Native Vegetation Clearing Permit Application

Supporting Document

April 2024

M31/210, M31/219, M31/220, M31/295, M28/166, M28/167.

Table of Contents

List of Figures

List of Tables

List of Appendices

1 SUMMARY

This document has been prepared in support of an application for a native vegetation clearing permit under Part V of the *Environmental Protection Act 1986* (EP Act).

This supporting document outlines the key activities associated with proposed clearing, the existing environment of the clearing permit application area, and an assessment of the native vegetation clearing proposed using the ten clearing principles (DER, 2014).

Project Name: Qena Project

Project Location: Mining Leases M31/220, M31/295, M31/210, M31/219 (Qena Project), M28/166, M28/167 (CDO Solar Farm Stage 3) (Figure 1-1). Located in the Shire of Menzies, approximately 120 km northeast of Kalgoorlie Boulder.

Purpose: Expansion of mining operations, including: the Qena underground mine proposed at the existing Luvironza gold mine, and CDO Solar Farm Stage 3.

Clearing area: This clearing permit application seeks to clear up to 280 ha within the proposed clearing permit application area shown in Figure 1-1.

Timing of Clearing: Clearing is planned to commence on 1 July 2024.

Contact details: Cliff Bennison – Principal Environmental Advisor
Level 4, 500 Hay St
Subiaco
WA, 6008

Vegetation, flora and fauna surveys, and a targeted Malleefowl survey have been completed to identify and describe vegetation within the clearing permit application area.

A vegetation clearing impact assessment has been conducted for the clearing permit application area, and determined the proposed clearing is not at variance, or not likely to be at variance, with 8 of the 10 clearing principles. Clearing activities may be at variance with Clearing Principles B (clearing Threatened fauna habitat) and F (clearing in an environment associated with a watercourse):

- **Principle B** - Clearing of Malleefowl habitat will be required, however no significant residual impacts to Malleefowl will result from the clearing.
- **Principle F -** drainage lines in the clearing permit area support sparse to mid-dense acacia shrublands which are not considered typical of riparian vegetation.

The clearing permit application area has also been designed to avoid known populations of Priority 3 flora species *Eremophila arachnoides* subsp. *tenera*. Some scattered individuals of this species are known to occur in the clearing permit application area. No clearing will occur within 10 m of any Priority flora.

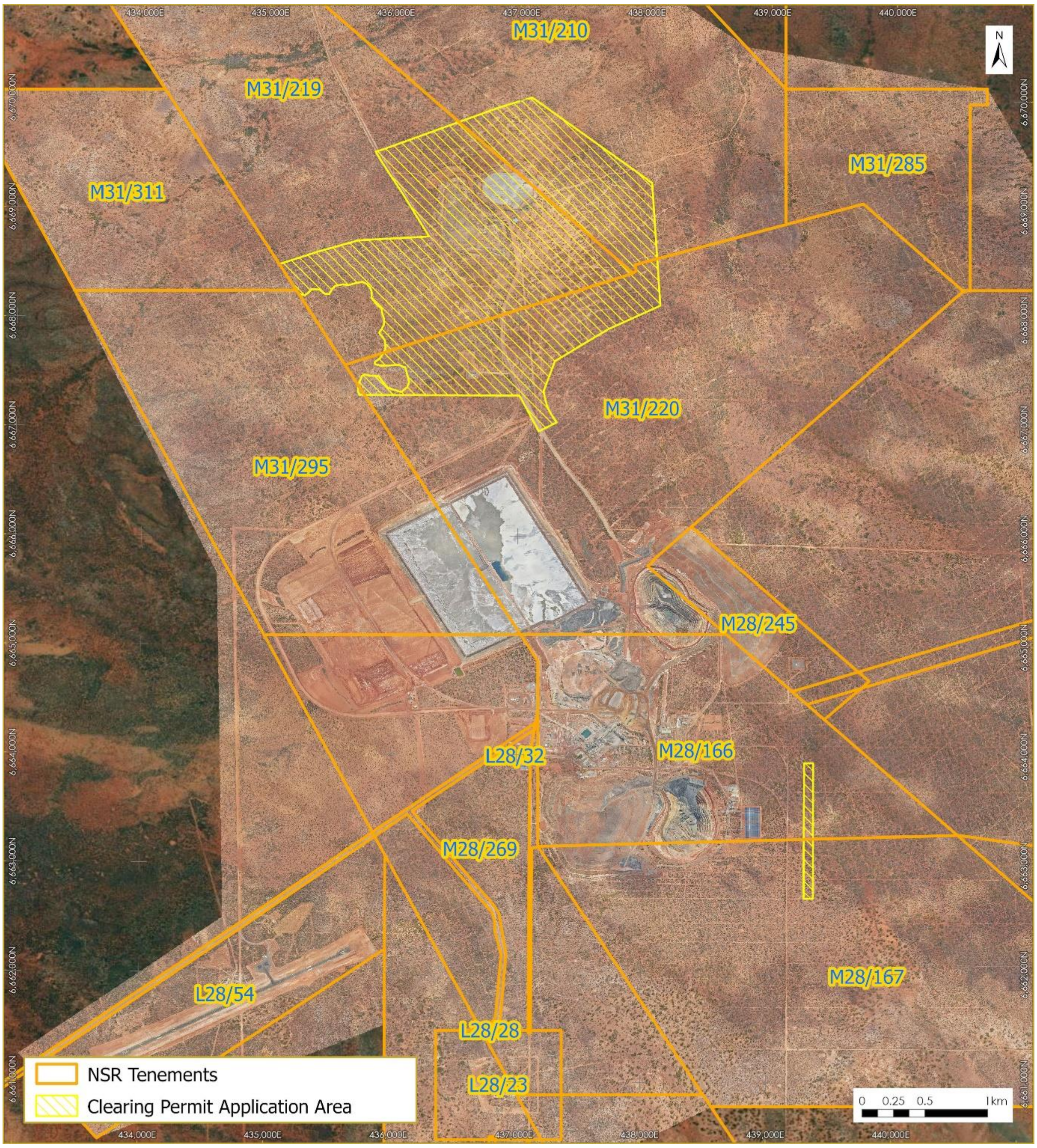


Figure 1-1: Proposed Clearing Permit Application Area

2 PROJECT DESCRIPTION

Carosue Dam Operations (CDO) is a gold mining operation located in the Shire of Menzies, approximately 120 km northeast of Kalgoorlie Boulder. Mining at CDO commenced in the early 2000s. The mining operation currently comprises four open pits and two underground mines, associated waste rock dumps, a central processing plant facility, two tailings storage facilities (one paddock style TSF and a historic in-pit tailings facility), as well as supporting auxiliary infrastructure, such as roads, buildings and workshops.

Northern Star (Carosue Dam) Pty Ltd (Northern Star) is now planning the next phase of mining at CDO, which will include the development of a third underground mine (the Qena Project), and expansion of the CDO solar farm:

- The Qena Project will be located within the immediate are of the historic Luvironza gold mine, on Mining Lease M31/210, M31/219, M31/220, M31/285. Luvironza is an open pit gold mine originally mined until the early 2010s, with the open pit currently utilised as an in-pit TSF, which ceased deposition when it reached capacity shortly following mining conclusion. The Qena project is expected to include a new box-cut and underground mine, two waste rock dumps, a ROM pad, and supporting infrastructure such as workshops, offices, fuel storage, laydown, two turkey's nests, roads and powerlines, topsoil stockpiles and any other supporting infrastructure associated with the project. (Figure 2-1). As shown in Figure 2-1, historic disturbance associated with the Luvironza gold mine will be utilised wherever practicable to minimise clearing requirements.
- The existing CDO Solar Farm is planned for expansion within mining tenements M28/166 and M28/167 (Figure 2-2). Note Figure 2-2 shows the maximum potential clearing anticipated to facilitate, noting that wherever practicable, existing disturbance will be utilised to mitigate clearing impacts in the area.

The proposed activities will require up to 280 ha of additional native vegetation clearing.

Native vegetation clearing is planned to commence on 1 July 2024.

Vegetation clearing will be minimised as far as practicable. Measures to avoid, minimise and mitigate clearing are described in Section 3.

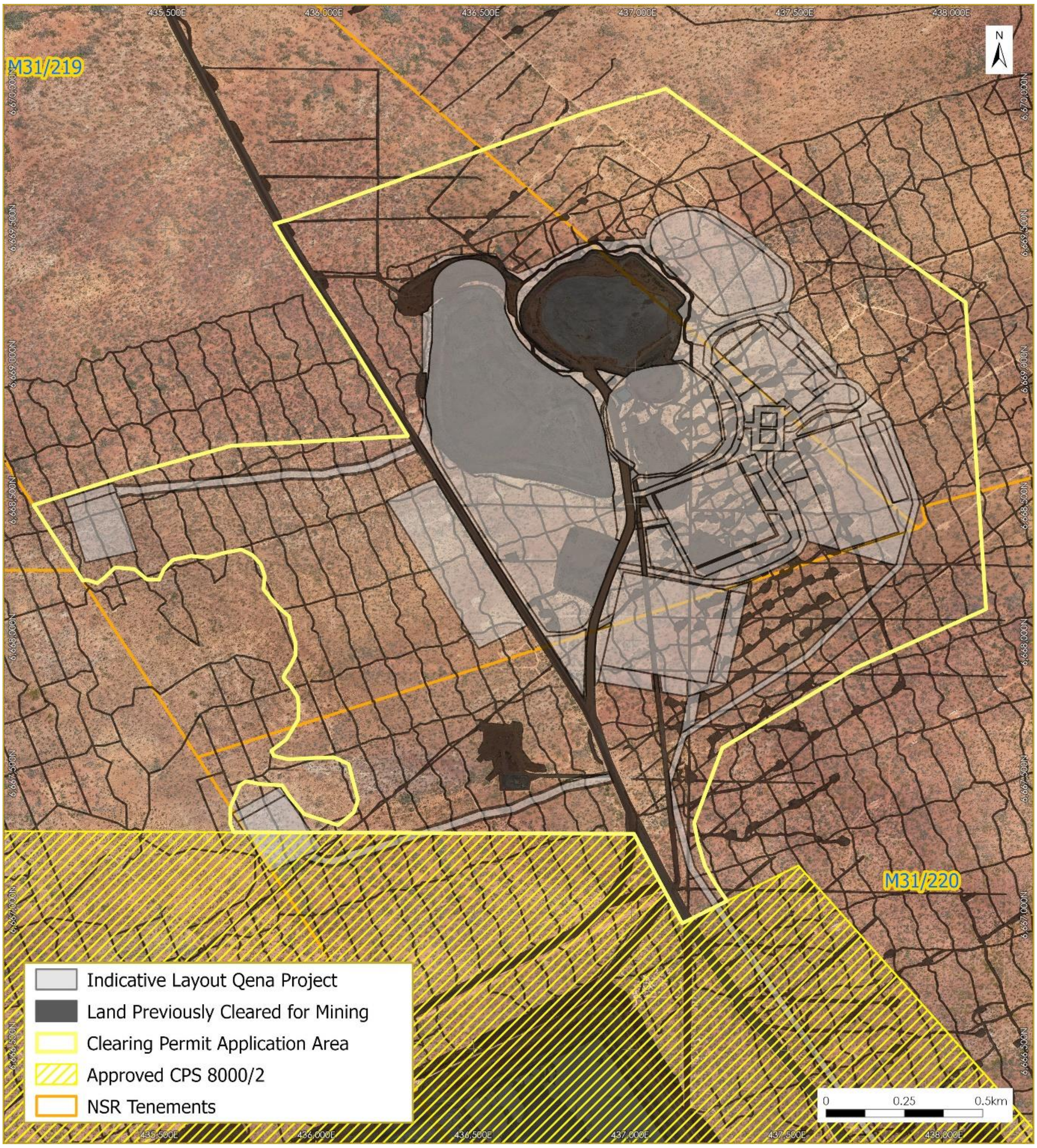


Figure 2-1 Indicative Layout for the Qena Project

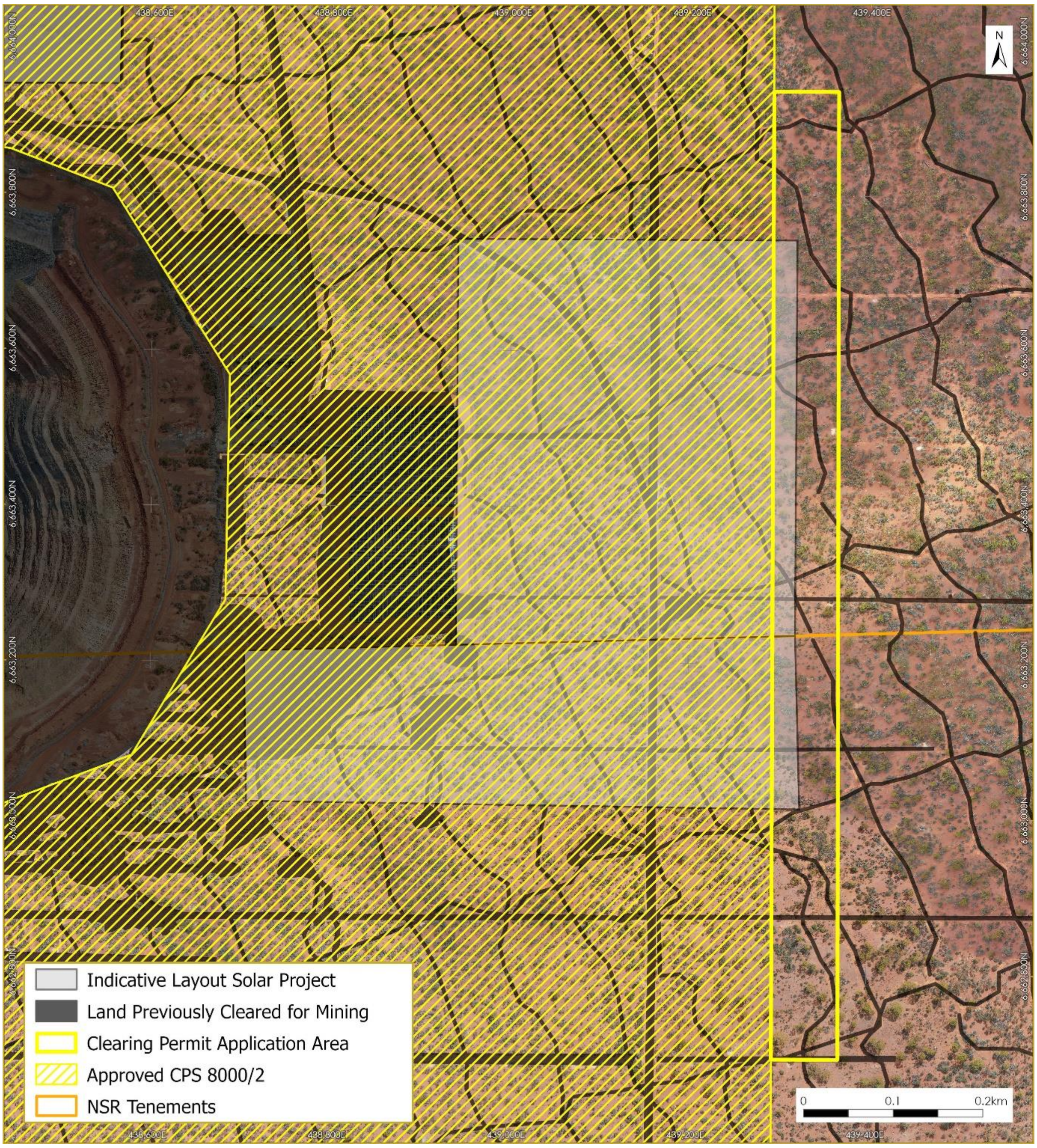


Figure 2-2 Indicative Layout of Solar Farm Expansion

3 CLEARING OF NATIVE VEGETATION

3.1 Measures to Avoid, Minimise and Mitigate Clearing Impacts

Northern Star operates on a hierarchy of avoid, minimise, rehabilitate, and offset. This hierarchy is achieved primarily through changes in design during mine planning and implementation. Measures to avoid, minimise and mitigate clearing impacts are outlined below.

3.1.1 Avoid

It will not be possible to avoid the proposed additional clearing, as additional disturbance will be required to accommodate the expansion of mining infrastructure.

3.1.2 Minimise

Design considerations to minimise clearing requirements for this project are summarised below. These will be implemented as far as practicable.

Where possible, clearing requirements will be reduced further during detailed design and implementation of both projects.

- **Qena Project**
    - A lift will be constructed on the existing Luvironza waste rock dump to reduce the amount of clearing required for additional waste rock dumps.
    - The project was actively designed to avoid Malleefowl nesting mounds and minimise the area of clearing within suitable habitat as far as practicable to facilitate the project.
    - Mining infrastructure will be preferentially constructed within previously disturbed areas of the Luvironza gold mine.
    - Proposed service corridor infrastructure (pipelines, powerlines, and access roads) will be constructed within existing service corridors and actively avoid any impact to Priority flora.
- **CDO Solar Farm Expansion**
    - The solar farm will be designed to minimise the spacing between solar panels to reduce the overall amount of clearing required.
    - The associated construction laydown area will be constructed within an area that will be utilised for future mining activities, to reduce any temporary clearing requirements.
    - All project infrastructure (laydowns, access roads and power cabling) will be constructed within previously cleared land so far as practicable.

3.1.3 Rehabilitate

Native vegetation clearing will be rehabilitated in accordance with mine closure obligations under the *Mining Act 1978*.

While some clearing such as that for mining voids will be permanent (and have applicable closure obligations committed upon mine closure), other areas, such as supporting infrastructure and waste rock dumps, will be rehabilitated at closure.

3.1.4 Offset

The proposed native vegetation clearing will not result in any significant residual impacts to the environment and therefore an offset is not required.

3.2 Vegetation Management

Clearing will be implemented in accordance with Northern Star Environmental Management System (EMS) and management conditions outlined in the Clearing Permit approval. As a minimum, the following vegetation management conditions will be adhered to (unless otherwise stated in the approved permit), including:

- **Avoid, minimise and reduce the impacts and extent of clearing**

  In determining the amount of native vegetation to be cleared under this Permit, the Permit Holder must apply the following principles, set out in descending order of preference:

  (a) avoid the clearing of native vegetation;

  (b) minimise the amount of native vegetation to be cleared; and

  (c) reduce the impact of clearing on any environmental value.

- **Weed control**

  When undertaking any clearing or other activity authorised under this Permit, the Permit Holder must take the following steps to minimise the risk of the introduction and spread of weeds:

  (a) clean earth-moving machinery of soil and vegetation prior to entering and leaving the area to be cleared;

  (b) ensure that no known weed-affected soil, mulch, fill or other material is brought into the area to be cleared; and

  (c) restrict the movement of machines and other vehicles to the limits of the areas to be cleared.

- **Vegetation Management**

  (a) where practicable the Permit Holder shall avoid clearing riparian vegetation; and

  (b) where a watercourse is to be impacted by clearing, the Permit Holder shall ensure that the existing surface flow is maintained.

- **Fauna Management – Malleefowl**

  Where clearing authorised under this Permit is to occur between 1 September and 31 January, the Permit Holder shall:

  (a) Within two weeks prior to undertaking any clearing, engage an environmental specialist to conduct an inspection of the area to be cleared to identify active (in use) Malleefowl (*Leipoa ocellata*) mounds.

  (b) Where an active (in use) Malleefowl mound is identified under Condition 8(a) of this Permit, the Permit Holder shall ensure that no clearing occurs within 50 metres of the mound, during the months of September through to January, unless first approved by the CEO.

- **Flora Management**

  Where priority flora have been identified and their written locations provided to the CEO, the Permit Holder shall ensure that:

  (i) no clearing of identified priority flora occurs; and

  (ii) no clearing occurs within 10 metres of identified priority flora, unless first approved by the CEO.

4 SUMMARY OF BIOLOGICAL SURVEYS

4.1 Qena Project

Holm (2023a) conducted a vegetation, flora and fauna survey (Appendix A), and a targeted Malleefowl survey (Appendix B), to inform planning and approvals for the Qena Project.

The surveys were conducted over 2100 ha across tenements M31/219, M31/210, M31/220 and M31/285 during the following dates:

- Vegetation and flora reconnaissance survey: 3 - 9 October 2023
- Basic fauna survey, including Malleefowl habitat mapping: 23-28 October 2023
- Targeted Malleefowl survey: 6-13 November 2023

4.1.1 Vegetation, Flora and Fauna Survey

The results of the vegetation, flora and fauna survey are summarised below.

- Eight vegetation communities were recorded across the survey area including:
  - GHAS: Greenstone hill acacia shrubland
  - SACS: Sandplain acacia shrubland
  - SIAS: Stony ironstone acacia shrubland
  - FHSX: Felsic hill mixed shrubland
  - PACS: Plain acacia casuarina shrubland
  - CCAS: Calcareous casuarina acacia shrubland or woodland
  - CAHS: Casuarina halophyte shrubland
  - PXHS: Plain mixed halophyte low shrublands
  - DRAS: Drainage tract acacia shrubland
- Vegetation condition is altered to significantly altered with only 2% of vegetation in excellent condition with unaltered structure.
- No Threatened Ecological Communities (TECs) or Priority Ecological Communities (PECs) were recorded in the survey area.
- No threatened flora taxa were identified during the survey.
- Two populations of the Priority 3 species *Eremophila arachnoides* subsp. *tenera* occurred across tenements M31/219, M31/220, M31/285 and M31/295.
- A total of 129 flora species were recorded.
- Malleefowl were the only conservation significant fauna species to be detected during the survey.

4.1.2 Targeted Malleefowl Survey

The results of the targeted Malleefowl survey found:

- Malleefowl are active within the broader survey area.
- One live bird was sighted.
- Four active and six inactive nests were found within the survey area, one additional active nest was also found just outside the survey area.
- Critical breeding and foraging habitat of low basaltic and lateritic rises and moderate preference for plains supporting mulga shrublands covered 728 ha of the survey area.
- Foraging and dispersal habitat of basalt hills covers 14 ha of the survey area.
- Halophytic shrublands, which are mostly not used by Malleefowl covered 1,376 ha of the survey area.
- A review of 10,000 ha of Malleefowl habitats previously surveyed in the surrounding area found 3,900 ha of breeding habitat, 370 ha of forage and dispersal habitat and 6,821 ha of unsuitable habitat.

4.2 Solar Farm Expansion

4.2.1 CDO Seismic Survey Vegetation, Flora and Fauna Survey

The proposed solar farm expansion will be located within an area previously surveyed by Holm (2019) (Appendix C). The survey assessed an approximately 3,136 ha area.

The survey had three components:

- A reconnaissance vegetation and flora survey from January 7 -12, 2019.
- A reconnaissance fauna survey from January14-17, 2019.
- A targeted flora survey for *Eremophila arachnoides* subsp. *tenera* from February 4- 13, 2019.

Results of the survey found:

- Eleven vegetation communities were recorded across the broader survey area:
    - GHAS: Greenstone hill acacia shrubland
    - BRXS: Breakaway mixed shrubland
    - SAMA: Sandplain mallee spinifex
    - GHMW: Greenstone hill mixed shrubland
    - HPMS: Hardpan plain mulga shrubland
    - PECW: Plain eucalypt chenopod shrubland
    - PAES: Pain acacia ecusalypt shrubland
    - SIAS: Stony ironstone acacia shrubland
    - CCAS: Calcareous casuarina acacia shrubland or woodland
    - PXHS: Plain mixed halophyte low shrublands
    - DRAS: Drainage tract acacia shrubland
- The survey area has been disturbed by recent and historic mining activity and is mostly within a pastoral lease and has been grazed. Vehicle tracks, cut lines and pastoral fences cross the area.
- No Threatened Ecological Communities (TECs) or Priority Ecological Communities (PECs) were recorded in the survey area.

- No threatened flora taxa were identified during the survey.
- The only Priority flora species recorded was *Eremophila arachnoides* subsp. *tenera* (Priority 3).
- No alien to Western Australia (weed) species were located during survey although *Carthamus lanatus* (saffron thistle) was noted growing along road verges.

4.2.2 CDO Solar Farm Stage 3 Malleefowl Activity and Habitat Assessment

A site inspection was conducted to assess Malleefowl habitat and activity within the proposed solar farm area (Appendix D). The survey assessed an approximately 68 ha area to the east and south of the existing solar farm on M28/166 and M28/167.

The results of the survey included:

- Vegetation is characterised by 'Plains supporting acacia shrublands'
- The survey area is characterised by Malleefowl foraging habitat and is not representative of breeding habitat critical for survival of the species, due to the present of shallow basement geology and intractable soils.
- No Malleefowl mounds were recorded in the survey area, but evidence of a failed attempt at a mound was recorded.
- Malleefowl are active in the area, evidenced by Malleefowl tracks.

5 FLORA & VEGETATION

5.1 Flora

Flora within the clearing permit application area is typical of the region:

- Across the broader survey area, 129 flora taxa representing 30 families were identified.
- Two weed species were recorded: *Centaurea melitensis* (Maltese cockspur) and *Lysimachia arvensis* (Scarlet pimpernel). No weeds listed as Weeds of National Significance or Declared Pests listed under the *Biosecurity and Agriculture Management Act 2007* (BAM Act) we recorded in the survey area.
- No Threatened flora species were identified.
- One Priority 3 flora species occurs in the area, *Eremophila arachnoides* subsp. *tenera*. This species was previously known from the area.

Two populations of the *Eremophila arachnoides* subsp. *tenera* were recorded in the broader survey area (Figure 5-1):

- A population of 2,500 *Eremophila arachnoides* subsp. *tenera* plants across approximately 125 ha was identified on tenements M31/219, M31/220 and extending outside of the survey area into M31/295.
- The second population of 680 plants is located on tenements M31/284 and M31/220 across approximately 9 ha. The second population is located approximately 1km outside of the clearing permit application area. In addition, seven individual plants were located across the survey area, in favourable microenvironments, these were determined as outliers.

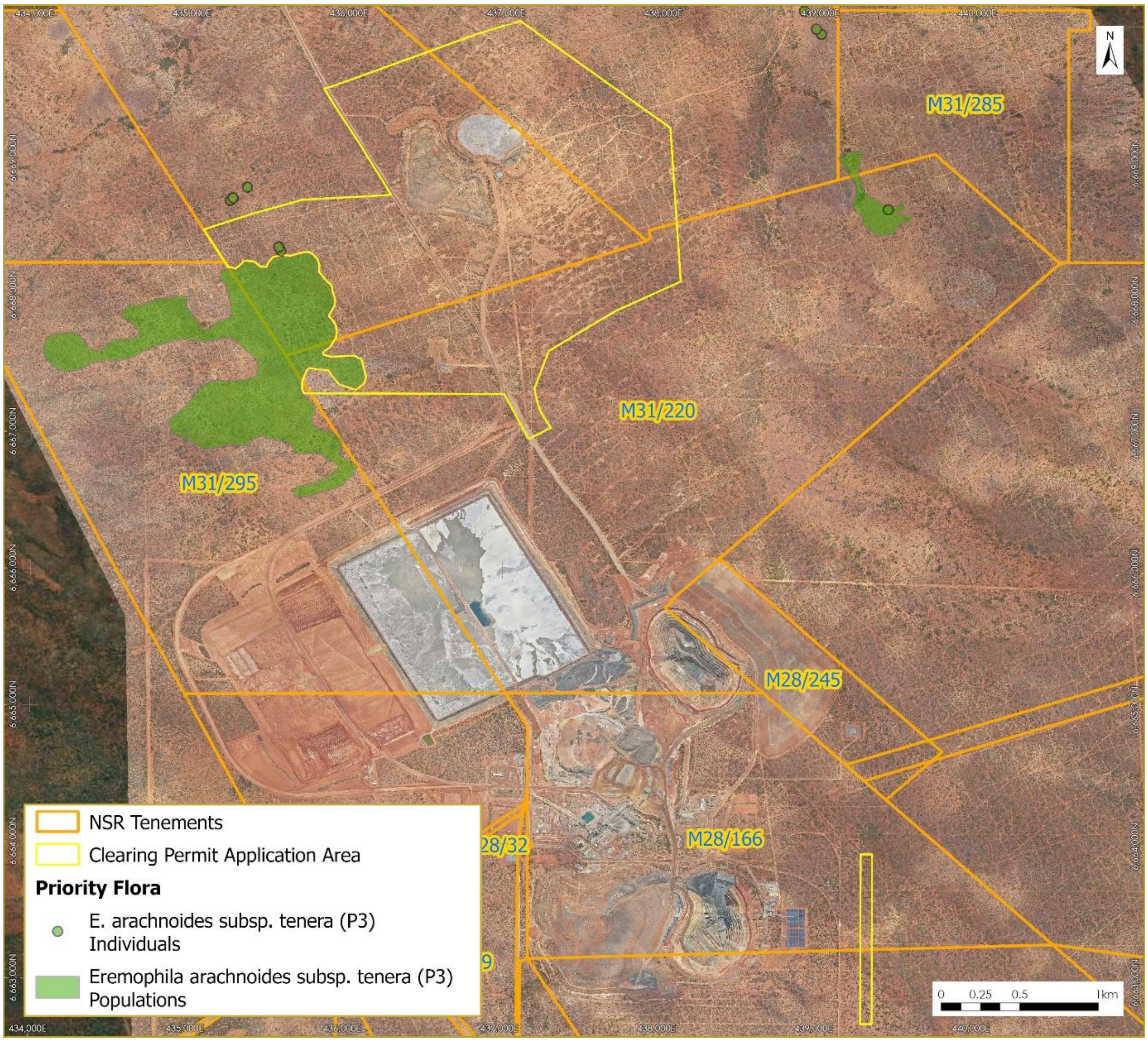


Figure 5-1 *Eremophila arachnoides* subsp. *tenera* plant populations

5.2 Vegetation Associations and Representation

The clearing permit application area is characterised by one Pre-European vegetation association, vegetation association 20, which has been described as low woodland; mulga mixed with *Allocasuarina cristata* and *Eucalyptus* sp (Shepherd, 2007).

The local and regional representation of this vegetation association is summarised in Table 5-1 below.

Table 5-1 Vegetation Representation (Government of WA, 2019)

Vegetation association	Scale	Pre-European Extent (ha)	Current Extent	% Remaining	% Remaining in DBCA Reserve
20	**Statewide**	1,295,103.38	1,292,474.58	99.80	19.38
	IBRA Bioregion Murchison	1,174,259.16	1,171,630.80	99.78	15.49
	IBRA Sub-region Eastern Murchison	1,174,259.17	1,171,630.81	99.78	15.49
	Local Government Authority Shire of Menzies	561,828.47	561,279.68	99.90	33.63

5.3 Vegetation Communities

Seven vegetation communities have been mapped within the clearing permit application area (Table 5-2, Figure 5-2). Vegetation communities are dominated by halophytic shrublands and acacia shrublands, which are common and widespread in the region.

Table 5-2 Vegetation Communities

Vegetation Community	Vegetation Description	Area within Survey Area		Area within clearing permit application area (ha)
		Holm 2023	Holm 2019	
Land Unit 1c - Felsic hills and footslopes				
FHSX Felsic hill mixed shrubland	Very sparse mid-height shrubland dominated by *Acacia hemiteles Scaevola spinescens*, *Maireana sedifolia* and *Senna artemisioides* subsp. *filifolia* with very sparse overstorey of *Casuarina pauper*.	20	-	2.5
BRXS Felsic Hill Breakaways and footslopes	Open low or mixed height shrubland (PFC 10-30%) dominated by *Scaevola spinescens*, *Acacia erinacea*, *Eremophila scoparia* and *Senna artemisioides* subsp. *filifolia* with very sparse overstorey of Casuarina pauper of *Eucalyptus oleosa* subsp. *oleosa* and occasionally open woodlands of *Eucalyptus lesouefii*.	-	167	0.8
Land Unit 4a - Plains supporting acacia shrublands				
PACS Plain acacia casuarina shrubland	Very sparse to sparse, sometimes patchy acacia shrublands dominated by *Acacia incurvaneura*. *A. burkittii* and *A. hemiteles*, and very sparse lower shrubs including *Dodonaea* lobulata, *Senna artemisioides* subsp. filifolia, and *Scaevola spinescens* with overstoreys of *Casuarina pauper* or *Eucalyptus oleosa* subsp. *oleosa*.	370	-	25.1
PAES Plains supporting acacia shrublands	Open tall acacia shrublands (PFC 10 -30%) dominated by *Acacia incurvaneura*. *A. ayersiana, A. burkittii, A. hemiteles, A. tetragonophylla* and very sparse lower shrubs including *Dodonaea lobulata*, *Senna artemisioides* subsp. *filifolia*, and *Ptilotus obovatus* with overstoreys of isolated *Casuarina pauper* or *Eucalyptus oleosa* subsp. *oleosa*.	-	1327.8	13.2
Land Unit 4c - Calcareous plains supporting chenopod shrublands				

Vegetation Community	Vegetation Description	Area within Survey Area		Area within clearing permit application area (ha)
		Holm 2023	Holm 2019	
CCAS Calcareous casuarina acacia shrubland or woodland	Sparse, mostly degraded, *Maireana sedifolia* shrubland with colonizing shrubs including *Senna artemisioides* subsp. *filifolia*, *Eremophila scoparia, Acacia burkittii* and *A. hemiteles* with very sparse overstorey of *Acacia incurvaneura* or *Casuarina pauper*.	932	233	349.5
Land Unit 5a - Alluvial plains supporting chenopod shrublands				
PXHS Plain mixed halophyte low shrublands	Very sparse to sparse halophytic shrublands dominated by *Maireana sedifolia* or *Atriplex vesicaria* or *Cratystylis subspinescens* or in poor condition dominated by *Senna artemisioides* subsp. *filifolia*, *Eremophila scorparia*, *E. arachnoides* subsp *tenera*, with very sparse overstorey of *Casuarina pauper* and/or *Acacia incurvaneura.*	246	716	47.1
Land Unit 6 – Drainage tracts				
DRAS Drainage tracts	Open to mid-close (PFC 20-60%), tall acacia shrubland and occasional thickets dominated by *Acacia incurvaneura*, *A. ayersiana* and *A. burkittii* with isolated *Eucalyptus oleosa* subsp. *oleosa*, *Brachychiton gregorii* or *Cauarina pauper* or less commonly *Bursaria occidentalis*. *Senna artemisioides* subsp. *filifolia*, *Grevillea nematophylla* subsp. *nematophylla* and *Teucrium teucriiflorum*.	215	154.1	0.9

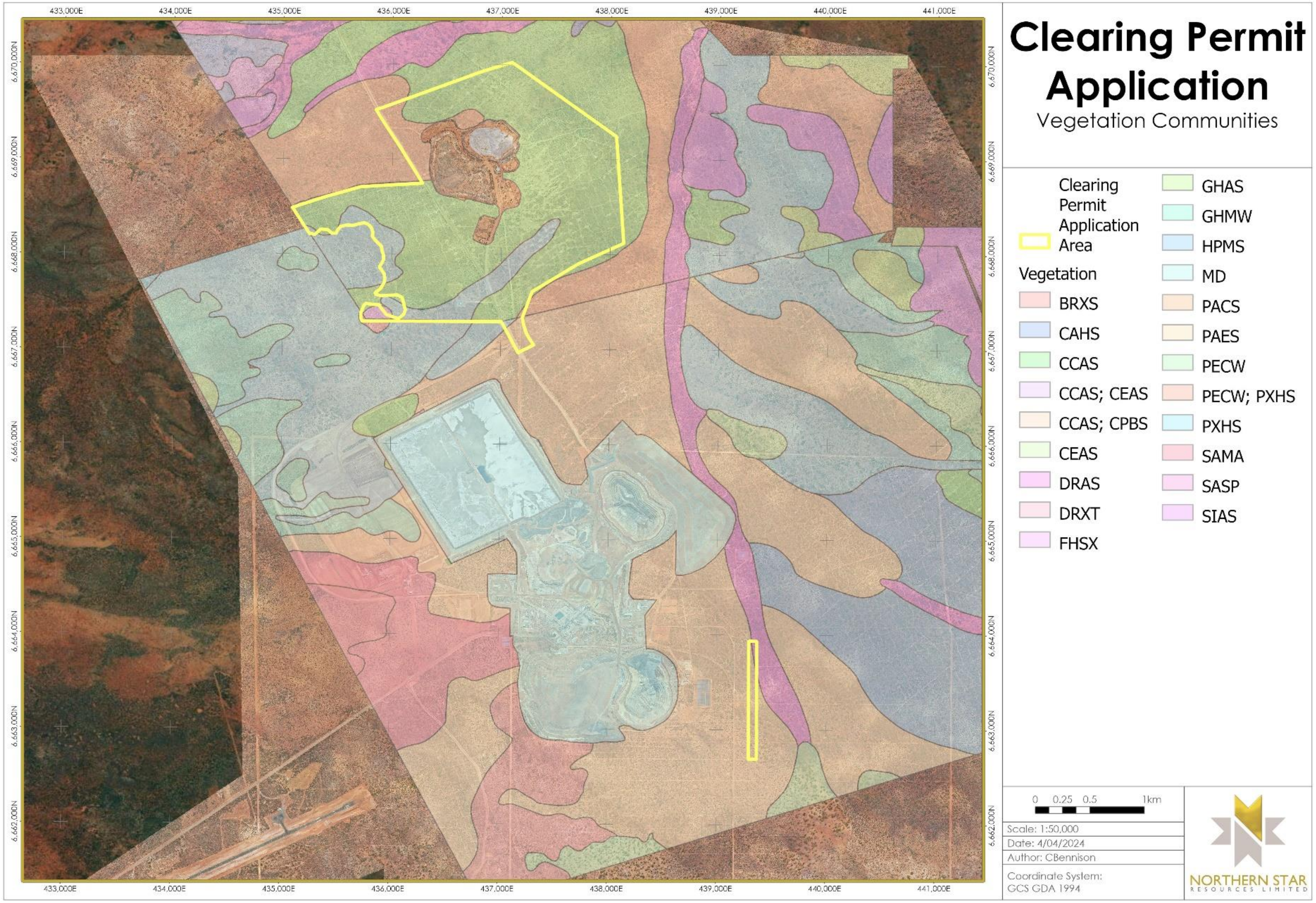


Figure 5-2 Vegetation communities

5.4 Vegetation Condition

Mining and sheep grazing has occurred both historically and recently across the Qena survey area The Qena survey area mapped excellent to degraded vegetation, with no area supporting pristine vegetation (Figure 5-3). However, vegetation condition mapping conducted during the vegetation survey was very coarse and underestimated mining disturbance. Finer scale mapping of mining disturbance was conducted for mining rehabilitation fund reporting, which indicates approximately 128 ha of the 525 ha clearing permit application area was previously cleared.Table 5-3 Qena Vegetation condition (Holm 2023a)

Vegetation Condition	Survey Area	Area within clearing permit application area (ha)
Excellent	31.8	20.0
Very Good	1,015.6	116.3
Good	800.8	212.7
Degraded	276.2	71.7
Cleared	70.0	70.0

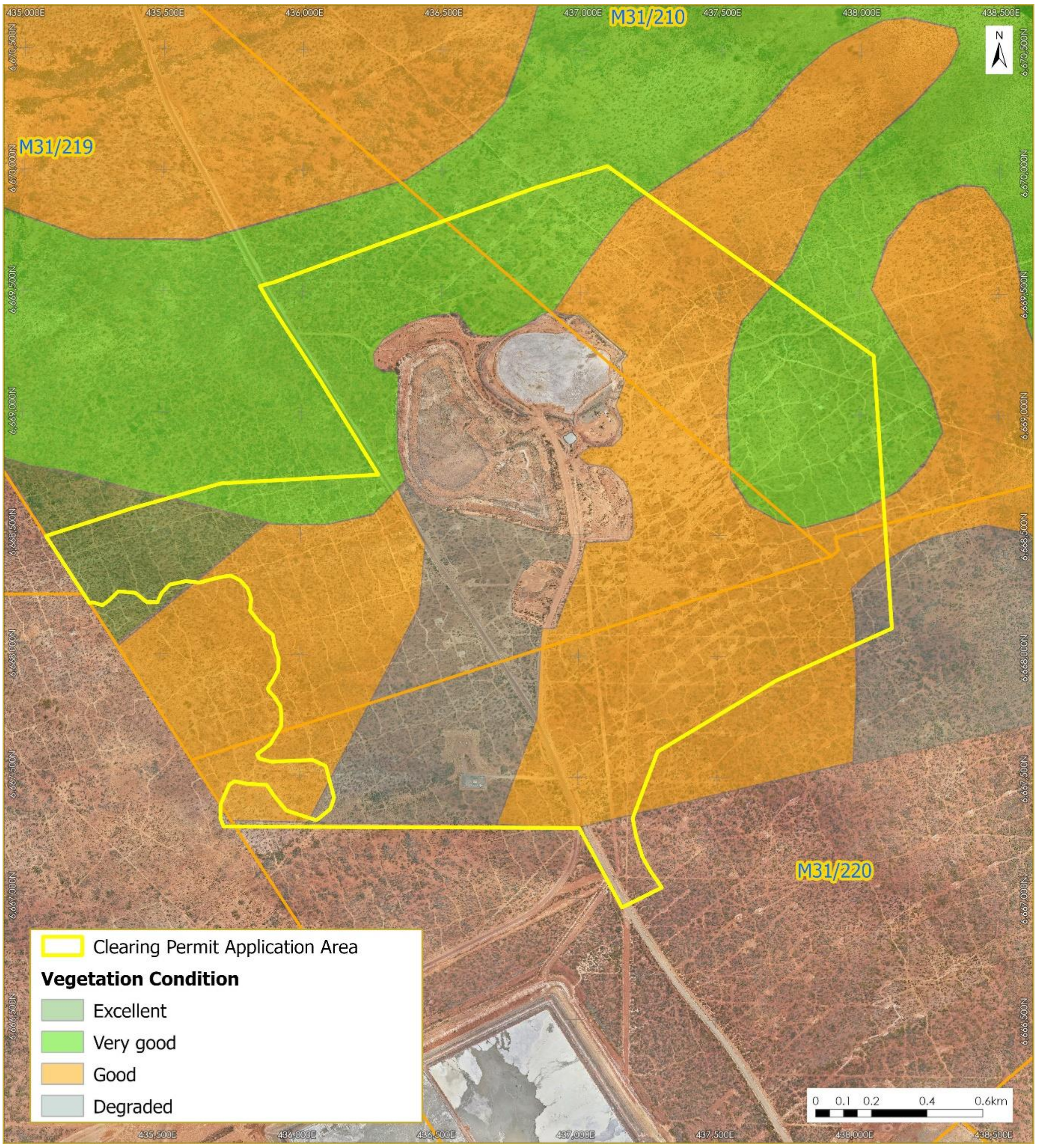


Figure 5-3 Qena Vegetation Condition

6 FAUNA

Twenty-four vertebrate fauna species were recorded by Alexander olm & Associates (2023a) in the broader survey area, comprising, 22 birds and two reptiles. A trapdoor spider was also sighted. Evidence of four non-native species included, cow (*Bos taurus)*, European rabbit (*Oryctolagus cuniculus)*, cat (*Felis catus)* and red fox (*Vulpes vulpes*).

