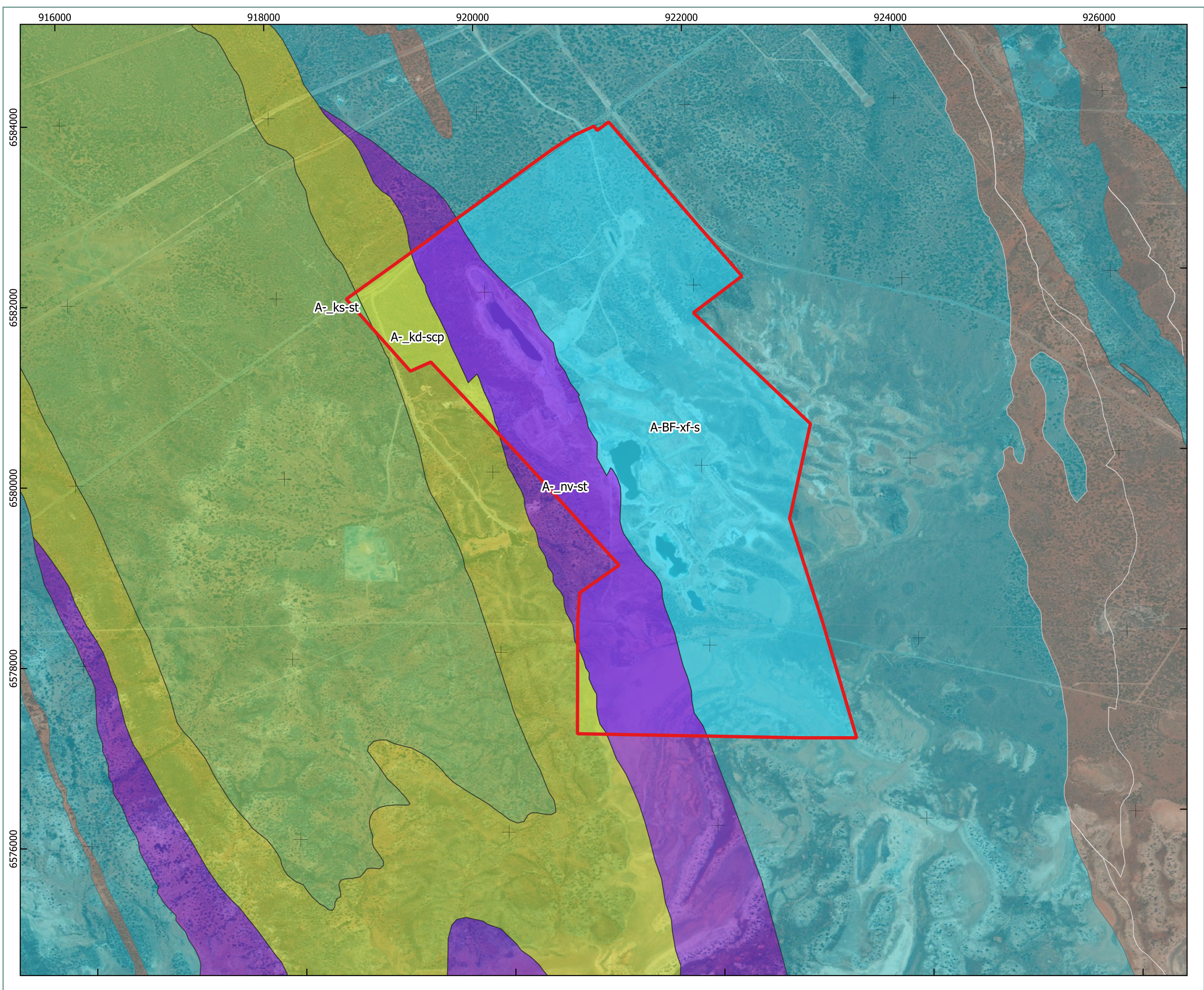
The geology of Western Australia has been mapped at a scale of 1:500,000 (DMIRS 2020), which is currently the finest-scale digital mapping available for the area. Seven units have been mapped within the Study Area; these are listed in Table 1.1 and displayed on Map 1.2.

The Black Flag Group geological unit has the largest occurrence within the Study Area, covering a total of 65.6%, which comprises 0.4% of the wider Coolgardie bioregion. The Abattoir West Gabbro geological unit is relatively very small and is also restricted to the Coolgardie bioregion, with 44.8% of its total extent occurring within the Study Area. The Navajo Sandstone unit is also both relatively small and restricted to Coolgardie, with 19.8% of its total extent occurring in the Study Area. The remaining five geological units all have less than 2% of their total extents within the Study Area.

**Table 1.1: Geological Units of the Study Area**

Unit Name	Unit Code	Description	Area in Study Area (ha)	% of Study Area	Total WA Extent (ha)	Total Coolgardie Extent (ha)	% of Coolgardie Extent Within Study Area
Abattoir West Gabbro	A-_aw-og	Gabbro; differentiated; metamorphosed	298.7	8.4	666.1	666.1	44.8
Black Flag Group	A-BF-xf-s	Felsic volcanoclastic and siliciclastic rocks; includes subordinate felsic and mafic volcanic rocks; metamorphosed	2,334.3	65.6	593,091.6	578,457.8	0.4
Kalgoorlie Group	A-KG-b	Mafic volcanic rock dominant; metamorphosed	25.6	0.7	171,485.6	136,016.5	<0.1
Kambalda Komatiite	A-KGkm-uk	Komatiite; basal pyroxenite; peridotite and picrite; minor sedimentary rock; metamorphosed	234.8	6.6	30,747.6	30,747.6	0.8
Douglas Lake Conglomerate Member	A-_kd-scp	Conglomerate, sandy conglomerate, and pebbly sandstone; metamorphosed	141.9	4.0	9516.2	9516.2	1.5
Navajo Sandstone	A-_nv-st	Quartz-rich sandstone with subordinate cobble-pebble conglomerate; tabular to trough cross-bedding; local clast-supported conglomerate; metamorphosed	518.0	14.6	2,620.4	2620.4	19.8
Seven Mile Sandstone Member	A-_ks-st	Quartz-rich sandstone; massive to planar bedded; rare pebbly sandstone; rare cross-bedding; metamorphosed	2.7	0.1	17,067.1	17,067.1	<0.1





**Legend**

Survey Area

**Vegetation Associations**

**Geology Clip Survey Area**

A-<sub>k</sub>d-scp

A-<sub>k</sub>s-st

A-<sub>n</sub>v-st

A-BF-xf-s

Not in Survey Area

0 0.5 1 km  
Scale 1:25,000 @ A3

Coordinate System: GDA 1994 MGA Zone 51  
Projection: Transverse Mercator  
Units: Metre

Spectrum  
ECOLOGY • SPATIAL

Author: EM Approved: AH Date: 07-12-2021

**Geology of the Survey Area (1:500,000)**

Binduli South

Prepared for  
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**MAP 1.2**



## 1.8. Pre-European Vegetation

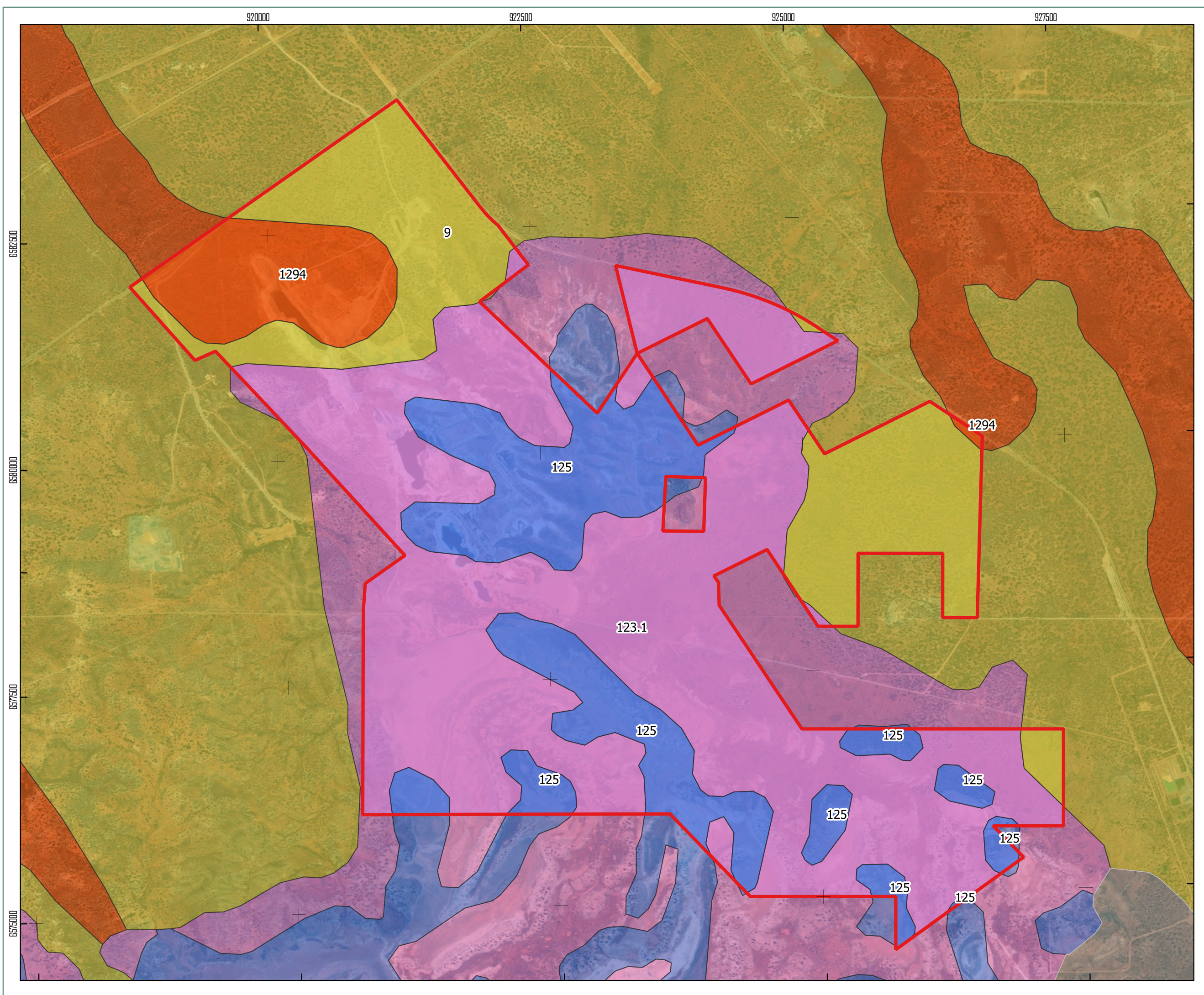
Pre-European vegetation mapping was originally undertaken by Beard at various scales across the state and has since been updated to be consistent with the National Vegetation Information System (NVIS) descriptions at a scale of 1:250,000 (DPIRD, 2019). State-wide vegetation statistics are available from 2018 for these associations which lists pre-European extent, current extent, area in DBCA managed lands and is a useful tool to determine if a vegetation association is rare or otherwise significant (Gov. of WA, 2019).

Four vegetation sub-associations (SA) were located within the Study Area; SA9, SA123.1, SA125 and SA1294. Vegetation SAs 123.1 and 1294 are the most restricted, with relatively very small extents occurring only within the Coolgardie IBRA region. SA123.1 consists of open chenopod shrubland occurring around salt lakes, and is significant in that it is also locally restricted, with 21.2% of its total extent occurring within the Survey Area. As with SA1294, SA9 is comprised mainly of Eucalypt woodlands, but also occurs across two IBRA regions: Coolgardie and Mallee. The remaining vegetation SA (125) is widespread across most of WA, and consists of salt lakes and fringing samphire shrublands. All four SAs have more than 90% of their pre-European extent remaining and have not been extensively cleared (Table 1.2). The four SAs are listed in Table 1.2 and shown on Map 1.3 below.

**Table 1.2: Beard Vegetation Sub-Associations**

SA	NVIS Description	Area in Study Area (ha)	% of Study Area	Pre-European Extent WA	Current Extent WA (ha)	% Remaining	% of Current Extent in Study Area	% Current Extent in DBCA Lands
9	<i>Eucalyptus</i> woodland consisting of: Upper layer: <i>Eucalyptus torquata</i> , <i>Eucalyptus lesouefii</i> and <i>Eucalyptus clelandii</i> . Middle layer: <i>Eremophila scoparia</i> , <i>Eremophila glabra</i> and <i>Eremophila oldfieldii</i> .	705	53	240,509	235,162	98	0.3	8
123.1	<i>Atriplex</i> mixed open chenopod shrubland consisting of: Upper layer: <i>Casuarina cristata</i> , <i>Myoporum platycarpum</i> , and <i>Callitris columellaris</i> . Middle layer: <i>Eremophila miniata</i> and <i>Grevillea sarissa</i> . Ground Layer: <i>Atriplex hymenotheca</i> and <i>Maireana</i> sp.	1,891	19	9,090	8,902	98	21.2	0
125	Salt lakes (bare areas) and open Samphire shrubland consisting of: Ground layer: <i>Tecticornia halocnemoides</i> , <i>Arthrocnemum leiostachyum</i> , <i>Sesuvium portulacastrum</i> .	702	7	3,485,785	3,146,487	90	<0.1	8
1294	<i>Eucalyptus</i> woodland consisting of: Upper layer: <i>Eucalyptus torquata</i> .	258	20	6,296	6,047	96	4.3	2





**Legend**  

Study Area

**Vegetation Associations**

	9.0
	123.1
	125.0
	1294.0
	Not in Study Area

Scale: 1:50,000 @ A3  
Coordinate System: GDA 1994 MGA Zone 51  
Projection: Transverse Mercator  
Units: Metre

Author: JH    Approved: AH    Date: 17-02-2022

Beard Vegetation of the Study Area

Binduli South

Prepared for  
Talis Consultants | Norton

**MAP**  
**3.3**



## 1.9. Significant Lands

Several significant lands are located in the vicinity of the Study Area. These are listed in Table 1.3, displayed in Map 1.4 and described in the following sections.

**Table 1.3: Environmentally Significant Areas within 100 km of the Study Area**

Reserve Name (Protected Area ID)	Distance from Study Area	Size (ha)
<b>Conservation Estates</b>		
Rowles Lagoon (WA04274)	65 km NW	404.7
Goldfields Woodlands (WA46127)	54 km SW	34,408.7
Victoria Rock (WA08480)	64 km SW	259.0
Yallari Timber Reserve (WA19212)	22 km SSW	6,077.1
Bullock Holes Timber Reserve (WA19825)	41 km NE	13,230.3
Kangaroo Hills Timber Reserve (WA19211)	33 km SW	3,120.9
Lakeside Timber Reserve (WA19214)	10 km E	2,390.9
Scahill Timber Reserve (WA19621)	29 km SW	6,915.0
Kalgoorlie Arboretum (WA23840)	9 km N	26.5
Credo (N7121)	60km NW	202,111.8
Clear And Muddy Lakes (WA07634)	65km NW	1,926.2
Kambalda (WA33300)	29km SSW	3,705.3
Kurrawang (WA35453)	<1km W	635.4
Dordie Rocks (WA03211)	78 km S	119.8
Binaronca (WA32552)	93 km S	186.0
Unnamed WA17804	88 km WSW	202.0
Wallaroo Rock (WA27655)	83 km W	1,214.0
Burra (WA07038)	63 km WSW	791.0
<b>TECs</b>		
Emu Land System (Priority 3)	38 km NE	395.4
<b>Wetlands</b>		
Rowles Lagoon System	63°km NW	32.0
Lake Marmion	100°km N	46.0

### 1.9.1. Conservation Estate

The Western Australian conservation estate includes land and waters vested in the Conservation and Parks Commission under the *Conservation and Land Management Act* (1984). The conservation estate is generally managed by the Department of Biodiversity, Conservation and Attractions (DBCA) to protect Western Australia's biodiversity and includes National Parks, Nature Reserves, Conservation Reserves, and other areas managed primarily for biodiversity conservation (DoEE 2016). A total of 18 Conservation Reserves occur within 100 km of the Study Area, including five Conservation Parks, six Reserves, six Nature Reserves and one Nature Reserve in progress (Table 1.2).



### 1.9.2. Environmentally Sensitive Areas

Environmentally Sensitive Areas (ESA) are defined by the Department of Water and Environmental Regulation (DWER 2019) as:

- A defined wetland and the area within 50 m of a wetland;
- The area covered by vegetation within 50 m of Threatened flora, to the extent to which the vegetation is continuous with the vegetation in which the Threatened flora is located;
- The area covered by a Threatened Ecological Community (TEC);
- A Bush Forever site;
- Areas covered by the Gngangara Mound Crown Land Policy and Western Swamp Tortoise Policy; and
- Areas covered by lakes, wetlands, and fringing vegetation of the Swan Coastal Plain Lakes Policy, including South-west Agricultural Zone Wetlands Policy and Swan and Canning Rivers Policy.

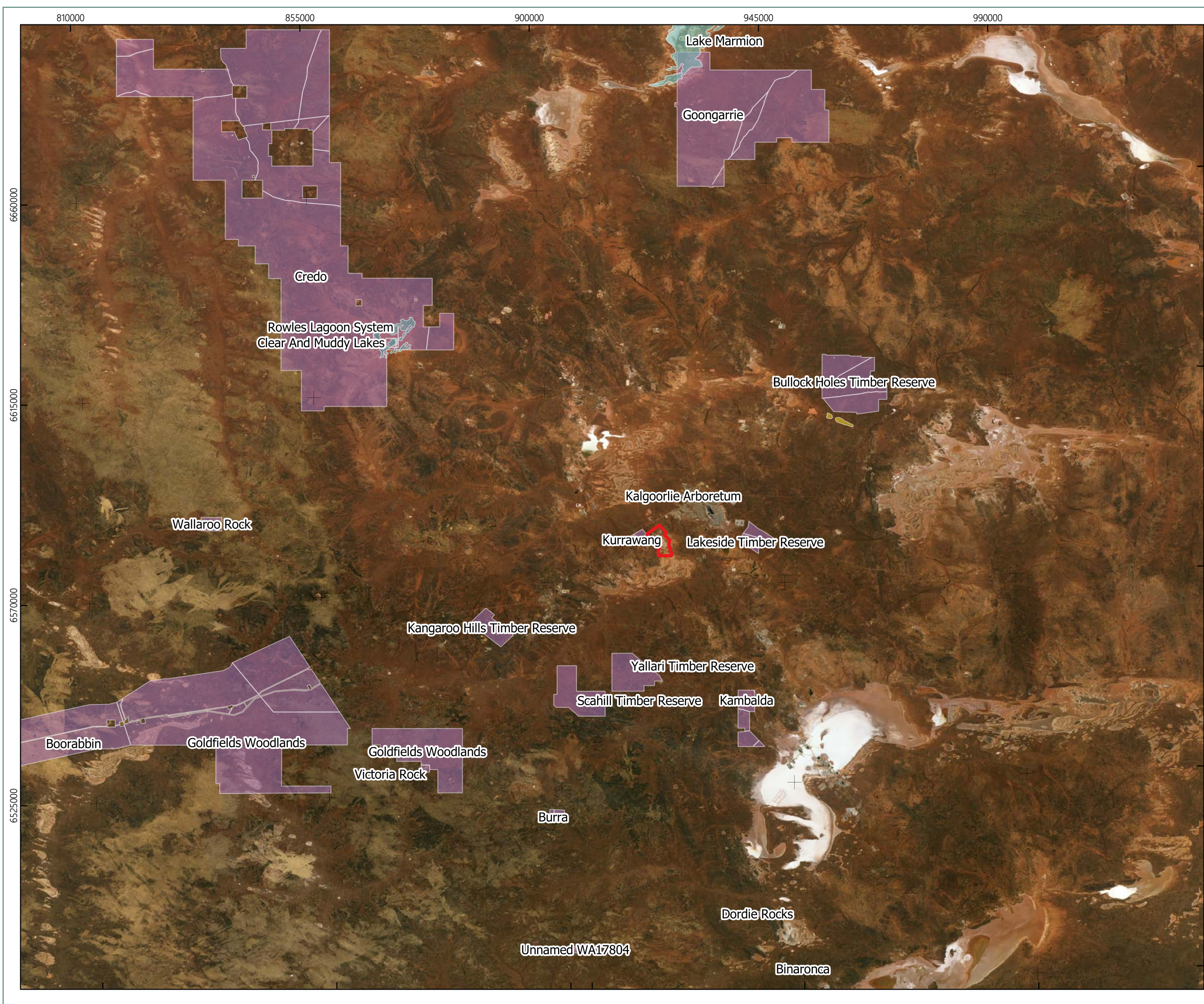
There is one ESA located within 40 km of the Study Area. The Emu Land System Threatened Ecological Community (TEC) is listed as a Priority 3 system (Table 1.3; Map 1.4). The major threat to this system is over grazing (DBCA 2020c).

### 1.9.3. Australian Wetlands Database





The Australian Wetlands Database includes nationally significant wetlands (as listed in the directory of important wetlands), wetlands listed under the Ramsar convention, wetlands that are representative, rare, or unique, or wetlands that are considered of international importance (DotEE 2019).

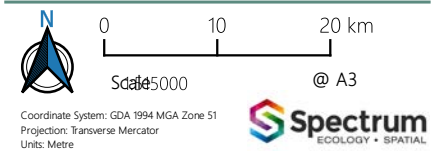
No nationally significant wetlands, including Ramsar wetlands, were mapped within the Study Area. The closest wetland of national significance is the Rowles Lagoon System which is located 63 km to the north-west (Table 1.3; Map 1.4).





Legend

-  Study Area
-  Conservation Estates
-  Important Wetlands
-  Emu Land System (Priority 3)



Author: JH    Approved: AH    Date: 18-02-2022

## Significant Lands in the Region

Binduli South



## 2. METHODS

### 2.1. Desktop Assessment

#### 2.1.1. Biological Database Searches

A desktop review of all relevant and available biological data sources was undertaken prior to the field survey to assess the fauna likely to occur in the Survey Area (Table 2.1).

**Table 2.1: Database Searches**

Data Source	Custodian	Details
Commonwealth Protected Matters Search Tool (PMST)	Department of the Environment and Energy (DoEE)	Buffer: 40 km Centre Point: -30.84986, 121.42327
NatureMap	Department Biodiversity Conservation and Attractions (DBCAs) / Western Australian Museum (WAM)	Buffer: 40 km Centre Point: -30.84986, 121.42327
DBCAs Threatened Fauna Database	DBCAs	Buffer: 70 km Centre Point: -30.84986, 121.42327
Invertebrate Fauna Databases	WAM	Arachnida & Myriapoda/ Mollusca/ Crustacea: 22/07/2021 Buffer: 100 km Coordinates: Top left: -30.5394, 121.1149 Bottom Right: -31.1937, 121.6574

#### 2.1.2. Previously Conducted Biological Assessments

Previously conducted assessments within 80 km of the Study Area were reviewed for significant fauna. Reports were incorporated if they were provided by Norton, or if they were publicly available. The eight reports incorporated into the desktop assessment are listed in Table 2.2, and the approximate locations of the surveys, where possible, are displayed in Map 2.1. Two additional unpublished reports from Spectrum Ecology's internal database were included with all the regional species listed in Appendix A.

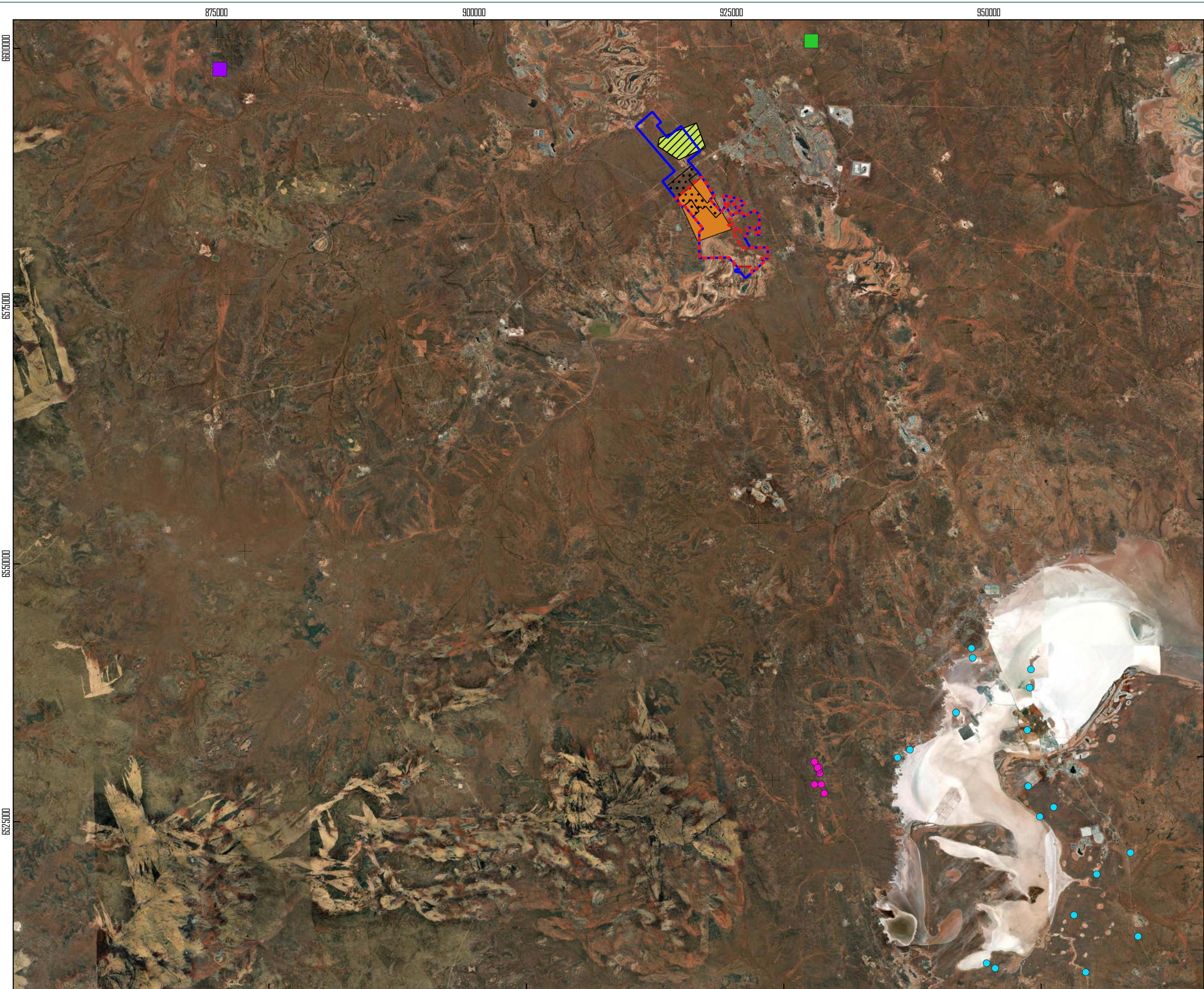
**Table 2.2: Previously Conducted Biological Assessments**

Reference	Survey Level	Title	Client	Distance to Study Area
Marianna Partners (Marianna Partners 1996a)	Fauna – Level 1	Binduli Project Area, Panel 3 and Tailings Dam Proposal, Pre-mining Environmental Survey	Croesus Mining	0 km
Marianna Partners (Marianna Partners 1996b)	Fauna – Level 1	Binduli Project Area Open Pit Proposal, Pre-mining Environmental Survey, Study Area 2 incorporating part of the Lake Douglas Recreation Reserve	Croesus Mining	0 km
GHD (GHD, 2005)	Fauna – Level 1	Coolgardie- Esperance Highway Emu Rocks and Spargoville Gravel Pit, Preliminary Environmental Impact Assessment and Biological Survey Assessment and Biological Survey	Main Roads	50 km
GHD (GHD, 2009)	Fauna – Level 1	Report for Navajo Chief, Development Activities, Level 1 Fauna Assessment	Paddington Gold	0 km



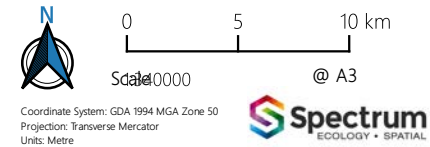
Reference	Survey Level	Title	Client	Distance to Study Area
Eco Logical (2016d)	Fauna – Level 1, Targeted & Level 2 SRE	Biological Assessment – Binduli Expansion Project Level 1 Vertebrate Fauna and Short-range Endemic Invertebrate Survey	Norton Gold Fields	0 km
Phoenix (Phoenix 2018)	Fauna – Level 1 Vertebrate & Level 2 SRE	Terrestrial fauna survey for the St Ives Gold Mine Beyond 2018 Project	St Ives Gold Mining Company	55 km
Spectrum Ecology (Spectrum Ecology, 2020)	Fauna – Desktop	Binduli North Expansion Project, Desktop Report Review	Norton Gold Fields	0 km
Onshore (Onshore 2021)	Fauna – Detailed & Targeted	Detailed and Targeted Fauna Survey, By-product Storage Site	Lynas Kalgoorlie Pty Ltd	15 km





Legend

- Study Area
- Previous Survey Boundaries**
  - Jim's Seeds, Weeds and Trees (2005)
  - ATA Environmental (2006)
  - Botanica Consulting (2008)
  - GHD (2009)
  - Eco Logical (2016a, b, c)
- Previous Survey Points**
  - GHD (2005) Survey Sites
  - Phoenix (2018) Survey Sites
  - NVS (2020)
  - Onshore (2021)



Author: JH    Approved: AH    Date: 18-02-2022

Previous Fauna  
Assessments in the  
Region  
Binduli South



## 2.2. Likelihood of Occurrence Assessment

The following information was collated for each significant fauna taxon identified during the desktop assessment:

- Conservation status (EPBC Act, BC Act, DBCA listing);
- Description of species habitat requirements and presence of this habitat within the Survey Area;
- Summary of relevant records including source of record (DBCA, previous report etc) and accuracy of the record location; and
- Likelihood of occurrence criteria assigned and justification of likelihood of occurrence that considers known habitats, survey effort etc. The likelihood of occurrence will be determined based on the criteria outlined in Table 2.3.

A likelihood of occurrence assessment was then conducted using the criteria listed in Table 2.3. This included assessing the distance of the record from the project (historical database records considered not accurate were excluded if required), presence of appropriate habitats within the Survey Area (using land systems, geology, vegetation mapping, and/or aerial imagery), and the age of the record. During the field survey, the preliminary assessment of the likelihood of occurrence of significant fauna species occurring within the Survey Area was reviewed and amended.

**Table 2.3: Likelihood of Occurrence Criteria for Significant Species**

Likelihood	Fauna Criteria
<b>Recorded</b>	Species recorded within the Survey Area within the previous ten years.
<b>High</b>	Species recorded within or in proximity to the Survey Area within the previous 20 years. Suitable habitat occurs in the Survey Area.
<b>Medium</b>	Species recorded within or in proximity to the Survey Area more than 20 years ago. Species recorded outside the Survey Area but within 50 km. Suitable habitat occurs in the Survey Area.
<b>Low</b>	Species rarely or not recorded within 50 km of the Survey Area. Suitable habitat does not occur within or in proximity to the Survey Area.
<b>Very Low</b>	Species not recorded within 50 km despite multiple recent surveys. Suitable habitat does not occur within the Survey Area. Species considered locally extinct.

## 2.3. Nomenclature

Nomenclature for mammals, birds, reptiles, and amphibians followed the Western Australian Museum (WAM) Checklist of the Vertebrates of Western Australia (June 2021). Fauna species identifications were completed based on information provided in references listed in Table 2.4. Nomenclature for Short-range Endemic (SRE) invertebrates is based on data provided by the WAM and relevant experts.

**Table 2.4: References Used for Identification of Fauna Species**

Fauna Group	Reference
Mammals	Churchill (Churchill, 2009), Menkhorst and Knight (2001), van Dyck and Strahan (2008a).
Birds	Menkhorst <i>et al.</i> (2019).
Reptiles & Amphibians	Wilson and Swan (2021), Cogger (2018), Tyler and Doughty (2009).



### 2.3.1. Significant Fauna Definitions

- Being identified as a Threatened or Priority species, see definitions in Appendix B;
- Species with restricted distribution;
- Degree of historical impact from threatening processes; or
- Providing an important function required to maintain the ecological integrity of a significant ecosystem.

## 2.4. Survey Timing

The basic, targeted and SRE survey was completed by two zoologists over five days from the 25–29 October 2021. The climatic conditions leading up to the fauna field surveys are illustrated in Figure 1.2 and were sourced from Kalgoorlie-Boulder Airport station (BoM # 12038), located approximately 6 km north-east of the Survey Area. The rainfall pattern preceding the survey varied as is typical from an arid climate.

The following rainfall was recorded at Kalgoorlie prior to the survey:

- The 12 months preceding the field survey (November 2020 to October 2021) recorded 305.2 mm of rainfall, 39.2 mm higher than the sum of the long-term annual median of 266.0 mm; and
- The three-months preceding the field survey (August - October 2021) recorded 32.8 mm of rainfall, 17.4 mm lower than the sum of the long-term annual median for the same three months (50.2 mm).

Climatic conditions are considered to be key factors for certain fauna groups when planning terrestrial fauna surveys. The basic fauna assessment focuses on confirming fauna habitat types and does not include any fauna sampling, therefore survey timing is generally not a consideration for this level of assessment. The warmer months following the cooler, higher rainfall period over winter are known to trigger an increase in activity and, therefore, detectability in many fauna species, including those targeted by the survey.

Timing is also not a consideration for surveys targeting Malleefowl, Carnaby's Cockatoo, Hooded Plover, Western Rosella and Peregrine Falcon. Typically, migratory shorebirds are only present during the summer months due to their migration patterns. The presence of both the migratory shorebirds and the aquatic macroinvertebrates in the Study Area is dependent on the availability of water in White Lake, located to the south of the Survey Area. As this is an ephemeral salt lake, spring is the considered the best time to survey for the target species; shorebirds may have already arrived and macroinvertebrates have had time to develop after winter rainfall.

The EPA guidance for sampling SREs indicates the optimal timing for surveys is during or immediately following rainfall events; therefore, spring in the Coolgardie IBRA region is considered suitable. The initial surveys to detect the host ant species associated with the ABAB and Inland Hairstreak Butterfly are not season-specific; however, surveys to target the butterflies should ideally be conducted between mid-September and late October (Department of Biodiversity Conservation and Attractions, 2020c). In addition, the butterfly surveys should only be conducted during fine weather, with a maximum temperature of more than 23°C (Department of Biodiversity Conservation and Attractions, 2020c).

During the survey, maximum temperatures were cooler than the long term average of 26°C, with only Monday reaching above the average (34.7°C), as detailed in Table 2.5. Conditions were windy and overcast, with some rainfall occurring on Wednesday at the Survey Area which was not recorded at the Kalgoorlie-Boulder Airport station. The survey conditions were sub-optimal for the butterflies, due to overcast, windy conditions and temperatures below the recommended 23°C (Department of Biodiversity Conservation and Attractions, 2020c).

Table 2.5: Weather Conditions Recorded During the Survey (Bureau of Meteorology, 2021)

Weather Observations	Date					Mean
	25/10/2021	26/10/2021	27/10/2021	28/10/2021	29/10/2021	
Max Temp (°C)	34.7	21.7	20.7	20	20.3	23.48°C
Min Temp (°C)	19.7	9.6	8.2	6.4	8	10.38°C
Rainfall (mm)	0	0	0	1.4	0	0.28

### 2.4.1. Project Team

Spectrum personnel involved with this assessment are listed in Table 2.6, along with their role and years of experience. The field survey was conducted under Regulation 27 licence BA27000523.

Table 2.6: Project Team

Staff	Role & Project Tasks	Years of Experience
Damien Cancilla	Principal Zoologist – report review	16
Jesse Harper	Senior Zoologist – report writing and review	8
Erica MacIntyre	Senior Zoologist – field work and report writing	8
Nicola Palmer	Senior Zoologist – report review	6
Melinda Henderson	Zoologist – report writing	3
Louise Ridgeway	Zoologist – field work and report writing	2
Dr. Gabrielle Beca	Zoologist – report writing	1

## 2.5. Field Methods & Sampling Effort

### 2.5.1. Basic Terrestrial Fauna Assessment

The basic terrestrial vertebrate fauna survey was consistent with the Technical Guidance: Terrestrial Vertebrate Fauna Surveys (EPA 2020a). The approach of the basic survey was to:

- Verify and update the vertebrate fauna habitats described by Eco Logical (2016d) across the Survey Area (see Section 2.5.2);
- Complete active searches to describe the vertebrate fauna assemblages present; and
- Record all opportunistic sightings of vertebrate fauna.

Spectrum conducted 33 habitat assessments, and utilised information from 26 flora relevés conducted by Spectrum botanists (Spectrum, 2022a) across the Survey Area, to inform the habitat mapping (Map 2.2). A variety of survey techniques were used to assess the fauna assemblage associated with the Study Area, as outlined in Table 2.7, with further details for specific targeted survey methods outlined in Section 2.5.3.

Table 2.7: Basic Fauna Survey Techniques

Fauna	Survey Technique
Mammals	Direct sightings and indirect evidence such as tracks, scats and diggings were recorded across the Survey Area.
Birds	Direct sightings and calls, as well as indirect evidence such as feathers, pellets and nests were recorded across the Survey Area.
Reptiles & Amphibians	Direct sightings and indirect evidence such as calls, tracks, diggings, skins and latrines were recorded across the Survey Area and targeted searches were undertaken in areas with suitable habitat.
SRE Invertebrate Fauna	Direct sightings or evidence.

### 2.5.2. Fauna Habitat Mapping

Fauna habitat mapping identifies areas of vegetation and land features that are distinguishable from other areas. Typically, each fauna habitat supports a characteristic fauna assemblage that is adapted to the features of the fauna habitat. Fauna habitat types are identified and mapped based on the following information:

- General vegetation type (Shepherd, Beeston and Hopkins, 2001);
- Verify and update fauna habitat mapping previously completed within the Survey Area (Eco Logical Australia, 2016d);
- Vegetation mapping of the Survey Area updated by Spectrum (2022a)
- Vegetation structure;
- Landforms;
- Geological units;
- Soil substrate;
- Aerial imagery;
- Fauna assemblage; and
- Field observations.

The fauna habitat was recorded at each survey site, opportunistically while traversing the Survey Area on foot, and when travelling between sites.

### 2.5.3. Targeted Survey – Significant Fauna

Twenty-nine species listed under the EPBC Act, gazetted under the BC Act or listed under the DBCA Priority fauna categories were identified during the literature review (Section 3.1.2). These were specifically targeted using the field survey techniques as listed in Table 2.8, which follow the Threatened species guidelines (where applicable). Species with a low likelihood of occurrence were only assessed using habitat assessments to confirm the likelihood status.

The targeted terrestrial vertebrate fauna and SRE surveys were carried out in accordance with the Technical Guidance: Terrestrial Vertebrate Fauna Surveys (EPA 2020a) and Technical Guidance: Sampling of Short Range Endemic Invertebrate Fauna (Environmental Protection Authority, 2016b).

**Table 2.8: Significant Species Survey Methods**

Species	Conservation Status			Survey Method
	EPBC Act	BC Act	DBCA	
Mammals				
Numbat, Walpurti ( <i>Myrmecobius fasciatus</i> )	EN	EN		<ul style="list-style-type: none"><li>• Desktop assessment and literature review</li><li>• Habitat assessment during the survey</li></ul>
Chuditch, Western Quoll ( <i>Dasyurus geoffroii</i> )	VU	VU		<ul style="list-style-type: none"><li>• Desktop assessment and literature review</li><li>• Habitat assessment during the survey</li></ul>
Greater Bilby, Dalgyte, Ninu ( <i>Macrotis lagotis</i> )	VU	VU		<ul style="list-style-type: none"><li>• Desktop assessment and literature review</li><li>• Habitat assessment during the survey</li></ul>

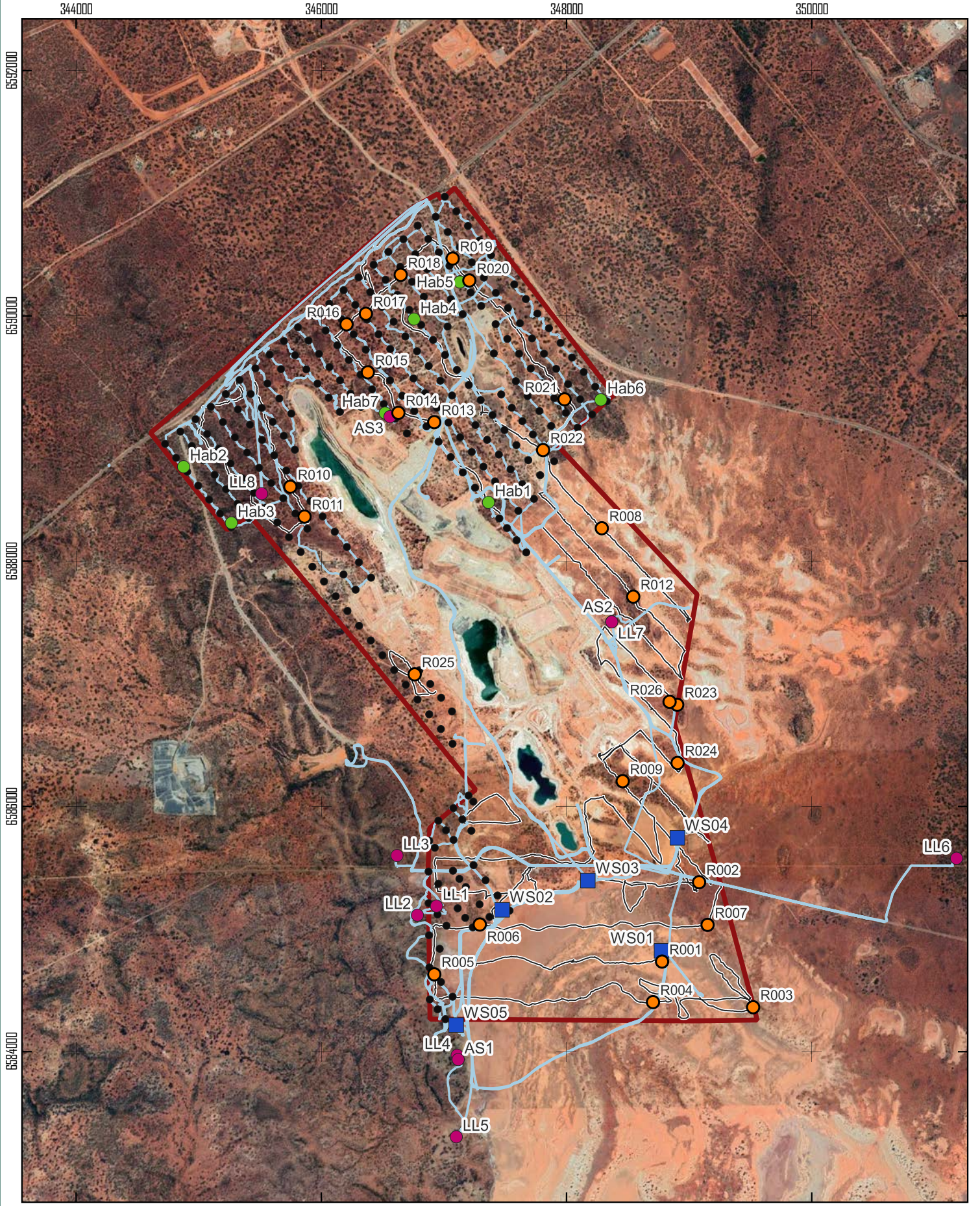


Species	Conservation Status			Survey Method
	EPBC Act	BC Act	DBCA	
Birds				
Malleefowl ( <i>Leipoa ocellata</i> )	VU	VU		<ul style="list-style-type: none"><li>• Desktop assessment and literature review</li><li>• Habitat assessment during the survey</li><li>• Targeted searches for suitable habitat by completing transects (160 m spacing ) within marginal habitat</li><li>• Opportunistic sightings of secondary evidence and mounds, including checking previously recorded mounds</li><li>• Utilisation of botanists for opportunistic sightings and evidence</li></ul>
Fork-tailed Swift ( <i>Apus pacificus</i> )				<ul style="list-style-type: none"><li>• Desktop assessment and literature review</li><li>• Habitat assessment during the survey</li><li>• Opportunistic searches in suitable habitat</li></ul>
Blue-billed Duck ( <i>Oxyura australis</i> )			P4	<ul style="list-style-type: none"><li>• Desktop assessment and literature review</li><li>• Habitat assessment during the survey</li></ul>
Curlew Sandpiper ( <i>Calidris ferruginea</i> )	CR/MI	CR		<ul style="list-style-type: none"><li>• Desktop assessment and literature review</li><li>• Habitat assessment during the survey</li></ul>
Migratory Shorebirds (13 species)	MI	MI		<ul style="list-style-type: none"><li>• Desktop assessment and literature review</li><li>• Habitat assessment during the survey</li><li>• Opportunistic searches in suitable habitat</li></ul>
Hooded Plover ( <i>Thinornis cucullatus</i> )			P4	<ul style="list-style-type: none"><li>• Desktop assessment and literature review</li><li>• Habitat assessment during the survey</li><li>• Opportunistic searches in suitable habitat</li></ul>
Night Parrot ( <i>Pezoporus occidentalis</i> )	EN	CR		<ul style="list-style-type: none"><li>• Desktop assessment and literature review</li><li>• Habitat assessment during the survey</li></ul>
Carnaby’s Cockatoo ( <i>Calyptorhynchus latirostris</i> )	EN	EN		<ul style="list-style-type: none"><li>• Desktop assessment and literature review</li><li>• Habitat assessment during the survey</li><li>• Opportunistic searches in suitable habitat including secondary evidence – chewed hollows and feeding signs or debris</li><li>• Any Salmon Gum or other Eucalypt recorded at Arid Bronze Azure Butterfly sample points with a diameter at breast height (DBH) of &gt;300 mm were recorded.</li></ul>
Western Rosella ( <i>Platycercus icterotis xanthogenys</i> )			P4	<ul style="list-style-type: none"><li>• Desktop assessment and literature review</li><li>• Habitat assessment during the survey</li><li>• Opportunistic searches in suitable habitat</li></ul>
Grey Falcon ( <i>Falco hypoleucos</i> )		VU		<ul style="list-style-type: none"><li>• Desktop assessment and literature review</li><li>• Habitat assessment during the survey</li><li>• Opportunistic searches in suitable habitat</li></ul>
Peregrine Falcon ( <i>Falco peregrinus</i> )	OS	OS		<ul style="list-style-type: none"><li>• Desktop assessment and literature review</li><li>• Habitat assessment during the survey</li><li>• Opportunistic searches in suitable habitat</li><li>• Searching of tall structures and trees for nesting evidence</li></ul>


Species	Conservation Status			Survey Method
	EPBC Act	BC Act	DBCA	
Grey Wagtail ( <i>Motacilla cinerea</i> )	MI	MI		<ul style="list-style-type: none"> <li>Desktop assessment and literature review</li> <li>Habitat assessment during the survey</li> <li>Bird surveys in suitable habitat</li> <li>Opportunistic searches in suitable habitat</li> </ul>
<b>Reptiles</b>				
Western Spiny-tailed Skink ( <i>Egernia stokesii badia</i> )	EN	VU		<ul style="list-style-type: none"> <li>Desktop assessment and literature review</li> <li>Habitat assessment during the survey</li> </ul>
<b>Invertebrates</b>				
Arid Bronze Azure Butterfly (ABAB) ( <i>Ogyris subterrestris</i> subsp. <i>petrina</i> )	CR	CR		<ul style="list-style-type: none"> <li>Desktop assessment and literature review</li> <li>Habitat assessment during the survey</li> <li>Targeted transect survey of sugar ant <i>Camponotus</i> sp. nr. <i>terebrans</i> as outlined in the guidelines (DBCA 2020d, DBCA 2020a)</li> <li>Opportunistic sightings of ABAB</li> </ul>
Inland Hairstreak Butterfly ( <i>Jalmenus aridus</i> )			P1	<ul style="list-style-type: none"> <li>Desktop assessment and literature review</li> <li>Habitat assessment during the survey</li> <li>Potential habitat searched for associated Froglet ant species <i>Froggatella kirbii</i> using ABAB techniques</li> <li>Active Search: 1 site</li> </ul>
Aquatic Fairy Shrimp ( <i>Branchinella denticulata</i> )			P3	<ul style="list-style-type: none"> <li>Desktop assessment and literature review</li> <li>Habitat assessment during the survey showed no suitable habitat present (no water present in White Lake), therefore no further survey techniques were possible</li> </ul>
<b>SRE Invertebrates</b>				
Millipedes ( <i>Antichiropus</i> 'binduli' and <i>A.</i> 'kalgoorlie')				<ul style="list-style-type: none"> <li>Desktop assessment and literature review</li> <li>Habitat assessment during the survey</li> <li>Leaf litter collection: 8 sites</li> <li>Leaf litter and soil sieving: at 6 of the leaf litter sites</li> <li>Active searches: 1 site south of the Survey Area</li> </ul>
Wolf Spider ( <i>Tetranychus baudinettei</i> )				<ul style="list-style-type: none"> <li>Desktop assessment and literature review</li> <li>Habitat assessment during the survey</li> <li>Dry pitfall trapping: 5 sites and 100 trap nights</li> <li>Active searches: at each dry pitfall trapping site and one additional site on the eastern part of the Survey Area</li> </ul>

The fauna survey effort completed for the above species is displayed in Map 2.2. Survey methods for invertebrate and SRE invertebrate species are detailed in Sections 2.5.3.1 to 2.5.3.4.