6.1 Threatened and Priority Fauna

The desktop assessment identified nine conservation significant species with potential to utilise the clearing permit application area, including six birds, two mammals and one reptile (Table 6-1).

The only conservation significant species recorded during the survey was the Malleefowl. Malleefowl are listed as Vulnerable under the Commonwealth E*nvironment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and State *Biodiversity Conservation Act 2016 (*BC Act). Malleefowl are discussed further in Section 6.3.

Although not detected during the survey, the Southern Whiteface may also be present due the presence of suitable habitat. This species is listed as Vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). It is not listed under the State *Biodiversity Conservation Act 2016* (BC Act).

The remaining conservation significant species were assessed as either vagrant species that may be incidental visitors to the area, unlikely to occur due to lack of suitable habitat, or presumed locally extinct.

Table 6-1 Threatened and Priority Flora Possibly Residing within the Survey Area

Fauna	Common name	Conservation status	Likely occurrence in survey area
Bird			
Aphelocephala leucopsis	Southern Whiteface	Vulnerable	Potential resident
Calidris ferruginea	Curlew Sandpiper	Critically endangered	Vagrant
Falco hypoleucos	Grey Falcon	Vulnerable	Vagrant
Leipoa ocellata	Malleefowl	Vulnerable	Recorded resident
Pezoporus occidentalis	Night Parrot	Endangered	Vagrant
Polytelis alexandrae	Princess Parrot	Vulnerable	Vagrant
Mammal			
Dasyurus geoffroii	Chuditch	Vulnerable	Probably locally extinct
Sminthopsis psammophila	Sandhill Dunnart	Endangered	No suitable habitat
Reptile			
Liopholis kintorei	Great Desert Skink	Vulnerable	No suitable habitat

6.2 Fauna Habitat

The fauna survey did not identify distinctive delineations of fauna habitats as the vegetation types are mainly sparse shrublands with occasional thickets on slopes and plains.

Holm (2023a) identified three land units in the broader survey area that may support fauna species not found throughout the entire survey area, due to the presence of different soils and hydrology:

- Land unit 1d sandy ridges (vegetation community SACS)
- Land unit 6b drainage (vegetation community DRAS)
- Land unit 7b saline drainage (vegetation community PXHS).

Five land units and associated habitat were identified and considered comparable to fauna habitats (Table 6-2). The remainder of the land within the clearing permit application area was mapped as mining disturbance.

Table 6-2 Land Units and Fauna Habitats in the clearing permit application area

Fauna Habitat	Area within the Survey Area (ha)		Area within the clearing permit application area (ha)
	Holm 2023	Holm 2019	
Land unit 5a Alluvial plains supporting chenopod shrublands	246	716	48.3
Land unit 4c Calcareous plains supporting chenopod shrublands	932	412	349.9
Land unit 1c Felsic hills and footslopes	20	166	3.2
Land unit 4a Plains supporting acacia shrublands	370	1328	36.9
Land unit 6 Drainage tracts	215	154	0.9

6.3 Malleefowl

The Carosue Dam Operations is located with a widely dispersed population of Malleefowl, with an unknown defined extent. Malleefowl have been recorded at the Mt Celia Project, approximately 70 km north of central CDO operations, and throughout the central mining areas of Luvironza, Karari and Whirling Dervish (Holm 2022 and 2023c). Regionally, records of Malleefowl extend in all directions beyond these locations (DPaW 2016).

Broad scale habitat availability at CDO has been estimated based on land unit mapping throughout the region (Holm 2023c) (Figure 6-1). A 10,351 ha area, encompassing the CDO operations, contains an estimated 3,900 ha of breeding habitat considered critical for survival of the species, 370 ha was suitable for foraging and the remainder has either been previously disturbed or is unsuitable for foraging or breeding (Figure 6-1). It should be noted that breeding habitat is also considered suitable foraging habitat.

Based on land systems present, it has been estimated that there is over 18,000 ha of habitat within 10km of CDO, characterised by the Deadman, Kirgella, Lawrence and Leonora land systems (Holm 2022, 2023c). The majority of malleefowl nesting mounds within the CDO area have been recorded in the Deadman land system, characterised by level to gently undulating plains with casuarina-acacia shrublands. Nesting mounds also occur in favoured locations within the extensive Kirgella land system characterised by sandplain supporting spinifex and acacia/eucalypt shrublands.

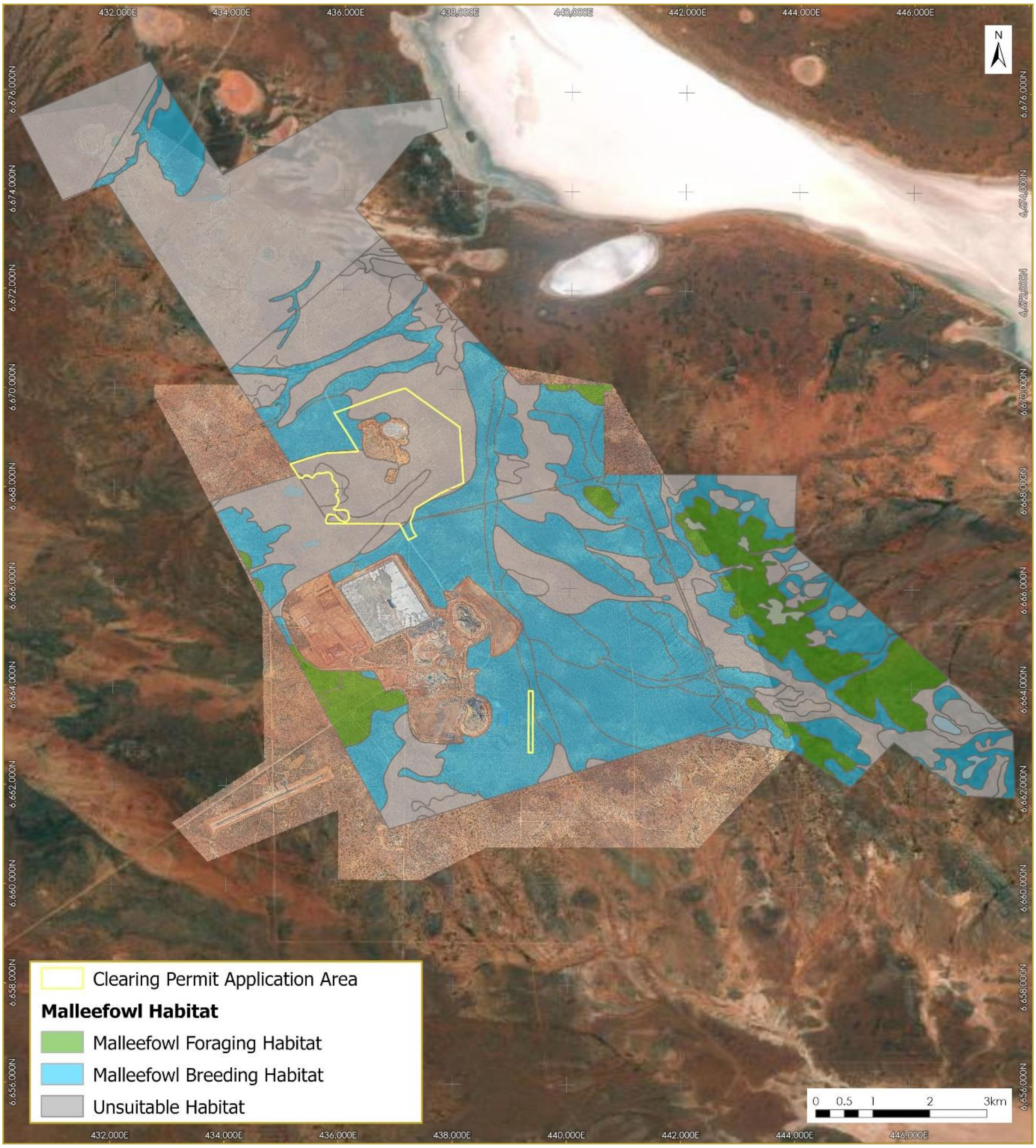


Figure 6-1 Extended Malleefowl Habitat

In October 2023, a Targeted Malleefowl survey was conducted by Holm (2023b) for a 2,100 ha that encompasses the Qena project (Appendix B).

The survey identified that Malleefowl are actively present within the survey area, with a single bird, four active and six inactive mounds found recorded, with an additional active mound recorded just outside the survey area. However, there was no Malleefowl activity, such as tracks or nesting mounds, found within the proposed Qena Project area, with the closest active mound approximately 1km from the project. Two inactive long-unused nests are within 400m of the project, and two inactive recent nests are within 150m of the Project.

The malleefowl habitat present within the survey area was mapped as 728 ha critical breeding habitat, 24 ha of foraging and dispersal habitat and 1,376 ha of unsuitable habitat (Figure 6-2). Within the Qena Project locality, the clearing permit application area includes 22.2 ha of Malleefowl breeding habitat.

Within the CDO solar farm locality, Malleefowl habitat was originally mapped in 2021 as part of a Targeted Malleefowl survey for the CDO TSF Cell 4 Project (Holm, 2022). At the time, the clearing permit application area near the solar farm was mapped as containing 7.6 ha of breeding habitat and 0.9 ha of foraging habitat. This was based on broad scale mapping of land units. However, this mapping in this area was not verified by ground truthing surveys.

Further habitat assessment of Malleefowl habitat in this location was conducted in November 2023 to support the development of the CDO solar farm (Appendix D). Malleefowl were assessed as actively utilising the area, however no mounds were identified. Evidence of a failed mound attempt was recorded. Holm (2023b) determined that the habitat is unlikely to be considered breeding habitat critical for survival of the species due to shallow basement geology and the presence of intractable soils, thus the area was redefined as foraging habitat (Holm, 2023c).

Overall, the clearing permit application area contains a total of 30.8 ha of Malleefowl habitat, comprising 22.2 ha of Malleefowl breeding habitat and 8.6 ha of Malleefowl foraging habitat. No nesting mounds have been recorded in the clearing permit application area, as these were actively avoided during project design.

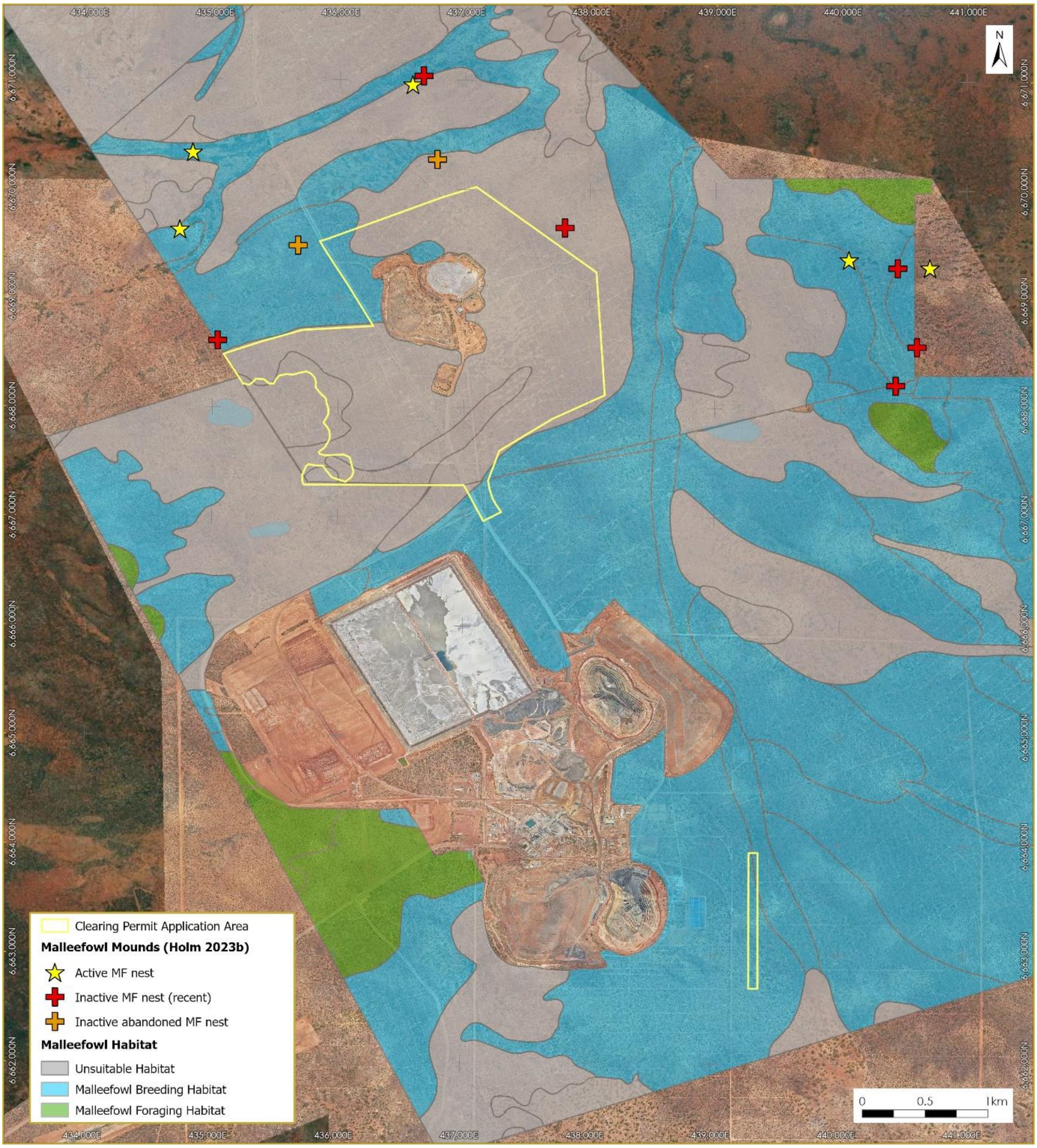


Figure 6-2 Malleefowl Habitat in the Clearing Permit Area

7 SOILS AND LANDFORMS

The clearing permit application area lies within the Kambalda soil landscape zone, within the Kalgoorlie Province of the Western Region (Tille , 2006). This zone is characterised as having flat to undulating plains (with hills, ranges and some salt lakes and stony plains) on greenstone and granitic rocks of the Yilgarn Craton.

Two soil landscape systems have been mapped within the clearing permit application area:

- Deadman system - Calcareous plains supporting acacia, black oak and mallee shrublands/woodlands adjacent to salt lake systems.
- Moriarty system – Low greenstone rises and stony plains supporting chenopod shrublands with patchy eucalypt overstoreys.

A soil and landform assessment was conducted for the area in 2023 (MBS Environmental 2024) (Appendix E). Two soil types were mapped in the Luvironza / Qena locality:

- Calcareous loamy earths (DAFWA Soil Group 542) - Typically consisted of a shallow red-brown loamy sand topsoil layer (<10 cm) which trended into a gravelly/sand/clay subsoil (to approximately 1 m) which in turn overlay indurated calcretes.
- Calcareous shallow loams (DAFWA Soil Group 521) - In some areas the calcareous soils were classified as calcareous shallow loams due to having a much shallower profile (<0.5 m), and lower clay content than the Calcareous loamy earths.

Laboratory analysis demonstrated that soils from the Qena locality are characterised by sandy clay loams on a textural basis due to the presence of >20% clay (by mass).

All but one sample had Emerson Class ratings of either 3 or 4, indicating that the spontaneous dispersion of clay materials is unlikely.

8 WATER

8.1 Surface Water

Surface water drainage at Luvironza / Qena is principally towards Lake Rebecca which is located about 10 km to the east. Runoff occurs as sheet flow in very shallow and broad drainage lines over deposits of gravel, sand and silt.

8.2 Groundwater

Groundwater levels in the Luvironza / Qena area are 13 to 18 metres below ground level (Pennington Scott, 2024).

Groundwater recharge is very low due to a high average annual potential evaporation of 2,665 mm and an average rainfall of about 250 mm (average of Kalgoorlie airport and Laverton) (Pennington Scott, 2024). Recharge, when it occurs, follows prolonged winter wet periods and very rare flood events following ex-tropical cyclone depressions.

Net groundwater recharge rates are exceedingly low, with any water recharging the groundwater system lost to evaporation from Lake Rebecca. Annual average groundwater recharge is likely to be in the order of 0.3 to 0.5 mm (equivalent to between 0.1% and 0.2% of annual rainfall) (Pennington Scott, 2024).

There are no public drinking water source areas within the clearing permit area or surrounds. However, the clearing permit area lies within the Goldfields groundwater management area.

Beneficial uses of groundwater are limited due to the high salinity, which has been recorded at 50,000 to 250,000 mg/L TDS.

9 ASSESSMENT AGAINST THE TEN CLEARING PRINCIPLES

An assessment of the proposed clearing permit area has been conducted to inform the clearing permit application. The clearing assessment was informed by environmental surveys conducted in 2023 and 2019.

The native vegetation clearing assessment included an assessment against the native vegetation clearing principles (EP Act 1986, Schedule 5). The assessment identified that native vegetation clearing may to be at variance with Clearing Principle B and Principle F.

(a) Native vegetation should not be cleared if it comprises a high level of biological diversity.

Comments	Outcome
Assessment	The clearing permit application area is located within the Eastern Murchison (MUR1) subregion of the Murchison Interim Biogeographic Regionalisation of Australia (IBRA) bioregion. The Eastern Murchison subregion was described by CALM (2002) as vegetation dominated by Mulga woodlands often rich in ephemerals; hummock grasslands, saltbush shrublands and *Tecticornia* shrublands. Seven vegetation communities were recorded in the clearing permit application area: • FHSX: Felsic hill mixed shrubland • BRXS: Breakaway mixed shrubland • PACS: Plain acacia casuarina shrubland • PAES: Plain acacia eucalypt shrubland • CCAS: Calcareous casuarina acacia shrubland or woodland • PXHS: Plain mixed halophyte low shrublands • DRAS: Drainage tract acacia shrubland Vegetation within the clearing permit application area was mapped as Degraded to Excellent condition (Holm, 2023a). Approximately 128 ha of the 525 ha clearing permit application area was previously cleared. No TECs, PECs or otherwise significant vegetation occur within in the clearing permit area. Two populations *Eremophila arachnoides* subsp. *tenera* (Priority 3 flora species) have been identified in the broader area. These areas have been excised from the clearing permit application area, however scattered individuals occur in the clearing permit application area on the margins of these populations. Vegetation proposed for clearing is typical of the region and not representative of an area of high biodiversity, the proposed clearing is therefore **not likely to be at variance** with this principle. Potential impacts to Priority flora species will continue to be managed in accordance Northern Star procedures, which includes no clearing within 10 m of Priority flora unless approved by the CEO.
Methods	Threatened and Priority Flora (DBCA-036) Holm 2023a

(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.

Comments	Outcome
Assessment	The clearing permit application area includes a total of 30.8 ha of Malleefowl habitat, comprising 22.2 ha of Malleefowl breeding habitat and 8.6 ha of Malleefowl foraging habitat. Holm (2023b) recorded no Malleefowl activity in the clearing permit application area at Qena, no tracks or nesting mounds. Malleefowl tracks were recorded near the solar farm and evidence of failed attempt to construct a mound was recorded (Holm 2023c). There is approximately 4,270 ha and 18,000 ha of Malleefowl habitat available at a local and regional level, respectively (Holm, 2023b). The proposed clearing would therefore reduce the availability of Malleefowl habitat by up to 0.7% and 0.17% at a local and regional scale, respectively. However, this is a conservative estimate and clearing of Malleefowl habitat is expected to be less. The proposed clearing will not significantly impact Malleefowl on the basis that: • The proposed clearing will not disrupt the breeding cycle of Malleefowl in the region. No active Malleefowl nesting mounds will be cleared. • The proposed clearing will not result in a significant reduction in the availability of habitat. The proposed clearing is predicted to reduce Malleefowl habitat available by up to 0.7% and 0.17% at a local and regional scale, respectively. • The proposed clearing will not significantly reduce the area of occupancy by Malleefowl. Malleefowl in the region occur as a sparse population over an extensive area and have been demonstrated to persist in the area despite ongoing mining activity. • The Goldfields region is relatively uncleared and characterised by relatively contiguous habitat. The proposed clearing will not result in fragmentation of Malleefowl habitat and movement of Malleefowl will not be obstructed. The proposal requires clearing of Malleefowl habitat and therefore **may to be at variance** with this principle. Potential impacts to Malleefowl can continue to be managed through Northern Star procedures, which requires pre-clearing Malleefowl surveys during breeding season and avoidance of active Malleefowl mounds, unless otherwise approved by the CEO.
Methods	Threatened and Priority Fauna (DBCA-037) Holm (2023a, 2023b and 2023c)

(c) Native vegetation should not be cleared if it includes, or is necessary for the continued existence of, rare flora.

Comments	Outcome
Assessment	No Threatened flora were recorded in the clearing permit application area during vegetation and flora surveys and therefore the proposed clearing is **not at variance** with this principle.
Methods	Threatened and Priority Flora (DBCA-036) Holm (2019) Holm (2023a)

(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.

Comments	Outcome
Assessment	No TECs listed under State or Federal legislation were recorded in the clearing permit application area during vegetation and flora surveys and therefore the proposed clearing is **not at variance** with this principle.
Methods	Threatened Ecological Communities (DBCA-038) Holm (2019) Holm (2023a)

(e) Native vegetation should not be cleared if it is significant as a remnant of native vegetation in an area that has been extensively cleared.

Comments	Outcome
Assessment	One Pre-European vegetation association has been mapped within the clearing permit area expansion area: Vegetation association 20 - Low woodland; mulga mixed with *Allocasuarina cristata* and *Eucalyptus* sp. The local and regional representation of these vegetation associations is summarised in the table below.

Vegetation association	Scale	Pre-European Extent (ha)	Current Extent	% Remaining	% Remaining in DBCA Reserve
20	**Statewide**	1,295,103.38	1,292,474.58	99.80	19.38
	IBRA Bioregion Murchison	1,174,259.16	1,171,630.80	99.78	15.49
	IBRA Sub-region Eastern Murchison	1,174,259.17	1,171,630.81	99.78	15.49
	Local Government Authority Shire of Menzies	561,828.47	561,279.68	99.90	33.63

	National objectives and targets for biodiversity conservation in Australia have a target to prevent clearance of ecological communities with an extent 30% of that present pre-1750, below which species loss appears to accelerate exponentially at ecosystem level (Environment Australia, 2001; EPA, 2000 and 2008). The proposed clearing will not reduce the extent of Vegetation Association 20 below this threshold. The proposed clearing is unlikely to impact on the conservation status for Beard Vegetation Association 20 within the Murchison bioregion, and vegetation in the region is relatively intact and contiguous. The proposed clearing with therefore not affect a significant remnant of vegetation in an area that has been extensively cleared. The proposed clearing is therefore **not at variance** with this principle.
Methods	Pre-European Vegetation (DPIRD-006) Statewide Vegetation Statistics (Government of Western Australia, 2019) Holm (2023a)

(f) Native vegetation should not be cleared if it is growing in, or in association with, an environment associated with a watercourse or wetland.

Comments	Outcome
Assessment	No permanent wetlands or watercourses occur within the proposed clearing permit application area. However, this area is intersected by ephemeral sheet flows and diffuse drainage lines that drain to the north-east towards Lake Rebecca (Pennington Scott, 2024). The drainage lines support sparse to mid-dense acacia shrublands which are not considered typical riparian vegetation (Holm, 2023a). However, the proposed clearing **may be at variance** with this principle since it is includes an environment associated with a watercourse. Vegetation associated with watercourses will continue to be managed in accordance with Northern Star commitments, which requires surface water flow to be maintained and clearing of riparian vegetation to be minimised.
Methods	Hydrography, linear (DWER-031) Holm (2023a) Pennington Scott (2024)

(g) Native vegetation should not be cleared if the clearing of the vegetation is likely to cause appreciable land degradation.

Comments	Outcome
Assessment	Mining and sheep grazing has occurred both historically and recently across the clearing permit application area. The clearing area consists of mostly degraded to very good vegetation. Soils within the clearing permit application area are characterised by the Deadman and Moriarty land systems; the Deadman land system is generally not susceptible to soil erosion, the Moriarty land system is moderately prone to water erosion, particularly when soil surface are disturbed (Pringle et al., 1994) A soil landform assessment conducted for the Qena project determined soils typically have an Emerson Class rating of either 3 or 4, indicating spontaneous dispersion of clay materials is unlikely. The proposed clearing is therefore **not likely to be at variance** with this principle.
Methods	Soil Landscape Mapping – Best Available (DPIRD-027) MBS Environmental (2024)

(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.

Comments	Outcome
Assessment	The closest conservation area is Goongarrie National Park, about 60 km west of the clearing permit area. Given the distance of the application area from Goongarrie National Park, the proposed clearing is not likely to provide a significant ecological linkage or fauna movement corridor and is not likely to impact the environmental values of the conservation area. The proposed clearing is therefore **not at variance** with this principle.
Methods	DBCA Legislated Lands and Waters (DBCA-011) Holm (2023a)

(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.

Comments	Outcome
Assessment	The clearing permit application area is not located within a Public Drinking Water Source Area. The application area is located within the proclaimed Goldfields groundwater area under the *Rights in Water and Irrigation Act 1914*. Accordingly, all water abstraction is conducted in accordance with approved groundwater licences. The proposed clearing is unlikely to cause deterioration of surface water or groundwater quality on the basis that:

	• There are no permanent surface water features in the clearing permit application area or surrounds. • Ephemeral drainage tracts intersect the application area. These drainage tracts are dry for most of the year and only flow for short durations during extreme rainfall events, where turbid water from intense rainfall events will flow to Lake Rebecca 10 km downstream from the application area. • There are limited beneficial uses for groundwater due the hypersaline quality of the aquifer, which has been recorded with TDS concentrations from 50,000 to 250,000 mg/L. The proposed clearing is therefore **not likely to be at variance** with this principle.
Methods	PDWSAs (DWER-033) RIWI Groundwater Areas (DWER-034) Pennington Scott 2024

(j) Native vegetation should not be cleared if clearing the vegetation is likely to cause, or exacerbate, the incidence or intensity of flooding.

Comments	Outcome
Assessment	There are no permanent water courses or waterbodies within the clearing permit application area. Ephemeral drainage lines are common in the region and temporary localised flooding can occur during extreme rainfall events. The clearing is unlikely to result in a significant change to runoff since the vegetation present is sparse and there is little to no groundwater infiltration. Given the diffuse nature of surface water drainage, no significant changes to surface water drainage patterns would occur as a result of the clearing. The proposed clearing is unlikely to increase the incidence or intensity of natural flooding events and is therefore **not likely to be at variance** with this principle. Surface water flows will continue to be maintained in accordance with Northern Star procedures.
Methods	Hydrography, linear (DWER-031) Pennington Scott, 2024

10 REFERENCES

DER (2014) A guide to the assessment of applications to clear native vegetation: Under Part V Division of the Environmental Protection Act 1986. Government of Western Australia, Department of Environment Regulation.

CALM. 2002. A Biodiversity Audit of Western Australia's 53 Biogeographical Subregions. Murchison 1 (MUR1 – East Murchison subregion) Department of Conservation and Land Management, Western Australia

Department of Parks and Wildlife (2016b). Malleefowl (Leipoa ocellata) records in the Great Victoria Desert Western Australia. Report to the Great Victoria Desert Biodiversity Trust.: pp 59.

Environmental Australia (2001) National Objectives and Targets for Biodiversity Conservation 2001–2005 Environment Australia, Canberra.

EPA (2000). Environmental Protection of Native Vegetation in Western Australia: Clearing Native Vegetation with particular reference to the Agricultural Area. Position Statement No. 2. Environmental Protection Authority, Perth.

EPA (2008) Environmental Guidance for Planning and Development. Guidance Statement No. 33. Environmental Protection Authority, Perth.

Government of Western Australia. (2019). 2018 Statewide Vegetation Statistics incorporating the CAR Reserve Analysis (Full Report). Accessed on 19 March 2024. WA Department of Biodiversity, Conservation and Attractions, Perth, https://catalogue.data.wa.gov.au/dataset/dbca-statewide-vegetation-statistics

Holm (2019) Environmental Assessment: Proposed Seismic Survey Area. Unpublished report prepared for Saracen Gold Mines. Alexander Holm & Associates, Natural Resources Management Services.

Holm (2022) Assessment of Impacts on Malleefowl of Proposed Expansion of Carosue Dam Tailings Storage Facility. Prepared for Northern Star Resources Ltd.

Holm (2023a) Vegetation, Flora and Fauna Survey: M31/219, M31/210, M31/220 and M31/285. Unpublished report prepared for Northern Star Resources Ltd. Alexander Holm & Associates, Natural Resources Management Services.

Holm (2023b) Targeted Malleefowl Survey: M31/219, M31/210, M31/220 and M31/285. Unpublished report prepared for Northern Star Resources Ltd. Alexander Holm & Associates, Natural Resources Management Services.

Holm (2023c)Malleefowl Activity and Habitat Assessment within Proposed Expansion of Carosue Dam Solar Farm. Unpublished report prepared for Northern Star Resources Ltd. Alexander Holm & Associates, Natural Resources Management Services.

MBS Environmental (2024) Carosue Dam Operations Qena Project Soil and Landform Assessment. Unpublished report prepared for Northern Star Resources Ltd.

Pennington Scott (2024) Qena Project – Carosue Dam Operation: Water Investigations. Unpublished Report prepared for Northern Star Resources Ltd.

Pringle, H.J.R., Van Vreeswyk, A.M.E. & Gilligan, S.A. (1994) An Inventory and Condition Survey of Rangelands in the North-eastern Goldfields, Western Australia. Department of Agriculture. Technical Bulletin 87. pp 323

Shepherd, D.P. (2007). Adapted from: Shepherd, D.P., Beeston, G.R., and Hopkins, A.J.M. (2001), Native Vegetation in Western Australia. Technical Report 249. Department of Agriculture Western Australia, South Perth. Includes subsequent updates for 2006 from Vegetation Extent dataset ANZWA1050000124

Tille, P., J (2006). Soil-landscapes of Western Australia's rangeland and arid interior. Department of Primary Industries and Reginal Development, Western Australia.

APPENDICES

Appendix A: Qena Vegetation, Flora and Fauna Survey

Vegetation, Flora and Fauna Survey:

M31/219, M31/210, M31/220 and M31/285

Northern Star Resources Ltd

Alexander Holm & Associates
Natural Resource Management Services

December 2023

1

[1] Front page: stunted *Eucalyptus griffithsii* near Lake Rebecca

Contents

Tables

Figures

Attachments

Summary

Northern Star Resources Ltd operates the Carosue Gold Mine approximately 115km northeast of Kalgoorlie and is proposing further mining in the vicinity of the Luvironza pit. Alexander Holm & Associates were contracted to conduct a vegetation, flora and fauna survey of a 2200ha area (survey area) on tenements M31/219, M31/210, M32/220 and M31/285 to inform planning of future mining operations. Scope of the survey comprised:

- A reconnaissance vegetation and flora survey.
- A basic fauna survey.

There are no Threatened Ecological Communities (TECs) or Priority Ecological Communities (PECs) within the survey area, and no conservation areas are nearby.

Eleven land units, as discrete assemblages of vegetation, soil and landform, and considered analogous to fauna habitat types, were mapped within the survey area. Eight vegetation communities are described and mapped. Flora composition and vegetation communities recorded are typical of the region and not considered unusually diverse.

None of the survey area supports pristine vegetation and only 2% supports unaltered vegetation structure. Vegetation over the remainder of the survey area has been impacted by disturbance, primarily historic livestock grazing, with nearly 50% significantly to severely impacted.

No threatened flora taxa were found during the survey.

Two populations of *Eremophila arachnoides* subsp. *tenera* (EAT), a Priority 3 flora species listed by DBCA, and known from previous surveys, occur within the survey area:

- A population of 2500 plants over an approximately 125ha. Located in the southwest of the survey area in tenements M31/219 and M31/220 and extending outside the survey area into M31/295.
- A population of 680 plants over approximately 9ha. Located in the southeast of the survey area in tenements M31/285 and M31/220.

These populations occur almost exclusively on land unit 5a: Alluvial plains supporting chenopod shrublands.

While no new populations of EAT were found, several singleton outliers to these populations were found. No other priority listed species were found.

No weeds listed as Weeds of National Significance or Declared Pests under the *Biosecurity and Agriculture Management Act 2007* (BAM Act) were recorded in the survey area.

The only Threatened fauna species recorded during the survey was Malleefowl (*Leiopoa ocellata*), which is listed as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and *Biodiversity Conservation Act 2016* (BC Act).

1 Scope of works

Alexander Holm & Associates were contracted by Northern Star Resources Ltd (Northern Star) to conduct the following survey in the Carosue Dam area. Bamford Consulting Ecologists (BCE), were sub-contracted by Alexander Holm & Associates to undertake and report on the fauna component of the assessment.

Northern Star operates the Carosue Gold Mine and is proposing further mining in the vicinity of the existing Luvironza open pit gold mine. The survey area on mining tenements M31/219, M31/210, M31/220 and M31/285 covers an area of 2200ha (Figure 1).

The survey scope included:

- A desktop review of available information on likelihood of a) presence of threatened (rare) or priority plant species and b) threatened plant communities in the general search area.
- A reconnaissance flora and vegetation survey.
- A basic fauna survey.
- An assessment of soil type, landscape stability and condition.
- A description of land units (habitat) and relate information on fauna, flora, vegetation communities, soil type and landscape stability to these units.
- Locations (if any) of priority and threatened flora/fauna.
- Map outputs provided in geo-referenced digital files and IBSA data sets.
- An integrated report covering flora, vegetation and fauna within a local and regional context.

The scope of works is to comply with Western Australian Environmental Protection Authority (EPA) objectives for protection of the environment specifically to “ensure that flora and vegetation surveys provide sufficient information to address both biodiversity conservation and ecological function values within the context of the type of proposal being considered” and to “enable an assessment of impacts on the conservation values and status of the site in a regional and local context” (Environmental Protection Authority, 2004).

Specifically the vegetation and flora survey was conducted in accordance with methods for reconnaissance surveys in EPA’s “Technical Guidance: Flora and Vegetation Surveys for Environmental Impact Assessment Environmental Protection Authority (2016)

The basic fauna survey was conducted in accordance with methods detailed in EPA’s Technical Guidance: Terrestrial vertebrate fauna surveys for environmental impact assessment (Environmental Protection Authority 2020).

A Targeted Malleefowl Survey has been conducted and provided as a separate report.

2 Regional overview

2.1 Regional setting

Carosue Dam Operations is located approximately 115 km northeast of Kalgoorlie Boulder, and southeast of Lake Rebecca (Figure 1). It is within the north-eastern Goldfields region and Kalgoorlie-Boulder local government area. It is located in the southeast of Eastern Murchison (MUR 1) bio-geographic subregion (Cowan 2001; Desmond et al. 2003).

The most extensive land use in the region is pastoralism and over 80% of this region is pastoral leasehold. Most of the remainder is unallocated crown land and less than 1% is set aside for nature conservation.

Figure 1: Survey area (crosshatched) in relation to Lake Rebecca and associated mining tenements.

2.2 Climate

Rainfall in the region is unreliable and inconsistent. Winter rainfall consists of light showers from April to October. Significant summer rainfall events originating from the north-west as tropical cyclones are most likely between January and March. The highest recorded daily rainfall at Kalgoorlie is 177.8 mm (in February) and 92.6 mm (in January) at Laverton. For Kalgoorlie, one in one hundred years rainfall events of 1 hour and 72 hours are estimated to result in 43 and 173 mm of rain respectively. (Data from www.bom.gov.au).

The average potential pan evaporation rate at Carosue Dam is approximately 2800 mm per annum[2].

Winds are mostly light easterlies.

2.3 Topography and drainage

Landform patterns in the general area comprise extensive sand plain, sub-parallel greenstone belts and breakaways with often extensive lower pediments which give way to level to very gently inclined sheet flood plains. Relief is subdued. There are no major river systems. South-east trending, broad, saline, palaeo-drainage systems traverse the region and are defining features of the Yilgarn block of south-western Australia (Gentilli, 1979). These drainage systems have very low gradients and contain playa lakes including Lake Rebecca, Carey and Raeside. Lakes form local depo-centres with poorly developed radial drainage systems. During occasional intense rainfall events lakes may fill, and in very rare events some may overflow, link-up and discharge to the Nullarbor Plain through Ponton Creek (Pringle, Van Vreeswyk & Gilligan, 1994).

2.4 Hydrogeology

Groundwater occurs throughout the region within sparse fractures in basement rocks, within the weathering profile, and in alluvial sediments. Regional water table elevations vary from around 350 m above sea level around Lake Raeside to 400 – 450 m above sea level around Lake Carey and are generally 30 to 100 m below surface. Groundwater recharge occurs from major, but infrequent, rainfall events, mainly on drainage divides, and locally at site specific intake areas such as drainage lines or sandplains and dune fields. Groundwater is in hydraulic continuity and flows from drainage divides towards palaeo-drainages and then south-easterly toward the Nullarbor Plain. Groundwater beneath catchment divides occurs as lenses of less than 5000 mg/l TDS which are superimposed on a regional field of saline groundwater with linear bodies of hypersaline groundwater along palaeo-drainages, and local brine pools associated with salt lakes.

2.5 Vegetation and soils

The region lies within the Eremaean botanical province, mainly in the Austin botanical district, with the eastern edge approaching the Helms botanical district (Beard, 1976). Lake Ballard/Lake Rebecca form a major vegetation divide with characteristic *Acacia aneura* (mulga) low woodlands associated with red loams over siliceous hardpan to the north and low woodlands of mixed mulga and *Casuarina obesa* (black oak) and *Eucalyptus* species on alkaline and calcareous soils to the south. Spinifex hummock grassland with eucalypt overstory on sand plain is common. Halophytic vegetation occurs throughout the region on palaeo-drainage systems, breakaways and on some

[2] http://www.bom.gov.au/cgi-bin/climate/cgi_bin_scripts/evaporation.cgi.

stony and alluvial plains. Highly saline soils support *Atriplex* (saltbush), *Maireana* (bluebush) and *Tecticornia* (samphire) shrublands, while less saline soils support eucalypt or mulga with saltbush or bluebush understoreys.

The survey area includes two of the most common vegetation associations in the region include Beard Vegetation Association 20 (Low woodland: mulga mixed with *Casuarina obesa* and *Eucalyptus* spp.), and 389 (Succulent steppe with open low woodland; mulga over saltbush) and 529 (Succulent steppe with open low woodland) one of the less common associations (Table 1).

Table 1: Vegetation associations (Beard, 1976) in survey area in comparison with South Laverton area (SLA), total area in WA and area within conservation reserves

Veg Assn	Description	Survey Area	SLA Area	Reserve priority	Western Australia		
					Area	Within reserve	
		ha	ha		ha	ha	%
20	Low woodland; mulga mixed with *Casuarina obesa* and *Eucalyptus* spp.	1746	789,200	L	1,304,500	217,300	16.7
389	Succulent steppe with open low woodland; mulga over salt bush	86	234,400	M	646,500	23,000	3.6
529	Succulent steppe with open low woodland; mulga and sheoak over salt bush	368	4,660	H	10,280	10	0.1

L*: Low; M: Medium; H: High priority for reservation

3 Desktop assessment

3.1 WA conservation listed species

The Species and Communities interim “NatureMap” search service provided records of all conservation listed flora and fauna within a 40 km radius of the study area (DCBA search reference number: 36-0923NM). The following flora and fauna were identified:

Thryptomene eremaea, a Priority 2 taxon is an erect open shrub, 0.5 to 1.5m high, producing pink or white flowers from July to September and grows on red or yellow sands on sandplains and shallow sandy soils over granite.

Eremophila arachnoides subsp. *tenera*, a Priority 3 taxon is an erect shrub, 0.5 to 2m high producing blue flowers growing on saline alluvial plains.

Hysterobaeckea ochropetala subsp. *cometes*, a Priority 3 taxon is a shrub with several stems to 2m with white flowers growing in red sand with mallees.

Leipoa ocellata (Malleefowl) is listed as Vulnerable.

3.2 EPBC Act protected matters

The Commonwealth Department of Climate Change, Energy, the Environment and Water’s protected matters search tool was used to identify all matters protected under the EPBC Act with potential to occur within a 50km radius of the survey area[3] (Attachment 2).

No flora of significance were identified.

Six bird, two mammal and one reptile, listed as threatened species, were identified as possible residents (Attachment 2).

3.3 Flora and fauna surveys

The following surveys from the general area were reviewed for records of declared flora and fauna and to assess likelihood of occurrence in the survey area:

Environmental assessment: Old Plough Dam– Saracen Gold Mines. Alexander & Associates 2012

No currently listed Threatened or Priority Flora were recorded.

Environmental assessment: proposed Wallbrook mine sites and surrounds. Saracen Gold Mines. Alexander Holm & Associates 2009.

No Threatened or Priority Flora were recorded.

Level 1 Flora and vegetation survey of tenements associated with development of Million Dollar Mine and associated infrastructure. Botanica Consulting 2010.

No Threatened or Priority Flora were recorded.

Environmental assessment: Safari to Lake Raeside. Saracen Gold Mines. Alexander Holm & Associates 2019.

Two small populations of *Tecticornia mellarium* were located on Lake Raeside margins. May occur in similar habitat near Lake Rebecca.

[3] Protected Matters Search Tool - DCCEEW

Melaleuca apostiba was collected from one site associated with a drainage depression. May occur in similar habitat near Lake Rebecca.

Environmental assessment: Proposed seismic survey area. Saracen Gold Mines. Alexander Holm & Associates 2019.

Three populations consisting of over 2500 plants of *Eremophila arachnoides* subsp. *tenera* were located.

Malleefowl were active in the survey area and there were three sightings of birds during this survey.

Environmental assessment: Relief hill survey area. Saracen Gold Mines. Alexander Holm & Associates 2020.

Several populations each with scores of individuals of *Thryptomene eremaea* were found mostly confined to upland basalt surfaces. May occur on small basalt hills in the Southeast of the survey area.

Malleefowl were active in the survey area. Two fresh mounds were found during limited survey suggesting that there are likely to be many more in the survey area.

Environmental assessment: proposed expansion of Carosue Dam Tailings Storage Facility. Northern Star Resources Ltd. Alexander Holm & Associates 2021.

Eremophila arachnoides subsp. *tenera* is prevalent on saline alluvial plains.

While malleefowl had been active in the survey area, there was little evidence of current activity.

3.4 Threatened and priority ecological communities

The likelihood of presence of threatened ecological communities within the general survey area was assessed was assessed using the protected matters search tool (Attachment 2).

Other threatened ecosystems in the southeast of Eastern Murchison (MUR 1) bio-geographic subregion, identified during “A Biodiversity Audit of Western Australia’s 53 Biogeographical Subregions in 2002”, are listed in Cowan (2001).

Priority ecological communities in the area were assessed from Department of Parks and Wildlife listing (Version 34, December 21, 2022).

3.5 Land systems land units and vegetation communities

Land systems and land units were derived from a land resource survey of northeastern Goldfields (Pringle, Van Vreeswyk & Gilligan, 1994).

Vegetation communities were established firstly with reference to those listed in Pringle et al. (1994) where they are listed as ‘site types’, secondly with reference to those listed in adjacent surveys of Sandstone, Yalgoo Paynes Find (Payne et al., 1998) and Kambalda north (Payne, Mitchell & Hennig, 1998) and thirdly, where no comparable community could be found, a new classification was proposed.

Tentative land units were identified by examination of high-resolution aerial photography. Boundaries were checked in the field, transferred to geo-referenced ortho-photo maps and captured digitally. Vegetation communities were visually associated with each land unit.

4 Assessment methodology

4.1 Assessment personnel

The work was managed and conducted by Dr Alexander Holm (Alexander Holm & Associates). Dr Holm is an ecologist with over 35 years experience in arid environments and Goldfield regions and an accredited environmental consultant with the Environmental Consultants Association of Western Australia.

Mr Geoffrey Eliot was soil and landscape technician for the Western Australian Department of Agriculture's rangeland surveys and has over 20 years experience in Western Australian arid regions.

Field work for the vegetation and flora surveys was conducted by Mr Eliot and Dr Holm.

Mr Andrew Mitchell was assisting botanist to Western Australian Department of Agriculture's rangeland surveys, senior author of "Arid Shrubland Plants of Western Australia" (Mitchell and Wilcox 1994) and recently retired botanist with AQIS (Australian Quarantine and Inspection Service). Mr Mitchell provided off-site assistance in expert identification of flora specimens collected in the field and preliminary land unit mapping.

Dr Mike Bamford is a wildlife biologist, scientific illustrator and science communicator and with his wife Mandy, he has operated Bamford Consulting Ecologists since the mid 1980s. The business specialises in fauna investigations for Environmental Impact Assessment and to meet conditions of approval, such as monitoring of impacts and monitoring of rehabilitation. Some work is also done on environmental education and interpretation. Mike has extensive experience in the south-west of Western Australia, Western Australia's Goldfields, Pilbara, Kimberley, the Western Deserts, the Northern Territory, Christmas Island and far north Queensland.

Mr Peter Smith has 30 years of experience for environmental surveys, including Malleefowl surveys and specialises in searches for rare trapdoor spiders.

Field work for the fauna survey was conducted by Peter Smith and Rifka McClure under direction of Dr Mike Bamford of Bamford Consulting Ecologists.

4.2 License

Alexander Holm holds a "Flora taking (Biological Assessment) License" FB62000365, issued by the Department of Biodiversity, Conservation and Attractions and valid until August 19, 2024.

4.3 Timing of survey and seasonal conditions

Vegetation and flora reconnaissance survey was from October 3 to 9, 2023.

Fauna basic survey was from October 23 -28, 2023.

Rainfall at Carosue Dam averages 242mm a year with more rain falling over summer. Rainfall for Carosue Dam was below average in 2021 (181mm) and 2022 (151mm) and only 125mm has fallen to date in 2023 (Figure 2). There have been few effective rainfalls over winter or spring since 2016 with rainfall in 2019 of 91mm being one of the lowest on record.

Vegetation throughout the survey area and surrounds is severely droughted with most re-colonising shrubs, mostly Senna and Eremophila species, now dead. At the time of survey there were a few annual herbs and grasses within favoured, water-run on, locations.

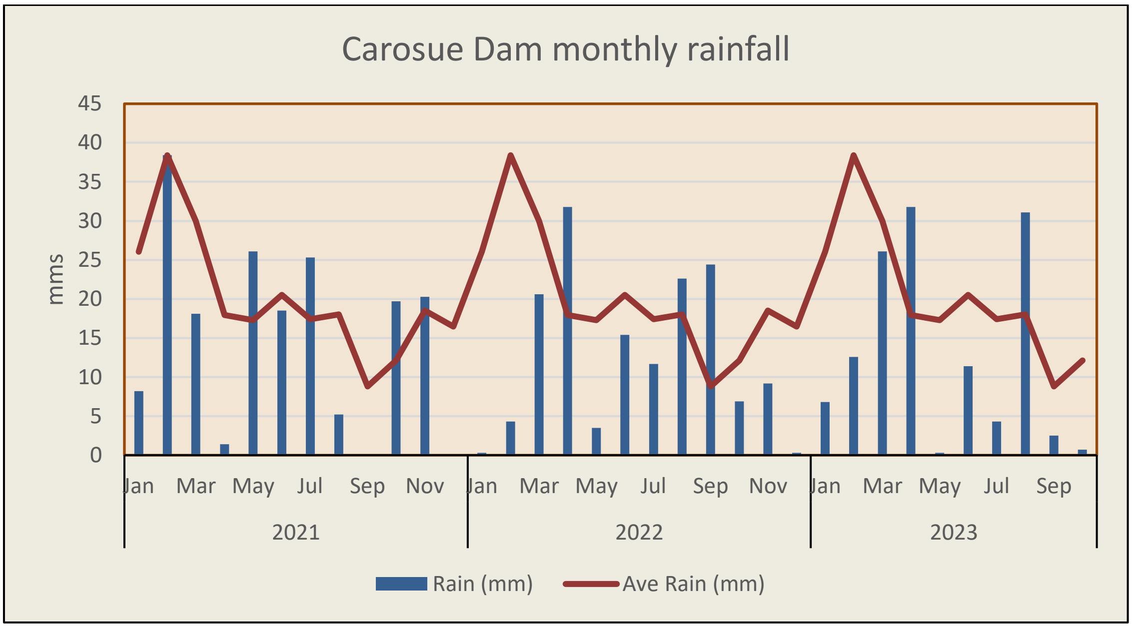


Figure 2: Monthly rainfall at Carosue dam.

4.4 Field survey

4 4.1 Reconnaissance vegetation and flora survey

The survey and reporting were conducted to comply with the EPA's "Technical Guidance – flora and vegetation surveys for environmental impact assessment" (Environmental Protection Authority 2016). A reconnaissance level survey was considered appropriate in the first instance in view of results of several vegetation and flora surveys in or adjacent to the study area (Figure 3).

	Environmental assessment: Old Plough Dam – Saracen Gold Mines. Alexander & Associates 2012
	Environmental assessment: Proposed seismic survey area. Saracen Gold Mines. Alexander Holm & Associates 2019.
	Environmental assessment: Relief hill survey area. Saracen Gold Mines. Alexander Holm & Associates 2020.

Figure 3: Proposed survey area (red) and locations of existing flora and vegetation surveys.

Sixty five inventory sites (relevés) were selected to 1) sample each land unit within the survey area, 2) provide systematic coverage of the survey area, and 3) to encompass variations in pattern within each land unit. Each inventory site was located by GPS and the following information recorded:

- Digital photographs.
- All flora species within approximately 50m of a central location and in the same land unit were inventoried and voucher specimens collected of all taxa which were also compiled within a reference field herbarium.
- Vegetation condition were visually estimated using rating scales of Environmental Protection Authority (2016) and soil erosion compared with standard rating scales used for rangeland surveys and described by Pringle *et al*. (2004).
- Vegetation community and land unit descriptions using terminology from Payne et al. (1998).

- Vegetation cover, landform, slope, relief, surface coarse fragment characteristics and surface water flow characteristics (Anon, 2009).
- Soil characteristics (texture, reaction to acid and fragment characteristics) of A horizon to maximum of 30cm (Anon, 2009).

Inventory data from sites from the three complementary surveys to the south and north (Figure 3) were included in the analysis to augment data from this survey for land units where inventory data was sparse or absent.

Locations of inventory sites and walking traverses (>50km) are shown in Figure 4.

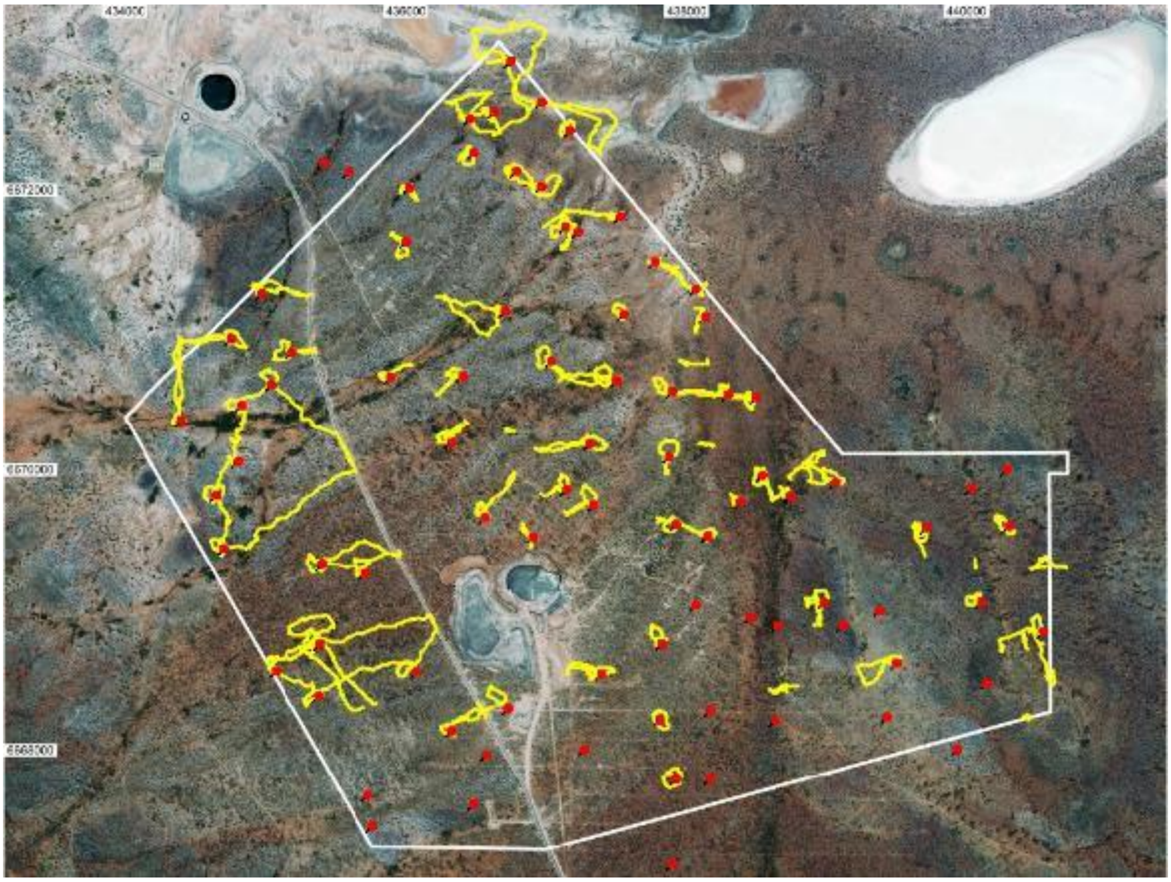


Figure 4: Location of inventory sites (red) and walking traverses (yellow) during flora survey.

4 4.2 Priority flora

Four priority listed flora taxa have either known to occur within the survey area or have been found in nearby surveys (Section 3.3):

- *Eremophila arachnoides* subsp. *tenera* (EAT) (Priority 3)
- *Thryptomene eremaea* (Priority 2)
- *Melaleuca apostiba* (Priority 3)

Two other flora taxa are known to occur in the general area:

- *Hysterobaeckea ochropetala* subsp. *cometes* (HOC) (Priority 3)
- *Tecticornia mellarium* (Priority 1)

EAT occurs within the survey area in two separate populations of several hundred plants. Extensions of these populations was assessed by foot traverse within similar habitat and opportunistically elsewhere.

Habitat suitable for *M. apositiba*, HOC and *T. mellarium* near was searched by foot traverse along Lake Rebecca margins both within the survey area and extending up to 300m beyond the survey area (Figure 4).

Small basalt hills in the southeast of the survey area were checked for presence of *T. eremaea.*

4 4.3 Basic fauna survey

The site visit involved looking around as much of the project area as possible in daylight; as shown in Figure 5. In general, walks were unstructured and two personnel travelled 20-40m apart, with the track determined by areas of interest, requirement to traverse all land units and with intention to cover as much ground as possible.

Opportunistic observations of evidence of Malleefowl activity (tracks, scats and mounds) were recorded during the field survey. A Targeted Malleefowl Survey including more detailed searches and analysis of Malleefowl habitat was conducted as a separate scope of works and is reported separately.

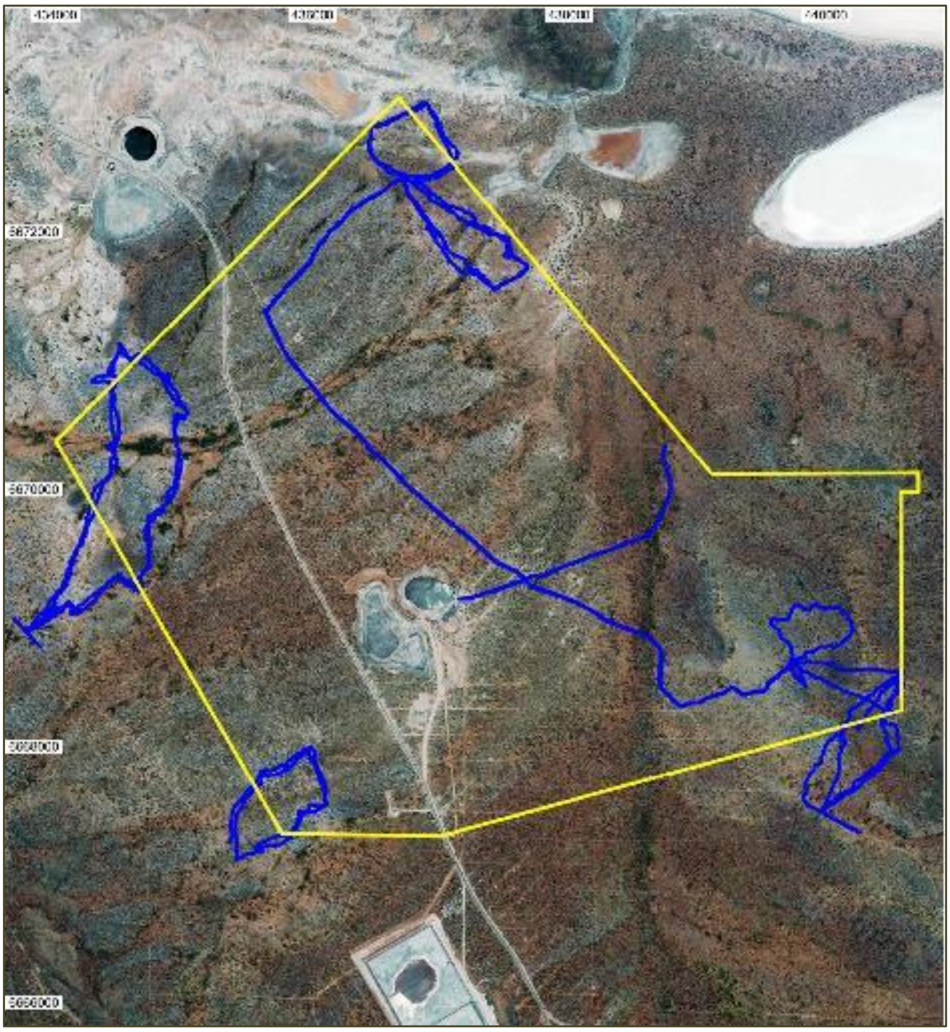


Figure 5: Vehicle and walking traverses during fauna survey.

5 Results

5.1 Vegetation associations

Beard Vegetation Association 20 (Low woodland: mulga mixed with Casuarina and Eucalyptus spp.) is the most common vegetation association in the survey area occupying 65%. Vegetation Association 529 (Succulent steppe with open low woodland; mulga and sheoak over salt bush) occupies 17% and the remaining 1% is Vegetation Association 389 (Succulent steppe with open low woodland; mulga over salt bush) (Beard 1976).

5.2 Land systems and landforms

Approximately 65% of the survey area is plains with eucalypt woodlands with halophytic undershrubs of Deadman land system; 14% consists of low greenstone hills and stony plains supporting chenopod shrublands of Moriarty land system; 16% consists of extensive gently undulating, calcareous saline stony plains supporting bluebush shrublands of Gundockerta land system and the remaining 5% by salt lake fringing land forms of Carnegie and low hills and plains of Leonora land systems (Table 2).

Table 2: Descriptions of land systems within the survey area (Pringle, Van Vreeswyk & Gilligan, 1994).

Land type	Land system	Description	Soil and land management
Low greenstone hills	Leonora (Leo)	Low greenstone hills and stony plains supporting mixed stony chenopod shrublands	Drainage tracts highly susceptible to erosion.
Erosional surfaces of low relief	Gundockerta (Gun)	Extensive gently undulating plains on weathered greenstone with stony mantles and lower alluvial tracts	Saline plains and adjacent alluvial tracts are susceptible to water erosion.
Depositional plains with calcareous red earths	Deadman (Dea)	Level to gently undulating plains with casuarina-acacia shrublands.	Generally not susceptible to soil erosion
	Moriarty (Mor)	Low greenstone hills and stony plains, supporting chenopod shrublands with patchy eucalypt overstoreys.	Slopes of low rises, alluvial plains and narrow drainage tracts are moderately susceptible to soil erosion.
Salt lakes and fringing plains	Carnegie (Cag)	Salt lakes with fringing alluvial plains with halophytic shrubs; and dunes of kopi and sand	Generally not susceptible to erosion except lake margins which are vulnerable to wind.

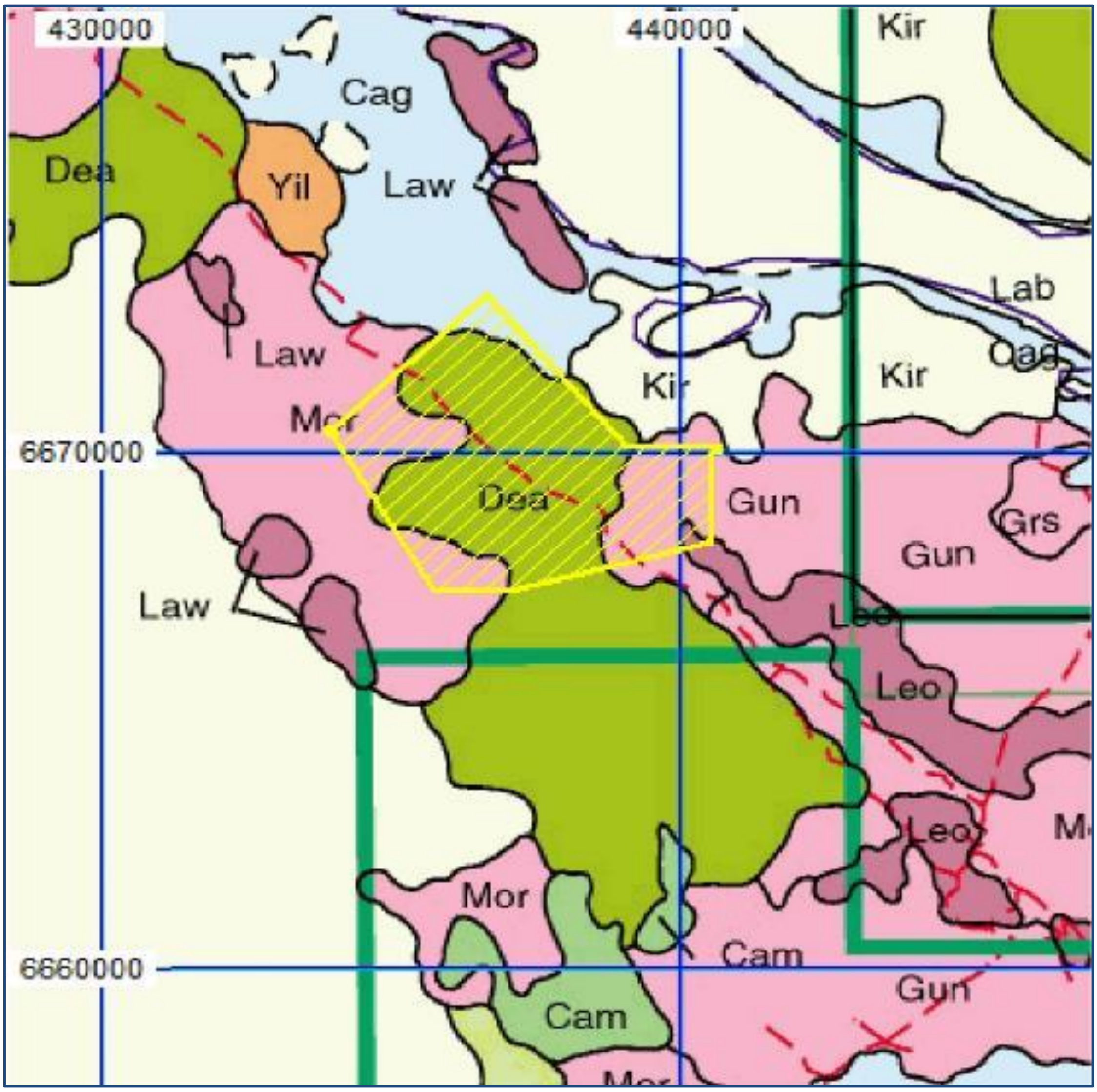


Figure 6: Land systems within the survey area (in yellow)

5.3 Land units soil types vegetation communities and habitat

5 5.1 Land unit descriptions and mapping

Thirteen land units and associated vegetation communities and soil types are described (Table 4). Land units, as discrete assemblages of vegetation, soil and landform, are considered analogous to fauna habitat.

A map of land units is overlain on an aerial photograph and presented in Attachment 1.

Table 3: Land unit descriptions, their soil type, vulnerability to erosion and associated vegetation communities.

Land unit	Land form and soil type	Vegetation community
1a. Lateritic hills		
	Lateritic hills with relief to 20m with slopes up to 8%, very abundant surface mantles of ironstone coarse and medium gravel and occasional quartz. Shallow sandy loams or sandy clay loams over calcrete or parent laterite. Run-off source zones, nil vulnerability to erosion.	Very sparse mixed shrubland dominated by *Acacia sibirica, A. tetragonophila* and *Scaevola spinescens (Eremophila forrestii* very common elsewhere*)* with very sparse overstorey of *Casuarina pauper* and occasional *Acacia incurvaneura.* "Stony ironstone acacia shrubland" (SIAS vegetation community)
1b. Basalt hills		
	Basalt hills with relief to 30m, slopes from 3-10%, abundant surface mantles of coarse gravel and cobbles of basalt and occasional quartz or calcrete. Sandy loams less than 30cm in depth often highly calcareous. Run-off source zones, nil vulnerability to erosion.	Very sparse acacia shrubland dominated by *Acacia burkittii, A. sibirica* and *Dodonaea lobulata* and *Senna artemisioides* subsp. *filifolia* with very sparse overstorey of *Casuarina pauper*. "Greenstone hill acacia shrubland" (GHAS vegetation community)

Land unit	Land form and soil type	Vegetation community
1c. Felsic hills and footslopes		
	Low hills to 12m with slopes of 5% and footslopes with slopes of 2%, Common to very abundant surface mantles of medium to coarse gravel and cobbles of felsic rocks and occasional quartz. Shallow, often calcareous, sandy clay loam over calcrete. Run-off source zones, nil vulnerability to erosion.	Very sparse mid-height shrubland dominated by *Acacia hemiteles Scaevola spinescens, Maireana sedifolia* and *Senna artemisioides* subsp. *filifolia* with very sparse overstorey of *Casuarina pauper*. “Felsic hill mixed shrubland” (FHXS vegetation community)
1d. Sandy rises		
	Sandy rises to 10m with gently inclined back slopes and bare wind-swept areas. Deep non-calcareous sands or loamy sands. Most rain water infiltrates. Slight vulnerability to erosion.	Sparse to very sparse acacia shrublands dominated by *Acacia incurvaneura A. ramulosa,* and *A. kalgoorliensis and Casuarina pauper* over a diverse shrubland including *Scaevola spinescens Eremophila miniata* and *Rhagodia drummondii*. “Sandplain acacia shrubland” (SACS vegetation community).

Land unit	Land form and soil type	Vegetation community
2a. Low lateritic rises		
	Gentle low rises with slopes to 3%, relief up to 6m, abundant surface mantles of fine and medium gravel of ironstone with occasional calcrete and quartz. Variable depth sandy clay loams often highly calcareous. Stable run-off source zones with diffuse overland flows. Nil to slight vulnerability to erosion.	Very sparse to sparse acacia shrubland dominated by *Acacia incurvaneura, A. ramulosa* and *A kempeana with isolated Casuarina pauper* over very sparse understorey including Scaevola spinescens, *Dodonaea lobulata,* and *Ptilotus obovatus.* "Stony ironstone acacia shrubland" (SIAS vegetation community).
2b. Low rises on basalt		
	Gently rounded hills, rises and gentle slopes many to abundant mantles of basalt, quartz and calcrete. Shallow calcareous sandy loams over calcrete. Run –off source zones to lower parts of the landscape occasionally via shallow incised drainage channels. Nil to slight vulnerability to erosion.	Very sparse to mixed height shrublands dominated by *Dodonaea lobulata*, *Senna artemisioides* subsp. *filifolia*, *Acacia burkittii, Ptilotus obovatus* or less frequently, *Maireana sedifolia* and *Atriplex nummularia* subsp*. spathulata* with isolated to very sparse overstorey of *Casuarina pauper* and occasionally *Acacia incurvaneura*. "Greenstone hill acacia shrubland" (GHAS vegetation community).

Land unit	Land form and soil type	Vegetation community
4a. Plains supporting acacia shrublands		
	Very gently inclined to near level plains (slopes <1.5%); mostly very sparse to sparse mantles of ironstone fine gravel, calcrete nodules and quartz fragments. Deep sandy loam to sandy clay loams mostly non-calcareous. Broad transfer zones with diffuse overland flows over mostly intact surfaces with occasional sheet and rill erosion. Nil to slight vulnerability to erosion.	Very sparse to sparse, sometimes patchy acacia shrublands dominated by *Acacia incurvaneura. A. burkittii* and *A. hemiteles,* and very sparse lower shrubs including *Dodonaea lobulata*, *Senna artemisioides* subsp. *filifolia*, and *Scaevola spinescens* with overstoreys of *Casuarina pauper* or *Eucalyptus oleosa* subsp. *oleosa.* Plain acacia casuarina shrubland (PACS vegetation community)
4c. Calcareous plains supporting chenopod shrublands		
	Gently inclined plains (slopes <1.5%); mostly very sparse to sparse mantles of calcrete nodules and quartz fragments in south tending to abundant quartz fragments northwards. Mostly deep gradational calcareous sandy clay loams over light clay. Broad transfer zones with diffuse overland flows over mostly intact surfaces. Nil to slightly vulnerable to erosion with very minor soil surface deflation.	Sparse, mostly degraded, *Maireana sedifolia* shrubland with colonizing shrubs including *Senna artemisioides* subsp. *filifolia*, *Eremophila scoparia, Acacia burkittii* and A.hemiteles with very sparse overstorey of *Acacia incurvaneura or Casuarina pauper.* Most *Senna* and *Eremophilia* re-colonizing shrubs have died during the ongoing drought. “Calcareous casuarina acacia shrubland” (CCAS vegetation community).

Land unit	Land form and soil type	Vegetation community
5a. Alluvial plains supporting chenopod shrublands.		
	Near level to gently inclined (slopes <1.5%) plains with mostly sparse surface mantles of quartz fragments and calcrete nodules. Deep sandy clay loams often gradational to light clay and calcareous especially at depth. Subject to occasional shallow sheet flow, occasionally more concentrated. Stripped soil surfaces common. Moderate vulnerability to erosion.	Very sparse to sparse halophytic shrublands dominated by *Maireana sedifolia or Atriplex vesicaria or Cratystylis subspinescens* or in poor condition dominated by *Senna artemisioides* subsp. *filifolia*, *Eremophila scorparia, E.arachnoides* subsp *tenera,* with very sparse overstorey of *Casuarina pauper* and/or *Acacia incurvaneura.* "Plain mixed halophyte shrubland" (PXHS vegetation community).
5b. Saline plains supporting halophytic shrublands		
	Gently inclined saline plains (slopes <1.5%) with very sparse to sparse mantles of quartz fragments. Mostly deep calcareous sandy clay loam gradational to light clay or sandy loam over light clay duplex soils. Subject to shallow sheet flow, occasionally more concentrated. Extensive deflated soil surfaces common. Moderate vulnerability to erosion.	Sparse chenopod shrublands dominated by *Maireana sedifolia* together with *Atriplex vesicaria* and *Frankenia spp.* or sparse halophytic shrublands dominated by either *Cratystylis subspinescens* or *Frankenia spp.* and in poor condition dominated by *Senna artemisioides* subsp. *filifolia* or *Eremophila scorparia, Acacia hemiteles* with very sparse *Casuarina pauper*. "Casuarina halophyte shrubland" (CAHS vegetation community).

Land unit	Land form and soil type	Vegetation community
6b. Drainage tracts		
	Gently sloping (1%) drainage tracts 50 – 200m wide with occasional minor channels, mostly without surface mantles. Deep non-calcareous sandy clay loam gradational to light clay. Subject to sheet flow and some more concentrated flow zones with deflated surfaces and shallow channels to 40cm deep. Slight to moderate vulnerability to water erosion.	Very sparse to mid-dense patchy acacia shrubland and occasional thickets dominated by *Acacia incurvaneura*. *A. aptaneura* and *A. burkittii* with isolated *Eucalyptus oleosa* subsp. *oleosa,* Santalum spicatum and *Casuarina pauper* over varied understories of *Maireana sedifolia, M. pyramidata, Senna artemisioides* ssp*. filifolia and Eremophila metallicorum* “Drainage tract acacia shrubland” (DRAS vegetation community)
7b. Saline drainage tracts and plains adjoining salt lakes		
	Drainage tracts and saline plains and birridas adjoining salt lakes. Deep non-calcareous duplex soils of sand or sandy loam over light clay within birridas. Shallow variable depth sandy loam over ferruginous hardpan in braided creek systems. Frequently with minor to moderate soil erosion with deflated areas and concentrated flow zones.	Birridas support sparse halophyte shrublands variously dominated by *Frankenia* spp, *Maireana atkinsiana, Cratystylis subspinescens* or *Tecticornia* spp. “Plain mixed halophyte shrubland” (PXHS vegetation community). Braided creeks systems are lined by *Eucalyptus griffithsii* and *Eremophila oppositifolia*.

5 5.2 Land unit areas

Chenopod shrublands, which are mostly degraded, occur on approximately 60% of the survey area on calcareous plains (land unit 4c) alluvial plains (land unit 5a) and saline plains (land units 5b and 7b). Plains supporting acacia shrublands (land unit 4a) occupy 17% of the survey area. Sand plains and sandy rises occupy 6% of the area. Low hills and rises on laterite, basalt or felsic rocks occupy 8% and broad drainage tracts 10%. The remaining 3% is mining disturbance (Table 4).

Table 4: Area of each land unit within the survey area

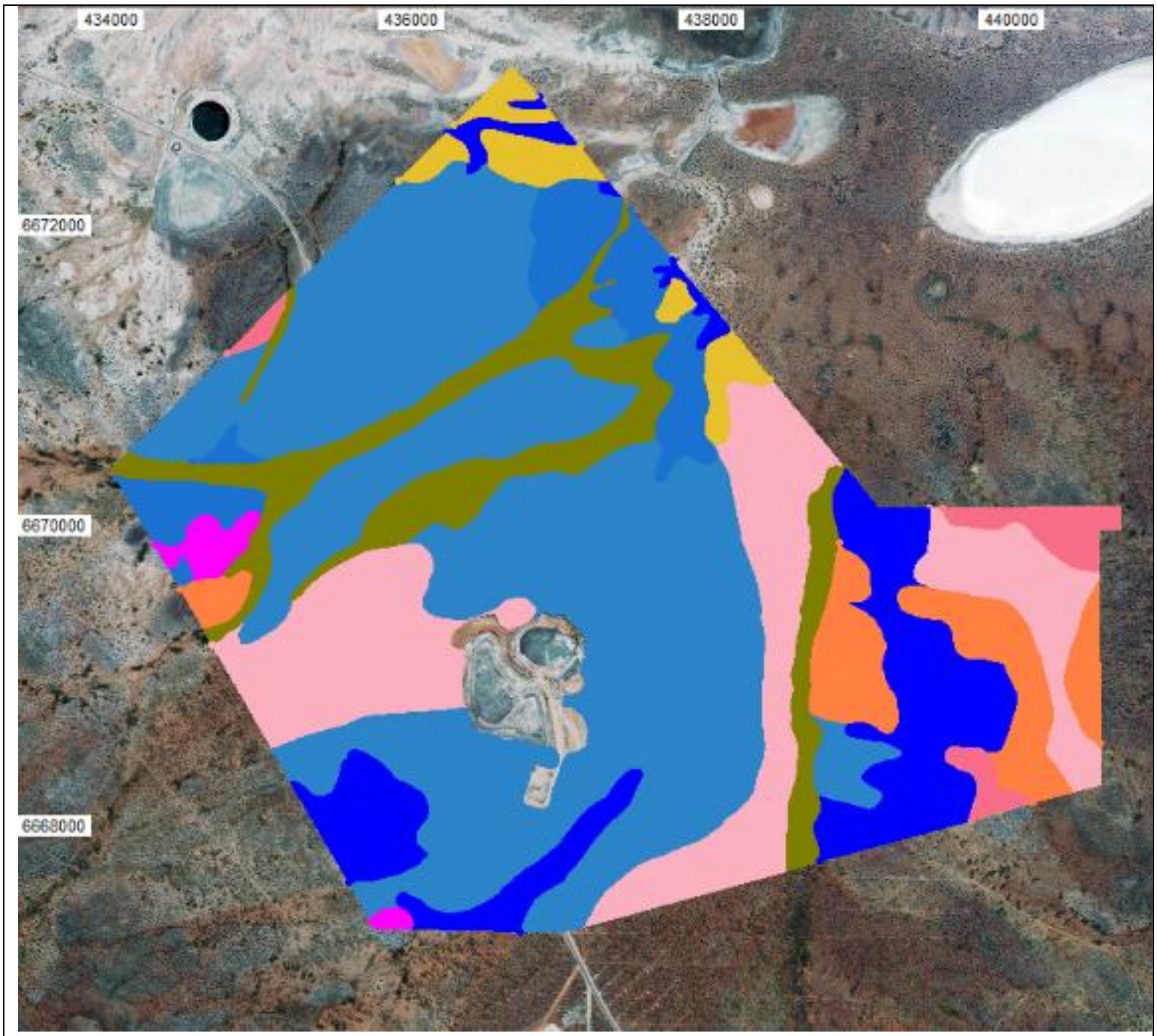
Land unit	Description	Hectares	%
1b.	Basalt hills	24.7	1.1
1c.	Felsic hills and footslopes	19.3	0.9
1d.	Sandy rises	56.4	2.6
2a.	Low lateritic rises	126.5	5.7
2b.	Low rises on basalt	16.0	0.7
4a.	Plains supporting acacia shrublands	370.7	16.8
4c.	Calcareous plains supporting chenopod shrublands	931.8	42.3
5a.	Alluvial plains supporting chenopod shrublands	226.1	10.3
5b.	Saline plains supporting halophytic shrublands	124.6	5.7
6b.	Drainage tracts	214.7	9.8
7b.	Saline drainage tracts and plains adjoining salt lakes	20.3	0.9
MD	Mining disturbance	70.4	3.2
Total		2201.3	100.00

5 5.3 Vegetation communities

Elevated land units on laterite are mostly occupied by ‘Stony ironstone acacia shrubland’ (SIAS) while elevated land units on basalt are occupied by ‘Greenstone hill acacia shrubland’ (GHAS) while those on felsic geology are ‘Felsic hill mixed shrubland’ (FHXS). Sandplain acacia shrublands occupy sandy rises associated with Lake Rebecca (Table 5; Figure 7).

‘Plain acacia casuarina shrubland’ (PACS) occupy 17% (370ha) of the survey area on non-saline plains which adjoin extensive degraded saline plains occupied by ‘Casuarina halophyte shrubland’ (CHAS), ‘Plain mixed halophyte shrubland’ (PXHS) and Calcareous casuarina acacia shrubland' (CCAS) together occupying 69% (1302ha) of the survey area.

Mostly broad, drainage tracts occupied by 'Drainage tract acacia shrubland' (DRAS), pass through the survey area eventually discharging to Lake Rebecca, and occupy 10% (215ha).



	GHAS	Greenstone hill acacia shrubland
	SACS	Sandplain acacia shrubland
	SIAS	Stony ironstone acacia shrubland
	FHSX	Felsic hill mixed shrubland
	PACS	Plain acacia casuarina shrubland
	CCAS	Calcareous casuarina acacia shrubland or woodland
	CAHS	Casuarina halophyte shrubland
	PXHS	Plain mixed halophyte low shrublands
	DRAS	Drainage tract acacia shrubland

Figure 7: Common vegetation communities within the survey area

Table 5: Vegetation communities and associated land units.

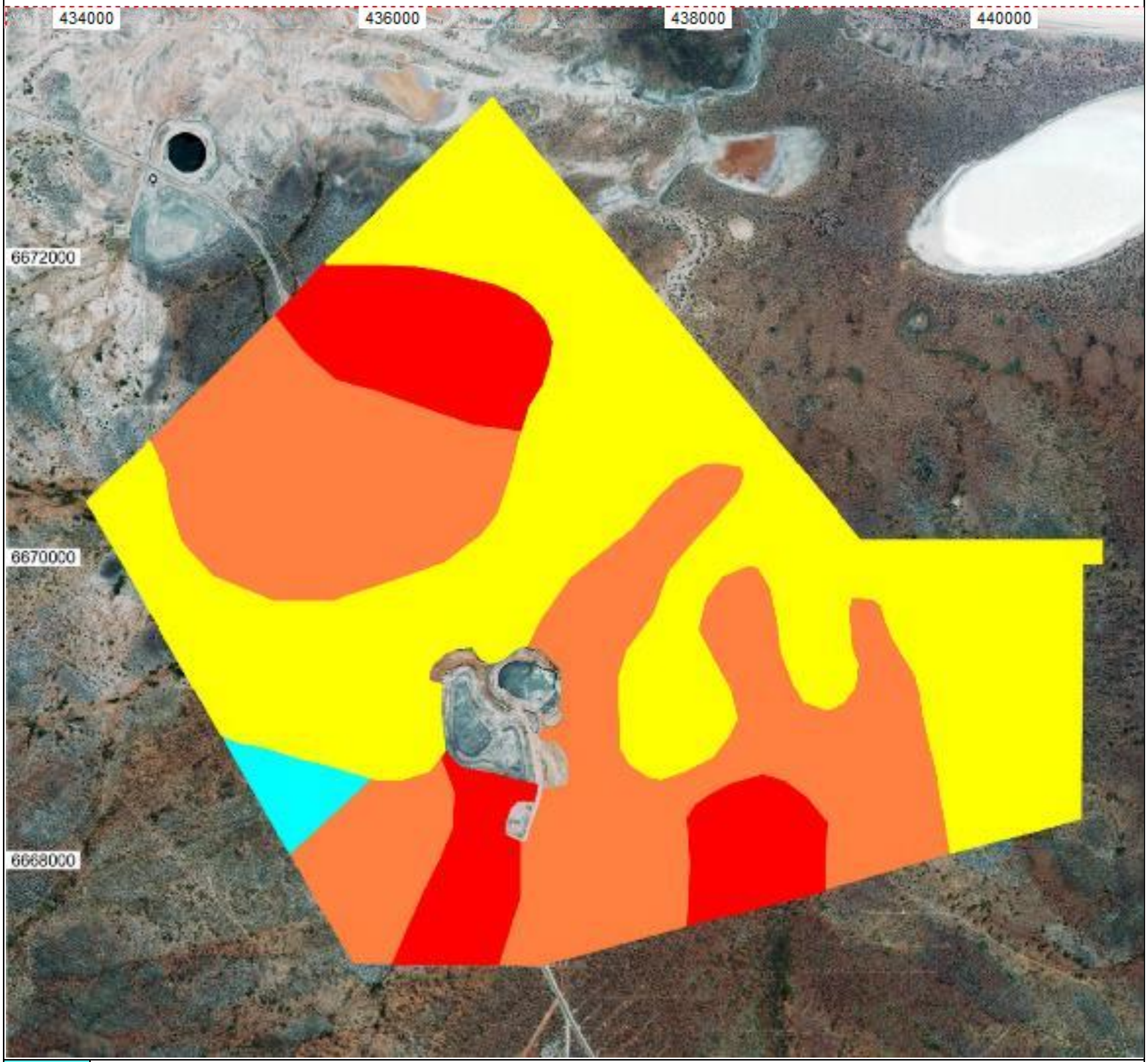
Vegetation community	Description	Land unit	Area	
			Ha	%
GHAS	Greenstone hill acacia shrubland (N)	1b 2b	41	2
SACS	Sandplain acacia shrubland (N)	1d	56	2
SIAS	Stony ironstone acacia shrubland (N)	2a	126	6
FHSX	Felsic hill mixed shrubland (new)	1c	20	1
PACS	Plain acacia casuarina shrubland (new)	4a	370	17
CCAS	Calcareous casuarina acacia shrubland or woodland (N)	4c	932	42
CAHS	Casuarina halophyte shrubland (new)	5b	124	6
PXHS	Plain mixed halophyte low shrublands (N)	5a 7b	246	11
DRAS	Drainage tract acacia shrubland (S)	6b	215	10
MD	Mining disturbance		70	3

*(N)(Pringle, Van Vreeswyk & Gilligan, 1994); (S) (Payne et al. 1998)

5.4 Vegetation condition and soil erosion

The survey area has been disturbed by recent and historic mining activity. Vehicle tracks and cut lines cross the area. Historical sheep grazing is associated with widespread vegetation change and soil erosion (Pringle et al. 1994). Vegetation, palatable to sheep, has been lost and replaced by un-palatable Eremophila, Senna and Acacia species many of which have died during the past years of below average rainfall (Figure 2).