- Legend**
- Survey Area
  - ABAB Survey Points
  - Habitat Assessment Sites
  - Leaf Litter and Active Search Sites
  - Flora Sites
  - Wolf Spider Trapping Sites
  - Fauna Survey Tracks
  - Flora Traverses



0 0.4 0.8 1.2 km

Scale 1:40000 @ A4

Coordinate System: GDA 1994 MGA Zone 51  
Projection: Transverse Mercator  
Units: Meter



Author: EM Date: 18-02-2022



### 2.5.3.1. Arid Bronze Azure Butterfly (*Ogyris subterrestris petrina*)

The Arid Bronze Azure Butterfly (ABAB) is listed as Critically Endangered under both the EPBC Act and BC Act. To date, little is known about the Arid Bronze Azure Butterfly and all known records are restricted to three locations: Barbalin Nature Reserve (11 km north-west of Mukinbudin in the central wheatbelt), an undisclosed location 90 km from the Barbalin NR, and previously from Douglas Lake near Kalgoorlie in the Goldfields region where the population is now considered locally extinct. The Mukinbudin and Kalgoorlie locations are approximately 320 km apart.

The ABAB has an obligate association with the sugar ant *Camponotus* sp. nr. *terebrans* whereby the ABAB larvae lives and develops within the ant colony's nest. The most critical habitat factor determining occupancy by the ABAB is the presence of large populations of the host ant that can support this parasitic species (DBCA 2020d). The habitat associated with ABAB are smooth-barked Eucalypt woodlands consisting of mostly Gimlet (*E. salubris*), Salmon Gum (*E. salmonophloia*), York Gum (*E. loxophleba*) and Wheatbelt Wandoo (*E. capillosa*) with large ant nests occurring beneath these trees (DBCA 2020d). Due to the obligate association of the ABAB with the host ant, surveys to detect the ABAB need to consider both species. A large ant colony is a strong indicator of potential presence of the ABAB and the absence, or presence of only a small number of ants is an indication that ABAB is absent (DBCA 2020d).

A targeted survey was conducted to determine the presence of *Camponotus* sp. nr. *terebrans* within the Survey Area using the methods outlined in the survey guidelines (DBCA 2020d, 2020b). A search area was defined based on vegetation mapping by Eco Logical (2016c) whereby the presence of Salmon Gum and other smooth-barked eucalypts within the Survey Area, had been identified (approximately 600 ha). Due to the size of the Survey Area and the area of mapped Eucalypt woodland, diurnal survey methods were selected as the most efficient option.

As per the guideline advice, an area of approximately 600 ha would require approximately 250 sample points with 160 m spacing. Approximately 35 km of transects were walked with 217 sample points completed at 160 m spacing within suitable habitat (Map 2.3, Appendix E). The closest smooth-barked Eucalypt to the sample point was selected as a sample tree. If no suitable trees were located within approximately 75 m of the point, no tree was sampled. The diameter at breast height (DBH) and tree species if easily identifiable was recorded. The base of each sample tree was searched for evidence of the target ant species. If any ants were identified, a small area was disturbed to cause the ants to come out of their nest. Ants were either collected or photographed *in-situ*. Guidelines suggest that photos are sufficient to confirm the species with qualified taxonomists (e.g. Matthew Williams, DBCA; Brian Heterick, WAM).

The survey was conducted during the peak-flying season for the ABAB. Any ABAB detected during the survey were photographed *in-situ* where possible, and if not, caught and photographed in a suitable container before immediate release (subject to Section 40 licence conditions).

### 2.5.3.2. Inland Hairstreak Butterfly (*Jalmenus aridus*)

The Inland Hairstreak Butterfly was originally described from a specimen found at Douglas Lake; however, the species has not been recorded from this location since 1997. Little is known about its biology or ecology, but it is likely that adults stay close to breeding habitats. There are presumed to be two generations per year, although adults are absent in some years (Braby, 2016).

Based on historical records, the larvae of this species is thought to feed on the leaves and flowers of young shrubs of *Senna nemophila* (recent taxonomic revisions classify them as *Senna artemisioides* subsp. *×coriacea*) and mature trees of *Acacia tetragonophylla*, which grow in shallow gullies with gentle slopes (Braby, 2016). The larvae of the butterfly are attended by the Froglet ant, *Froggatarella kirbii* (Braby, 2016).

Data from Eco Logical's (2016a) flora and vegetation assessment indicated that *Acacia tetragonophylla*, *Senna artemisioides* subsp. *×artemisioides* and *Senna artemisioides* subsp. *filifolia* were recorded from several quadrats within the Survey Area. These were located in the mixed Eucalypt open woodland on red-brown loam plains habitat in the north-west and central east sections of the Survey Area. The presence of the Froglet Ant was surveyed at the transects and sample points searched for the ABAB (Map 2.3). An additional active search was completed in *Acacia* shrubland habitat. If ants were detected, specimens were collected to confirm the species identification. If any Inland Hairstreak butterflies were detected, they would be photographed *in situ* where possible, and if not, caught and photographed in a suitable container before immediate release (subject to Section 40 licence conditions).



346000

348000

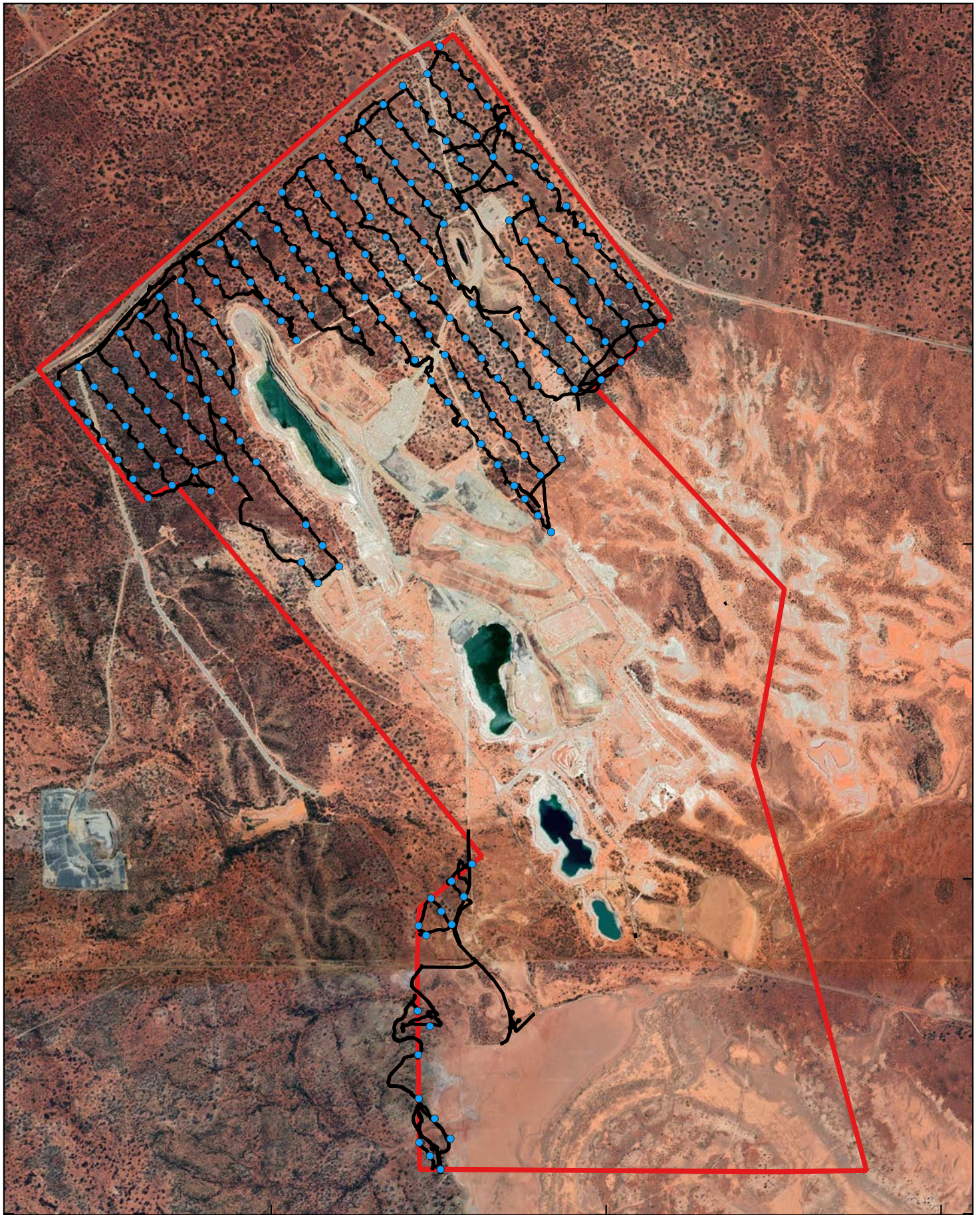
350000

6590000

6588000

6586000

6584000



#### Legend

- Survey Area
- Sample Points
- Transects



0 0.4 0.8 1.2 km

Scale 1:30000

@ A4

Coordinate System: GDA 1994 MGA Zone 51  
 Projection: Transverse Mercator  
 Units: Meter



Author: EM

Date: 18-02-2022

#### ABAB & Inland Hairstreak Survey Points and Transects

Binduli South

Prepared for Talis  
 Consultants/Norton

Map

2.3



#### 2.5.3.3. Millipedes *Antichiropus* 'binduli' and A. 'kalgoorlie'

Although none of the confirmed or potential SRE taxa identified by Eco Logical's (2016d) Level 2 SRE assessment are expected to be restricted to the Survey Area, two species, *Antichiropus* 'binduli' and A. 'kalgoorlie', are currently only known from this location and are therefore at higher risk of significant impact.

Details of the methods used during the SRE invertebrate fauna surveys are described below:

- **Leaf litter collection:** Three 1 m<sup>2</sup> quadrats were collected from eight sites where suitable leaf litter or soil was present. Five sites were located outside and three sites were located inside the Survey Area. The samples were collected using a leaf litter reducer, placed into plastic zip-lock bags and transported back to Perth where they were placed under Tullgren funnels in order to extract the invertebrates. The subsequent samples were then processed by Spectrum and any potential SRE specimens were collected and sent to specialist taxonomists for identification to the highest possible taxonomic resolution.
- **Leaf litter and soil sieving:** At suitable leaf litter collection sites, 1 m<sup>2</sup> quadrats of leaf litter and soil were excavated and processed through graduated geology sieves to search for millepedes. Each separated size class of particles was also searched simultaneously for relevant SRE taxa (e.g. snails and large spiders in the large particle class, and pseudoscorpions in the smaller particle class). All relevant SRE specimens were collected for identification.
- **Active searches:** Targeted active searches for *Antichiropus* in suitable microhabitats were conducted, including raking or sifting leaf litter and soil under shrubs and searching under and inside woody debris. Any other invertebrates from SRE target groups were also opportunistically collected or recorded, where possible.

#### 2.5.3.4. Wolf Spider *Tetrallycosa baudinettei*

The wolf spider, *Tetrallycosa baudinettei*, was recently described by Framenau and Hudson (2017) and is a confirmed SRE species. Its distribution is currently known from only two salt-lakes; Lake Lefroy, approximately 50 km south-east of the Survey Area, and Lake Goonarrie, approximately 100 km north. The following survey methods were used to target this species:

- **Dry pitfall trapping:** Five dry pitfall sites were installed in suitable salt-lake habitat, with four sites located around White Lake and one at a smaller unnamed salt lake to the north-east (Map 2.2). Each site consisted of five pitfall traps measuring 10 cm wide x 15 cm deep, spaced approximately every 2.5 m. A 10 m long, 30 cm high fence was installed to direct fauna in to the traps. The fence passed across the top of each pit in the middle and to the edge of the pits on either end (Figure 2.1). The traps were checked each morning, and any SRE target group specimens were collected. Vertebrate by-catch was identified and released immediately. A total of 100 trap nights were completed.
- **Active searches:** Targeted active searches for this species in suitable microhabitats were conducted. If any burrows were found during active searches, specimens were collected by excavating the burrows, if required.



Figure 2.1: Dry Pitfall Trapping Grid

#### 2.5.4. SRE Invertebrate Fauna Identification

Leaf litter samples were processed immediately following the field survey to ensure maximum survivorship before the samples were placed in Tullgren funnels (Figure 2.2). Identification of SRE specimens collected during the survey was completed by Erich Volschenk (Alacran Environmental Science). Alacran collaborate with the Western Australian Museum (WAM), which results in the taxa identification aligning with the museum collection. These specimens were identified to the lowest possible taxonomic level.



Figure 2.2: Tullgren Funnel Setup

### 2.5.5. Determination of SRE Status

The SRE status of invertebrates is based on categories which were developed by the WAM. For consistency purposes, identifications completed by Alacran followed the WAM categories outlined in Table 2.9. Following the precautionary principle, all data deficient species from known SRE target groups are regarded as potential short-range endemics.

Table 2.9: SRE Categories

Categories	Defining Characteristics
Confirmed SRE	<ul style="list-style-type: none"> <li>Known distribution of &lt;10,000 km<sup>2</sup>.</li> <li>Taxonomy is well understood.</li> <li>Species is well represented in collections.</li> <li>Region of occurrence has been comprehensively sampled.</li> </ul>
Potential SRE	<ul style="list-style-type: none"> <li>Limited sampling has resulted in incomplete knowledge of the species distribution.</li> <li>Poor or limited taxonomic resolution.</li> <li>Species not well represented in collections.</li> </ul>
Not SRE	<ul style="list-style-type: none"> <li>Known distribution of &gt;10,000 km<sup>2</sup>.</li> <li>Taxonomy is well understood.</li> <li>Species is well represented in collections.</li> <li>Region of occurrence has been comprehensively sampled.</li> </ul>

In order to align with sub-categories previously used by the WAM, the following sub-categories were used by Alacran to further clarify a species' ranking as a potential SRE (Table 2.10).

Table 2.10: WAM Sub-Categories Used to Justify Potential SRE Status

Sub-Category	Description
Data Deficient (DD)	<ul style="list-style-type: none"> <li>There is insufficient data available to determine SRE status.</li> <li>Factors that fall under this category include: <ul style="list-style-type: none"> <li>Lack of geographic information (DDG),</li> <li>Lack of taxonomic information (DDT), and/or</li> <li>inappropriate life stages prevent identification to species level.</li> </ul> </li> </ul>
Habitat Indicators (H)	<ul style="list-style-type: none"> <li>It is becoming increasingly clear that habitat data can elucidate SRE status; and</li> <li>Where habitat is known to be associated with SRE taxa and vice versa, it will be noted here.</li> </ul>
Morphology Indicators (M)	<ul style="list-style-type: none"> <li>A suite of morphological characters are characteristic of SRE taxa; and</li> <li>Where morphological characters are known to be associated with SRE taxa and vice- versa, it will be noted here.</li> </ul>
Unpublished Research & Expertise (U)	<ul style="list-style-type: none"> <li>Previous research and/ or WAM expertise elucidates taxon SRE status; and</li> <li>This category takes into account the expert knowledge held within the WAM.</li> </ul>



## 2.6. Limitations and Constraints

Survey specific limitations and constraints are discussed in Table 2.11.

**Table 2.11: Limitations & Constraints**

Limitation	Constraint	Comment
Availability of the contextual information at a regional and local scale.	No	Beard vegetation and geology were used to determine regional significance of vegetation types. Land systems mapping is not available for the Survey Area. Database searches provided detailed information, adequate to guide field survey design and effort for the flora and fauna survey. Eco Logical (2016d) undertook a Level 1 (basic) and SRE survey over the Survey Area that has been used in this assessment.
Competency/ experience of the consultant carrying out the survey including experience in bioregion surveyed.	No	The zoologists (Senior Zoologist, Erica MacIntyre and Zoologist, Louise Ridgeway) involved in the field survey have many combined years of experience completing fauna surveys throughout Western Australia and are familiar with the Coolgardie fauna assemblages.
Timing/weather/ season/cycle.	Partial	The field survey was conducted during the optimal season for fauna surveys in the Coolgardie region and South-western Interzone Botanical Province. Seasonal conditions were lower than average, and rainfall was below the long-term mean rainfall for the two months previous to the survey. However, the rainfall for October 2021 was above average. Basic level fauna surveys are not dependent on seasonal timing. SRE fauna are generally easier to locate after rainfall. The SRE survey was conducted just outside of the optimal survey period for SREs, although above average rainfall occurred during October 2021. Maximum temperatures during the survey were below average. It was also very windy, with some rain falling on Wednesday, 27/11. Therefore, the weather for detecting the ABAB was not optimal.
Disturbances (e.g., fire, flood, accidental human intervention) which affected results of survey.	No	No disturbances were recorded at the Survey Area that have affected the results of the fauna assessment.
Remoteness and/or access problems.	No	Due to high fire danger, certain tracks could not be driven on 25/10/2021. However, this did not adversely impact the survey.
Scope (what faunal groups were sampled and were some sampling methods not able to be employed because of constraints such as weather conditions).	Partial	Sampling techniques were adequate for a basic terrestrial fauna survey. All fauna groups were sampled, and no survey constraints were experienced. Malleefowl were also targeted by both the zoologists and botanists during the field survey. Not all of the proposed ABAB ant transects were able to be walked due to time constraints, although over 90% were completed. Due to limited rainfall during the previous months and the ephemeral nature of salt lakes, no water was present during the time of the survey. Therefore, surveys for waterbirds, including migratory species, were not completed as these taxa only use the salt lake when inundated. In addition, no surveys could be conducted for macroinvertebrates (e.g. fairy shrimp) that may inhabit the salt lake during these periods of inundation.
Proportion of fauna identified, recorded, and/or collected.	No	All vertebrate fauna species encountered were identified in the field. Basic survey methods do not require the identification of all fauna species present within the Survey Area. Collected SRE invertebrate samples, including potential wolf spiders which were identified to the lowest possible level.

Limitation	Constraint	Comment
The proportion of the task achieved and further work which might be needed.	Partial	The majority (>90%) of the proposed ABAB ant transects were surveyed. Surveys for macroinvertebrates and waterbirds were not completed due to the absence of water in White Lake.
Resources (degree of expertise available in animal identification to taxon level).	No	Fauna resources available were adequate and did not compromise the outcome of the survey.
Intensity (in retrospect, was the intensity adequate).	No	A basic fauna assessment was considered adequate to identify faunal assemblages and fauna habitat present within the Survey Area. In addition, targeted surveys were undertaken for several species, including SREs. Additional targeted Malleefowl mound surveys were conducted concurrently by the suitably experienced botanist during flora and vegetation transects across the Survey Area. The survey intensity conducted was considered adequate for the Survey Area.
Completeness (was the relevant area fully surveyed).	Partial	All major fauna habitat types were sampled and defined. Habitat types that may host significant fauna species were surveyed. The majority of the targeted surveys for conservation significant fauna were completed. Due to White Lake being dry at the time of the survey, surveys for macroinvertebrates and waterbirds that may inhabit this lake during periods of inundation were not completed.

## 2.7. Data for the Index of Biodiversity Surveys for Assessment (IBSA)

The Environmental Protection Authority (EPA) has given instruction that all biological surveys collecting data on biodiversity submit the report and associated raw data to IBSA as an IBSA data package. All survey data collected at the Project was provided electronically following the completion of the surveys to comply with IBSA data standards.

### 3. RESULTS & DISCUSSION

#### 3.1. Fauna Desktop Assessment

##### 3.1.1. Terrestrial Fauna

To provide information to support the current assessment, eight fauna surveys and two internal database reports were accessed as part of the desktop assessment. This includes three opportunistic assessments, three basic assessments with a targeted component, one site visit and one detailed assessment also with a targeted component. Three reports include SRE assessments which are detailed below in Section 3.1.3. Details of the completed database searches are listed in Table 2.1, and the previous assessments are shown in Map 2.1.

The literature review and database searches identified 16 non-volant native mammals, 11 introduced mammals, 10 bats, 159 birds, 77 reptiles and six amphibians previously recorded in the region surrounding the Study Area. Two invertebrate species listed on the EPBC Act and one DBCA Priority species were also included. A summary of the total number of species identified during the desktop assessment is presented in Table 3.1 below.

**Table 3.1: Summary of Terrestrial Fauna Species Previously Recorded**

Data Source	Level of Survey	Mammals (Native/ Introduced)	Birds	Bats	Reptiles	Amphibians	EPBCA Listed Invertebrates	Total
<b>Within Study Area</b>								
Marianna Partners (Marianna Partners - Environmental Services, 1996a)	Opportunistic	-/2	3	-	-	-	-	5
Marianna Partners (Marianna Partners - Environmental Services, 1996b)	Opportunistic	-/2	4	-	-	-	-	6
GHD (GHD, 2009)	Level 1	3/3	29	-	8	-	-	43
Eco Logical (2016d)	Level 1, Targeted & SRE	2/5	40	-	13	1	-	61
<b>Regional (with distance away)</b>								
Spectrum Ecology (Spectrum Ecology, 2020); 0 km	Desktop & Site Visit	1/1	16	-	-	-	-	18
Onshore (Onshore Environmental	Level 2 & Targeted	3/5	45	5	15	-	-	73



Data Source	Level of Survey	Mammals (Native/ Introduced)	Birds	Bats	Reptiles	Amphibians	EPBCA Listed Invertebrates	Total
Consultants, 2021); 15 km								
GHD (GHD, 2005); 50 km	Level 1	1/1	17	-	-	-	-	19
Phoenix (Phoenix Environmental Sciences, 2018); 55 km	Level 1 Vert. & Level 2 SRE	-/3	19	2	9	-	-	33
<b>Database</b>								
Spectrum Ecology Internal	Basic	1/3	34	6	7	-	-	51
NatureMap	Desktop	15/6	137	8	75	6	2	249
DBCA Threatened Fauna	Desktop	1	17	-	1	-	2	20
PMST	Desktop	10/8	17	-	1	-	2	38
<b>Total</b>		<b>16/11</b>	<b>159</b>	<b>10</b>	<b>77</b>	<b>6</b>	<b>2</b>	<b>284</b>

### 3.1.2. Conservation Significant Fauna

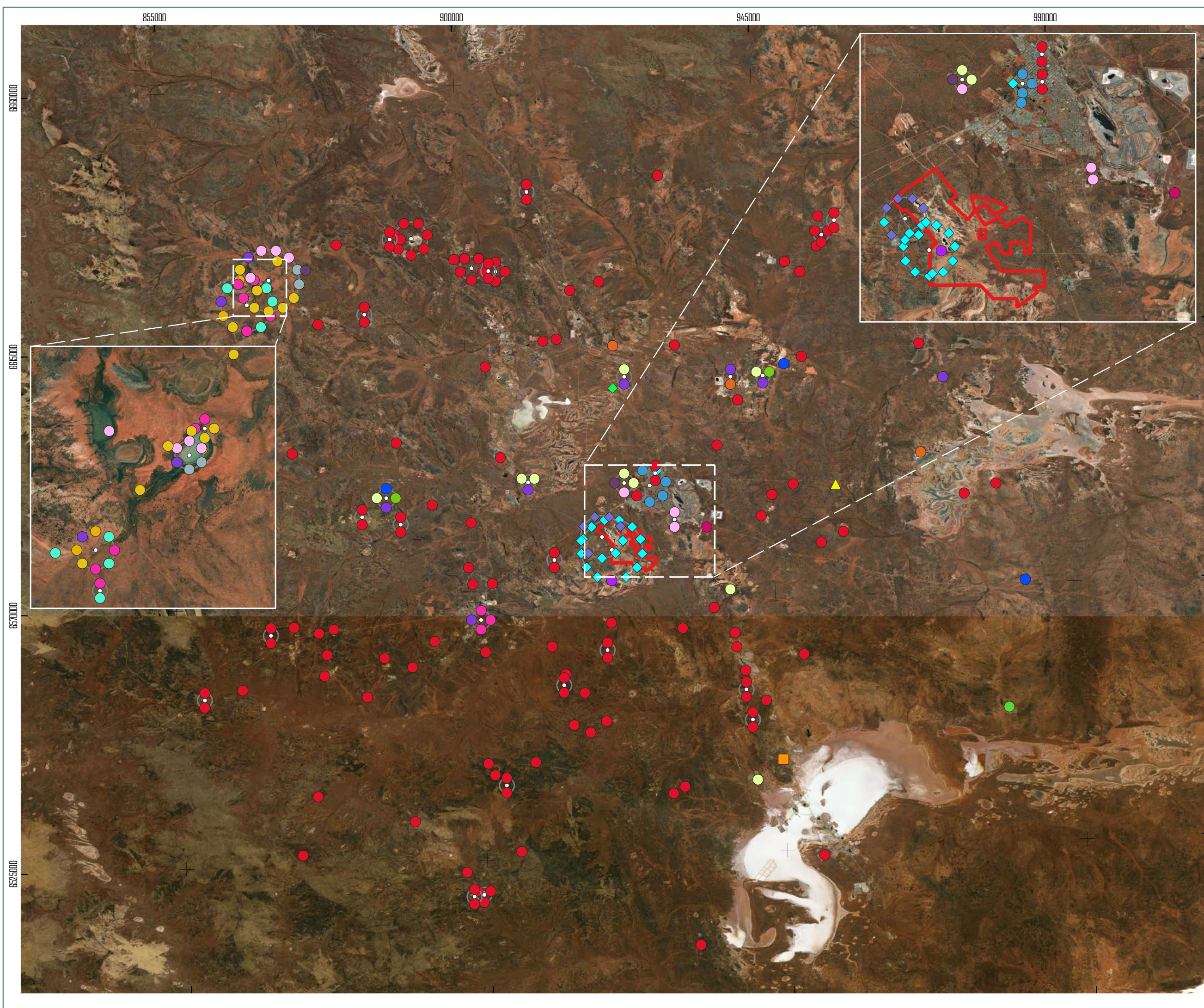
The desktop assessment identified 29 conservation significant fauna species potentially occurring within the Study Area, including three mammals, 22 birds, one reptile and three invertebrates (Table 3.2). Of these, 15 species are considered to have a Medium to High likelihood of occurrence based on their known distributions and the habitats occurring within the Study Area. The remaining 14 species identified in the desktop assessment are considered to have a low likelihood of occurring in the Study Area. Those species identified by the DBCA database search are shown in Map 3.1. Definitions of the relevant conservation status codes are also shown in Appendix B.

Table 3.2: Significant Fauna Recorded during Databases Searches

Species	Conservation Status			Database Record			Likelihood Eco Logical (2016d)	No. Surveys Recorded	Preliminary Likelihood of Occurrence
	EPBC Act	BC Act	DBCA	PMST	DBCA	NatureMap			
<b>Mammals</b>									
Numbat, Walpurti <i>Myrmecobius fasciatus</i>	EN	EN	-	P	P	-	No		Very Low
Chuditch, Western Quoll <i>Dasyurus geoffroii</i>	VU	VU	-	P	-	-	Not assessed		Very Low
Greater Bilby, Dalgyte, Ninu <i>Macrotis lagotis</i>	VU	VU	-	-	P	-	No		Very Low
<b>Birds</b>									
Curlew Sandpiper <i>Calidris ferruginea</i>	CR, MI	CR	-	P	P	P	Potential	0	Medium
Night Parrot <i>Pezoporus occidentalis</i>	EN	CR	-	P	-	-	No	0	Very Low
Carnaby's Cockatoo <i>Calyptrorhynchus latirostris</i>	EN	EN	-	-	P	P	Not assessed	0	Medium
Malleefowl <i>Leipoa ocellata</i>	VU	VU	-	P	P	P	Potential	1	Medium
Grey Falcon <i>Falco hypoleucos</i>	-	VU	-	P	-	-	Not assessed	0	Low
Common Greenshank <i>Tringa nebularia</i>	MI	MI	-	P	P	P	Potential	0	High
Common Sandpiper <i>Tringa hypoleucos</i>	MI	MI	-	P	P	P	Not assessed	0	Medium
Fork-tailed Swift <i>Apus pacificus</i>	MI	MI	-	P	-	-	Potential	0	Medium
Glossy Ibis <i>Plegadis falcinellus</i>	MI	MI	-	-	P	-	Likely	0	Low
Grey-tailed Tattler <i>Tringa brevipes</i>	MI	MI	-	-	P	P	Not assessed	0	Low
Grey Wagtail <i>Motacilla cinerea</i>	MI	MI	-	P	-	-	No	0	Low
Oriental Plover <i>Charadrius veredus</i>	MI	MI	-	P	-	-	Not assessed	0	Medium
Pectoral Sandpiper <i>Calidris melanotos</i>	MI	MI	-	P	-	-	Not assessed	0	Low
Red-necked Stint <i>Calidris ruficollis</i>	MI	MI	-	-	P	P	Potential	0	High

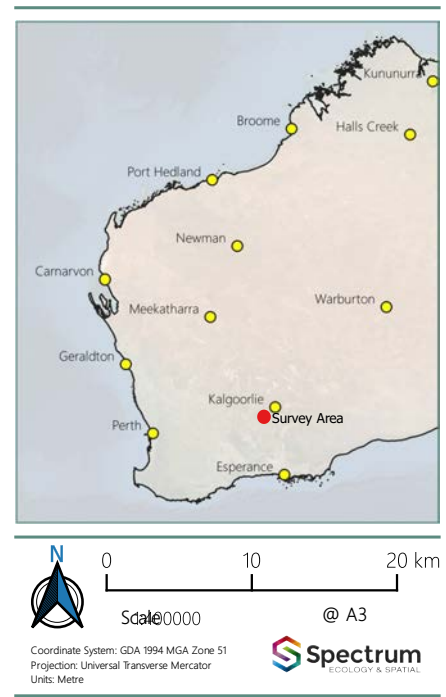
Species	Conservation Status			Database Record			Likelihood Eco Logical (2016d)	No. Surveys Recorded	Preliminary Likelihood of Occurrence
	EPBC Act	BC Act	DBCA	PMST	DBCA	NatureMap			
Ruddy Turnstone <i>Arenaria interpres</i>	MI	MI	-	P	-	-	Not assessed	0	Very Low
Sanderling <i>Calidris alba</i>	MI	MI	-	-	P	P	Not assessed	0	Low
Sharp-tailed Sandpiper <i>Calidris acuminata</i>	MI	MI	-	P	P	P	Likely	0	Medium
Wood Sandpiper <i>Tringa glareola</i>	MI	MI	-	-	P	P	Potential	0	High
Peregrine Falcon <i>Falco peregrinus</i>	-	OS	-	-	P	-	Not assessed	0	Medium
Blue-billed Duck <i>Oxyura australis</i>	-	-	P3	-	P	-	Not assessed	0	Low
Hooded Plover <i>Thinornis rubricollis</i>	-	-	P4	P	P	P	Potential	0	Medium
Western Rosella <i>Platycercus icterotis xanthogenys</i>	-	-	P4	-	-	-	Not assessed	0	Medium
<b>Reptiles</b>									
Western Spiny-tailed Skink <i>Egernia stokesii badia</i>	EN	VU	-	-	P	P	No	0	Very Low
<b>Invertebrates</b>									
Arid Bronze Azure Butterfly <i>Ogyris subterrestris subsp. petrina</i>	CR	CR	-	P	P	P	Not assessed	0	Medium
Inland Hairstreak Butterfly <i>Jalmenus aridus</i>	-	-	P1	-	P	P	Not assessed	0	Medium
Aquatic Fairy Shrimp <i>Branchinella denticulata</i>	-	-	P3	-	P	P	Not assessed	0	Low





Legend

- Survey Area
- Fairy Shrimp
- Arid Bronze Azure Butterfly
- Blue-billed Duck
- Carnaby's Cockatoo
- Chuditch/ Western Quoll
- Common Greenshank
- Common Sandpiper
- Curlew Sandpiper
- Glossy Ibis
- Grey-tailed Tattler
- hooded plover, hooded dotterel
- Hooded Plover, Hooded Dotterel
- Inland Hairstreak Butterfly
- malleefowl
- Malleefowl
- Oriental Plover
- Peregrine Falcon
- Red-necked Stint
- Ruddy Turnstone
- Sanderling
- Sharp-tailed Sandpiper
- Western Rosella (inland)
- Western Spiny-tailed Skink
- Wood Sandpiper



Author: JH    Approved: AH    Date: 18-02-2022

DBCA Threatened Fauna Database Search Results

Binduli South



### 3.1.3. SRE Invertebrate Fauna

The literature review identified two reports with level 2 SRE components, including one in the Study Area (Eco Logical Australia, 2016d) and another 55 km to the south (Phoenix Environmental Sciences, 2018b) (Map 2.1). A desktop survey report covering both the Binduli North and South areas has also previously been completed (Eco Logical Australia, 2016e).

The West Australian Museum database search identified 12 Arachnid (five Mygalomorph, five Araneomorph and two Pseudoscorpion), five Polydesmid millipede, one Isopod and two Mollusc taxa of SRE fauna recorded within 100 km of the Study Area (Table 3.3; Map 3.2). Other previous surveys in the region have identified an additional 18 Mygalomorph, seven Araneomorph, eight Pseudoscorpion, three Scorpion, three Polydesmid, two Crustacean, 15 Mollusc and two Carabid taxa of confirmed or potential SREs (Table 3.3).

None of the confirmed or potential SRE invertebrate taxa recorded by the Eco Logical (2016d) survey are expected to be restricted to the Study Area, as all of the SRE fauna habitats were determined to be contiguous and widespread in the region.

**Table 3.3: SRE Invertebrate Taxa Recorded in the Region**

Class/Order/Family	Taxa	Binduli Desktop (Eco Logical, 2016d)	Binduli Level 2 Survey (Eco Logical, 2016b)	St Ives Survey (Phoenix 2018b)	WAM SRE Database (2021)
<b>Mygalomorphae (Spiders)</b>					
Actinopodidae	<i>Missulena harewoodi</i>				✓
Nemesiidae	<i>Aname</i> 'MYG213'	P			
	<i>Aname</i> 'MYG223'	P		P	
	<i>Aname</i> 'MYG347-DNA'	P			
	<i>Aname</i> 'SIGM121'			P	
	<i>Aname</i> 'SIGM122'			P	
	<i>Aname</i> sp. indet.			P	
	<i>Chenistonia</i> 'sp. indet. (male)'	P			
	<i>Kwonkan goongarriensis</i>	P			
	<i>Kwonkan</i> sp. nov.		P		
	<i>Kwonkan</i> sp. indet.			P	
	<i>Teyl</i> 'sp. indet. (door building sp.?)'	P			
	Nemesiidae 'SIGM104'			P	
Barychelidae	<i>Idiommatia</i> 'kalgoorlie'				✓
	<i>Synothele goongarrie</i>	P			
Halonoproctidae	<i>Conothele</i> 'MYG554'				✓
Idiopidae	<i>Aganippe</i> 'goldfields sp. group'	P			
	<i>Aganippe</i> 'MYG191'	P			
	<i>Aganippe</i> 'MYG244'	P			
	<i>Aganippe</i> 'MYG256'		P		
	<i>Aganippe</i> sp. indet.			P	

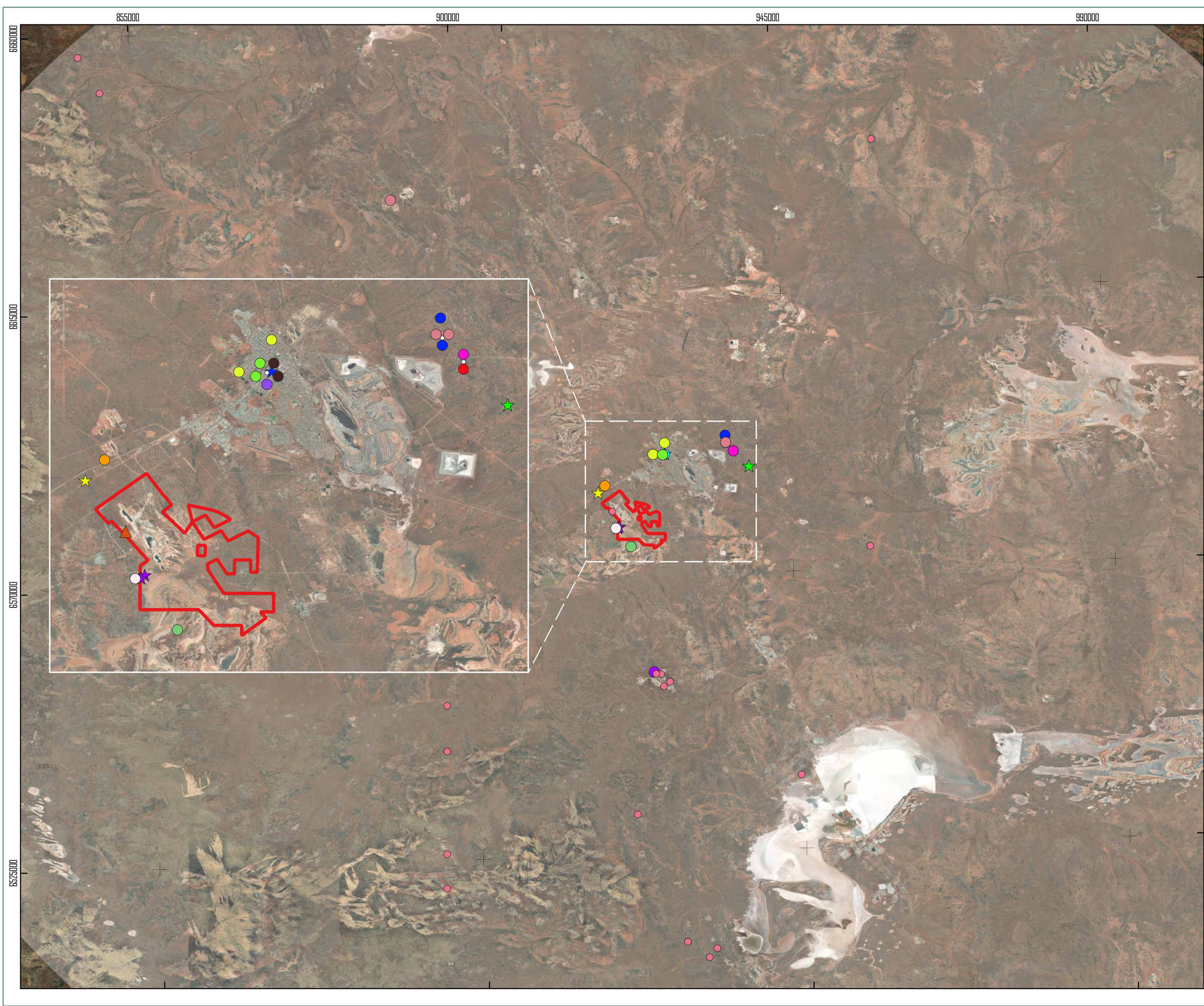
Class/Order/Family	Taxa	Binduli Desktop (Eco Logical, 2016d)	Binduli Level 2 Survey (Eco Logical, 2016b)	St Ives Survey (Phoenix 2018b)	WAM SRE Database (2021)
Idiopidae	<i>Idiopidae</i> 'gen. indet.' 'sp. indet.'		P		
	<i>Idiosoma</i> 'goldfields sp. group'	P			✓
	<i>Idiosoma</i> 'kalgoorlie'				✓
<b>Araneomorphae (Spiders)</b>					
Araneidae	<i>Heuroides</i> 'sp. Indet. (juvenile)'				✓
Corinnidae	<i>Poecilopoda rawlinsonae</i>				✓
Oxyopidae	<i>Oxyopes</i> 'salinus'				✓
Salticidae	<i>Holoplatys kalgoorlie</i>				✓
	<i>Maratus</i> 'PES0340'			P	
Zodariidae	<i>Neostorena</i> 'sp. Indet'				✓
Lycosidae	<i>Tetranychus</i> 'baudineti'	C		C	
	<i>Tetranychus</i> 'sp indet.'			P	
Myrmecopidae	<i>Myrmecopidae</i> 'sp. 01'	P			
	<i>Myrmecopidae</i> 'sp. 03'	P			
	' <i>Myrmecopidae</i> ?' 'sp. 06'	P			
Trochanteridae	<i>Trachyspina goongarrie</i>	P			
<b>Pseudoscorpiones (Pseudoscorpions)</b>					
Chthoniidae	<i>Austrochthonius</i> 'sp. Indet. or sp. nov.?'		P		✓
Chernetidae	<i>Nesidiochernes</i> 'sp. Indet.'		P		✓
	<i>Conicochernes</i> 'PSE024'	P			
	<i>Conicochernes</i> 'sp. Nov.'	P			
	<i>Conicochernes</i>	P			
Garypidae	<i>Synsphyronus</i> 'PSE025'	P			
	<i>Synsphyronus</i> 'PSE078'	P			
	<i>Amblyolpium</i> 'sp. Indet. (juvenile)'	P			
	<i>Amblyolpium</i> 'sp.'	P			
Oliopidae	<i>Beierolpium</i> 'sp. 8/4'		P		
<b>Scorpiones (Scorpions)</b>					
Buthidae	<i>Lychas</i> 'SIGM132'			P	
Urodacidae	<i>Urodacus</i> 'SIGM131'			P	
	<i>Urodacus</i> 'Lefroy'			P	
<b>Polydesmida (Millipedes)</b>					
Paradoxosomatidae	<i>Antichiropus</i> 'binduli'		C		
	<i>Antichiropus</i> 'broad arrows'				✓
	<i>Antichiropus</i> 'DIP065'				✓



Class/Order/Family	Taxa	Binduli Desktop (Eco Logical, 2016d)	Binduli Level 2 Survey (Eco Logical, 2016b)	St Ives Survey (Phoenix 2018b)	WAM SRE Database (2021)
Paradoxosomatidae	<i>Antichiropus</i> `DIP067`				✓
	<i>Antichiropus</i> `kalgoorlie, DIP145`		C		✓
	<i>Antichiropus incomptus</i>	C			
	<i>Antichiropus nadineae</i>	C			
<b>Isopoda (Slaters)</b>					
Armadillidae	<i>Buddelundia frontosa</i>				✓
Philosciidae	Philosciidae `lefroy`			P	
	<i>Cubaris</i> `lefroy`			P	
<b>Mollusca (Snails)</b>					
Camaenidae/ Bothriembryontidae	-		P		
Camaenidae	<i>Sinumelon cf. jimberlanensis</i>	P			✓
	<i>Sinumelon sp. (juv.)</i>	P			
	<i>Sinumelon sp.</i>	P			
	<i>Sinumelon cf. vagente</i>	P			
	<i>Sinumelon cf. kalgum</i>	P			
	<i>Sinumelon kalgum</i>	P			
Bothriembryontidae	<i>Bothriembryon cf. sedgwicki</i>	P			
	<i>Bothriembryon sp.</i>	P			✓
	<i>Bothriembryon</i> `Coolgardie` <i>sp. Nov.</i>	P			
Punctidae	<i>Westralaoma expicta</i>	P			
	<i>Westralaoma cf. expicta</i>	P			
	<i>Westralaoma sp.</i>	P			
Pupillidae	<i>Pupilla cf. ficulnea</i>	P			
Succineidae	<i>Succinea sp.</i>	P			
	<i>Succinea aridicola</i>	P			
	<i>Succinea cf. aridicola</i>	P			
<b>Coleoptera (Beetles)</b>					
Carabidae	<i>Cicindela salicursoria</i>			P	
	<i>Cicindela necopinata</i>			P	

C = Confirmed SRE; P = Potential SRE





Legend

- Survey Area
- WAM\_Arachnida\_only
- Austrochthonius 'sp. indet. or sp. nov?'
- Conothele 'MYG554'
- Heurodes 'sp. indet. (juvenile)'
- Holoplatys kalgoorlie
- Idiommatata 'kalgoorlie'
- Idiosoma 'goldfields sp. group'
- Idiosoma 'kalgoorlie'
- Missulena harewoodi
- Neostorena 'sp. indet.'
- Nesidiochernes 'sp. indet.'
- Oxyopes 'salinus'
- Poecilipta rawlinsonae
- Diplopods
- Antichiropus 'broad arrows'
- Antichiropus 'DIP065'
- Antichiropus 'DIP067'
- Antichiropus 'kalgoorlie'
- Cylindroiulus britannicus
- Crustaceans
- Buddelundia frontosa



N

0 5 10 15 km

Scale 1:10000

@ A3

Coordinate System: GDA 1994 MGA Zone 51  
Projection: Universal Transverse Mercator  
Units: Metre

Spectrum

ECOLOGY • SPATIAL

Author: JH    Approved: AH    Date: 18-02-2022

WAM SRE Database  
Search Results

Binduli South

MAP  
3.2

Prepared for  
Talis Consultants | Norton



## 3.2. Basic Assessment

### 3.2.1. Terrestrial Fauna

A total of 47 vertebrate fauna species were recorded during the survey: two native mammals, two introduced mammals, 35 birds, and eight reptile species (Table 3.4, Appendix A). No conservation significant vertebrate fauna were recorded during the survey.

**Table 3.4: Vertebrate Fauna Recorded at the Survey Area**

Common name	Scientific name	Details
<b>Mammals</b>		
Western Grey Kangaroo	<i>Macropus fuliginosus</i>	
Euro	<i>Macropus robustus</i>	
Rabbit*	<i>Oryctolagus cuniculus</i>	Scats, diggings, burrows, skeleton, sightings
Goat*	<i>Capra aegagrus hircus</i>	Scats and two skeletons
<b>Birds</b>		
Emu	<i>Dromaius novaehollandiae</i>	
Tawny Frogmouth	<i>Podargus strigoides</i>	
Spotted Nightjar	<i>Eurostopodus argus</i>	
Fan-tailed Cuckoo	<i>Cacomantis flabelliformis</i>	
Crested Pigeon	<i>Ocyphaps lophotes</i>	
Wedge-tailed Eagle	<i>Aquila audax</i>	
Rainbow Bee-eater	<i>Merops ornatus</i>	
Australian Kestrel	<i>Falco cenchroides</i>	
Mulga Parrot	<i>Psephotellus varius</i>	
White-winged Fairy-wren	<i>Malurus leucopterus</i>	
Singing Honeyeater	<i>Gavicalis virescens</i>	
Yellow-Plumed Honeyeater	<i>Ptilotula ornata</i>	
Grey-fronted Honeyeater	<i>Ptilotula plumula</i>	
Red Wattlebird	<i>Anthochaera carunculata</i>	
Spiny-cheeked Honeyeater	<i>Acanthagenys rufogularis</i>	
Yellow-throated Miner	<i>Manorina flavigula</i>	
Striated Pardalote	<i>Pardalotus striatus</i>	
Weebill	<i>Smicrornis brevirostris</i>	
Inland Thornbill	<i>Acanthiza apicalis</i>	
White-browed Babbler	<i>Pomatostomus superciliosus</i>	
Black-faced Woodswallow	<i>Artamus cinereus</i>	
Australian Magpie	<i>Gymnorhina tibicen</i>	
Grey Butcherbird	<i>Cracticus torquatus</i>	
Pied Butcherbird	<i>Cracticus nigrogularis</i>	
Grey Currawong	<i>Strepera versicolor</i>	
Black-faced Cuckoo-shrike	<i>Coracina novaehollandiae</i>	
Crested Bellbird	<i>Oreoica gutturalis</i>	
Rufous Whistler	<i>Pachycephala rufiventris</i>	



Common name	Scientific name	Details
Grey Shrike-thrush	<i>Colluricincla harmonica</i>	
Willie Wagtail	<i>Rhipidura leucophrys</i>	
Australian Raven	<i>Corvus coronoides</i>	
Hooded Robin	<i>Melanodryas cucullata</i>	
Welcome Swallow	<i>Hirundo neoxena</i>	
Tree Martin	<i>Petrochelidon nigricans</i>	
Australian Pipit	<i>Anthus australis</i>	
<b>Reptiles</b>		
Western Beaked Gecko	<i>Rhynchoedura ornata</i>	
Marble-faced Delma	<i>Delma australis</i>	
Bicycle Dragon	<i>Ctenophorus cristatus</i>	
Salt Pan Dragon	<i>Ctenophorus salinarum</i>	
Lozenge-marked Dragon	<i>Ctenophorus scutulatus</i>	
Southern Spinifex Ctenotus	<i>Ctenotus atlas</i>	
Bobtail	<i>Tiliqua rugosa</i>	Sightings and skeleton
Sand Monitor	<i>Varanus gouldii</i>	

\* Introduced species

### 3.2.2. Eco Logical (2016d) Fauna Habitats

The previous fauna survey undertaken by Eco Logical (2016d) included a habitat assessment, where six broad fauna habitat types were determined to occur in the Study Area as outlined in Table 3.5 and Map 3.3.