None of the survey area supports pristine vegetation and only 32ha (2%) of vegetation is in excellent condition with unaltered structure (Table 6). Vegetation structure over the remainder of the survey area has been altered with nearly 50% (1079ha) significantly to severely impacted by disturbance (Figure 8).



	Vegetation structure intact.
	Vegetation structure altered, obvious signs of disturbance
	Vegetation structure significantly altered by very obvious signs of disturbance
	Basic vegetation structure severely impacted by disturbance

Figure 8: Vegetation condition within the survey area

Minor to moderate soil erosion is evident on alluvial plains, saline drainage tracts and sandy rises (land units 1d, 5a and 7b).

Table 6: Vegetation condition within the survey area (Keighery 1994)

Condition	Area (ha)	%
1. Pristine or nearly so.	0	0
2. Excellent Vegetation structure intact, disturbance affecting individual species.	32	2
3. Very good Vegetation structure altered, obvious signs of disturbance.	1020	46
4. Good Vegetation structure significantly altered by very obvious signs of multiple disturbance, retains basic vegetation structure or ability to regenerate it.	801	36
5. Degraded Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management.	278	13
6. Completely degraded The structure of the vegetation is no longer intact and the area is completely or almost without native species.	(70 MD)*	(3)

* Mining disturbance

5.5 Threatened ecosystems and wetlands.

5 5.1 Threatened and priority ecological communities

There are no identified threatened ecological communities (TECs) in the MUR1 biogeographic subregion (Cowan, 2001).

There are no listed priority ecological communities (PECs) in the area.

None of the vegetation communities identified in the field survey were representative of TECs listed under the EPBC Act or BC Act, or PECs listed by DBCA.

5 5.2 Significant wetlands

There are no nationally significant wetlands in the survey area (Appendix 1). Lake Rebecca, located about 2.5 km northeast of the survey area, is a major wetland with local and regional significance.

5 5.3 Riparian vegetation

The survey landscape mainly drains via overland flow into broad drainage tracts (land unit 6b) which discharge into Lake Rebecca. Drainage tracts support sparse to mid-dense acacia shrublands typical of the northern Goldfields and are not considered typical riparian vegetation.

5.6 Flora

5 6.1 General

One hundred and twenty-nine flora taxa representing 30 families were found during the reconnaissance survey (Table 7). Chenopodiaceae accounted for 31 taxa, Fabaceae 18 taxa and Scrophulariaceae 15 taxa.

A list of species within each family found at each inventory site is presented in Attachment 3. Species typifying the survey area include *Senna artemisioides* subsp. *filifolia, Casuarina pauper, Acacia burkittii, Scaevola spinescens, Ptilotus obovatus* and *Maireana sedifolia*, all present on at least 75% of sites.

5 6.2 Local endemics

No taxa are considered to be locally endemic.

5 6.3 Declared weed species

Centaurea melitensis (Maltese cockspur), a common weed species in the Goldfields, was noted growing along road verges and depressions near Luvironza.

Lysimachia arvensis (Scarlet pimpernel), a widespread weed throughout Australia, was located at one site within Land unit 6b (-30.08422; 122.34823).

No weeds listed as Weeds of National Significance or Declared Pests under the *Biosecurity and Agriculture Management Act 2007* (BAM Act) were recorded in the survey area.

5 6.4 Threatened and Priority flora

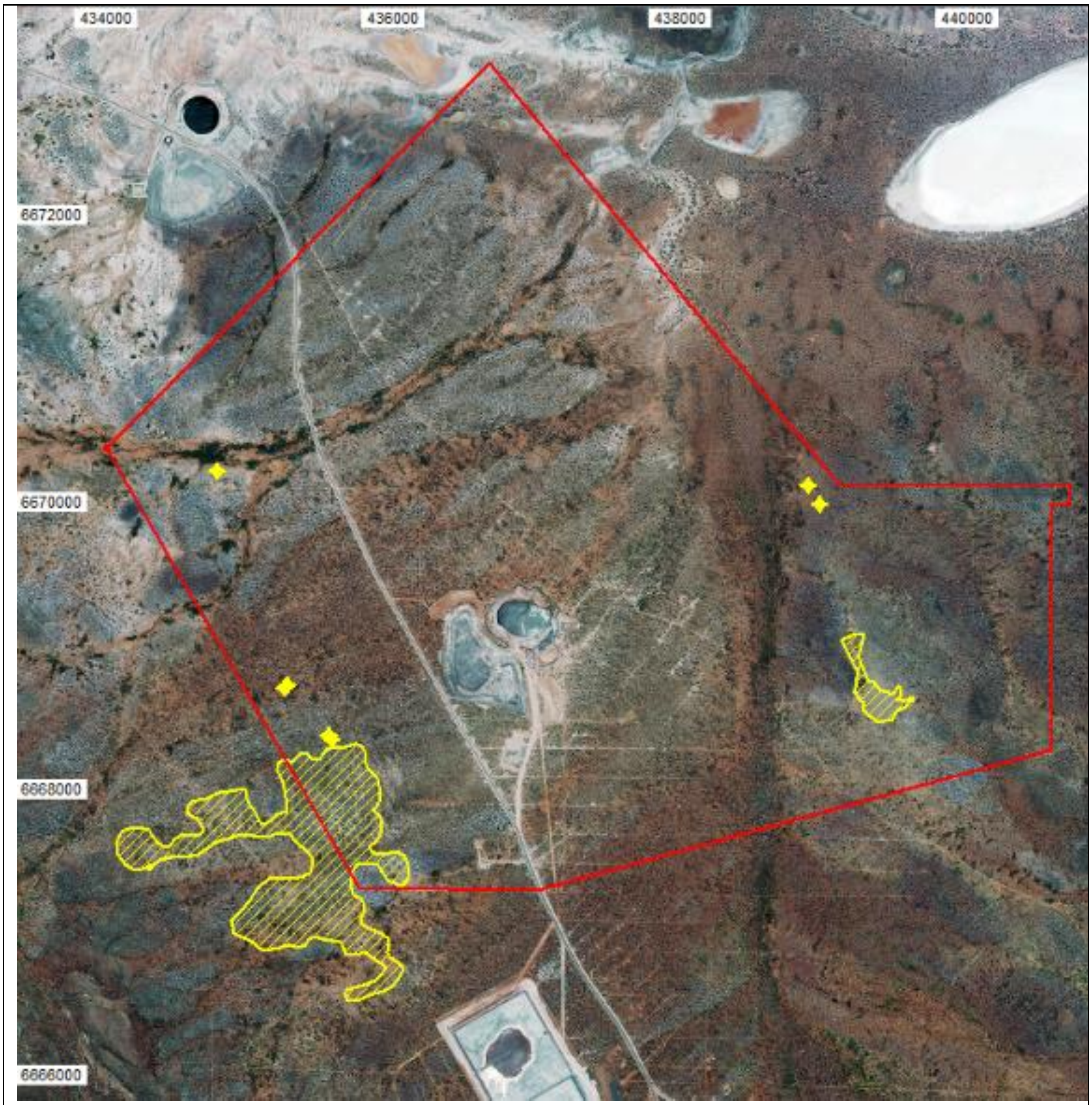
No Threatened flora taxa were found during survey.

There are two known populations of (EAT) (Priority 3) within the survey area:

- A population of 2500 plants, over approximately 125ha, identified by Alexander Holm & Associates (2019). Located in the southwest of the survey area in tenements M31/219 and M31/220 and extending outside the survey area into M31/295.
- A population of 680 plants, over approximately 9ha, previously identified by NSR personnel and verified during this survey. Located in the southeast of the survey area in tenements M31/285 and M31/220.

These populations occur almost exclusively on land unit 5a: Alluvial plains supporting chenopod shrublands (Figure 9).

Seven individual plants of EAT were located during survey. These appeared to be outliers from the above two main populations, occurring within favourable micro-environments in different land units (Figure 9). No additional plants were found during extensive searches in the vicinity of these individuals.



	Outlier EAT plants
	EAT populations of ~2500 plants in the west and ~680 plants in the east

Figure 9: Location of *Eremophila arachnoides* subsp. *tenera* populations and outliers

Table 7: List of flora taxa found during field survey in October 2023.

Family	Taxa	Land units									
		1C	1D	2A	4A	4B	4C	5A	5B	6b	7c
Amaranthaceae	*Ptilotus obovatus* var. *obovatus*	Y	Y	Y	Y	Y		Y	Y	Y	Y
Amaranthaceae	*Ptilotus exaltatus*								Y		
Apocynaceae	*Alyxia buxifolia*				Y	Y					
Apocynaceae	*Marsdenia australis*	Y	Y	Y	Y	Y	Y	Y	Y		Y
Asparagaceae	*Lomandra effusa*		Y								
Asteraceae	*Asteraceae sp.*		Y								
Asteraceae	*Asteridea athrixioides*					Y			Y		
Asteraceae	*Brachyscome perpusilla*					Y		Y		Y	
Asteraceae	*Brachyscome trachycarpa*				Y	Y			Y		
Asteraceae	*Cratystylis microphylla*		Y								
Asteraceae	*Cratystylis subspinescens*		Y	Y	Y	Y	Y	Y	Y	Y	
Asteraceae	*Olearia muelleri*		Y	Y	Y	Y	Y	Y	Y	Y	
Asteraceae	*Olearia pimeleoides*		Y		Y				Y		
Asteraceae	*Vittadinia sulcata*					Y			Y		
Azioaceae	*Gunniopsis quadrifida*		Y		Y	Y	Y			Y	
Boraginaceae	*Halgania cyanea*				Y						
Brassicaceae	*Lepidium platypetalum*							Y			
Casuarinaceae	*Casuarina pauper*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Chenopodiaceae	*Atriplex bunburyana*	Y		Y	Y	Y	Y	Y	Y	Y	Y
Chenopodiaceae	*Atriplex vesicaria*		Y				Y	Y		Y	
Chenopodiaceae	*Atriplex codonocarpa*							Y		Y	
Chenopodiaceae	*Atriplex nummularia* subsp. *spathulata*	Y		Y	Y	Y	Y	Y	Y		Y
Chenopodiaceae	*Chenopodium gaudichaudianum*					Y		Y	Y		
Chenopodiaceae	*Enchylaena lanata*				Y	Y			Y		
Chenopodiaceae	*Enchylaena tomentosa* var. *tomentosa*		Y		Y	Y	Y	Y	Y		
Chenopodiaceae	*Eriochiton sclerolaenoides*	Y						Y			Y
Chenopodiaceae	*Maireana amoena*						Y			Y	
Chenopodiaceae	*Maireana atkinsiana*									Y	
Chenopodiaceae	*Maireana georgei*		Y		Y	Y	Y	Y	Y	Y	
Chenopodiaceae	*Maireana glomerifolia*	Y	Y			Y		Y		Y	Y
Chenopodiaceae	*Maireana integra*				Y	Y			Y		
Chenopodiaceae	*Maireana planifolia*								Y		
Chenopodiaceae	*Maireana pyramidata*	Y			Y		Y	Y	Y	Y	Y
Chenopodiaceae	*Maireana sedifolia*	Y	Y	Y	Y	Y	Y	Y	Y		Y

Family	***Taxa***	**Land units**									
		1C	**1D**	**2A**	**4A**	**4B**	**4C**	**5A**	**5B**	**6b**	**7c**
Chenopodiaceae	*Maireana tomentosa* subsp. *tomentosa*				Y	Y	Y	Y	Y	Y	
Chenopodiaceae	*Maireana trichoptera*							Y			
Chenopodiaceae	*Maireana triptera*	Y	Y		Y	Y		Y	Y	Y	Y
Chenopodiaceae	*Maireana suaedifolia*				Y						
Chenopodiaceae	*Rhagodia drummondii*		Y		Y		Y	Y	Y		
Chenopodiaceae	*Rhagodia eremaea*	Y	Y	Y	Y	Y		Y	Y	Y	Y
Chenopodiaceae	*Salsola australis*				Y	Y				Y	
Chenopodiaceae	*Sclerolaena cuneata*					Y	Y	Y		Y	
Chenopodiaceae	*Sclerolaena densiflora*							Y		Y	
Chenopodiaceae	*Sclerolaena diacantha*		Y		Y	Y	Y	Y	Y	Y	
Chenopodiaceae	*Sclerolaena eurotioides*							Y		Y	
Chenopodiaceae	*Sclerolaena obliquicuspis*				Y	Y			Y		
Chenopodiaceae	*Sclerolaena fusiformis*				Y				Y		
Chenopodiaceae	*Tecticornia disarticulata*							Y			
Chenopodiaceae	*Tecticornia pruinosa*									Y	
Crassulaceae	*Crassula colorata* var. *colorata*								Y		
Fabaceae	*Acacia aptaneura*				Y	Y		Y	Y		
Fabaceae	*Acacia burkittii*	Y	Y	Y	Y	Y	Y	Y	Y		Y
Fabaceae	*Acacia ceasaneura*				Y						
Fabaceae	*Acacia hemiteles*		Y	Y	Y	Y	Y	Y	Y		
Fabaceae	*Acacia inceana* subsp. *conformis*		Y		Y			Y		Y	
Fabaceae	*Acacia incurvaneura*	Y	Y	Y	Y	Y	Y	Y	Y		Y
Fabaceae	*Acacia jennerae*	Y	Y	Y	Y	Y		Y	Y		Y
Fabaceae	*Acacia nyssophylla*		Y	Y	Y	Y		Y	Y		
Fabaceae	*Acacia oswaldii*		Y	Y	Y	Y	Y	Y	Y		
Fabaceae	*Acacia ramulosa* var. *ramulosa*		Y	Y	Y				Y		
Fabaceae	*Acacia* sp.			Y	Y						
Fabaceae	*Acacia tetragonophylla*	Y		Y	Y	Y	Y	Y	Y	Y	Y
Fabaceae	*Acacia ayersiana*		Y	Y							
Fabaceae	*Acacia sibirica*		Y	Y	Y	Y			Y		
Fabaceae	*Senna artemisioides* subsp. ×*artemisioides*				Y						
Fabaceae	*Senna artemisioides* subsp. *filifolia*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Fabaceae	*Senna cardiosperma*						Y				
Fabaceae	*Templetonia incrassata*		Y	Y	Y	Y	Y	Y	Y		
Frankeniaceae	*Frankenia fecunda*									Y	

Family	***Taxa***	**Land units**									
		1C	**1D**	**2A**	**4A**	**4B**	**4C**	**5A**	**5B**	**6b**	**7c**
Frankeniaceae	*Frankenia interioris*		Y			Y	Y	Y		Y	
Frankeniaceae	*Frankenia setosa*									Y	
Goodeniaceae	*Goodenia havilandii*				Y	Y					
Goodeniaceae	*Scaevola spinescens*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Lamiaceae	*Prostanthera althoferi* subsp. *althoferi*		Y		Y	Y					
Lamiaceae	*Teucrium teucriiflorum*					Y					
Loranthaceae	*Amyema gibberula*					Y					
Loranthaceae	*Lysiana murrayi*		Y			Y			Y		
Malvaceae	*Abutilon cryptopetalum*					Y					
Malvaceae	*Brachychiton gregorii*			Y	Y						
Malvaceae	*Sida* sp. dark green fruits (S van Leeuwen 2260)				Y	Y					
Malvaceae	*Sida spodochroma*					Y					
Moniaceae	*Calandrinia polyandra*		Y							Y	
Myrtaceae	*Eucalyptus griffithsii*				Y						
Myrtaceae	*Eucalyptus loxophleba* subsp. *supralaevis*		Y						Y	Y	
Myrtaceae	*Eucalyptus oleosa* subsp. *oleosa*			Y	Y	Y		Y	Y		
Myrtaceae	*Eucalyptus yilgarnensis*		Y								
Myrtaceae	*Eucalyptus salmonophloia*					Y					
Myrtaceae	*Melaleuca eleuterostachya*									Y	
Pittosporaceae	*Pittosporum angustifolium*						Y		Y	Y	
Poaceae	*Aristida contorta*		Y		Y	Y			Y		
Poaceae	*Austrostipa scabra*			Y	Y	Y		Y	Y		
Poaceae	*Austrostipa elegantissima*		Y		Y	Y			Y	Y	
Poaceae	*Enteropogon ramosus*							Y		Y	
Poaceae	*Eragrostis lanipes*		Y								
Poaceae	*Paspelidium gracile*		Y								
Poaceae	*Rytidosperma robertsoniae*	Y				Y					Y
Poaceae	*Triodia scariosa*		Y								
Primulaceae	*Lysimachia arvensis*								Y		
Proteaceae	*Grevillea acuaria*		Y		Y					Y	
Proteaceae	*Grevillea sarissa* subsp. *anfractifolia*		Y					Y			
Proteaceae	*Hakea preissii*		Y				Y		Y		
Rubiaceae	*Psydrax suaveolens*		Y								
Santalaceae	*Exocarpos aphyllus*		Y		Y	Y	Y	Y	Y	Y	
Santalaceae	*Santalum spicatum*		Y	Y	Y	Y	Y	Y	Y		

Family	Taxa	Land units									
		1C	1D	2A	4A	4B	4C	5A	5B	6b	7c
Sapindaceae	*Alectryon oleifolius* subsp. *canescens*			Y	Y	Y			Y		
Sapindaceae	*Dodonaea lobulata*	Y		Y	Y	Y		Y	Y		Y
Sapindaceae	*Dodonaea viscosa*			Y							
Sapindaceae	*Dodoneaa rigida*		Y		Y	Y	Y	Y			
Scrophulariaceae	*Eremophila alternifolia*		Y			Y		Y	Y		
Scrophulariaceae	*Eremophila caperata*									Y	
Scrophulariaceae	*Eremophila decipiens* subsp. *decipiens*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Scrophulariaceae	*Eremophila eriocalyx*		Y	Y		Y					
Scrophulariaceae	*Eremophila forrestii subsp. forrestii*		Y	Y		Y					
Scrophulariaceae	*Eremophila glabra*			Y			Y		Y		
Scrophulariaceae	*Eremophila granitica*		Y	Y	Y	Y	Y	Y	Y	Y	
Scrophulariaceae	*Eremophila latrobei* subsp. *latrobei*			Y	Y	Y					
Scrophulariaceae	*Eremophila oldfieldii* subsp. *angustifolia*	Y		Y	Y	Y		Y	Y		Y
Scrophulariaceae	*Eremophila oppositifolia* subsp. *angustifolia*		Y		Y	Y	Y	Y		Y	
Scrophulariaceae	*Eremophila scoparia*		Y	Y	Y	Y	Y	Y	Y	Y	
Scrophulariaceae	*Eremophila serrulata*			Y							
Scrophulariaceae	*Eremophila arachnoides* subsp. *tenera*				Y		Y				
Scrophulariaceae	*Eremophila longifolia*		Y	Y		Y			Y		
Scrophulariaceae	*Eremophila miniata*		Y								
Solanaceae	*Solanum lasiophyllum*			Y	Y	Y			Y		
Solanaceae	*Solanum plicatile*				Y						
Thymelaeaceae	*Pimelea microcephala* subsp. *microcephala*								Y		
Zygophyllaceae	*Roepera eremaea*				Y	Y					
Zygophyllaceae	*Roepera ovata*					Y					

.

5.7 Fauna

5 7.1 General

Twenty two bird and two reptile species were observed during field survey. Tracks were observed for Dingo (*Canis lupuis dingo*) and Echidna (*Tachyglossus aculeatus*) diggings noted. A trapdoor spider (*Gaius* sp.) burrow was located in a stony cobbled hillslope of land unit 1b (Basalt hills).

Table 8: List of fauna found during survey in October 2023

Taxa	Common name
Bird	
Acanthagenys rufogularis	Spiny-cheeked Honeyeater
Acanthiza apicalis	Inland Thornbill
Acanthiza uropygialis	Chestnut-rumped Thornbill
Barnardius zonarius	Australian Ringneck
Cheramoeca leucosterna	White-backed Swallow
Coracina novaehollandiae	Black-faced Cuckoo-shrike
Falco berigora	Brown Falcon
Gavicalis virescens	Singing Honeyeater
Gymnorhina tibicen	Australian Magpie
Hirundo neoxena	Welcome Swallow
Leiopoa ocellata	Malleefowl
Manorina flavigula	Yellow-throated Miner
Melanodryas cucullata	Hooded Robin
Merops ornatus	Rainbow Bee-eater
Ocyphaps lophotes	Crested Pigeon
Petrochelidon nigricans	Tree Martin
Petroica goodenovii	Red-capped Robin
Podargus strigoides	Tawny Frogmouth
Pomatostomus superciliosus	White-browed Babbler
Rhipidura albiscapa	Grey Fantail
Rhipidura leucophrys	Willie Wagtail
Smicrornis brevirostris	Weebill
Reptiles	
Ctenophrus scutalatus	Lozenge-Marked Dragon
Varanus gouldii	Goulds Monitor

Tracks of non-native animals included Cow (*Bos taurus*), European Rabbit (*Oryctolagus cuniculus*) and cat (*Felis catus*). A Red Fox (*Vulpes vulpes*) den was found in a sandy low rise (land unit 1d) adjacent to Lake Rebecca.

Numerous ancient Burrowing Bettong (Boodie: *Bettongia lesueur*) warrens occur throughout the survey area indicating the now mainland-extinct mammal was once widespread in this region.

5 7.2 Threatened and Priority fauna

Of the six EPBC listed threatened birds, four are vagrants and unlikely to be residents in the survey area, Malleefowl are active in the area and Southern Whiteface is a likely resident but was not observed (Table 9).

Of the two mammals, the Chuditch listed as vulnerable, is believed to locally extinct and now restricted to south-western areas. The Sandhill Dunnart listed as endangered, and in common with the Great Desert Skink listed as vulnerable, occur in broad sandplains interspersed with dunes, spinifex and mixed shrubs. There being only isolated spinifex in the survey area these species are unlikely to be present.

Table 9: List of EPBC act threatened fauna and likely occurrence in survey area

Fauna	Common name	Threatened category	Likely occurrence in survey area
Bird			
Aphelocephala leucopsis	Southern Whiteface	Vulnerable	Cryptic resident
Calidris ferruginea	Curlew Sandpiper	Critically endangered	Migratory wetland species -vagrant
Falco hypoleucos	Grey Falcon	Vulnerable	Vagrant
Leipoa ocellata	Malleefowl	Vulnerable	Resident
Pezoporus occidentalis	Night Parrot	Endangered	Vagrant
Polytelis alexandrae	Princess Parrot	Vulnerable	Vagrant
Mammal			
Dasyurus geoffroii	Chuditch	Vulnerable	Probably locally extinct
Sminthopsis psammophila	Sandhill Dunnart	Endangered	No suitable habitat
Reptile			
Liopholis kintorei	Great Desert Skink	Vulnerable	No suitable habitat

5 7.3 Fauna habitat

All the vegetation types are effectively sparse shrublands with occasional thickets on slopes and plains, with soils ranging from sand to sandy loams and loamy-clays sometimes underlain by calcrete. Thus, there are no very distinctive patterns in terms of fauna habitats, although some land units and vegetation communities are likely to support fauna species not found across the entire project area. These are: land unit 1d (sandy ridges; vegetation community SACS), land unit 6b (drainage; vegetation community DRAS) and land unit 7b (saline drainage; vegetation community PXHS)(Table 3). These land units have soil types and hydrological conditions not found across the whole project area.

The Malleefowl, the only fauna species of conservation significance detected during the site inspection, will favour land units with gravelly loam soils and thickets of vegetation for breeding.

5.8 Survey limitations

The limitations of the survey have been considered in accordance with EPA guidelines (Table 10). No potential limitations are identified. While on-going dry conditions restricted abundance of fauna and annual flora taxa, this information was augmented by information from other nearby surveys which had been conducted during more favourable seasons.

Table 10: Consideration of potential survey limitations

Limitation	Limitation for this survey?	Comments
Availability of contextual information at a regional and local scale	No	Previous biological and soil surveys for Northern Star together with geological maps provided excellent local scale information. Regional scale information from Land System mapping assisted land unit/habitat description
Competency/experience of the team carrying out the survey, including experience in the bioregion surveyed	No	Alexander Holm, who managed the survey and prepared the report, has many years experience in WA arid environments and has worked specifically in the Goldfields since 2005. Dr Mike Bamford has operated Bamford Consulting Ecologists since the mid 1980s and has extensive experience in the Western Australia's Goldfields. Mr Peter Smith has 30 years of experience for environmental surveys.
Any identification issues	No	All flora taxa except one Acacia were positively identified. All observed fauna taxa were positively identified.
Was the appropriate area fully surveyed (effort and extent)	No	Over 60 inventory sites were sampled for vegetation, flora, land form and soil type providing a comprehensive data set for this component of the survey. Fauna observations were conducted over 5 days with several extensive on foot traverses which is considered adequate for a basic fauna survey.

Limitation	**Limitation for this survey?**	**Comments**
Access restrictions within the survey area	No	All areas were accessible by vehicle or on foot.
Survey timing, rainfall, season of survey	Partly	Survey was conducted in summer following a light winter rainy season resulting in limited suite of annual flora taxa. A prolonged drought in this region has resulted in extensive plant death. Flora and fauna information from this survey was augmented from previous surveys in the immediate area during more favourable seasons.
Disturbance that may have affected the results of survey	No	No disturbances.

6 Discussion

Northern Star operates the Carosue Gold Mine and is proposing further mining in the vicinity of the existing Luvironza open pit gold mine. The survey area covers 2200ha and encompasses all areas likely to be impacted by mining activity. The southern 835ha of the survey area has been covered by an earlier environmental assessment (Alexander Holm & Associates 2019) and site information from this, together with an adjoining survey in the Relief Hill area (Alexander Holm & Associates 2020) and another to the north (Alexander Holm & Associates 2012), are included in this report.

Flora composition and vegetation communities recorded in the survey area are typical of the region and not considered unusually diverse. There are no Threatened Ecological Communities (TECs) and no Priority Ecological Communities within or adjacent to the survey area.

No listed Threatened flora species were found during this survey in or nearby the survey area. Three populations consisting of over 2500 plants of *Eremophila arachnoides* subsp. *tenera* (EAT), a Priority 3 listed taxa (P3), are located within the survey area. While no new populations of EAT were found, several singleton outliers to these populations were found. No other priority listed species were found.

Centaurea melitensis (Maltese cockspur), a common weed species in the Goldfields, was noted growing along road verges and depressions near Luvironza. *Lysimachia arvensis* (Scarlet pimpernel), a widespread weed throughout Australia, was located at one site within Land unit 6b.

No weeds listed as Weeds of National Significance or Declared Pests under the *Biosecurity and Agriculture Management Act 2007* (BAM Act) were recorded in the survey area.

The only Threatened fauna species recorded in the survey area was Malleefowl and are the subject of a separate survey and report. No Priority fauna species were recorded in the survey area.

The survey area has been disturbed by recent and historic mining activity. Historic sheep grazing is associated with widespread vegetation change and soil erosion (Pringle et al. 1994). Vegetation, palatable to sheep, has been lost and replaced by un-palatable Eremophila, Senna and Acacia species many of which have died during the past years of below average rainfall.

Land units supporting vegetation, preferentially grazed by livestock, are degraded and few areas are in good condition. Vegetation structure on lateritic, basaltic and felsic hills is mostly intact and with little change in composition while lower slopes on laterite and basalt are often in poorer condition. Minor to moderate soil erosion is evident on alluvial plains, saline drainage tracts and sandy rises.

The survey landscape drains via overland flow to drainage tracts (land unit 6b) which flow into Lake Rebecca to the north. Lake Rebecca, located about 2.5 km northeast of the survey area is a major wetland with local and regional significance. None of the vegetation within the survey area is representative of riparian vegetation.

7 References

Alexander Holm & Associates (2012). Environmental assessment: Old Plough Dam: 96.

Alexander Holm & Associates (2019). Environmental assessment: Proposed Seismic Survey pp 136.

Alexander Holm & Associates (2020). Environmental assessment: Relief Hill Survey Area pp 109.

Beard, J.S. (1976). *Vegetation Survey of Western Australia - Sheet 6. Murchison*. Nedlands, Western Australia: University of Western Australia Press

Cowan, M. (2001). Murchison 1 (MUR1 - East Murchison subregion). In N.L. McKenzie, & J.E. May (Eds.), *A biodiversity audit of Western Australia's 53 biogeographical subregions in 2002* (pp. 466-479). Perth: The Department of Conservation and Land Management

Desmond, A., Cowan, M., & Chant, A. (2003). Murchison 2 (MUR2 - Western Murchison subregion). In N.L. McKenzie, & J.E. May (Eds.), *A Biodiversity Audit of Western Australia's 53 Biogeographical Subregions in 2002* (pp. 480-496). Perth The Department of Conservation and Land Management

Environmental Protection Authority (2016). Technical guidance. Flora and Vegetation Surveys for Environmental Impact Assessment: 42.

Environmental Protection Authority (2020). Technical Guidance – Terrestrial vertebrate fauna surveys for environmental impact assessment: pp 52.

Mitchell, A.A., & Wilcox, D.G. (1994). *Arid Shrubland Plants of Western Australia*. (2 ed.). Perth: University of Western Australia Press

Payne, A.L., Van Vreeswyk, A.M.E., Pringle, H.J.R., Leighton, K.A., & Hennig, P. (1998). An inventory and condition survey of the Sandstone-Yalgoo- Paynes Find area, Western Australia: 372.

Pringle, H.J.R., Van Vreeswyk, A.M.E., & Gilligan, S.A. (1994). An Inventory and Condition Survey of Rangelands in the North-eastern Goldfields, Western Australia: pp 323.

Disclaimer

While Alexander Holm & Associates has carried out some enquiries concerning data, assumptions and information supplied to it, those enquiries were limited and Alexander Holm & Associates does not accept responsibility for their accuracy. Accordingly, Alexander Holm & Associates does not accept any legal responsibility to any person, organisation or company for any loss or damage suffered by them resulting from their use of the report however caused, and whether by breach of contract, negligence or otherwise

Within the limitation imposed by the scope of review, the data assessment and preparation of the report have been undertaken in a professional manner and in accordance with generally accepted practices using a degree of care ordinarily exercised by professional environmental consultants. No other warranty, expressed or implied, is made.

8 Attachments

Attachment 1: ‘NatureMap’ report

Row Labels	COUNT
Animalia	**396**
AMPHI	**3**
(blank)	3
Cyclorana platycephala	2
Neobatrachus sutor	1
BIRD	**248**
VU	54
Leipoa ocellata	54
(blank)	194
Acanthagenys rufogularis	8
Acanthiza apicalis	7
Acanthiza chrysorrhoa	5
Acanthiza robustirostris	2
Acanthiza uropygialis	6
Anthochaera carunculata	2
Anthus australis	2
Aphelocephala leucopsis	3
Aquila audax	4
Artamus cinereus	3
Artamus personatus	1
Barnardius zonarius	1
Cacatua roseicapilla	2
Cacatua roseicapilla subsp. assimilis	1
Cheramoeca leucosternus	2
Chrysococcyx basalis	1
Chrysococcyx osculans	1
Cinclosoma castanotus	2
Climacteris affinis	4
Colluricincla harmonica	3
Coracina maxima	4
Coracina novaehollandiae	3
Corvus bennetti	2
Corvus coronoides	2
Corvus orru	1
Cracticus nigrogularis	3
Cracticus tibicen	2
Cracticus torquatus	3
Cuculus pallidus	1
Dicaeum hirundinaceum	1
Dromaius novaehollandiae	4
Eolophus roseicapillus	1
Epthianura albifrons	2
Epthianura tricolor	1
Eurostopodus argus	2
Falco berigora	2
Falco cenchroides	3
Glossopsitta porphyrocephala	1
Grallina cyanoleuca	1

Hirundo neoxena	2
Hirundo nigricans	1
Lalage tricolor	1
Lichenostomus leucotis	1
Lichenostomus ornatus	1
Lichenostomus virescens	10
Lichmera indistincta	4
Malacorhynchus membranaceus	1
Malurus leucopterus	3
Malurus splendens	2
Manorina flavigula	7
Melithreptus brevirostris	1
Melopsittacus undulatus	1
Merops ornatus	2
Microeca fascinans	1
Ninox novaeseelandiae	1
Ocyphaps lophotes	3
Oreoica gutturalis	6
Pachycephala rufiventris	3
Pardalotus striatus	2
Pardalotus striatus subsp. westraliensis	2
Petrochelidon nigricans	1
Petroica cucullata	2
Petroica goodenovii	5
Phaps chalcoptera	2
Phylidonyris albifrons	1
Platycercus varius	2
Platycercus zonarius	2
Podargus strigoides	1
Pomatostomus superciliosus	3
Ptilonorhynchus maculatus subsp. guttatus	1
Ptilotula plumulus	1
Purnella albifrons	2
Pyrrholaemus brunneus	3
Rhipidura fuliginosa	1
Rhipidura leucophrys	3
Smicrornis brevirostris	3
Strepera versicolor	2
Tadorna tadornoides	1
Taeniopygia guttata	2
Tyto alba	1
Vanellus tricolor	1
FISH	**1**
(blank)	1
Galaxias maculatus	1
INVERT	**15**
(blank)	15
Asadipus yundamindra	1
Aurecocrypta lugubris	1
beetle sp.	1

Hogna salifodina	2
Latrodectus hasseltii	1
Nephila edulis	1
Parartemia sp.	4
Phryganoporus candidus	1
Scolopendra morsitans	1
Urodacus hoplurus	2
MAMMAL	**27**
(blank)	27
Bos taurus	2
Canis lupus subsp. dingo	2
Canis lupus subsp. familiaris	1
Capra hircus	1
Capra sp.	1
Felis catus	1
Macropus fuliginosus	1
Macropus robustus	1
Macropus robustus subsp. erubescens	2
Macropus rufus	2
Mus musculus	2
Ningaui ridei	1
Oryctolagus cuniculus	2
Pseudomys hermannsburgensis	4
Sminthopsis crassicaudata	1
Sminthopsis dolichura	1
Tachyglossus aculeatus	2
REPTILE	**102**
(blank)	102
Acanthophis pyrrhus	2
Caimanops amphiboluroides	2
Cryptoblepharus australis	1
Ctenophorus cristatus	4
Ctenophorus fordi	5
Ctenophorus reticulatus	2
Ctenophorus salinarum	5
Ctenophorus scutulatus	9
Ctenotus atlas	2
Ctenotus leonhardii	3
Ctenotus schomburgkii	5
Ctenotus severus	1
Ctenotus uber subsp. uber	1
Diplodactylus pulcher	2
Egernia depressa	4
Egernia formosa	6
Gehyra variegata	2
Heteronotia binoei	14
Lerista picturata	1
Liopholis inornata	1
Moloch horridus	2
Morethia butleri	1

Parasuta monachus	2
Pogona minor subsp. minor	1
Pseudechis australis	1
Pseudonaja modesta	3
Ramphotyphlops bituberculatus	1
Rhynchoedura ornata	1
Simoselaps bertholdi	2
Tiliqua occipitalis	2
Tiliqua rugosa	2
Tiliqua rugosa subsp. rugosa	3
Underwoodisaurus milii	3
Varanus caudolineatus	3
Varanus gouldii	2
Varanus tristis subsp. tristis	1
Fungi	**20**
FUNGUS	**4**
(blank)	4
Uromycladium fusisporum	1
Uromycladium tepperianum	3
LICHEN	**16**
(blank)	16
Aspicilia calcarea	2
Buellia albula	2
Candelariella xanthostigmoides	1
Flavoparmelia sp.	2
Fulgensia sp.	1
Physcia albata	3
Protoparmelia pulchra	3
Psora crystallifera	1
Psora decipiens	1
Plantae	**214**
DICOT	**199**
P2	4
Thryptomene eremaea	4
(blank)	195
Acacia aneura	2
Acacia burkittii	1
Acacia colletioides	1
Acacia craspedocarpa	1
Acacia effusifolia	1
Acacia hemiteles	2
Acacia heteroneura var. prolixa	1
Acacia inceana subsp. inceana	1
Acacia kalgoorliensis	1
Acacia ligulata	3
Acacia oswaldii	3
Acacia papyrocarpa	1
Acacia pteraneura	1
Acacia ramulosa var. ramulosa	3
Acacia rigens	1

Acacia sibirica	2
Acacia tetragonophylla	1
Acacia warramaba	1
Allocasuarina eriochlamys subsp. eriochlamys	2
Allocasuarina helmsii	1
Amyema fitzgeraldii	1
Baeckea sp.	1
Bossiaea walkeri	1
Bursaria occidentalis	1
Callistemon phoeniceus	2
Calothamnus gilesii	1
Calytrix depressa	1
Centaurea melitensis	1
Chrysocephalum puteale	1
Chthonocephalus pseudevax	1
Comesperma integerrimum	1
Convolvulus remotus	1
Coopernookia strophiolata	1
Cryptandra aridicola	2
Dampiera tenuicaulis var. tenuicaulis	1
Dicrastylis flexuosa	1
Dodonaea lobulata	2
Einadia nutans	1
Eremophila caperata	3
Eremophila clarkei	1
Eremophila decipiens subsp. decipiens	3
Eremophila forrestii subsp. forrestii	1
Eremophila forrestii subsp. hastieana	1
Eremophila glandulifera	3
Eremophila granitica	1
Eremophila maculata subsp. brevifolia	1
Eremophila margarethae	1
Eremophila metallicorum	1
Eremophila oldfieldii subsp. angustifolia	1
Eremophila oppositifolia subsp. angustifolia	1
Eremophila parvifolia subsp. auricampa	1
Eremophila platythamnos subsp. platythamnos	1
Eremophila sp.	1
Eremophila youngii subsp. youngii	2
Eriochiton sclerolaenoides	1
Erodium crinitum	1
Erodium cygnorum	1
Eucalyptus comitae-vallis	2
Eucalyptus concinna	1
Eucalyptus cylindrocarpa	1
Eucalyptus ebbanoensis subsp. ebbanoensis	1
Eucalyptus ewartiana	1
Eucalyptus gracilis	2
Eucalyptus horistes	1
Eucalyptus hypolaena	1

Eucalyptus longissima	2
Eucalyptus loxophleba subsp. lissophloia	1
Eucalyptus orbifolia	1
Eucalyptus sp. Mulga Rock (K.D. Hill & L.A.S. Johnson KH 2668)	1
Eucalyptus transcontinentalis	2
Eucalyptus trichopoda	1
Eucalyptus websteriana	1
Eucalyptus websteriana subsp. websteriana	1
Eucalyptus yilgarnensis	1
Eucalyptus youngiana	1
Frankenia fecunda	1
Grevillea acacioides	2
Grevillea acuaria	1
Grevillea juncifolia subsp. temulenta	1
Grevillea nematophylla subsp. nematophylla	1
Grevillea sarissa subsp. sarissa	1
Hakea lorea subsp. lorea	1
Halgania cyanea var. Charleville (R.W. Purdie +111)	1
Helipterum craspedioides	1
Homalocalyx thryptomenoides	2
Isotoma petraea	1
Jacksonia arida	1
Lawrencella davenportii	2
Lawrencia squamata	2
Lechenaultia striata	1
Leiocarpa semicalva subsp. semicalva	1
Lysimachia arvensis	1
Maireana atkinsiana	1
Maireana tomentosa subsp. tomentosa	1
Maireana trichoptera	1
Medicago laciniata	1
Melaleuca eleuterostachya	1
Olearia incana	1
Olearia muelleri	3
Olearia pimeleoides	2
Olearia stuartii	2
Olearia subspicata	2
Oligocarpus calendulaceus	1
Persicaria prostrata	1
Phebalium tuberculosum	1
Philotheca tomentella	1
Podolepis capillaris	2
Prostanthera althoferi subsp. althoferi	1
Prostanthera campbellii	1
Pseudognaphalium luteoalbum	1
Ptilotus chamaecladus	1
Ptilotus exaltatus	1
Ptilotus obovatus	3
Radyera farragei	1
Rhagodia drummondii	1

Rhagodia ulicina	1
Rhodanthe charsleyae	1
Rhodanthe floribunda	1
Rhodanthe laevis	1
Rhodanthe pygmaea	2
Scaevola spinescens	1
Schoenia ayersii	1
Schoenia cassiniana	1
Sclerolaena cuneata	1
Sclerolaena decurrens	1
Senecio gregorii	2
Senna artemisioides	2
Senna artemisioides subsp. filifolia	1
Senna artemisioides subsp. x artemisioides x artemisioides subsp. filifolia	1
Senna sp. Meekatharra (E. Bailey 1-26)	1
Seringia velutina	2
Sida calyxhymenia	1
Silene gallica var. gallica	1
Solanum cleistogamum	1
Solanum lasiophyllum	1
Solanum terraneum	2
Surreya diandra	1
Swainsona beasleyana	1
Swainsona canescens	1
Swainsona purpurea	1
Swainsona rostellata	1
Tecticornia chartacea	1
Tecticornia pruinosa	1
Tecticornia pterygosperma subsp. pterygosperma	1
Templetonia incrassata	2
Teucrium teucriiflorum	1
Thryptomene urceolaris	2
Velleia rosea	1
Verticordia helmsii	2
Westringia rigida	1
Zygophyllum ovatum	1
FERN	**1**
(blank)	1
Marsilea sp.	1
GYMNO	**3**
(blank)	3
Callitris columellaris	1
Callitris verrucosa	2
MONOCOT	**11**
(blank)	11
Amphipogon caricinus	1
Aristida contorta	1
Aristida sp.	1
Austrostipa nitida	1
Austrostipa trichophylla	1

Digitaria brownii	1
Isolepis congrua	1
Thyridolepis mitchelliana	1
Thysanotus manglesianus	1
Triodia irritans	1
Triodia scariosa	1
Grand Total	**630**