**Table 3.5: Eco Logical (2016d) Fauna Habitat Types**

Fauna Habitat	Description	Area (ha) Mapped in Survey Area	% of Study Area
1	Mixed open shrublands on red sandy loam	853.6	14.3
2	Mixed open <i>Eucalyptus</i> woodlands on red clay loam and gravel or pebble rises	3,093.4	51.7
3	Sparse <i>Eucalyptus-Callitris</i> woodland on gypsum rises	215.0	3.6
4	Chenopod shrublands on clay pans and flats	1,077.6	18.0
5	<i>Melaleuca</i> open shrublands on seasonally wet claypans	44.1	0.7
6	<i>Acacia</i> open shrubland on granitic sandy loam	45.3	0.8
-	Previously cleared areas (mining operations, tracks/roads etc.)	654.1	10.9
	<b>Total</b>	<b>5983.1</b>	<b>100.0</b>

The Study Area was dominated by mixed open *Eucalyptus* woodlands (51.7%) as well as chenopod shrublands (18%) and mixed open shrublands (14.3%) (Eco Logical 2016d).



344000

348000

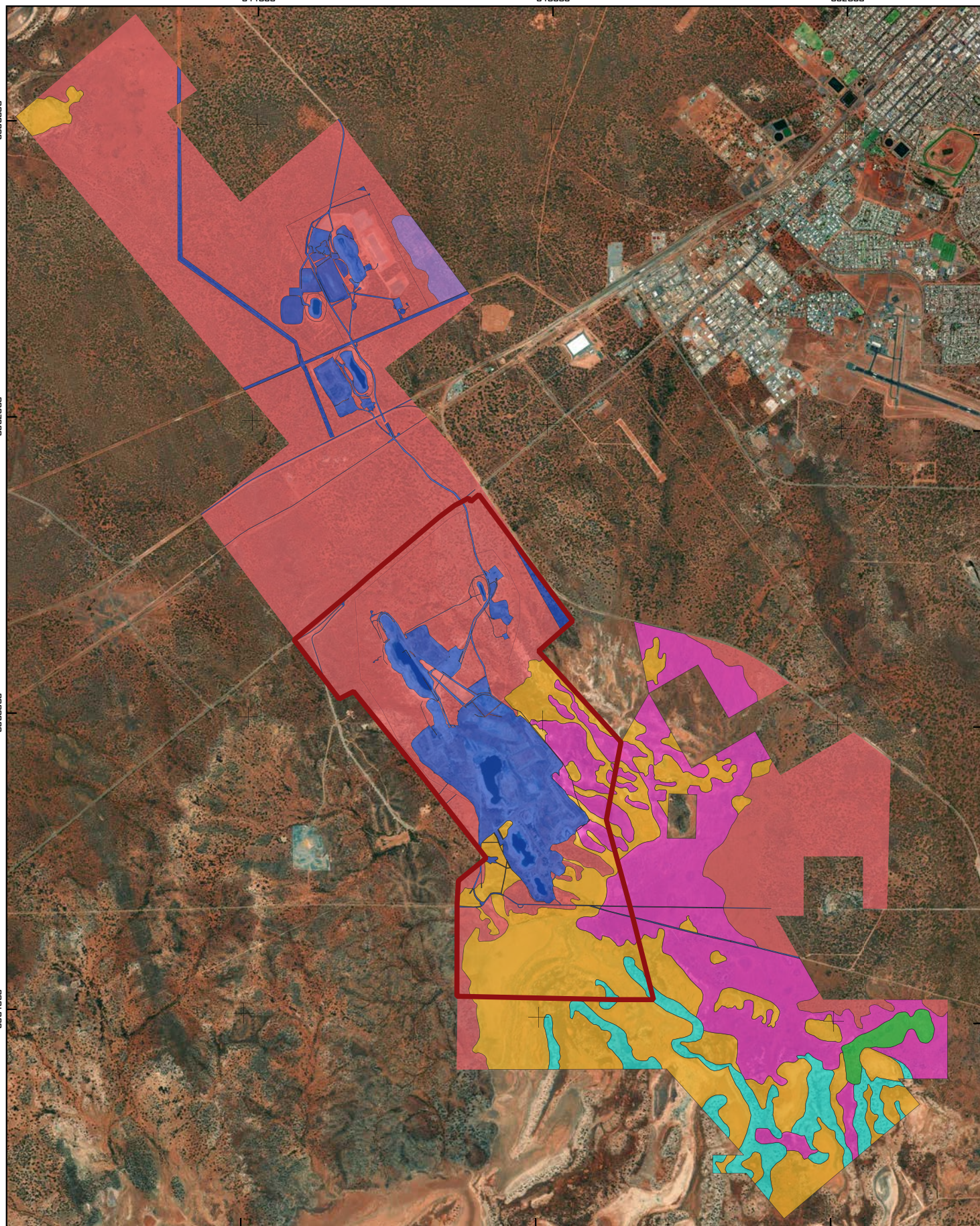
352000

6596000

6592000

6588000

6584000



### Legend

Survey Area

### Vegetation\_Communities

- 1
- 2
- 3

4

5

6

Existing Mining Operations  
Tracks  
Roads



0 0.5 1 1.5 2 km

Scale 1:80000

@ A4

Coordinate System: GDA 1994 MGA Zone 51  
Projection: Transverse Mercator  
Units: Meter

Spectrum  
ECOLOGICAL & SPATIAL

Author: EM

Date: 18-02-2022

Fauna Habitat Mapping of the  
Study Area (Eco Logical 2016b)

Binduli South

Prepared for Talis  
Consultants/Norton

Map  
3.3



### 3.2.3. Current Assessment – Fauna Habitats

Ten major habitat types, including cleared areas, were recorded from the Survey Area and were based on the updated vegetation mapping by Spectrum (Spectrum Ecology, 2022b) and previous fauna habitat mapping by Eco Logical (2016d). Their extents are listed in Table 3.6 and shown on Map 3.4. Detailed habitat descriptions can be found in the following sections.

**Table 3.6: Fauna Habitats in the Survey Area**

Fauna Habitat No.	Habitat Type	Eco Logical (2016d) Habitat No.	Spectrum (Spectrum Ecology, 2022b) Vegetation Type	Extent Survey Area (ha)	% of Survey Area
1	Mixed Eucalypt open woodland over mixed shrubland on undulating plains on red-orange sandy clay soils	1	P1	467.0	28%
2	Mixed Eucalypt low woodland with sparse shrubs over low hummock grassland on orange sandplains	1	P2	67.7	4%
3	<i>Allocasuarina</i> over mixed shrubland on rocky plains and rises	1	P3	24.6	1%
4	<i>Acacia</i> and <i>Eremophila</i> shrubland on sandplains and floodplains on orange clay loam to sand	6	P4 & P5	159.8	10%
5	<i>Acacia</i> shrubland on rocky granitic slopes	6	S1	69.6	4%
6	<i>Callitris</i> and Eucalypt woodland over sparse shrubland on Kopi and gypseous dunes	3	S2	12.0	1%
7	Eucalypt woodland over mixed shrubland on low rocky hills with ironstone and quartz over red-orange sandy-clay	1	S3	26.9	2%
8	Eucalypt woodland over mixed shrubland in drainage lines on red-orange sandy-clay-loam	1	D1	18.7	1%
9	Low sparse chenopod shrubland on salt lakes and salt pans	4	D2, D3 & D4	333.7	20%
10	Cleared areas	NA	-	473.5	29%
Total				1,653.6	



### 3.2.3.1. Mixed Eucalypt open woodland over mixed shrubland on undulating plains on red-orange sandy clay soils

The mixed open woodland habitat was the most common habitat type covering 467.0 ha, representing 28% of the Survey Area. This habitat type is located mainly within the northern part of the Survey Area and is intersected by cleared areas from previous mining activities and tracks. This habitat was dominated by *Eucalyptus griffithsii*, *Eucalyptus lesouefii*, and *Eucalyptus oleosa* subsp. *oleosa* mid open woodland over mid-tall sparse shrubland of *Eremophila scoparia*, *Senna artemisioides* subsp. *filifolia*, and *Scaevola spinescens*, over low open shrubland of *Atriplex vesicaria* and *Maireana sedifolia* (Figure 3.1). The ground layer consisted of red-orange sandy-clay soils with common to abundant leaf litter and moderate woody debris.

This habitat type also contained Salmon Gum (*Eucalyptus salmonophloia*), which was restricted to the north-eastern boundary of the Survey Area. In addition, Gimlet (*Eucalyptus salubris*) was also recorded and occurred only in the northern section of this habitat type.



Figure 3.1: Mixed Eucalypt open woodland over mixed shrubland on undulating plains on red-orange sandy clay soils



### 3.2.3.2. Mixed Eucalypt low woodland with sparse shrubs over low hummock grassland on orange sandplains

The mixed low woodland over low hummock grasslands habitat type covered 67.7 ha, representing 4% of the Survey Area. This habitat type was located in the middle of the Survey Area, near the salt lakes. It was characterised by *Eucalyptus flocktoniae* subsp. *flocktoniae* and *Eucalyptus cylindrocarpa* low woodland over tall sparse shrubs of *Acacia hemiteles*, *Grevillea sarissa* subsp. *bicolor*, *Melaleuca hamata* over *Triodia scariosa* low open hummock grassland (Figure 3.2). The substrate consisted of orange sand with moderate leaf litter and woody debris.



Figure 3.2: Mixed Eucalypt low woodland with sparse shrubs over low hummock grassland on orange sandplains



### 3.2.3.3. *Allocasuarina* over mixed shrubland on rocky plains and rises

The *Allocasuarina* over mixed shrubland was recorded from only one patch, located on the western boundary of the Survey Area on rocky plains and rises (Map 3.4). This habitat type covered 24.6 ha or just 1% of the Survey Area. The vegetation was dominated by *Allocasuarina corniculata* low isolated trees over tall open shrubland of *Acacia tetragonophylla*, *Dodonaea lobulata* and *Eremophila oldfieldii* subsp. *angustifolia*, over low sparse shrubland of *Scaevola spinescens*, *Senna artemisioides* subsp. *filifolia* and *Ptilotus obovatus*. The substrate consisted of red-orange sandy-clay soils with abundant ironstone rocks. Wood and leaf litter was sparse and limited to that found beneath vegetation (Figure 3.3).



Figure 3.3: *Allocasuarina* over mixed shrubland on rocky plains and rises



#### 3.2.3.4. *Acacia* and *Eremophila* shrubland on sandplains and floodplains on orange clay loam to sand

The *Acacia* and *Eremophila* shrubland was located on sandy-clay flood plains surrounding the salt lake and on sand plains between the salt pan, in the south and south-east of the Survey Area. This habitat type covered 159.8 ha, which represents 10% of the Survey Area. The vegetation of this fauna habitat was characterised by *Eremophila scoparia*, *Acacia densiflora*, *Acacia masliniana* and *Eremophila miniata* tall open shrubland over mid open shrubland of *Alyxia buxifolia*, *Scaevola spinescens*, *Exocarpos aphyllus* and *Cratystylis subspinescens* over *Frankenia fecunda* and *Eremophila glabra* subsp. *glabra* low sparse shrubland (Figure 3.4). The substrate varied between orange clay-loam and orange sand with limited leaf and wood litter present.



Figure 3.4: *Acacia* and *Eremophila* shrubland on sandplains and floodplains on orange clay loam to sand



### 3.2.3.5. *Acacia* shrubland on rocky granitic slopes

The *Acacia* shrubland on rocky granitic slopes habitat type was recorded from a few scattered locations throughout the Survey Area, covering 69.6 ha and representing 4% of the total area. This habitat was vegetated by a tall open shrubland of *Acacia acuminata* with some *Melaleuca hamata* over *Eremophila granitica*, *Exocarpos aphyllus*, and *Scaevola spinescens* mid sparse shrubland. The substrate consisted of red-orange sandy-clay with pebbles and rocky outcropping. Some woody debris was present from dead shrubs, with leaf litter restricted to beneath shrubs (Figure 3.5).



Figure 3.5: *Acacia* shrubland on rocky granitic slopes



### 3.2.3.6. *Callitris* and Eucalypt woodland over sparse shrubland on Kopi and gypseous dunes

The *Callitris* and Eucalypt woodland on Kopi and gypseous dunes was the least common habitat type, covering only 12 ha, representing just 1% of the Survey Area. This habitat type was recorded from two small dunes located in the south-east of the Survey Area (Map 3.4). The vegetation was characterised by *Callitris columellaris* with some *Eucalyptus griffithsii* low open woodland over *Dodonaea viscosa* subsp. *angustissima* mid sparse shrubland over a low sparse shrubland of *Lawrenzia helmsii*, *Scaevola spinescens*, and *Rhagodia drummondii* Figure 3.6. The substrate consisted of Kopi dunes and gypseous dunes with limited leaf litter and woody debris.



Figure 3.6: *Callitris* and Eucalypt woodland over sparse shrubland on Kopi and gypseous dunes



### 3.2.3.7. Eucalypt woodland over mixed shrubland on low rocky hills with ironstone and quartz over red-orange sandy-clay

The Eucalypt woodland over mixed shrublands on low rocky hills was recorded from small sections along the western boundary of the Survey Area. This habitat type covered only 26.9 ha, representing 2% of the Survey Area. The vegetation was dominated by *Eucalyptus griffithsii* low open woodland over mid to tall open shrubland of *Eremophila oldfieldii* subsp. *angustifolia*, *Eremophila maculata* subsp. *brevifolia* and *Senna artemisioides* subsp. *filifolia* over *Atriplex vesicaria*, *Scaevola spinescens* and *Ptilotus obovatus* low sparse shrubland (Figure 3.7). The soil was a red-orange sandy-clay beneath a layer of ironstone and quartz. Leaf litter was limited to under trees, and wood litter was abundant.



Figure 3.7: Eucalypt woodland over mixed shrubland on low rocky hills with ironstone and quartz over red-orange sandy-clay



### 3.2.3.8. Eucalypt woodland over mixed shrubland in drainage lines on red-orange sandy-clay-loam

The Eucalypt woodland over mixed shrubs in drainage lines was recorded from two areas intersecting the mixed Eucalypt open woodland over mixed shrubland on undulating plains on red-orange sandy clay soils habitat type. This habitat type covered 18.7 ha, representing just 1% of the Survey Area. The vegetation was characterised by *Eucalyptus salubris* and/or *Eucalyptus longissima* low open woodland over *Acacia acuminata*, *Acacia tetragonophylla*, and *Alyxia buxifolia* tall shrubland, over a mid open shrubland of *Dodonaea lobulata* and *Scaevola subspinescens*. The substrate was red-orange sandy-clay-loam with a few scattered ironstone rocks. This habitat type had abundant leaf litter and moderate woody debris present.



Figure 3.8: Eucalypt woodland over mixed shrubland in drainage lines on red-orange sandy-clay-loam

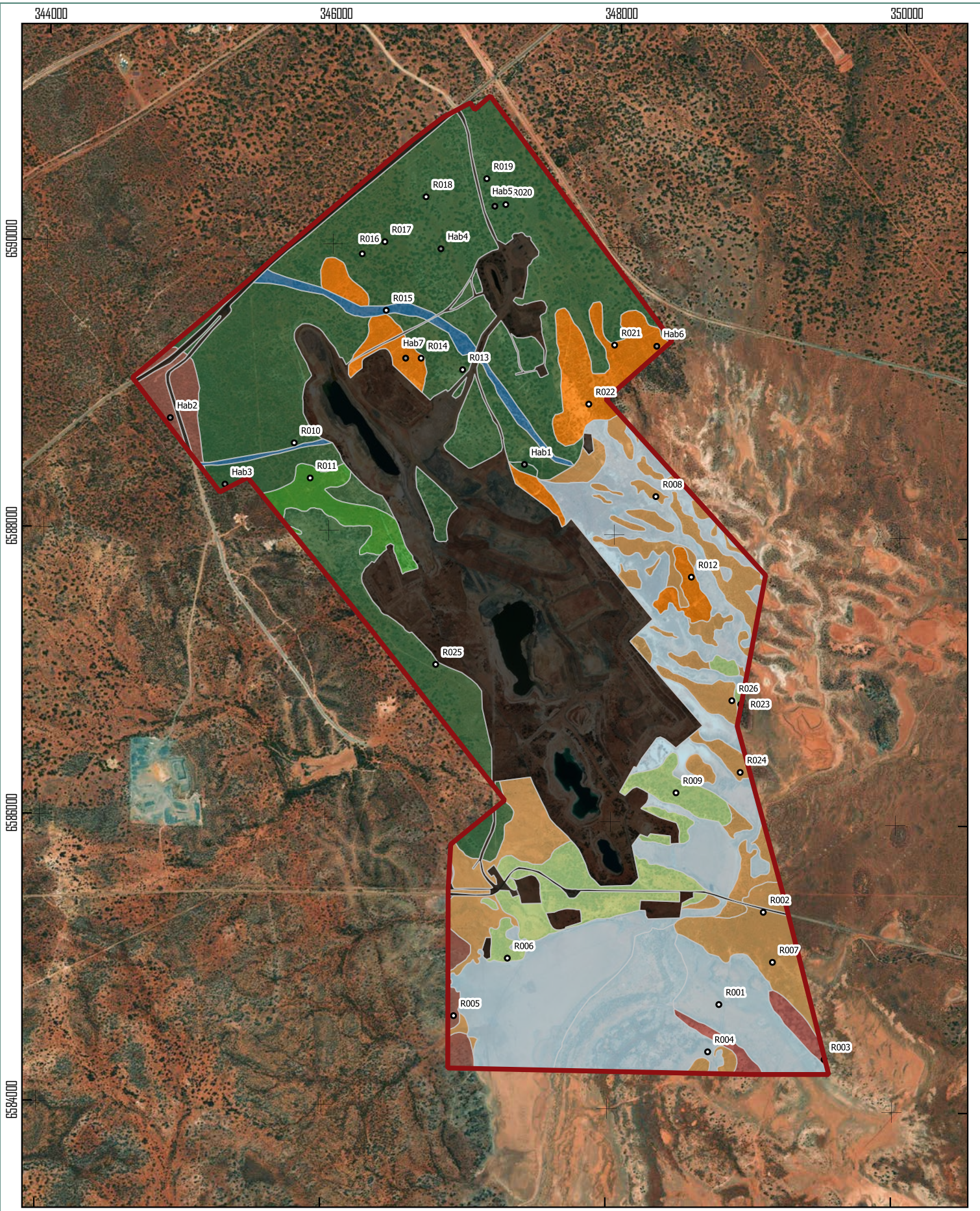
### 3.2.3.9. Low sparse chenopod shrubland on salt lakes and salt pans

This habitat type is the combination of three vegetation types due to their similarity from a faunal habitat perspective. This habitat type is located on the salt lake, salt pans and margins of the salt pans, which includes large areas of the southern and south-eastern parts of the Survey Area (Map 3.4). It was the second most common habitat type, occupying 333.7 ha and 20% of the Survey Area. The vegetation was dominated by *Tecticornia indica* subsp. *bidens*, *Tecticornia disarticulata*, *Atriplex vesicaria*, *Cratystylis subspinescens*, *Frankenia interioris*, *Surreya diandra*, *Atriplex holocarpa* and *Olearia exiguiifolia* low sparse shrubland. The substrate was a combination of brown-orange, orange to orange-cream clay or sandy-clay. There was minimal wood or leaf litter present.



Figure 3.9: Low sparse chenopod shrubland on salt lakes and salt pans





- Legend**
- Survey Area
  - Fauna Habitat Sites
  - Spectrum 2021 Flora Sites
- Binduli South Fauna Habitats**
- Cleared/Disturbed

- |  |  |
|--|--|
| <span style="display: inline-block; width: 15px; height: 15px; background-color: #4F81BD; vertical-align: middle;"></span> FHab1 | <span style="display: inline-block; width: 15px; height: 15px; background-color: #C44E52; vertical-align: middle;"></span> FHab6 |
| <span style="display: inline-block; width: 15px; height: 15px; background-color: #99CC99; vertical-align: middle;"></span> FHab2 | <span style="display: inline-block; width: 15px; height: 15px; background-color: #A67C8D; vertical-align: middle;"></span> FHab7 |
| <span style="display: inline-block; width: 15px; height: 15px; background-color: #4CAF50; vertical-align: middle;"></span> FHab3 | <span style="display: inline-block; width: 15px; height: 15px; background-color: #42A5F5; vertical-align: middle;"></span> FHab8 |
| <span style="display: inline-block; width: 15px; height: 15px; background-color: #FFCC80; vertical-align: middle;"></span> FHab4 | <span style="display: inline-block; width: 15px; height: 15px; background-color: #BBDEFB; vertical-align: middle;"></span> FHab9 |
| <span style="display: inline-block; width: 15px; height: 15px; background-color: #FF9800; vertical-align: middle;"></span> FHab5 |  |

0      0.4      0.8      1.2 km

Scale 1:40000 @ A4

Coordinate System: GDA 1994 MGA Zone 51  
Projection: Transverse Mercator  
Units: Meter

Author: EM

Date: 18-02-2022



### 3.3. Targeted Assessment

#### 3.3.1. Malleefowl (*Leipoa ocellata*)

No sightings, additional mounds or secondary evidence of Malleefowl were observed during the survey. Surveying of the ABAB transects and botanists tracks were considered sufficient for Malleefowl as the habitat present was considered marginal. The previously identified Malleefowl mound (MFM01: 345018E, 6588970N, GDA94/MGA51) by Eco Logical (2016d) was revisited and found to be eroded and difficult to detect; it is likely a very old (100+ years) mound (Figure 3.10).



Figure 3.10: Malleefowl Mound (MFM01)

### 3.3.2. Carnaby's Cockatoo (*Calyptrorhynchus latirostris*)

No sightings or evidence of Carnaby's Cockatoo were recorded during the survey. A total of 77 trees were recorded within the Survey Area with a DBH above 300 mm during the ABAB sample point surveys (Table 3.7). This included 21 Salmon Gum (*Eucalyptus salmonophloia*), a known breeding tree for this species. Of these, 25 had a DBH of more than 500 mm, including 13 Salmon Gum. Additional Salmon Gum that were not surveyed are likely to meet the minimum DBH requirements of 300 mm or more in the Survey Area. The majority of Salmon Gum are restricted to the north-east of the Survey Area (Map 3.5).

**Table 3.7: Potential Breeding Habitat & Roosting Trees for Carnaby's Cockatoo**

Tree Species	No. of Trees over 300 mm	No. of Trees over 500 mm	Total
Salmon Gum ( <i>Eucalyptus salmonophloia</i> )	8	13	21
All other Eucalypt species	44	12	56
<b>Total</b>	<b>52</b>	<b>25</b>	<b>77</b>

### 3.3.3. Migratory Birds and Hooded Plover

No water was present within White Lake or the surrounding smaller salt lake areas during the survey period. Therefore, no surveys were conducted for Migratory waterbird species or the Hooded Plover.

### 3.3.4. Arid Bronze Azure Butterfly (*Ogyris subterrestris petrina*)

Approximately 35 km of transects were walked, with 217 sample points completed at 160 m spacing (Appendix E). Some of the areas of vegetation mapped by Eco Logical (2016d) as Eucalypt Woodland was not recorded at a fine scale, therefore some areas of unsuitable habitat were excluded during the survey. In addition, not all trees sampled during the survey were smooth-barked; many were mallees with rough-barked stockings.

Four *Camponotus* sp. specimens were collected for identification. Two records came from the base of Salmon Gums, one from Gimlet and one unidentified *Eucalypt* sp.. None of these specimens was identified as the target species (*Camponotus* sp. nr. *terebrans*). The location of the ants and their identifications are outlined in Table 3.8.

**Table 3.8: Potential *Camponotus* sp. nr. *terebrans* Specimens**

Ant ID	Easting*	Northing*	Ant Species
C01	344942	6588926	<i>Camponotus gouldianus</i>
C02	347329	6590278	<i>Camponotus gouldianus</i>
C03	347364	6590516	<i>Camponotus gouldianus</i>
C04	347356	6590469	<i>Camponotus gouldianus</i>

\* - CRS: GDA 1994/MGA 1994, Zone 51

### 3.3.5. Inland Hairstreak Butterfly (*Jalmenus aridus*)

The same 217 sample points used for the ABAB surveys were utilised to survey for the Inland Hairstreak's obligate ant species and the Inland Hairstreak butterfly. In addition, an active search was conducted in a patch of *Acacia* shrubland. The vegetation in the areas surveyed for ABAB contained some plant species that the larvae are thought to feed on, such as *Senna artemisioides* subsp. *filifolia* and *Acacia tetragonophylla* (Braby, 2016). However, no ant specimens similar to the Froglet ant *Froggattella kirbii*, or Inland Hairstreak Butterflies were recorded in the Survey Area.



346000

348000

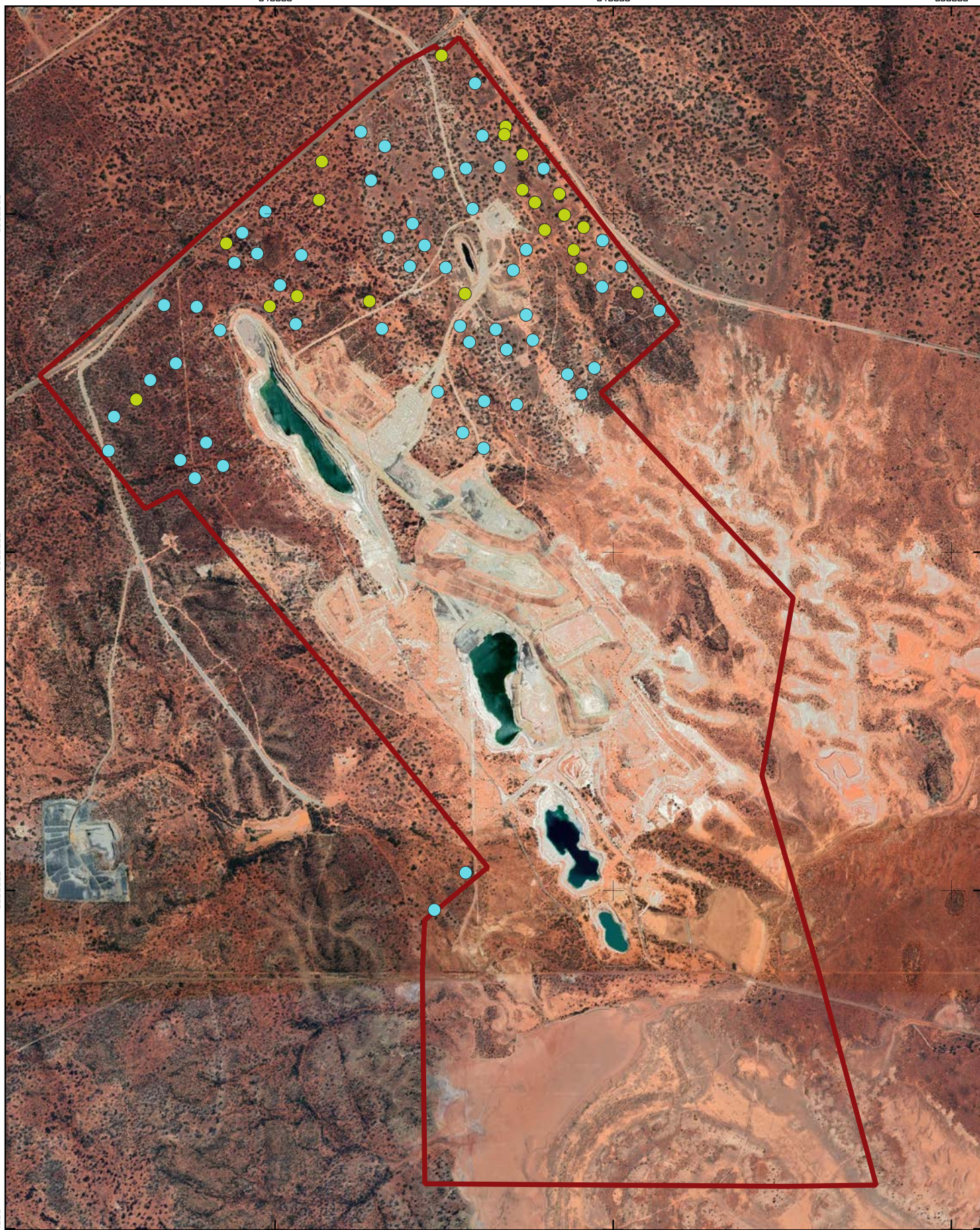
350000

6590000

6588000

6586000

6584000



#### Legend

 Survey Area

#### Trees with DBH > 300 mm

 Salmon Gum

 Other Eucalypt



0 0.4 0.8 1.2 km

Scale 1:30000

@ A4

Coordinate System: GDA 1994 MGA Zone 51  
Projection: Transverse Mercator  
Units: Meter

 **Spectrum**  
ECOLOGICAL & SPATIAL

Author: EM

Date: 18-02-2022

Potential Carnaby's Cockatoo  
Breeding and Roosting Trees

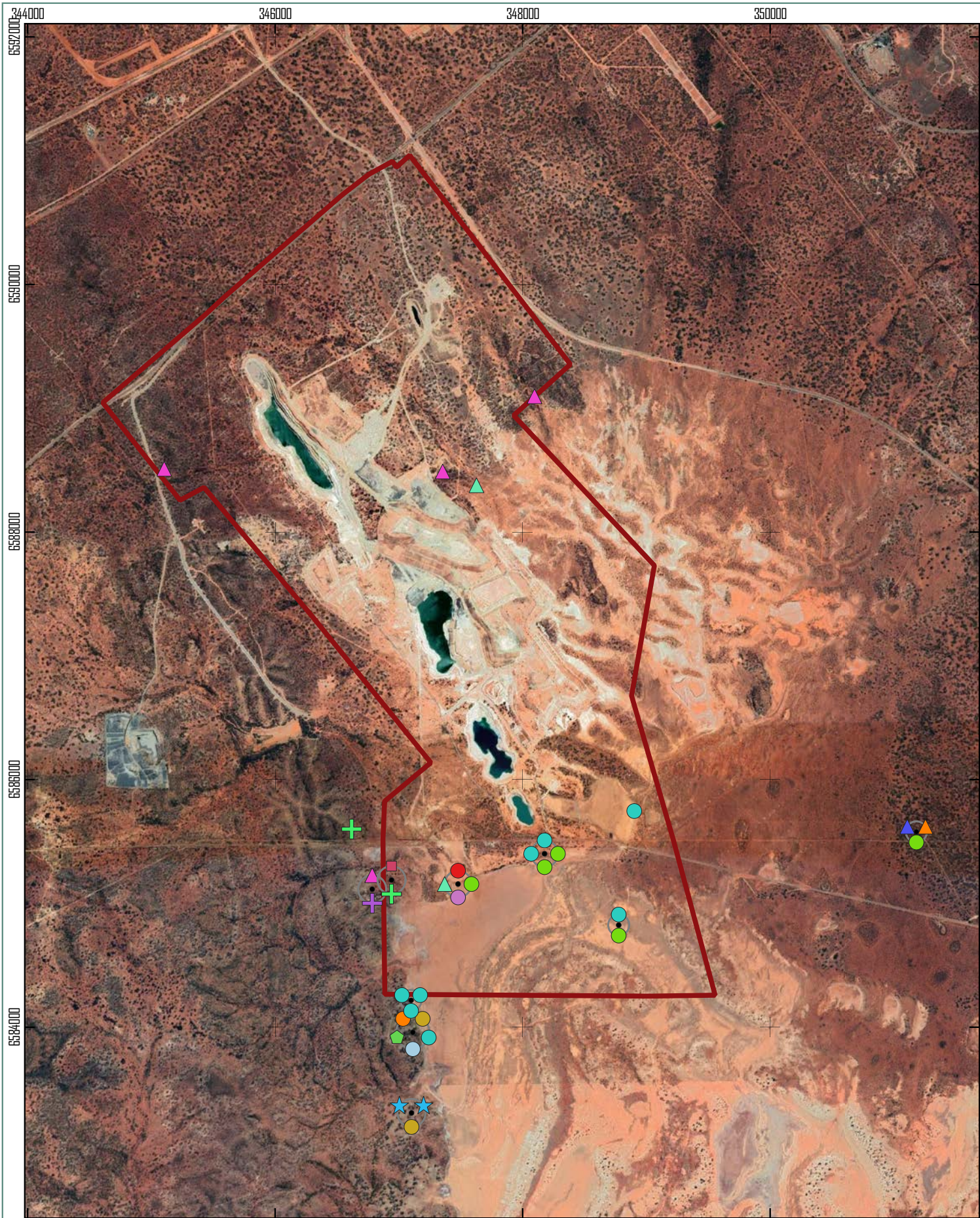
Binduli South

Prepared for Talis  
Consultants/Norton

Map

3.5





#### Legend

	Survey Area		Chernetidae 'Bi01'		Lycosidae sp.
<b>Invertebrate &amp; SRE Fauna Records</b>			Cryptops sp.		Paradoxosomatidae sp.
	Aname 'Bi01'		Dermaptera sp.		Pupoides adelaidae
	Araneomorphae sp.		Gastrocopta margaretae		Sepedonophilus sp.
	Beierolpium '8/4 Bi01'		Gnaphosidae sp.		Sinumelon sp.
	Bothriembryon sp.		Lycosidae 'Bi01'		Symphyla sp.



0 0.4 0.8 1.2 km

Scale 1:40000

@ A4

Coordinate System: GDA 1994 MGA Zone 51  
Projection: Transverse Mercator  
Units: Meter



Author: EM

Date: 18-02-2022

#### Invertebrate & SRE Fauna Records

Binduli South

Prepared for Talis  
Consultants/Norton

Map

3.6



### 3.3.6. SRE Invertebrate Fauna Assemblage

A total of 34 invertebrate specimens were collected during the survey from dry pit fall traps, leaf litter samples, active searches and opportunistically (Table 3.9, Appendix F, Appendix G). The 34 specimens were represented by 16 taxa, with 12 taxa belonging to SRE target groups and four non-target taxa (Appendix F & Appendix G). Nine of the 12 taxa are considered potential SREs (one Araneomorph spider, one Mygalomorph spider, two Pseudoscorpions, one Geophilomorph centipede, one Scolopendromorph centipede, one Polydesmid millipede, one Symphyla pseudocentipede and one Eupulmonata snail), with three species, not previously recorded (Map 3.6).

The 12 taxa are discussed in Sections 3.3.6.1 to 3.3.6.7, with two of the 12 specimens captured from the dry pitfall trapping outlined separately in Section 3.3.6.1.

**Table 3.9: Invertebrate Fauna Recorded**

Class/Order/Family	Taxa	Site Recorded	Habitat Type	Total No. Recorded	SRE Status
ARACHNIDA					
Araneae (Spiders)					
Anamidae	<i>Aname</i> 'Bi01'	WS02	Low sparse chenopod shrubland on salt lakes and salt pans	1	Potential SRE
Gnaphosidae	Gnaphosidae sp.	AS01	Eucalypt woodland over mixed shrubland on low rocky hills with ironstone and quartz over red-orange sandy-clay	1	Non-target
Lycosidae	<i>Lycosidae</i> sp.	WS01, WS04 & WS05	Low sparse chenopod shrubland on salt lakes and salt pans	8	Non-target
		WS03	Mixed Eucalypt low woodland with sparse shrubs over low hummock grassland on orange sandplains		
	<i>Lycosidae</i> sp. Bi01	WS02	Low sparse chenopod shrubland on salt lakes and salt pans	1	Potential SRE
-	Araneomorphae sp.	WS01 & WS02	Low sparse chenopod shrubland on salt lakes and salt pans	5	Non-target
		WS03	Mixed Eucalypt low woodland with sparse shrubs over low hummock grassland on orange sandplains		
		LL06	Mixed Eucalypt open woodland over mixed shrubland on undulating plains on red-orange sandy clay soils		
Pseudoscorpiones (Pseudoscorpions)					
Chernetidae	Chernetidae 'Bi01'	LL04 & LL05	Eucalypt woodland over mixed shrubland on low rocky hills with ironstone and quartz over red-orange sandy-clay	2	Potential SRE
Olpiidae	<i>Beierolpium</i> '8/4 Bi01'	LL04	Eucalypt woodland over mixed shrubland on low rocky hills with ironstone and quartz over red-orange sandy-clay	1	Potential SRE



Class/Order/Family	Taxa	Site Recorded	Habitat Type	Total No. Recorded	SRE Status
<b>CHILOPODA</b>					
<b>Geophilomorpha (Soil Centipedes)</b>					
Geophilidae (Chilenophilidae)	<i>Sepedonophilus</i> sp.	LL02	Eucalypt woodland over mixed shrubland on low rocky hills with ironstone and quartz over red-orange sandy-clay	1	Potential SRE
<b>Scolopendromorpha (Centipedes)</b>					
Cryptopidae	<i>Cryptops</i> sp.	LL01, LL03	Eucalypt woodland over mixed shrubland on low rocky hills with ironstone and quartz over red-orange sandy-clay	2	Potential SRE
<b>DIPLOPODA</b>					
<b>Polydesmida (Millipedes)</b>					
Paradoxosomatidae	Paradoxosomatidae ( <i>Antichiropus</i> ) sp.	LL05	Eucalypt woodland over mixed shrubland on low rocky hills with ironstone and quartz over red-orange sandy-clay	2	Potential SRE
<b>GASTROPODA</b>					
<b>Eupulmonata (Snails)</b>					
Bothriembryontidae	<i>Bothriembryon</i> sp.	LL02 & one opportunistic site	Eucalypt woodland over mixed shrubland on low rocky hills with ironstone and quartz over red-orange sandy-clay	4	Potential SRE
		Opportunistic site	Eucalypt open woodland over mixed shrubland on undulating plains on red-orange sandy clay soils		
			<i>Acacia</i> shrubland on rocky granitic slopes		
Camaenidae	<i>Sinumelon</i> sp.	WS02	Low sparse chenopod shrubland on salt lakes and salt pans	2	Widespread
		Opportunistic site	<i>Acacia</i> and <i>Eremophila</i> shrubland on sandplains and floodplains on orange clay loam to sand		
Pupillidae	<i>Gastrocopta margaretae</i>	LL06	Mixed Eucalypt open woodland over mixed shrubland on undulating plains on red-orange sandy clay soils	1	Widespread
	<i>Pupoides adelaidae</i>	LL06	Mixed Eucalypt open woodland over mixed shrubland on undulating plains on red-orange sandy clay soils	1	Widespread
<b>INSECTA</b>					
<b>Dermaptera (Earwig)</b>					
-	Dermaptera sp.	LL04	Eucalypt woodland over mixed shrubland on low rocky hills with ironstone and quartz over red-orange sandy-clay	1	Non-target
<b>SYMPHYLA (Pseudocentipedes)</b>					
-					
-	Symphyla sp.	LL01	Eucalypt woodland over mixed shrubland on low rocky hills with ironstone and quartz over red-orange sandy-clay	1	Potential SRE

### 3.3.6.1. Wolf Spider *Tetrallycosa baudinettei*

During the targeted assessment for the Wolf Spider (*Tetrallycosa baudinettei*), a total of 16 specimens were collected from the five dry pitfall trapping sites. Of these, none were identified as the target species, two were identified as potential SRE taxa, and the remaining 14 were either non-target or widespread species. The two potential SRE specimens are discussed below.

### 3.3.6.2. Araneae (Spiders)

#### Lycosidae 'Bi01' (Wolf Spider)

Category: Potential SRE

Sub-category: DDT

A single sub-adult sample was collected from a dry pitfall at site WS02. This site is located within the Low sparse chenopod shrubland on salt lakes and salt pans habitat on the edge of White Lake. The colour pattern of this individual specimen indicates it may be a halophile. It was collected from the edge of the salt lake within habitat dominated by *Teticornia* species. It is possible this spider is a salt lake specialist.

There is a requirement for male adult specimens to complete species level identification. As this species was a juvenile, species level identification was not feasible. The markings on this individual were similar to samples collected by Dr Erich Volshank (Alacran) at Lake Ballard, and, therefore, may be related. This species is considered a potential SRE due to taxonomic data deficiency. Further taxonomic resolution may be gained from DNA sequencing.

#### *Aname* 'Bi01' (Open hole Trapdoor spider)

Category: Potential SRE

Sub-category: DDT

A single adult male specimen was collected from a dry pitfall at site WS02. This site is located within the Low sparse chenopod shrubland on salt lakes and salt pans habitat on the edge of the White Lake. The WAM Database search returned two described species and two morphospecies *Aname* 'mainae', *Aname* 'armigera group', *Aname lillianae* (previously *Aname* 'MYG522') and *Aname simonae* (previously *Aname* 'MYG523') (Harvey *et al.*, 2020). These species and morphospecies are widespread and therefore not considered SREs. The collected specimen does not match these species or morphospecies, so it was assigned the interim morphospecies *Aname* 'Bi01'. This species is considered a potential SRE due to taxonomic data deficiency. Further taxonomic resolution may be gained from comparing its DNA sequences with those in the WA Museum sequence database.

### 3.3.6.3. Pseudoscorpiones (Pseudoscorpions)

#### Chernetidae 'Bi01'

Category: Potential SRE

Sub-category: DDT

Two sub-adult samples were collected from two leaf litter sites, LL04 and LL05. Both of these sites were located within the Eucalypt woodland over mixed shrubland on low rocky hills with ironstone and quartz over red-orange sandy-clay habitat, just outside the Survey Area. Regional vegetation mapping indicates that this habitat type is widespread within the surrounding region (Map 1.3). The sub-adult specimens were unusually assigned as a morphospecies due to their distinctive granulose morphosculpture. This

morphospecies is a potential SRE due to taxonomic data deficiency with greater taxonomic certainty potentially attained from DNA sequencing.

***Beierolpium* '8/4-Bi01'**

Category: Potential SRE

Sub-category: DDT

The genus *Olpidae* is diverse and poorly known taxonomically in WA, with many undescribed species discovered from the use of DNA barcoding. Three genera, including *Beierolpium* are particularly diverse, and determining the identity of specimens from this family should be confirmed using molecular data.

Two samples were collected from one leaf litter site, LL04, represented by one female and one sub-adult. This site was located in Eucalypt woodland over mixed shrubland on low rocky hills with ironstone and quartz over red-orange sandy-clay habitat, just outside the Survey Area. Eco Logical (2016d) recorded three specimens of *Beierolpium* '8/4' during their survey in the same habitat type. Regional vegetation mapping indicates that this habitat type is widespread within the surrounding region (Map 1.3)

**3.3.6.4. Chilopoda (Centipedes)**

***Sepedonophilus* sp.**

Category: Potential SRE

Sub-category: DDT

Centipedes from the Geophilomorpha (soil centipedes) Order are poorly known taxonomically. This is the most species-rich Order, with an assessment of WA specimens using DNA sequencing revealing many species.

A single specimen was recorded from leaf litter site LL02, in Eucalypt woodland over mixed shrubland on low rocky hills with ironstone and quartz over red-orange sandy-clay habitat, just outside the Survey Area. Regional vegetation mapping indicates that this habitat type is widespread within the surrounding region (Map 1.3). DNA sequencing is required to identify this order to species level, which could enable the assessment of the regional context and conservation significance of this species. Therefore, this species is considered a potential SRE due to taxonomic data deficiency.

***Cryptops* sp.**

Category: Potential SRE

Sub-category: DDT

Two specimens were collected from leaf litter sites LL01 and LL03, both within the same habitat type, Eucalypt woodland over mixed shrubland on low rocky hills with ironstone and quartz over red-orange sandy-clay. Site LL01 is located within the Survey Area on the western boundary, while site LL03 is located just outside to the north-east. Regional vegetation mapping indicates that this habitat type is widespread within the surrounding region (Map 1.3).

The taxonomy of the genus *Cryptops* is poorly known in WA; however, in arid regions, they often appear to be SREs. These two samples are considered potential SREs due to taxonomic data deficiency. DNA sequencing could determine their identity and it could be possible for two species to be present.



### 3.3.6.5. Diplopoda (Millipedes)

#### Paradoxosomatidae (*Antichiropus*) sp.

Category: Potential SRE

Sub-category: DDT

Two juvenile specimens were collected from leaf litter site LL05, located within the Eucalypt woodland over mixed shrubland on low rocky hills with ironstone and quartz over red-orange sandy-clay habitat, south of the Survey Area. The Paradoxosomatidae family requires examination of characters of the male gonopods for genus and species identification. As no adult male specimens were present, species identification was not possible based on morphology only. DNA sequencing may provide greater taxonomic resolution for these specimens.

The genus *Antichiropus* is the only known paradoxosomatid from this region of WA, so it is very likely that the specimens belong to this genus.

It is likely that these specimens belong to one of the two confirmed SRE specimens, *Antichiropus* 'binduli' and A. 'kalgoorlie' that Eco Logical's (2016d) SRE survey recorded. These species were only recorded from within the Study Area, while LL05 is located outside of the current Survey Area boundary in a habitat type that is widespread in the surrounding region (Map 1.3).

### 3.3.6.6. Symphyla (Pseudocentipedes)

#### Symphyla sp.

Category: Potential SRE

Sub-category: DDT

Two specimens from leaf litter site LL01 were recorded. This site is located in the Eucalypt woodland over mixed shrubland on low rocky hills with ironstone and quartz over red-orange sandy-clay habitat type within the Survey Area on the eastern boundary.

Symphyla are rarely recorded from arid environments, with DNA sequencing usually discovering new species. Therefore, these specimens are potential SREs due to taxonomic data deficiency. There is also a possibility that two species are present.

The habitat type this species was recorded from is widespread within the surrounding region (Map 1.3).

### 3.3.6.7. Gastropoda (Snails)

#### *Bothriembryon* sp.

Category: Potential SRE

Sub-category: DDT

This taxon was represented by four specimens. One was collected from leaf litter site LL02 located just outside of the Survey Area, while the remaining specimens were recorded opportunistically at three locations within the Survey Area. This taxon was recorded from three different habitat types: mixed Eucalypt open woodland over mixed shrubland on undulating plains on red-orange sandy clay soils; Eucalypt woodland over mixed shrubland on low rocky hills with ironstone and quartz over red-orange sandy-clay, and *Acacia* shrubland on rocky granitic slopes. All of these habitats are widespread in the surrounding region (Map 1.3)..

All of the collected samples were dead shells, so species level resolution was not achievable. The genus *Bothriembryon* contains many undescribed and SRE species; consequently, these specimens are potential SREs due to taxonomic data deficiency. Live specimens would be required from the Survey Area to achieve taxonomic resolution.

Eco Logical (2016d) also collected dead snail shells from this family in two broad habitat types mixed *Eucalyptus* woodlands on red clay loam and gravel or pebble rises and Chenopod shrublands on clay pans and flats. As these snails have been collected from a variety of habitats, it is unlikely that they would be restricted to the Survey Area or immediate surroundings.

***Sinumelon* sp.**

Category: Not SRE

This taxon was represented by two specimens, with one collected at WS02, a dry pitfall trapping site, and one opportunistically. Species level identification was impossible as both samples were dead shells. All of the species within the genus *Sinumelon* in WA are widespread and not considered SREs.

***Gastrocopta margaretae***

Category: Not SRE

One specimen of this species was collected from leaf litter site LL06. This species is widespread and not considered an SRE.

***Pupoides adelaidae***

Category: Not SRE

One specimen of this species was collected from leaf litter site LL06. This species is widespread and not considered an SRE.

### 3.4. Conservation Significant Fauna

The conservation significant fauna species identified in the desktop assessment were given a likelihood of occurrence scoring following the field survey. The desktop assessment identified 29 conservation significant fauna species potentially occurring in the Survey Area, including three mammals, 22 birds, one reptile and three invertebrates. Following the field survey, 14 conservation significant fauna species are considered to have a Medium likelihood of occurrence based on the relevant species distributions and habitats occurring within the Survey Area (Table 3.10). Fifteen species identified in the desktop assessment are considered to have a Low to Very Low likelihood of occurring in the Survey Area. Species descriptions for those assigned a Medium likelihood of occurrence are provided in Section 3.4.1 to Section 3.4.9. Definitions of the relevant conservation status codes are also shown in Appendix B.

Table 3.10: Conservation Significant Fauna

Species	Con Sig Status			Preferred Habitats	Previous Records	Likelihood (Eco Logical 2016d)	Likelihood of Occurrence
	EPBC Act	BC Act	DBCA				
Mammals							
Numbat, Walpurti ( <i>Myrmecobius fasciatus</i> )	EN	EN		Eucalypt/Wandoo woodland, jarrah forest. Previously found in wide range of woodland types including York Gum and mallee and Mulga (Van Dyck and Strahan, 2008b).	One historical preserved specimen record exists in NatureMap, dating back to 1927. The species has not been recorded in the region during recent surveys.	No	<b>Very Low</b> No recent records known from the region. The species is considered locally extinct.
Chuditch, Western Quoll ( <i>Dasyurus geoffroii</i> )	VU	VU		Exists in ~5% of its pre-European range (Rayner et al., 2012). Occurs in sclerophyll, riparian, and Jarrah forest, dry woodland, heath and mallee shrubland (Van Dyck and Strahan, 2008b). Low, fragmented populations occur in the Goldfields and wheatbelt (Dept. Environment & Conservation 2012; Rayner et al., 2012).	The species was recorded as an observational sighting in 1974 39 km away from the Survey Area (DBCA Threatened Fauna Database).	Not assessed	<b>Very Low</b> No further observations or evidence of this species has been recorded since 1974, despite further surveys. Although some suitable habitat is likely to be present in proximity to the Survey Area, the range of <i>D. geoffroii</i> has contracted to the Jarrah forests of SW Australia (Van Dyck and Strahan, 2008b; Rayner et al., 2012).
Greater Bilby, Dalgyte, Ninu ( <i>Macrotis lagotis</i> )	VU	VU		A variety of habitats with suitable soil substrates and plant species that are fed on directly or host insect larvae. Habitats can include spinifex hummock grassland, acacia shrubland, open woodland and cracking clays (Dzimirski and Carpenter, 2016, 2018).	The species has not been recorded in the region during previous surveys. Three historical preserved specimen records exist in NatureMap, the most recent being in 1976.	No	<b>Very Low</b> No records known from the region and suitable habitat is not likely to exist in proximity to the Survey Area. <i>M. lagotis</i> range is not known to occur as far South as the Survey Area (Van Dyck and Strahan, 2008b). The species is considered locally extinct.
Birds							
Curlew Sandpiper ( <i>Calidris ferruginea</i> )	CR/MI	CR		Tidal flat systems and freshwater to brackish wetlands. Ephemeral and permanent lakes, dams and waterholes, usually with bare edges, mud and sand (Morcombe, 2003; Menkhorst et al., 2019).	The species was recorded 32 km W of the Study Area in 2006 (DBCA).	Potential	<b>Medium</b> The species has been recorded within 50 km of Survey Area within the last 20 years. The habitat present in the Survey Area is marginal for this species and would only be used occasionally when White Lake or the smaller salt lake/pans areas are inundated.



Species	Con Sig Status			Preferred Habitats	Previous Records	Likelihood (Eco Logical 2016d)	Likelihood of Occurrence
	EPBC Act	BC Act	DBCA				
Night Parrot ( <i>Pezoporus occidentalis</i> )	EN	CR		Long, unburnt Triodia hummock grassland and Samphire (Morcombe, 2003).	No previous records, however habitat or species may occur in the area (PMST).	No	<b>Very Low</b> This species is unlikely to occur as no suitable habitat or records occur within or in proximity to the Survey Area.
Carnaby's Cockatoo ( <i>Calyptrorhynchus latirostris</i> )	EN	EN		Breeds in tree hollows of Wandoo, Tuart, Jarrah, York gum, Karri, Marri and Salmon Gum. Forages in woodlands, forests, riparian vegetation, heath and Banksia woodland as well as introduced species (Morcombe, 2003; Menkhorst et al., 2019).	Recent records exist for three consecutive years (2016, 2017 & 2018) and are within 8 km NE of Study Area in the Kalgoorlie town centre (DBCA).	Not assessed	<b>Medium</b> Records of the species are recent and very close to the Survey Area. Some Salmon Gum are present in fauna habitat 1. Carnaby's Cockatoos use Salmon Gums for both breeding and night roosting.
Malleefowl ( <i>Leipoa ocellata</i> )	VU	VU		Semi-arid dense shrubland and low woodlands dominated by unburnt mallee vegetation with sandy or gravelly soils, abundant litter and low scrub (Morcombe, 2003; Menkhorst et al., 2019).	There are numerous records surrounding the Study Area, the closest being 7 km SW in 2002 (DBCA).	Potential	<b>Medium</b> Multiple records in close proximity to the Survey Area, with previous survey within the Survey Area only recording old mound. Potential foraging habitat occurs in the Survey Area.
Grey Falcon ( <i>Falco hypoleucos</i> )		VU		Varied and widespread habitat, usually within interior plains, patrolling low groundcover below treetop level (Morcombe, 2003). Distribution is centred inland on lightly timbered lowlands, particularly Acacia shrubland and drainage systems (Olson and Olson, 1986).	No previous records however habitat or species may occur in the area (PMST).	Not assessed	<b>Low</b> Although habitat is varied, there are no records and species is considered rare and sparsely distributed (Morcombe, 2003; Menkhorst et al., 2019).
Common Greenshank ( <i>Tringa nebularia</i> )	MI	MI		Variety of coastal to inland permanent and ephemeral wetlands, swamps, lakes, waterholes and well as open mudflats (Morcombe, 2003; Menkhorst et al., 2019).	There are multiple records of the species, the closest being 13 km NW of the Study Area in 2001. The species was most recently recorded in 2017 65 km away from Study Area (DBCA).	Potential	<b>Medium</b> Multiple recordings exist within 50 km of the Survey Area. Despite this, the habitat present in the Survey Area would only be used occasionally when White Lake (salt lake) or the smaller salt lake/pans areas are inundated.

Species	Con Sig Status			Preferred Habitats	Previous Records	Likelihood (Eco Logical 2016d)	Likelihood of Occurrence
	EPBC Act	BC Act	DBCA				
Common Sandpiper ( <i>Actitis hypoleucos</i> )	MI	MI		Coastal and inland ephemeral wetland habitat types. Sheltered, narrow and steep shorelines. Mangrove-lined creeks and varied wetland habitats including areas of mud with outcropping rocks, sewage ponds and dams (Morcombe, 2003; Menkhorst et al., 2019).	Three records exist 22 km SW of Study Area from 2011, 2013 & 2014 (DBCA). Additional records exist 65 km from Study Area.	Not assessed	<b>Medium</b> The species has been recorded within 50 km of the Survey Area within the last 20 years. The habitat present in the Survey Area would only be used occasionally when White Lake (salt lake) or the smaller salt lake/pans areas are inundated.
Fork-tailed Swift ( <i>Apus pacificus</i> )	MI	MI		Extremely diverse habitat; coastal, rainforest, semi-desert and inland plains. In Australia, the species has an almost entirely aerial lifestyle (Morcombe, 2003; Menkhorst et al., 2019).	Species is listed in Protected Matters Search Tool (PMST) search as likely to occur in the area. A previous survey has recorded the species ~45 km from the Study Area (Phoenix Environmental Sciences, 2018b).	Potential	<b>Medium</b> The species occupies diverse habitat and is generally associated with storm fronts therefore has the potential to occur in proximity to the Survey Area.
Glossy Ibis ( <i>Plegadis falcinellus</i> )	MI	MI		Freshwater waterbodies, marshes, lakes and river lagoons, flood-plains, wet meadows, swamps, sewage ponds. Occasionally found in estuarine waters or dry grassland (Morcombe, 2003; Menkhorst et al., 2019).	Two historical records exist from December 1981 with one sighting 6 km NNE of Study Area.	Likely	<b>Low</b> One record exists very close to the Survey Area, however, there are no further observations since 1981. No suitable habitat exists in the Survey Area. This species may occasionally utilise the freshwater lake, Douglas Lake, located <1 km W of the Survey Area
Grey-tailed Tattler ( <i>Tringa brevipes</i> )	MI	MI	P4	Coastal, brackish wetlands, sandy beaches, saltmarsh, lakes, pools and tidal flats (Morcombe, 2003; Menkhorst et al., 2019).	One single record exists from 2017 within the Study Area, however this has been queried due to the unsuitable habitat in the area (DBCA). All other records are coastal >280 km away from Study Area.	Not assessed	<b>Low</b> The species is limited to coastal habitats therefore it is unlikely to occur within the Survey Area.
Grey Wagtail ( <i>Motacilla cinerea</i> )	MI	MI		Migratory species rarely reaching Australian fresh streams, mowed grass, ploughed land or sewage ponds (Morcombe, 2003).	No previous records however species or habitat may occur within the area (PMST).	No	<b>Low</b> No records exist and suitable habitat is unlikely to occur in the Survey Area.

Species	Con Sig Status			Preferred Habitats	Previous Records	Likelihood (Eco Logical 2016d)	Likelihood of Occurrence
	EPBC Act	BC Act	DBCA				
Oriental Plover ( <i>Charadrius veredus</i> )	MI	MI		Semi-arid regions with open grassland, claypans, gibberstone or thinly vegetated plains (Morcombe, 2003; Menkhorst et al., 2019).	Three records exist 65 km NW from 2012 & 2013 (DBCA).	Not assessed	<b>Medium</b> This migratory species was recorded > 50 km away from Survey Area. The habitat in the Survey Area is marginal and would only be used occasionally.
Pectoral Sandpiper ( <i>Calidris melanotos</i> )	MI	MI		Coastal wetlands, both fresh and saline, also inland on permanent and temporary wetlands. Prefers sites with mudflats, fringing vegetation or swamps with heavy vegetation (Morcombe, 2003).	No records however this species or species habitat may occur in the area (PMST).	Not assessed	<b>Low</b> No species records in proximity to the Survey Area. Habitat present in the Survey Area would only be used very occasionally when White Lake (salt lake) or the smaller salt lake/pans areas are inundated.
Red-necked Stint ( <i>Calidris ruficollis</i> )	MI	MI		Tidal and inland, mudflats, salt marshes, beaches, salt fields and temporary floodwaters (Morcombe, 2003).	The closest record is 32 km WNW of Study Area in 2006 (DBCA).	Potential	<b>Medium</b> Species recorded within last 20 years < 50 km from Survey Area. Habitat present in the Survey Area would only be used occasionally when White Lake (salt lake) or the smaller salt lake/pans areas are inundated.
Ruddy Turnstone ( <i>Arenaria interpres</i> )	MI	MI		Ocean coasts with exposed rock, stony or shell beaches, mudflats, exposed reefs and wave platforms. Occasionally inland on shallow pools (Morcombe, 2003).	The species was recorded 65 km NW of the Study Area in 2016 (DBCA).	Not assessed	<b>Very Low</b> Only one record > 40 km from Survey Area and no suitable habitat occurs within or in proximity to, the Survey Area.
Sanderling ( <i>Calidris alba</i> )	MI	MI		Coastal, open sandy beaches and occasionally on sandy tidal flats (Morcombe, 2003; Menkhorst et al., 2019).	The species was recorded 9 km NE of the Study Area in 2016 (DBCA).	Not assessed	<b>Low</b> Although record is in close proximity to Survey Area and has been verified by DBCA, it is unusual as suitable habitat does not occur within or in proximity to Survey Area. The species is considered to be restricted to coastal habitats and is thought to have stopped inland to forage and rest on its way to the coast (Morcombe, 2003; Menkhorst et al., 2019; DBCA 2021).



Species	Con Sig Status			Preferred Habitats	Previous Records	Likelihood (Eco Logical 2016d)	Likelihood of Occurrence
	EPBC Act	BC Act	DBCA				
Sharp-tailed Sandpiper ( <i>Calidris acuminata</i> )	MI	MI		Inland lakes, and coastal, along brackish and freshwater wetlands, saltmarsh, lakes and pools (Morcombe, 2003).	Species was recorded 6 km N of Study Area in 1980. The most recent record is 40 km from the Study Area in 2012 (DBCA).	Likely	<b>Medium</b> Species has been recorded in proximity to the Survey Area within the last 20 years. The habitat present in the Survey Area would only be used occasionally when White Lake (salt lake) or the smaller salt lake/pans areas are inundated.
Wood Sandpiper ( <i>Tringa glareola</i> )	MI	MI		Well-vegetated, shallow freshwater wetlands, lakes, pools and swamps. Usually near shorelines either on mud or in shallow water (Morcombe, 2003; Menkhurst et al., 2019).	Species has been recorded 5 km NE of Study Area in 2005 (DBCA).	Potential	<b>Low</b> Species recorded in close proximity to Survey Area. However, no suitable freshwater habitat occurs in the Survey Area. The freshwater lake, Douglas Lake, located <1 km W of the Survey Area is not likely to form suitable habitat for this species as it is not well-vegetated.
Peregrine Falcon ( <i>Falco peregrinus</i> )	OS	OS		Very diverse; rainforest to arid scrub and coastal heath to alpine. Cliff faces are preferred nesting sites (Morcombe, 2003; Menkhurst et al., 2019).	Two records 66 km NW of Study Area in 2013 & 2014 (DBCA).	Not assessed	<b>Medium</b> Although records are over 40 km away from Survey Area, the species occupies extremely diverse habitats and therefore could be recorded inside or in close proximity to the Survey Area. Nesting habitat is not present inside the Survey Area.
Blue-billed Duck ( <i>Oxyura australis</i> )			P4	Deep fresh to saline, permanent open wetlands and vegetated lakes (Morcombe, 2003).	All recordings in the vicinity of Study Area are from a single wetland 65 km to the NW, the most recent in 2016 (DBCA).	Not assessed	<b>Low</b> There are no records within 40 km of the Survey Area. The water bodies in proximity to Survey Area are not likely to form suitable habitat for this species.

Species	Con Sig Status			Preferred Habitats	Previous Records	Likelihood (Eco Logical 2016d)	Likelihood of Occurrence
	EPBC Act	BC Act	DBCA				
Hooded Plover ( <i>Thinornis cucullatus</i> )			P4	Inland margins and shallows of salt lakes, estuaries, coastal lakes and ocean beaches (Morcombe, 2003; Menkhorst et al., 2019).	Species recorded most recently in 2001, 47 km NE and historically in 1980 and 1992 30 km N & NNE from the Study Area (DBCA).	Potential	<b>Medium</b> Only one species records within 50 km of the Survey Area since 2001. This species seems rarely recorded from around Kalgoorlie. The habitat present in the Survey Area would only be used occasionally when White Lake (salt lake) or the smaller salt lake/pans areas are inundated.
Western Rosella ( <i>Platycercus icterotis xanthogenys</i> )			P4	Mallee and dry woodland preferably with salmon gum and wandoo, farmland with scattered trees (Morcombe, 2003).	One record 59 km SE of Survey Area in 2008 (DBCA).	Not assessed	<b>Medium</b> Species not recorded within 50 km of Survey Area; however, suitable habitat occurs within and in proximity to Survey Area.
<b>Reptiles</b>							
Western Spiny-tailed Skink ( <i>Egernia stokesii badia</i> )	EN	VU		Woodlands, where it shelters in hollow logs, rock crevices, trees and branches (brown form). Also associated with granite outcrops (black form) (Wilson and Swan, 2021).	Single historic record 32 km SW of Study Area from 1930 (DBCA).	No	<b>Very Low</b> Suitable habitat occurs within the Survey Area. However the species has not been recorded in the region since 1930, and this record is >300 km outside of the species current known range (DBCA 2021).
<b>Invertebrates</b>							
Arid Bronze Azure Butterfly ( <i>Ogyris subterrestris</i> subsp. <i>petrina</i> )	CR	CR		Only known from two locations, Douglas Lake (in 1991) and Barbalin NR in the Avon Wheatbelt. Associated with the sugar ant ( <i>Camponotus terebrans</i> ) at the base of smooth-barked trees and shrubs.	Multiple records in close proximity to Study Area and the species was recorded inside the Study Area in 1991 (DBCA). Douglas Lake is one of two known locations of this species which extends inside the Southern section of the Study Area.	Unlikely	<b>Medium</b> All records are from over 20 years ago. Despite surveys in adjacent areas and the wider region, the species has not been recorded from this location since 1991. Suitable habitat occurs within and in close proximity to the Survey Area.
Inland Hairstreak Butterfly ( <i>Jalmenus aridus</i> )			P1	Larvae feeds on leaves and flowers of <i>Acacia tetragonophylla</i> and <i>Senna artemisioides</i> Adults remain close to breeding habitat.	The species was recorded 0.5 km W of the Study Area in 1997 (DBCA).	Potential	<b>Medium</b> There are five historical records between 1985 and 1997. Suitable habitat occurs within the Survey Area.

Species	Con Sig Status			Preferred Habitats	Previous Records	Likelihood (Eco Logical 2016d)	Likelihood of Occurrence
	EPBC Act	BC Act	DBCA				
Fairy Shrimp <i>Branchinella denticulata</i>			P3	Uncommon species. Occurs from Carnarvon to Kalgoorlie. Little is known about its preferred habitat. Found in fresh, turbid waters (Timms, 2015a). However, some species of Branchinella have been recorded in lakes that are normally saline but are temporarily fresh due to major episodic filling events (Timms, 2015b).	This species was recorded at Gidgi Lake, 23 km N of the Study Area in 1937 (DBCA). More recent records exist from the Lake Carey wetlands in 2003/2004, located approximately 205 km NE of the Study Area (Timms, Brian V, Datson, B, Coleman, 2006).	Unlikely	<b>Low</b> No recent records exist for this species in the vicinity of the Survey Area. However, this may be due to the lack of surveys within the Goldfields area, where this species may occur. Suitable habitat is unlikely to exist for this species due to the saline nature of White Lake and the other smaller salt lakes/pans.



### 3.4.1. Malleefowl (*Leipoa ocellata*)

#### Conservation Status

- EPBC Act/ BC Act: Vulnerable

#### Distribution, Ecology and Habitat

The Malleefowl is a large, ground-dwelling bird species. It is restricted to the mainland of Australia where it inhabits semi-arid and arid habitats. In its range, the density of the Malleefowl population is generally greater in areas of higher rainfall and where shrub diversity is greatest (Benshemesh, 2007; Malleefowl Recovery Team, 2018).

The Malleefowl is a generalist feeder with a diet consisting of seeds, fruits, flowers, fungi, invertebrates, herbs and legumes, depending on location and season (Benshemesh, 2007). The species mates for life and each pair builds large mounds (3-5 m in diameter) which are used as nests for the incubation of eggs. Egg laying typically begins in September when one egg is laid every 5-7 days (total of about 15-25 eggs) until the end of summer. The incubation period is approximately 60 days depending on the temperature of the nest. The eggs are incubated by heat generated by the decomposition of leaf litter and plant material, as well as the heat from the sunlight later in the season (summer). Whilst the male predominantly attends the eggs and maintains the temperature for incubation, the female spends most of her time feeding for egg production and only rarely visits the nest (Benshemesh, 2007).

Once common and widespread across semi-arid southern Australia, Malleefowl have declined severely in the last century, with a 50% decrease in area of occupancy (Benshemesh, 2007). Their current distribution is highly fragmented and the species is at risk of extinction (Benshemesh, 2007). Malleefowl occupy habitats consisting of mallee thickets, mulga or other dense litter-forming shrublands as well as dry forest dominated by other *Eucalyptus* and *Acacia* species (Johnstone and Storr, 1998; Benshemesh, 2007). They prefer sandy substrate with leaf litter to build their nesting mounds with, so the highest breeding density appears to be located in vegetation that is at least 40 years post-fire (Woinarski, 1989; Benshemesh, 1990, 1992). The Malleefowl rarely breeds in vegetation that has been burnt within the last 15 years.

#### Occurrence in the Survey Area

There are numerous records within 20 km of the Survey Area, some of which have been made within the past five years, including one 10 km west from 2019 (Map 3.1). A previous field survey targeting the Malleefowl found a very old inactive mound in the Survey Area, and another in the adjacent Binduli North area (Eco Logical Australia, 2016d). The Malleefowl mound previously identified in the Survey Area was inspected during the survey and is now eroded and very difficult to detect.

Overall the fauna habitats recorded within the Survey Area, including the area of moderate Malleefowl habitat previously identified by Eco Logical (2016d), would be considered very marginal. As a result, Malleefowl would likely only use the area for foraging.

### 3.4.2. Carnaby's Cockatoo (*Calyptrorhynchus latirostris*)

#### Conservation Status

- EPBC Act/BC Act: Endangered

#### Distribution, Ecology and Habitat

The Carnaby's Cockatoo is endemic to the south-west of Western Australia. It occurs between the Murchison River and Esperance, and inland to Coorow, Kellerberrin and Lake Cronin (Cale, 2003). There has been a shift in its breeding range to the west and the south since the mid-1900s. It is now primarily located in the Jarrah-Marri forest of the Darling Scarp and the Tuart forests of the Swan Coastal Plain. Breeding takes place from July to mid-December (Johnstone and Johnstone, 2006). The Carnaby's Cockatoo lives in pairs that mate for life, and only one chick per year will be raised, which can stay with the parents for up to 18 months (Shah, 2006).

The Carnaby's Cockatoo utilises a variety of forests, shrublands and banksia woodlands. The species uses native shrubland, kwongan heathland and woodland, including banksia woodland with species for foraging such as *Hakea* spp., *Dryandra* spp., *Grevillea* spp. and *Callistemon* spp., as well as some introduced species. Roost sites are often associated with riparian vegetation and large trees such as pines or Eucalypts with a closed canopy. They use the same roost sites for many years, and breeding habitat consists of woodland or forests that provide hollows in live or dead trees (any Eucalypt species). Typical breeding trees include Wandoo, Tuart, Jarrah, Salmon Gum York Gum, Karri and Marri (CoA 2017). Carnaby's Cockatoos often move up to 13 km in a day, with the greatest distances covered in the early morning and late evening when they travel between roost sites, foraging sites and wetlands for drinking (Shah, 2006).

#### Occurrence in the Survey Area

The species has been recorded within 8 km of the Study Area in the Kalgoorlie town centre for three consecutive years from 2016 (DBCA 2021; Map 3.1). However, the Survey Area occurs over 250 km outside of the current modelled distribution for this species (DSEWPac 2012; CoA 2017), and the nearest previous records occur approximately 150 km south of Kalgoorlie (DBCA 2021). This suggests that the recent records consist of individuals dispersing in an atypical manner. However, the species is thought to be expanding inland during recent years, most likely due to increasingly scarce foraging habitat. No evidence or sightings of Carnaby's Cockatoo occurred during the survey. Some preferred breeding habitat is located within the Survey Area, within the mixed Eucalypt open woodland over mixed shrubland on undulating plains on red-orange sandy clay soils fauna habitat. This habitat type contains at least 34 Salmon Gum with a DBH of more than 300 mm. This species of Eucalypt is also used for night roosting. Therefore, this species may use the Eucalypt woodlands present in the Survey Area during periodic dispersal events further inland.

### 3.4.3. EPBC Act/BC Act Listed Shorebirds

Database searches returned 13 shorebirds listed as Migratory under the EPBC Act that could potentially occur in the Study Area. The Curlew Sandpiper is also listed as Critically Endangered by both the EPBC and BC Acts. Six of these were scored a Medium likelihood of occurrence (Table 3.10), all of which are primarily associated with coastal or inland water bodies. The species names and their EPBC Act and BC Act listing status are summarised in Table 3.11.

Table 3.11: EPBC Act Listed Migratory Bird Species

Common name	Species name	EPBC Act/BC Act Listing
Curlew Sandpiper	<i>Calidris ferruginea</i>	Critically Endangered, Migratory / Critically Endangered
Common Greenshank	<i>Tringa nebularia</i>	Migratory
Common Sandpiper	<i>Actitis hypoleucos</i>	Migratory
Oriental Plover	<i>Charadrius veredus</i>	Migratory
Red-necked Stint	<i>Calidris ruficollis</i>	Migratory
Sharp-tailed Sandpiper	<i>Calidris acuminata</i>	Migratory

### Distribution, Ecology and Habitat

There are 37 species of migratory shorebirds in Australia that utilise the East-Asian-Australasian Flyway (EAAF). This flyway describes the migratory pattern whereby birds breed in the Northern hemisphere and migrate through Eastern Asia to spend a non-breeding period in the southern hemisphere (Hansen *et al.*, 2016). While movements vary between species, the non-breeding period spent in Australia is typically from the Austral spring to autumn (CoA 2015). Feeding and roosting habitats used by migratory shorebirds in Australia include coastal and inland wetlands, estuaries, mudflats, tidal flats, rocky inlets, sandy beaches, floodplains, artificial wetlands as well as farm and grassland areas. The non-breeding diet of most species consists of invertebrates, including crustaceans, gastropods and bivalves (CoA 2015).

### Occurrence in the Survey Area

All six shorebird species have been recorded outside but within 50 km of the Study Area from 1980 to 2017 (Map 3.1). The claypans and ephemeral salt-lake habitat in the south and eastern parts of the Study Area are likely to provide foraging habitat for shorebirds that feed on aquatic invertebrates. However, as these species are non-breeding migrants to Australia, their presence in the Survey Area is expected to be sporadic and temporary, depending on the availability of water.

#### 3.4.4. Fork-tailed Swift (*Apus pacificus*)

##### Conservation Status

- EPBC Act: Migratory
- BC Act: Migratory

### Distribution, Ecology and Habitat

The Fork-tailed Swift is a terrestrial migratory visitor to Australia from Asia, occurring across all states. Within Western Australia records are highest along the coast, south-west, Pilbara, and Kimberly regions, and most sparse inland especially in the wheatbelt (DBCA 2021). This medium-sized swift is characterised by its forked tail and white rump with back-swept wings that taper to a fine point (Menkhorst *et al.*, 2019). The species is known to be highly nomadic and rarely lands, spending much of its time foraging in large flocks high above the canopy. The Fork-tailed Swift is insectivorous, but its precise food sources are relatively unknown within Australia (Menkhorst *et al.*, 2019).



### Occurrence in the Survey Area

The Fork-tailed Swift was stated in the EPBC Act Protected Matters Report as being likely to occur in proximity to the Study Area. The species has also been recorded 49 km south of the Study Area during a recent field survey (Phoenix Environmental Sciences, 2018b). No fork-tailed Swifts were recorded during the survey. Their diverse habitat preferences as well as their almost entirely aerial lifestyle in Australia means there is potential for the species to fly over the Survey Area, but it is very unlikely to land there.

#### 3.4.5. Hooded Plover (*Thinornis cucullatus*)

##### Conservation Status

- DBCA: Priority 4

##### Distribution, Ecology and Habitat

The Hooded Plover is a medium-sized endemic wader of Southern Australia (Newbey, 1996a). The species occupies the sandy beaches and inland lakes of Southern Australia from Cape Naturaliste to Eyre, as far north as Lake Cowan, Lake Moore and west to the coastal lakes south of Mandurah. Their preferred habitat consists of beaches with large amounts of washed up seaweed and sparsely vegetated dunes, whilst low densities also occur on narrow, steep beaches with few or no dunes (Birdlife Australia, 2020). It is only in WA that the species commonly nests away from the coast, inhabiting inland lakes where breeding activity has been observed (Newbey, 1996b; Dowling and Weston, 1999).

Hooded Plovers opportunistically feed on a variety of invertebrates, foraging at all levels of the beach during all tide phases. It is most frequently seen on the water's edge in small groups or pairs (Birdlife Australia, 2020). Nesting occurs on upper levels of the beach above the high tide mark in sand dunes or on lake shores (Birdlife Australia, 2020).

### Occurrence in the Survey Area

There are three regional records of the Hooded Plover, which are all 30-47 km away from the Survey Area to the north and north-east (Map 3.1). Two of these are historical records from 1980 and 1992, and one is from 2001 (DBCA). This species is rarely recorded from around the Kalgoorlie area. No records of this species have been made within the Survey Area despite the apparent suitable salt lake wetland habitat to the south (White Lake), and smaller salt lakes/pans to the east. However it may occur occasionally during periods of inundation.

#### 3.4.6. Peregrine Falcon (*Falco peregrinus*)

##### Conservation Status

- BC Act: Other Specially Protected Fauna

##### Distribution, Ecology and Habitat

The Peregrine Falcon is one of the most widespread birds in the world, breeding on all continents except Antarctica (Olsen *et al.*, 2006). It occurs across most of Australia though is an uncommon species across all states and territories (Bird Life Australia, 2012). It is known to be either a nomadic or sedentary species and is uncommon in the Kimberley, Hamersley and Darling Ranges (Olsen *et al.*, 2006). The species inhabits cliffs, coastal habitats, rivers, wooded water courses and lakes as well as urban environments. Peregrine Falcons usually nest by making a scrape on a high cliff edge but will also use stick nests of other large birds and tree hollows in some areas (Olsen *et al.*, 2006). Hunting is mainly done during the day and feeding is primarily on small to medium sized birds caught in flight, often above drainage lines and rivers. Favoured prey species

include the Galah (*Eolophus roseicapilla*) and Sulphur-crested Cockatoo (*Cacatua galerita*) (Bird Life Australia, 2012).

### Occurrence in the Survey Area

The Peregrine Falcon was recorded in 2013 and 2014 at wetland habitat 65 km north-west of the Survey Area, suggesting they use this habitat for foraging (Map 3.1). Foraging habitat may also be present in the Survey Area; however, it is unlikely the habitat available would be used for breeding. No Peregrine Falcon's were observed during the survey. This species typically occurs in low densities and is likely only to be observed infrequently.

#### 3.4.7. Western Rosella (*Platycercus icterotis xanthogenys*)

##### Conservation Status

- DBCA: Priority 4

##### Distribution, Ecology and Habitat

This inland subspecies has a smaller and creamier cheek patch, and males have a stronger red and black scalloping on their back than the other subspecies. They occur in the inland of the south-west corner of Australia and appear to have a sedentary lifestyle (Birdlife Australia, 2018). They breed in hollow logs of trees where the male feeds the female whilst she incubates the eggs. The inland subspecies inhabits dry mallee woodland, preferably with Salmon Gum and Wandoo as well as farmland with scattered trees (Morcombe, 2003). It feeds on grasses and herbaceous plants as well as fruits, flowers, insects and larvae which they forage for on the ground (Birdlife Australia, 2018).

### Occurrence in the Survey Area

The species was recorded 59 km south-east of the Survey Area in 2008 (Map 3.1). There have been no further recordings despite suitable habitat within the region and Survey Area. This species may utilise the Survey Area sporadically.

#### 3.4.8. Arid Bronze Azure Butterfly (*Ogyris subterrestris* subsp. *petrina*)

##### Conservation Status

- EPBC Act: Critically Endangered
- WC/BC Act: Critically Endangered

##### Distribution, Ecology and Habitat

The Arid Bronze Azure Butterfly (ABAB) was discovered in 1982 at Douglas Lake within the south-west corner of the Study Area. Specimens were regularly collected in the area until 1992 when the local population underwent a severe decline, with only two specimens being recorded in 1993 (Williams and Williams, 2008). Despite numerous and regular surveys being conducted between 1994 and 2007, no evidence of this species has since been recorded and this population is now considered to be locally extinct (Williams and Williams, 2008). The species is currently only known from two populations located in the northern Wheatbelt region near the town of Mukinbudin. The first population was discovered at Barbalin Nature Reserve in 2006 and a second population was recently discovered 90 km from there (M. Williams, pers. comm., 2020). However, both populations are located over 300 km from the Survey Area.

The ABAB has an obligate ecological association with a sugar ant species, *Camponotus* sp. nr. *terebrans*. The ABAB's larvae live entirely within the ant's nest during their development. The ants protect the larvae

from predators and are thought to be rewarded with secretions produced by the larvae. The larvae themselves feed either on the immature stages of the ants or on ant regurgitations (Braby, 2000). The most critical factor for habitat occupancy by the butterfly is the presence of large populations of this host ant. Only large ant colonies can support an ABAB population because, as a parasitic species, it requires large numbers of host ants (DBCA 2020d).

At the sites where the extant population of ABAB is currently known, the vegetation mainly consists of mature mixed Gimlet (*Eucalyptus salubris*) and Salmon Gum (*E. salmonophloia*) woodlands over an open understorey on red-brown loam soils (DBCA 2020d). A variety of other smooth-barked Eucalypts also occur there, and at Douglas Lake the woodland is likewise dominated by the smooth-barked Victoria Desert mallee (*E. concinna*).

Detailed surveys of the known breeding area at Douglas Lake determined that the host ant species (*C. sp. nr. terebrans*) was absent. This was attributed to the colonisation of increasingly disturbed areas by meat ants (*Iridomyrmex purpureus*), which are known to negatively impact *Camponotus sp. nr. terebrans* colonies (Williams and Williams, 2008). The main threats to the ABAB are therefore land clearing and associated habitat degradation. However, suitable vegetation and the host ant species are both widespread, occurring from near Shark Bay and across the northern and eastern Wheatbelt into the Great Western Woodland (M. Williams, pers. comm. 2020). Host ant colonies, and thus Arid Bronze Azure populations, appear to persist for several years, potentially decades, before dying out like the population at Douglas Lake (Matthew Williams Pers. Comm. 2020).

### Occurrence in the Survey Area

The Survey Area is adjacent to Douglas Lake, which is one of only three known locations for the Arid Bronze Azure Butterfly (ABAB), the other two of which are 90 km apart and over 300 km away. Seventeen historical records of the species exist in the DBCA database, in close proximity to the Survey Area (Map 3.1). These range from the first historical record in Kalgoorlie in 1911, with the rest occurring between 1982 and 1991. There were also two individuals observed in the area in 1993; however, none have been seen since then (Williams and Williams, 2008). Despite more recent surveys, no further observations of the species have been made. No evidence of *Camponotus sp. nr. terebrans* colonies were recorded during a recent survey targeting this species within the Binduli North Study Area (Spectrum Ecology, 2020).

During this survey, four *Camponotus sp.* specimens were collected for identification. However, none of these specimens were identified as the target species. In addition, no ABAB individuals were sighted during the survey period. However, there is suitable habitat for this species within the Survey Area.

### 3.4.9. Inland Hairstreak Butterfly (*Jalmenus aridus*)

#### Conservation Status

- DBCA: Priority 1

#### Distribution, Ecology and Habitat

The Inland Hairstreak Butterfly was originally described from a specimen found at Douglas Lake (Map 3.1); however the species has not been recorded from this location since 1997. Little is known about its biology or ecology, but it is likely that adults stay close to breeding habitats. There are presumed to be two generations per year, although adults are absent in some years (Braby, 2016).

Based on historical records, the larvae of this species is thought to feed on the leaves and flowers of young shrubs of *Senna nemophila* (recent taxonomic revisions classify them as *Senna artemisioides* subsp.



×*coriacea*) and mature trees of *Acacia tetragonophylla*, which grow in shallow gullies with gentle slopes (Braby, 2016). The larvae of the butterfly are attended by the Froglet ant *Froggatella kirbii* (Braby, 2016).

### Occurrence in the Survey Area

Data from Ecological's (Eco Logical Australia, 2016b) flora and vegetation assessment indicated that *Acacia tetragonophylla*, *Senna artemisioides* subsp. ×*artemisioides* and *Senna artemisioides* subsp. *filifolia* were recorded from several quadrats within the Study Area. These were located in the mixed Eucalypt open woodland on red-brown loam plains habitat in the north-west and central east sections of the Study Area (Eco Logical Australia, 2016b).

During this survey, *Senna artemisioides* subsp. *filifolia* and *Acacia tetragonophylla* were recorded from four fauna habitats: Eucalypt woodland over mixed shrubland on low rocky hills with ironstone and quartz over red-orange sandy-clay, mixed Eucalypt open woodland over mixed shrubland on undulating plains on red-orange sandy clay soils, *Allocasuarina* over mixed shrubland on rocky plains and rises, and *Acacia* shrubland on rocky granitic slopes.

No evidence of Froglet ant or Inland Hairstreak were recorded during the survey. However, some potential habitat for this species exists within the Survey Area.

## 4. CONCLUSIONS

### 4.1. Terrestrial Fauna

Ten fauna habitats were mapped within the Survey Area:

- Mixed Eucalypt open woodland over mixed shrubland on undulating plains on red-orange sandy clay soils;
- Mixed Eucalypt low woodland with sparse shrubs over low hummock grassland on orange sandplains;
- *Allocasuarina* over mixed shrubland on rocky plains and rises;
- *Acacia* and *Eremophila* shrubland on sandplains and floodplains on orange clay loam to sand;
- *Acacia* shrubland on rocky granitic slopes;
- *Callitris* and Eucalypt woodland over sparse shrubland on Kopi and gypseous dunes;
- Eucalypt woodland over mixed shrubland on low rocky hills with ironstone and quartz over red-orange sandy-clay;
- Eucalypt woodland over mixed shrubland in drainage lines on red-orange sandy-clay-loam;
- Low sparse chenopod shrubland on salt lakes and salt pans; and
- Cleared areas.

No conservation significant fauna species were recorded during the survey. However, 14 species were assigned a Medium likelihood of occurrence based on their habitat preferences and regional records. These species are:

- Curlew Sandpiper (*Calidris ferruginea*);
- Carnaby's Cockatoo (*Calyptorhynchus latirostris*);
- Malleefowl (*Leipoa ocellata*);
- Common Greenshank (*Tringa nebularia*);
- Common Sandpiper (*Actitis hypoleucos*);
- Fork-tailed Swift (*Apus pacificus*);
- Oriental Plover (*Charadrius veredus*);
- Red-necked Stint (*Calidris ruficollis*);
- Sharp-tailed Sandpiper (*Calidris acuminata*);
- Peregrine Falcon (*Falco peregrinus*);
- Hooded Plover (*Thinornis cucullatus*);
- Western Rosella (*Platycercus icterotis xanthogenys*);
- Arid Bronze Azure Butterfly (*Ogyris subterrestris* subsp. *petrina*); and
- Inland Hairstreak Butterfly (*Jalmenus aridus*).

## 4.2. SRE Invertebrates

A large number of confirmed or potential SRE taxa have been recorded in the wider region, but their general distributions are, for the most part, unknown. Although the microhabitat requirements of these species might be met by the habitats in the Survey Area, previous survey work has assessed that none of the SRE fauna habitats present are restricted or isolated in any way (Eco Logical Australia, 2016d).

During this survey, a total of nine potential SRE species were collected: one Araneomorph spider, one Mygalomorph spider, two Pseudoscorpions, one Geophilomorph centipede, one Scolopendromorph centipede, one Polydesmid millipede, one Symphyla pseudocentipede and one Eupulmonata snail.

None of the habitats in which the potential SREs were recorded appear to be restricted to the Survey Area. Therefore, this indicates that the SRE species likely have distributions extending beyond the Survey Area, thus limiting the likelihood that impacts will be significant.



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## Appendix A: Fauna Regional & Desktop Review





Species Name	Common Name	Conservation Status			Within Study Area						Regional			Databases			
		EPBC Act	BC Act	DBCA	Marianna Partners (1996a)	Marianna Partners (1996b)	GHD (2009)	Eco Logical (2016b)	Spectrum Ecology (2020)	This Survey	Onshore (2021)	GHD (2005)	Phoenix (2018)	Spectrum Ecology Internal	NatureMap	DBCA Threatened Fauna	PMST
Mammals																	
Tachyglossidae																	
Tachyglossus aculeatus	Short-beaked Echidna						X	X			X				X		
Dasyuridae																	
Dasyurus geoffroii	Chuditch, Western Quoll	VU	VU													X	X
Ningau i yvonneae	Southern Ningau i														X		
Sminthopsis crassicaudata	Fat-tailed Dunnart														X		
Sminthopsis dolichura	Little Long-tailed Dunnart														X		
Sminthopsis gilberti	Gilbert's Dunnart														X		
Sminthopsis ooldea	Ooldea Dunnart														X		
Myrmecobiidae																	
Myrmecobius fasciatus	Numbat, Walpurti	EN	EN												X		
Thylacomyidae																	
Macrotis lagotis	Bilby, Dalgyte, Ninu	VU	VU												X		
Burramyidae																	
Cercartetus concinnus	Western Pygmy-possum, Mundarda										X				X		
Macropodidae																	
Macropus fuliginosus	Western Grey Kangaroo				S	S	X	X	S	X	X			X	X		
Macropus robustus	Euro						X								X		
Macropus rufus	Red Kangaroo									X		X			X		
Muridae																	
Notomys mitchellii	Mitchell's Hopping-mouse														X		
Pseudomys bolami	Bolam's Mouse														X		
Pseudomys hermannsburgensis	Sandy Inland Mouse														X		

Species Name	Common Name	Conservation Status			Within Study Area						Regional			Databases			
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Emballonuridae																	
Taphozous hilli	Hill's Sheathtail-bat										X				X		
Molossinae																	
Austronomus australis	White-striped Free-tailed Bat												X	X			
Ozimops kitcheneri	Western Free-tailed Bat													X			
Vespertilionidae																	
Chalinolobus gouldii	Gould's Wattled Bat										X		X	X	X		
Chalinolobus morio	Chocolate Wattled Bat													X	X		
Nyctophilus geoffroyi	Lesser Long-eared Bat														X		
Scotorepens balstoni	Inland Broad-nosed Bat													X	X		
Vespadelus baverstocki	Inland Forest Bat										X				X		
Vespadelus finlaysoni	Finlayson's Cave Bat										X				X		
Vespadelus regulus	Southern Forest Bat										X			X	X		
Introduced Mammals																	
Muridae																	
Mus musculus	House Mouse							X			X				X		X
Leporidae																	
Oryctolagus cuniculus	Rabbit				S	S	X	X	S	X	X	X	X	S	X		X
Canidae																	
Canis familiaris familiaris	Dog													S			X
Vulpes vulpes	Red Fox						X	X			X						X
Felidae																	
Felis catus	Cat							X	S		X				X		X
Equidae																	
Equus africanus asinus	Donkey																X
Equus ferus caballus	Horse																X

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Camelidae																	
Camelus dromedarius	Dromedary, Camel																X
Bovidae																	
Bos taurus	European Cattle										X		X	S	X		
Capra aegagrus hircus	Goat						X	X		X			X		X		X
Ovis aries	Sheep				S	S									X		
Birds																	
Casuariidae																	
Dromaius novaehollandiae	Emu				X	X		X	S	X	X	X	X	X	X		
Anatidae																	
Cygnus atratus	Black Swan							X							X		
Stictonetta naevosa	Freckled Duck														X		
Tadorna tadornoides	Australian Shelduck							X					X		X		
Malacorhynchus membranaceus	Pink-eared Duck														X		
Chenonetta jubata	Australian Wood Duck														X		
Spatula rhynchotis	Australian Shoveler														X		
Anas superciliosa	Pacific Black Duck														X		
Anas platyrhynchos	Mallard														X		
Anas gracilis	Grey Teal							X							X		
Aythya australis	Hardhead														X		
Oxyura australis	Blue-billed Duck			P4												X	
Biziura lobata	Musk Duck														X		
Megapodiidae																	
Leipoa ocellata	Malleefowl	VU	VU										S		X	X	X



Species Name	Common Name	Conservation Status			Within Study Area						Regional			Databases			
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Phasianidae																	
<i>Cotornix pectoralis</i>	Stubble Quail														X		
Podargidae																	
<i>Podargus strigoides</i>	Tawny Frogmouth							X		X	X				X		
Caprimulgidae																	
<i>Eurostopodus argus</i>	Spotted Nightjar									X					X		
Aegothelidae																	
<i>Aegotheles cristatus</i>	Australian Owlet-nightjar														X		
Apodidae																	
<i>Apus pacificus</i>	Fork-tailed Swift	MI	MI										X				X
Otididae																	
<i>Ardeotis australis</i>	Australian Bustard														X		
Cuculidae																	
<i>Chalcites basalis</i>	Horsfield's Bronze Cuckoo						X				X				X		
<i>Chalcites osculans</i>	Black-eared Cuckoo														X		X
<i>Heteroscenes pallidus</i>	Pallid Cuckoo														X		
<i>Cacomantis flabelliformis</i>	Fan-tailed Cuckoo									X					X		
Columbidae																	
<i>*Columba livia</i>	Domestic Pigeon														X		X
<i>*Spilopelia chinensis</i>	Spotted Turtle-dove																X
<i>*Spilopelia senegalensis</i>	Laughing Turtle-dove														X		X
<i>Phaps chalcoptera</i>	Common Bronzewing						X	X			X			X	X		
<i>Ocyphaps lophotes</i>	Crested Pigeon						X	X		X	X	X		X	X		
Rallidae																	
<i>Tribonyx ventralis</i>	Black-tailed Native-hen														X		
<i>Porzana fluminea</i>	Australian Spotted Crane														X		

Species Name	Common Name	Conservation Status			Within Study Area						Regional			Databases			
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<i>Fulica atra</i>	Eurasian Coot													X			
Podicipedidae																	
<i>Tachybaptus novaehollandiae</i>	Australasian Grebe													X			
<i>Poliiocephalus poliocephalus</i>	Hoary-headed Grebe													X			
Turnicidae																	
<i>Turnix velox</i>	Little Button-quail													X			
Recurvirostridae																	
<i>Himantopus himantopus</i>	Black-winged Stilt													X			
<i>Cladorrhynchus leucocephalus</i>	Banded Stilt													X			
<i>Recurvirostra novaehollandiae</i>	Red-necked Avocet						X							X			
Charadriidae																	
<i>Vanellus tricolor</i>	Banded Lapwing													X			
<i>Erythrogonyx cinctus</i>	Red-kneed Dotterel													X			
<i>Charadrius ruficapillus</i>	Red-capped Plover													X			
<i>Thinornis cucullatus</i>	Hooded Plover			P4										X	X	X	
<i>Charadrius veredus</i>	Oriental Plover														X		
<i>Elseyornis melanops</i>	Black-fronted Dotterel									X				X			
Scolopacidae																	
<i>Arenaria interpres</i>	Ruddy Turnstone	MI	MI												X		
<i>Calidris acuminata</i>	Sharp-tailed Sandpiper	MI	MI											X	X	X	
<i>Calidris ruficollis</i>	Red-necked Stint	MI	MI											X	X		
<i>Calidris alba</i>	Sanderling	MI	MI											X	X		
<i>Calidris ferruginea</i>	Curlew Sandpiper	CR & MI	CR											X	X	X	
<i>Calidris melanotos</i>	Pectoral Sandpiper	MI	MI													X	
<i>Actitis hypoleucos</i>	Common Sandpiper	MI	MI											X	X	X	

Species Name	Common Name	Conservation Status			Within Study Area						Regional			Databases			
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<i>Tringa brevipes</i>	Grey-tailed Tattler	MI	MI	P4										X	X		
<i>Tringa nebularia</i>	Common Greenshank	MI	MI											X	X	X	
<i>Tringa glareola</i>	Wood Sandpiper	MI	MI											X	X		
Laridae																	
<i>Larus novaehollandiae</i>	Silver Gull													X			
Anhingidae																	
<i>Anhinga novaehollandiae</i>	Australasian Darter													X			
Phalacrocoracidae																	
<i>Microcarbo melanoleucos</i>	Little Pied Cormorant													X			
<i>Phalacrocorax sulcirostris</i>	Little Black Cormorant													X			
Threskiornithidae																	
<i>Threskiornis spinicollis</i>	Straw-necked Ibis													X			
<i>Threskiornis falcinellus</i>	Glossy Ibis	MI	MI												X		
<i>Platalea flavipes</i>	Yellow-billed Spoonbill													X			
Ardeidae																	
<i>Bubulcus coromandus</i>	Eastern Cattle Egret															X	
<i>Ardea pacifica</i>	White-necked Heron													X			
<i>Ardea alba</i>	Great Egret													X			
<i>Ardea novaehollandiae</i>	White-faced Heron													X			
Accipitridae																	
<i>Elanus axillaris</i>	Black-shouldered Kite													X			
<i>Hiraaetus morphnoides</i>	Little Eagle						X							X			
<i>Aquila audax</i>	Wedge-tailed Eagle							X	X	X	X	X		X			
<i>Accipiter fasciatus</i>	Brown Goshawk													X			
<i>Accipiter cirrocephalus</i>	Collared Sparrowhawk													X			
<i>Haliastur sphenurus</i>	Whistling Kite													X			



Species Name	Common Name	Conservation Status			Within Study Area						Regional			Databases			
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Tytonidae																	
Tyto javanica	Eastern Barn Owl													X			
Alcedinidae																	
Todiramphus sanctus	Sacred Kingfisher													X			
Todiramphus pyrrhopygius	Red-backed Kingfisher												X	X			
Meropidae																	
Merops ornatus	Rainbow Bee-eater						X			X			X	X	X		X
Falconidae																	
Falco cenchroides	Australian Kestrel						X	X		X		X			X		
Falco longipennis	Australian Hobby							X							X		
Falco berigora	Brown Falcon						X	X			X		X	X	X		
Falco hypoleucos	Grey Falcon		VU														X
Falco peregrinus	Peregrine Falcon		OS													X	
Cacatuidae																	
Nymphicus hollandicus	Cockatiel														X		
Calyptorhynchus latirostris	Carnaby's Cockatoo	EN	EN												X	X	
Eolophus roseicapilla	Galah						X				X	X		X	X		
Cacatua sanguinea	Little Corella														X		
Psittaculidae																	
Polytelis anthopeplus	Regent Parrot														X		
Psephotellus varius	Mulga Parrot							X		X			X		X		
Platyercus icterotis	Western Rosella															X	
Barnardius zonarius	Australian Ringneck						X	X	X		X	X		X	X		
Barnardius zonarius zonarius	Port Lincoln Parrot														X		
Pezoporus occidentalis	Night Parrot	EN	CR														X
Parvipsitta porphyrocephala	Purple-crowned Lorikeet							X	X				X	X			

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Melopsittacus undulatus	Budgerigar														X		
Maluridae																	
Malurus pulcherrimus	Blue-breasted Fairy-wren														X		
Malurus splendens	Splendid Fairy-wren						X				X			X	X		
Malurus leucopterus	White-winged Fairy-wren							X		X	X			X	X		
Meliphagidae																	
Epthianura tricolor	Crimson Chat										X				X		
Epthianura albifrons	White-fronted Chat										X				X		
Gliciphila melanops	Tawny-crowned Honeyeater												X				
Lichmera indistincta	Brown Honeyeater						X	X						X	X		
Nesoptilotis leucotis	White-eared Honeyeater						X				X		X	X	X		
Nesoptilotis leucotis novaenorcae	Western White-eared Honeyeater														X		
Melithreptus brevirostris	Brown-headed Honeyeater														X		
Melithreptus chloropsis	Western White-naped Honeyeater							X									
Purnella albifrons	White-fronted Honeyeater										X	X		X	X		
Lichenostomus cratitius	Purple-gaped Honeyeater												X				
Gavicalis virescens	Singing Honeyeater						X	X	X	X	X	X					
Ptilotula ornata	Yellow-Plumed Honeyeater						X			X	X			X			
Ptilotula keartlandi	Grey-headed Honeyeater							X			X						
Ptilotula plumula	Grey-fronted Honeyeater									X							
Anthochaera carunculata	Red Wattlebird					X	X	X	X	X	X		X	X	X		
Acanthagenys rufogularis	Spiny-cheeked Honeyeater						X		X	X	X			X	X		
Manorina flavigula	Yellow-throated Miner					X	X	X		X	X			X	X		