Attachment 2: ‘Protected matters’ search tool output

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 20-Oct-2023

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance (Ramsar	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	9
Listed Migratory Species:	7

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	10
Whales and Other Cetaceans:	None
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None
Habitat Critical to the Survival of Marine Turtles:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	None
Regional Forest Agreements:	None
Nationally Important Wetlands:	None
EPBC Act Referrals:	5
Key Ecological Features (Marine):	None
Biologically Important Areas:	None
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

Listed Threatened Species			[Resource Information]
Status of Conservation Dependent and Extinct are not MNES under the EPBC Act. Number is the current name ID.			
Scientific Name	Threatened Category	Presence Text	Buffer Status
BIRD			
Aphelocephala leucopsis Southern Whiteface [529]	Vulnerable	Species or species habitat known to occur within area	In feature area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area	In feature area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat may occur within area	In feature area
Leipoa ocellata Malleefowl [934]	Vulnerable	Species or species habitat known to occur within area	In feature area
Pezoporus occidentalis Night Parrot [59350]	Endangered	Species or species habitat may occur within area	In feature area
Polytelis alexandrae Princess Parrot, Alexandra's Parrot [758]	Vulnerable	Species or species habitat may occur within area	In feature area
MAMMAL			
Dasyurus geoffroii Chuditch, Western Quoll [330]	Vulnerable	Species or species habitat may occur within area	In buffer area only
Sminthopsis psammophila Sandhill Dunnart [291]	Endangered	Species or species habitat likely to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
REPTILE			
Liopholis kintorei			
Great Desert Skink, Tjakura, Warrarna, Mulyamiji [83160]	Vulnerable	Species or species habitat may occur within area	In buffer area only

Listed Migratory Species [Resource Information]

Scientific Name	Threatened Category	Presence Text	Buffer Status
Migratory Marine Birds			
Apus pacificus			
Fork-tailed Swift [678]		Species or species habitat likely to occur within area	In feature area
Migratory Terrestrial Species			
Motacilla cinerea			
Grey Wagtail [642]		Species or species habitat may occur within area	In feature area
Motacilla flava			
Yellow Wagtail [644]		Species or species habitat may occur within area	In buffer area only
Migratory Wetlands Species			
Actitis hypoleucos			
Common Sandpiper [59309]		Species or species habitat may occur within area	In feature area
Calidris acuminata			
Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area	In feature area
Calidris ferruginea			
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area	In feature area
Calidris melanotos			
Pectoral Sandpiper [858]		Species or species habitat may occur within area	In feature area

Other Matters Protected by the EPBC Act

Listed Marine Species			[Resource Information]
Scientific Name	Threatened Category	Presence Text	Buffer Status
Bird			
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area	In feature area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area	In feature area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area	In feature area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area overfly marine area	In feature area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area overfly marine area	In feature area
Chalcites osculans as Chrysococcyx osculans Black-eared Cuckoo [83425]		Species or species habitat known to occur within area overfly marine area	In feature area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area overfly marine area	In feature area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area overfly marine area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area overfly marine area	In buffer area only
Thinornis cucullatus as Thinornis rubricollis Hooded Plover, Hooded Dotterel [87735]		Species or species habitat may occur within area overfly marine area	In feature area

Extra Information

EPBC Act Referrals				[Resource Information]
Title of referral	Reference	Referral Outcome	Assessment Status	Buffer Status
Northern Star Resources - Carosue Dam TSF Cell 4	2021/9026		Post-Approval	In buffer area only
Controlled action				
Tropicana Gold Project-Develop open cut gold mine, and associated infrastructure	2008/4270	Controlled Action	Post-Approval	In buffer area only
Not controlled action				
Construction of a bypass road, haulage contractor workshop & laydown yard	2012/6639	Not Controlled Action	Completed	In buffer area only
Improving rabbit biocontrol: releasing another strain of RHDV, sthn two thirds of Australia	2015/7522	Not Controlled Action	Completed	In feature area
Saracen Gold-Carosue Dam Aerodrome, WA	2017/7925	Not Controlled Action	Completed	In buffer area only

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

Department of Climate Change, Energy, the Environment and Water
GPO Box 3090
Canberra ACT 2601 Australia
+61 2 6274 1111

Attachment 3: List of flora taxa found at each inventory site

Family	Taxa	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
Amaranthaceae	*Ptilotus obovatus* var. *obovatus*	Y	Y	Y	Y	Y		Y	Y		Y	Y	Y	Y	Y	Y
Amaranthaceae	*Ptilotus exaltatus*															
Apocynaceae	*Alyxia buxifolia*		Y									Y		Y		
Apocynaceae	*Marsdenia australis*	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y		Y	
Asparagaceae	*Lomandra effusa*															
Asteraceae	*Asteraceae sp.*															
Asteraceae	*Asteridea athrixioides*								Y							
Asteraceae	*Brachyscome perpusilla*															
Asteraceae	*Brachyscome trachycarpa*	Y		Y		Y		Y	Y		Y		Y		Y	
Asteraceae	*Cratystylis microphylla*															
Asteraceae	*Cratystylis subspinescens*															
Asteraceae	*Olearia muelleri*			Y			Y	Y		Y	Y	Y		Y	Y	
Asteraceae	*Olearia pimeleoides*															
Asteraceae	*Vittadinia sulcata*	Y		Y				Y								
Azioaceae	*Gunniopsis quadrifida*															
Boraginaceae	*Halgania cyanea*															
Brassicaceae	*Lepidium platypetalum*															
Casuarinaceae	*Casuarina pauper*		Y	Y	Y		Y	Y	Y	Y	Y	Y		Y	Y	Y
Chenopodiaceae	*Atriplex bunburyana*		Y									Y				
Chenopodiaceae	*Atriplex vesicaria*															
Chenopodiaceae	*Atriplex codonocarpa*															
Chenopodiaceae	*Atriplex nummularia* subsp. *spathulata*											Y	Y			
Chenopodiaceae	*Chenopodium gaudichaudianum*													Y		
Chenopodiaceae	*Enchylaena lanata*	Y					Y	Y	Y							
Chenopodiaceae	*Enchylaena tomentosa* var. *tomentosa*	Y						Y	Y			Y				
Chenopodiaceae	*Eriochiton sclerolaenoides*															
Chenopodiaceae	*Maireana amoena*															
Chenopodiaceae	*Maireana atkinsiana*															
Chenopodiaceae	*Maireana georgei*			Y				Y			Y	Y		Y		Y
Chenopodiaceae	*Maireana glomerifolia*															
Chenopodiaceae	*Maireana integra*											Y			Y	
Chenopodiaceae	*Maireana planifolia*															
Chenopodiaceae	*Maireana pyramidata*							Y								
Chenopodiaceae	*Maireana sedifolia*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Chenopodiaceae	*Maireana tomentosa* subsp. *tomentosa*															
Chenopodiaceae	*Maireana trichoptera*															
Chenopodiaceae	*Maireana triptera*		Y	Y				Y			Y	Y				
Chenopodiaceae	*Maireana suaedifolia*															
Chenopodiaceae	*Rhagodia drummondii*															
Chenopodiaceae	*Rhagodia eremaea*					Y			Y	Y		Y	Y		Y	Y
Chenopodiaceae	*Salsola australis*													Y		
Chenopodiaceae	*Sclerolaena cuneata*															
Chenopodiaceae	*Sclerolaena densiflora*															
Chenopodiaceae	*Sclerolaena diacantha*							Y				Y				
Chenopodiaceae	*Sclerolaena eurotioides*															
Chenopodiaceae	*Sclerolaena obliquicuspis*															

Family	Taxa	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
Chenopodiaceae	*Sclerolaena fusiformis*							Y				Y				
Chenopodiaceae	*Tecticornia disarticulata*															
Chenopodiaceae	*Tecticornia pruinosa*															
Crassulaceae	*Crassula colorata* var. *colorata*							Y								
Fabaceae	*Acacia aptaneura*	Y	Y	Y	Y	Y			Y	Y	Y					Y
Fabaceae	*Acacia burkittii*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y
Fabaceae	*Acacia ceasaneura*											Y				Y
Fabaceae	*Acacia hemiteles*													Y		
Fabaceae	*Acacia inceana* subsp. *conformis*											Y				
Fabaceae	*Acacia incurvaneura*	Y			Y	Y		Y	Y	Y	Y	Y	Y	Y		Y
Fabaceae	*Acacia jennerae*	Y		Y						Y		Y	Y	Y		Y
Fabaceae	*Acacia nyssophylla*						Y						Y			
Fabaceae	*Acacia oswaldii*						Y					Y	Y	Y	Y	
Fabaceae	*Acacia ramulosa* var. *ramulosa*							Y	Y			Y	Y			Y
Fabaceae	*Acacia* sp.															
Fabaceae	*Acacia tetragonophylla*	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y
Fabaceae	*Acacia ayersiana*															
Fabaceae	*Acacia sibirica*											Y				
Fabaceae	*Senna artemisioides* subsp. ×*artemisioides*															
Fabaceae	*Senna artemisioides* subsp. *filifolia*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Fabaceae	*Senna cardiosperma*															
Fabaceae	*Templetonia incrassata*			Y			Y				Y	Y	Y	Y	Y	
Frankeniaceae	*Frankenia fecunda*															
Frankeniaceae	*Frankenia interioris*															
Frankeniaceae	*Frankenia setosa*															
Goodeniaceae	*Goodenia havilandii*										Y					
Goodeniaceae	*Scaevola spinescens*	Y	Y		Y	Y	Y			Y		Y	Y	Y	Y	Y
Lamiaceae	*Prostanthera althoferi* subsp. *althoferi*										Y					
Lamiaceae	*Teucrium teucriiflorum*															
Loranthaceae	*Amyema gibberula*						Y									
Loranthaceae	*Lysiana murrayi*				Y				Y							
Malvaceae	*Abutilon cryptopetalum*				Y											
Malvaceae	*Brachychiton gregorii*															
Malvaceae	*Sida* sp. dark green fruits (S van Leeuwen 2260)															
Malvaceae	*Sida spodochroma*															
Moniaceae	*Calandrinia polyandra*															
Myrtaceae	*Eucalyptus griffithsii*												Y			
Myrtaceae	*Eucalyptus loxophleba* subsp. *supralaevis*															
Myrtaceae	*Eucalyptus oleosa* subsp. *oleosa*															
Myrtaceae	*Eucalyptus yilgarnensis*															
Myrtaceae	*Eucalyptus salmonophloia*															
Myrtaceae	*Melaleuca eleuterostachya*															
Pittosporaceae	*Pittosporum angustifolium*															
Poaceae	*Aristida contorta*	Y	Y	Y	Y	Y					Y	Y				Y
Poaceae	*Austrostipa scabra*	Y	Y	Y	Y	Y			Y	Y	Y	Y		Y	Y	Y
Poaceae	*Austrostipa elegantissima*				Y	Y				Y		Y			Y	

Family	Taxa	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
Poaceae	*Enteropogon ramosus*															
Poaceae	*Eragrostis lanipes*															
Poaceae	*Paspelidium gracile*															
Poaceae	*Rytidosperma robertsoniae*	Y														
Poaceae	*Triodia scariosa*															
Primulaceae	*Lysimachia arvensis*															
Proteaceae	*Grevillea acuaria*															
Proteaceae	*Grevillea sarissa* subsp. *anfractifolia*															
Proteaceae	*Hakea preissii*															
Rubiaceae	*Psydrax suaveolens*															
Santalaceae	*Exocarpos aphyllus*															
Santalaceae	*Santalum spicatum*			Y			Y	Y	Y	Y		Y	Y			Y
Sapindaceae	*Alectryon oleifolius* subsp. *canescens*			Y			Y	Y		Y		Y	Y	Y	Y	
Sapindaceae	*Dodonaea lobulata*	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Sapindaceae	*Dodonaea viscosa*															
Sapindaceae	*Dodoneaa rigida*												Y			
Scrophulariaceae	*Eremophila alternifolia*	Y						Y		Y					Y	
Scrophulariaceae	*Eremophila caperata*															
Scrophulariaceae	*Eremophila decipiens* subsp. *decipiens*	Y	Y	Y							Y	Y			Y	
Scrophulariaceae	*Eremophila eriocalyx*			Y						Y	Y					
Scrophulariaceae	*Eremophila forrestii subsp. forrestii*															
Scrophulariaceae	*Eremophila glabra*															
Scrophulariaceae	*Eremophila granitica*			Y		Y		Y	Y	Y		Y				
Scrophulariaceae	*Eremophila latrobei* subsp. *latrobei*		Y													
Scrophulariaceae	*Eremophila oldfieldii* subsp. *angustifolia*			Y		Y	Y	Y	Y			Y	Y	Y	Y	Y
Scrophulariaceae	*Eremophila oppositifolia* subsp. *angustifolia*															
Scrophulariaceae	*Eremophila scoparia*							Y								
Scrophulariaceae	*Eremophila serrulata*															
Scrophulariaceae	*Eremophila arachnoides* subsp. *tenera*											Y				
Scrophulariaceae	*Eremophila longifolia*							Y	Y		Y					
Scrophulariaceae	*Eremophila miniata*															
Solanaceae	*Solanum lasiophyllum*		Y		Y					Y	Y					
Solanaceae	*Solanum plicatile*															
Thymelaeaceae	*Pimelea microcephala* subsp. *microcephala*							Y								
Zygophyllaceae	*Roepera eremaea*	Y												Y		
Zygophyllaceae	*Roepera ovata*													Y		

Family	*Taxa*	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Amaranthaceae	*Ptilotus obovatus* var. *obovatus*		Y	Y	Y	Y	Y	Y			Y	Y	Y	Y	Y	Y
Amaranthaceae	*Ptilotus exaltatus*															
Apocynaceae	*Alyxia buxifolia*															
Apocynaceae	*Marsdenia australis*	Y	Y	Y	Y		Y	Y	Y			Y	Y	Y	Y	
Asparagaceae	*Lomandra effusa*															
Asteraceae	*Asteraceae sp.*															
Asteraceae	*Asteridea athrixioides*															
Asteraceae	*Brachyscome perpusilla*															
Asteraceae	*Brachyscome trachycarpa*	Y														
Asteraceae	*Cratystylis microphylla*															
Asteraceae	*Cratystylis subspinescens*						Y			Y					Y	Y
Asteraceae	*Olearia muelleri*		Y	Y	Y	Y	Y				Y	Y	Y	Y	Y	Y
Asteraceae	*Olearia pimeleoides*															
Asteraceae	*Vittadinia sulcata*			Y												
Azioaceae	*Gunniopsis quadrifida*															Y
Boraginaceae	*Halgania cyanea*															
Brassicaceae	*Lepidium platypetalum*														Y	
Casuarinaceae	*Casuarina pauper*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Chenopodiaceae	*Atriplex bunburyana*			Y				Y						Y	Y	Y
Chenopodiaceae	*Atriplex vesicaria*								Y	Y						
Chenopodiaceae	*Atriplex codonocarpa*									Y						
Chenopodiaceae	*Atriplex nummularia* subsp. *spathulata*			Y			Y	Y	Y					Y	Y	
Chenopodiaceae	*Chenopodium gaudichaudianum*			Y		Y			Y							
Chenopodiaceae	*Enchylaena lanata*			Y												
Chenopodiaceae	*Enchylaena tomentosa* var. *tomentosa*			Y		Y								Y	Y	
Chenopodiaceae	*Eriochiton sclerolaenoides*							Y		Y						
Chenopodiaceae	*Maireana amoena*															
Chenopodiaceae	*Maireana atkinsiana*															
Chenopodiaceae	*Maireana georgei*					Y				Y				Y		Y
Chenopodiaceae	*Maireana glomerifolia*							Y		Y					Y	
Chenopodiaceae	*Maireana integra*					Y								Y		Y
Chenopodiaceae	*Maireana planifolia*															
Chenopodiaceae	*Maireana pyramidata*			Y				Y	Y	Y						
Chenopodiaceae	*Maireana sedifolia*		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Chenopodiaceae	*Maireana tomentosa* subsp. *tomentosa*								Y	Y						Y
Chenopodiaceae	*Maireana trichoptera*								Y	Y						
Chenopodiaceae	*Maireana triptera*		Y	Y		Y		Y				Y			Y	Y
Chenopodiaceae	*Maireana suaedifolia*															
Chenopodiaceae	*Rhagodia drummondii*			Y					Y						Y	
Chenopodiaceae	*Rhagodia eremaea*			Y	Y			Y						Y	Y	
Chenopodiaceae	*Salsola australis*					Y								Y		
Chenopodiaceae	*Sclerolaena cuneata*									Y						Y
Chenopodiaceae	*Sclerolaena densiflora*															
Chenopodiaceae	*Sclerolaena diacantha*			Y					Y	Y					Y	Y
Chenopodiaceae	*Sclerolaena eurotioides*															
Chenopodiaceae	*Sclerolaena obliquicuspis*													Y		

Family	*Taxa*	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Chenopodiaceae	*Sclerolaena fusiformis*															
Chenopodiaceae	*Tecticornia disarticulata*								Y	Y						
Chenopodiaceae	*Tecticornia pruinosa*															
Crassulaceae	*Crassula colorata* var. *colorata*															
Fabaceae	*Acacia aptaneura*								Y							
Fabaceae	*Acacia burkittii*	Y	Y	Y	Y	Y	Y	Y	Y			Y	Y	Y	Y	Y
Fabaceae	*Acacia ceasaneura*															
Fabaceae	*Acacia hemiteles*				Y	Y						Y	Y	Y	Y	Y
Fabaceae	*Acacia inceana* subsp. *conformis*														Y	
Fabaceae	*Acacia incurvaneura*	Y		Y	Y			Y						Y	Y	Y
Fabaceae	*Acacia jennerae*	Y	Y		Y	Y	Y	Y			Y	Y		Y	Y	
Fabaceae	*Acacia nyssophylla*		Y		Y						Y	Y	Y		Y	
Fabaceae	*Acacia oswaldii*	Y		Y		Y	Y				Y				Y	
Fabaceae	*Acacia ramulosa* var. *ramulosa*	Y														
Fabaceae	*Acacia* sp.				Y											
Fabaceae	*Acacia tetragonophylla*	Y	Y	Y	Y	Y	Y	Y	Y			Y	Y		Y	
Fabaceae	*Acacia ayersiana*															
Fabaceae	*Acacia sibirica*															
Fabaceae	*Senna artemisioides* subsp. ×*artemisioides*	Y														
Fabaceae	*Senna artemisioides* subsp. *filifolia*	Y	Y	Y	Y	Y	Y	Y	Y			Y	Y	Y	Y	Y
Fabaceae	*Senna cardiosperma*															
Fabaceae	*Templetonia incrassata*		Y	Y	Y	Y					Y	Y			Y	
Frankeniaceae	*Frankenia fecunda*															
Frankeniaceae	*Frankenia interioris*								Y	Y					Y	Y
Frankeniaceae	*Frankenia setosa*															
Goodeniaceae	*Goodenia havilandii*															
Goodeniaceae	*Scaevola spinescens*	Y	Y		Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y
Lamiaceae	*Prostanthera althoferi* subsp. *althoferi*															
Lamiaceae	*Teucrium teucriiflorum*															
Loranthaceae	*Amyema gibberula*															
Loranthaceae	*Lysiana murrayi*															
Malvaceae	*Abutilon cryptopetalum*															
Malvaceae	*Brachychiton gregorii*	Y														
Malvaceae	*Sida* sp. dark green fruits (S van Leeuwen 2260)															
Malvaceae	*Sida spodochroma*															
Moniaceae	*Calandrinia polyandra*															
Myrtaceae	*Eucalyptus griffithsii*															
Myrtaceae	*Eucalyptus loxophleba* subsp. *supralaevis*															
Myrtaceae	*Eucalyptus oleosa* subsp. *oleosa*	Y				Y									Y	Y
Myrtaceae	*Eucalyptus yilgarnensis*															
Myrtaceae	*Eucalyptus salmonophloia*		Y													
Myrtaceae	*Melaleuca eleuterostachya*															
Pittosporaceae	*Pittosporum angustifolium*			Y												
Poaceae	*Aristida contorta*															
Poaceae	*Austrostipa scabra*	Y		Y	Y					Y		Y	Y	Y		Y
Poaceae	*Austrostipa elegantissima*		Y	Y								Y	Y			

Family	*Taxa*	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Poaceae	*Enteropogon ramosus*															
Poaceae	*Eragrostis lanipes*															
Poaceae	*Paspelidium gracile*															
Poaceae	*Rytidosperma robertsoniae*							Y								Y
Poaceae	*Triodia scariosa*															
Primulaceae	*Lysimachia arvensis*															
Proteaceae	*Grevillea acuaria*															
Proteaceae	*Grevillea sarissa* subsp. *anfractifolia*															
Proteaceae	*Hakea preissii*			Y												
Rubiaceae	*Psydrax suaveolens*															
Santalaceae	*Exocarpos aphyllus*			Y						Y			Y		Y	
Santalaceae	*Santalum spicatum*	Y		Y			Y		Y							
Sapindaceae	*Alectryon oleifolius* subsp. *canescens*				Y	Y	Y					Y				
Sapindaceae	*Dodonaea lobulata*	Y	Y	Y	Y	Y	Y	Y	Y		Y		Y		Y	
Sapindaceae	*Dodonaea viscosa*															
Sapindaceae	*Dodoneaa rigida*	Y												Y	Y	
Scrophulariaceae	*Eremophila alternifolia*			Y									Y		Y	Y
Scrophulariaceae	*Eremophila caperata*															
Scrophulariaceae	*Eremophila decipiens* subsp. *decipiens*		Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y		Y
Scrophulariaceae	*Eremophila eriocalyx*															
Scrophulariaceae	*Eremophila forrestii subsp. forrestii*															
Scrophulariaceae	*Eremophila glabra*															
Scrophulariaceae	*Eremophila granitica*	Y		Y								Y			Y	
Scrophulariaceae	*Eremophila latrobei* subsp. *latrobei*															
Scrophulariaceae	*Eremophila oldfieldii* subsp. *angustifolia*	Y	Y	Y	Y		Y	Y	Y		Y					Y
Scrophulariaceae	*Eremophila oppositifolia* subsp. *angustifolia*					Y					Y					
Scrophulariaceae	*Eremophila scoparia*		Y	Y		Y				Y	Y			Y	Y	Y
Scrophulariaceae	*Eremophila serrulata*															
Scrophulariaceae	*Eremophila arachnoides* subsp. *tenera*															
Scrophulariaceae	*Eremophila longifolia*															
Scrophulariaceae	*Eremophila miniata*															
Solanaceae	*Solanum lasiophyllum*			Y												
Solanaceae	*Solanum plicatile*															
Thymelaeaceae	*Pimelea microcephala* subsp. *microcephala*															
Zygophyllaceae	*Roepera eremaea*															
Zygophyllaceae	*Roepera ovata*															

Family	*Taxa*	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Amaranthaceae	*Ptilotus obovatus* var. *obovatus*		Y	Y	Y	Y	Y	Y			Y	Y	Y	Y	Y	Y
Amaranthaceae	*Ptilotus exaltatus*															
Apocynaceae	*Alyxia buxifolia*															
Apocynaceae	*Marsdenia australis*	Y	Y	Y	Y		Y	Y	Y			Y	Y	Y	Y	
Asparagaceae	*Lomandra effusa*															
Asteraceae	*Asteraceae sp.*															
Asteraceae	*Asteridea athrixioides*															
Asteraceae	*Brachyscome perpusilla*															
Asteraceae	*Brachyscome trachycarpa*	Y														
Asteraceae	*Cratystylis microphylla*															
Asteraceae	*Cratystylis subspinescens*						Y			Y					Y	Y
Asteraceae	*Olearia muelleri*		Y	Y	Y	Y	Y				Y	Y	Y	Y	Y	Y
Asteraceae	*Olearia pimeleoides*															
Asteraceae	*Vittadinia sulcata*			Y												
Azioaceae	*Gunniopsis quadrifida*															Y
Boraginaceae	*Halgania cyanea*															
Brassicaceae	*Lepidium platypetalum*														Y	
Casuarinaceae	*Casuarina pauper*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Chenopodiaceae	*Atriplex bunburyana*			Y				Y						Y	Y	Y
Chenopodiaceae	*Atriplex vesicaria*								Y	Y						
Chenopodiaceae	*Atriplex codonocarpa*									Y						
Chenopodiaceae	*Atriplex nummularia* subsp. *spathulata*			Y			Y	Y	Y					Y	Y	
Chenopodiaceae	*Chenopodium gaudichaudianum*			Y		Y			Y							
Chenopodiaceae	*Enchylaena lanata*			Y												
Chenopodiaceae	*Enchylaena tomentosa* var. *tomentosa*			Y		Y								Y	Y	
Chenopodiaceae	*Eriochiton sclerolaenoides*							Y		Y						
Chenopodiaceae	*Maireana amoena*															
Chenopodiaceae	*Maireana atkinsiana*															
Chenopodiaceae	*Maireana georgei*					Y				Y				Y		Y
Chenopodiaceae	*Maireana glomerifolia*							Y		Y					Y	
Chenopodiaceae	*Maireana integra*					Y								Y		Y
Chenopodiaceae	*Maireana planifolia*															
Chenopodiaceae	*Maireana pyramidata*			Y				Y	Y	Y						
Chenopodiaceae	*Maireana sedifolia*		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Chenopodiaceae	*Maireana tomentosa* subsp. *tomentosa*								Y	Y						Y
Chenopodiaceae	*Maireana trichoptera*								Y	Y						
Chenopodiaceae	*Maireana triptera*		Y	Y		Y		Y				Y			Y	Y
Chenopodiaceae	*Maireana suaedifolia*															
Chenopodiaceae	*Rhagodia drummondii*			Y					Y						Y	
Chenopodiaceae	*Rhagodia eremaea*			Y	Y			Y						Y	Y	
Chenopodiaceae	*Salsola australis*					Y								Y		
Chenopodiaceae	*Sclerolaena cuneata*									Y						Y
Chenopodiaceae	*Sclerolaena densiflora*															
Chenopodiaceae	*Sclerolaena diacantha*			Y					Y	Y					Y	Y
Chenopodiaceae	*Sclerolaena eurotioides*															
Chenopodiaceae	*Sclerolaena obliquicuspis*													Y		

Family	*Taxa*	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Chenopodiaceae	*Sclerolaena fusiformis*															
Chenopodiaceae	*Tecticornia disarticulata*								Y	Y						
Chenopodiaceae	*Tecticornia pruinosa*															
Crassulaceae	*Crassula colorata* var. *colorata*															
Fabaceae	*Acacia aptaneura*								Y							
Fabaceae	*Acacia burkittii*	Y	Y	Y	Y	Y	Y	Y	Y			Y	Y	Y	Y	Y
Fabaceae	*Acacia ceasaneura*															
Fabaceae	*Acacia hemiteles*				Y	Y						Y	Y	Y	Y	Y
Fabaceae	*Acacia inceana* subsp. *conformis*														Y	
Fabaceae	*Acacia incurvaneura*	Y		Y	Y			Y						Y	Y	Y
Fabaceae	*Acacia jennerae*	Y	Y		Y	Y	Y	Y			Y	Y		Y	Y	
Fabaceae	*Acacia nyssophylla*		Y		Y						Y	Y	Y		Y	
Fabaceae	*Acacia oswaldii*	Y		Y		Y	Y				Y				Y	
Fabaceae	*Acacia ramulosa* var. *ramulosa*	Y														
Fabaceae	*Acacia* sp.				Y											
Fabaceae	*Acacia tetragonophylla*	Y	Y	Y	Y	Y	Y	Y	Y			Y	Y		Y	
Fabaceae	*Acacia ayersiana*															
Fabaceae	*Acacia sibirica*															
Fabaceae	*Senna artemisioides* subsp. ×*artemisioides*	Y														
Fabaceae	*Senna artemisioides* subsp. *filifolia*	Y	Y	Y	Y	Y	Y	Y	Y			Y	Y	Y	Y	Y
Fabaceae	*Senna cardiosperma*															
Fabaceae	*Templetonia incrassata*		Y	Y	Y	Y					Y	Y			Y	
Frankeniaceae	*Frankenia fecunda*															
Frankeniaceae	*Frankenia interioris*								Y	Y					Y	Y
Frankeniaceae	*Frankenia setosa*															
Goodeniaceae	*Goodenia havilandii*															
Goodeniaceae	*Scaevola spinescens*	Y	Y		Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y
Lamiaceae	*Prostanthera althoferi* subsp. *althoferi*															
Lamiaceae	*Teucrium teucriiflorum*															
Loranthaceae	*Amyema gibberula*															
Loranthaceae	*Lysiana murrayi*															
Malvaceae	*Abutilon cryptopetalum*															
Malvaceae	*Brachychiton gregorii*	Y														
Malvaceae	*Sida* sp. dark green fruits (S van Leeuwen 2260)															
Malvaceae	*Sida spodochroma*															
Moniaceae	*Calandrinia polyandra*															
Myrtaceae	*Eucalyptus griffithsii*															
Myrtaceae	*Eucalyptus loxophleba* subsp. *supralaevis*															
Myrtaceae	*Eucalyptus oleosa* subsp. *oleosa*	Y				Y									Y	Y
Myrtaceae	*Eucalyptus yilgarnensis*															
Myrtaceae	*Eucalyptus salmonophloia*		Y													
Myrtaceae	*Melaleuca eleuterostachya*															
Pittosporaceae	*Pittosporum angustifolium*			Y												
Poaceae	*Aristida contorta*															
Poaceae	*Austrostipa scabra*	Y		Y	Y					Y		Y	Y	Y		Y
Poaceae	*Austrostipa elegantissima*		Y	Y								Y	Y			

Family	*Taxa*	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Poaceae	*Enteropogon ramosus*															
Poaceae	*Eragrostis lanipes*															
Poaceae	*Paspelidium gracile*															
Poaceae	*Rytidosperma robertsoniae*							Y								Y
Poaceae	*Triodia scariosa*															
Primulaceae	*Lysimachia arvensis*															
Proteaceae	*Grevillea acuaria*															
Proteaceae	*Grevillea sarissa* subsp. *anfractifolia*															
Proteaceae	*Hakea preissii*			Y												
Rubiaceae	*Psydrax suaveolens*															
Santalaceae	*Exocarpos aphyllus*			Y						Y			Y		Y	
Santalaceae	*Santalum spicatum*	Y		Y			Y		Y							
Sapindaceae	*Alectryon oleifolius* subsp. *canescens*				Y	Y	Y					Y				
Sapindaceae	*Dodonaea lobulata*	Y	Y	Y	Y	Y	Y	Y	Y		Y		Y		Y	
Sapindaceae	*Dodonaea viscosa*															
Sapindaceae	*Dodoneaa rigida*	Y												Y	Y	
Scrophulariaceae	*Eremophila alternifolia*			Y									Y		Y	Y
Scrophulariaceae	*Eremophila caperata*															
Scrophulariaceae	*Eremophila decipiens* subsp. *decipiens*		Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y		Y
Scrophulariaceae	*Eremophila eriocalyx*															
Scrophulariaceae	*Eremophila forrestii subsp. forrestii*															
Scrophulariaceae	*Eremophila glabra*															
Scrophulariaceae	*Eremophila granitica*	Y		Y								Y			Y	
Scrophulariaceae	*Eremophila latrobei* subsp. *latrobei*															
Scrophulariaceae	*Eremophila oldfieldii* subsp. *angustifolia*	Y	Y	Y	Y		Y	Y	Y		Y					Y
Scrophulariaceae	*Eremophila oppositifolia* subsp. *angustifolia*					Y					Y					
Scrophulariaceae	*Eremophila scoparia*		Y	Y		Y				Y	Y			Y	Y	Y
Scrophulariaceae	*Eremophila serrulata*															
Scrophulariaceae	*Eremophila arachnoides* subsp. *tenera*															
Scrophulariaceae	*Eremophila longifolia*															
Scrophulariaceae	*Eremophila miniata*															
Solanaceae	*Solanum lasiophyllum*			Y												
Solanaceae	*Solanum plicatile*															
Thymelaeaceae	*Pimelea microcephala* subsp. *microcephala*															
Zygophyllaceae	*Roepera eremaea*															
Zygophyllaceae	*Roepera ovata*															

Family	Taxa	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Amaranthaceae	*Ptilotus obovatus* var. *obovatus*		Y	Y	Y	Y	Y	Y			Y	Y	Y	Y	Y	Y
Amaranthaceae	*Ptilotus exaltatus*															
Apocynaceae	*Alyxia buxifolia*															
Apocynaceae	*Marsdenia australis*	Y	Y	Y	Y		Y	Y	Y			Y	Y	Y	Y	
Asparagaceae	*Lomandra effusa*															
Asteraceae	*Asteraceae sp.*															
Asteraceae	*Asteridea athrixioides*															
Asteraceae	*Brachyscome perpusilla*															
Asteraceae	*Brachyscome trachycarpa*	Y														
Asteraceae	*Cratystylis microphylla*															
Asteraceae	*Cratystylis subspinescens*						Y			Y					Y	Y
Asteraceae	*Olearia muelleri*		Y	Y	Y	Y	Y				Y	Y	Y	Y	Y	Y
Asteraceae	*Olearia pimeleoides*															
Asteraceae	*Vittadinia sulcata*			Y												
Azioaceae	*Gunniopsis quadrifida*															Y
Boraginaceae	*Halgania cyanea*															
Brassicaceae	*Lepidium platypetalum*														Y	
Casuarinaceae	*Casuarina pauper*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Chenopodiaceae	*Atriplex bunburyana*			Y				Y						Y	Y	Y
Chenopodiaceae	*Atriplex vesicaria*								Y	Y						
Chenopodiaceae	*Atriplex codonocarpa*									Y						
Chenopodiaceae	*Atriplex nummularia* subsp. *spathulata*			Y			Y	Y	Y					Y	Y	
Chenopodiaceae	*Chenopodium gaudichaudianum*			Y		Y			Y							
Chenopodiaceae	*Enchylaena lanata*			Y												
Chenopodiaceae	*Enchylaena tomentosa* var. *tomentosa*			Y		Y								Y	Y	
Chenopodiaceae	*Eriochiton sclerolaenoides*							Y		Y						
Chenopodiaceae	*Maireana amoena*															
Chenopodiaceae	*Maireana atkinsiana*															
Chenopodiaceae	*Maireana georgei*					Y				Y				Y		Y
Chenopodiaceae	*Maireana glomerifolia*							Y		Y					Y	
Chenopodiaceae	*Maireana integra*					Y								Y		Y
Chenopodiaceae	*Maireana planifolia*															
Chenopodiaceae	*Maireana pyramidata*			Y				Y	Y	Y						
Chenopodiaceae	*Maireana sedifolia*		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Chenopodiaceae	*Maireana tomentosa* subsp. *tomentosa*								Y	Y						Y
Chenopodiaceae	*Maireana trichoptera*								Y	Y						
Chenopodiaceae	*Maireana triptera*		Y	Y		Y		Y				Y			Y	Y
Chenopodiaceae	*Maireana suaedifolia*															
Chenopodiaceae	*Rhagodia drummondii*			Y					Y						Y	
Chenopodiaceae	*Rhagodia eremaea*			Y	Y			Y						Y	Y	
Chenopodiaceae	*Salsola australis*					Y								Y		
Chenopodiaceae	*Sclerolaena cuneata*									Y						Y
Chenopodiaceae	*Sclerolaena densiflora*															
Chenopodiaceae	*Sclerolaena diacantha*			Y					Y	Y					Y	Y
Chenopodiaceae	*Sclerolaena eurotioides*															

Family	Taxa	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Chenopodiaceae	*Sclerolaena obliquicuspis*													Y		
Chenopodiaceae	*Sclerolaena fusiformis*															
Chenopodiaceae	*Tecticornia disarticulata*								Y	Y						
Chenopodiaceae	*Tecticornia pruinosa*															
Crassulaceae	*Crassula colorata* var. *colorata*															
Fabaceae	*Acacia aptaneura*								Y							
Fabaceae	*Acacia burkittii*	Y	Y	Y	Y	Y	Y	Y	Y			Y	Y	Y	Y	Y
Fabaceae	*Acacia ceasaneura*															
Fabaceae	*Acacia hemiteles*				Y	Y						Y	Y	Y	Y	Y
Fabaceae	*Acacia inceana* subsp. *conformis*														Y	
Fabaceae	*Acacia incurvaneura*	Y		Y	Y			Y						Y	Y	Y
Fabaceae	*Acacia jennerae*	Y	Y		Y	Y	Y	Y			Y	Y		Y	Y	
Fabaceae	*Acacia nyssophylla*		Y		Y						Y	Y	Y		Y	
Fabaceae	*Acacia oswaldii*	Y		Y		Y	Y				Y				Y	
Fabaceae	*Acacia ramulosa* var. *ramulosa*	Y														
Fabaceae	*Acacia* sp.				Y											
Fabaceae	*Acacia tetragonophylla*	Y	Y	Y	Y	Y	Y	Y	Y			Y	Y		Y	
Fabaceae	*Acacia ayersiana*															
Fabaceae	*Acacia sibirica*															
Fabaceae	*Senna artemisioides* subsp. ×*artemisioides*	Y														
Fabaceae	*Senna artemisioides* subsp. *filifolia*	Y	Y	Y	Y	Y	Y	Y	Y			Y	Y	Y	Y	Y
Fabaceae	*Senna cardiosperma*															
Fabaceae	*Templetonia incrassata*		Y	Y	Y	Y					Y	Y			Y	
Frankeniaceae	*Frankenia fecunda*															
Frankeniaceae	*Frankenia interioris*								Y	Y					Y	Y
Frankeniaceae	*Frankenia setosa*															
Goodeniaceae	*Goodenia havilandii*															
Goodeniaceae	*Scaevola spinescens*	Y	Y		Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y
Lamiaceae	*Prostanthera althoferi* subsp. *althoferi*															
Lamiaceae	*Teucrium teucriiflorum*															
Loranthaceae	*Amyema gibberula*															
Loranthaceae	*Lysiana murrayi*															
Malvaceae	*Abutilon cryptopetalum*															
Malvaceae	*Brachychiton gregorii*	Y														
Malvaceae	*Sida* sp. dark green fruits (S van Leeuwen 2260)															
Malvaceae	*Sida spodochroma*															
Moniaceae	*Calandrinia polyandra*															
Myrtaceae	*Eucalyptus griffithsii*															
Myrtaceae	*Eucalyptus loxophleba* subsp. *supralaevis*															
Myrtaceae	*Eucalyptus oleosa* subsp. *oleosa*	Y				Y									Y	Y
Myrtaceae	*Eucalyptus yilgarnensis*															
Myrtaceae	*Eucalyptus salmonophloia*		Y													
Myrtaceae	*Melaleuca eleuterostachya*															
Pittosporaceae	*Pittosporum angustifolium*			Y												
Poaceae	*Aristida contorta*															

Family	Taxa	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Poaceae	*Austrostipa scabra*	Y		Y	Y					Y		Y	Y	Y		Y
Poaceae	*Austrostipa elegantissima*		Y	Y								Y	Y			
Poaceae	*Enteropogon ramosus*															
Poaceae	*Eragrostis lanipes*															
Poaceae	*Paspelidium gracile*															
Poaceae	*Rytidosperma robertsoniae*							Y								Y
Poaceae	*Triodia scariosa*															
Primulaceae	*Lysimachia arvensis*															
Proteaceae	*Grevillea acuaria*															
Proteaceae	*Grevillea sarissa* subsp. *anfractifolia*															
Proteaceae	*Hakea preissii*			Y												
Rubiaceae	*Psydrax suaveolens*															
Santalaceae	*Exocarpos aphyllus*			Y						Y			Y		Y	
Santalaceae	*Santalum spicatum*	Y		Y			Y		Y							
Sapindaceae	*Alectryon oleifolius* subsp. *canescens*				Y	Y	Y					Y				
Sapindaceae	*Dodonaea lobulata*	Y	Y	Y	Y	Y	Y	Y	Y		Y		Y		Y	
Sapindaceae	*Dodonaea viscosa*															
Sapindaceae	*Dodoneaa rigida*	Y												Y	Y	
Scrophulariaceae	*Eremophila alternifolia*			Y									Y		Y	Y
Scrophulariaceae	*Eremophila caperata*															
Scrophulariaceae	*Eremophila decipiens* subsp. *decipiens*		Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y		Y
Scrophulariaceae	*Eremophila eriocalyx*															
Scrophulariaceae	*Eremophila forrestii subsp. forrestii*															
Scrophulariaceae	*Eremophila glabra*															
Scrophulariaceae	*Eremophila granitica*	Y		Y								Y			Y	
Scrophulariaceae	*Eremophila latrobei* subsp. *latrobei*															
Scrophulariaceae	*Eremophila oldfieldii* subsp. *angustifolia*	Y	Y	Y	Y		Y	Y	Y		Y					Y
Scrophulariaceae	*Eremophila oppositifolia* subsp. *angustifolia*					Y					Y					
Scrophulariaceae	*Eremophila scoparia*		Y	Y		Y				Y	Y			Y	Y	Y
Scrophulariaceae	*Eremophila serrulata*															
Scrophulariaceae	*Eremophila arachnoides* subsp. *tenera*															
Scrophulariaceae	*Eremophila longifolia*															
Scrophulariaceae	*Eremophila miniata*															
Solanaceae	*Solanum lasiophyllum*			Y												
Solanaceae	*Solanum plicatile*															
Thymelaeaceae	*Pimelea microcephala* subsp. *microcephala*															
Zygophyllaceae	*Roepera eremaea*															
Zygophyllaceae	*Roepera ovata*															

Family	*Taxa*	61	62	63	64	65	Counts
Amaranthaceae	*Ptilotus obovatus* var. *obovatus*	Y	Y	Y	Y	Y	51
Amaranthaceae	*Ptilotus exaltatus*						1
Apocynaceae	*Alyxia buxifolia*						3
Apocynaceae	*Marsdenia australis*	Y	Y	Y	Y	Y	48
Asparagaceae	*Lomandra effusa*						1
Asteraceae	*Asteraceae sp.*						1
Asteraceae	*Asteridea athrixioides*	Y					2
Asteraceae	*Brachyscome perpusilla*	Y					4
Asteraceae	*Brachyscome trachycarpa*						11
Asteraceae	*Cratystylis microphylla*						1
Asteraceae	*Cratystylis subspinescens*						16
Asteraceae	*Olearia muelleri*	Y	Y				38
Asteraceae	*Olearia pimeleoides*						3
Asteraceae	*Vittadinia sulcata*	Y					6
Azioaceae	*Gunniopsis quadrifida*						8
Boraginaceae	*Halgania cyanea*						2
Brassicaceae	*Lepidium platypetalum*						1
Casuarinaceae	*Casuarina pauper*	Y	Y	Y	Y	Y	53
Chenopodiaceae	*Atriplex bunburyana*		Y	Y			18
Chenopodiaceae	*Atriplex vesicaria*						6
Chenopodiaceae	*Atriplex codonocarpa*						4
Chenopodiaceae	*Atriplex nummularia* subsp. *spathulata*		Y				13
Chenopodiaceae	*Chenopodium gaudichaudianum*						5
Chenopodiaceae	*Enchylaena lanata*		Y				7
Chenopodiaceae	*Enchylaena tomentosa* var. *tomentosa*						15
Chenopodiaceae	*Eriochiton sclerolaenoides*						2
Chenopodiaceae	*Maireana amoena*						2
Chenopodiaceae	*Maireana atkinsiana*						1
Chenopodiaceae	*Maireana georgei*						24
Chenopodiaceae	*Maireana glomerifolia*						10
Chenopodiaceae	*Maireana integra*						8
Chenopodiaceae	*Maireana planifolia*						1
Chenopodiaceae	*Maireana pyramidata*						12
Chenopodiaceae	*Maireana sedifolia*	Y	Y	Y	Y		51
Chenopodiaceae	*Maireana tomentosa* subsp. *tomentosa*						14
Chenopodiaceae	*Maireana trichoptera*						2
Chenopodiaceae	*Maireana triptera*						24
Chenopodiaceae	*Maireana suaedifolia*						1
Chenopodiaceae	*Rhagodia drummondii*						12
Chenopodiaceae	*Rhagodia eremaea*			Y	Y		21
Chenopodiaceae	*Salsola australis*						10
Chenopodiaceae	*Sclerolaena cuneata*						8
Chenopodiaceae	*Sclerolaena densiflora*						3
Chenopodiaceae	*Sclerolaena diacantha*	Y					18
Chenopodiaceae	*Sclerolaena eurotioides*						5

Family	*Taxa*	61	62	63	64	65	Counts
Chenopodiaceae	*Sclerolaena obliquicuspis*						3
Chenopodiaceae	*Sclerolaena fusiformis*						2
Chenopodiaceae	*Tecticornia disarticulata*						2
Chenopodiaceae	*Tecticornia pruinosa*						1
Crassulaceae	*Crassula colorata* var. *colorata*						1
Fabaceae	*Acacia aptaneura*	Y		Y			20
Fabaceae	*Acacia burkittii*	Y	Y	Y			53
Fabaceae	*Acacia ceasaneura*						2
Fabaceae	*Acacia hemiteles*		Y				28
Fabaceae	*Acacia inceana* subsp. *conformis*						8
Fabaceae	*Acacia incurvaneura*	Y	Y	Y	Y	Y	43
Fabaceae	*Acacia jennerae*				Y	Y	24
Fabaceae	*Acacia nyssophylla*		Y				18
Fabaceae	*Acacia oswaldii*	Y		Y		Y	19
Fabaceae	*Acacia ramulosa* var. *ramulosa*		Y		Y	Y	13
Fabaceae	*Acacia* sp.						2
Fabaceae	*Acacia tetragonophylla*	Y	Y		Y	Y	43
Fabaceae	*Acacia ayersiana*				Y	Y	6
Fabaceae	*Acacia sibirica*				Y		11
Fabaceae	*Senna artemisioides* subsp. ×*artemisioides*						2
Fabaceae	*Senna artemisioides* subsp. *filifolia*	Y	Y	Y		Y	54
Fabaceae	*Senna cardiosperma*						1
Fabaceae	*Templetonia incrassata*						19
Frankeniaceae	*Frankenia fecunda*						1
Frankeniaceae	*Frankenia interioris*						13
Frankeniaceae	*Frankenia setosa*						1
Goodeniaceae	*Goodenia havilandii*						2
Goodeniaceae	*Scaevola spinescens*	Y		Y	Y	Y	52
Lamiaceae	*Prostanthera althoferi* subsp. *althoferi*						4
Lamiaceae	*Teucrium teucriiflorum*						1
Loranthaceae	*Amyema gibberula*						1
Loranthaceae	*Lysiana murrayi*						7
Malvaceae	*Abutilon cryptopetalum*						1
Malvaceae	*Brachychiton gregorii*				Y	Y	4
Malvaceae	*Sida* sp. dark green fruits (S van Leeuwen 2260)						2
Malvaceae	*Sida spodochroma*						4
Moniaceae	*Calandrinia polyandra*						2
Myrtaceae	*Eucalyptus griffithsii*						1
Myrtaceae	*Eucalyptus loxophleba* subsp. *supralaevis*						4
Myrtaceae	*Eucalyptus oleosa* subsp. *oleosa*					Y	12
Myrtaceae	*Eucalyptus yilgarnensis*						1
Myrtaceae	*Eucalyptus salmonophloia*						1
Myrtaceae	*Melaleuca eleuterostachya*						1
Pittosporaceae	*Pittosporum angustifolium*						3
Poaceae	*Aristida contorta*		Y				13

Family	*Taxa*	61	62	63	64	65	Counts
Poaceae	*Austrostipa scabra*	Y	Y				35
Poaceae	*Austrostipa elegantissima*	Y	Y	Y			22
Poaceae	*Enteropogon ramosus*						2
Poaceae	*Eragrostis lanipes*						1
Poaceae	*Paspelidium gracile*						1
Poaceae	*Rytidosperma robertsoniae*	Y					5
Poaceae	*Triodia scariosa*						1
Primulaceae	*Lysimachia arvensis*						1
Proteaceae	*Grevillea acuaria*						5
Proteaceae	*Grevillea sarissa* subsp. *anfractifolia*						5
Proteaceae	*Hakea preissii*						5
Rubiaceae	*Psydrax suaveolens*						1
Santalaceae	*Exocarpos aphyllus*		Y				13
Santalaceae	*Santalum spicatum*	Y	Y	Y			24
Sapindaceae	*Alectryon oleifolius* subsp. *canescens*		Y	Y			18
Sapindaceae	*Dodonaea lobulata*	Y	Y	Y	Y	Y	41
Sapindaceae	*Dodonaea viscosa*				Y	Y	2
Sapindaceae	*Dodoneaa rigida*						9
Scrophulariaceae	*Eremophila alternifolia*						12
Scrophulariaceae	*Eremophila caperata*						1
Scrophulariaceae	*Eremophila decipiens* subsp. *decipiens*						27
Scrophulariaceae	*Eremophila eriocalyx*				Y	Y	8
Scrophulariaceae	*Eremophila forrestii subsp. forrestii*				Y		4
Scrophulariaceae	*Eremophila glabra*					Y	4
Scrophulariaceae	*Eremophila granitica*		Y				28
Scrophulariaceae	*Eremophila latrobei* subsp. *latrobei*				Y	Y	5
Scrophulariaceae	*Eremophila oldfieldii* subsp. *angustifolia*	Y	Y	Y	Y	Y	28
Scrophulariaceae	*Eremophila oppositifolia* subsp. *angustifolia*						9
Scrophulariaceae	*Eremophila scoparia*			Y			25
Scrophulariaceae	*Eremophila serrulata*				Y		1
Scrophulariaceae	*Eremophila arachnoides* subsp. *tenera*						3
Scrophulariaceae	*Eremophila longifolia*					Y	8
Scrophulariaceae	*Eremophila miniata*						2
Solanaceae	*Solanum lasiophyllum*	Y					14
Solanaceae	*Solanum plicatile*						1
Thymelaeaceae	*Pimelea microcephala* subsp. *microcephala*						1
Zygophyllaceae	*Roepera eremaea*						3
Zygophyllaceae	*Roepera ovata*						1

Attachment 4: Inventory site data on landform soil type and erosion.

Site	Land unit	Geol. unit	Slope	Relief	Land form	Soil type		Erosion	Geomorphological description	Soil description
			%	m		A	B			
QE01	4c	CZc	<1		flat	scl*	lc	stable	Near level extensive plain with minor deflated surfaces	Deep calcareous gradational
QE02	4c	CZc	<1		flat	scl	lc	90% stable	Near level extensive plain with minor deflated surfaces and diffuse overland flows	Deep calcareous gradational
QE03	4c	CZc	<1		flat	scl	lc	95% stable	Near level extensive plain with diffuse overland flow and more concentrated broad flow zones	Deep calcareous gradational
QE04	4c	CZc	<1		flat	scl	lc	stable	Near level extensive plain with diffuse overland flow	Deep calcareous gradational
QE05	6a	CZc	<1		flat	scl	lc	70% stable	Broad flow zone with diffuse overland flow with moderate deflated surfaces	Deep slightly calcareous gradational
QE06	4c	CZc	<1		flat	scl	lc	90% stable	Slightly elevated above extensive near level plain with abundant quartz fragments	Deep calcareous gradational
QE07	6a	Qa	1		drainage tract	scl	lc	90% stable	Broad drainage tract with incised channels 30cmx2m wide deeper towards Lake Rebecca	Deep non-calcareous gradational
QE08	6a	Qa	1.5		drainage tract	scl	lc	70%stable	Broad drainage tract with incised channels and extensive bare scalded flow zones with multiple unstable shallow rills.	Deep non-calcareous gradational
QE09	4c	CZc	<1		flat	lc	lc	stable	Near level extensive plain with diffuse overland flow	Deep calcareous light clay
QE10	4c	CZc	<1		flat	scl	lc	stable	Near level extensive plain with diffuse overland flow	Deep calcareous gradational
QE11	4a	CZc	1.5		lower slope	sl	scl	70%stable	Gently inclined plain with extensive deflated surfaces and minor rilling within concentrated flow zones	Deep calcareous gradational
QE12	4a	CZc	1.5		mid slope	scl	lc	stable	Broad sandy rise with diffuse overland flow. MF nest nearby	Deep non-calcareous gradational
QE13	4c	CZc	1.5		mid slope	sl	sl	stable	Gently inclined plain with diffuse overland flow and no concentrated flow zones	Shallow sandy loam over calcrete
QE14	4c	CZc	1		lower slope	scl	scl	stable	Gently inclined plain with diffuse overland flow and minor concentrated flow zones	Shallow sandy clay loam over calcrete
QE15	4a	CZc	1.5		lower slope	scl	lc	80%stable	Gently inclined plain with diffuse overland flow and moderate scalds in concentrated flow zones	Deep calcareous gradational
QE16	4a	CZc	1.5			scl		90% stable	Gently inclined plain with diffuse overland flow.	Shallow sandy clay loam over calcrete
QE17	4c	CZc	1	5	upper slope	scl		stable	Gentle quartzy rise with diffuse overland flow	Shallow sandy clay loam over calcrete
QE18	6a	Qa	2		drainage tract	scl	lc	80%stable	Broad drainage tract with numerous incised channels to 50cm deep.	Deep non-calcareous gradational
QE19	2a	CZc	2	5	mid slope	scl	scl	stable	Gentle rise to 5m with an abundant mantle of ironstone fine gravel and quartz fragments	Deep calcareous sandy clay loam
QE20	4c	CZc	<1		flat	scl	scl	95% stable	Near level plain with diffuse overland flow and mostly intact surfaces	Deep calcareous sandy clay loam
QE21	2a	CZc	2.5	10	upper slope	scl		stable	Gentle rise to 10m with an abundant mantle of ironstone fine gravel and quartz outcrops	Shallow sandy clay loam over calcrete

Site	Land unit	Geol. unit	Slope	Relief	Land form	Soil type		Erosion	Geomorphological description	Soil description
			%	m		A	B			
QE22	1c	AFS	4	10	Hillock	scl		stable	Rounded hillock to 10m with exposed felsics and 100% mantle of gravels and cobbles	Shallow sandy clay loam over calcrete
QE23	5b	CZc	1.5		lower slope	scl	lc	60% stable	Broad alluvial gently inclined plain with extensive erosion	Deep calcareous gradational
QE24	5b	CZc	1		flat	scl	lc	mostly stable	Saline alluvial gently inclined plain with extensive deflated surfaces	Deep calcareous gradational
QE25	4c	CZc	1.5	5	mid slope	sl	scl	stable	Gently inclined plain with diffuse overland flow	Shallow gradational over calcrete
QE26	4c	CZc	<1		flat	scl		stable	Extensive near level plain with diffuse overland flow	Deep calcareous sandy clay loam
QE27	4c	CZc	1		drainage tract	scl	lc	stable	Minor drainage tract within unit 4c. Mostly un-channelled drainage	Deep calcareous gradational
QE28	4c	CZc	1		flat	sl	slc	stable	Extensive gently inclined plain with diffuse overland flow	Deep calcareous gradational
QE29	5b	CZc	1		flat	sl	scl	stable	Extensive gently inclined plain with diffuse overland flow, deflated surfaces and minor concentrated flow zones	Deep calcareous gradational
QE30	4c	CZc	1			scl	lc	mostly stable	Extensive gently inclined plain with diffuse overland flow	Deep calcareous gradational
QE31	1d	CZc	3	5	dune	ls		mostly stable	Sandy rise surrounding birridah with gently inclined back slopes	Deep non-calcaereous loamy sand
QE32	1d	CZc	2	4	dune	s		mostly unstable	Low sandy rise adjoining lake Rebecca with extensive bare windswept areas	Deep non-calcaereous sand
QE33	7c	CZc				s	lc	stable	Slightly elevated surfaces above lake bed	Deep non-calcareous duplex
QE34	1d	CZc	1	2	dune	ls		60% stable	Low sandy rise adjoining birridah with extensive bare windswept areas	Deep non-calcaereous loamy sand
QE35	7c	CZc	0.5		flat	sl	lc	mostly unstable	Birridah adjoining lake Rebecca with extensive deflated areas and concentrated drainage channels	Deep non-calcareous duplex
QE36	5b	CZc	0.5		flat	sl	lc	stable	Lake fringing system very gently inclined towards the lake with generally diffuse overland flow	Deep non-calcareous duplex
QE37	6a	Qa	1		drainage tract	scl	lc	mostly stable	Broad drainage tract with mostly diffuse flows and shallow channels to 40cm deep	Deep non-calcareous gradational
QE38	5b	CZc	1		flat	scl	lc	stable	Broad gently inclined plain with diffuse overland flow and extensive deflated surfaces	Deep calcareous gradational
QE39	4c	CZc	<1		flat	scl	lc	stable	Extensive near level plain with diffuse overland flow	Deep calcareous gradational
QE40	6a	CZc	1		flat	scl	lc	20% stable	Broad gently inclined wash plain with mostly diffuse overland flow and extensive deflated surfaces and minor concentrated flow zones	Deep non-calcareous gradational
QE41	4c	CZc	<1		flat	scl	scl	mostly stable	Extensive gently inclined plain with diffuse overland flow	Shallow variable depth sandy clay loam over calcrete

Site	Land unit	Geol. unit	Slope	Relief	Land form	Soil type		Erosion	Geomorphological description	Soil description
			%	m		A	B			
QE42	6a	CZc	1.5		flat	scl	lc	mostly stable	Gently inclined plain with generally diffuse overland flow and extensive deflated areas and some more concentrated flow zones	Deep non-calcareous gradational
QE43	1d	CZc	2	3	dune	sl	scl	mostly stable	Low sandy rise with extensive wind deflated surfaces	Deep non-calcareous gradational
QE44	7c	Qa	2		major creek	sl	scl	mostly unstable	Braided creek system flowing towards lake Rebecca . Low banks lined with eucgrif and erecap ereopp	Shallow variable depth sandy loam over ferruginous hardpan
QE45	1d	CZc	1.5	4	hillock	ls		60% stable	Low sandy rise with extensive wind deflated surfaces	Deep non-calcareous loamy sand
QE46	5b	CZc	1		flat	ls	lc	stable	Gently inclined saline plain with diffuse overland flows and shallow incised drainage	Shallow variable depth duplex over ferruginous hardpad
QE47	4a	CZc	1.5		flat	ls	sl	mostly stable	Gently inclined plain with diffuse overland flow	Deep non-calcareous gradational
QE48	4a	CZc	1		flat	sl		mostly stable	Gently inclined plain with diffuse overland flow and mostly intact surfaces	Deep non-calcareous sandy loam
QE49	5a	CZc	<1		flat	scl	lc	mostly stable	Gently inclined saline plain with mostly non-incised drainage	Deep calcareous gradational
QE50	4c	CZc	<1		flat	scl	lc	stable	Near level plain with diffuse overland flow and intact surfaces	Deep calcareous gradational
QE51	4c	CZc	<1		flat	scl	lc	stable	Near level plain with diffuse overland flow and intact surfaces	Deep calcareous gradational
QE52	6a	CZc	1		drainage tract	lc	lc	stable	Broad drainage tract with diffuse overland flows and no incised drainage	deep non-calcareous light clay
QE53	4a	CZc	1		flat	scl	lc	stable	Broad gently inclined plain with diffuse overland flow and intact surfaces	Deep non-calcareous gradational
QE54	4a	CZc	<1		flat	scl	lc	mostly stable	Broad gently inclined plain with diffuse overland flow and mostly intact surfaces with open bare areas	Deep non-calcareous gradational
QE55	2a	CZc	2	5	upper slope	scl	scl	stable	Gently rounded rise with abundant ironstone fine gravel mantle	Deep calcareous sandy clay loam
QE56	5a	CZc	2		flat	scl	lc	mostly unstable	Gently inclined saline plain with extensive active surface flow erosion	Deep calcareous duplex
QE57	4c	CZc	<1		flat	scl	lc	95% stable	Near level plain with diffuse overland flow and intact surfaces	Deep calcareous gradational
QE58	4c	CZc	<1		flat	scl	lc	95% stable	Near level plain with diffuse overland flow and intact surfaces	Deep calcareous gradational
QE59	4a	CZc	<1		flat	scl	scl	80% stable	Near level plain with diffuse overland flow and mostly intact surfaces	Deep calcareous sandy clay loam

Site	Land unit	Geol. unit	Slope	Relief	Land form	Soil type		Erosion	Geomorphological description	Soil description
			%	m		A	B			
QE60	4c	CZc	<1			scl	lc	mostly stable	Near level plain with diffuse overland flow and intact surfaces	Deep calcareous gradational
QE61	4c	CZc	<1		flat	scl	lc	stable	Near level plain with diffuse overland flow and intact surfaces	Deep calcareous gradational
QE62	4a	CZc	1		lower slope	scl	lc	90% stable	Gently inclined plain with diffuse overland flow and mostly intact surfaces with abundant ironstone fine gravel mantle	Deep calcareous gradational
QE63	4a	CZc	1.5		flat	scl	lc	mostly stable	Very gently inclined plain with diffuse overland flow and mostly intact surfaces with abundant ironstone fine gravel mantle	Deep calcareous gradational
QE64	2a	Czu	3	6	mid slope	scl	scl	stable	Low laterite rise with gentle slopes and 100% fine ironstone/calcrete gravel mantle. Diffuse overland flow and intact surfaces	Variable depth sandy clay loam
QE65	2a		2		lower slope	scl		stable	Gentle slope with diffuse overland flows and 100% fine ironstone gravel and patches of calcrete nodules	Deep non-calcareous sandy clay loam

*S: sand;
SL: sandy loam
SCL: sandy clay loam
LC: light clay

Attachment 5: Inventory site data on dominant flora vegetation cover and condition.

Site	Land unit	Veg. type	Land system	Upper storey		Mid storey		Lower storey		Total cover %	Veg. cond.	Site vegetation description
				Dominate	%	Dominate	%	Dominate	%			
QE01	4c	PLMS	DEA	acainc	4	acabur	5	maised	6	15	3	Sparse acacia shrubland with very sparse maised understorey
QE02	4c	PSAS	DEA	acaapt	4	acabur	2	maised	10	16	4	Sparse degraded chenopod shrubland most recolonizing shrubs dead with very sparse acacia overstorey
QE03	4c	PSAS	DEA	acaapt	6	acabur	6	maised	8	20	3	Very sparse degraded chenopod shrubland with sparse acacia overstorey and isolated caspau. Many recolonising shrubs dead
QE04	4c	PSAS	DEA	acainc	3	acabur	7	maised	5	15	3	Very sparse degraded chenopod shrubland with sparse acacia overstorey and isolated caspau. Many recolonising shrubs dead
QE05	6a	DACS	DEA	acainc	1	acabur	4	maised	2	7	4	Very sparse patchy acacia shrubland over very sparse degraded chenopod shrubland. Many recolonizing shrubs dead.
QE06	4c	CAHW	DEA	caspau	5	snnfil	2	maised	5	12	4	Very sparse degraded chenopod shrubland with very sparse caspau overstorey . Many recolonising shrubs dead
QE07	6a	DRAS	DEA	acainc	10	acabur	25	maipyr	20	55	3	Mid dense acacia shrubland with isolated caspau over sparse chenopod shrubland
QE08	6a	DRAS	DEA	acainc	5	acabur	5	maised	2	12	5	Very sparse acacia shrubland with isolated chenopods. Many losses.
QE09	4c	PSAS	DEA	acainc	2	acabur	8	maised	5	15	3	Very sparse degraded chenopod shrubland with isolated acacia and caspau. Many recolonising shrubs dead
QE10	4c	PSAS	DEA	acainc	5			maised	7	12	4	Very sparse degraded chenopod shrubland most recolonizing shrubs dead with very sparse acacia overstorey
QE11	4a	CAHW	DEA	caspau	3	acabur	7	maised	10	20	3	Very sparse caspau woodland with sparse acacia chenopod understorey
QE12	4a	CAHW	DEA	caspau	8	acabur	20	ptiobo	2	30	2	Sparse mid-height multi-species shrubland with very sparse caspau acacia overstory
QE13	4c	CPBS	MOR	caspau	4	acabur	10	scvspi	6	20	2	Sparse mid-height shrubland with very sparse caspau overstory. Many recolonizing shrubs dead
QE14	4c	CPBS	DEA	caspau	2	acabur	10	maised	3	15	3	Very sparse degraded chenopod shrubland with sparse acacia overstorey and isolated caspau. Many recolonising shrubs dead
QE15	4a	PLMS	DEA	caspau	1	acabur	14	scvspi	5	20	3	Sparse acacia shrubland with isolated caspau. Many recolonizing shrubs dead.
QE16	4a	PLMS	DEA	acainc	4	acabur	10	scvspi	6	20	3	Sparse acacia shrubland
QE17	4c	CAHW	MOR	caspau	3	snnfil	5	maised	3	11	4	Very sparse degraded chenopod shrubland with very sparse caspau overstorey and isolated eucalypt groves. Many recolonising shrubs dead
QE18	6a	DRAS	DEA	acainc	5	acabur	30	maipyr	5	40	3	Sparse to mid dense acacia shrubland with very sparse degraded chenopod understorey

Site	Land unit	Veg. type	Land system	Upper storey		Mid storey		Lower storey		Total cover %	Veg. cond.	Site vegetation description
				Dominate	%	Dominate	%	Dominate	%			
QE19	2a	CCAS	DEA	caspau	2	snnfil	10	scvspi	10	13	4	Totally degraded chenopod shrubland with very sparse recolonizing shrubs and isolated caspau. Many recolonizing shrubs dead
QE20	4c	CCAS	MOR	caspau	1	acabur	24	scvspi	2	27	4	Degraded chenopod shrubland with sparse recolonizing shrubs and isolated caspau
QE21	2a	SIAS	MOR	caspau	2	acabur	10	scvspi	3	15	3	Very sparse caspau woodland with very sparse mid height shrubland
QE22	1c	FHXS	MOR	caspau	4	acahem	5	maised	1	10	3	Very sparse mid-height shrubland with very sparse caspau overstory. Many recolonizing shrubs dead
QE23	5b	CAHW	MOR	caspau	1	snnfil	1	maised	18	20	4	Sparse chenopod shrubland with isolated caspau and mulga
QE24	5b	CHAS	MOR	caspau	1	eresco	10	maised	14	25	4	Sparse degraded chenopod shrubland with numerous recolonizing shrubs and isolated caspau
QE25	4c	CHAS	MOR	caspau	4	acakem	6	maised	5	15	4	Very sparse degraded chenopod shrubland with very sparse caspau overstorey . Many recolonising shrubs dead
QE26	4c	CHAS	DEA	caspau		acahem	25	maised	5	30	5	Severely degraded sparse chenopod shrubland with sparse recolonizing shrubs and isolated caspau
QE27	4c	DRMS	DEA	caspau	5	snnfil	50	maised		55	3	Mid dense shrubland with very sparse caspau
QE28	4c	CAHS	DEA	caspau	2	snnfil	10	maised	5	17	4	Very sparse degraded chenopod shrubland with recolonizing shrubs (many dead) and isolated caspau
QE29	5b	SAGE	DEA	caspau	5	snnfil	3	crasub	15	29	3	Sparse sage chenopod shrubland with very sparse caspau overstorey
QE30	4c	?	DEA	caspau	2	acabur	15	maised	5	22	3	Transitional site between 5x and 4c. Degraded very sparse chenopod shrubland with isolated caspau and eucalypts
QE31	1d	SACS	CAG	acainc	3	acaram	10	scvspi	7	20	3	Sparse low to mid height diverse shrubland with very sparse mulga and caspau overstorey
QE32	1d	LSCS	CAG	caspau	3	dodrig	5	rhadru		8	4	Very sparse caspau mulga over very sparse understorey
QE33	7c	FRAN	CAG					fraint	20	20	2	Sparse halophyte low shrubland with sage dominate on lower surfaces and atrves on slightly elevated surfaces
QE34	1d	PLMS	CAG	acainc	4	acaram	10	eregra	2	16	3	Sparse acacia shrubland with many juvenile acacia over very sparse understorey
QE35	7c	PXHS	CAG	acainc				maipyr	20	20	3	Sparse halophyte low shrubland with isolated stunted acacias
QE36	5b	FRAN	CAG	caspau		eresco	10	fraint	5	15	3	Sparse halophyte shrubland with recolonizing shrubs and isolated eucalypt groves
QE37	6a	DRAS	DEA	caspau	2	acabur	30			32	3	Sparse acacia shrubland with very sparse caspau overstory. Many tree and shrub deaths
QE38	5b	SAGE	DEA	caspau	2	exoaph	3	crasub	10	15	4	Sparse degraded halophyte shrubland with recolonizing shrubs and isolated caspau
QE39	4c	?	DEA	acainc	4			maised	2	6	4	Severely degraded and drought affected very sparse chenopod shrubland with very sparse mulga and most recolonizing shrubs dead

Site	Land unit	Veg. type	Land system	Upper storey Dominate	%	Mid storey Dominate	%	Lower storey Dominate	%	Total cover %	Veg. cond.	Site vegetation description
QE40	6a	PEAW	DEA	caspau	1	acahem	15	maised	5	21	4	Very sparse degraded chenopod shrubland with sparse recolonizing shrubs and isolated caspau mulga and eucalypts
QE41	4c	CAHS	DEA	caspau	1	acahem	9	maised	2	12	3	Very sparse degraded chenopod shrubland with recolonizing shrubs (many dead) and isolated caspau
QE42	6a	PEAW	DEA	acainc	1	eresco	9	maised	5	15	3	Very sparse degraded chenopod shrubland with recolonizing shrubs (many dead) and isolated caspau and mulga
QE43	1d	SACS	CAG	caspau	2	acaincea	6	scvspi	4	12	3	Very sparse mixed species low to mid height shrubland with isolated caspau
QE44	7c	FRAN	CAG	eucgrif	4	acaincea	2	fraint	10	16	3	Low islands and fringing areas support sparse frankenia shrubland with patchy eremophila and acaincea
QE45	1d	SACS	DEA	acainc	5	acaincea	10	scvspi	5	20	3	Very sparse acacia shrubland with isolated caspau. Many losses.
QE46	5b	FRAN	DEA	caspau	1	eresco	1	fraint	18	20	2	Sparse halophytic shrubland with fringing eucgrif groves
QE47	4a	?	DEA	caspau	1	eresco	15	scvspi	4	20	3	Very sparse acacia eremophila shrubland with isolated caspau and eucalypts
QE48	4a	?	DEA	eucole	2	acahem	15	scvspi		17	4	Degraded chenopod? shrubland with sparse recolonizing acahem shrubs and isolated caspau and eucalypts
QE49	5a	SAGE	DEA	caspau	4	eresco	1	crasub	15	20	3	Sparse halophytic shrubland with very sparse caspau overstorey. crasub in lower areas maised in higher
QE50	4c	CCAS	DEA	acainc	3	acabur	7	maised	10	20	3	Very sparse degraded chenopod shrubland with recolonizing shrubs (many dead) and isolated mulga
QE51	4c	CCAS	DEA	acainc	1	acabur	5	maised	2	8	4	Very sparse degraded chenopod shrubland with recolonizing shrubs (many dead) and isolated caspau and mulga
QE52	6a	DRAS	DEA	eucole	1	acabur	30			30	3	Sparse to mid dense acacia shrubland with isolated eucalypts
QE53	4a	PEAW	DEA	eucole	3	acasib	27	maised		30	3	Sparse acacia shrubland with very sparse eucalypt overstorey
QE54	4a	PLMS?	DEA	caspau	2	acabur	15	scvspi	1	19	4	Diverse patchy acacia shrubland with very sparse caspau mulga overstorey and minimal undershrubs
QE55	2a	SIAS	DEA	caspau	3	acabur	10	scvspi	2	15	3	Very sparse acacia shrubland with very sparse caspau mulga overstorey and very sparse understorey
QE56	5a	PXHS	GUN	caspau	1	eresco	4	atrves	20	25	3	Sparse to mid-dense halophyte shrubland dominated by atrves with very sparse mid-height shrubs and isolated stunted caspau
QE57	4c	PACS	DEA	acaapt	2	acabur	2	maised	5	9	3	Very sparse degraded chenopod shrubland with recolonizing shrubs (many dead) and very sparse mulga
QE58	4c	PACS/ CCAS	DEA	acainc	2	snnfil	2	maised	2	6	4	Very sparse degraded chenopod shrubland with recolonizing shrubs (many dead) and very sparse mulga
QE59	4a	PACS	DEA	caspau	3	acabur	17	scvspi	1	21	3	Sparse acacia shrubland with very sparse caspau mulga overstorey and very sparse understorey. Many dead
QE60	4c	CPBS	DEA	acaapt	2	acabur	2	maised	1	5	5	Very sparse degraded chenopod shrubland with recolonizing shrubs (many dead) and very sparse mulga

Site	Land unit	Veg. type	Land system	Upper storey		Mid storey		Lower storey		Total cover %	Veg. cond.	Site vegetation description
				Dominate	%	Dominate	%	Dominate	%			
QE61	4c	CPBS	DEA	acainc	2	acabur	2	maised	2	6	4	Very sparse degraded chenopod shrubland with recolonizing shrubs (many dead) and very sparse mulga
QE62	4a	CAHW	GUN	caspau	2	acabur	10	ptiobo		12	3	Diverse patchy acacia shrubland with very sparse caspau mulga overstorey and minimal undershrubs. Transitional site
QE63	4a	CAWH	GUN	acainc	4	acabur	10	scvspi	1	15	3	Very sparse acacia shrubland with very sparse mulga overstorey and isolated caspau
QE64	2a	SIAS	GUN	acakem	9	acaram	5	scvspi	1	15	3	Very sparse acaia shrubland with minimal undershrubs and isolated caspau
QE65	2a	SIAS	GUN	acainc	3	acakem	17	scvspi	1	21	3	Sparse acacia shrubland with isolated caspau.

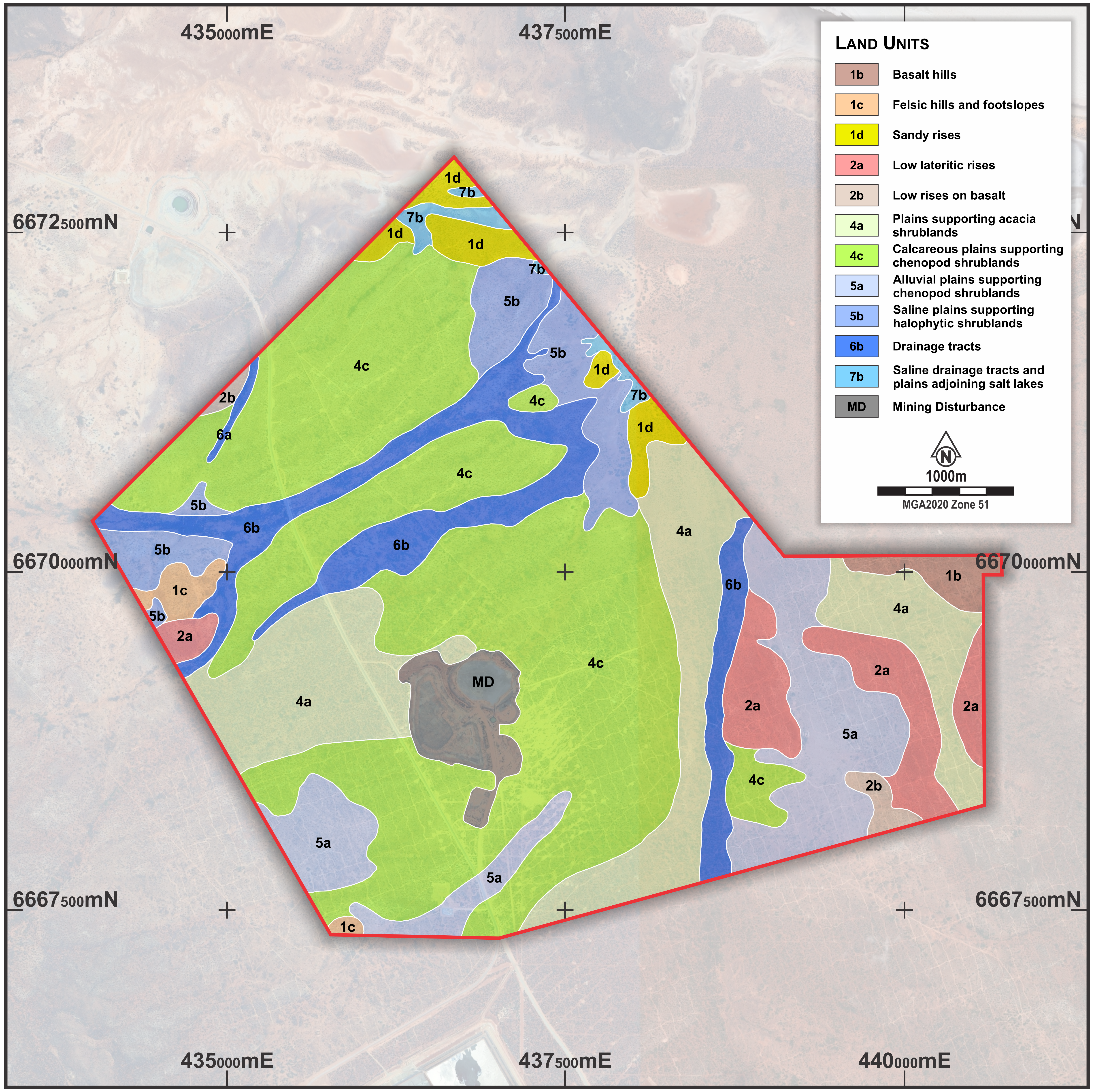
Fieldcode	Taxa
acabur	*Acacia burkittii*
acaapt	*Acacia aptaneura*
acaincea	*Acacia inceana* subsp*. conformis*
acahem	*Acacia hemiteles*
acainc	*Acacia incurvaneura*
acakem	*Acacia kempeana*
acaram	*Acacia ramulosa* var. *linophylla*
acasib	*Acacia sibirica*
atrves	*Atriplex vesicaria*
caspau	*Casuarina pauper*
dodlob	*Dodonaea lobulata*
dodrig	*Dodonaea rigida*
eregra	*Eremophila granitica*
eremin	*Eremophila miniata*
eresco	*Eremophila scoparia*
eucgrif	*Eucalyptus griffithsii*
eucole	*Eucalyptus oleosa* subsp. *oleosa*
exoaph	*Exopcarpus aphylla*
fraint	*Frankenia interiois*
maipyr	*Maireana pyramidata*
maised	*Maireana sedifolia*
olemue	*Olearia muelleri*
ptiobo	*Ptilotus obovatus*
scvspi	*Scaevola spinescens*
sidcal	*Sida calyxhymenia*
snnart	*Senna artemisioides* subsp. x *artemisioides*
snnfil	*Senna artemisioides* subsp*. filifolia*

Attachment 6: Location of inventory sites

Site				Easting	Northing
QE01	GDA94	UTM	51J	436871	6669541
QE02	GDA94	UTM	51J	437305	6669772
QE03	GDA94	UTM	51J	437114	6669888
QE04	GDA94	UTM	51J	436536	6669688
QE05	GDA94	UTM	51J	436294	6670219
QE06	GDA94	UTM	51J	436375	6670683
QE07	GDA94	UTM	51J	435860	6670673
QE08	GDA94	UTM	51J	436672	6671146
QE09	GDA94	UTM	51J	437886	6669630
QE10	GDA94	UTM	51J	438100	6669552
QE11	GDA94	UTM	51J	435363	6668797
QE12	GDA94	UTM	51J	435049	6668599
QE13	GDA94	UTM	51J	435352	6668426
QE14	GDA94	UTM	51J	436048	6668593
QE15	GDA94	UTM	51J	435386	6669356
QE16	GDA94	UTM	51J	435686	6669298
QE17	GDA94	UTM	51J	434732	6670940
QE18	GDA94	UTM	51J	434388	6670371
QE19	GDA94	UTM	51J	434950	6671269
QE20	GDA94	UTM	51J	435164	6670853
QE21	GDA94	UTM	51J	434680	6669461
QE22	GDA94	UTM	51J	434635	6669840
QE23	GDA94	UTM	51J	434778	6670084
QE24	GDA94	UTM	51J	434812	6670479
QE25	GDA94	UTM	51J	435025	6670624
QE26	GDA94	UTM	51J	435968	6671634
QE27	GDA94	UTM	51J	435996	6672019
QE28	GDA94	UTM	51J	436450	6672266
QE29	GDA94	UTM	51J	436930	6672026
QE30	GDA94	UTM	51J	436750	6672132
QE31	GDA94	UTM	51J	437137	6672427
QE32	GDA94	UTM	51J	436716	6672910
QE33	GDA94	UTM	51J	436937	6672620
QE34	GDA94	UTM	51J	436590	6672552
QE35	GDA94	UTM	51J	436426	6672508
QE36	GDA94	UTM	51J	437488	6671815
QE37	GDA94	UTM	51J	437190	6671702
QE38	GDA94	UTM	51J	437099	6671741
QE39	GDA94	UTM	51J	437351	6668579
QE40	GDA94	UTM	51J	437465	6670658
QE41	GDA94	UTM	51J	437008	6670793
QE42	GDA94	UTM	51J	437511	6671125
QE43	GDA94	UTM	51J	437732	6671496
QE44	GDA94	UTM	51J	438027	6671301
QE45	GDA94	UTM	51J	438091	6671106
QE46	GDA94	UTM	51J	437854	6670571
QE47	GDA94	UTM	51J	438450	6670531
QE48	GDA94	UTM	51J	438248	6670559
QE49	GDA94	UTM	51J	439011	6669936
QE50	GDA94	UTM	51J	437276	6670200
QE51	GDA94	UTM	51J	437838	6670114
QE52	GDA94	UTM	51J	438694	6669835
QE53	GDA94	UTM	51J	438493	6669981
QE54	GDA94	UTM	51J	438334	6669800
QE55	GDA94	UTM	51J	438934	6669083
QE56	GDA94	UTM	51J	439442	6668655
QE57	GDA94	UTM	51J	437783	6668791

QE58	GDA94	UTM	51J	437767	6668254
QE59	GDA94	UTM	51J	437887	6667837
QE60	GDA94	UTM	51J	436689	6668339
QE61	GDA94	UTM	51J	436291	6668178
QE62	GDA94	UTM	51J	439655	6669612
QE63	GDA94	UTM	51J	440242	6669623
QE64	GDA94	UTM	51J	440045	6669089
QE65	GDA94	UTM	51J	440484	6668876
SE32	GDA94	UTM	51J	439875	6668046
SE35	GDA94	UTM	51J	438025	6669069
SE36	GDA94	UTM	51J	438417	6668982
SE37	GDA94	UTM	51J	438607	6668926
SE38	GDA94	UTM	51J	440221	6670024
SE39	GDA94	UTM	51J	439973	6669890
SE40	GDA94	UTM	51J	439322	6669020
SE41	GDA94	UTM	51J	439061	6668928
SE42	GDA94	UTM	51J	438122	6668327
SE43	GDA94	UTM	51J	438585	6668258
SE44	GDA94	UTM	51J	438125	6667846
SE45	GDA94	UTM	51J	439373	6668271
SE46	GDA94	UTM	51J	440081	6668511
SE47	GDA94	UTM	51J	437857	6667239
SE48	GDA94	UTM	51J	437236	6668045
SE49	GDA94	UTM	51J	436547	6668009
SE50	GDA94	UTM	51J	436454	6667663
SE51	GDA94	UTM	51J	435737	6667504
SE52	GDA94	UTM	51J	435701	6667722
M13	GDA94	UTM	51J	435573	6672132
M31	GDA94	UTM	51J	435390	6672198
M16	GDA94	UTM	51J	435877	6673060

Attachment 7: Land unit map



Land units within the Qena survey area
November 2023
Prepared by Alexander Holm & Associates for
Northern Star Resources

Appendix B: Qena Targeted Malleefowl Survey

Targeted Malleefowl Survey M31/219, M31/210, M31/220 & M31/285

Northern Star Resources Ltd

Alexander Holm & Associates

Natural Resource Management Services

November 28, 2023

Title page: An active Malleefowl nest QE23-8

Table of Contents

List of Figures

List of Tables

Summary

Northern Star intends to conduct further mining in areas adjoining the Luvironza open pit gold mine which operated until mid-2005, prior to being used as an In-Pit TSF.

The proposed mining operations are contained within a 2,100ha survey area situated approximately 7km north of CDO operations centre and 2km north of the CDO Tailings Storage Facility. The northern haul road to Porphyry mining operations passes through the western portion of the survey area.

Alexander Holm & Associates were contracted by Northern Star to conduct a Targeted Malleefowl (*Leipoa ocellata*) Survey and to provide details on Malleefowl presence and habitat within the survey area.