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Pardalotidae																	
<i>Pardalotus punctatus</i>	Spotted Pardalote										X				X		
<i>Pardalotus striatus</i>	Striated Pardalote				X		X	X	X	X	X			X	X		
Acanthizidae																	
<i>Smicronis brevirostris</i>	Weebill						X	X	X	X	X		X	X	X		
<i>Calamanthus cautus</i>	Shy Groundwren														X		
<i>Pyrrholaemus brunneus</i>	Redthroat										X				X		
<i>Gerygone fusca</i>	Western Gerygone														X		
<i>Acanthiza apicalis</i>	Inland Thornbill						X			X	X				X		
<i>Acanthiza uropygialis</i>	Chestnut-rumped Thornbill														X		
<i>Acanthiza iredalei</i>	Samphire Thornbill (Slender-billed Thornbill)										X						
<i>Acanthiza chrysorrhoa</i>	Yellow-rumped Thornbill										X				X		
<i>Acanthiza robustirostris</i>	Slaty-backed Thornbill														X		
<i>Aphelocephala leucopsis</i>	Southern Whiteface										X				X		
Pomatostomidae																	
<i>Pomatostomus superciliosus</i>	White-browed Babbler						X	X		X					X		
Cinclosomatidae																	
<i>Cinclosoma clarum</i>	Western Chestnut Quail-thrush													X			
Artamidae																	
<i>Artamus personatus</i>	Masked Woodswallow							X						X	X		
<i>Artamus cinereus</i>	Black-faced Woodswallow							X		X				X	X		
<i>Artamus cyanopterus</i>	Dusky Woodswallow						X							X	X		
<i>Gymnorhina tibicen</i>	Australian Magpie							X	X	X	X	X	X	X	X		
<i>Cracticus torquatus</i>	Grey Butcherbird				X			X		X	X	X			X		



Species Name	Common Name	Conservation Status			Within Study Area						Regional			Databases			
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<i>Cracticus nigrogularis</i>	Pied Butcherbird						X	X		X	X				X		
<i>Strepera versicolor</i>	Grey Currawong							X	X	X	X	X	X		X		
<b>Campephagidae</b>																	
<i>Coracina maxima</i>	Ground Cuckoo-shrike														X		
<i>Coracina novaehollandiae</i>	Black-faced Cuckoo-shrike						X	X		X	X	X		X	X		
<i>Lalage tricolor</i>	White-winged Triller														X		
<b>Neosittidae</b>																	
<i>Daphoenositta chrysoptera</i>	Varied Sittella								X		X			X	X		
<b>Oreocidae</b>																	
<i>Oreocia gutturalis</i>	Crested Bellbird							X	X	X	X			X	X		
<b>Pachycephalidae</b>																	
<i>Pachycephala inornata</i>	Gilbert's Whistler													X	X		
<i>Pachycephala rufiventris</i>	Rufous Whistler								X	X	X			X	X		
<i>Colluricincla harmonica</i>	Grey Shrike-thrush						X	X		X	X	X		X	X		
<b>Rhipiduridae</b>																	
<i>Rhipidura leucophrys</i>	Willie Wagtail						X	X	X	X	X	X	X	X	X		
<i>Rhipidura albiscapa</i>	Grey Fantail														X		
<b>Monarchidae</b>																	
<i>Grallina cyanoleuca</i>	Magpie-lark							X			X	X	X		X		
<b>Corvidae</b>																	
<i>Corvus orru</i>	Torresian Crow														X		
<i>Corvus bennetti</i>	Little Crow					X			X						X		
<i>Corvus coronoides</i>	Australian Raven						X	X		X	X	X	X		X		
<b>Petroicidae</b>																	
<i>Drymodes brunneopygia</i>	Southern Scrub-robin														X		
<i>Eopsaltria griseogularis</i>	Western Yellow Robin														X		

Species Name	Common Name	Conservation Status			Within Study Area						Regional			Databases			
		EPBC Act	BC Act	DBCA	Marianna Partners (1996a)	Marianna Partners (1996b)	GHD (2009)	Eco Logical (2016b)	Spectrum Ecology (2020)	This Survey	Onshore (2021)	GHD (2005)	Phoenix (2018)	Spectrum Ecology Internal	NatureMap	DBCA Threatened Fauna	PMST
<i>Melanodryas cucullata</i>	Hooded Robin									X							
<i>Microeca fascians</i>	Jacky Winter							X			X				X		
<i>Petroica goodenovii</i>	Red-capped Robin										X				X		
<b>Hirundinidae</b>																	
<i>Cheramoeca leucosterna</i>	White-backed Swallow														X		
<i>Hirundo neoxena</i>	Welcome Swallow						X	X		X		X		X	X		
<i>Petrochelidon ariel</i>	Fairy Martin														X		
<i>Petrochelidon nigricans</i>	Tree Martin							X		X				X	X		
<b>Zosteropidae</b>																	
<i>Zosterops lateralis</i>	Grey-breasted White-eye, Silvereye														X		
<b>Dicaeidae</b>																	
<i>Dicaeum hirundinaceum</i>	Mistletoebird														X		
<b>Estrildidae</b>																	
<i>Taeniopygia guttata</i>	Zebra Finch												X		X		
<b>Motacillidae</b>																	
<i>Motacilla cinerea</i>	Grey Wagtail	MI	MI														X
<i>Anthus australis</i>	Australian Pipit						X			X					X		
<b>Reptiles</b>																	
<b>Cheluidae</b>																	
<i>Chelodina oblonga</i>	Oblong Turtle														X		
<b>Carphodactylidae</b>																	
<i>Nephurus vertebralis</i>	Midline Knob-tailed Gecko														X		
<i>Underwoodisaurus milii</i>	Barking Gecko							X			X			X	X		
<b>Diplodactylidae</b>																	
<i>Diplodactylus granariensis</i>	Western Stone Gecko										X			X	X		

Species Name	Common Name	Conservation Status			Within Study Area						Regional			Databases			
		EPBC Act	BC Act	DBCA	Marianna Partners (1996a)	Marianna Partners (1996b)	GHD (2009)	Eco Logical (2016b)	Spectrum Ecology (2020)	This Survey	Onshore (2021)	GHD (2005)	Phoenix (2018)	Spectrum Ecology Internal	NatureMap	DBCA Threatened Fauna	PMST
<i>Diplodactylus pulcher</i>	Fine-faced Gecko										X				X		
<i>Hesperoedura reticulata</i>	Reticulated Velvet Gecko												X		X		
<i>Lucasium maini</i>	Main's Ground Gecko										X				X		
<i>Rhynchoedura ornata</i>	Western Beaked Gecko									X	X				X		
<i>Strophurus assimilis</i>	Goldfields Spiny-tailed Gecko														X		
<i>Strophurus elderi</i>	Jewelled Gecko														X		
<b>Gekkonidae</b>																	
<i>Christinus marmoratus</i>	Marbled Gecko												X				
<i>Gehyra purpurascens</i>	Purple Dtella										X			X	X		
<i>Gehyra variegata</i>	Variegated Gehyra						X	X			X				X		
<i>*Hemidactylus frenatus</i>	Asian House Gecko														X		X
<i>Heteronotia binoei</i>	Bynoe's Gecko							X			X		X	X	X		
<b>Pygopodidae</b>																	
<i>Delma australis</i>	Marble-faced Delma							X		X					X		
<i>Delma butleri</i>	Spinifex Delma														X		
<i>Lialis burtonis</i>	Burton's Legless Lizard														X		
<i>Pygopus lepidopus</i>	Common Scaly-foot														X		
<i>Pygopus nigriceps</i>	Western Hooded Scaly-foot														X		
<b>Agamidae</b>																	
<i>Ctenophorus caudicinctus</i>	Ring-tailed Dragon														X		
<i>Ctenophorus cristatus</i>	Bicycle Dragon						X			X	X		X		X		
<i>Ctenophorus fordi</i>	Mallee Sand Dragon														X		
<i>Ctenophorus isolepis citrinus</i>	Yellowy Military Dragon														X		
<i>Ctenophorus nuchalis</i>	Central Netted Dragon														X		
<i>Ctenophorus reticulatus</i>	Western Netted Dragon							X							X		
<i>Ctenophorus salinarum</i>	Salt Pan Dragon						X	X		X			X		X		



Species Name	Common Name	Conservation Status			Within Study Area						Regional			Databases			
		EPBC Act	BC Act	DBCA	Marianna Partners (1996a)	Marianna Partners (1996b)	GHD (2009)	Eco Logical (2016b)	Spectrum Ecology (2020)	This Survey	Onshore (2021)	GHD (2005)	Phoenix (2018)	Spectrum Ecology Internal	NatureMap	DBCA Threatened Fauna	PMST
<i>Ctenophorus scutulatus</i>	Lozenge-marked Dragon						X			X					X		
<i>Moloch horridus</i>	Thorny Devil														X		
<i>Pogona minor minor</i>	Western Bearded Dragon							X			X				X		
<i>Tympanocryptis pseudosephos</i>	Goldfields Pebble-mimic Dragon														X		
<b>Scincidae</b>																	
<i>Cryptoblepharus buchanani</i>	Buchanan's Snake-eyed Skink						X								X		
<i>Cryptoblepharus plagiocephalus</i>	Peron's Snake-eyed Skink														X		
<i>Ctenotus atlas</i>	Southern Spinifex Ctenotus									X					X		
<i>Ctenotus leonhardii</i>	Common Desert Ctenotus														X		
<i>Ctenotus schomburgkii</i>	Barred Wedge-snouted Ctenotus						X								X		
<i>Ctenotus uber</i>	Spotted Ctenotus						X								X		
<i>Cyclodomorphus melanops elongatus</i>	Slender Blue-tongue														X		
<i>Egernia depressa</i>	Southern Pygmy Spiny-tailed Skink														X		
<i>Egernia formosa</i>	Goldfields Crevice Skink														X		
<i>Egernia stokesii badia</i>	Western Spiny-tailed Skink	EN	VU												X	X	
<i>Eremiascincus richardsonii</i>	Broad-banded Sand Swimmer														X		
<i>Hemiergis initialis initialis</i>	South-Western Earless Skink										X			X	X		
<i>Hemiergis peronii peronii</i>	Peron's Earless Skink														X		
<i>Lerista desertorum</i>	Great Desert Slider										X						
<i>Lerista kingi</i>	King's Three-toed Slider							X							X		
<i>Lerista muelleri</i>	Mueller's Three-toed Slider														X		

Species Name	Common Name	Conservation Status			Within Study Area						Regional			Databases			
		EPBC Act	BC Act	DBCA	Marianna Partners (1996a)	Marianna Partners (1996b)	GHD (2009)	Eco Logical (2016b)	Spectrum Ecology (2020)	This Survey	Onshore (2021)	GHD (2005)	Phoenix (2018)	Spectrum Ecology Internal	NatureMap	DBCA Threatened Fauna	PMST
<i>Lerista picturata</i>	Southern Robust Slider														X		
<i>Lerista stictopleura</i>	Spotted Broad-striped Slider														X		
<i>Lerista timida</i>	Timid Slider														X		
<i>Liopholis inornata</i>	Desert Skink							X							X		
<i>Menetia greyii</i>	Common Dwarf Skink							X			X				X		
<i>Morethia adelaidensis</i>	Saltbush Morethia Skink														X		
<i>Morethia butleri</i>	Woodland Dark-flecked Morethia														X		
<i>Morethia obscura</i>	Shrubland Pale-flecked Morethia														X		
<i>Tiliqua occipitalis</i>	Western Bluetongue												X		X		
<i>Tiliqua rugosa</i>	Bobtail							X		X	X		X	S	X		
<b>Varanidae</b>																	
<i>Varanus caudolineatus</i>	Stripe-tailed Pygmy Monitor														X		
<i>Varanus gouldii</i>	Sand Monitor						X			X			X	X	X		
<i>Varanus tristis</i>	Racehorse Goanna														X		
<b>Typhlopidae</b>																	
<i>Anilius waitii</i>	Southern Beaked Blind Snake										X						
<b>Pythonidae</b>																	
<i>Morelia spilota imbricata</i>	Carpet Python												X		X		
<b>Elapidae</b>																	
<i>Acanthophis pyrrhus</i>	Desert Death Adder														X		
<i>Brachyuropsis fasciolatus</i>	Narrow-banded Shovel-nosed Snake														X		
<i>Brachyuropsis semifasciatus</i>	Southern Shovel-nosed Snake														X		
<i>Demansia psammophis</i>	Yellow-faced Whipsnake														X		

Species Name	Common Name	Conservation Status			Within Study Area						Regional			Databases			
		EPBC Act	BC Act	DBCA	Marianna Partners (1996a)	Marianna Partners (1996b)	GHD (2009)	Eco Logical (2016b)	Spectrum Ecology (2020)	This Survey	Onshore (2021)	GHD (2005)	Phoenix (2018)	Spectrum Ecology Internal	NatureMap	DBCA Threatened Fauna	PMST
<i>Furina ornata</i>	Moon Snake														X		
<i>Neelaps bimaculatus</i>	Black-naped Snake														X		
<i>Pseudechis australis</i>	Mulga Snake							X							X		
<i>Pseudonaja mengdeni</i>	Western Brown Snake														X		
<i>Pseudonaja modesta</i>	Ringed Brown Snake														X		
<i>Pseudonaja nuchalis</i>	Gwardar, Northern Brown Snake														X		
<i>Simoselaps bertholdi</i>	Jan's Banded Snake														X		
<i>Suta fasciata</i>	Rosen's Snake														X		
<i>Suta gouldii</i>	Gould's Hooded Snake														X		
<i>Suta monachus</i>	Inland Hooded Snake														X		
<b>Amphibians</b>																	
<b>Pelodyadidae</b>																	
<i>Litoria moorei</i>	Motorbike Frog														X		
<b>Limnodynastidae</b>																	
<i>Neobatrachus kunapalari</i>	Kunapalari Frog							X							X		
<i>Neobatrachus pelobatoides</i>	Humming Frog														X		
<i>Neobatrachus sutor</i>	Shoemaker Frog														X		
<i>Neobatrachus wilsmorei</i>	Plonking Frog														X		
<b>Myobatrachidae</b>																	
<i>Pseudophryne occidentalis</i>	Western Toadlet														X		

S=Secondary evidence



## Appendix B: Conservation Codes



## Appendix A1: Definitions of Conservation Categories under the EPBC Act

Category	Definition
<b>Extinct</b>	A native species is eligible to be included in the extinct category at a particular time if, at that time, there is no reasonable doubt that the last member of the species has died.
<b>Extinct in the Wild</b>	A native species is eligible to be included in the extinct in the wild category at a particular time if, at that time: (a) it is known only to survive in cultivation, in captivity or as a naturalised population well outside its past range; or (b) it has not been recorded in its known and/or expected habitat, at appropriate seasons, anywhere in its past range, despite exhaustive surveys over a time frame appropriate to its life cycle and form.
<b>Critically Endangered</b>	A native species is eligible to be included in the critically endangered category at a particular time if, at that time, it is facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with the prescribed criteria.
<b>Endangered</b>	A native species is eligible to be included in the endangered category at a particular time if, at that time: (a) it is not critically endangered; and (b) it is facing a very high risk of extinction in the wild in the near future, as determined in accordance with the prescribed criteria.
<b>Vulnerable</b>	A native species is eligible to be included in the vulnerable category at a particular time if, at that time: (a) it is not critically endangered or endangered; and (b) it is facing a high risk of extinction in the wild in the medium-term future, as determined in accordance with the prescribed criteria.
<b>Conservation Dependent</b>	A native species is eligible to be included in the conservation dependent category at a particular time if, at that time: (a) the species is the focus of a specific conservation program the cessation of which would result in the species becoming vulnerable, endangered, or critically endangered; or (b) the following subparagraphs are satisfied: (i) the species is a species of fish; (ii) the species is the focus of a plan of management that provides for management actions necessary to stop the decline of, and support the recovery of, the species so that its chances of long-term survival in nature are maximised; (iii) the plan of management is in force under a law of the Commonwealth or of a State or Territory; (iv) cessation of the plan of management would adversely affect the conservation status of the species.

## Appendix A2: Definitions of Conservation Categories under the BC Act (DBCA 2019)

**Threatened Species:** Listed by order of the Minister as Threatened in the category of critically endangered, endangered, or vulnerable under section 19(1), or is a rediscovered species to be regarded as Threatened species under section 26(2) of the Biodiversity Conservation Act 2016 (BC Act).

**Threatened fauna** is that subset of 'Specially Protected Fauna' listed under schedules 1 to 3 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018 for Threatened Fauna.

Threatened flora is that subset of 'Rare Flora' listed under schedules 1 to 3 of the Wildlife Conservation (Rare Flora) Notice 2018 for Threatened Flora.

The assessment of the conservation status of these species is based on their national extent and ranked according to their level of threat using IUCN Red List categories and criteria as detailed below.

Category	Definition
CR	<p><b>Critically endangered species</b></p> <p>Threatened species considered to be "facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with criteria set out in the ministerial guidelines".</p> <p>Listed as critically endangered under section 19(1)(a) of the BC Act in accordance with the criteria set out in section 20 and the ministerial guidelines. Published under schedule 1 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018 for critically endangered fauna or the Wildlife Conservation (Rare Flora) Notice 2018 for critically endangered flora.</p>
EN	<p><b>Endangered species</b></p> <p>Threatened species considered to be "facing a very high risk of extinction in the wild in the near future, as determined in accordance with criteria set out in the ministerial guidelines".</p> <p>Listed as endangered under section 19(1)(b) of the BC Act in accordance with the criteria set out in section 21 and the ministerial guidelines. Published under schedule 2 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018 for endangered fauna or the Wildlife Conservation (Rare Flora) Notice 2018 for endangered flora.</p>
VU	<p><b>Vulnerable species</b></p> <p>Threatened species considered to be "facing a high risk of extinction in the wild in the medium-term future, as determined in accordance with criteria set out in the ministerial guidelines".</p> <p>Listed as vulnerable under section 19(1)(c) of the BC Act in accordance with the criteria set out in section 22 and the ministerial guidelines. Published under schedule 3 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018 for vulnerable fauna or the Wildlife Conservation (Rare Flora) Notice 2018 for vulnerable flora.</p>

**Extinct species:** Listed by order of the Minister as extinct under section 23(1) of the BC Act as extinct or extinct in the wild.

Category	Definition
EX	<p><b>Extinct species</b></p> <p>Species where "there is no reasonable doubt that the last member of the species has died", and listing is otherwise in accordance with the ministerial guidelines (section 24 of the BC Act).</p> <p>Published as presumed extinct under schedule 4 of the Wildlife Conservation (Specially Protected Fauna) Notice 2018 for extinct fauna or the Wildlife Conservation (Rare Flora) Notice 2018 for extinct flora.</p>
EW	<p><b>Extinct in the wild species</b></p> <p>Species that "is known only to survive in cultivation, in captivity or as a naturalised population well outside its past range; and it has not been recorded in its known habitat or expected habitat, at appropriate seasons, anywhere in its past range, despite surveys over a time frame appropriate to its life cycle and form", and listing is otherwise in accordance with the ministerial guidelines (section 25 of the BC Act).</p> <p>Currently there are no Threatened fauna or Threatened flora species listed as extinct in the wild. If listing of a species as extinct in the wild occurs, then a schedule will be added to the applicable notice.</p>



**Specially protected species:** Listed by order of the Minister as specially protected under section 13(1) of the BC Act. Meeting one or more of the following categories: species of special conservation interest; migratory species; cetaceans; species subject to international agreement; or species otherwise in need of special protection.

Species that are listed as Threatened species (critically endangered, endangered, or vulnerable) or extinct species under the BC Act cannot also be listed as Specially Protected species.

MI	<p><b>Migratory species</b></p> <p>Fauna that periodically or occasionally visit Australia or an external Territory or the exclusive economic zone; or the species is subject of an international agreement that relates to the protection of migratory species and that binds the Commonwealth; and listing is otherwise in accordance with the ministerial guidelines (section 15 of the BC Act). Includes birds that are subject to an agreement between the government of Australia and the governments of Japan (JAMBA), China (CAMBA) and The Republic of Korea (ROKAMBA), and fauna subject to the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention), an environmental treaty under the United Nations Environment Program. Migratory species listed under the BC Act are a subset of the migratory animals, that are known to visit Western Australia, protected under the international agreements or treaties, excluding species that are listed as Threatened species.</p> <p>Published as migratory birds protected under an international agreement under <b>schedule 5</b> of the Wildlife Conservation (Specially Protected Fauna) Notice 2018.</p>
CD	<p><b>Species of special conservation interest (Conservation dependant fauna)</b></p> <p>Fauna of special conservation need being species dependent on ongoing conservation intervention to prevent it becoming eligible for listing as Threatened, and listing is otherwise in accordance with the ministerial guidelines (section 14 of the BC Act).</p> <p>Published as conservation dependent fauna under <b>schedule 6</b> of the Wildlife Conservation (Specially Protected Fauna) Notice 2018.</p>
OS	<p><b>Other specially protected species</b></p> <p>Fauna otherwise in need of special protection to ensure their conservation, and listing is otherwise in accordance with the ministerial guidelines (section 18 of the BC Act).</p> <p>Published as other specially protected fauna under <b>schedule 7</b> of the Wildlife Conservation (Specially Protected Fauna) Notice 2018.</p>
<p><sup>1</sup> The definition of flora includes algae, fungi, and lichens.</p> <p><sup>2</sup> Species includes all taxa (plural of taxon - a classificatory group of any taxonomic rank, e.g. a family, genus, species or any infraspecific category i.e. subspecies or variety, or a distinct population).</p>	

### Appendix A3: Definitions of Priority Species Classification (DBCA 2019)

**Priority species:** Possibly Threatened species that do not meet survey criteria, or are otherwise data deficient, are added to the Priority Fauna or Priority Flora Lists under Priorities 1, 2 or 3. These three categories are ranked in order of priority for survey and evaluation of conservation status so that consideration can be given to their declaration as Threatened fauna or flora.

Species that are adequately known, are rare but not Threatened, or meet criteria for near Threatened, or that have been recently removed from the Threatened species or other specially protected fauna lists for other than taxonomic reasons, are placed in Priority 4. These species require regular monitoring.

Assessment of Priority codes is based on the Western Australian distribution of the species, unless the distribution in WA is part of a contiguous population extending into adjacent States, as defined by the known spread of locations.

Category	Definition
P1	<b>Priority 1: Poorly-known species</b> Species that are known from one or a few locations (generally five or less) which are potentially at risk. All occurrences are either: very small; or on lands not managed for conservation, e.g. agricultural or pastoral lands, urban areas, road and rail reserves, gravel reserves and active mineral leases; or otherwise under threat of habitat destruction or degradation. Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under immediate threat from known threatening processes. Such species are in urgent need of further survey.
P2	<b>Priority 2: Poorly-known species</b> Species that are known from one or a few locations (generally five or less), some of which are on lands managed primarily for nature conservation, e.g. national parks, conservation parks, nature reserves and other lands with secure tenure being managed for conservation. Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under threat from known threatening processes. Such species are in urgent need of further survey.
P3	<b>Priority 3: Poorly-known species</b> Species that are known from several locations, and the species does not appear to be under imminent threat, or from few but widespread locations with either large population size or significant remaining areas of apparently suitable habitat, much of it not under imminent threat. Species may be included if they are comparatively well known from several locations but do not meet adequacy of survey requirements and known threatening processes exist that could affect them. Such species are in need of further survey.
P4	<b>Priority 4: Rare, Near Threatened and other species in need of monitoring</b> (a) Rare. Species that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently Threatened or in need of special protection but could be if present circumstances change. These species are usually represented on conservation lands. (b) Near Threatened. Species that are considered to have been adequately surveyed and that are close to qualifying for vulnerable but are not listed as Conservation Dependent. (c) Species that have been removed from the list of Threatened species during the past five years for reasons other than taxonomy

## Appendix C: Site Locations








## Site Locations



Site ID	Site Type	Easting*	Northing*
LL01	Leaf Litter	346939	6585187
LL02	Leaf Litter	346783	6585113
LL03	Leaf Litter	346617	6585599
LL04	Leaf Litter	347107	6583971
LL05	Leaf Litter	347101	6583306
LL06	Leaf Litter	351180	6585576
LL07	Leaf Litter	348369	6587505
LL08	Leaf Litter	345513	6588550
AS01	Active Search	347116	6583936
AS02	Active Search	348369	6587505
AS03	Active Search	346559	6589178
Hab01	Habitat Assessment	347363	6588479
Hab02	Habitat Assessment	344876	6588770
Hab03	Habitat Assessment	345266	6588312
Hab04	Habitat Assessment	346756	6589974
Hab05	Habitat Assessment	347130	6590276
Hab06	Habitat Assessment	348279	6589316
Hab07	Habitat Assessment	346520	6589208
R001	Releve	348779	6584735
R002	Releve	349081	6585382
R003	Releve	349522	6584362
R004	Releve	348705	6584404
R005	Releve	346921	6584631
R006	Releve	347292	6585037
R007	Releve	349150	6585034
R008	Releve	348287	6588268
R009	Releve	348458	6586205
R010	Releve	345747	6588607
R011	Releve	345862	6588363
R012	Releve	348544	6587710
R013	Releve	346920	6589133
R014	Releve	346628	6589209
R015	Releve	346379	6589540
R016	Releve	346205	6589931
R017	Releve	346363	6590018
R018	Releve	346647	6590335
R019	Releve	347071	6590467
R020	Releve	347207	6590289
R021	Releve	347983	6589320
R022	Releve	347808	6588906
R023	Releve	348902	6586829

Site ID	Site Type	Easting*	Northing*
R024	Releve	348905	6586354
R025	Releve	346761	6587077
R026	Releve	348840	6586853

\* CRS – GDA94 / MGA94 Zone 51

### SRE Dry Pitfall Site Details

Site name	Easting*	Northing*	Habitat Type	Photo
WS01	348775	6584824	Low sparse chenopod shrubland on salt lakes and salt pans	
WS02	347477	6585156	Low sparse chenopod shrubland on salt lakes and salt pans	
WS03	348176	6585400	Just on the edge of the salt lake in: Mixed Eucalypt low woodland with sparse shrubs over low hummock grassland on orange sandplains	

Site name	Easting*	Northing*	Habitat Type	Photo
WS04	348901	6585745	Low sparse chenopod shrubland on salt lakes and salt pans	
WS05	347097	6584216	Low sparse chenopod shrubland on salt lakes and salt pans	

\* CRS – GDA94 / MGA94 Zone 51



## Appendix D: Carnaby's Cockatoo Trees



## Carnaby's Cockatoo Trees – Salmon Gum &amp; Other Eucalypts in the Survey Area

Site ID	Tree DBH (mm)	Tree Species	Easting*	Northing*
CAM01	30	Other Eucalypt	347329	6590278
CAM02	67	Salmon Gum	347364	6590516
CAM03	50	Salmon Gum	347356	6590469
CC10	33	Other Eucalypt	347094	6589337
CC11	35	Other Eucalypt	347149	6589242
CC12	56	Other Eucalypt	347429	6588873
CC13	43	Other Eucalypt	345015	6588600
CC15	70	Other Eucalypt	345439	6588545
CC16	33	Salmon Gum	345179	6588902
CC17	51	Other Eucalypt	347369	6589198
CC18	50	Other Eucalypt	347305	6589317
CC19	41	Other Eucalypt	345525	6588438
CC2	40	Other Eucalypt	347233	6588615
CC20	60	Salmon Gum	347123	6589528
CC21	40	Other Eucalypt	347009	6589683
CC22	44	Other Eucalypt	346884	6589814
CC23	48	Other Eucalypt	346813	6589943
CC25	31	Other Eucalypt	346567	6590199
CC27	33	Other Eucalypt	347128	6590269
CC28	93	Salmon Gum	347463	6590143
CC29	36	Other Eucalypt	347226	6590463
CC3	40	Other Eucalypt	347110	6588707
CC30	67	Salmon Gum	346984	6590937
CC31	40	Other Eucalypt	347183	6590772
CC32	61	Other Eucalypt	347127	6586105
CC34	39	Other Eucalypt	348273	6589429
CC36	45	Other Eucalypt	347937	6589843
CC36	38	Other Eucalypt	348047	6589688
CC37	100	Salmon Gum	348143	6589536
CC38	78	Salmon Gum	347825	6589921
CC39	81	Salmon Gum	347711	6589994
CC4	44	Other Eucalypt	346963	6588948
CC40	111	Salmon Gum	347681	6590118
CC41	63	Other Eucalypt	347588	6590268
CC42	34	Salmon Gum	347462	6590350
CC43	66	Other Eucalypt	345943	6590014
CC44	30	Other Eucalypt	346155	6589757
CC45	88	Salmon Gum	346130	6589514
CC46	95	Other Eucalypt	346029	6589579
CC47	40	Other Eucalypt	345894	6589766
CC48	39	Other Eucalypt	345806	6589889

Site ID	Tree DBH (mm)	Tree Species	Easting*	Northing*
CC49	57	Salmon Gum	345711	6589826
CC5	44	Other Eucalypt	346632	6589321
CC50	36	Other Eucalypt	345760	6589711
CC51	57	Salmon Gum	345968	6589454
CC52	37	Other Eucalypt	346122	6589349
CC6	54	Salmon Gum	346558	6589484
CC7	33	Salmon Gum	346277	6590310
CC8	38	Other Eucalypt	346671	6589863
CC9	63	Other Eucalypt	346797	6589690
CCLR1	33	Salmon Gum	346260	6590083
CCLR10	43	Other Eucalypt	347485	6589403
CCLR12	31	Other Eucalypt	346649	6590400
CCLR13	68	Other Eucalypt	346507	6590486
CCLR14	37	Other Eucalypt	346966	6590242
CCLR15	33	Other Eucalypt	347168	6590031
CCLR16	56	Other Eucalypt	347408	6589667
CCLR17	32	Other Eucalypt	347888	6589089
CCLR19	31	Other Eucalypt	346942	6585885
CCLR2	37	Other Eucalypt	347237	6588893
CCLR20	38	Other Eucalypt	347485	6589789
CCLR21	31	Salmon Gum	347537	6590068
CCLR22	38	Salmon Gum	347595	6589905
CCLR23	48	Salmon Gum	347766	6589787
CCLR24	37	Salmon Gum	347811	6589679
CCLR25	33	Other Eucalypt	347934	6589569
CCLR26	37	Other Eucalypt	345536	6589451
CCLR27	31	Other Eucalypt	345674	6589312
LRCC28	37	Other Eucalypt	345343	6589461
CCLR29	38	Other Eucalypt	345413	6589117
CCLR3	37	Other Eucalypt	345047	6588801
CCLR4	51	Other Eucalypt	345692	6588510
CCLR5	42	Other Eucalypt	345592	6588648
CCLR6	38	Other Eucalypt	345261	6589018
CCLR7	35	Other Eucalypt	347812	6588936
CCLR8	32	Other Eucalypt	347730	6589052
CCLR9	42	Other Eucalypt	347524	6589254

\* CRS – GDA94 / MGA94 Zone 51



## Appendix E: ABAB Sample Points



Tree ID	Easting*	Northing*	Date	DBH (mm)	Ants Present	Leafhoppers Present	Comments
1	346884	6584426	26/10/2021	25	No	No	
2	346948	6584345	26/10/2021	26	No	No	
3	347011	6584265	26/10/2021	29	No	No	
4	346881	6584687	26/10/2021	16	No	No	
5	346975	6584568	26/10/2021	21	No	No	
6	347070	6584448	26/10/2021	28	No	No	
7	346878	6584949	26/10/2021	23	No	No	
9	346874	6585211	26/10/2021	21	No	No	
10	346947	6585119	26/10/2021	26	No	No	
18	346880	6585720	28/10/2021	27	No	No	
19	346925	6585662	28/10/2021	23	No	No	
25	346954	6585883	28/10/2021	42	No	No	
26	347016	6585805	28/10/2021	24	No	No	
27	347078	6585727	28/10/2021	31	No	No	
32	344725	6588956	26/10/2021	22	No	No	
33	344815	6588843	26/10/2021	11	No	No	
34	344905	6588729	26/10/2021	20	No	No	
35	344995	6588615	26/10/2021	43	No	No	
36	345085	6588502	26/10/2021	12	No	No	
37	345175	6588388	26/10/2021	25	No	No	
38	345265	6588275	26/10/2021	19	No	No	
39	347077	6585986	28/10/2021	61	No	No	
40	347150	6585894	28/10/2021	16	No	No	
42	344850	6589057	26/10/2021	23	No	No	
43	344943	6588939	26/10/2021	27	Yes	No	CAM01
44	345036	6588822	27/10/2021	37	No	No	
45	345129	6588704	27/10/2021	24	No	No	
46	345222	6588587	27/10/2021	23	No	No	
47	345315	6588469	27/10/2021	18	No	No	
48	345408	6588352	27/10/2021	27	No	No	
49	347200	6586089	28/10/2021	16	No	No	
52	345069	6589038	26/10/2021	14	No	No	
53	345164	6588917	26/10/2021	33	No	No	
54	345260	6588797	26/10/2021	14	No	No	
55	345355	6588677	26/10/2021	12	No	No	
56	345450	6588556	26/10/2021	70	No	No	
57	345545	6588436	26/10/2021	42	No	No	
58	345641	6588316	26/10/2021	61	No	No	
74	345098	6589258	27/10/2021	28	No	No	
75	345197	6589134	27/10/2021	23	No	No	
76	345295	6589010	27/10/2021	38	No	No	

Tree ID	Easting*	Northing*	Date	DBH (mm)	Ants Present	Leafhoppers Present	Comments
77	345394	6588885	27/10/2021	21	No	No	
78	345492	6588761	27/10/2021	22	No	No	
79	345590	6588637	27/10/2021	42	No	No	
80	345689	6588513	27/10/2021	51	No	No	
81	345787	6588388	28/10/2021	20	No	No	
83	346181	6587891	28/10/2021	33	No	No	
84	346279	6587767	28/10/2021	12	No	No	
89	345220	6589362	28/10/2021	23	No	No	
90	345319	6589237	28/10/2021	31	No	No	
91	345418	6589113	28/10/2021	38	No	No	
92	345516	6588988	28/10/2021	11	No	No	
93	345615	6588863	28/10/2021	21	No	No	
94	345714	6588739	28/10/2021	23	No	No	
95	345813	6588614	28/10/2021	30	No	No	
96	345911	6588489	28/10/2021	19	No	No	
99	346208	6588115	28/10/2021	42	No	No	
100	346306	6587990	28/10/2021	46	No	No	
101	346405	6587866	28/10/2021	8	No	No	
102	345333	6589477	28/10/2021	37	No	No	
103	345423	6589364	28/10/2021	24	No	No	
104	345513	6589250	28/10/2021	25	No	No	
105	345603	6589136	28/10/2021	14	No	No	
106	345693	6589022	28/10/2021	15	No	No	
107	345784	6588908	28/10/2021	23	No	No	
108	345462	6589572	28/10/2021	18	No	No	
109	345559	6589449	28/10/2021	33	No	No	
110	345657	6589326	28/10/2021	37	No	No	
111	345754	6589203	28/10/2021	29	No	No	
112	345578	6589684	28/10/2021	27	No	No	
113	345671	6589566	28/10/2021	24	No	No	
114	345694	6589795	28/10/2021	57	No	No	
115	345785	6589679	28/10/2021	36	No	No	
116	345877	6589564	28/10/2021	26	No	No	
117	345968	6589448	28/10/2021	57	No	No	
118	346060	6589333	28/10/2021	16	No	No	
119	346151	6589217	28/10/2021	37	No	No	
120	345809	6589907	28/10/2021	39	No	No	
121	345895	6589799	28/10/2021	40	No	No	
123	346066	6589582	28/10/2021	95	No	No	
124	346152	6589474	28/10/2021	88	No	No	
125	346237	6589366	28/10/2021	17	No	No	



Tree ID	Easting*	Northing*	Date	DBH (mm)	Ants Present	Leafhoppers Present	Comments
127	345940	6590000	28/10/2021	66	No	No	
128	346034	6589880	28/10/2021	24	No	No	
129	346129	6589760	28/10/2021	30	No	No	
130	346224	6589641	28/10/2021	20	No	No	
131	346319	6589521	28/10/2021	19	No	No	
133	346509	6589281	28/10/2021	14	No	No	
136	346065	6590100	26/10/2021	54	No	No	
137	346164	6589975	26/10/2021	24	No	No	
138	346263	6589850	26/10/2021	18	No	No	
139	346362	6589724	26/10/2021	21	No	No	
140	346461	6589599	26/10/2021	27	No	No	
141	346560	6589474	26/10/2021	36	No	No	
142	346659	6589349	26/10/2021	44	No	No	
143	346758	6589224	26/10/2021	25	No	No	
144	346857	6589099	26/10/2021	21	No	No	
145	346956	6588974	26/10/2021	44	No	No	
146	347055	6588849	26/10/2021	28	No	No	
147	347154	6588724	26/10/2021	40	No	No	
148	347253	6588599	26/10/2021	40	No	No	
149	347352	6588474	26/10/2021	22	No	No	
150	347451	6588348	26/10/2021	22	No	No	
151	347514	6588270	26/10/2021	18	No	No	
152	347592	6588170	26/10/2021	16	No	No	
153	347671	6588071	26/10/2021	26	No	No	
154	346182	6590210	26/10/2021	23	No	No	
155	346277	6590090	26/10/2021	33	No	No	
156	346372	6589970	26/10/2021	13	No	No	
157	346467	6589850	26/10/2021	16	No	No	
158	346562	6589730	26/10/2021	28	No	No	
159	346657	6589610	26/10/2021	24	No	No	
160	346752	6589490	26/10/2021	24	No	No	
161	346847	6589370	26/10/2021	27	No	No	
162	346941	6589250	26/10/2021	27	No	No	
163	347036	6589130	26/10/2021	26	No	No	
164	347131	6589010	26/10/2021	15	No	No	
165	347226	6588890	26/10/2021	37	No	No	
166	347321	6588770	26/10/2021	26	No	No	
167	347416	6588650	26/10/2021	24	No	No	
168	347511	6588531	26/10/2021	28	No	No	
169	347606	6588411	26/10/2021	20	No	No	
170	346303	6590314	26/10/2021	33	No	No	

Tree ID	Easting*	Northing*	Date	DBH (mm)	Ants Present	Leafhoppers Present	Comments
171	346399	6590194	26/10/2021	28	No	No	
172	346494	6590073	26/10/2021	21	No	No	
173	346589	6589953	26/10/2021	25	No	No	
174	346685	6589832	26/10/2021	38	No	No	
175	346780	6589712	26/10/2021	63	No	No	
176	346875	6589592	26/10/2021	17	No	No	
177	346971	6589471	26/10/2021	24	No	No	
178	347066	6589351	26/10/2021	33	No	No	
179	347161	6589230	26/10/2021	35	No	No	
180	347257	6589110	26/10/2021	21	No	No	
181	347352	6588989	26/10/2021	22	No	No	
182	347447	6588869	26/10/2021	56	No	No	
183	347543	6588749	26/10/2021	21	No	No	
184	347638	6588628	26/10/2021	20	No	No	
185	347733	6588508	26/10/2021	28	No	No	
186	346426	6590417	27/10/2021	52	No	No	
187	346523	6590294	27/10/2021	14	No	No	
188	346620	6590172	27/10/2021	24	No	No	
189	346717	6590049	27/10/2021	26	No	No	
190	346814	6589927	27/10/2021	48	No	No	
191	346911	6589804	27/10/2021	44	No	No	
192	347008	6589681	27/10/2021	40	No	No	
193	347105	6589559	27/10/2021	60	No	No	
194	347202	6589436	27/10/2021	41	No	No	
195	347299	6589314	27/10/2021	50	No	No	
196	347396	6589191	27/10/2021	51	No	No	
197	347493	6589069	27/10/2021	12	No	No	
198	347590	6588946	27/10/2021	21	No	No	
201	346546	6590522	27/10/2021	68	No	No	
202	346643	6590400	27/10/2021	31	No	No	
203	346740	6590278	27/10/2021	21	No	No	
204	346836	6590157	27/10/2021	64	No	No	
205	346933	6590035	27/10/2021	18	No	No	
206	347029	6589913	27/10/2021	21	No	No	
207	347467	6589360	27/10/2021	43	No	No	
208	347553	6589251	27/10/2021	42	No	No	
209	347639	6589142	27/10/2021	28	No	No	
210	347726	6589033	27/10/2021	32	No	No	
211	347812	6588924	27/10/2021	35	No	No	
213	346669	6590625	27/10/2021	27	No	No	
214	346766	6590503	27/10/2021	28	No	No	

Tree ID	Easting*	Northing*	Date	DBH (mm)	Ants Present	Leafhoppers Present	Comments
215	346863	6590381	27/10/2021	21	No	No	
216	346959	6590258	27/10/2021	37	No	No	
217	347056	6590136	27/10/2021	18	No	No	
218	347153	6590014	27/10/2021	33	No	No	
219	347407	6589694	27/10/2021	56	No	No	
220	347586	6589467	27/10/2021	23	No	No	
221	347682	6589346	27/10/2021	24	No	No	
222	347778	6589224	27/10/2021	21	No	No	
223	347874	6589103	27/10/2021	32	No	No	
224	347971	6588981	27/10/2021	20	No	No	
225	346785	6590736	27/10/2021	24	No	No	
226	346872	6590627	27/10/2021	15	No	No	
227	346958	6590518	27/10/2021	26	No	No	
228	347045	6590409	27/10/2021	31	No	No	
229	347131	6590299	27/10/2021	29	No	No	
230	347218	6590190	27/10/2021	33	No	No	
232	347421	6589933	28/10/2021	25	No	No	
233	347517	6589812	28/10/2021	38	No	No	
234	347612	6589692	28/10/2021	25	No	No	
235	347708	6589571	28/10/2021	26	No	No	
236	347803	6589450	28/10/2021	21	No	No	
237	347899	6589330	28/10/2021	26	No	No	
238	347994	6589209	28/10/2021	30	No	No	
239	348090	6589089	28/10/2021	13	No	No	
240	346932	6590808	27/10/2021	19	No	No	
241	347031	6590684	27/10/2021	18	No	No	
242	347129	6590560	27/10/2021	23	No	No	
243	347227	6590436	27/10/2021	36	No	No	
244	347325	6590312	27/10/2021	30	Yes	No	CAM01
245	347423	6590188	27/10/2021	93	No	No	
246	347522	6590064	28/10/2021	31	No	No	
247	347620	6589940	28/10/2021	38	No	No	
248	347718	6589816	28/10/2021	48	No	No	
249	347816	6589692	28/10/2021	37	No	No	
250	347914	6589568	28/10/2021	40	No	No	
251	348013	6589444	28/10/2021	24	No	No	
252	348111	6589320	28/10/2021	19	No	No	
253	348209	6589196	28/10/2021	13	No	No	
254	347007	6590972	27/10/2021	67	No	No	
256	347101	6590853	27/10/2021	40	No	No	
257	347196	6590734	27/10/2021	29	No	No	



Tree ID	Easting*	Northing*	Date	DBH (mm)	Ants Present	Leafhoppers Present	Comments
258	347290	6590614	27/10/2021	67	Yes	No	CAM02
258/2	347384	6590495	28/10/2021	50	Yes	No	Additional tree nearby to 258 CAM03
259	347479	6590376	28/10/2021	34	No	No	
260	347573	6590257	28/10/2021	63	No	No	
261	347667	6590138	28/10/2021	111	No	No	
262	347762	6590018	28/10/2021	81	No	No	
263	347856	6589899	28/10/2021	78	No	No	
264	347951	6589780	28/10/2021	100	No	No	
265	348045	6589661	28/10/2021	38	No	No	
266	348139	6589542	28/10/2021	45	No	No	
267	348234	6589422	28/10/2021	39	No	No	
268	348328	6589303	28/10/2021	16	No	No	

\* CRS – GDA94 / MGA94 Zone 51

## Appendix F: SRE Invertebrate Fauna Assemblage



## SRE and Non-SRE Invertebrate Fauna Recorded in the Survey Area

Family	Species	Taxonomy Remarks	Site Code	Easting*	Northing*	Males	Females	Juveniles	Total Number	Sre Status
Anamidae	<i>Aname</i> sp.	Bi01	WS02	347477	6585156	1			1	Potential SRE: DDT
Araneomorphae^	Araneomorphae sp.	non-target	WS01	348775	6584824		1		1	No (non-target)
Araneomorphae^	Araneomorphae sp.	non-target	WS03	348176	6585400			1	1	No (non-target)
Araneomorphae^	Araneomorphae sp.	non-target	WS02	347477	6585156			1	1	No (non-target)
Araneomorphae^	Araneomorphae sp.	non-target	WS03	348176	6585400	1			1	No (non-target)
Araneomorphae^	Araneomorphae sp.	non-target	LL06	351180	6585576			1	1	No (non-target)
Gnaphosidae	Gnaphosidae sp.	non-target	AS01	347116	6583936			1	1	No (non-target)
Lycosidae	Lycosidae sp.	Bi01	WS02	347477	6585156			1	1	Potential SRE: DDT
Lycosidae	Lycosidae sp.	non-target	WS05	347097	6584216			1	1	No (non-target)
Lycosidae	Lycosidae sp.	non-target	WS05	347097	6584216			1	1	No (non-target)
Lycosidae	Lycosidae sp.	non-target	WS03	348176	6585400	1			1	No (non-target)
Lycosidae	Lycosidae sp.	non-target	AS01	347116	6583936			1	1	No (non-target)
Lycosidae	Lycosidae sp.	non-target	WS01	348775	6584824		1		1	No (non-target)
Lycosidae	Lycosidae sp.	non-target	WS05	347097	6584216			1	1	No (non-target)
Lycosidae	Lycosidae sp.	non-target	WS04	348901	6585745			1	1	No (non-target)
Lycosidae	Lycosidae sp.	non-target	WS03	348176	6585400			1	1	No (non-target)
Chernetidae	Chernetidae sp.	Bi01	LL05	347101	6583306			1	1	Potential SRE: DDT
Chernetidae	Chernetidae sp.	Bi01	LL04	347107	6583971			1	1	Potential SRE: DDT
Olpiidae	<i>Beierolpium</i> '8/4'	Bi01	LL04	347107	6583971		1	1	2	Potential SRE: DDT
Geophilidae (Chilenophilidae)	<i>Sepedonophilus</i> sp.		LL02	346783	6585113			1	1	Potential SRE: DDT
Cryptopidae	<i>Cryptops</i> sp.		LL03	346617	6585599				1	Potential SRE: DDT
Cryptopidae	<i>Cryptops</i> sp.		LL01	346939	6585187				1	Potential SRE: DDT
Paradoxosomatidae	Paradoxosomatidae sp.		LL05	347101	6583306			4	4	Potential SRE: DDT
Paradoxosomatidae	Paradoxosomatidae sp.		LL05	347101	6583306			1	1	Potential SRE: DDT



Family	Species	Taxonomy Remarks	Site Code	Easting*	Northing*	Males	Females	Juveniles	Total Number	Sre Status
Bothriembryontidae	<i>Bothriembryon</i> sp.		sn01	345103	6588511				1	Potential SRE: DDT
Bothriembryontidae	<i>Bothriembryon</i> sp.		S01	347353	6588489				1	Potential SRE: DDT
Bothriembryontidae	<i>Bothriembryon</i> sp.		LRSNAIL2	348095	6589097					Potential SRE: DDT
Bothriembryontidae	<i>Bothriembryon</i> sp.		LL02	346783	6585113				1	No (non-target)
Camaenidae	<i>Sinumelon</i> sp.		WS02	347477	6585156				3	No (non-target)
Camaenidae	<i>Sinumelon</i> sp.		SNAIL LR1	347627	6588378				1	No
Pupillidae	<i>Gastrocopta margaretae</i>		LL06	351180	6585576				1	No
Pupillidae	<i>Pupoides adelaidae</i>		LL06	351180	6585576				1	No
Dermaptera^	Dermaptera sp.	non-target	LL04	347107	6583971			1	1	No (non-target)
Symphyla^	Symphyla sp.		LL01	346939	6585187				2	Potential SRE: DDT

\* CRS – GDA94 / MGA94 Zone 51

## Appendix G: SRE Identification Report (Alacran)



## Identification and Short-range endemic Assessment of Invertebrates from the Binduli South Project

Prepared for  
**Spectrum Ecology**



*Paradoxosomatidae* sp.



## EXECUTIVE SUMMARY

In December 2021 Spectrum Ecology requested taxonomic identification and SRE assessment of a collection of invertebrates from the Binduli South Project. The collection contained 34 samples and 16 taxa. Of these 16 taxa, four(4) were non-target, three (3) were widespread and nine (9) taxa were identified from SRE category groups. These nine SRE category taxa were:

- Lycosidae 'Bi01', a possible salt lake specialist spider
- *Aname* 'Bi01', an open-hole trapdoor spider
- Chernetidae 'Bi01', a pseudoscorpion
- *Beierolpium* '8/4-Bi01', a pseudoscorpion
- *Sepedonophilus* sp., a soil centipede
- *Cryptops* sp., cryptic centipede
- Symphyla sp., a pseudocentipede
- Paradoxosomatidae sp., a flat-back millipede
- *Bothriembryon* sp., a land snail

All of these SRE category taxa are potential SREs owing to taxonomic data deficiency. In all of these cases (except for *Bothriembryon* sp.) assessment of DNA sequences may improve taxonomic resolution and regional context. *Bothriembryon* sp. was only represented by old dead shells that are unlikely to yield useful DNA sequences. Greater taxonomic resolution for this taxon would require collection of live material to better assess shell morphology and possibly DNA sequencing.