Malleefowl are classified as "vulnerable" and listed as a Matter of National Environmental Significance (MNES) under the Environment Protection and Biodiversity Conservation Act (EPBC Act).

The survey found that Malleefowl are active within the area. A live bird was sighted, five active nests, one of which was just outside the survey area, and six inactive recent nests located, numerous fresh tracks found and much litter disturbance in favoured habitat.

Most Malleefowl activity is distant from mining operations. The four active nests within the survey area are all at least 1.5km from Luvironza and 600m from the haul road. Nesting mound QE23-4, which is 800m distant from Luvironza, is classed as recent active and may have been used within the past 5 years.

Malleefowl show a high preference for broad drainage tracks, low basaltic and lateritic rises and moderate preference for plains supporting mulga shrublands. All are considered critical habitat for breeding and survival and are found on 728ha - 33% of the survey area. This habitat is also important for foraging and dispersal, as is the small area of basalt hills which occupy 14ha.

Halophytic shrublands occupying 58% of the survey area are mostly not used by Malleefowl. The two nesting mounds found in these shrublands occur in highly restricted niches with favourable soil conditions and Malleefowl tracks are mostly minor incursions from adjacent more favourable habitat.

The survey area has a long history of mining activity and has been exposed to extensive seismic testing and exploration drilling. Exploration drilling continues throughout the area. Nevertheless, Malleefowl remain active and continue to breed in suitable habitat in areas surrounding and remote from the areas of mining activity as confirmed by this survey and monitoring of known Malleefowl nesting mounds by Northern Star within the wider Carosue Dam region.

1 Introduction

Northern Star Resources Ltd (Northern Star) owns and operates Carosue Dam Operations (CDO) approximately 100km northeast of the City of Kalgoorlie-Boulder, Western Australia.

Northern Star intends to conduct further mining within mining tenements M31/219, M31/210, M31/220 and M31/285. The Luvironza open pit gold mine operated in this area in the 2000s. It was then used for in-pit tailings storage.

The proposed mining operations are contained within a 2,100ha survey area situated approximately 7km north of CDO operations centre and 2km north of the CDO Tailings Storage Facility as shown in Figure 1. The northern haul road to Porphyry mining operations passes through the western portion of the survey area.

2 Scope of Works

Alexander Holm & Associates were contracted by Northern Star to conduct a Targeted Malleefowl (*Leipoa ocellata*) survey.

The Targeted Malleefowl survey was conducted in accordance with EPA (2020) guidelines for vertebrate fauna surveys. The survey included activity searches and habitat mapping to assess the presence of Malleefowl within the survey area and identify habitat areas as:

a) critical habitat for breeding.

b) suitable habitat for foraging/dispersal or

c) unsuitable habitat for breeding, foraging or dispersal.

Figure 1: Survey area (crosshatched) in relation to Lake Rebecca and associated mining tenements.

3 Background

3.1 Species and Habitat Information

3.1.1 Biology

Malleefowl are a stocky ground-dwelling bird belonging to the family Megopodiidae. This species builds large distinctive on ground mounds to incubate their eggs. Breeding season usually begins in September when egg laying begins and ends in late January. Chicks typically begin hatching in November, with most chicks emerging from mounds by January, however it has been noted that in some seasons hatching may continue until March (Benshemesh 2007).

3.1.2 Distribution and Habitat

Historically, Malleefowl have been found in semi-arid mallee shrublands and woodlands across southern Australia (Department of Parks and Wildlife 2016b), but their range has been greatly reduced, mostly attributed to extensive land clearing for agriculture (Department of Parks and Wildlife 2016b).

Several environmental factors contribute to habitat critical for successful Malleefowl breeding, of which those attributes facilitating construction of suitable nesting mounds are essential. Less critical habitat in surrounding areas may be used for foraging (Benshemesh 2007).

In Western Australia, Malleefowl habitat commonly consists of acacia-dominated shrublands and woodlands dominated by mallee eucalypts. Malleefowl require a sandy substrate and abundance of leaf litter for construction of mounds (Department of Parks and Wildlife 2016a). Deep sandy loam or loamy sand soils appear highly desirable for Malleefowl nesting mounds. Soils with higher clay content or shallow sandy soils over heavier soils were generally avoided; or attempts to establish nesting mounds in heavier soils were found to have failed in other habitat surveys within the Goldfields Region, by Alexander Holm & Associates (2022b).

Habitats characterised by numerous food plants (especially leguminous shrubs and herbs), a dense canopy cover and open ground layer are generally associated with high breeding densities of this species. While Malleefowl also prefer long unburnt country, traditional patch burning practices are recommended to stimulate regeneration in spinifex habitats in which the birds feed (Benshemesh 2007).

Stenhouse (2022), in a study of factors affecting Malleefowl distribution on the Eyre Peninsular in South Australia, identified total vegetation cover as the most important determinant of breeding activity. Herbs, shrubs and their seeds make up a large part of Malleefowl diet and vegetation cover also provides habitat for invertebrate food sources that Malleefowl eat. While published work suggests Malleefowl movement patterns are partially driven by food availability. Stenhouse (2022) found the influence of food plants on habitat use was small and possibly reflects that Malleefowl have a highly variable diet and opportunistically feed on what is available within their surroundings.

While definitive habitat preferences were not defined, Stenhouse (2022) found Malleefowl movement was positively influenced by availability of litter and taller canopy cover, possibly for heat or predator avoidance.

3.1.3 Conservation Status

Malleefowl are a Threatened fauna species listed as Vulnerable under the State *Biodiversity Conservation Act 2016* and Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) whereby approval may be required for a proposed activity that significantly adversely affects their wellbeing.

3.1.4 Nesting Mound Characterisation

The National Malleefowl Monitoring Manual defines 'active' nesting mounds as "Currently being used by Malleefowl as an incubator for their eggs, and is likely to contain eggs" (National Malleefowl Recovery Team 2020).

Four other categories are proposed for this report:

- 'Inactive recent': Potentially used within the last 5 years. Mound well-formed, litter often still present, no evidence of inner crusting or growth of annual herbs or grasses.
- 'Inactive abandoned': Likely unused for more than 5-10 years and possibly abandoned. Mound somewhat degraded, often crusted, annual herbs or grasses may be present.

- 'Long unused': Evidence of an extended period of inactivity such as shrubs or trees growing from hollows or mounds, very degraded/poorly formed. Highly unlikely to become active in the future.
- 'Failed': Evidence of an attempt to prepare a nesting mound resulting in a small, abandoned hole with no evidence of subsequent use.

3.2 Environmental Information

3.2.1 Climate

The Goldfields region is classified as arid to semi-arid with average annual rainfall decreasing from about 250mm in the south-west to 200mm in the north-east. The area experiences hot summers and mild winters with cold nights. Rainfall varies widely between years and droughts are common. Remnants of tropical cyclones occasionally bring heavy summer rain and can cause localised short-term flooding. The area transitions between desert summer and winter dominated rainfall and desert: non-seasonal bioclimatic (Beard 1990).

Rainfall at Carosue Dam averages 242mm a year with more rain falling over summer. Rainfall for Carosue Dam was below average in 2021 (181mm) and 2022 (151mm) and only 125mm has fallen to date in 2023 (Figure 2). There have been few effective rainfalls over winter or spring since 2016 with rainfall in 2019 of 91mm being one of the lowest on record.

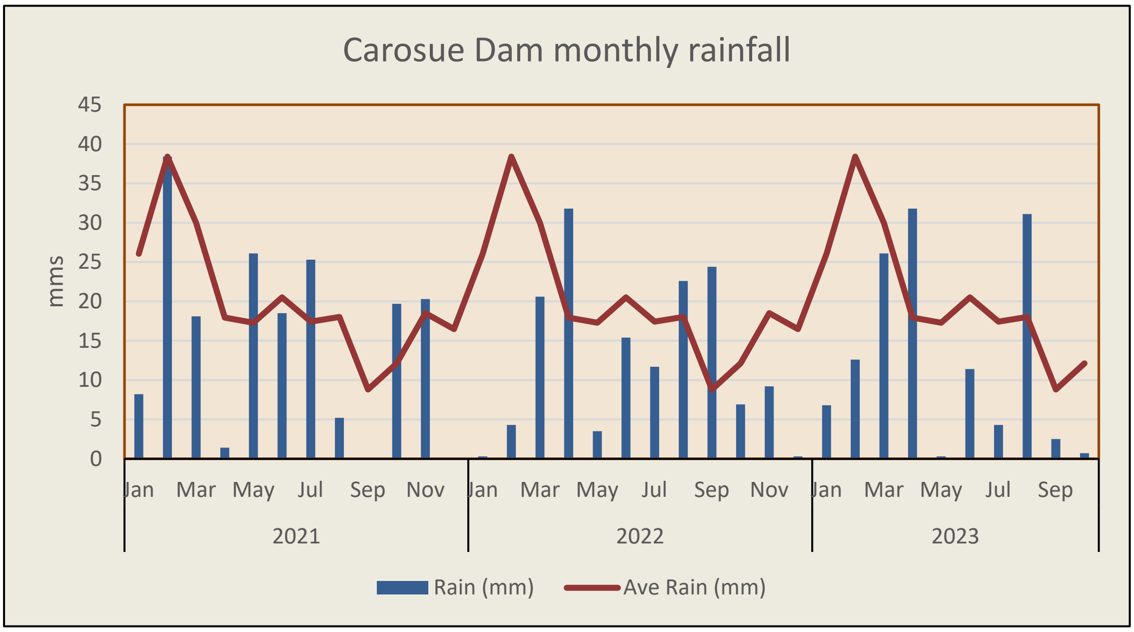


Figure 2: Carosue Dam monthly rainfall

3.2.2 Vegetation and Soil

The region lies within the Eremaean botanical province, mainly in the Austin botanical district, with the eastern edge approaching the Helms botanical district (Beard, 1976). Lake Ballard/Lake Rebecca form a major vegetation divide with characteristic *Acacia aneura* (mulga) low woodlands associated with red loams over siliceous hardpan to the north and low woodlands of mixed mulga and Casuarina (black oak) and *Eucalyptus* species on alkaline and calcareous soils to the south. Spinifex hummock grassland with eucalypt overstorey on sand plain is common. Halophytic vegetation occurs throughout the region on palaeo-drainage systems, breakaways and on some stony and alluvial plains.

3.3 Previous Surveys

Environmental assessment: proposed seismic survey area. Saracen Gold Mines. Alexander Holm & Associates 2019.

A level 1 reconnaissance flora and fauna survey of a 4300ha area south and partially encroaching on the current survey area.

Malleefowl were active in the survey area and there were three sightings of birds during this survey.

Malleefowl appeared to have a habitat preference for low basalt hills and acacia woodlands with sandy loam soil.

Environmental assessment: Relief hill survey area. Saracen Gold Mines. Alexander Holm & Associates 2020.

A level 1 reconnaissance flora and fauna survey of a 2080ha area abutting the southeast of the current survey area.

Malleefowl were active in the survey area. Two fresh mounds were found during limited survey suggesting that there are likely to be many more in the survey area.

Environmental assessment: proposed expansion of Carosue Dam Tailings Storage Facility. Northern Star Resources Ltd. Alexander Holm & Associates 2021.

A systematic on-ground survey to locate, record and map evidence of Malleefowl within a 842ha area associated with a proposed expansion of the CDO TSF.

While malleefowl had been active in the survey area, there was little evidence of current activity.

Assessment of impacts on malleefowl of proposed expansion of Carosue Dam Tailings Storage Facility. Northern Star Resources Ltd. Alexander Holm & Associates 2022

An updated impact assessment and habitat quality score for the 842ha area associated with the expansion of the CDO TSF. An assessment of the extent and location of suitable Malleefowl habitat outside the disturbance envelope.

Sandy rises with spinifex scored the highest for Malleefowl habitat followed by acacia shrublands, spinifex sandplain, and basalt footslopes which all rate highly. Alluvial plains with chenopod shrublands and lateritic rises are of limited value.

There are no 'active' nesting mounds within or near the development envelope and there appears to have been no Malleefowl activity at least within the previous 12 to 18 months. It was concluded that expansion of the TSF will have negligible impact on the widely dispersed Malleefowl population in this region as there is extensive habitat in adjacent areas for Malleefowl use and breeding.

Environmental assessment: Qena survey area. Northern Star Resources Ltd. Alexander Holm & Associates 2023.

A level 1 reconnaissance flora and fauna survey.

Eleven land units, analogous to habitat type, are described and mapped. Additional data was collected from the 65 inventory sites specific to Malleefowl habitat: depth to intractable soil layer; litter abundance and disturbance (grid line clearing, haul road proximity etc.). Land unit descriptions and additional data from inventory sites is summarised in Table 1.

3.4 LiDAR Analysis

Northern Star engaged Anditi[1], a spatial analytics company specialising in the transformation, classification, analysis and visualisation of geospatial data, to analyse LiDAR data, acquired in March 2023 over the survey area, to provide predictions of Malleefowl nesting mounds across the extent of the LiDAR data.

The Anditi analysis algorithms look for ground features in the point cloud that best approximate a typical Malleefowl mound shape. Based on the algorithm match to shape and manual checks, a mound is classed from 1 to 4.

I. Very closely matches a typical Malleefowl mound shape and is highly likely to be a Malleefowl mound.

II. Is similar to a Malleefowl mound shape and could be a Malleefowl mound.

III. Is a mound shape that is approximately within the parameters of size for a Malleefowl mound. This could be an old Malleefowl mound, a mound of earth around a living or dead tree/vegetation, natural hummocks around waterways, etc.

IV. Is a mound shape that is approximately within the parameters of size for a Malleefowl mound but isn't very similar to a typical Malleefowl mound. This could be a broken Malleefowl mound, a mound of earth around a living or dead tree/vegetation, natural hummocks around waterways, tussock vegetation etc.

The Anditi analysis provided a predictive data set over the survey area consisting of 7 class I; 4 class II; 18 class III and several thousand class IV targets.

[1] Anditi

4 Methods

4.1 Personnel

The habitat assessment is based on the aforementioned survey and the resulting land unit map of the survey area which was conducted by Alexander Holm and Geoffrey Eliot.

Dr Holm is an ecologist with over 35 years' experience in arid environments and Goldfields regions. He has conducted Malleefowl surveys and habitat assessments in the Goldfields region since 2010. He is an accredited environmental consultant with the Environmental Consultants Association of Western Australia.

Mr Geoffrey Eliot was a soil and landscape technician for the Western Australian Department of Agriculture's rangeland surveys and has over 20 years' experience in Western Australian arid regions. He has assisted Alexander Holm & Associates in conducting several Malleefowl surveys and habitat assessments within the Goldfields region.

The targeted Malleefowl activity survey was conducted by Holm and Philip Smyth from Alexander Holm & Associates, with assistance of three Northern Star personnel. Mr Smyth has assisted Alexander Holm & Associates in previous Malleefowl surveys in this region.

This report was prepared by Dr Holm (Alexander Holm & Associates).

4.2 Timing of Survey

The Malleefowl habitat mapping was conducted from October 23 to 28, 2023; while the targeted Malleefowl activity survey was completed from November 6 to 13, 2023.

4.3 Targeted Malleefowl Search and Activity Survey

4.3.1 Survey Techniques

The basis for the assessment is the predictive analysis of potential Malleefowl nesting mounds by Anditi using LiDAR data, as described in the National Malleefowl Monitoring Manual (2020). It is accepted that the analysis accurately identifies nesting mounds, and this was tested over a 458ha validation area by intensive search by foot traverse. The validation area is located to encompass potential future mining areas.

Malleefowl activity was assessed by inspection of all Class I, II and III nesting targets for nesting activity and by structured search for tracks along foot traverses 20m apart within the validation area and 250m apart throughout the remaining 1700ha of the survey area. A high proportion of Class IV targets within the validation area were encountered during the intensive search.

An additional random selection of Class IV targets outside the validation area was also assessed.

4.3.2 Intensive Gridline Searches

In accordance with the National Malleefowl Monitoring Manual (2020), operators searched within the 458ha validation area along tracklines 20m apart using GPS devices to maintain position (Figure 3). A total of 271km was traversed along tracklines which took over 90 person hours to complete thereby exceeding the survey guidelines for Australia's threatened birds (2017) which recommends 10 hours/50ha for such searches in semi-arid zones.

Operators looked for nesting mounds that had not been identified through the LiDAR analysis and for other evidence of Malleefowl activity (disturbance of litter, tracks and sightings) during traverse. Visible evidence of predators was also noted.

It is considered that search procedures were sufficient to ensure any recently active nesting mounds would have been found/intercepted. While animal tracks were difficult to spot on some land surfaces, most included some softer sandy surfaces where tracks were obvious leading to a high level of confidence that habitat favoured by Malleefowl could be distinguished from non-favoured habitat.

4.3.3 Controlled Foot Traverse

Malleefowl activity in the remaining 1700ha of the survey area was assessed by GPS controlled searches 250m apart (Figure 3), by Holm and Smyth - double the 500m interval recommended in Survey guidelines for Australia's threatened birds (2017). Operators looked for evidence of Malleefowl activity (disturbance of litter, tracks and sightings) during traverse.

A total of 109km were traversed over 32 hours well in excess of 166ha/hour recommended in 'Survey guidelines for Australia's threatened birds' (2017).

4.3.4 LiDAR Nesting Mound Assessment

All Class I and II and some III nesting mounds within the survey area and those within 100m beyond the survey area, as identified from the LiDAR analysis, were inspected by Holm and Eliot during the preceding habitat survey.

The remaining Class III targets and a random selection of 42 Class IV targets were inspected by Holm and Smyth during this current survey.

Nesting mounds were photographed, measured and evidence of Malleefowl activity noted in accordance with the procedures outlined in the *National Malleefowl Monitoring Manual* referenced at item 9a (National Malleefowl Recovery Team 2020), with utmost care taken to avoid disturbance to active nests.

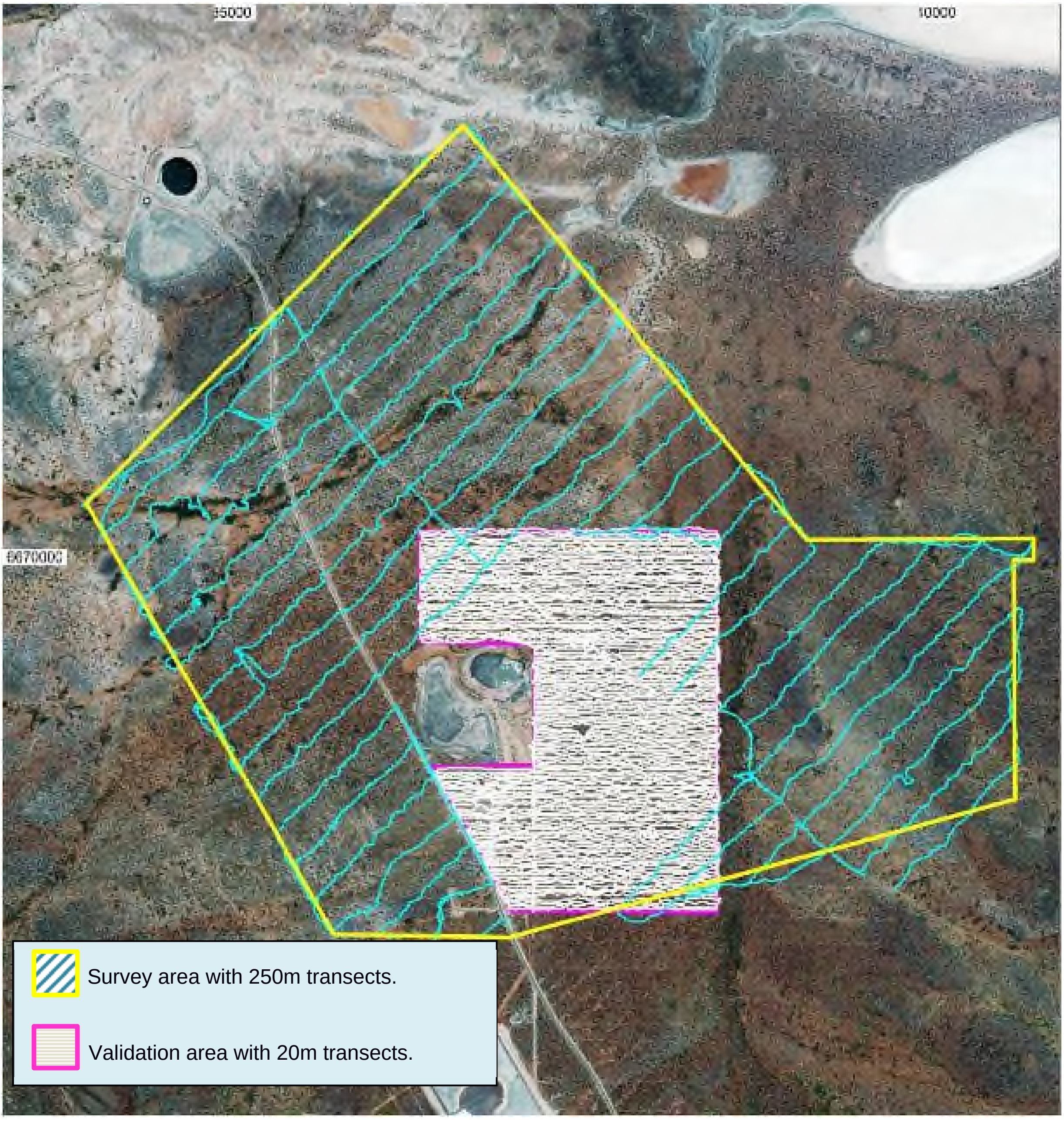


Figure 3: Malleefowl targeted survey showing foot traverse in November 2023.

4.4 Habitat Assessment

4.4.1 Habitat Mapping and Description

The basis for habitat assessment was spatially-described information within land units, each occupying a similar topographic position, vegetation and soil type (Christian and Stewart 1953). As such land units are analogous with habitat types. Eleven habitat types (land units) were mapped over the area during the preceding survey in October 2023 and while these are fully described in the accompanying report a summary is presented in Table 1.

Table 1: Summary of land units within the survey area and Malleefowl habitat characteristics

Land unit	Area (ha)	Description	Soil and depth to intractable layer (cm)	Litter	Cover %	Favourable vegetation
1b. Basalt hills	24.69	Hills with relief to 30m, slopes from 3-10% Very sparse acacia shrubland with very sparse overstorey of *Casuarina pauper*	Sandy loams 10-30 ($\bar{X}$=20)	Minimal	10-40 ($\bar{X}$=19)	Nil to minimal
1c. Felsic hills and footslopes	19.30	Low hills to 12m with slopes of 5% and footslopes with slopes of 2%. Very sparse mid-height shrubland with very sparse overstorey of *Casuarina pauper.*	Sandy clay loam over calcrete 0-10	Nil to moderate	10-15	Nil to minimal
1d. Sandy rises	56.43	Sandy rises to 10m with gently inclined back slopes and bare wind-swept areas. Sparse to very sparse acacia shrublands.	Sands or loamy sands >30	Minimal to moderate	8-20 ($\bar{X}$=13)	Nil to moderate
2a. Low lateritic rises	126.48	Gentle low rises with slopes to 3%, relief up to 6m. Very sparse to sparse acacia shrubland.	Sandy clay loams 10 - >30	Minimal to moderate	8-20 ($\bar{X}$=13)	Minimal to abundant
2b. Low rises on basalt	15.99	Gently rounded hills, rises and gentle slopes. Very sparse mixed height shrublands with isolated to very sparse overstorey of *Casuarina pauper* and occasionally *Acacia incurvaneura.*	Sandy loams over calcrete. 0-30 ($\bar{X}$=18)	Minimal to moderate	5-30 ($\bar{X}$=20)	Nil to moderate
4a. Plains supporting acacia shrublands	370.69	Very gently inclined to near level plains (slopes <1.5%). Very sparse to sparse, sometimes patchy acacia shrublands with overstoreys of *Casuarina pauper* or *Eucalyptus oleosa* subsp. *oleosa*	Sandy loam to sandy clay loams. 10->30	Moderate	7-30 ($\bar{X}$=18)	Nil to abundant
4c. Calcareous plains supporting chenopod shrublands	931.78	Gently inclined plains (slopes <1.5%). Sparse, mostly degraded, *Maireana sedifolia* shrubland with re-colonizing shrubs.	Gradational sandy clay loams over light clay 0-30 ($\bar{X}$=20)	Minimal to moderate	4-55 ($\bar{X}$=12)	Nil to abundant
5a. Alluvial plains supporting chenopod shrublands	226.04	Near level to gently inclined (slopes <1.5%) plains. Very sparse to sparse halophytic shrubland with very sparse overstorey of *Casuarina pauper and/or Acacia incurvaneura.*	Sandy clay loam or sandy loam over light clay. 15->30	Nil to minimal	5-26 ($\bar{X}$=10)	Nil to minimal

Land unit	**Area (ha)**	**Description**	**Soil and depth to intractable layer (cm)**	**Litter**	**Cover %**	**Favourable vegetation**
5b. Saline plains supporting halophytic shrublands	124.53	Gently inclined saline plains (slopes <1.5%). Sparse chenopod shrublands or halophytic shrublands with very sparse *Casuarina pauper.*	Sandy clay loam or sandy loam over light clay. 5-10 ($\bar{X}$=9)	Nil to minimal	2-10 ($\bar{X}$=6)	Nil to minimal
6b. Drainage tracts	214.64	Gently sloping (1%) drainage tracts 50 – 200m wide. Very sparse to mid-dense patchy acacia shrubland and occasional thickets.	Sandy clay loam gradational to light clay 0-30 ($\bar{X}$=16)	Minimal to abundant	5-80 ($\bar{X}$=30)	Moderate to abundant
7b. Saline drainage tracts and plains adjoining salt lakes	20.25	Drainage tracts and saline plains and birridas adjoining salt lakes. Birridas support sparse halophyte shrublands.	Sand or sandy loam over light clay (Birrida). Sandy loam over ferruginous hardpan in braided creek systems 5-20 ($\bar{X}$=12)	Nil to minimal	0-6	Nil to minimal

4.4.2 Breeding Habitat Assessment

Critical Malleefowl breeding habitat was assessed from field survey information collected during the October 2023 survey using a set of environmental variables, as informed by the National Malleefowl Recovery Plan (Benshemesh 2007), which consisted of an analysis of i) site suitability, ii) site context and iii) Malleefowl activity.

The southern 835ha of the survey area has been covered by an earlier environmental assessment (Alexander Holm & Associates 2019) and site information from this, together with relevant site information from an adjoining survey in the Relief Hill area (Alexander Holm & Associates 2020), are included in the analysis to augment data from this survey for land units where inventory data is sparse or absent.

Site Suitability

Malleefowl habitat characteristics were assessed using an unweighted sum of values from inventory site ratings, including:

- Depth to intractable soil layer, hardpan or parent material.
- Litter abundance (nil:0; minimal: 0.25; moderate: 0.5; abundant: 1.0).
- Upper and mid-storey canopy cover.
- Presence of mallee, mulga type trees or spinifex.
- Vegetation condition (totally degraded: 0 – pristine: 1)

These criteria were rated for each land unit with factor scores expressed as a proportion of inventory sites sampled within each land unit with the desired character.

Site Context

Site context refers to the freedom and ability to support Malleefowl to breed, forage and disperse. Factors assessed were:

- Disturbances (vehicle tacks, clearing).
- Constraints to movement to and from surrounding habitat suitable for Malleefowl (mining infrastructure, haul roads, fences).

Malleefowl Activity

Information collected during the intensive gridline and controlled transect searches for evidence of Malleefowl activity (tracks and active or recently active nesting mounds), were ranked from nil (no evidence of present or past activity) to 1 (high incidence of tracks and active or recently active nesting mounds).

Assessment

Evidence of Malleefowl activity, being of over-riding significance, was accorded a 60% weighting with 20% allocated to site suitability and to site context. Composite indexes were then summed to provide a summary index for each land unit. This was expressed on a scale of 0 to 10 where scores above 7 are considered critical habitat for breeding and survival of Malleefowl.

4.4.3 Forage and Dispersal Habitat Assessment

Factors, considered relevant for assessment of habitat suitability for forage and dispersal were derived from information within the National Malleefowl Recovery Plan (Benshemesh 2007), the PhD thesis of Stenhouse (2022) and observations from earlier surveys (e.g. Alexander Holm & Associates 2022a). Factor scores are expressed as a proportion of inventory sites sampled within each land unit with the desired character. Factors assessed were:

- Observations of Malleefowl activity (50%).
- Upper and mid-storey canopy cover (10%)
- Litter abundance (10%).
- Presence of mallee, mulga type trees or spinifex (10%).
- Disturbances (vehicle tacks, cut lines, clearing) (10%).
- Constraints to movement to and from surrounding habitat suitable for Malleefowl (mining infrastructure, haul roads, fences) (10%).

Assessment

Composite indexes were then summed to provide a summary index for each land unit expressed on a scale of 0 to 10 where scores above 5 are considered suitable habitat for foraging and dispersal.

5 Results

5.1 Malleefowl Activity Survey

5.1.1 LiDAR results analysis

All seven Class I and four Class II targets, predicted through the LiDAR analysis, proved to be Malleefowl nesting mounds (Table 2).

Of the 18 Class III predictions, two were Malleefowl nesting mounds, ten failed nesting mound attempts, five mechanical excavations and one a Boodie (Burrowing Bettong: *Bettongia lesueur*) warren.

An example of a ‘failed’ nesting mound attempt.

None of the many hundreds of Class IV targets encountered during the intensive search of the validation area were nesting mounds. Of the 42 Class IV targets inspected during the controlled foot traverse of the remaining area within the survey area, none were nesting mounds, 15 were scours in flowlines, 13 indeterminate, eight mechanical excavations, four bush mounds, one a Boodie warren and one an upturned tree root hole. An ancient, failed attempt and a highly degraded, long unused nesting mound were not identified (Table 2).

Numerous Boodie warrens were located throughout the survey area indicating that, these now-mainland extinct animals, were once abundant in this environment. Boodie warrens were often re-colonised by rabbit and goanna and occasionally by Malleefowl. Boodie warrens were built in highly localised micro-habitats with favourable soil conditions – usually associated with calcrete.

No active or recently active nesting mounds were found other than those predicted through the LiDAR analysis.

Table 2: Field evaluation of LiDAR nesting mound predictions

Prediction class	LiDAR ID	Field evaluation
Class I	13325	Nest: Inactive recent
	14476	Nest: Inactive abandoned
	14635	Nest Active
	15355	Nest: Active
	17259	Nest Inactive recent
	18111	Nest: Long unused
	18409	Nest: Active
Class II	12876	Nest: Inactive recent
	12790	Nest: Inactive recent
	16428	Nest: Inactive recent
	20860	Nest: Active

Prediction class	LiDAR ID	Field evaluation
Class III	9354	Mechanical excavation
	11095	Mechanical excavation
	12221	Failed nest
	12568	Failed nest
	13333	Failed nest
	13391	Failed nest
	13608	Failed nest
	14593	Mechanical excavation
	15347	Nest: Inactive recent
	15870	Mechanical excavation
	16096	Failed nest
	18137	Mechanical excavation
	19183	Failed nest
	20649	Failed nest
	20671	Failed nest
	21676	Nest: Inactive recent
	23816	Boodie warren
	24511	Failed nest
Class IV	5267	Creek scour
	6246	Mechanical excavation
	10775	Indeterminate
	11347	Indeterminate
	12282	Mechanical excavation
	12716	Creek scour
	12871	Boodie warren
	14384	Creek scour
	14386	Creek scour
	14388	Creek scour
	14632	Creek scour
	15352	Treehole
	15663	Bush mound
	16828	Indeterminate
	16861	Creek scour
	16941	Mechanical excavation
	17114	Mechanical excavation
	17124	Indeterminate
	17332	Creek scour
	17338	Creek scour
	17366	Indeterminate
	17423	Bush mound
	17928	Creek scour
	17999	Indeterminate
	18332	Creek scour
	19320	Bush mound
	19448	Mechanical excavation
	19586	Creek scour
	19663	Creek scour

Prediction class	LiDAR ID	Field evaluation
	19668	Creek scour
	19781	Mechanical excavation
	19794	Mechanical excavation
	19812	Mechanical excavation
	19824	Indeterminate
	20136	Indeterminate
	20139	Indeterminate
	20155	Indeterminate
	20163	Indeterminate
	20938	Indeterminate
	21225	Indeterminate
	21719	Creek scour
	21988	Bush mound
Missed		Failed nest
Missed		Nest: Long unused

5.1.2 Malleefowl nesting mounds and Malleefowl activity

Malleefowl are active in the area. A live bird was sighted, four active and six inactive recent nests located, numerous fresh tracks found and much litter disturbance in favoured habitat. Details of nesting mounds are shown in Table 3 and location of nesting mounds and tracks shown in Figure 4: Assessment of Malleefowl habitat within the survey area..

Table 3: Malleefowl nesting mounds located during survey in October November 2023

Details	Comment	Photo
QE23-01 (18111*) Record date: 3/10/2023 Outer rim: 460cm Inner rim: 3360cm Depth: 70cm. Location: 436781E 6670272S	Long unused. Within Boodie warren. Shrubs growing on rim	
QE23-02 (18409) Record date: 3/10/2023 Outer rim: 370cm Inner rim: 0cm Depth: 0cm Location: 436580E 6670957S	Active. Recently tended. Within Boodie warren	
QE23-03 (21676) Record date: 3/10/2023 Outer rim: 390cm Inner rim: 130cm Depth: 33cm Location: 436668E 6671037S	Inactive recent.	

* LiDAR ID

Details	Comment	Photo
QE23-04 (16428) Record date: 3/10/2023 Outer rim: 380cm Inner rim: 230cm Depth: 50cm Location: 437800E 6669651S	Inactive recent. Soil friable to 20cm	
QE23-05 (12876) Record date: 4/10/2023 Outer rim: 340cm Inner rim: 220cm Depth: 70cm Location: 435039E 6668610S	Inactive recent. Favoured micro-niche: Friable soil and dense vegetation.	
QE23-06 (14476) Record date: 4/10/2023 Outer rim: 360cm Inner rim: 200cm Depth: 45cm Location: 435674E 6669482S	Inactive abandoned. Favoured micro-niche: Friable soil >30cm.	
QE23-07 (17259) Record date: 5/10/2023 Outer rim: NR Inner rim: NR Depth: 45cm Location: 434732E 6669625S	Inactive recent. Nest partially rehabilitated. Bird heard nearby. No activity on motion camera	

Details	Comment	Photo
QE23-08 (20860) Record date: 5/10/2023 Outer rim: 330cm Inner rim: 130cm Depth: 10cm Location: 434834E 6670332S	Active. Shallow soil. Mound elevated.	
QE23-09 (14635) Record date: 9/10/2023 Outer rim: 340cm Inner rim: 160cm Depth: 0cm Location: 440708E 6669296S	Active. Favoured micro-niche. Calcrete.	
QE23-10 (15347) Record date: 9/10/2023 Outer rim: 380cm Inner rim: 260cm Depth: 60cm Location: 440452E 6669292S	Inactive recent.	
QE23-11 (15355) Record date: 9/10/2023 Outer rim: 430cm Inner rim: 320cm Depth: 0cm Location: 440064E 6669365S	Active.	

Details	Comment	Photo
QE23-12 (13325) Record date: 9/10/2023 Outer rim: 360cm Inner rim: 260cm Depth: 20cm Location: 440610E 6668570S	Inactive recent. Favoured micro-niche. Calcrete	
QE23-13 (12790) Record date: 9/10/2023 Outer rim: 420cm Inner rim: 270cm Depth: 20cm Location: 440440E 6668216S	Inactive recent. Basalt hill footslope.	

5.2 Habitat Assessment

5.2.1 Critical Habitat for Breeding

The factors considered within this assessment of the presence of critical habitat for breeding: Malleefowl activity, Site suitability and Site context, as listed in Section 1.1.1 and based on information from a) searches for Malleefowl activity and b) data from inventory sites during habitat surveys, are summarised in Table 4.

Malleefowl Activity

Malleefowl are active in the survey area (Figure 4). There was one Malleefowl sighting during field work for this survey and five active nesting mounds were found, one of which was just outside the survey area, together with numerous recent tracks and litter disturbance.

Most activity is distant from mining operation. The four active nests in the survey area are all at least 1.5km from Luvironza and 600m from the haul road. Nesting mound QE23-4, which is 800m distant from Luvironza, is classed as recent active and may have been used within the past 5 years.

Malleefowl show a high preference for broad drainage tracks (land unit 6b) and low lateritic rises (land unit 2a) and moderate preference for plains supporting mulga shrublands (land unit 4a).

Halophytic shrublands associated with land units 4c, 5a, 5b and 7c are mostly not used by Malleefowl. The two nesting mounds found in land unit 4c occur in highly restricted niches with favourable soil conditions. The few Malleefowl tracks found in these land units are mostly minor incursions from adjacent more favourable habitat.

Site Suitability

Vegetation within the survey area has been structurally altered from historical stock grazing. Historical sheep grazing is associated with widespread vegetation change and soil erosion (Pringle et al. 1994). Vegetation, palatable to sheep, has been lost and replaced by un-palatable Eremophila, Senna and Acacia species many of which have died during the past years of below average rainfall.

Land units supporting vegetation, preferentially grazed by livestock, are degraded and few areas are in good condition. Vegetation structure on lateritic, basaltic and felsic hills is mostly intact and with little change in composition while lower slopes on laterite and basalt are often in poorer condition.

Vegetation, apparently favoured by Malleefowl, such as mulga-type acacias is prevalent in drainage tracts and plains supporting mulga shrublands.

Most areas supported sparse to very sparse shrublands and isolated casuarina and eucalypts with canopy cover generally less than 40%, except for restricted sections within the drainage system of land unit 6b.

Opportunities for nesting mound construction is often constrained by depth to the intractable layer resulting in birds seeking out favourable niches such as remnant Boodie warrens or by construction of higher mounds where soil depth is shallow such as in land unit 6b.

Litter is generally scarce in all except the broad drainage tracks of land unit 6b and to a lesser extent in plains with mulga shrublands of land unit 4a.

Site Context

Connectivity within the survey area and surrounding country is mostly unrestricted, although the haul road and mining infrastructure around Luvironza and to the south affects bird access to land units 4a, 4c, 5a and 6b somewhat more than others.

Overall rating for breeding habitat

When indices for Malleefowl activity, Site suitability and Site context, are combined and expressed on a scale of 0 to 10, habitat ratings for land units range from 2.2 to 8.6 (Table 4).

Given these ratings, where scores above 5 are considered marginal habitat and above 7 critical habitat for breeding and survival, land units 2a (rating 8.3) and 6b (rating 8.9) are rated critical habitat for breeding and survival.

The habitat rating of 6.7 for plains supporting acacia shrubland (land unit 4a) suggest this land unit provides marginal habitat for breeding and survival. Elsewhere, in nearby surveys, this unit was assessed as critical habitat for breeding (Alexander Holm & Associates 2022a), and as active nesting mounds are known to be present within this unit (Northern Star Malleefowl monitoring program), land unit 4a is also rated as critical habitat for breeding.

The habitat rating of 4.4 for low rises on basalt (land unit 2b) is inconsistent with higher ratings accorded in a nearby survey where this unit was assessed as critical habitat for breeding due to presence of nesting mounds (Alexander Holm & Associates 2022a). Land unit 2b occurs in two restricted locations of 11ha which limits opportunities for nest construction. Accordingly, land unit 2b is also rated as critical habitat for breeding.

Habitat rated critical for breeding occupies 728ha, 33% of the survey area.

5.2.2 Foraging/Dispersal Habitat

The factors considered in the assessment of habitat suitable for Malleefowl foraging and dispersal, as listed in Section 4.4.3 and based on information from a) intensive search for Malleefowl activity and b) data from inventory sites during habitat surveys, are summarised in Table 5.

When factor scores are combined and expressed on a scale of 0 to 10, habitat ratings for land units range from 2.2 (land unit 5b) to 8.6 (land unit 6b).

Given these ratings, where scores above 5 are considered suitable habitat for Malleefowl foraging and dispersal, land unit 1b occupying 24ha is suitable habitat for foraging and dispersal.

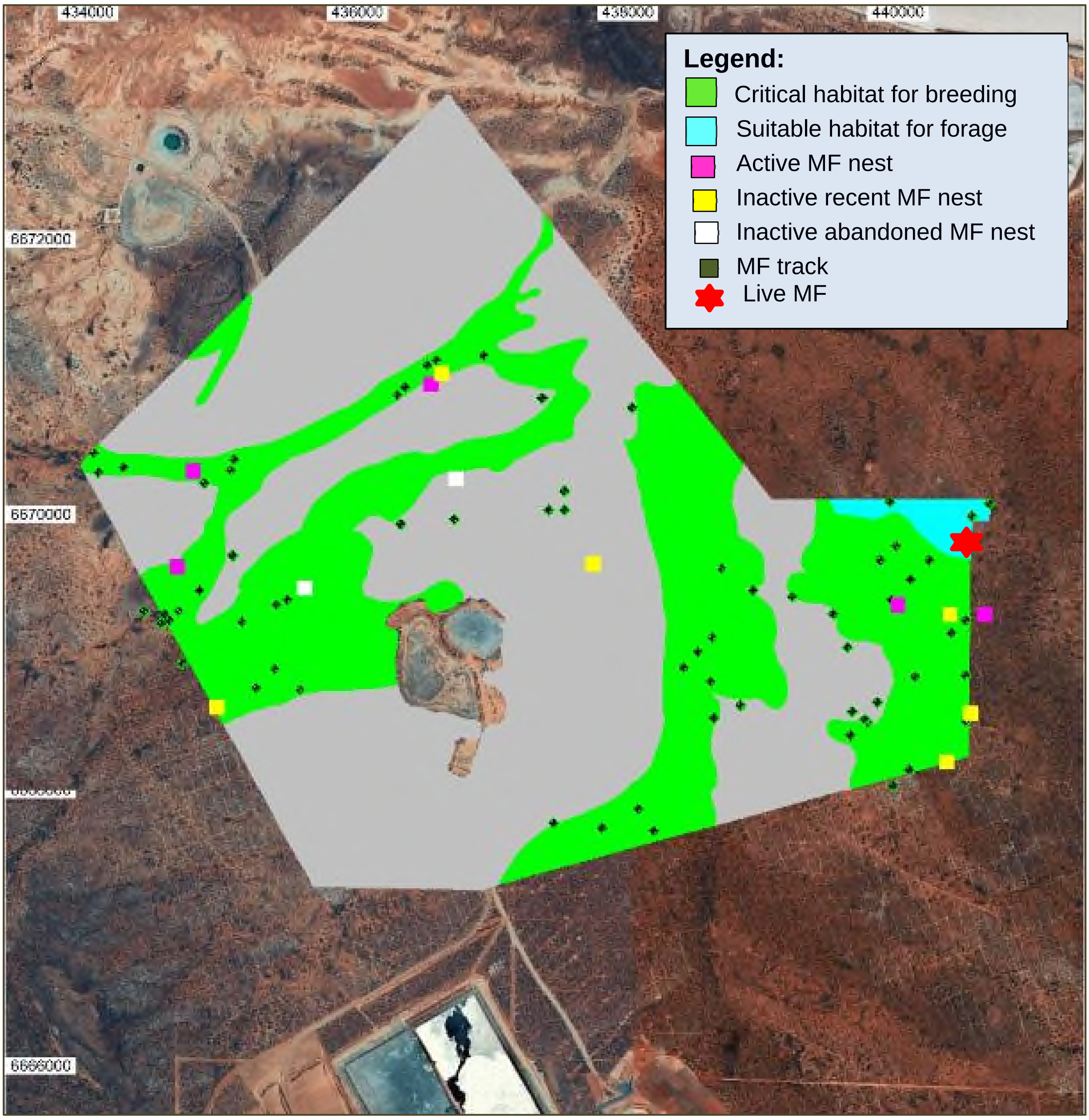


Figure 4: Assessment of Malleefowl habitat within the survey area.