## SCOPE

In December (2020), Spectrum Ecology (Spectrum) requested identification and SRE assessment of a collection of invertebrate samples from the Binduli South Project, in the W.A. Goldfields Western Australia. Spectrum requested identification of SRE category invertebrates from this collection.

## BACKGROUND

### SHORT-RANGE ENDEMISM

Short-range endemics (SREs) are organisms with small geographic distributions (Harvey 2002; Ponder *et al.* 2002), nominally less than 10,000 km<sup>2</sup>(Harvey 2002). These organisms are typically characterised by one or more of the following features:

- limited dispersal capabilities,
- seasonal activity (cooler or wetter periods),
- slow growth, and
- low levels of fecundity.

Their limited dispersal capabilities result in small populations being isolated from each other by inhospitable geographic features such as rivers, rocky ridges or plains. Prolonged isolation between populations eventually results in speciation, with each population becoming genetically and, or morphologically distinct over time. Two types of short-range endemism have been recognised: Relictual Endemism and Habitat Specialist Endemism (Harvey 2002; Ponder *et al.* 2002).

**Relictual SREs** result when speciation occurs following the fragmentation of continuous habitat into two or more refugia. In Australia, the primary driver of this over the last 65 million years has been aridification, which acted to isolate formerly widespread species living in mesic forests to small patches of mesic refugia. Relictual SREs include scorpions in the genus *Aops* (Volschenk *et al.* 2008), pseudoscorpions in the genera *Tyrannochthonius* (Harvey 1991; Edward *et al.* 2008), *Indohya* (Harvey 1993b; Harvey *et al.* 2007b) and *Idioblothrus* (Muchmore 1982; Harvey 1993a; Harvey *et al.* 2008a) and millipedes in the genus *Antichiropus* (Car *et al.* 2013b; Car *et al.* 2014).

**Habitat specialist SREs** are species that have adapted to very specific environment types, including those found in arid environments (*e.g.* rocky outcrops, isolated dune systems and salt lakes). These habitats are often relatively young (<10 million years) and therefore are not refugial. Examples of habitat specialist SREs include spiders in the family Selenopidae, pseudoscorpions in the genus *Synsphyronus* (Harvey 2011, 2012), scorpions in the genera *Lychas* and *Urodacus* and tiger beetles in the genus *Pseudotetracha* (Lopez-Lopez *et al.* 2016)

## METHODS

### ASSESSMENT OF SHORT-RANGE ENDEMISM

Assessment of short-range endemism can be challenging when data for evaluation are absent or limited. Limitations may include any of the following:

- **Poor survey coverage**, e.g. the fauna of an area has not been sampled extensively enough to enable assessment of species distributions. The absence of a species from survey records may not mean that it is absent from the area.
- **Poor taxonomic resolution**, e.g. a species has not been subject to systematic investigation, and/or the identity is either difficult or impossible to determine. Good taxonomic resolution does not necessarily need to be in the form of published revisions, as it can be facilitated by any of the following:
  - a researcher actively working on the group who can authorise identifications,
  - a publicly accessible reference collection, and/or;
  - assessment of species boundaries using genomic methods such as DNA barcoding (Hebert et al. 2003a; Hebert et al. 2003b).
- **Identification issues**, e.g. surveys sampled life stages of SREs that are impossible to identify based on morphological characters. Examples of relevant taxa include juvenile or female millipedes, mygalomorph spiders and *Urodacus* scorpions.

There are no published systems for assessing the SRE potential for a species. The W.A. Museum previously employed the following system to assess SRE-status of invertebrates:

- **Confirmed SRE**: This category applies when the identity of the taxon is unambiguous and its distribution is less than 10 000 km<sup>2</sup> based on publicly available vouchered records. Supporting data can be either genomic (from DNA sequences) or morphological, ideally both.
- **Potential SRE**: This category applies to situations where there are knowledge gaps for the taxon. The following sub-categories further elucidate this status:
  - **Data Deficiency (DD)**: This category covers taxa for which there is insufficient data available to determine SRE status. Factors that fall under this category include:
    - insufficient geographic information (DDG),
    - insufficient taxonomic information (DDT), and/or
    - inappropriate life stages prevent identification to species level.
  - **Habitat Indicators (H)**: This category employs habitat characteristics to evaluate SRE status when habitats are known to support SRE taxa. For example, many species sampled from subterranean habitats are known to be range restricted; a new species discovered from such habitat therefore has greater potential to be range restricted (i.e. a SRE) than widespread.
  - **Morphological Evidence (M)**: This category uses one or more morphological characters that are characteristic of SRE taxa inhabiting restricted environments,



e.g. the specialised morphological features of animals adapted to subterranean habitats, including body markings that are absent or significantly paler than surface dwelling relatives, eyes that are absent or significantly reduced, and/or longer appendages (legs and antennae) than surface relatives.

- **Unpublished Research & Expertise (U):** This category relies on unpublished research or expertise to develop SRE status. **Widespread (not an SRE):** This category applies when vouchered evidence demonstrates a distribution greater than 10,000 km<sup>2</sup>.

## TAXONOMY

The taxonomic nomenclature of invertebrates follows the references detailed in Table 2.2. Morphospecies designations follow the parataxonomy of the scientist(s) working on the group; these informal names are written between single quotation marks rather than being italicised as they are not valid under the International Code of Zoological Nomenclature (1999).

In defining morphospecies, Alacran follows the “Phylogenetic Species Concept” (Cracraft 1983):

“A species is the smallest **diagnosable** cluster of individual organisms within which there is a parental pattern of ancestry and descent.”

## Morphological Identification (Traditional Taxonomy)

For this report, all identifications were carried out by the Dr Erich Volschenk. The references used for species determination are summarised in Table 2.2.

**Table 2.1. The following references and collections were used to assist with morphospecies designations.**

Order	Taxonomic reference	Morphospecies and reference
Pseudoscorpiones	(Harvey 1992; Muriene <i>et al.</i> 2008; Harvey 2012, 2013b)	W.A. Museum reference collection.
Scorpiones	(Glauert 1925b, a; Acosta 1990; Kovařík 1997; Fet <i>et al.</i> 2000; Volschenk <i>et al.</i> 2000; Volschenk <i>et al.</i> 2008; Volschenk <i>et al.</i> 2010)	Morphospecies designation by Dr Erich S Volschenk, W.A. Museum reference collection.
Chilopoda	(Koch 1983b, a, c, 1984; Koch <i>et al.</i> 1984; Koch 1985; Colloff <i>et al.</i> 2005)	W.A. Museum reference collection.
Eupulmonata	(Solem 1985, 1988, 1997; Whisson <i>et al.</i> 2012; Whisson <i>et al.</i> 2014; Stanasic <i>et al.</i> 2017)	W.A. Museum reference collection.

## RESULTS

The collection contained 34 samples which was represented by 16 taxa of which three belonged to non-target taxa. The target taxa represented groups known to contain SREs, of which two were represented by described (formally named) species; four were represented by undescribed morphospecies, all of which were only known from this collection; six were ambiguously identified to taxonomic ranks above species owing to specimen immaturity or damage.

A taxonomic summary of the SRE target species (with corresponding SRE categories and justifications) are summarised in Table 2. The list of representative samples for all samples in this collection are provided in Appendix 1.

**Table 2. List of species present in this collection from SRE target groups.**

Order	Family	Species	SRE category
<b>Arachnida</b>			
Araneae	Anamidae	<i>Aname</i> 'Bi01'	Potential SRE: DDT
Araneae	Lycosidae	Lycosidae 'Bi01'	Potential SRE: DDT
Pseudoscorpiones	Chernetidae	Chernetidae 'Bi01'	Potential SRE: DDT
Pseudoscorpiones	Olpiidae	<i>Beierolpium</i> '8/4-Bi01'	Potential SRE: DDT
<b>Chilopoda</b>			
Geophilomorpha	Geophilidae	<i>Sepedonophilus</i> sp.	Potential SRE: DDT
Scolopendromorpha	Cryptopidae	<i>Cryptops</i> sp.	Potential SRE: DDT
<b>Diplopoda</b>			
Polydesmida	Paradoxosomatidae	Paradoxosomatidae sp.	Potential SRE: DDT
<b>Symphyla</b>			
		Symphyla sp.	Potential SRE: DDT
<b>Gastropoda</b>			
Eupulmonata	Bothriembryontidae	<i>Bothriembryon</i> sp.	Potential SRE: DDT
Eupulmonata	Camaenidae	<i>Sinumelon</i> sp.	Widespread
Eupulmonata	Pupillidae	<i>Gastrocopta margaretae</i>	Widespread
Eupulmonata	Pupillidae	<i>Pupoides adalaidae</i>	Widespread

## DISCUSSION

Species identifications and SRE justification for each taxon are discussed below.

### ARACHNIDA

#### Araneae, Araneomorphae (Modern Spiders)

Several samples of Araneomorphae were present in this collection; however, only one appears likely to be from an SRE group.

#### Family Lycosidae (Wolf Spiders)

**Lycosidae 'Bi01'** was represented by a single subadult sample. The colour pattern of this specimen indicates that it may be a halophile. Assessment of the potential habitat specialisation will be further informed by its

collection locality. If directly from the playa surface, then it is likely to be a halophile. Data supplied with the specimens indicates collection from samphire which may support its own habitat specialists.

Species level identification of most spiders requires assessment of adult specimens, usually males. As this sample was juvenile, species level identification was not possible. The markings of this specimen were similar to samples collected by the author from Lake Ballard so it may be related. This species is a potential SRE owing to taxonomic data deficiency. Greater taxonomic resolution may be obtained using DNA sequences.

## Araneae, Mygalomorphae (Trapdoor Spiders)

### Family Anamidae (Open hole Trapdoor spiders)

*Aname* 'Bi01' was represented by a single adult male specimen. Two described species and two W.A. Museum morphospecies were identified from an area search undertaken by Spectrum: *Aname* 'mainae', *Aname* 'armigera group', *Aname lillianae* (previously *Aname* 'MYG522') and *Aname simonae* (previously *Aname* 'MYG523') (Harvey *et al.* 2020). None of these species or morphospecies match the sample from this collection and it was assigned the interim morphospecies name *Aname* 'Bi01'. This species is a potential SRE owing to taxonomic data deficiency. Greater resolution of this species may be possible through comparisons of its DNA sequences with sequences in the WA Museum sequence database.

## Pseudoscorpiones (Pseudoscorpions)

Pseudoscorpions superficially resemble scorpions, but they are not closely related to them. They are generally much smaller than most scorpions and lack the distinctive tail-like abdomen and stinging telson for which scorpions are infamous.

In Western Australian pseudoscorpions are represented by 19 families (Harvey 2013a). They occur in most undisturbed terrestrial habitats but escape our attention owing to their small size and cryptic behaviour. The W.A. pseudoscorpion fauna is poorly known with only a few groups receiving taxonomic attention over the last decade and these are primarily focussed on subterranean species: (Harvey *et al.* 2007a; Harvey *et al.* 2007b; Edward *et al.* 2008; Harvey *et al.* 2008b). The epigeal (surface dwelling) fauna flagged as SREs or Potential SREs are largely undescribed.

### Family Chernetidae

**Chernetidae 'Bi01'**. This morphospecies was represented by two samples, both of which are subadults. The morphosculpture of this species is very granulose making it fairly distinctive and was the reason for the unusual step of assigning a morphospecies to a subadult. This is a potential SRE owing to taxonomic data deficiency and greater taxonomic resolution may be achieved by assessing the DNA sequences of this morphospecies.

### Family Olpiidae

In Western Australian, Olpiidae is diverse and poorly known taxonomically. The application of DNA barcoding to assist and test morphological species delimitation has revealed many undescribed species. The genera *Beierolpium*, *Austrohorus* and *Indolpium* are particularly diverse; however, determining the identity of representatives from this family should be verified using molecular data.



*Beierolpium* '8/4-Bi01' was represented by a single sample. The identity of this morphospecies needs to be confirmed using DNA sequences

## INSECTA AND ENTOGNATHA (INSECTS AND ALLIES)

Few insects are considered to be SRE candidates owing to their ability to disperse through flight. Notable Insect groups containing SREs are flightless tiger beetles (Cicindelinae), representatives of the silverfish family Nicoletiidae and troglobites, species specialised for life in air-filled subterranean void networks.

While not true insects, representatives of the order Diplura (Entognatha) are also likely to be SRE. Subterranean diplurans often appear to be range restricted; however, very little is known about the distributions of epigean diplurans in Western Australia.

This collection contained a single non-target insect sample from the order Dermaptera (earwigs).

## CHILOPODA (CENTIPEDES)

### Geophilomorpha (Soil Centipedes)

Centipedes from this order are very poorly known taxonomically. Geophilomorpha is the most species rich of centipede orders and assessment of W.A. specimens using DNA sequences has revealed many species. This order is likely to contain many SRE species.

#### Family Geophilidae

*Sepedonophilus* sp. was represented by a single specimen. Species level identification from this order need to be determined using DNA Sequences. That identification would enable assessing the regional context and conservation significance of this species. In the absence of this information, this species is a potential SRE owing to taxonomic data deficiency.

### Scolopendromorpha

#### Family Cryptopidae

*Cryptops* sp. was represented by two samples. The taxonomy of W. A. *Cryptops* is poorly known; however, in arid regions they frequently appear to be SREs. Both of these samples should be sequenced in order to determine their identity. This taxon is a potential SRE owing to taxonomic data deficiency and one or two species may present.

## DIPLOPODA (MILLIPEDES)

### Polydesmida (Flat-back millipedes)

#### Family Paradoxosomatidae

**Paradoxosomatidae (*Antichiropus*) sp.** This taxon was represented by two samples in this collection. In both cases all of the specimens are juveniles. Species and genus identification in Paradoxosomatidae requires examination of characters on the male gonopods (Car *et al.* 2013a; Car *et al.* 2013b; Car *et al.* 2014). Since no adult males were present in this collection, species determination was not possible using morphology alone.

Greater taxonomic resolution may be obtained by comparing DNA sequences of the specimens in this collection.

It is very likely that these samples are representatives of the genus *Antichiropus* as this is the only paradoxosomatid known from this region of W.A.

## Symphyla

**Symphyla sp.** was represented by a single sample of two specimens. Symphyla are rarely collected from arid environments and DNA sequencing of these generally reviles new species. For this reason this taxon is a potential SRE owing to taxonomic data deficiency and there is a small chance that two species may be present.

## Gastropoda

### Eupulmonata

#### Family Bothriembryontidae

**Bothriembryon sp.** was represented by four samples. Species identification of WA Bothriembryon requires assessment of DNA sequences. All of the samples in this collection were represented by dead shells, therefore, species level resolution was unobtainable. Bothriembryon contains many undescribed and SRE species, therefore this taxon is a potential SRE owing to taxonomic data deficiency. Live specimens will need to be collected from these sites in order to obtain greater taxonomic resolution and conservation assessment.

#### Family Camaenidae

**Sinumelon sp.** was represented by two samples. Both samples were represented by old dead shells making species level identification impossible. All W.A. species of *Sinumelon* species have widespread distributions (Stanasic *et al.* 2017).

#### Family Pupilidae

**Gastrocopta margaretae** and **Pupoides adelaidae** were each represented in this collection by single specimens. Both species are Widespread (Stanasic *et al.* 2017).

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Attachment: Appendix 1: 2141-Spectrum-Bunsuli South-20220120.xls

**Appendix E: Phoenix Environmental Sciences (2017) Level 1  
subterranean fauna assessment for the Binduli Expansion Project**



# PHOENIX

ENVIRONMENTAL SCIENCES

## **Level 1 subterranean fauna assessment for the Binduli Expansion Project**

**Prepared for Norton Gold Fields Ltd**

**May 2017**

**Final report**





Level 1 subterranean fauna assessment for the Binduli Expansion Project

Prepared for Norton Gold Fields Ltd

Final Report

Author: Volker Framenau

Reviewer: Karen Crews

Date: 23 May 2017

Submitted to: Andrew Mack, Elina Vuorenmaa (Talis Consultants Pty Ltd)

Chain of authorship and review			
Name	Task	Version	Date
Volker Framenau	Draft for client comments	1.0	26 January 2016
Volker Framenau	Draft for client comments	2.0	30 April 2017
Volker Framenau	Final to client	2.1	23 May 2017

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## EXECUTIVE SUMMARY

In January 2016, Phoenix Environmental Sciences Pty Ltd (Phoenix) was commissioned by Talis Consultants Pty Ltd on behalf of Norton Gold Fields Ltd to undertake a Level 1 subterranean fauna assessment for the Binduli Expansion Project (the 'Project') situated approximately 3 km west of City of Kalgoorlie-Boulder north and south of the Great Eastern Highway.

Norton is investigating the feasibility of further expansion to the current pits of its Binduli operations and the development of associated infrastructure to process the ore. The Project has an estimated gold production of 150,000 oz/annum. The Project is anticipated to cover an area of approximately 5,300 ha (the 'study area') and proposes a number of new pits and cutbacks to the existing pits resulting in three areas of expansion:

- Northern Expansion Area (749,900 m<sup>2</sup>)
- Southern Expansion Area (3,099,800 m<sup>2</sup>)
- Apache Project (226,600 m<sup>2</sup>).

Due to the large Project footprint and associated potential environmental impacts, a referral pursuant to Part IV of the *Environmental Protection Act 1986* (EP Act) to the Environmental Protection Authority (EPA) will be submitted.

The assessment methodology of this assessment complied with the Environmental Protection Authority's (EPA's) requirements for an environmental impact assessment (EIA) of subterranean invertebrates as outlined in the Environmental Factor Guideline *Subterranean fauna* and Technical Guidance *Sampling methods for subterranean fauna*.

Subterranean fauna are animals, predominantly invertebrates, which have evolved to live underground to escape harsh environmental conditions such as extreme heat and dryness of exposed environments. They are classified into two types:

- troglofauna – animals that live in air-filled subterranean networks
- stygofauna – animals that live in water-filled subterranean networks.

Habitats likely to support troglofauna are karstic limestone, channel iron deposits (CIDs; in particular pisolite in inverted landscape geomorphology), groundwater calcretes above the water table, alluvium/colluvium in valley-fill settings, banded iron formations (BIFs) and weathered and fractured sandstone. Stygofauna are likely where there are groundwater voids present, for example in karst limestone, calcretes, alluvial formations and fractured rock.

The objective of this Level 1 subterranean fauna survey was to assess the likelihood of subterranean fauna to occur in the study area by reviewing of relevant databases, available technical reports, literature and spatial data. A pilot troglofauna survey (bore scrapes only) was conducted on 22 August 2016 targeting a total of 15 bores, 12 in the Northern Expansion Area and three in the Apache Project.

Data from the database searches and literature reviews showed no troglofauna or stygofauna records within approximately 100 km of the study area.

The study area lies within the Eastern Goldfields Province of the Yilgarn Craton, which essentially consists of a granite-greenstone terrane of Archaean age with linear, north-northwest trending belts of supracrustal volcanic and metasedimentary rocks and granite intrusions. The Roe palaeodrainage system is incised into the Archaean bedrock and filled with Tertiary sediment (Wollubar Sandstone, Perkolilli Shale). The Cainozoic deposits characteristic for the majority of the study area represent units of Aeolian, alluvial and colluvial origin including scree from Kurrawang Formation. Alluvial deposits occur within the poorly defined drainage lines and are between 3 to 6 m thick. Extensive

playa lakes occur in association with the palaeodrainages throughout the region. They contain saline and gypsiferous clay and silt, often up to 10 m thick. The study area features some Archaean outcrops of the Black Flag Group and Kurrawang Formation.

Three main groundwater systems are located in the Kalgoorlie region, of which two are covered by the study area: local aquifers in fractured and deeply weathered bedrock systems, and Ferricrete and alluvial systems. The third is the Wollubar Sandstone within the palaeochannels and is the principal aquifer of the region. The natural groundwater flow is towards these palaeodrainages and playa lakes, where the groundwater table is at or near the surface. Elsewhere throughout the study area, groundwater levels were about 40–50 m bgl before mine pit dewatering commenced in the early 1990's. This dewatering activity in the Southern Expansion Area has lowered the groundwater level to 70–80 m bgl, but it has stabilized and started recovering since groundwater abstraction ceased in 2013.

Groundwater salinities are generally hypersaline (60,000–230,000 mg/L TDS), although some water quality measurements in mining pits have returned brackish (5,000–8,300 mg/L TDS at Ben Hur 2 in the Southern Expansion Area) to saline (30,000 mg/L TDS at Janet Ivy in the Northern Expansion Area) conditions, possibly caused by surface water run-off into the pits.

Troglofauna cannot persist in areas of permanently saturated aquifers, such as those in the palaeodrainage channels and neighbouring salt lakes and salt pans. With groundwater levels of generally 50 m bgl pre-dewatering elsewhere in the study area, troglofauna may potentially occur above the permanently saturated aquifers within the weathered and/or fractured bedrock and lower saprolite/saprock, and possible Cainozoic (Quaternary) deposits if these are of sufficient depth. Suitable conditions for troglofauna are limited to the metasedimentary weathered siltstone and sandstone of the Northern and the northern part of the Southern Expansion Areas. Based on the geological information at hand, subterranean fauna habitat, if present, is likely to be continuous beyond the areas of direct impact in both areas and therefore troglofauna are unlikely to be limited to the expansion areas.

Due to the generally hypersaline groundwater quality it is highly unlikely that stygofauna are present in the study area, in particular towards the aquifers of the palaeochannels. Stygofauna are also unlikely to occur in the Northern Expansion Area if the measured comparatively low saline groundwater conditions at Janet Ivy is considered an artefact of surface water inflow to the pit.

The pilot survey did result in the capture of a poorly preserved specimen of centipede, possibly belonging to the family Scolopendridae in the northern-most sampled bore of the Northern Expansion Area (Janet Ivy). The poor condition of the specimens did not allow to unambiguously identify it as a obligate subterranean. This partly reflects an overall low likelihood of catching troglofauna specimens in similar geologies.

To further assess the likelihood of troglofauna to occur in the Northern Expansion Area, it is recommended to expand the pilot survey to a Level 2 survey, in particular to also cover reference sites and geologies not likely to be impacted by future mining developments.

# 1 INTRODUCTION

In January 2016, Phoenix Environmental Sciences Pty Ltd (Phoenix) was commissioned by Talis Consultants Pty Ltd (Talis) on behalf of Norton Gold Fields Ltd (Norton) to undertake a Level 1 subterranean fauna assessment for the Binduli Expansion Project ('the Project') west of City of Kalgoorlie-Boulder (Figure 1-1). This report describes the findings of this assessment.

## 1.1 BACKGROUND

Norton operates the Paddington mining and exploration tenements north and west of Kalgoorlie, with the Paddington Mill located 35 km north of Kalgoorlie as central hub of the operations. The Binduli Project, approximately 3 km west of Kalgoorlie, forms part of the Paddington Operations and Norton is investigating the feasibility of further expansion to the current pits and the development of associated infrastructure to process the ore. The Binduli Expansion Project, including pits and associated infrastructure, is anticipated to cover an area of approximately 5,300 ha north and south of the Great Eastern Highway with an estimated gold production of 170,000 oz/annum.

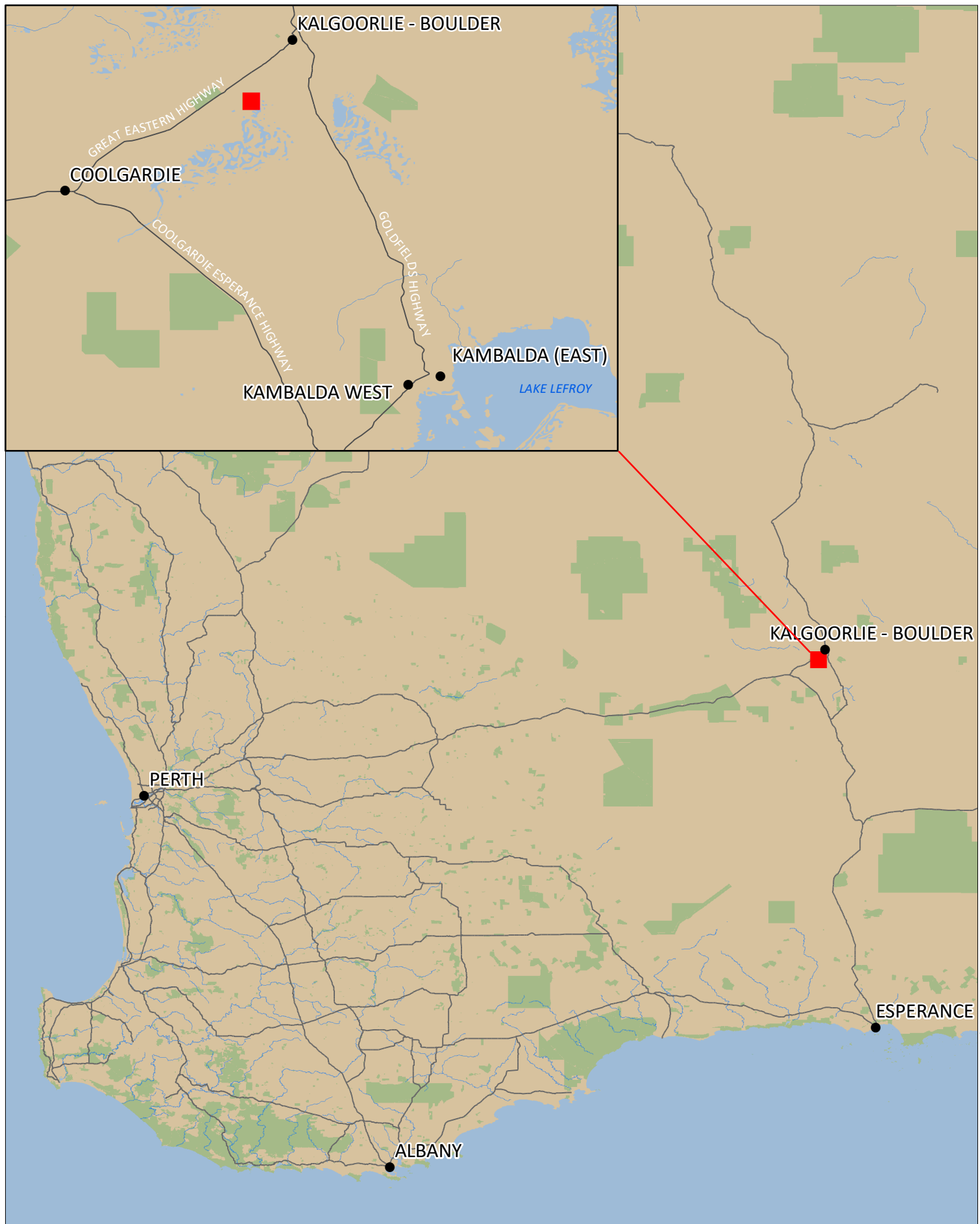
The Project covers a total of 23 tenements (the 'study area'; Figure 1-2) and is disturbed to a large extent as a result of historic mining operations throughout the 1990's. The current Binduli Project consists of a total of nine pits, eight waste rock dumps, and associated infrastructure such as run of mine pads (ROM), roads and pipelines; however, most of the current pits are not operational. For example, mining at Janet Ivy and Navajo Chief recommenced in the late 2000's, however, operations at Navajo Chief have since ceased. Mining of Fort Scott commenced in 2015 (Talis 2016) and ceased in early 2016.

The Project is proposed to include three pit expansion areas with a number of historic pits (Figure 1-2):

- Northern Expansion Area (approximately 749,900 m<sup>2</sup>): expansion to the Janet Ivy pit; Fort William and Fort Scott are situated just to the south-west
- Southern Expansion Area (3,099,800 m<sup>2</sup>): includes Navajo Chief and Beaver, Centurion in the centre and Ben Hur 1 and 2 to the south
- Apache Project (226,600 m<sup>2</sup>): situated to the east of the Southern Expansion Area.

Due to the large Project footprint and associated potential environmental impacts, a referral pursuant to Part IV of the *Environmental Protection Act 1986* (EP Act) to the Environmental Protection Authority (EPA) will be submitted.





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**Figure 1-1**  
**Location of the**  
**Binduli Expansion Project**

Client: Norton Gold Fields Pty Ltd  
Project: Binduli Expansion Project

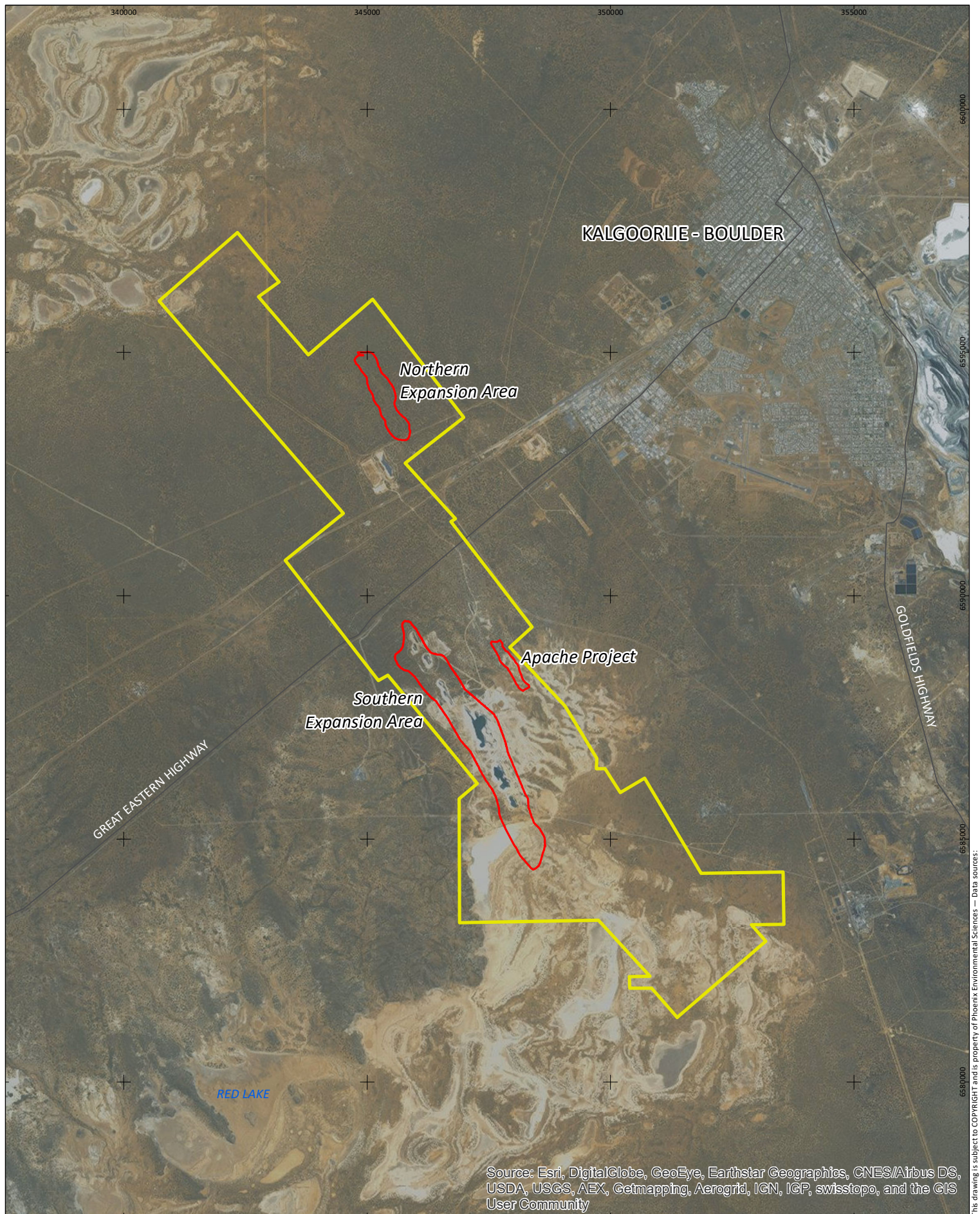
Author: K. Wyatt  
Date: 23-May-17

Coordinate System: GDA94  
Datum: GDA 1994

■ Project Location

0 20 40 80 120 Kilometres  
1:4,500,000





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**Figure 1-2**  
Study area for the Level 1  
subterranean fauna assessment  
for the Binduli Expansion Project  
and proposed pit expansion areas

Client: Norton Gold Fields Pty Ltd  
Project: Binduli Expansion Project

Author: K. Wyatt  
Date: 23-May-17

Coordinate System: GDA 1994 MGA Zone 51  
Projection: Transverse Mercator  
Datum: GDA 1994

0 0.5 1 2 3 Kilometres  
1:100,000

  Proposed pit expansion areas  
  Study area



## 1.2 STUDY OBJECTIVE AND SCOPE OF WORK

The objective of the Level 1 assessment was to assess the likelihood of subterranean fauna, both troglofauna and stygofauna, to occur in the study area of the Project (Figure 1-2).

The scope of works undertaken to achieve these objectives was a review of relevant databases, available technical reports, literature and spatial data relevant to the Project and to conduct a pilot survey in the study area.

The assessment methodology complied with the Environmental Protection Authority's (EPA's) requirements for an environmental impact assessment (EIA) of subterranean invertebrates as outlined in Environmental Factor Guideline: *Subterranean fauna* (EPA 2016a) and Technical Guidance: *Sampling methods for subterranean fauna* (EPA 2016c).



## 2 LEGISLATIVE CONTEXT

The protection of fauna in Western Australia (WA) is principally governed by three Acts:

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

### 2.1 COMMONWEALTH

Under the EPBC Act, actions that have, or are likely to have, a significant impact on a matter of national environmental significance (NES), require approval from the Australian Government Minister for the Environment.

The EPBC Act provides for the listing of threatened fauna, flora and ecological communities as matters of NES. Conservation categories applicable to threatened fauna, flora and ecological communities under the EPBC Act are:

- Extinct (EX)<sup>1</sup> – there is no reasonable doubt that the last individual has died
- Extinct in the Wild (EW) – taxa known to survive only in captivity
- Critically Endangered (CR) – taxa facing an extremely high risk of extinction in the wild in the immediate future
- Endangered (EN) – taxa facing a very high risk of extinction in the wild in the near future
- Vulnerable (VU) – taxa facing a high risk of extinction in the wild in the medium-term
- Conservation Dependent<sup>1</sup> – taxa whose survival depends upon ongoing conservation measures; without these measures, a conservation dependent taxon would be classified as Vulnerable or more severely threatened.

---

<sup>1</sup> Species listed as Extinct and Conservation Dependent are not matters of NES and therefore do not trigger the EPBC Act.

## 2.2 STATE

In WA, the WC Act provides for the listing of native fauna (Threatened Fauna) species which are under identifiable threat of extinction. Threatened Fauna are assigned to one of seven categories under the WC Act (Western Australian Government 2015):

- Schedule 1 – fauna that is rare or is likely to become extinct as critically endangered (CR) fauna
- Schedule 2 – fauna that is rare or is likely to become extinct as endangered (EN) fauna
- Schedule 3 – fauna that is rare or is likely to become extinct as vulnerable (VU) fauna
- Schedule 4 – fauna presumed to be extinct (EX)
- Schedule 5 – Migratory birds protected under an international agreement
- Schedule 6 – fauna that is of special conservation need as conservation dependent fauna
- Schedule 7 – other specially protected (SP) fauna.

Assessments for listing of fauna are based on the International Union for Conservation of Nature (IUCN) threat categories.

The Department of Parks and Wildlife (DPaW) administers the WC Act and also maintains a non-statutory list of Priority fauna species, most recently updated on 3 February 2017 (DPaW 2017). Priority species are still considered to be of conservation significance – that is they may be rare or threatened – but cannot be considered for listing under the WC Act until there is adequate understanding of their threat levels. Species on the Priority fauna lists are assigned to one of five priority (P) categories, P1 (highest) – P5 (lowest), based on level of knowledge/concern.

A total of 23 troglofauna and 20 stygofauna species are currently listed as either Threatened or Priority in Western Australia, with the majority from the Pilbara and Carnarvon IBRA regions (Appendix 1).

The Minister for Environment may also list ecological communities which are at risk of becoming destroyed as ‘threatened’. DPaW maintains a list of ministerially-endorsed Threatened Ecological Communities (TECs) (DPaW 2016a) as well as a non-statutory list of Priority Ecological Communities (PECs) (DPaW 2016c) which are also assigned to one of five categories.

Nine subterranean TECs (Appendix 2) and 86 subterranean PECs (Appendix 3) are listed from Western Australia. Of the 86 PECs, 77 are stygofauna communities in the groundwater of calcretes of the Yilgarn Craton in the Midwest and northern Goldfields regions (i.e. Cooper *et al.* 2008; Guzik *et al.* 2008; Humphreys *et al.* 2009).

### 3 BIOLOGICAL CONTEXT

Subterranean fauna live within air- or water-filled underground networks. They are predominantly invertebrates, although the subterranean fauna in WA also includes fish and reptiles (Larson *et al.* 2013; Rabosky *et al.* 2004). Organisms specialised for living in air-filled subterranean networks are referred to as troglofauna, while those inhabiting water-filled subterranean networks are referred to as stygofauna (Howarth 1983; Humphreys 2000).

Subterranean habitats are perpetually dark, are extremely constant in temperature and humidity (air-filled networks) and very low in nutrients and energy that are required to support organisms (Howarth 1993). Evolution under such conditions has resulted in much specialised organisms that are restricted to the void networks in which they have evolved (Harvey 2002; Holsinger 2000; Howarth 1993; Ponder & Colgan 2002). Such species are obligated to living in subterranean networks and cannot live in epigeal (surface) environments.

Organisms specialised to live in subterranean networks are likely to represent narrow or short-range endemics (SREs) with limited capabilities of dispersal (Harvey 2002; Ponder & Colgan 2002; Volschenk & Prendini 2008). Short-range endemics are species with naturally small distributions; nominally less than 10,000 km<sup>2</sup> (Harvey 2002) although a lower threshold for subterranean species of 1,000 km<sup>2</sup> was subsequently proposed (Eberhard *et al.* 2009). It is these subterranean species that are considered to be of conservation significance because they are at greatest risk of extinction from development projects.

In WA, and particularly in the Pilbara region (including Cape Range Peninsula and Barrow Island) and the Yilgarn, there has been a recent renaissance in the study of subterranean biodiversity (i.e. Humphreys 2008) driven by the growth of the mineral resources industry and mining environmental impact assessment (EPA 2016a, c). Despite the extensive survey work undertaken in parts of WA, relatively little knowledge on SRE diversity and biology has emerged from the primary literature. The biology, diversity and distribution of most of WA's subterranean fauna is still poorly understood (Guzik *et al.* 2011).

#### 3.1 TROGLOFAUNA

Troglofauna are typically divided into three categories of specialisation to subterranean life:

- troglobites, that are restricted to subterranean habitats and usually perish on exposure to the surface environment (Barr 1968; Howarth 1983; Humphreys 2000)
- troglophiles, which facultatively use subterranean habitats but are not reliant on them for survival (Barr 1968; Howarth 1983; Humphreys 2000)
- troglonexes, which use subterranean systems for specific purposes, such as roosts for reproduction (bats and swiftlets).

Both troglobites and troglophiles may be SREs and are therefore conservation significant.

Troglobites are organisms that have adapted to exploit the special characteristics of air-filled subterranean networks. They are often characterised by specialised adaptations to subterranean life, such as:

- lack or reduction of eyes
- lack or reduction of wings (for species that are normally winged)
- lack or reduction of body pigmentation



- heightened chemosensory and mechano-sensory systems
- loss of circadian rhythms
- very low metabolic rate.

These adaptations allow troglobites to exploit the dark, humid, nutrient-poor subterranean void networks (Howarth 1983, 1993; Humphreys 2000; Poulson & Lavoie 2000). Several soil and litter dwelling groups are blind and pale, making determination of troglobitic status extremely difficult. In these instances, DNA sequencing is used to obtain regional context for such finds (Subterranean Ecology 2010a); that is to determine if any records are conspecific with other recorded specimens.

Troglophiles are species that can live and reproduce in subterranean networks, but are not restricted to them. These species are usually very tiny and exist within the soil. Some troglophiles appear to be widespread species, while others, like diplurans and cryptopids, are often SREs (Phoenix, unpublished data).

In WA, troglofauna invertebrates have been recorded from a number of taxonomic groups, in particular:

- arachnids:
  - spiders (Araneae) (Baehr *et al.* 2012; Burger *et al.* 2010; Harvey 2001b; Platnick 2008)
  - short-tailed whipscorpions (Schizomida) (Abrams & Harvey 2015; Harvey 2001a; Harvey *et al.* 2008)
  - pseudoscorpions (Pseudoscorpiones) (Edward & Harvey 2008; Harms & Harvey 2013)
  - scorpions (Scorpiones, (Volschenk & Prendini 2008)
- palpigrades (Barranco & Harvey 2008)
- myriapods:
  - millipedes (Diplopoda): (Humphreys & Shear 1993; Shear & Humphreys 1996)
  - centipedes (i.e. Scolopendromorpha) (Edgecombe 2005)
- crustaceans:
  - isopods (S. Judd, unpublished data)
- insects:
  - cockroaches (Roth 1991)
  - beetles
  - bugs (Hoch 1993).

## 3.2 STYGOFAUNA

Stygofauna represent the fauna living within subterranean water bodies or aquifers (Humphreys 2000). They typically show similar traits to troglobites in their specialisation to subterranean life, including loss of body pigment, eyes and heightened mechano-sensory systems. Stygofauna are similarly termed to troglofauna:

- stygobites, that are restricted to subterranean habitats and usually perish on exposure to the surface environment
- stygophiles, which facultatively use subterranean habitats but are not reliant on them for survival (Humphreys 2008)
- stygoxenes, species inhabiting surface water which may also be able to freely move from surface to subterranean systems and back (Humphreys 2000).

Short-range endemic stygofauna are only represented by stygobitic species.

In WA, stygofauna invertebrates have mainly been recorded within the crustaceans and insects, in particular (but not limited to):

- crustaceans:
  - ostracods (Karanovic 2007; Reeves *et al.* 2007)
  - copepods (Karanovic *et al.* in press; Karanovic *et al.* 2013)
  - amphipods (Bradbury & Williams 1996a; Finston *et al.* 2007)
  - syncarids (Abrams *et al.* 2013)
  - isopods (Finston *et al.* 2009; Keable & Wilson 2006)
- insects:
  - beetles, in particular water beetles (Dytiscidae) (Cooper *et al.* 2002; Leys *et al.* 2003)
- oligochaetes (Pinder 2001)
- nematodes (i.e. Halse *et al.* 2014).

## 3.3 IDENTIFYING TROGLOFAUNA AND STYGOFAUNA

The characterisation of subterranean fauna into troglobites or stygobites is largely based on an understanding of species habitat requirements. The recognition and identification of these species are usually limited to the presence of troglomorphies, such as reduction or loss of eyes or wings etc. Troglomorphies are used to infer a species that have become specialised to subterranean existence over many generations of confinement to subterranean habitats.

The use of troglomorphies may be justified when a species being identified belongs to a genus (or other higher taxonomic rank) in which epigeal species do not exhibit troglomorphic characteristics. Some groups, such as diplurans, cryptopid centipedes and atelurine silverfish, are more difficult to assess since all members of these groups, whether subterranean or not, lack eyes and are generally pale.

An additional complication to identification of subterranean SREs arises from some clearly troglomorphic species (such as some species of *Nocticola*) which have been found to have wide distributions, well beyond the 10,000 km<sup>2</sup> threshold which limits the recognition of SREs. Widespread subterranean fauna appear to be rare and their means of dispersal is not well understood.

Taxonomic resolution is also difficult to achieve in taxa for which there is no expertise to provide regional context. The apparently strong evolutionary pressure of subterranean habitats has resulted in highly convergent, morphologically-similar species (Finston *et al.* 2004; Finston & Johnson 2004; Finston *et al.* 2007). Molecular techniques such as 'barcoding' (Hebert *et al.* 2003a; Hebert *et al.* 2003b) are routinely employed to overcome these identification problems. Barcoding methods can also resolve specimen identification where specimens represent taxonomically uninformative life stages or sexes.

### 3.4 THREATENING PROCESSES

Impacts to subterranean fauna can be classed as either:

- **primary impacts** – impacts that physically destroy the subterranean void networks
- **secondary impacts** – impacts that change the subterranean habitat without physically destroying the void networks.

Primary impacts are obvious, whereas secondary impacts tend to be cumulative and may affect a far greater area than that being developed (Hamilton-Smith & Eberhard 2000). There are commonly two key threatening processes from mining activities that impact subterranean fauna through the direct loss of habitat:

- **Development of mine pits** – the most obvious primary impact to subterranean habitats occurs as a result of their physical removal during mining. Troglifauna require air-filled void networks and most of this habitat exists in the overburden, which is typically destroyed during pit construction/excavation. Similarly, direct loss of stygofauna habitat may be caused by the removal of geological formations if any aquifers are associated with these formations.
- **Depletion of an aquifer leading to loss of stygofauna habitat** – depletion of an aquifer that is identified as suitable for stygofauna represents a direct loss of stygofauna habitat. The significance of the impact is dependent on the depth of drawdown, the size and extent of the aquifer and the connectivity of the aquifer with adjacent habitat for stygofauna.

Secondary impacts are those that affect the physicochemical properties of subterranean habitats. The nature of these changes can be difficult to measure and there is limited empirical evidence to support or refute these putative impacts. There are four secondary impacts that may be relevant to the Project:

- **Depletion of an aquifer leading to altered relative humidity** – troglifauna are dependent on high relative humidity (Barr 1968; Humphreys 1991; Humphreys 2000). Dewatering may impact troglifauna habitat in unsaturated strata above the water table by lowering relative humidity.
- **Nutrient starvation** – surface vegetation is the primary source of nutrients entering subterranean systems. Large-scale clearing of vegetation may result in the localised nutrient starvation of underlying subterranean habitat. Smothering of these nutrient sources on which subterranean systems depend, in the form of waste and overburden stockpiles and tailings ponds, may reduce inflow of nutrients to subterranean systems and lead to nutrient deficient habitats (Howarth 1993; Humphreys 2000; Poulson & Lavoie 2000).
- **Vibration** – shock waves through subterranean strata from blasting or heavy vehicle traffic may result in the collapse of less-consolidated void spaces and also impact physically on subterranean fauna. There is little data to challenge or corroborate these observations and impacts may generally be localised rather than critically threatening.



- **Contamination:** contamination of subterranean habitats from spills, such as diesel fuel, may degrade the quality of subterranean habitats. Such impacts would generally be highly localised and minor in scale; however, major contamination of subterranean habitats may have significant impacts.

## 4 REGIONAL ENVIRONMENT

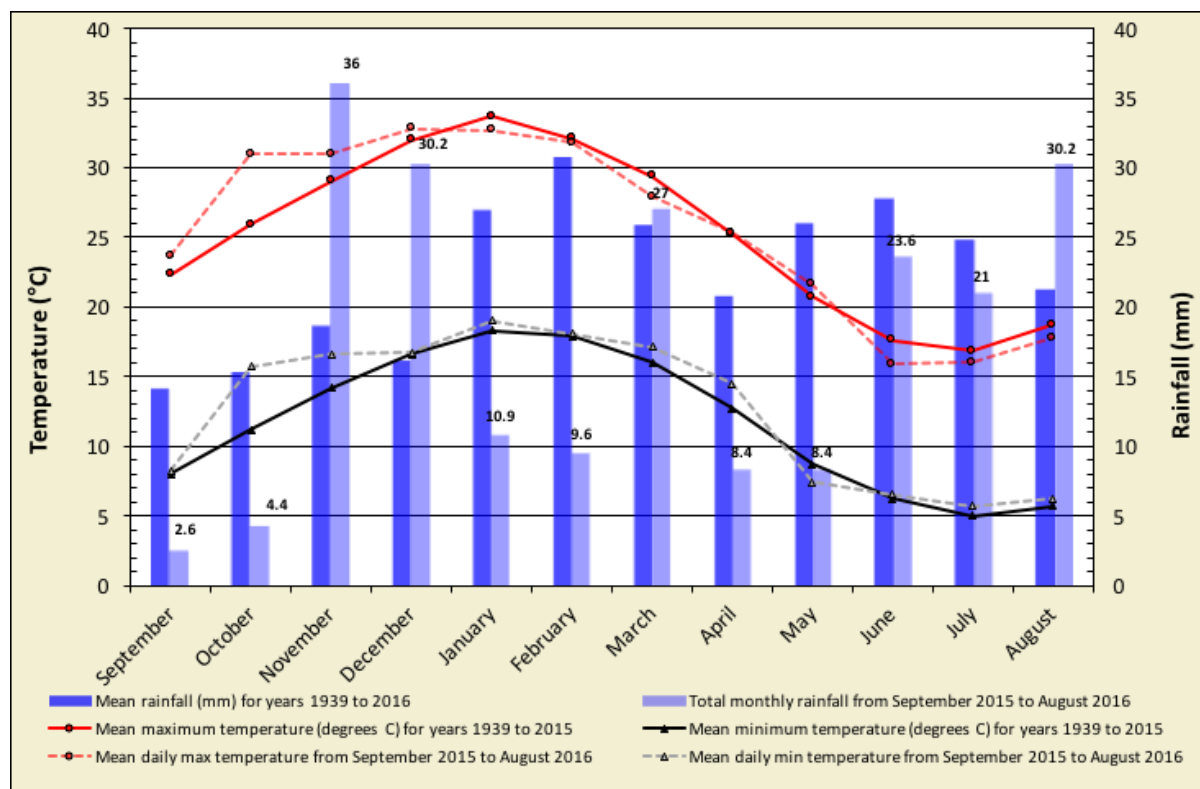
### 4.1 CLIMATE

Rainfall is considered to be an important climatic parameter for troglofauna and stygofauna since both of these groups are dependent on groundwater and are thought to respond to the influx of nutrients carried into subterranean void networks by rain (EPA 2016a, c).

The Coolgardie IBRA subregion, in which the Project is situated, has a semi-arid hot climate with hot summers and mild to cool winters (Department of the Environment 2008). The nearest Bureau of Meteorology (BoM) weather station is located at Kalgoorlie-Boulder Airport (no: 12038; latitude: 30.78°S longitude: 121.45°E). This weather station records the highest maximum mean monthly temperature (33.7°C) in January, the lowest minimum mean annual temperature (5.0°C) in July and an average annual rainfall of 268.1 mm (BoM 2016) (Figure 4-1).

February is on average the wettest month and September the driest (Figure 4-1), although rainfall patterns may be highly variable. Remnant tropical cyclones and thunderstorms associated with cyclonic activities in the north of the WA can occasionally bring heavy rains and result in flooding during the cyclone season (November to March).

During the three months before the field survey (June to August 2016), mean monthly minimum and maximum temperatures were about similar to the long-term averages recorded for these months (Figure 4-1). Similarly, rainfall pattern followed long-term averages, with August 2016 being somewhat wetter (Figure 4-1), providing ideal conditions for subterranean fauna surveys.



**Figure 4-1** Average monthly temperatures (maximum and minimum) and rainfall recorded from Kalgoorlie-Boulder Airport (BoM 2016)

## 4.2 IBRA

The Interim Biogeographic Regionalisation of Australia (IBRA) defines 'bioregions' as large land areas characterised by broad, landscape-scale natural features and environmental processes that influence the functions of entire ecosystems (Department of the Environment 2014b; Thackway & Cresswell 1995). They categorise the large-scale geophysical patterns that occur across the Australian continent that are linked to fauna and flora assemblages and processes at the ecosystem scale (Thackway & Cresswell 1995).

Western Australia contains 26 IBRA bioregions and 53 subregions. The study area falls within the Coolgardie bioregion, which covers an area of 129,117 km<sup>2</sup> (Thackway & Cresswell 1995) and is divided into three subregions (Department of the Environment 2014b): Mardabilla (COO1), Southern Cross (COO2) and Eastern Goldfields (COO3).

The study area is situated in the Eastern Goldfields 3 (COO3) subregion. With respect to subterranean fauna, this subregion lies on the Yilgarn Craton's Eastern Goldfields Province (Archibald *et al.* 1978; Cowan 2001). The relief is dominated by gently undulating plains interrupted in the west by low hills and ridges of Archaean greenstones and in the east by Proterozoic basic granulite. The underlying geology is of gneisses and granites eroded into a flat plane covered with tertiary soils and with scattered exposures of bedrock (Cowan 2001). Calcareous earths are the dominant soil group and cover much of the plains and greenstone areas. A series of large playa lakes in the western half are the remnants of an ancient major drainage line. Subterranean fauna as an environmental factor was not specifically mentioned in the characterisation of the subregion (Cowan 2001).

## 4.3 LANDFORMS AND VEGETATION

The dominant landform in the study area is the Kambalda system which is characterised by stony plains with *Acacia* and halophytic shrublands, low hills with *Acacia* or eucalypt woodlands with halophytic understorey, or alluvial plains with eucalypt woodlands and halophytic understorey (Tille 2006). The dominant soil types are calcareous red earths and red loamy earths, with minor salt lake soils, red-brown shallow loams over hardpans and red sandy duplex soil. Soil salinity is common on the stony plains.

The development of gold mining leading to a major alteration to the vegetation cover occurred in the early part of the 20<sup>th</sup> century. Deforestation was extensive to provide fuel for condensers, mines, and pump stations and to support pits, potentially affecting geological stability of the subsoils and hydrological regime. Tramways, locally known as woodlines, extended throughout the area, and major cutting occurred as late as the 1950's. The tree roots were left in place, and in many areas, regrowth can be seen from the original stumps (Commander *et al.* 1992).

## 4.4 GEOLOGY

The study area lies within the Eastern Goldfields Province of the Yilgarn Craton. The regolith stratigraphy of the Yilgarn Craton has been reviewed in detail (Anand & Paine 2002), with some studies particularly covering the Roe Palaeochannel system around Kalgoorlie (Kern & Commander 1993; Skarwarnecki no date). Geological and soil studies aiming at resource estimation for the Project provide further geological (MBS Environmental 2009; Paddington 2009, 2010) and hydrological (Geological Survey of Western Australia 1994; GRM 2009) information for the study area.

The Yilgarn Craton province essentially consists of a granite-greenstone terrane of Archaean age with linear, north-northwest trending belts of supracrustal volcanic and metasedimentary rocks and granite intrusions (Griffin 1990). The study area lies within the Kalgoorlie Terrane of the Norseman-



Wiluna greenstone belt (Swager *et al.* 1990). Bedrock within the area consists of volcanoclastic and sedimentary rocks of the Black Flag Group and Kurrawang Conglomerates, and felsic porphyry intrusives (Swager *et al.* 1990).

The present topography of the Yilgarn Craton around Kalgoorlie is a peneplain of low relief which developed on a landscape incised by an early Tertiary drainage system (Anand & Paine 2002; Kern & Commander 1993). Weathering of the Archaean bedrock probably postdates the incision of the drainage system. The palaeochannel cross-sections of the region are generally V-shaped and have been infilled with up to 60 m of Late Eocene sediments (Kern & Commander 1993). These sediments consist generally of basal fluvial sand (Wollubar Sandstone) overlain by relatively impermeable lacustrine clay (Perkolilli Shale). The Wollubar Sandstone (Middle to early Late Eocene) is up to about 40 m thick and consists of grey, blue, yellow, and brown quartz sand, and minor amounts of conglomerate, clay, silt, carbonaceous silt, and lignite. The sand ranges from very coarse to fine; sandy clay occasionally occur at the top of the Wollubar Sandstone, especially the flanks of the palaeochannels, where it grades into the Perkolilli Shale (Kern & Commander 1993).

The Perkolilli Shale is made up of mottled, grey, dark-red, brown and yellow clay with small beds of sandy clay. It is generally plastic except near the surface, where it is weathered and friable. Similar to the Wollubar Sandstone, the formation is up to approximately 40 m thick and overlain by Cainozoic (Quaternary) deposits of between 4 and 6 m below the surface.

The Cainozoic deposits characteristic for the surface geology of majority of the study area represent units of Aeolian, alluvial and colluvial origin including scree from Kurrawang Formation (Kern & Commander 1993) (see Figure 4-2). Colluvium represents the detrital deposits in fans and broad-washed plains and consists of conglomerate, gravel, sand and clay derived from the laterite profile and the underlying Archaean bedrock. It is generally about 6 m thick, but may extend down the slope to more than 20 m below the surface (Anand & Paine 2002). Alluvial deposits occur within the poorly defined drainages lines and are between 3 to 6 m thick. They consist of sand (often very fine and silty), silt and clay and interfingering conglomerate near bedrock outcrops. Extensive playa lakes occur along the playa drainages throughout the region. They contain saline and gypsiferous clay and silt, often up to 10 m thick (Kern & Commander 1993).

The plain topography of the study area is disrupted by incised east to west breakaways which expose cross sections of saprolite and saprock (i.e. weathered Archaean bedrock), quartz-feldspar porphyries outcropping as low lying ridges or rocky area of sub-crop (Paddington 2010).







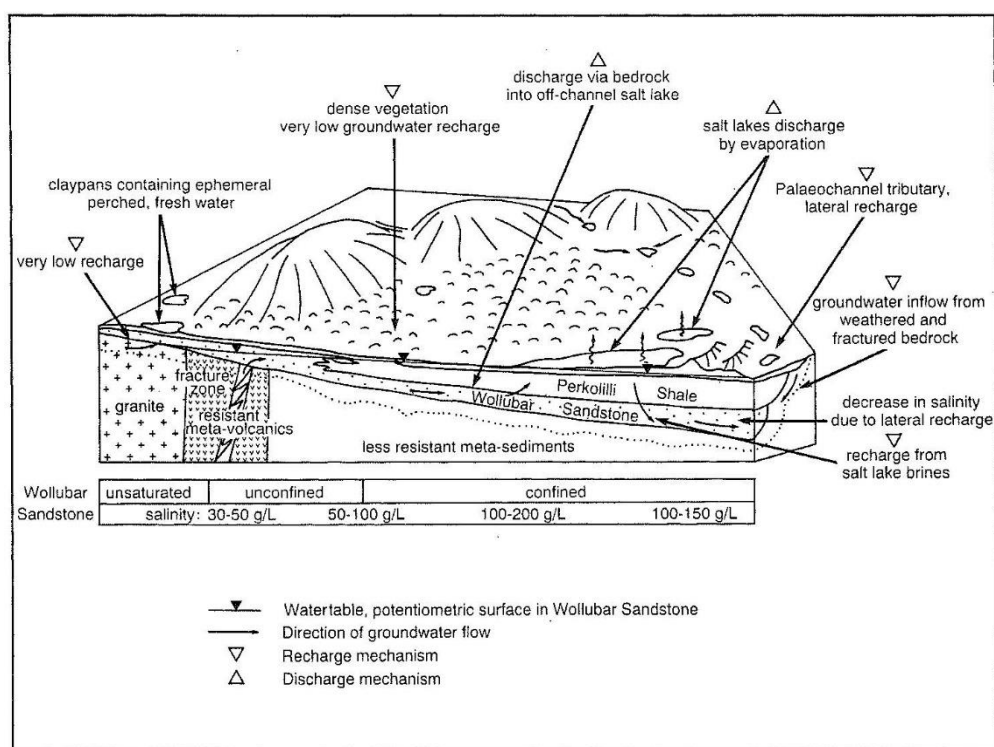
## 4.5 HYDROLOGY

The regional hydrology was explored in detail in the early 1990s (Commander *et al.* 1992; Geological Survey of Western Australia 1994; Kern 1995) and most recently reviewed by Talis (2016). It is complex, reflecting the variety of bedrock types, location of the palaeodrainage system and the structure and degree of weathering. Three main groundwater systems are located in the Kalgoorlie region, including (Kern 1995; Saprolite Environmental 2013)

- aquifers in the Wollubar Sandstone of the palaeochannel systems (coloured blue in Figure 4-4)
- local aquifers in fractured and deeply weathered bedrock systems (coloured brown in Figure 4-4)
- Ferricrete and alluvial systems (coloured yellow in Figure 4-4).

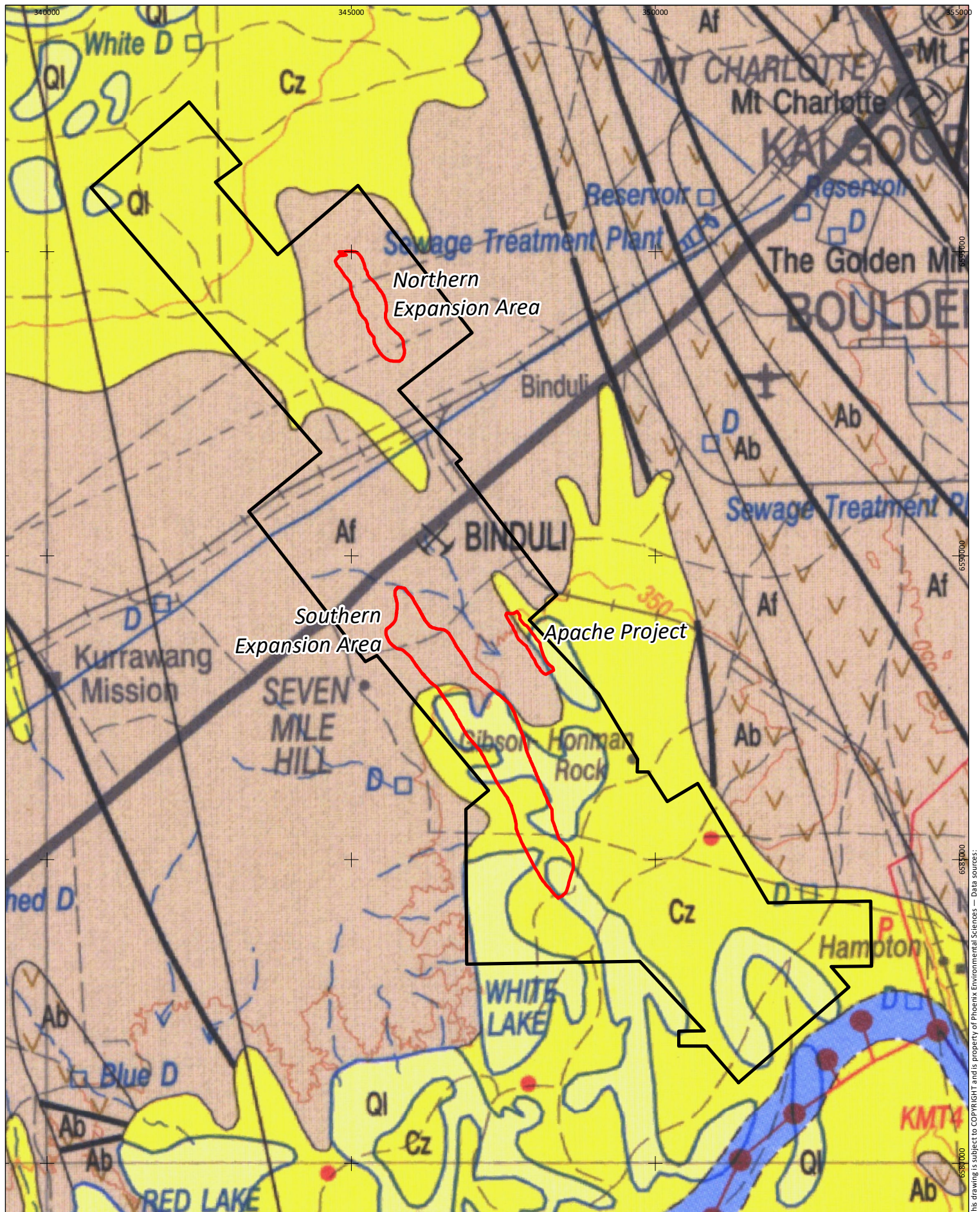
The principal aquifer in the region is the Wollubar Sandstone within the palaeochannels as the natural groundwater flow is towards these palaeodrainages and playa lakes, where the groundwater table is at or near the surface (Commander *et al.* 1992). Covered by the relatively impermeable Perkolilli Shale, the aquifer of the palaeochannels is unconfined and open for recharge generally only in the upper reaches of the palaeodrainages (Figure 4-3). However, recharge through rainfall and run-off is very low in the arid landscape.

Groundwater depletion occurs principally through evaporation from the salt lakes that formed in the palaeochannels. Otherwise, the groundwater flow pattern follows the palaeochannel system at the regional scale, although natural outflow via the channels is very small. Groundwater abstraction due to mining have resulted in an alteration of the groundwater flow, for example in the Hannan Palaeochannel (coloured blue in Figure 4-4) (Commander *et al.* 1992). Water-level changes away from pumping stations are generally low.



**Figure 4-3** Hydrodynamic model for the Roe Palaeochannel groundwater flows (reproduced from Commander *et al.* 1992)





**Figure 4-2**  
**Hydrogeology**  
**of the study area**

Client: Norton Gold Fields Pty Ltd  
 Project: Binduli Expansion Project

Author: K. Wyatt  
 Date: 23-May-17

Coordinate System: GDA 1994 MGA Zone 51  
 Projection: Transverse Mercator  
 Datum: GDA 1994

0 0.25 0.5 1 1.5 2 2.5 Kilometres  
 1:80,000

Proposed pit expansion areas  
 Study area





Deeply weathered and fractured bedrock aquifer systems result from tectonic and decompression fracturing which are additionally enhanced due to chemical dissolution along fracture lines. Fractured bedrock aquifers are most likely to occur in mafic, ultramafic and granitic rocks rather than sedimentary, felsic volcanic or volcanoclastic rocks (Kern 1995). Within the study area, groundwater in the bedrock aquifer systems has generally been found from 40–80 m bgl (Talis 2016). In areas where the weathered and fractured zone is unsaturated or poorly developed, a regional groundwater table may be absent (Kern 1995).

Ferricrete and alluvial aquifer systems typically occur from 5-40 m bgl in low lying areas and surface water catchments, and generally comprise an accumulation of sand, gravel and fractured Ferricrete within clays (Saprolite Environmental 2014).

The groundwater in the Wollubar Sandstone is saline or hypersaline having accumulated over at least a few hundred thousand years; brackish groundwater only occurs in the small, elevated aquifers, where recharge conditions are favourable (Commander *et al.* 1992). Throughout the region, groundwater salinity in the Wollubar Sandstone ranges from 28,000 to 197,000 mg/L TDS. It is lowest in the west, in the upstream parts of the palaeodrainage lines and increases in an easterly direction. Salinity increases markedly close to the salt lakes. For example, in the Hannan Palaeochannel, the salinity rises from 80,000 mg/L TDS at Barbara Surprise (ca. 20 km west-southwest of the study area) to 178,000 mg/L TDS at Southlakes borefield downstream of Brown Lake, ca. 11 km south-southeast of the study area (Commander *et al.* 1992). There appears to be a stratification of water salinity in the palaeochannels with high-salinity groundwater at the base of the aquifer. Limited areas of low brackish groundwater (1,000–3,000 mg/L TDS) are found in upland areas of granitoid rocks and perched aquifers; however, these areas are very difficult to locate (Kern 1995).

## 5 METHODS

### 5.1 DESKTOP REVIEW

This assessment followed EPA guidelines which state that desktop reviews for subterranean fauna should (EPA 2016a):

- search regional and project/site specific habitat data, including geological and hydrological information, previous studies of the area (published and unpublished), site photographs and databases including fauna records
- place the project area into a regional context
- make conclusions about whether the area is likely to provide habitat for subterranean fauna and consider impacts of the proposal.

#### 5.1.1 Database searches

The following database searches were requested or undertaken in January 2016 with a search grid extending approximately 100 km from the Project centre, database search area (north-west corner: -29.90 S/120.34 E; south-east corner: -31.71 S/122.34 E):

- WA Museum Crustacea and Arachnology/Myriapodology databases as most up-to-date databases to provide information on WA subterranean fauna
- EPBC Act Protected Matters database (Department of the Environment 2016)
- DPaW/WA Museum NatureMap search (DPaW 2016b).

#### 5.1.2 Literature review

A literature review of publicly available journal articles and EIA documents from nearby studies was undertaken to identify any subterranean fauna species records that may not be captured in the databases. Due to the paucity of subterranean fauna data in the southern Goldfields region and within the database search area, the desktop study was expanded to include data from surveys with similar characteristics further afield. These were chosen primarily from the Yilgarn Craton and on the basis of similar hydrological and geological conditions to the study area, i.e. the presence of palaeochannels and salt lakes or saline or hypersaline groundwater conditions (>3,000 mg/L TDS).

Recent geological and hydrological investigations conducted within the study area were reviewed to gain an understanding of the suitability of the subterranean environment for troglo- and stygofauna.

### 5.2 FIELD SURVEY

The desktop assessment suggested stygofauna unlikely to occur in the study area due to the high salinity of the groundwater (see section 6.1.5). Therefore, a pilot survey targeting troglofauna only was conducted on 22 August 2016 in the Northern Expansion Area and the Apache Project.

A total for 15 bores were surveyed for troglofauna, including 12 in the Northern Expansion Area (Janet Ivy) and three in the Apache Project (Table 5-1; Figure 1-1). Groundwater levels in the Southern Expansion Area were too high (generally less than 5 m) to allow for troglofauna surveys.



**Table 5-1 Location and details of bores sampled during the field survey**

Bore code	Survey area	Easting (GDA94, zone 50)	Northing (GDA94, zone 50)	Depth (m)	Groundwater present
JI01	Northern Expansion	345765	6593543	60	No
JI03	Northern Expansion	345581	6593389	37	No
JI26	Northern Expansion	345334	6593771	75	No
JI34	Northern Expansion	345444	6594138	46	No
JI35	Northern Expansion	345245	6594017	61	No
JI44	Northern Expansion	345387	6594345	20	No
JI49	Northern Expansion	345099	6594260	42	No
JI65	Northern Expansion	345178	6594640	57	No
JI75	Northern Expansion	345105	6594765	25	No
JI77	Northern Expansion	344921	6594611	63	No
JI82	Northern Expansion	345002	6594887	67	No
JI86	Northern Expansion	344818	6594733	55	No
AP2-53	Apache	347699	6588892	18	Yes
AP2-54	Apache	347734	6588922	25	Yes
AP2-63	Apache	347656	6589014	25	Yes

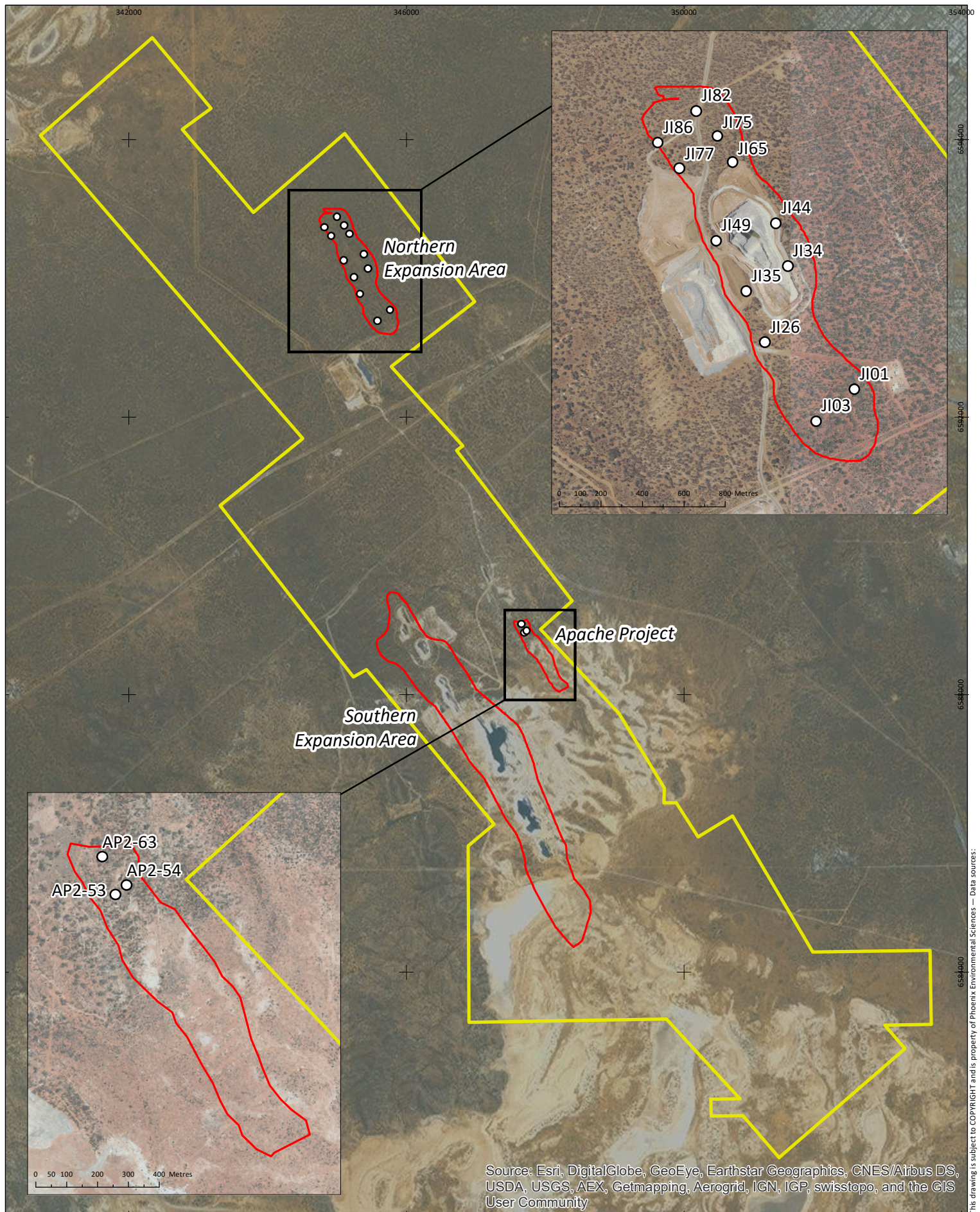
The troglofauna survey was conducted using troglofauna bore scrapes (Halse & Pearson 2014). A 150 µm net (diameter 90 mm) equipped with nylon 'ticklers' to collect any animals moving along the sides of the bores was lowered to the bottom of the borehole and then scraped back up the bore wall. As all target bores were angled, a single scrape only was conducted as it was impossible to scrape any other wall surface than that situated at the lower edge of the bore.

After each scrape, the strained contents was rinsed into a 120 ml plastic vial by squirting chilled (<2°C) 100% ethanol down the sides of the net and around the rim of the weight, carrying the sample contents into the vial with it. If not already full, the sample vial was topped up with 100% ethanol. Chilling specimens during fixation has been shown to significantly improve the quality of specimens and likelihood of extracting usable genomic DNA if the specimens are to be sequenced subsequently.

The net was thoroughly rinsed after each sample to avoid cross-contamination of samples.

At conclusion of the survey, samples were stored in a refrigerator in the laboratory, where they were sorted and specimens identified using high-magnification stereo microscopes.





**Figure 5-1**  
**Bore locations sampled**  
**during the field survey**

Client: Norton Gold Fields Pty Ltd  
 Project: Binduli Expansion Project

Author: K. Wyatt  
 Date: 23-May-17

Coordinate System: GDA 1994 MGA Zone 51  
 Projection: Transverse Mercator  
 Datum: GDA 1994

0 0.25 0.5 1 1.5 2 Kilometres  
 1:70,000

- Proposed pit expansion areas
- Study area
- Bore locations





### 5.3 PROJECT PERSONNEL

The personnel involved in the survey are presented (Table 5-2).

**Table 5-2 Project team**

Name	Qualifications	Role/s
Dr Volker Framenau	B.Eng. (Chem. Eng.), M.Sc. (Cons. Biol.), Ph.D. (Zool.)	Project manager, field survey, taxonomy, report writing
Ms Anna Leung	B.Sc. (Env. Sci.) (Hons)	Field survey
Ms Karen Crews	B.Sc. (Env. Sci.) (Hons)	Report review
Mrs Kathryn Wyatt	BIS. (GIS), Grad. Cert. (GIS)	GIS



## 6 RESULTS

### 6.1 DESKTOP REVIEW

#### 6.1.1 Database searches

No subterranean fauna, either troglofauna or stygofauna were identified from the desktop review area in the WA Museum database searches. Similarly, no records of subterranean fauna were recorded from the NatureMap or EPBC Protected Matters database searches.

#### 6.1.2 Threatened and priority species or ecological communities

No Western Australian subterranean fauna or ecological communities are listed as matters of NES (Department of the Environment 2014a).

No Threatened or Priority subterranean fauna species or ecological communities are listed from the southern Goldfields region (DPaW 2016a, c, 2017) (see also Appendices 1–3). A large number of subterranean stygofauna communities are listed as PECs from calcretes of the Yilgarn Craton; however, none of these occur in the southern Goldfields. Groundwater calcretes are predominantly known from north of the ‘Menzies Line’ which follows approximately latitude 30°S (Anand & Paine 2002). The southern-most known calcrete in the Goldfields is in the vicinity of Black Flag Lake, approximately 30 km north of the study area (Kern & Commander 1993).

#### 6.1.3 Literature review

Compared to other regions of the State, little is known about the subterranean fauna of the southern Goldfields. Despite a large number of mines operating in the Kalgoorlie area, predominantly gold and nickel operations, subterranean fauna assessments have apparently not been conducted regularly, possibly because the establishment of many these operations predate the requirements of the EPA guidance documents in relation to subterranean fauna (EPA 2016a, c). Within the desktop review area, subterranean assessments have only been conducted at Lake Lefroy, approximately 50 km south of the study area (Subterranean Ecology 2010b, c). These desktop reviews identified no stygofauna, but potential troglofauna habitat. No follow-up surveys were conducted as the most prospective geologies for troglofauna were outside the disturbance footprint (SIGM 2010; pp. 251–252, table 10-1). Geological and hydrological aspects at Lake Lefroy are comparable to those of the study area and some results of the above studies are relevant to the current assessment (section 6.1.5).

##### 6.1.3.1 Relevant subterranean surveys

Knowledge on the occurrence of subterranean fauna outside mineralized habitats (such as pisolitic mesas and Banded Iron Formation – BIF), with the exception of groundwater in karsts and calcretes in case of stygofauna, is limited because mine developments are the main trigger for subterranean surveys. However, troglofauna have been collected from basalt bedrock, saprolite, calcrete and alluvial deposits of the Yilgarn Craton (e.g. Barranco & Harvey 2008; Bennelongia 2013; Karanovic *et al.* 2013; Platnick 2008).

Three species of troglobitic isopods, diplurans and thysanurans were recorded in saprolitic rock at the Duketon Gold Project, approximately 100 km north of Laverton (Bennelongia 2010). Species of slaters, centipedes, diplurans and cockroaches were collected from channel-fill sediments, lower and upper saprolite, fine and coarse gravel and calcrete at the Tropicana Gold Project, approximate 350 km east

of the study area (Ecologia 2009b, c, 2010a, b; Lawrance 2009). Both troglofauna (pseudoscorpions, carabid beetle) and stygofauna (ameirid copepods) were recovered from fractured basalt bedrock at the Spotted Quoll Nickel deposit, near Forresteria, 250 km SW of the study area (EPA 2009; Karanovic *et al.* 2013). Ten troglofauna species were collected from ultramafic schist surrounding BIF and chert at the Carina Iron Ore Project, 140 km east-northeast south of the study area (Bennelongia 2009).

Surveys conducted in the southern Goldfields have yielded few, if any, stygofauna possibly due the generally high salinity of the groundwater in the region. Subterranean fauna surveys in the Yilgarn, in which water quality was found to be saline, have for example been completed at Tropicana Gold Project and the Carina Iron Ore Project (130 km east of the study area) with no stygofauna records (Bennelongia 2009; Ecologia 2009a; Subterranean Ecology 2009). Only nematodes or no stygofauna at all were collected from BIF aquifers in pilot-scale surveys at Lake Giles (80 km north-east of the study area) and Parker Range (190 km south-east) (Rockwater 2010, 2012). No stygofauna were found at the Carina Iron Ore Project (Bennelongia 2009).

#### 6.1.4 Geology and hydrology of the study area

Within the regional setting (sections 4.4 and 4.5), the likelihood of subterranean fauna to occur in the study area (and here primarily in the three expansion areas) is assessed based on the information of local geology and hydrology. At the time of compiling this report, little information was available in relation to the porosity of the prevailing geology, for example by examination of bore core data, with the exception for a geological analysis of the open faces of the Janet Ivy pit in the Northern Expansion Area (Witt 2011).

The study area straddles the drainage divide of two separate palaeochannels within the Roe Palaeochannel system, Bonnie Vale in the north and Hannan in the south (see Kern & Commander 1993) (see Figure 4-4). This setting largely determines the geological and hydrological characteristics of the Project, with lacustrine and alluvial deposits of White Flag Lake and its surrounding salt pans representing the infill of the Bonnie Vale palaeochannel in the north and those of Douglas Lake and White Lake that of the Hannan palaeochannels in the south. In between, the surface geology is mainly characterised by Quaternary Aeolian, alluvial and colluvial deposits, with some surface expressions of the weathered Archaean bedrock (see Figure 4-2).

##### 6.1.4.1 Geology

The three expansion zones have varying underlying surface geology (Figure 4-2; Table 6-1). The Northern Expansion Area is mainly characterised by the Cainozoic colluvial deposits. The southern halves of the Southern Expansion Area and the Apache Project are dominated by lacustrine deposits of salt lakes and pans that formed in and adjacent to the Hannan Palaeochannel. Both expansion areas feature some Archaean outcrops in their northern halves, and, in case of the Southern Expansion Area, colluvial deposits (Figure 4-2; Table 6-1).

**Table 6-1 Approximate surface geology of the Binduli expansion areas (based on Geological Survey of Western Australia 1993)**

Period	Abbreviation (Figure 4-2)	Characterisation (Wyche 1998)	Expansion area	Approximate area (%) of expansion area
Cainozoic	Czc	Cainozoic colluvium – including locally abundant white vein-quartz scree, which has been deposited as sheetwash or talus at the base of slopes	Northern	>95%
			Southern	20% (northern-most section)
	Czts	Cainozoic evaporites interbedded with clay and sands in playas	Southern	30%
			Apache	30%
	Cztd	Cainozoic sand, silt and gypsum in stabilized dunes adjacent to playas, derived from dried out lakes	Southern	40%
	Qa	Alluvium – clay, silt, sand and gravel in active stream channels	Apache	30%
Archaean	Afv	Archaean felsic volcanic and volcanistic rocks, widespread but not well exposed, form much of the upper part of the felsic volcanic and sedimentary Black Flag Group of the Kalgoorlie Terrane	Northern	< 5%
			Southern	< 5%
			Apache	30%
	Akc	Archaean Kurrawang Formation, cobble conglomerate, sandy pebble conglomerate and pebbly sandstone	Southern	< 5%
	Ap	Quartz and/or feldspar porphyry	Southern	< 5%

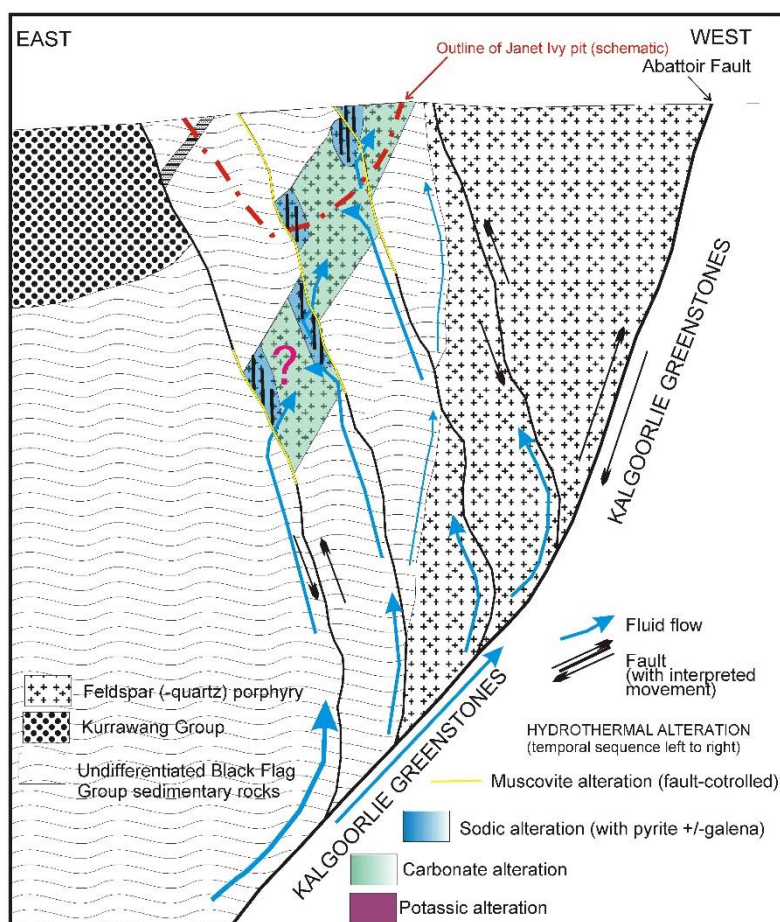
Drill results for Navajo Chief (Southern Expansion Area) provide information on the underlying lithologies (Paddington 2009, 2010). They include:

- alluvial and colluvial transported cover (approximately 1 m thick)
- laterite caprock (approximately 5 m thick)
- upper saprolite (approximately 25 m thick)
- lower saprolite (approximately 5–15 m thick)
- saprock (approximately 5–15 m thick)
- interbedded arenite and siltstone/Turbidite
- quartz Arenite/Navajo Sandstone (graded sandstone with very coarse quartz grains)
- felsic porphyry/ Navajo porphyry.



The dominant unit in the Navajo Chief area is a sequence of sandstones of varying grain size separated by siltstones. The sandstones are primarily arenites, as the matrix component is minor. Typically the sequence is normally graded, from fine to very coarse grained with well-developed bedding and cross-bedding. Soft sediment structures are observed throughout, involving mainly dewatering flame structures and impacted pebbles. The sandstone is generally dominated by rounded quartz with minor amounts of feldspar and rock fragments. Pebble lags occur occasionally within the series, although these intervals are discontinuous. Historically a distinction between the thinly bedded sandstones higher in the Turbidite sequence and the thick to massive bedded basal sandstones was made, however this distinction is not obvious in RC chips. The thick to massive bedded sandstone is characterized by a lack of well-developed sedimentary structures, a coarse to very coarse grain size, and an immature and sub-arkosic composition (Paddington 2010).

The main lithology at the Janet Ivy pit (Northern Expansion Area) consists of a northwest-striking feldspar porphyry intrusion which is in structural contact with metasedimentary rocks in the west (Figure 6-1)(Paddington 2012; Witt 2011). The sedimentary rocks are characterised by metamorphosed saprolitic siltstone and fine-grained sandstone (Figure 6-2) whereas the porphyry comprise euhedral feldspar with crystals of xenocrystic quartz (5–10% by volume)(e.g. Figure 6-3) (Witt 2011).



**Figure 6-1** Schematic section through the Janet Ivy deposit (fig. 7 reproduced from Witt 2011)



**Figure 6-2** Weathered and deformed sedimentary rocks exposed in the north of the Janet Ivy pit (plate 1a reproduced from Witt 2011)



**Figure 6-3** Feldspar porphyry at eastern face of Janet Ivy pit with carbonate alterations (plate 5a reproduced from Witt 2011)

Three rock types dominate the Fort William/Fort Scott project area (Paddington 2009, 2010, 2012):

- alluvials and regolith, including a laterite mottled zone
- sediments (conglomerates, sandstones, siltstones and mudstones), alternating shale and clay
- feldspar quartz porphyry/porphyry.

Porphyry intrudes into the overlying sedimentary units (arenites, siltstones, mudstones and conglomerates). Saprolite units at Fort William are present to a maximum depth of 75 m. Overburden is shallow (maximum depth of 8 m) and consists of alluvial sands and clays. Locally, alteration is dominated by hematite, sericite, silica and chlorite within the fresh rock and kaolinite and goethite in the saprock. Minor occurrences of tourmaline, epidote, fuchsite and biotite have also been noted. Alteration is reported to be patchy (vein selvages) or pervasive, and varies in strength from weak to strong (Paddington 2009).

At Fort Scott, alluvial quartz sands range from fine to medium grained and are found to a maximum depth of 4 m. Regolith consists of a well-developed saprolite horizon (both upper and lower saprolite) of variable thickness. Conglomerates in the sequence range from pebble through to cobble grain size. The clast composition is predominantly sediments ranging from mudstone through to sandstone, although porphyry clasts are also evident. Sandstones range from fine to coarse grained. Siltstones and mudstones are planar, well-bedded units but in diamond drill holes the rocks can display structural anomalies, such as slips and parasitic folds. Porphyries contain subangular to angular feldspars, and a low quartz concentration. Shearing where present, displays as a weak to moderately developed foliation (Paddington 2009).

#### 6.1.4.2 Hydrology

The study area does not reach the palaeodrainages in its north or south and is therefore mainly characterized by local Ferricrete and alluvial aquifers and those aquifers in fractured and deeply weathered bedrock systems (see Figure 4-4). Therefore, the hydrological regime of the study area appears complex, but is also likely influenced by other pits and dewatering systems in the region (Talis 2016).

Four current groundwater monitoring bores (NCMB01, NCMB02, NCMB02, NCMB04) are located within the study area along the northern and western margins of the Navajo Chief Pit (Southern Expansion Area) (Talis 2016). Regional groundwater summaries partially cover the study area (e. g. Saprolite Environmental 2013, 2014, 2015).

Groundwater depth in the study area is currently 70–80 m bgl at the Southern Expansion Area, following dewatering activities between 1993–2000 and 2010–2013; pre-dewatering depth was approximately 40–50 m bgl (Talis 2016). The groundwater depth at the Northern Expansion area is assumed to be around 45 m based on data from 2009 (Talis 2016). Close to salt lakes groundwater levels are at about 4 m bgl (E. Vuorenmaa, email to V.W. Framenau, 5 February 2016), indicating almost full saturation of these lakes and their associated palaeochannels (see Commander *et al.* 1992).

The water levels within the pits of the Southern Expansion Area reflect the local groundwater levels. Groundwater is considered to flow towards the Centurion Pit (Southern Expansion Area), which is the deepest pit within the study area. This suggests that regional flows, which are likely to be towards White Lake, have been locally altered through earlier dewatering activities. The water level data also shows that groundwater levels are still recovering after groundwater drawdown activities ceased in 2013 (Saprolite Environmental 2015; Talis 2016).

The aquifers within the study area were directly affected by these dewatering activities. Extensive monitoring demonstrated that high dewatering rates were required to maintain dry conditions in the



pits. Groundwater level data indicated a good hydraulic connection along strike between the pits of the Southern Expansion Area, as evidenced by rapid draw down responses in distal monitoring bores (GRM 2009). However, the connection across strike and in the weathered zone is thought to be less well developed as static water levels have been observed few metres below ground level (Talis 2016).

Water quality measurements are mainly available from the pits, some of which are influenced by surface water flows. Historic groundwater measurements in the pits at Pitman, Navajo, Centurion and Ben Hur 1 and 2 between 2010 and 2012 recorded pH values of 7.2–8.1, salinity ranged from 140,000 g/L TDS (Pitman Pit) to 230,000 mg/L TDS (Centurion). In this period, salinity at Fort William was between 190,000 mg/L TDS and 210,000 mg/L TDS. Salinity at Janet Ivy, measured in March 2012, was considerably lower (30,000 mg/L TDS), possibly influenced by surface water flows (Saprolite Environmental 2013; Talis 2016).

Groundwater parameters taken as recently as 2014 in the Southern Expansion Area showed salinities generally above 60,000 mg/L TDS and as high as 166,100 g/L TDS, with the exception of Ben Hur 2, which was subject to surface water flows (Table 6-2).

**Table 6-2 Groundwater quality parameters for the Southern Expansion Area 2014 (E. Vuorenmaa, email to V.W. Framenau, 5 February 2016)**

Production Pit	Date	Field pH	Field EC ( $\mu\text{S}/\text{cm}$ @ 25°C)	Field TDS (mg/L)
Pitman	March	7.55	154,400	150,000
	June	6.44	167,500	113,900
	September	7.15	180,900	123,000
	December	7.45	157,100	106,900
Navajo	March	7.78	87,400	62,000
	June	6.98	115,200	78,300
	September	7.58	132,200	89,900
	December	7.65	131,800	89,730
Centurion	March	7.7	161,000	190,500
	June	6.35	197,000	134,000
	September	7.55	225,000	153,000
	December	7.33	186,900	127,200
Ben Hur 1	March	7.24	200,000	120,000
	June	5.94	226,000	150,000
	September	7.3	244,300	166,100
	December	6.99	211,400	143,700
Ben Hur 2	March	8.53	9,000	5,000
	June	7.57	10,320	5,900
	September	8.85	11,370	7,730
	December	8.22	12,170	8,300

### 6.1.5 Likelihood of subterranean fauna to occur in the study area

Two factors predominantly determine the presence of subterranean fauna, i.e. the 'vugginess' (porosity) of the geology and presence and quality (in particular salinity) of groundwater. Habitats likely to support troglofauna are karstic limestone, channel iron deposits (CIDs) (in particular pisolite in inverted landscape geomorphology), groundwater calcretes above the water table, alluvium/colluvium in valley-fill settings, BIFs and weathered and fractured sandstone. Stygofauna are likely where there are groundwater voids present, for example in karst limestone, calcretes, alluvial formations and fractured rock (EPA 2016a).

Examples where troglofauna are unlikely to occur include geologies without cavities, voids or cave such as sand and clay dominated substrates and areas that have been submerged during seal level rise in the Holocene. Stygofauna are unlikely to occur include deep sands or clays (especially over solid rock) or hyper-saline (exceeding marine concentration, i.e. 35,000 mg/L TDS) groundwater (EPA 2016a).

#### 6.1.5.1 Troglofauna

The likelihood of troglofauna to occur must be considered within the different geological and hydrogeological units found in the study area. Troglofauna cannot survive in areas of permanently saturated aquifers, such as those in the palaeodrainage channels and neighbouring salt lakes and salt pans.

With groundwater levels of generally 50 m bgl pre-dewatering elsewhere in the study area, troglofauna may potentially occur above the permanently saturated aquifers within the bedrock, lower saprolite/saprock and possible Quaternary deposits if these are deep enough. The likelihood of occurrence of troglofauna here shifts to an assessment of the porosity and stability of the regolith, i.e. the outcropping Archaean bedrock, saprolite and saprock and Quaternary alluvial and colluvial sediments (e.g. Lawrance 2009).

The exposed faces of the current pits provide ample opportunity to assess the geologies for the required vugs and fissures for troglofauna to occur. A geological study of the Janet Ivy pit provided detailed images of the exposed lithologies (Witt 2011) (see section 6.1.4.1). Whilst some faults and fractures occur within the compact feldspar porphyry, these were subsequently filled by fluid flows (see Figure 6-1) and now form, for example, quartz veins and pyrite. Therefore, there is very low likelihood of troglofauna to occur in this lithology. The sedimentary unit of weathered (saprolitic) siltstone and fine-grained sandstone to the western side of the Janet Ivy pit has metamorphosed and is unlikely to contain any major fractures/fissures; however, the structure of this unit does not exclude porosity suitable for troglofauna (Figure 6-2).

Otherwise, little information is available on the structure of the bedrock and saprolite, although the geology within the expansion areas appears to be very similar across the strike length. It is mainly of Archaean origin (bedrock and saprolite) and appears highly compressed without vugs and pores to support troglofauna (E. Vuorenmaa, email to V.W. Framenau, 5 February 2016).

Troglofauna have been found in saprolitic rock in the Yilgarn, including the Great Victoria Desert (Bennelongia 2010; Ecologia 2010a, b; Lawrance 2009) and their presence from the study area, in particular outside the porphyry of the Northern Expansion Area, cannot be excluded. Bedrock containing faults, shears and fractures may also harbour subterranean fauna (Karanovic *et al.* 2013).

The dominant surface regolith cover sequences within the study area are Cainozoic unconsolidated to semi-consolidated colluvial and alluvial soils and these have been argued as



possible troglofauna habitat at Lake Lefroy (Subterranean Ecology 2010b). Shallow sediments of this nature are unlikely to maintain stable subterranean cavities capable of supporting troglofauna and are prone to strong surface dehydration with elevated surface temperatures and water inundation during high rainfall events. However, deeper alluvial sediments, not present at Lake Lefroy, have been shown to harbour troglofauna in the Yilgarn (Barranco & Harvey 2008). The Cainozoic soils in the study area are generally shallow, for example at the Northern Expansion Area only about 5 m thick. These will not provide stable, sufficiently moist conditions required by troglofauna.

#### 6.1.5.2 Stygofauna

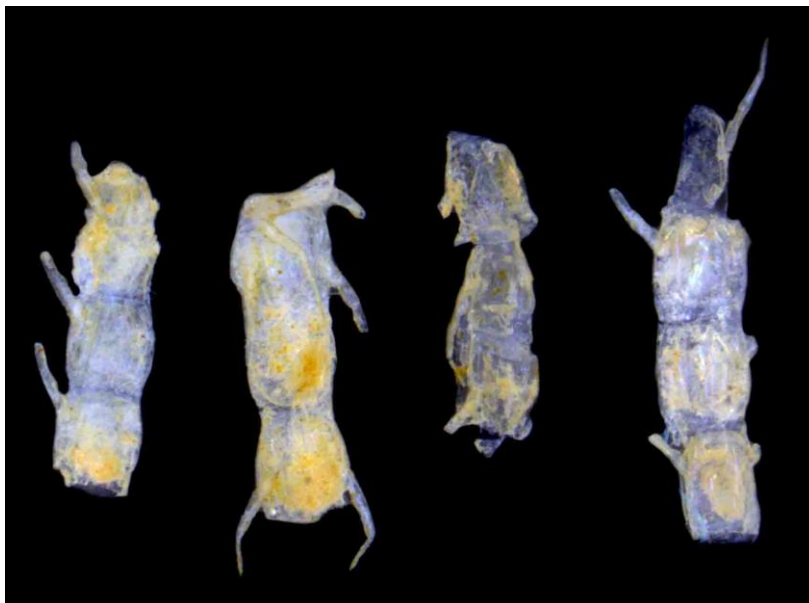
A number of factors contribute to the likelihood of stygofauna to occur, including, including sediment texture (chiefly related to hydraulic conductivity and correlated with size of pore spaces suitable for biota), hydraulic conductivity (controlling food and oxygen supply), depth from surface, water regime (timing, frequency, duration, extent and depth, and variability), energy (food) flow (in form of dissolved organic matter (DOM)), salinity (accepted upper tolerance approximately 70,000 mg/L TDS), dissolved oxygen (DO) and redox status of the groundwater (Subterranean Ecology 2010c).

Independent of all other factors, salinity appears to be the main limiting factor for the occurrence of stygofauna in the aquifers of the study area. The majority of non-marine stygofauna are intolerant to salinity. Most are found in freshwater (<3,000 mg/L TDS) but some will tolerate water with salinities above this level. Stygofauna have been collected in saline waters (3,000-70,000 mg/L TDS) in calcrete formations in the Yilgarn and Nullarbor regions of WA (Ecologia 2006; Humphreys 2008; Humphreys *et al.* 2004; Outback Ecology 2011). The ameirid copepods at Spotted Quoll inhabit groundwater characterised by salinity approximating seawater (26 000–34 000 mg/L TDS) (Karanovic *et al.* 2013). The EPA accepts that stygofauna in the Pilbara should be considered in salinities up to 60,000 mg/L TDS (EPA 2016c).

With groundwater salinities generally well over 70,000 mg/L throughout much of the study area, it is extremely unlikely that stygofauna are present, assuming that salinities below that level measured in the pits of Janet Ivy (30,000 mg/L TDS) (Saprolite Environmental 2013) are indeed an artefact of surface water run-off. If these salinities, however, reflect conditions of a local aquifer, the presence of stygofauna cannot be excluded and rest on similar assumptions on porosity of the regolith in the Northern Expansion Area, as for troglofauna.

## 6.2 FIELD SURVEY

The field survey resulted in a single potential troglotauna specimens collected at bore JI082. This specimen was represented by poorly preserved fragments of a tropical millipede (Scolopendromorpha) (Figure 6-4). Morphological assessment by the WA Museum concluded that the specimen most likely represents a member of the family Scolopendridae, but due to the poor preservation status, it was impossible to assess if it represents an obligate troglobite (Moulds & Waldock 2016).



**Figure 6-4** Unidentified centipede (Scolopendromorpha, ?Scolopendridae) collected at JI082 during field survey

## 6.3 SURVEY LIMITATIONS

The EPA *Technical Guide: Terrestrial fauna surveys* (EPA 2016e) identifies potential limitations that may be encountered during terrestrial fauna surveys. These were applied here as no equivalent guidance with respect to subterranean fauna exists (Table 6-3). With respect to the *Technical Guide*, the lack of current identifications of Cladocera is the only minor limitation for the survey.

**Table 6-3 Survey limitations based on EPA Technical Guide: Terrestrial fauna surveys (EPA 2016e)**

Limitations	Limitation for this survey?	Comments
Competency/experience of survey personnel, including taxonomy	No	The field and laboratory teams and report authors have extensive experience in survey of subterranean systems in WA. Independent taxonomic advice from the WA Museum was sought.
Scope and completeness - were all planned survey methods implemented successfully, was the study area fully surveyed	No	Suitable collecting methods were used based on comparable surveys in WA and consistent with subterranean pilot surveys conducted in WA.
Intensity - in retrospect, was the intensity adequate	No	The survey intensity of 15 bores was appropriate for a pilot troglofauna survey within the study area.
Proportion of fauna identified, recorded and/or collected.	No	Only a single potential troglofauna specimen was collected and identified to the lowest taxonomic level possible.
Availability of adequate contextual information	Yes	There is good regional contextual information in relation to subterranean surveys in the Goldfields, in particular with respect to the Yilgarn. Little information was available in the vicinity of the study area.
Timing, weather, season, cycle	No	The survey was conducted at a suitable time of the year and more than average rainfall.
Disturbances which affected the results of the survey	No	No disturbances occurring during the period of the field survey are considered to have impacted the results.
Remoteness and/or access problems	No	There were no access problems in the study area.



## 7 DISCUSSION

### 7.1 REGULATORY FRAMEWORK

The EPA's objective for subterranean fauna is its protection so that biological diversity and ecological integrity are maintained (EPA 2016b). Subterranean communities are often restricted to very small areas based on the limited dispersal capabilities of the fauna with short-range endemism interpreted at a much smaller scale than in terrestrial systems (Eberhard *et al.* 2009). There, activities that may impact on subterranean assemblages require attention at a much smaller scale.

A Level 1 desktop review represents the initial assessment on the likelihood of subterranean fauna to occur in an area of future development. A reconnaissance survey, generally aimed at investigating local geological features (i.e. presence of surface expressions of calcretes), may include or may be followed by a low intensity (Level 1) survey to further evaluate if subterranean fauna are present and therefore if a Level 2 survey is required.

The two categories of a Level 2 survey are (EPA 2016a):

- **comprehensive**, i.e. it should provide detailed information to allow an understanding of the subterranean faunal values of an area and to place it into appropriate context; it requires repeated sampling
- **targeted**, i.e. to provide answers to specific questions building on existing information.

EPA Technical Guidance: Sampling methods for subterranean fauna (EPA 2016c) elaborates on the sampling methods for subterranean fauna, in particular the minimum number of samples required for a particular survey and where these should be located in relation to the project impact. The key requirements for a Level 2 survey are:

- **stygo fauna**: a minimum of 40 samples taken from at least 10 bores within the impact zone, with the impact zone including those parts of the aquifer where significant drawdown occurs
- **troglo fauna**: at least 60 samples from areas that are likely to have significant troglo fauna values.

For both, stygo fauna and troglo fauna, sampling in two seasons is recommended. For stygo fauna, bores must be at least six months old to allow recolonisation. If they are less than three months old, sampling must occur over two seasons (EPA 2016c).

### 7.2 ASSESSMENT

This subterranean assessment represents, to our knowledge, the first appraisal of the potential of subterranean fauna to occur within the range of the Roe Palaeodrainage system. No subterranean fauna were recorded from database searches and no survey report was available from within 100 km distance of the study area in the southern Goldfields.

The desktop studies on subterranean fauna from Lake Lefroy represent the closest subterranean fauna assessments to the study area (Subterranean Ecology 2010b, c). Geology and hydrology of the Lake Lefroy Palaeodrainage system, similar to the Roe Palaeodrainage system, are characterised by Tertiary sedimentation of ancient palaeorivers incised into the Archaean bedrock; however, marine incursions reached the Lake Lefroy Palaeodrainage channels and marine deposits from the Late to Middle Eocene form part of the sedimentation process (Kern & Commander 1993). These, however, had little influence on the likelihood of subterranean fauna to occur, as similar to this study, subterranean fauna was most likely to occur in the Cainozoic (Quaternary) sediments and to a limited

extent in saprolitic fractured regolith and bedrock (Subterranean Ecology 2010b, c). However, subterranean surveys have not been conducted at Lake Lefroy as the most likely troglofauna habitat at Lake Lefroy was excluded from the disturbance footprint (SIGM 2010).

Our pilot study recovered only a single specimen of potential troglofauna in the study area, but its poor preservation status did not allow an unambiguous assessment for it to be obligate subterranean. If it is, as suggested by the WA Museum taxonomic report, a member of the family Scolopendridae (rather than of the leaf-dwelling and fossorial Cryptopidae), it more likely represents a troglobitic species as no small species with lack of pigmentation from terrestrial environments in this family is currently known (e.g. Colloff *et al.* 2005; Koch 1982, 1983a, b, c, 1985; Vahtera *et al.* 2013).

Low sampling success for troglofauna species is not uncommon in geologies similar to that of the study area. For example, as a result of 411 samples in seven phases of troglofauna surveys for the Tropicana Gold Project in the Great Victoria Desert, only 14 definite troglobitic specimens were collected (Ecologia 2010b). Overall, yields from troglofauna samples are low, and even in areas of WA that are very prospective for troglofauna (Pilbara and Yilgarn), bore scraping as the better collecting technique only records an average of about one specimen in two samples (Halse & Pearson 2014). The capture of only a single potential troglofauna specimen in the pilot study in the study area reflects this overall low capture rate.

### 7.3 RECOMMENDATIONS

This Level 1 troglofauna assessment suggests that the occurrence of troglofauna in the study area cannot be excluded. Troglofauna may mainly occur in the Northern Expansion Area away from the palaeodrainage lines but, if at all, only in weathered and/or fractured metasedimentary deposits around the Janet Ivy pit as evidenced by the potential subterranean centipede collected there. However, these sedimentary rocks reach far beyond the proposed pit expansion and it is unlikely that troglofauna, if present, is limited to the primary disturbance footprint. Troglofauna is unlikely to occur in the compact porphyry at Janet Ivy due to the lack of subterranean fractures or fissures.

It is recommended to expand the current troglofauna survey effort to a Level 2 assessment, i.e. a minimum of a total of 60 samples, concentrating on the western parts of the Northern Expansion Area. This approach would be consistent with applying the Precautionary Principle (EPA 2016b) (i.e. the scolopendramorph millipede is assumed to be a troglobite) and EPA (2016d; fig. 2), which proposes a Level 2 survey if subterranean fauna is found during Level 1 low intensity sampling.

Sampling in the Apache Project and the Southern Expansion Area documented a very high groundwater level, often only 2–3 m below the surface, which limits the habitat suitable for troglofauna to persist.

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**Appendix 1 Conservation significant subterranean fauna in Western Australia (DPaW 2017)**

Genus and species	Common name	Trogl-/ stygo fauna	Conservation rating (DPaW 2017)	Distribution (DPaW 2017)	Currently known records
<b>Arachnida</b>					
<b>Araneae (spiders)</b>					
<i>Tartarus mullamullangensis</i>	Mullamullalang Cave spider	T	VU	South Coast	Mullamullang Cave, Nullarbor Plain (Gray 1992)
<i>Tartarus murdochensis</i>	Murdoch Sink cave spider	T	VU	South Coast	Phyllistine Flattener Cave and Murdoch Sink, Nullarbor Plain (Gray 1992)
<i>Tartarus nurinensis</i>	Nurina Cave spider	T	VU	South Coast	Nurina Cave, Roe Plains (Gray 1992)
<i>Tartarus thampannensis</i>	Thampanna Cave spider	T	VU	South Coast	Thampanna Cave, Nullarbor Plain (Gray 1992)
<i>Troglodiplura lowryi</i>	Nullarbor cave trapdoor spider	T	VU	South Coast	Roaches Rest Cave and Cave NR. 6 Bore, Nullarbor Plain (Main & Gray 1985)
<b>Pseudoscorpiones</b>					
<i>Ideoblothrus linnaei</i>		T	P1	Pilbara	Mesa A (Harvey & Leng 2008)
<i>Ideoblothrus</i> sp. Mesa A (WAM T81374)		T	P1	Pilbara	Mesa A (Harvey & Edward 2007)
<i>Indohya damocles</i>	Cameron's Cave pseudoscorpion	T	CR	Pilbara	Cameron's Cave, Cape Range (Harvey & Volschenk 2007)
<i>Lagynochthonius asema</i>		T	P1	Pilbara	Mesa A (Edward & Harvey 2008)

Genus and species	Common name	Troglo-/ stygo fauna	Conservation rating (DPaW 2017)	Distribution (DPaW 2017)	Currently known records
<i>Tyrannochthonius</i> sp. Mesa A (WAM T81480)					Mesa A
<b>Schizomida</b>					
<i>Bamazomus subsolans</i>	Eastern Cape Range bamazomus	T	EN	Pilbara	Unnamed limestone quarry, Cape Range (Harvey 2001a)
<i>Bamazomus vespertinus</i>	western Cape Range bamazomus	T	EN	Pilbara	Cave C-215, Cape Range Peninsula (Harvey 2001a)
<i>Draculoides bramstokeri</i>	Barrow Island draculoides	T	VU	Pilbara	Barrow Island (Harvey & Humphreys 1995)
<i>Draculoides brooksi</i>	northern Cape Range draculoides	T	EN	Pilbara	North-eastern Cape Range Peninsula (Harvey <i>et al.</i> 2008)
<i>Draculoides julianneae</i>	western Cape Range draculoides	T	EN	Pilbara	Caves C-111 and C-215, Cape Range Peninsula (Harvey <i>et al.</i> 2008)
<i>Draculoides mesozeirus</i>	Middle Robe draculoides	T	VU	Pilbara	Middle Robe (Harvey <i>et al.</i> 2008)
<i>Draculoides vinei</i>	Cape Range Draculoides	T	P4	Pilbara	Caves within Tulki limestone of Cape Range (Harvey 2001a; Harvey <i>et al.</i> 2008)
<i>Paradraculoides anachoretus</i>	Mesa A paradraculoides	T	VU	Pilbara	Mesa A (Harvey <i>et al.</i> 2008)
<i>Paradraculoides bythius</i>	Mesa B/C paradraculoides	T	VU	Pilbara	Mesa B and Mesa C (Harvey <i>et al.</i> 2008)
<i>Paradraculoides gnophicola</i>	Mesa G paradraculoides	T	VU	Pilbara	Mesa G (Harvey <i>et al.</i> 2008)
<i>Paradraculoides kryptus</i>	Mesa K paradraculoides	T	VU	Pilbara	Mesa K (Harvey <i>et al.</i> 2008)



Genus and species	Common name	Troglo-/ stygo fauna	Conservation rating (DPAW 2017)	Distribution (DPAW 2017)	Currently known records
<b>Myriapoda</b>					
<i>Speleostrophus nesiotus</i>	Barrow Island millipede	T	VU	Pilbara	Barrow Island (Car <i>et al.</i> 2013; Hoffman 1994)
<i>Stygirochirus peculiaris</i>	Cameron's Cave millipede	T	CR	Pilbara	Camerons Cave, Cape Range Peninsula (Shear & Humphreys 1996)
<i>Stygirochirus isolatus</i>	Millipede	T	VU	Pilbara	Cave C-222, Cape Range Peninsula (Humphreys & Shear 1993)
<i>Stygirochirus sympatricus</i>	Millipede	T	VU	Pilbara	Cave C-111, Cape Range Peninsula (Humphreys & Shear 1993)
<b>Crustacea</b>					
<b>Amphipoda</b>					
<i>Bogidomma australis</i>	Barrow Island bogidomma amphipod	S	VU	Pilbara	Barrow Island (Bradbury & Williams 1996a)
<i>Hurleya</i> sp. (WAM 642–97)	Crystal Cave crangonyctoid amphipod	S	CR	Swan	Crystal Cave, Yanchep
<i>Liagoceradocus branchialis</i>	Cape Range liagoceradocus amphipod	S	EN	Pilbara	Bundera Sinkhole, Cape Range Peninsula (Bradbury & Williams 1996b)
<i>Liagoceradocus subthalassicus</i>	Barrow Island liagoceradocus amphipod	S	VU	Pilbara	Ledge Cave B-1, Barrow Island (Bradbury & Williams 1996b)
<i>Nedsia fragilis</i>	Freshwater amphipod	S	VU	Pilbara	Barrow Island (Bradbury & Williams 1996a)

Genus and species	Common name	Troglo-/ stygo fauna	Conservation rating (DPaW 2017)	Distribution (DPaW 2017)	Currently known records
<i>Nedsia humphreysi</i>	Freshwater amphipod	S	VU	Pilbara	Barrow Island (Bradbury & Williams 1996a)
<i>Nedsia hurlberti</i>	Freshwater amphipod	S	VU	Pilbara	Barrow Island (Bradbury & Williams 1996a)
<i>Nedsia macrosculptilis</i>	Freshwater amphipod	S	VU	Pilbara	Barrow Island (Bradbury & Williams 1996a)
<i>Nedsia sculptilis</i>	Freshwater amphipod	S	VU	Pilbara	Barrow Island (Bradbury & Williams 1996a)
<i>Nedsia straskraba</i>	Freshwater amphipod	S	VU	Pilbara	Barrow Island (Bradbury & Williams 1996a)
<i>Nedsia urifimbriata</i>	Freshwater amphipod	S	VU	Pilbara	Barrow Island (Bradbury & Williams 1996a)
<i>Nedsia chevronia</i>	Freshwater amphipod	S	P2	Pilbara	Barrow Island (Bradbury 2002)
<b>Copepoda</b>					
<i>Bunderia misophaga</i>	Copepod	S	CR	Pilbara	Bundera Sinkhole, Cape Range Peninsula (Jaume & Humphreys 2001)
<i>Speleophria bunderae</i>	Copepod	S	CR	Pilbara	Bundera Sinkhole, Cape Range Peninsula (Jaume <i>et al.</i> 2001)
<i>Stygocyclopia australis</i>	Copepod	S	CR	Pilbara	Bundera Sinkhole, Cape Range Peninsula (Jaume <i>et al.</i> 2001)
<b>Decapoda</b>					
<i>Stygiocaris lancifera</i>	Lance-beaked cave shrimp	S	VU	Pilbara	Cape Range Peninsula (Knott 1993)
<i>Stygiocaris stylifera</i>	Spear-beaked Cave Shrimp	S	P4	Pilbara	Cape Range Peninsula (Knott 1993)
<b>Isopoda</b>					

Genus and species	Common name	Troglo-/ stygo fauna	Conservation rating (DPaW 2017)	Distribution (DPaW 2017)	Currently known records
<i>Abebaioscia troglodytes</i>	Pannikin Plain Cave isopod	T	VU	South Coast	Pannikin Plain Cave, Nullarbor Plain (Vandel 1974 [imprint date 1973])
<i>Paraplatyarthus subterraneus</i>	Poseidon slater	T	P1		Pilbara (Javidkar & King 2015)
<b>Ostracoda</b>					
<i>Welesina kornickeri</i>	Ostracod	S	CR	Pilbara	Bundera Sinkhole, Cape Range Peninsula (Danielopol <i>et al.</i> 2000)
<b>Remipedia</b>					
<i>Kumonga exleyi</i>	Cape Range remiped	S	CR	Pilbara	Bundera Sinkhole, Cape Range Peninsula (Yager & Humphreys 1996)
<b>Polychaeta</b>					
<i>Prionospio thalANJI</i>	Bristle worm	S	CR	Pilbara	Bundera Sinkhole, Cape Range Peninsula (Wilson & Humphreys 2001)
<b>Insecta</b>					
<b>Blattaria</b>					
<i>Nocticola flabella</i>	Cape Range Blind Cockroach	T	P2	Pilbara	Cape Range Peninsula (Roth 1991)



**Appendix 2: Subterranean Threatened Ecological Communities in Western Australia (DPaW 2016a)**

Name of community	Description	Category of Threat and criteria met under WA criteria	Conservation Rating (EPBC Act 1999)	
Caves SP01	Aquatic Root Mat Community Number 1 of Caves of the Swan Coastal Plain	CR B) i), CR B) ii)	EN	Swan Coastal Plain
Caves Leeuwin01	Aquatic Root Mat Community Number 1 of Caves of the Leeuwin Naturaliste Ridge	CR B) i), CR B) ii)	EN	Warren
Caves Leeuwin02	Aquatic Root Mat Community Number 2 of Caves of the Leeuwin Naturaliste Ridge	CR B) i), CR B) ii)	EN	Warren
Caves Leeuwin03	Aquatic Root Mat Community Number 3 of Caves of the Leeuwin Naturaliste Ridge	CR B) i), CR B) ii)	EN	Warren
Caves Leeuwin04	Aquatic Root Mat Community Number 4 of Caves of the Leeuwin Naturaliste Ridge	CR B) i), CR B) ii)	EN	Warren
Cameron's	Cameron's Cave Troglobitic Community	CR B) i), CR B) ii)		Carnarvon Basin
Bundera	Cape Range Remiped Community	CR B) ii)		Carnarvon Basin
Ethel Gorge	Ethel Gorge aquifer stygobiont community	EN B) ii)		Pilbara
Depot Springs	Depot Springs stygofauna community	VU B)		Goldfields Region, Murchison Bioregion

**Appendix 3: Priority Ecological Communities (DPaW 2016c)**

Name of community	Description	Threats	Category (WA)
<b>Pilbara</b>			
Barrow Island subterranean fauna	Barrow Island stygofauna and troglotauna	Mining and industrial development	Priority 1
Subterranean invertebrate communities of mesas in the Robe Valley region	A series of isolated mesas occur in the Robe Valley in the state's Pilbara Region. The mesas are remnants of old valley infill deposits of the palaeo Robe River. The troglotic faunal communities occur in an extremely specialised habitat and appear to require the particular structure and hydrogeology associated with mesas to provide a suitable humid habitat. Short range endemism is common in the fauna. The habitat is the humidified pisolitic strata	Mining	Priority 1
Subterranean invertebrate community of pisolitic hills in the Pilbara	A series of isolated low undulating hills occur in the state's Pilbara region. The troglotauna are being identified as having very short range distributions	Mining	Priority 1
Mingah Springs calcrete groundwater assemblage type on Gascoyne palaeodrainage on Mingah Spring Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Stygofaunal community of the Bungaroo Aquifer	A unique assemblage of aquatic subterranean fauna including eels, snails and other stygofauna	Groundwater drawdown, mining	Priority 1
Stygofaunal communities of the Western Fortescue Plains freshwater aquifer	A unique assemblage of subterranean invertebrate fauna	Groundwater drawdown and salinisation	Priority 4(ii)
<b>Kimberley</b>			
Invertebrate community of Napier Range Cave	On Old Napier Downs, Karst No. KNI	Mine close by and tourist visitation	Priority 1
<b>Midwest</b>			
Badja calcrete groundwater assemblage type on Moore palaeodrainage on Badja Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1

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<b>Name of community</b>	<b>Description</b>	<b>Threats</b>	<b>Category (WA)</b>
Belele calcrete groundwater assemblage type on Murchison palaeodrainage on Belele Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Beringarra calcrete groundwater assemblage type on Murchison palaeodrainage on Beringarra Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Black Range South and Windsor groundwater calcrete assemblage type on Raeside and Murchison palaeodrainage on Lake Mason and Windsor Stations	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Bunnawarra calcrete groundwater assemblage type on Moore palaeodrainage on Bunnawarra Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Byro Central and Byro HS calcrete groundwater assemblage types on Murchison palaeodrainage on Byro Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Challa, Challa North and Wondinong calcrete groundwater assemblage type on Murchison palaeodrainage on Challa and Wondinong Stations	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Cogla Downs calcrete groundwater assemblage type on Murchison palaeodrainage on Yarrabubba Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Curbur calcrete groundwater assemblage type on Gascoyne palaeodrainage on Curbur Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Dalgety and Landor calcrete groundwater assemblage type on Gascoyne palaeodrainage on Dalgety Downs and Landor Stations	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Doolgunna calcrete groundwater assemblage type on Gascoyne palaeodrainage on Doolgunna Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Gabyon calcrete groundwater assemblage type on Moore palaeodrainage on Gabyon Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Gifford Creek, Mangaroon, Wanna calcrete groundwater assemblage type on Lyons palaeodrainage on Gifford Creek, Lyons and Wanna Stations	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Hillview calcrete groundwater assemblage type on Murchison palaeodrainage on Hillview Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1



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<b>Name of community</b>	<b>Description</b>	<b>Threats</b>	<b>Category (WA)</b>
Innouendy calcrete groundwater assemblage type on Murchison palaeodrainage on Innouendy Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Karalundi calcrete groundwater assemblage type on Murchison palaeodrainage on Karalundi Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Killara calcrete groundwater assemblage types on Murchison palaeodrainage on Killara Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Killara North calcrete groundwater assemblage types on Murchison palaeodrainage on Killara Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Lake Austin calcrete groundwater assemblage type on Murchison palaeodrainage on Austin Downs Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Maranalgo west calcrete assemblage type on Moore palaeodrainage on Maranalgo Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Meeberrie calcrete groundwater assemblage type on Murchison palaeodrainage on Meeberrie Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Meka calcrete groundwater assemblage type on Murchison palaeodrainage on Meka Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Milgun central calcrete groundwater assemblage types on Gascoyne palaeodrainage on Milgun Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Milgun south calcrete groundwater assemblage types on Gascoyne palaeodrainage on Milgun Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Milly Milly calcrete groundwater assemblage type on Murchison palaeodrainage on Milly Milly Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Mount Augustus calcrete groundwater assemblage type on Lyons palaeodrainage on Mount Augustus Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Mt Clere calcrete groundwater assemblage type on Gascoyne palaeodrainage on Mt Clere Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Mount Narryer calcrete groundwater assemblage type on Murchison palaeodrainage on Mount Narryer Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Mount Padbury calcrete groundwater assemblage type on Murchison palaeodrainage on Mount Padbury Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1

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<b>Name of community</b>	<b>Description</b>	<b>Threats</b>	<b>Category (WA)</b>
Muralgarra calcrete groundwater assemblage type on Murchison palaeodrainage on Muralgarra Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Murchison Downs calcrete groundwater assemblage type on Murchison palaeodrainage on Murchison Downs Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Ninghan calcrete groundwater assemblage type on Moore palaeodrainage on Ninghan Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Nowthanna Hill calcrete groundwater assemblage type on Murchison palaeodrainage on Yarrabubba Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Paroo calcrete groundwater assemblage type on Carey palaeodrainage on Paroo Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Polelle calcrete groundwater assemblage type on Murchison palaeodrainage on Polelle Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Taincrow calcrete groundwater assemblage type on Murchison palaeodrainage on Taincrow Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Three Rivers calcrete groundwater assemblage types on Gascoyne palaeodrainage on Three Rivers Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Three Rivers Plutonic calcrete groundwater assemblage types on Gascoyne palaeodrainage on Three Rivers Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Wagga Wagga and Yalgoo calcrete groundwater assemblage type on Yalgoo and Moore palaeodrainage on Wagga Wagga and Bunnawarra Stations	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Windimurra calcrete groundwater assemblage type on Murchison palaeodrainage on Windimurra Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Wooramel calcrete groundwater assemblage type on Wooramel palaeodrainage on Innouendy Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Yarrabubba east calcrete groundwater assemblage types on Murchison palaeodrainage on Yarrabubba Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Yarrabubba west calcrete groundwater assemblage types on Murchison palaeodrainage on Yarrabubba Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1

Name of community	Description	Threats	Category (WA)
Yoweragabbie calcrete groundwater assemblage type on Moore palaeodrainage on Yoweragabbie Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
<b>Goldfields</b>			
Albion Downs calcrete groundwater assemblage type on Carey palaeodrainage on Albion Downs Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Banjawarn and Melrose (Lake Darlot) calcrete groundwater assemblage type on Carey palaeodrainage on Banjawarn and Melrose Stations	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Barwidgee calcrete groundwater assemblage type on Carey palaeodrainage on Barwidgee Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Black Range North calcrete groundwater assemblage type on Raeside palaeodrainage on Lake Mason Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Cunyu SBF and Cunyu Sweetwater calcrete groundwater assemblage types on Nabberu palaeodrainage on Cunyu Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Dandaraga calcrete groundwater assemblage type on Raeside palaeodrainage on Dandaraga Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Glenayle and Carnegie Downs calcrete groundwater assemblage type on Burnside palaeodrainage on Glenayle Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Hinkler Well calcrete groundwater assemblage type on Carey palaeodrainage on Lake Way Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Lake Way South calcrete groundwater assemblage type on Carey palaeodrainage on Lake Way Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Jundee Homestead calcrete groundwater assemblage type on Carnegie palaeodrainage on Jundee Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Jundee South Hill calcrete groundwater assemblage type on Carnegie palaeodrainage on Jundee Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1



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<b>Name of community</b>	<b>Description</b>	<b>Threats</b>	<b>Category (WA)</b>
Kaluwiri calcrete groundwater assemblage type on Raeside palaeodrainage on Kaluwiri Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Lake Mason calcrete groundwater assemblage type on Raeside palaeodrainage on Lake Mason Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Lake Miranda east calcrete groundwater assemblage types on Carey palaeodrainage on Yakabindie Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Lake Miranda west calcrete groundwater assemblage types on Carey palaeodrainage on Yakabindie Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Lake Violet south and Lake Violet calcrete groundwater assemblage types on Carey palaeodrainage on Millbillillie Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Laverton Downs calcrete groundwater assemblage type on Carey palaeodrainage on Laverton Downs Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Lorna Glen calcrete groundwater assemblage type on Carnegie palaeodrainage on Lorna Glen Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Melita calcrete groundwater assemblage type on Raeside palaeodrainage on Melita Station (Sons of Gwalia)	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Millbillillie: Bubble calcrete groundwater assemblage type on Carey palaeodrainage on Millbillillie Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Mount Morgan calcrete groundwater assemblage type on Carey palaeodrainage on Mount Weld Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Nambi calcrete groundwater assemblage type on Carey palaeodrainage on Nambi Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Old Cunya calcrete groundwater assemblage type on Nabberu palaeodrainage on Cunyu Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Perrinvale (Pine Well) calcrete groundwater assemblage type on Raeside palaeodrainage on Perrinvale Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Pinnacles calcrete groundwater assemblage type on Raeside palaeodrainage on Pinnacles Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1

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<b>Name of community</b>	<b>Description</b>	<b>Threats</b>	<b>Category (WA)</b>
Sturt Meadows calcrete groundwater assemblage type on Raeside palaeodrainage on Sturt Meadows Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Uramurdah Lake calcrete groundwater assemblage type on Carey palaeodrainage on Millbillillie Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Wiluna BF calcrete groundwater assemblage type on Carey palaeodrainage on Millbillillie Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Windidda calcrete groundwater assemblage type on Carnegie palaeodrainage on Windidda Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Yakabindie calcrete groundwater assemblage type on Carey palaeodrainage on Yakabindie Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Yandal calcrete groundwater assemblage type on Carey palaeodrainage on Yandal Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Yeelirrie calcrete groundwater assemblage type on Carey palaeodrainage on Yeelirrie Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
Yuinmery calcrete groundwater assemblage types on Raeside palaeodrainage on Yuinmery Station	Unique assemblages of invertebrates have been identified in the groundwater calcretes	Mining	Priority 1
<b>Warren</b>			
Microbial mantles of Nullarbor caves (especially Weebubbie Cave)	Significant microbial communities in underwater sections of cave	Uncontrolled access	Priority 1
Subterranean faunal ecosystems of Nullarbor caves (known from Nurina Cave, Olwolgin Cave, Burnabbie Cave, N327, N1327)	The caves contain communities of invertebrates, other fauna and sensitive habitats including tree roots. Caves included in this community contain at least four troglobitic taxa.	Uncontrolled access	Priority 3(i)





## **Appendix F: Proof of Land Ownership**



## MINING TENEMENT SUMMARY REPORT

**MINING LEASE 26/115**

Status: Live

### TENEMENT SUMMARY

**Area:** 66.39000 HA      **Death Reason :**  
**Mark Out :** 30/06/1986 15:38:00      **Death Date :**  
**Received :** 04/07/1986 11:30:00      **Commence :** 17/03/1987  
**Term Granted :** 21 Years (Renewed)

### CURRENT HOLDER DETAILS

**Name and Address**

BELLAMEL MINING PTY LTD  
HETHERINGTON EXPLORATION & MINING TITLE SERVICES PTY LTD, C/- HETHERINGTON EXPLORATION  
& MINING TITLE SERVICES PTY LTD, SUITE 404, GROUND FLOOR, 50 ST GEORGES TERRACE, PERTH,  
WA, 6000, xxxxx@hemts.com.au, xxxxxx977

### DESCRIPTION

**Locality:** SEVEN MILE HILL  
**Datum:** DP SIT 3750M BRG 155DEG FROM SW CNR LATE  
SURV GML 5144E  
**Boundary:** THENCE: 5500 metres bearing 320 degrees 2000 metres  
bearing 50 degrees 900 metres bearing 140 degrees  
750 metres bearing 50 degrees 1550 metres bearing 140  
degrees

Area :	Type	Dealing No	Start Date	Area
	Surveyed		31/07/1993	66.39000 HA
	Dealing	Partial Surrender - Conditional KA107/923	30/07/1993	66.39000 HA
	Granted		17/03/1987	925.35000 HA
	Applied For		30/06/1986	925.35000 HA

### SHIRE DETAILS

Shire	Shire No	Start	End	Area
KALGOORLIE-BOULDER CITY	4280	04/07/1986		66.39000 HA



## MINING TENEMENT SUMMARY REPORT

**MINING LEASE 26/430**

Status: Live

### TENEMENT SUMMARY

**Area:** 130.55000 HA      **Death Reason :**  
**Mark Out :** 20/08/1993 14:40:00      **Death Date :**  
**Received :** 20/08/1993 15:10:00      **Commence :** 25/10/1993  
**Term Granted :** 21 Years (Renewed)

### CURRENT HOLDER DETAILS

**Name and Address**

BELLAMEL MINING PTY LTD  
HETHERINGTON EXPLORATION & MINING TITLE SERVICES PTY LTD, C/- HETHERINGTON EXPLORATION  
& MINING TITLE SERVICES PTY LTD, SUITE 404, GROUND FLOOR, 50 ST GEORGES TERRACE, PERTH,  
WA, 6000, xxxxx@hemts.com.au, xxxxxx977

### DESCRIPTION

**Locality:** SEVEN MILE HILL  
**Datum:** DATUM POST IS SITUATED 326.956 METRES  
BEARING 206 DEGREES 34 MINUTES 17 SECONDS  
FROM THE SOUTH WEST CORNER OF SURVEYED  
MINING LEASE 26/243 ON NORTHERN BOUNDARY  
OF PROSPECTING LICENCE 26/2442  
**Boundary:** THENCE 1600 METRES BEARING 140 DEGREES  
TO SOUTHERN BOUNDARY OF PROSPECTING  
LICENCE 26/2442 THENCE 880 METRES BEARING  
230 DEGREES TO SOUTH EAST CORNER OF MINING  
LEASE 26/420 THENCE 1900 METRES BEARING  
320 DEGREES ALONG EASTERN BOUNDARY OF  
MINING LEASE 26/420 AND PART OF MINING LEASE  
26/387 THENCE 460 METRES BEARING 50 DEGREES  
TO EASTERN BOUNDARY OF PROSPECTING  
LICENCE 26/2445 THENCE 300 METRES BEARING  
140 DEGREES TO SOUTH WEST CORNER OF  
PROSPECTING LICENCE 26/2448 THENCE 420  
METRES BEARING ALONG NORTHERN BOUNDARY  
OF PROSPECTING LICENCE 26/2442 BACK TO  
DATUM

Area :	Type	Dealing No	Start Date	Area
	Surveyed		26/10/1993	130.55000 HA
	Granted		25/10/1993	130.55000 HA
	Applied For		20/08/1993	155.00000 HA



**SHIRE DETAILS**

<b>Shire</b>	<b>Shire No</b>	<b>Start</b>	<b>End</b>	<b>Area</b>
KALGOORLIE-BOULDER CITY	4280	20/08/1993		130.55000 HA



## MINING TENEMENT SUMMARY REPORT

**MINING LEASE 26/243**

Status: Live

### TENEMENT SUMMARY

**Area:** 228.80000 HA      **Death Reason :**  
**Mark Out :** 14/03/1988 13:47:00      **Death Date :**  
**Received :** 15/03/1988 11:22:00      **Commence :** 12/06/1990  
**Term Granted :** 21 Years (Renewed)

### CURRENT HOLDER DETAILS

**Name and Address**

BELLAMEL MINING PTY LTD

HETHERINGTON EXPLORATION & MINING TITLE SERVICES PTY LTD, C/- HETHERINGTON EXPLORATION & MINING TITLE SERVICES PTY LTD, SUITE 404, GROUND FLOOR, 50 ST GEORGES TERRACE, PERTH, WA, 6000, xxxxx@hemts.com.au, xxxxxx977

### DESCRIPTION

**Locality:** BINDULI  
**Datum:** Datum Peg situated 860 metres bearing 346 degrees from north east corner of late surveyed GML 26/7190  
**Boundary:** THENCE: 2131 metres bearing 142 degrees 22 minutes along the eastern boundary of P26/919 797 metres bearing 228 degrees 12 minutes along the southern boundary of P26/919 65 metres bearing 135 degrees 36 minutes along the eastern boundary of GML26/7040 244 metres bearing 226 degrees 14 minutes along the southern boundary of GML26/7040 204 metres bearing 313 degrees 49 minutes along the western boundary of GML26/7040 17 metres bearing 46 degrees 38 minutes along the northern boundary of GML26/7040 2005 metres bearing 322 degrees 2 minutes along the western boundary of P26/919 669 metres bearing 48 degrees 32 minutes along the northern boundary of P26/919 100 metres bearing 327 degrees 55 minutes along the western boundary of P26/1176 254 metres bearing 58 degrees 23 minutes along the northern boundary P26/1176 56 metres bearing 152 degrees 18 minutes along the eastern boundary of P26/1176 135 metres bearing 48 degrees 12 minutes along the northern boundary of P26/919 BACK TO DATUM NOTE: Pursuant to Section 49 Mining Act 1978 and conditional surrenders of GML's 26/7040, 7136 and 7190

Area :	Type	Dealing No	Start Date	Area
	Surveyed		27/04/1993	228.80000 HA
	Granted		12/06/1990	227.50000 HA
	Applied For		14/03/1988	227.50000 HA

**SHIRE DETAILS**

<b>Shire</b>	<b>Shire No</b>	<b>Start</b>	<b>End</b>	<b>Area</b>
KALGOORLIE-BOULDER CITY	4280	14/03/1988		228.80000 HA





## MINING TENEMENT SUMMARY REPORT

**MINING LEASE 26/474**

Status: Live

### TENEMENT SUMMARY

**Area:** 893.55000 HA      **Death Reason :**  
**Mark Out :** 23/02/1995 15:38:00      **Death Date :**  
**Received :** 24/02/1995 09:30:00      **Commence :** 04/11/1997  
**Term Granted :** 21 Years (Renewed)

### CURRENT HOLDER DETAILS

**Name and Address**

BELLAMEL MINING PTY LTD

HETHERINGTON EXPLORATION & MINING TITLE SERVICES PTY LTD, C/- HETHERINGTON EXPLORATION & MINING TITLE SERVICES PTY LTD, SUITE 404, GROUND FLOOR, 50 ST GEORGES TERRACE, PERTH, WA, 6000, xxxxx@hemts.com.au, xxxxxx977

### DESCRIPTION

**Locality:** Binduli  
**Datum:** Datum situated at the southern most corner of surveyed M 26/243  
**Boundary:** THENCE: 243.71 metres bearing 45 degrees 49 minutes along surveyed boundary M 26/243 61.31 metres bearing 317 degrees 14 minutes along surveyed boundary M 26/243 194.6 metres bearing 48 degrees 48 minutes along surveyed boundary of M 26/243 1830 metres bearing 140 degrees along boundary of P 26/2442 740 metres bearing 230 degrees along boundary of P 26/2442 to the eastern most corner of surveyed M 26/430 1477.71 metres bearing 320 degrees along surveyed boundary of M 26/430 410 metres bearing 230 degrees along surveyed boundary of M 26/430 300 metres bearing 320 degrees along surveyed boundary of M 26/430 391.9 metres bearing 230 degrees along surveyed boundary of M 26/430 to the westernmost corner of surveyed M 26/430 1262.29 metres bearing 320 degrees along boundary of M 26/387 1020 metres bearing 230 degrees along boundaries of M 26/387 and P 26/2446 2480 metres bearing 325 degrees along boundaries of P 26/2447 and P 26/2448 3280 metres bearing 50 degrees along boundaries of P 26/2448 and P 26/2444 900 metres bearing 140 degrees along boundary of P 26/2444 110 metres bearing 230 degrees along boundary of P 26/2444 to the northernmost corner of surveyed M 26/115 1072.66 metres bearing 233 degrees 17 minutes along surveyed boundary of M 26/115 2679.28 metres bearing 142 degrees 43 minutes along surveyed boundaries of M 26/115 and M 26/243 15.59 metres bearing 211 degrees 45 minutes along surveyed boundary of M 26/243 202.62 metres bearing

133 degrees 51 minutes along surveyed boundary of  
M 26/243 BACK TO DATUM Application includes P  
26/2442,P 28/2443,P 26/2444 and P 26/2445, P 26/2447  
and P 26/2448

Area :	Type	Dealing No	Start Date	Area
	Surveyed		05/11/1997	893.55000 HA
	Granted		04/11/1997	893.55000 HA
	Applied For		23/02/1995	937.00000 HA

<b>SHIRE DETAILS</b>
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Shire	Shire No	Start	End	Area
KALGOORLIE-BOULDER CITY	4280	23/02/1995		893.55000 HA



ASIC

Australian Securities & Investments Commission

# Relational Company Extract

**Name: NORTON GOLD FIELDS PTY LTD**

**ACN: 112 287 797**

Date/Time: 04 December 2019 AEST 06:50:31 PM

This extract contains information derived from the Australian Securities and Investments Commission's (ASIC) database under section 1274A of the Corporations Act 2001.

Please advise ASIC of any errors or omission which you may identify.

ASIC expressly disclaims any liability arising from use of the service. If you require legal or other expert advice or assistance, you should seek the services of a competent professional person.

The following is an extract from the ASIC database showing where relevant;

- Companies in which the subject corporation is a member (only the top twenty members),
- Companies for which the subject corporation is the Ultimate Holding Company,
- Corporations for which the subject corporation is a director,
- Foreign companies for which the subject company is a local agent,
- Financial Services licences held by the subject company,
- Financial Services representative roles held by the subject company,
- Auditor roles in Financial Services licences held by the subject company,
- Securities dealers licenses held by the subject company,
- Securities investments advisers licenses held by the subject company,
- Futures dealers licenses held by the subject company,
- Futures advisers licenses held by the subject company,
- Managed Investment schemes for which the subject is the responsible entity,
- Asia Region Funds Passport for which the subject is the operator.

EXTRACT



Organisation Details	Document Number
<b>Current Organisation Details</b>	
Name: NORTON GOLD FIELDS PTY LTD ACN: 112 287 797 ABN: 23112287797 Registered in: New South Wales Registration date: 21/12/2004	
<b>Current Roles in Other Organisations</b>	
Role: Local Agent Name: BULLABULLING GOLD (UK) LIMITED ARBN: 143 978 376 ABN: 49143978376 Agent Address: 'Viskovich House' Level 1, 377 Hannan Street, KALGOORLIE WA 6430 Appointed: 16/06/2015	029569863
Role: Ultimate Holding Company Name: NORTON GOLD HOLDINGS PTY LTD ACN: 118 450 776 ABN: 51118450776 Address: Unknown	1E1832139
Role: Ultimate Holding Company Name: NORTON GOLD MINE PTY. LTD. ACN: 110 955 354 ABN: 40110955354 Address: 7 Potts Street, EAST BRISBANE QLD 4169	7E0886159
Role: Ultimate Holding Company Name: PADDINGTON GOLD PTY LIMITED ACN: 008 585 886 ABN: 98008585886 Address: STANLEY YEATES & ASSOCIATES, Level 1, 101 Edward Street, BRISBANE QLD 4000	7E1300858
Role: Ultimate Holding Company Name: NORTON COAL PTY. LTD. ACN: 131 025 502 Address: STANLEY YEATES & ASSOCIATES, Level 1, 101 Edward Street, BRISBANE QLD 4000	024263784
Role: Ultimate Holding Company Name: MOUNT MORGAN MINE PTY. LTD. ACN: 138 015 077 ABN: 53138015077 Address: STANLEY YEATES & ASSOCIATES, Level 1, 101 Edward Street, BRISBANE QLD 4000	1E5578054
Role: Ultimate Holding Company Name: KALGOORLIE MINING COMPANY PTY LTD ACN: 091 009 559 ABN: 44091009559 Address: Level 36, 2 The Esplanade, PERTH WA 6000	028797072

Current Shares/Interests Held				
Name: PADDINGTON GOLD PTY LIMITED ACN: 008 585 886 ABN: 98008585886 Address: Level 36, 2 The Esplanade, PERTH WA 6000				
Class	Number held	Beneficially held	Paid	Document number
ORDINARY SHARES	2	Y	Fully	7E5049058
Name: PADDINGTON GOLD PTY LIMITED ACN: 008 585 886 ABN: 98008585886 Address: Level 36, 2 The Esplanade, PERTH WA 6000				
Class	Number held	Beneficially held	Paid	Document number
REDEEMABLE PREFERENCE SHARES	538	Y	Partially	7E5049058
Name: NORTON GOLD MINE PTY. LTD. ACN: 110 955 354 ABN: 40110955354 Address: Level 36, 2 The Esplanade, PERTH WA 6000				
Class	Number held	Beneficially held	Paid	Document number
ORDINARY SHARES	100	Y	Fully	7E5049071
Name: NORTON GOLD HOLDINGS PTY LTD ACN: 118 450 776 ABN: 51118450776 Address: Level 36, 2 The Esplanade, PERTH WA 6000				
Class	Number held	Beneficially held	Paid	Document number
ORDINARY SHARES	1	Y	Fully	7E5049083
Name: BELLAMEL MINING PTY LTD ACN: 125 443 076 ABN: 55125443076 Address: Level 36, 2 The Esplanade, PERTH WA 6000				
Class	Number held	Beneficially held	Paid	Document number
ORDINARY SHARES	90000003	Y	Fully	7E5049090
Name: NORTON COAL PTY. LTD. ACN: 131 025 502 Address: Level 36, 2 The Esplanade, PERTH WA 6000				
Class	Number held	Beneficially held	Paid	Document number
ORDINARY	1	Y	Fully	7E5049117

Name: MOUNT MORGAN MINE PTY. LTD.

ACN: 138 015 077

ABN: 53138015077

Address: Level 36, 2 The Esplanade, PERTH WA 6000

Class	Number held	Beneficially held	Paid	Document number
ORDINARY SHARE	1	Y	Fully	7E5049130

Name: NORTON OPERATIONS PTY LTD

ACN: 151 083 359

Address: Level 36, 2 The Esplanade, PERTH WA 6000

Class	Number held	Beneficially held	Paid	Document number
ORDINARY SHARES	1	Y	Fully	7E5049141

Name: KALGOORLIE MINING COMPANY PTY LTD

ACN: 091 009 559

ABN: 44091009559

Address: 'Viskovich House' Level 1, 377 Hannan Street,  
KALGOORLIE WA 6430

Class	Number held	Beneficially held	Paid	Document number
ORDINARY SHARES	1301312252	Y	Fully	030586362

Name: BULLABULLING GOLD PTY LTD

ACN: 153 234 532

ABN: 50153234532

Address: 'Viskovich House' Level 1, 377 Hannan Street,  
KALGOORLIE WA 6430

Class	Number held	Beneficially held	Paid	Document number
ORDINARY	350811553	Y	Fully	030586361

Note: For each class of shares issued by a proprietary company, ASIC records the details of the top twenty members of the class (based on shareholdings). The details of any other members holding the same number of shares as the twentieth ranked member will also be recorded by ASIC on the database. Where available, historical records show that a member has ceased to be ranked amongst the top twenty members. This may, but does not necessarily mean, that they have ceased to be a member of the company.



## **Appendix G: City of Kalgoorlie-Boulder Written Consent**

Ref: AT:AB Core: 3547341

5 July 2022

Weifeng Jian  
General Manager – Binduli Project  
Norton Gold Fields  
PO Box 1653, Kalgoorlie,  
**KALGOORLIE WA 6430**

Dear Weifeng,

**RE: LETTER OF SUPPORT FOR BINDULI SOUTH PROJECT STAGE 1 - APACHE PROJECT**

I refer to your letter dated 19 May 2022. The City of Kalgoorlie-Boulder supports Norton Gold Fields Limited use of Reserve 8787 subject to the below conditions but not limited to:

1. Clearing of Vegetation to be minimised.
2. The activities are limited to the development as shown in Attachment 1: Binduli South Stage 1 Layout
3. Department of Mines, Industry Regulation and Safety (DMIRS) approval be obtained prior to commencement of any mining activities or works.
4. Public safety management and remediation in accordance with the mining proposal and project management plan approved by DMIRS.
5. Relocation of the memorial for Pitman Walsh to an agreed location.
6. The area being rehabilitated following completion of mining.
7. Norton Gold Fields Limited will attempt to reuse existing mining infrastructure (roads, laydowns) from previous projects to minimise environmental impacts wherever practical.

The City looks forward to an ongoing positive and proactive relationship with Norton Goldfields. If there are any questions in relation please contact Director Engineering, Kevin Ketterer via email at [Kevin.Ketterer@ckb.wa.gov.au](mailto:Kevin.Ketterer@ckb.wa.gov.au) or by telephoning 08 9021 9611.

Kind regards,



**ANDREW BRIEN**  
Chief Executive Officer

I refer to your email dated 07 July 2021, requesting amended approval for Norton Gold Fields Limited and subsidiary companies to utilise land within Lake Douglas Recreation Reserve 34317 (R34317) for activities related to the Binduli North mining and heap leach project.

The City approves Norton Gold Fields Limited use of the revised referenced portion of R34317 subject to the below conditions:

1. The activities are limited to the development envelope as shown in Attachment 1 – Revised Development Envelope – Southern End – A4P.
2. Clearing of vegetation to be minimised.
3. Department of Mines, Industry Regulation and Safety (DMIRS) approval be obtained prior to commencement of any mining activities or works;
4. Public safety management and remediation in accordance the mining proposal and project management plan approved by DMIRS.