Table 4: Habitat calculation worksheet for assessment of suitability of land units for Malleefowl breeding

Factor	Condition	1a	1b	1c	1d	2a	2b	4a	4c	5a	5b	6b	7c
Number of sites		11	18	3	6	6	9	15	30	6	6	11	3
Site suitability													
Soil depth	Depth to intractable soil layer, hardpan or parent material	0.4	0.6	0.1	0.9	0.7	0.6	0.7	0.6	0.7	0.2	0.4	0.3
Litter abundance	Nil:0; minimal: 0.25; moderate: 0.5; abundant: 1.0	0.4	0.3	0.2	0.5	0.4	0.4	0.6	0.4	0.2	0.1	0.7	0.1
Upper/mid canopy cover	Cover	0.4	0.7	0.2	0.4	0.4	0.7	0.6	0.3	0.4	0.1	0.7	0.1
Favourable vegetation	Prevalence of mallee, mulga type trees or spinifex	0.2	0.1	0.2	0.4	0.5	0.3	0.7	0.5	0.2	0.1	0.8	0.1
Vegetation condition	Totally degraded: 0 – pristine: 1	0.5	0.5	0.4	0.4	0.3	0.3	0.4	0.3	0.2	0.3	0.3	0.5
Habitat suitability score	Adjusted score out of 2	0.8	0.9	0.4	1.0	0.9	0.9	1.2	0.8	0.7	0.3	1.1	0.4
Site context													
Disturbances	Vehicle tacks, livestock grazing, clearing	1.0	1.0	1.0	1.0	0.4	1.0	0.5	0.4	1.0	0.8	0.9	1.0
Constraints to movement	Mining infrastructure, haul roads, fences	1.0	1.0	1.0	1.0	1.0	1.0	0.6	0.6	0.6	1.0	0.6	1.0
Habitat context score	Adjusted score out of 2	2.0	2.0	2.0	2.0	1.4	2.0	1.1	1.0	1.6	1.8	1.5	2.0
Activity													
High activity and nests	Numerous tracks; active or recent nests (1)					1.0						1.0	
Moderate activity and nests	Tracks and active or recent nests (0.8)							0.8					
Low activity and nests	Few tracks and active or recent nests (0.5)		0.5						0.5				
Low activity and no nests	Few tracks and no nests (0.3)				0.3		0.3			0.3			
No evidence of Malleefowl	No nesting mounds, tracks or litter disturbance (0)	0.0		0.0							0.0		0.0
Habitat activity score	Adjusted score out of 6	0.0	3.0	0.0	1.5	6.0	1.5	4.5	3.0	1.5	0.0	6.0	0.0
Combined habitat score	Score out of 10	2.8	5.9	2.4	4.5	8.3	4.4	6.7	4.8	3.8	2.2	8.6	2.4

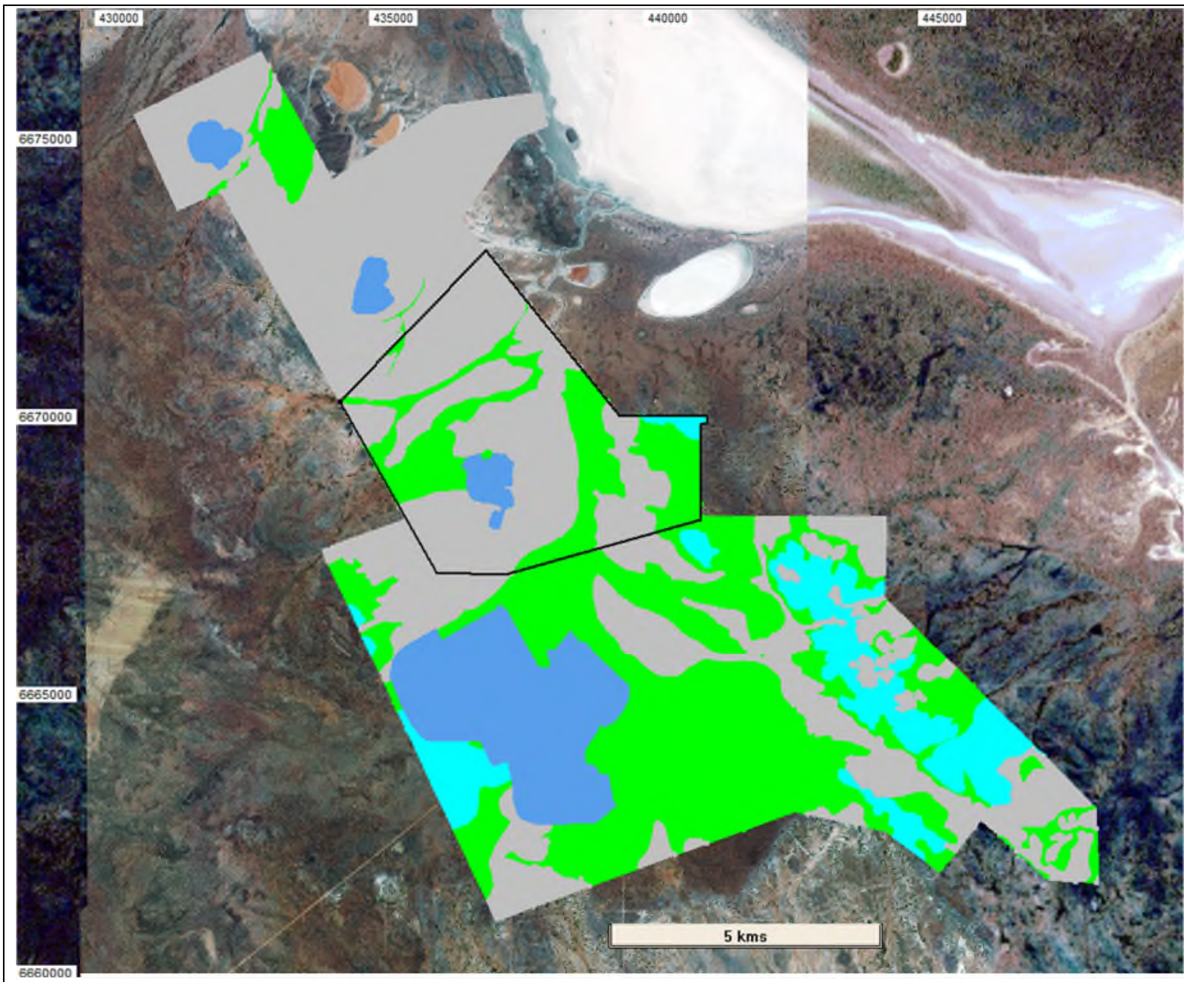
Table 5: Habitat calculation worksheet for assessment of suitability of land units for Malleefowl foraging and dispersal.

Factor	Condition	1a	1b	1c	1d	2a	2b	4a	4c	5a	5b	6b	7c
Number of sites		11	18	3	6	6	9	15	30	6	6	11	3
Malleefowl activity	Rating from no activity (0) to high activity (1)	0.0	0.5	0.0	0.3	1.0	0.3	0.8	0.5	0.3	0.0	1.0	0.0
Litter abundance	Nil:0; minimal: 0.25; moderate: 0.5; abundant: 1.0	0.4	0.3	0.2	0.5	0.4	0.4	0.6	0.4	0.2	0.1	0.7	0.1
Upper/mid canopy cover	Cover	0.4	0.7	0.2	0.4	0.4	0.7	0.6	0.3	0.4	0.1	0.7	0.1
Favourable vegetation	Prevalence of mallee, mulga type trees or spinifex	0.2	0.1	0.2	0.4	0.5	0.3	0.7	0.5	0.2	0.1	0.8	0.1
Disturbances	Vehicle tacks, livestock grazing, clearing	1.0	1.0	1.0	1.0	0.4	1.0	0.5	0.4	1.0	0.8	0.9	1.0
Constraints to movement	Mining infrastructure, haul roads, fences	1.0	1.0	1.0	1.0	1.0	1.0	0.6	0.6	0.6	1.0	0.6	1.0
Forage habitat score	Score out of 10 (Activity 50% rest 10%)	3.1	5.6	2.6	4.6	7.7	4.7	6.7	4.8	3.6	2.2	8.6	2.3

5.3 Habitat surrounding the Survey Area

Malleefowl habitat has previously been mapped in a survey overlapping and to the south of the survey area (Alexander Holm & Associates 2019) and habitat mapping is extended across surveys to the south east (Alexander Holm & Associates 2020) and north (Alexander Holm & Associates 2012). Habitat suitability was assessed using land unit descriptions and by extension across common map boundaries. The extended habitat map covers a total area of 10,351ha (Figure 5). Habitat totals have been adjusted for the 808ha overlap between the current survey and the 2019 Seismic survey.

Within the extended area, critical habitat for Malleefowl breeding totals approximately 3,900ha, 37% of the total area, forage and dispersal 370ha, 8% and the remaining 55% of the total area is unsuitable habitat or mining disturbance.



	Critical Malleefowl habitat for breeding
	Suitable Malleefowl habitat for forage and dispersal
	Unsuitable Malleefowl habitat
	Mining disturbance

Figure 5: Malleefowl habitat extended across surveys north and south of the current survey area

6 Survey Limitations

The limitations of the targeted Malleefowl activity survey and habitat assessment were considered in accordance with EPA's Technical Guidance: Terrestrial fauna surveys (2020) (Table 6).

No limitations were identified regarding conduct within the survey area. Extension of habitat analysis to areas previously surveyed was based on data not specifically collected for Malleefowl habitat definition.

Table 6: Survey limitations

Limitation	Limitation for this survey?	Comments
Availability of contextual information at a regional and local scale	No	Previous biological and soil surveys for Northern Star together with geological maps provided excellent local scale information. Regional scale information from Land System mapping assisted land unit/habitat description.
Competency/experience of the team carrying out the survey, including experience in the bioregion surveyed	No	Alexander Holm, who managed the survey and prepared the report, has many years experience in WA arid environments and has worked specifically in the Goldfields since 2005. Holm and his team have conducted Malleefowl search and habitat assessments since 2010.
Any identification issues	No	Recent Malleefowl nests are large and distinctive and unlikely to be missed. LiDAR interpreted data proved 100% reliable in identifying nests. While animal tracks were difficult to spot on some land surfaces, most included some softer sandy surfaces where tracks were obvious leading to a high level of confidence that habitat favoured by Malleefowl could be distinguished from non-favoured habitat.
Was the appropriate area fully surveyed (effort and extent)	Mostly	Intensity of sampling effort exceeded sampling intensity recommended in Survey guidelines for Australia's threatened birds' (2017). Extension of the habitat assessment to adjoining surveys was partly a desktop exercise. These surveys were all conducted by Alexander Holm & Associates using common methodology not specifically focused on Malleefowl habitat.

Limitation	Limitation for this survey?	Comments
Access restrictions within the survey area	No	All areas were accessible by vehicle or on foot.
Survey timing, rainfall, season of survey	No	The search for Malleefowl activity was in November optimal for nesting activity. Conditions were optimal for recent footprint identification.
Disturbance that may have affected the results of survey	No	A drilling team were active at one site of about 1ha within the survey area. This area was not searched however, as it was highly impacted by the drilling operation there was no possibility of Malleefowl activity on site.

7 Discussion and Conclusions

Malleefowl are active in the area. A live bird was sighted, five active, one just outside the survey area, and six inactive recent nests located, numerous fresh tracks found and much litter disturbance in favoured habitat. Most activity is distant from mining operation. The four active nests in the survey area are all at least 1.5km from Luvironza and 600m from the haul road.

Northern Star engaged Anditi to provide predictions of Malleefowl nesting mounds across the extent of the LiDAR data. The Anditi analysis provided a predictive data set over the survey area consisting of 7 Class I; 4 Class II; 18 Class III and several thousand Class IV targets, where Class I targets were considered definite MF nesting mounds and Class IV, highly unlikely to be nesting mounds.

All seven Class I and four Class II targets, predicted through the LiDAR analysis, proved to be Malleefowl nesting mounds. Of the 18 Class III predictions, two were Malleefowl nesting mounds, ten failed nesting mound attempts, five mechanical excavations and one a Boodie (Burrowing Bettong: *Bettongia lesueur*) warren. None of the many hundreds of Class IV targets encountered during the intensive search of the validation area were nesting mounds.

No active or recently active nesting mounds were found other than those predicted through the LiDAR analysis. Results of this survey provide good support for use of predictive modelling using LiDAR data to identify Malleefowl nesting mounds. Follow up ground survey is then required to establish actual Malleefowl activity and status of the predicted mounds.

Malleefowl show a high preference for broad drainage tracks and low lateritic rises and a high to moderate preference for plains supporting mulga shrublands. The low habitat rating for low rises on basalt is inconsistent with higher ratings accorded in a nearby survey where this unit was assessed as critical habitat for breeding due to presence of nesting mounds. Since this habitat is found in two restricted locations of 11ha, with limited opportunities for nest construction, it is also rated as critical habitat for breeding.

Habitat rated critical for breeding occupies 728ha, 33% of the survey area. This habitat is also important for foraging and dispersal, as is the small area of basalt hills which occupy 24ha.

Halophytic shrublands associated with land units 4c, 5a, 5b and 7c are mostly not used by Malleefowl. The two nesting mounds found in land unit 4c occur in highly restricted niches with favourable soil conditions. The few Malleefowl tracks found in these land units are mostly minor incursions from adjacent more favourable habitat.

Unsuitable habitat for Malleefowl is found on 1,376ha - 63% of the survey area.

Within an extended area of over 10,000ha, that includes the survey area and adjacent environmental surveys, critical habitat for Malleefowl breeding totals approximately 3,900ha, 37% of the total area, forage and dispersal 370ha (8%), and the remaining 55% is unsuitable habitat or mining disturbance.

8 References

Alexander Holm & Associates (2012). Environmental assessment: Old Plough Dam: 96.

Alexander Holm & Associates (2019). Environmental assessment: Proposed Seismic Survey pp 136.

Alexander Holm & Associates (2020). Environmental assessment: Relief Hill Survey Area pp 109.

Alexander Holm & Associates (2022a). Assessment of impacts on Malleefowl of proposed expansion of Carosue Dam Tailings Storage Facility pp 36.

Alexander Holm & Associates (2022b). Assessment of Malleefowl activity and habitat on Menangina Station Northeast Goldfields pp 37.

Beard, J.S. (1990). Plant Life of Western Australia. Kenthurst NSW: Kangaroo Press

Benshemesh, J. (2007). National Recovery Plan for Malleefowl.: pp 121.

Christian, C.S., & Stewart, G.A. (1953). Summary of general report on survey of Katherine-Darwin Region 1946.

Department of Parks and Wildlife (2016a). Fauna profiles. Malleefowl Leipoa ocellata: pp 2.

Department of Parks and Wildlife (2016b). Malleefowl (Leipoa ocellata) records in the Great Victoria Desert Western Australia. Report to the Great Victoria Desert Biodiversity Trust.: pp 59.

Department of the Environment Water Heritage and Arts (2017). Survey guidelines for Australia's threatened birds. Guidelines for detecting birds listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999: 278.

Environmental Protection Authority (2020). Technical Guidance – Terrestrial vertebrate fauna surveys for environmental impact assessment: pp 52.

National Malleefowl Recovery Team (2020). National Malleefowl Monitoring Manual: Edition v2020_1: pp 93.

Pringle, H.J.R., Van Vreeswyk, A.M.E., & Gilligan, S.A. (1994). An Inventory and Condition Survey of Rangelands in the North-eastern Goldfields, Western Australia: pp 323.

Stenhouse, P. (2022). Malleefowl and anthropogenic change: an integrated analysis of population trends, landscape genetics and movement ecology. PhD The University of Adelaide: p. 228.

Disclaimer

Within the limitation imposed by the scope of review, the data assessment and preparation of the report have been undertaken in a professional manner and in accordance with generally accepted practices using a degree of care ordinarily exercised by professional environmental consultants. No other warranty, expressed or implied, is made.

Appendix C: Seismic Survey Vegetation and Flora Survey

ENVIRONMENTAL ASSESSMENT:

PROPOSED SEISMIC SURVEY AREA

SARACEN GOLD MINES

Alexander Holm & Associates
Natural Resource Management Services

February 2019

Contents

Tables

Figures

Attachments

SUMMARY

This report for Saracen Gold Mines Pty Ltd covers environmental assessments to support clearing applications within a 4300ha area associated with a seismic survey in the Carosue dam area approximately 115km north east of Kalgoorlie.

The environmental assessment had three components:

- A reconnaissance vegetation and flora survey from January 7 -12, 2019.
- A reconnaissance fauna survey from January14-17, 2019.
- A targeted flora survey for *Eremophila arachnoides* subsp. *tenera* from February 4- 13, 2019.

Rainfall during winter in 2017 and 2018 was well below average (Figure 2). There were late winter rains in 2018 and as a result, some biannual herbs and grasses persisted from preceding seasons and were readily identified at the time of survey. There were few annual species.

Seventy-two inventory sites were assessed during the reconnaissance vegetation and flora survey which provided systematic coverage of the area and encompassed variations in photo-pattern. A systematic assessment of land-type, geology, relief, soil type and vegetation at each site enabled the area to be mapped into readily-identifiable land units.

Thirteen land units were identified, and eleven associated vegetation communities described. Approximately 40% of the survey area is occupied by plains supporting acacia shrublands with sparse overstoreys of eucalypts and casuarina. Chenopod shrublands occur on approximately 25% of the area either on calcareous plains or alluvial plains. Sand plains and sandy rises occupy 4% of the area and typically support spinifex tussock grasslands with sparse eucalypt overstoreys. Low hills and rises on laterite, basalt or felsic rocks occupy the remainder.

One hundred and twenty-nine flora taxa representing 26 families were found during the reconaisance survey. Chenopodiaceae accounted for 24 taxa, Fabaceae 19 taxa and Scrophulariaceae 17 taxa. There were four sterile specimens which were identified to genera level. Flora species composition and vegetation communities are typical of the area and not considered to be unusually diverse.

No listed species of rare or critically endangered flora were found during this survey and no records of Declared Rare Flora (DRF) in or nearby the survey area. Three populations consisting of over 2500 plants of *Eremophila arachnoides* subsp. *tenera*, a Priority 1 listed taxa (P1), were located within the survey envelope during the follow-up targeted flora survey. Priority flora are under consideration for listing as threatened species and as such require protection until their status is decided.

The collection of the following species at this location indicates a significant extension of their known distribution range:

- *Eucalyptus oleosa* subsp. *cylindroidea*

- *Thryptomene kochii*
- *Sclerolaena glabra*

No taxa are considered to be locally endemic.

No alien to Western Australia (weed) species were located during survey although *Carthamus lanatus* (saffron thistle) was noted growing along road verges.

Approximately 17% of the survey area is occupied by alluvial plains where moderate soil erosion is evident and are rated as moderately vulnerable to erosion. These alluvial systems support “Plain mixed halophyte low shrublands” and “Plain eucalypt chenopod woodland” vegetation communities which are degraded through over grazing. While, disturbance to alluvial plains has the potential to increase sediment discharge to drainage tracts down-slope and ultimately, and through extreme events, to Lake Rebecca, the proposed strip clearing is unlikely to result in significant increases in sediment discharge.

The survey landscape mainly drains via overland flow to a main drainage which flows into Lake Rebecca 5 km to the north. Southern areas drain southerly through various drainage systems again to Lake Rebecca. Lake Rebecca is a major wetland with local and regional significance. Survey lines will intercept these watercourses.

Malleefowl are active in the survey area. There were three sightings of birds during this survey and active mounds have been found in previous studies. Malleefowl is probably more abundant to the west where there are extensive sandy soils associated with land unit 1d and 4d occupying about 4.5% of the survey area. They may also be more abundant in rocky hills and low rises collectively occupying 17% of the survey area. Malleefowl mounds are of importance for the birds, whether or not they are active or recently-used.

Large Eucalypt trees, common in land unit 5b, may support nesting by the Peregrine Falcon (and other birds).

There are no Threatened Ecological Communities (TECs) within the north east Goldfields subregion and no Priority Ecological Communities within or adjacent to the survey area. No conservation areas are nearby.

It is recommended that, in planning and implementing seismic operations within the survey area, the proponent:

1. **Avoids disturbance to *Eremophila arachnoides* subsp. *tenera*.**
2. **Undertakes a Malleefowl survey especially within land units 1a, 1b, 1c, 1d, 2a and 2b and avoids disturbance within 50m of active Malleefowl nests during nesting and incubation.**
3. **Installs signage on access roads to the exploration area if Malleefowl are seen or suspected.**
4. **Avoids destruction of mature Eucalyptus trees with nesting hollows.**
5. **Takes measures to minimise erosion through soil disturbance and concentration of overland water flows on vulnerable land units, especially alluvial plains (land unit 5a and 5b).**
6. **Avoids disturbance to the main drainage channel (land unit 6).**

SCOPE OF WORKS

Alexander Holm & Associates were contracted by Saracen Gold Mines Pty Ltd (Saracen) to conduct the following surveys in the Carosue Dam area. Bamford Consulting Ecologists (BCE), were sub-contracted by Alexander Holm & Associates to undertake and report on the fauna component of the assessment.

Saracen operates the Carosue Gold Mine and is proposing intensive exploration around its existing mine. A siesmic survey is proposed over a 4300ha area requiring clearing of 3m wide access-lines at 90m spacing. Parts of this area have been covered by earlier environmental assessments. The current assessment envelope covers the balance of 3136ha.

Part A: An environmental assessment to include:

- A review of available information on likelihood of a) presence of threatened (rare) or priority plant species and b) threatened plant communities in the general search area.
- A reconnaissance level fauna, flora and vegetation survey.
- An assessment of landscape stability and condition.
- A description of land units and relate information on fauna, flora, vegetation communities and landscape stability to these units.
- A map of land units and associated vegetation communities.
- A report on findings within a local and regional context
- An assessment of the proposal in relation to impacts on fauna.
- An assessment of the proposal against clearing principles.

The scope of works is to comply with Western Australian Environmental Protection Authority (EPA) objectives for protection of the environment specifically to “ensure that flora and vegetation surveys provide sufficient information to address both biodiversity conservation and ecological function values within the context of the type of proposal being considered” and to “enable an assessment of impacts on the conservation values and status of the site in a regional and local context” (Environmental Protection Authority, 2004).

The work takes into account the following surveys that are either within or adjoin the proposed project envelope and will produce a unified landunit/ vegetation association map to cover these surveys:

- Mattiske Consulting Pty Ltd (2010) Flora and vegetation survey of the proposed airstrip.
- Mattiske Consulting Pty Ltd (2010) Flora and vegetation survey of the Karari pit extension.
- Alexander Holm & Associates (2010)Environmental assessment-proposed expansion of Whirling Dervish mine.
- Alexander Holm & Associates (2012b) Environmental assessment – proposed expansion of Tailings Storage Facility.

In addition, information on fauna was available from a number of previous studies in the area. These include:

- Alexander Holm and Assoc. (2017). Malleefowl survey of proposed airstrip. Saracen Gold Mines.
- Coffey environments (2010). Level 1 vertebrate fauna survey for the Carosue Dam Project, Saracen Gold.
- Biologic. (2010). Level 1 survey for a proposed pipeline from GGT to Carosue Dam and powerline from Black Swan to Carosue Dam. Tropicana JV and Saracen Gold Mine Pty Ltd.
- Henry-Hall *et al.* (1990). Report on survey of Goongarrie Nature Reserve.
- ABRS (2013). Bush Blitz; Biological survey of Credo Station Reserve WA.

Part B: A targeted survey to locate, record and map the extent of populations of *Eremophila arachanoides* subsp. *tenera,* a Priority 1 taxon, within and adjacent to habitats identified during the reconnaissance survey.

REGIONAL OVERVIEW

Regional setting

Carosue Dam TSF is approximately 115 km north east of Kalgoorlie Boulder, and south east of Lake Rebecca (Figure 1). It is within the north-eastern Goldfields region, Kalgoorlie-Boulder local government area, and partly within unallocated crown land (UCL), Gindalbie and Pinjin pastoral leases. It is located in the south-east of Eastern Murchison (MUR 1) bio-geographic subregion and adjacent to Shield and Eastern Goldfields bio-geographic sub-regions (Cowan 2001, Desmond, Cowan and Chant 2003).

The most extensive land use in the region is pastoralism and over 80% of this region is pastoral leasehold. Most of the remainder is unallocated crown land and less than 1% is set aside for nature conservation.

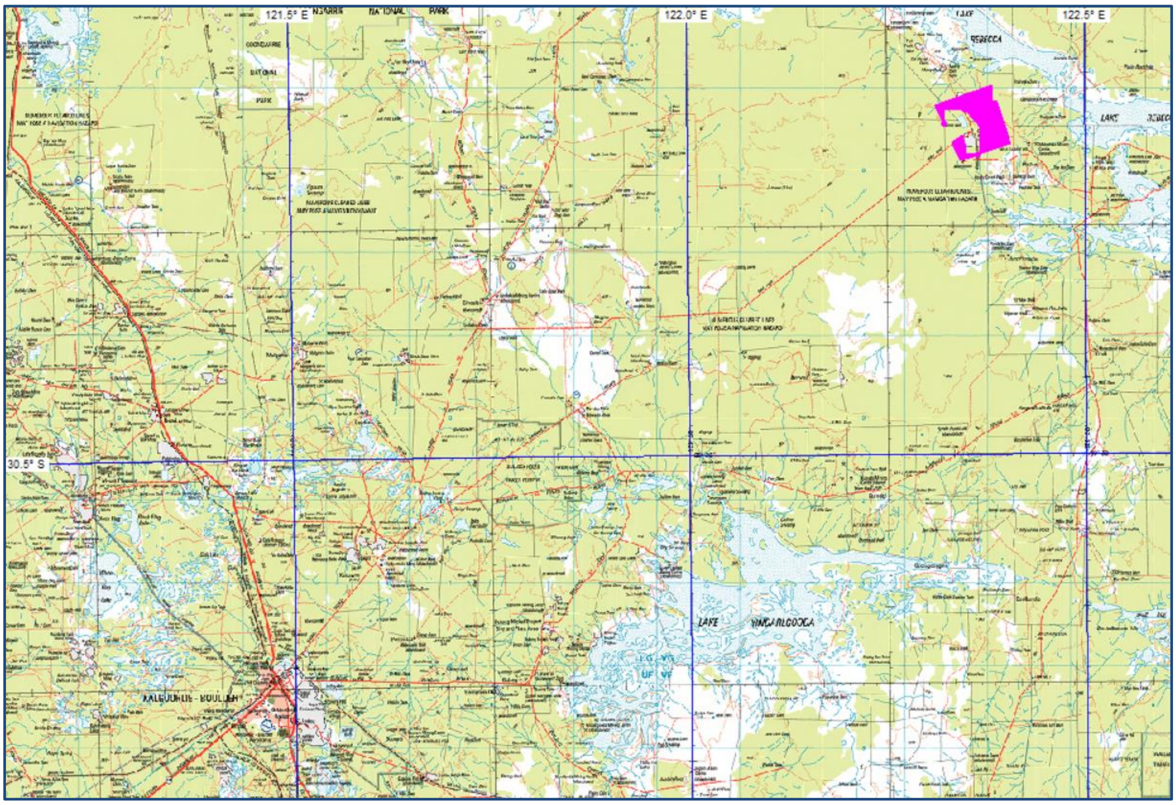


Figure 1: Survey area (in pink) in relation to Lake Rebecca and Kalgoorlie Boulder in the south west.

Climate

Rainfall in the region is unreliable and inconsistent. Winter rainfall consists of light showers from April to October. Significant summer rainfall events originating from the north-west as tropical cyclones are most likely between January and March. The highest recorded daily rainfall at Kalgoorlie is 177.8 mm (in February) and 92.6 mm (in January) at Laverton. For Kalgoorlie, one in one hundred years rainfall events of 1 hour and 72 hours are estimated to result in 43 and 173 mm of rain respectively. (Data from www.bom.gov.au).

The average potential pan evaporation rate at Carosue Dam is approximately 2800 mm per annum[1].

Winds are mostly light easterlies.

Topography and drainage

Landform patterns in the general area comprise extensive sand plain, sub-parallel greenstone belts and breakaways with often extensive lower pediments which give way to level to very gently inclined sheet flood plains. Relief is subdued. There are no major river systems. South-east trending, broad, saline, palaeo-drainage systems traverse the region and are defining features of the Yilgarn block of south-western Australia (Gentilli, 1979). These drainage systems have very low gradients and contain playa lakes including Lake Rebecca, Carey and Raeside. Lakes form local depo-centres with poorly developed radial drainage systems. During occasional intense rainfall events lakes may fill, and in very rare events some may overflow, link-up and discharge to the Nullarbor Plain through Ponton Creek (Pringle, Van Vreeswyk & Gilligan, 1994).

Hydrogeology

Groundwater occurs throughout the region within sparse fractures in basement rocks, within the weathering profile, and in alluvial sediments. Regional water table elevations vary from around 350 m above sea level around Lake Raeside to 400 – 450 m above sea level around Lake Carey and are generally 30 to 100 m below surface. Groundwater recharge occurs from major, but infrequent, rainfall events, mainly on drainage divides, and locally at site specific intake areas such as drainage lines or sandplains and dune fields. Groundwater is in hydraulic continuity and flows from drainage divides towards palaeo-drainages and then south-easterly toward the Nullarbor Plain. Groundwater beneath catchment divides occurs as lenses of less than 5000 mg/l TDS which are superimposed on a regional field of saline groundwater with linear bodies of hypersaline groundwater along palaeo-drainages, and local brine pools associated with salt lakes.

Vegetation and soils

The region lies within the Eremaean botanical province, mainly in the Austin botanical district, with the eastern edge approaching the Helms botanical district (Beard, 1976). Lake Ballard/Lake Rebecca form a major vegetation divide with characteristic *Acacia aneura* (mulga) low woodlands associated with red loams over siliceous hardpan to the north and low woodlands of mixed mulga and *Casuarina obesa* (black oak) and

[1] http://www.bom.gov.au/cgi-bin/climate/cgi_bin_scripts/evaporation.cgi.

Eucalyptus species on alkaline and calcareous soils to the south. Spinifex hummock grassland with eucalypt overstory on sand plain is common. Halophytic vegetation occurs throughout the region on palaeo-drainage systems, breakaways and on some stony and alluvial plains. Highly saline soils support *Atriplex* (saltbush), *Maireana* (bluebush) and *Tecticornia* (samphire) shrublands, while less saline soils support eucalypt or mulga with saltbush or bluebush understoreys.

The most common vegetation associations in the region include Beard Vegetation Association 20 (Low woodland: mulga mixed with *Casuarina obesa* and *Eucalyptus* spp.), 110 (Hummock grassland, shrub steppe and red mallee over spinifex) and 389 (Succulent steppe with open low woodland; mulga over saltbush) (Table 1).

Table 1: Vegetation associations (Beard, 1976) in project area in comparison with South Laverton area (SLA), total area in WA and area within conservation reserves

Veg Assn	Description	SLA Area km^2	Reserve priority	Western Australia Area km^2	Western Australia Within reserve km^2	Western Australia Within reserve %
20	Low woodland; mulga mixed with *Casuarina obesa* and *Eucalyptus* spp.	7892	L	13045	2173	16.7
24	Low woodland; *Casuarina obesa*	15.2	L	265.6	2.4	0.9
110	Hummock grassland; shrub steppe and red mallee over spinifex	356	M	4746	1201	25.3
389	Succulent steppe with open low woodland; mulga over salt bush	2344	M	6465	230	3.6
529	Succulent steppe with open low woodland; mulga and sheoak over salt bush	46.6	H	102.8	0.1	0.1

L*: Low; M: Medium; H: High priority for reservation

ASSESSMENT METHODOLOGY

Assessment personnel

The work was managed and conducted by Dr Alexander Holm (Alexander Holm & Associates). Dr Holm is an ecologist with over 35 years experience in arid environments and Goldfield regions and an accredited environmental consultant with the Environmental Consultants Association of Western Australia.

Mr Andrew Mitchell was assisting botanist to Western Australian Department of Agriculture's rangeland surveys, senior author of "Arid Shrubland Plants of Western Australia" (Mitchell and Wilcox 1994) and recently retired botanist with AQIS (Australian Quarantine and Inspection Service). Mr Mitchell provided off-site assistance in expert identification of flora specimens collected in the field and preliminary land unit mapping.

Mr Geoffrey Eliot was soil and landscape technician for the Western Australian Department of Agriculture's rangeland surveys and has over 20 years experience in Western Australian arid regions.

Field work for the vegetation and flora surveys was conducted by Mr Eliot and Dr Holm.

The identity of priority flora taxa *Eremophila arachanoides* subsp. *tenera* was confirmed by Mr Andrew Brown, recently retired botanist at the Western Australian Herbarium and author of "A field guide to the Eremophilas of Western Australia" (Brown and Buirchell 2011)

Dr Mike Bamford is a wildlife biologist, scientific illustrator and science communicator and with his wife Mandy, he has operated Bamford Consulting Ecologists since the mid 1980s. The business specialises in fauna investigations for Environmental Impact Assessment and to meet conditions of approval, such as monitoring of impacts and monitoring of rehabilitation. Some work is also done on environmental education and interpretation. Mike has extensive experience in the south-west of Western Australia, Western Australia's Goldfields, Pilbara, Kimberley, the Western Deserts, the Northern Territory, Christmas Island and far north Queensland.

Dr Barry Shepherd is an ecologist with more than 20 years working as an environmental consultant. Barry's core skills are around environmental and ecological impact assessment, and environmental approvals. Around this experience, he has conducted a large number of environmental baseline survey for birds, bats, small mammals and herpetofauna, and specialises in marine mammals and bats. He is also experienced in line transect population studies (Distance). Barry has undertaken extensive analysis of bat echolocation and calls and is competent on most ultra-sonic detection systems. Barry has written a large number of baseline survey reports, impact assessments and environmental approval documentation.

Field work for the fauna survey was conducted by Drs Bamford and Shepherd.

Timing of survey and seasonal conditions

Vegetation and flora reconnaissance survey from January 7 -12, 2019.
Fauna reconnaissance survey from January14-17, 2019.
Flora targeted survey from February 4- 13, 2019.

Rainfall during winter in 2017 and 2018 was well below average (Figure 2). There were late winter rains in 2018 and as a result, some biannual herbs and grasses persisted from preceding seasons and were readily identified at the time of survey. On the other hand, there were very few annual species.

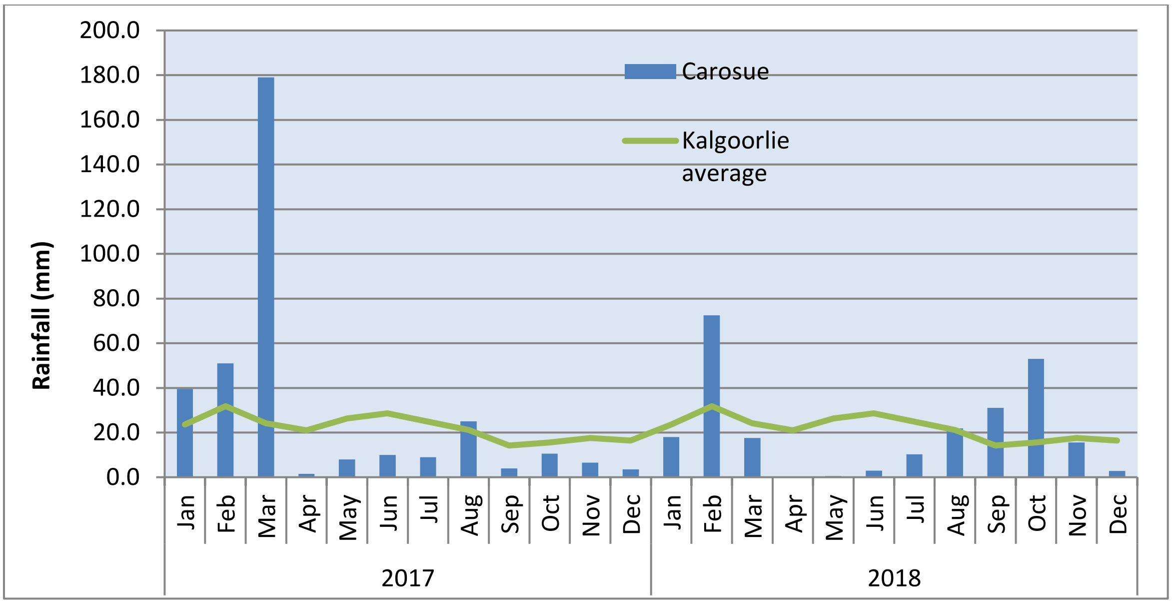


Figure 2: Monthly rainfall (mm) at Carosue Dam in comparison to averages at Kalgoorlie airport

Declared flora and fauna

The Department of Parks and Wildlife and the Western Australian Museum's "NatureMap"[2] was interrogated for records of all collected flora within a 40 km radius of the study area (Attachment 1). The list was augmented by other recent searches from nearby survey areas (Alexander Holm & Associates 2012a, Alexander Holm & Associates 2012b, Alexander Holm & Associates 2012c, Alexander Holm & Associates 2012d).

Thryptomene eremaea, a Priority 2 taxon, is recorded in NatureMap as being located within 40km of the study area. It is an erect open shrub, 0.5 to 1.5m high, producing pink or white flowers from July to September and grows on red or yellow sands on sandplains and shallow sandy soils over granite.

Eremophila arachnoides subsp. *tenera*, a Priority 1 taxon, was recorded by Alexander Holm and Associates (2012d) in an adjacent survey during 2012.

Declared flora and fauna listed on Commonwealth Department of Environment and Energy database of threatened species were identified within a 100km radius of the study area using the protected matters search tool3 (Attachment 2).

Gastrolobium graniticum is classed as Endangered under the EPBC Act 1999 and as a Declared Rare taxa under the Wildlife Conservation Act 1950 [WA]. This member of the Fabaceae is an erect shrub 0.9 to 1.2 m high with purple branches, and ovate leaves 2.5 to 6 cm long. The distribution of this species is restricted to the Kalgoorlie ad Coolgardie districts where it is found in sandy or sandy loam soils near granite rocks.

Records of bird observations in Australia, 1998-2019 from BirdLife Australia Atlas Database (Birdlife Australia) within a 40km radius of the study area.

Records of biodiversity data from multiple sources across Australia from Atlas of Living Australia and within a 40km radius of the study area.

Significant conservation fauna which may be present in the survey area, include one reptile, 19 birds and two mammals. The single reptile is a Priority 2 skink that may occur under leaf-litter around trees and mallee. The majority (9) of the birds are waterbirds that are either vagrants or irregular visitors and would not utilise the actual project area due to the lack of wetlands. Most other significant birds are expected only as vagrants but three species may use the site regularly: Malleefowl, Peregrine Falcon and Rainbow Bee-eater. Only two significant mammals are expected, with the Central Long-eared Bat potentially roosting in large trees, and the Brush-tailed Mulgara probably being locally extinct or possibly being a vagrant.

Threatened and priority ecological communities

The likelihood of presence of threatened ecological communities within the general survey area was assessed was assessed using the protected matters search tool (Attachment 2).

[2] https://naturemap.dpaw.wa.gov.au/default.aspx
[3] http://www.environment.gov.au/erin/ert/epbc/

Other threatened ecosystems in the south-east of Eastern Murchison (MUR 1) bio-geographic subregion, identified during “A Biodiversity Audit of Western Australia’s 53 Biogeographical Subregions in 2002”, are listed in Cowan (2001).

Priority ecological communities in the area were assessed from Department of Parks and Wildlife listing (Version 27, June 2017).

Land systems land units and vegetation communities

Land systems and land units were derived from a land resource survey of north eastern Goldfields (Pringle, Van Vreeswyk & Gilligan, 1994). Land systems for the region south of the north eastern Goldfield survey have been tentatively identified by desk-top photographic interpretation and extrapolation (Department of Agriculture and Food WA).

Vegetation communities were established firstly with reference to those listed in Pringle et al. (1994) where they are listed as ‘site types’, and secondly, where no comparable community could be found, with reference to those listed in adjacent surveys of Sandstone, Yalgoo Paynes Find (Payne et al., 1998) and Kambalda north (Payne, Mitchell & Hennig, 1998).

Tentative land units were identified by examination of high-resolution aerial photography. Boundaries were checked in the field, transferred to geo-referenced ortho-photo maps and captured digitally. Vegetation communities were visually associated with each land unit.

Field survey

Reconnaissance vegetation and flora survey

The survey and reporting were conducted to comply with the EPA’s “Technical Guidance – flora and vegetation surveys for environmental impact assessment” (Environmental Protection Authority 2016). A reconnaissance level survey was considered appropriate in the first instance in view of results of several vegetation and flora surveys in or adjacent to the study area (Figure 3).

Seventy two inventory sites (relevés) were selected to 1) sample each land unit within the survey area, 2) provide systematic coverage of the survey area, and 3) to encompass variations in pattern within each land unit. Each inventory site was located by GPS and the following information recorded:

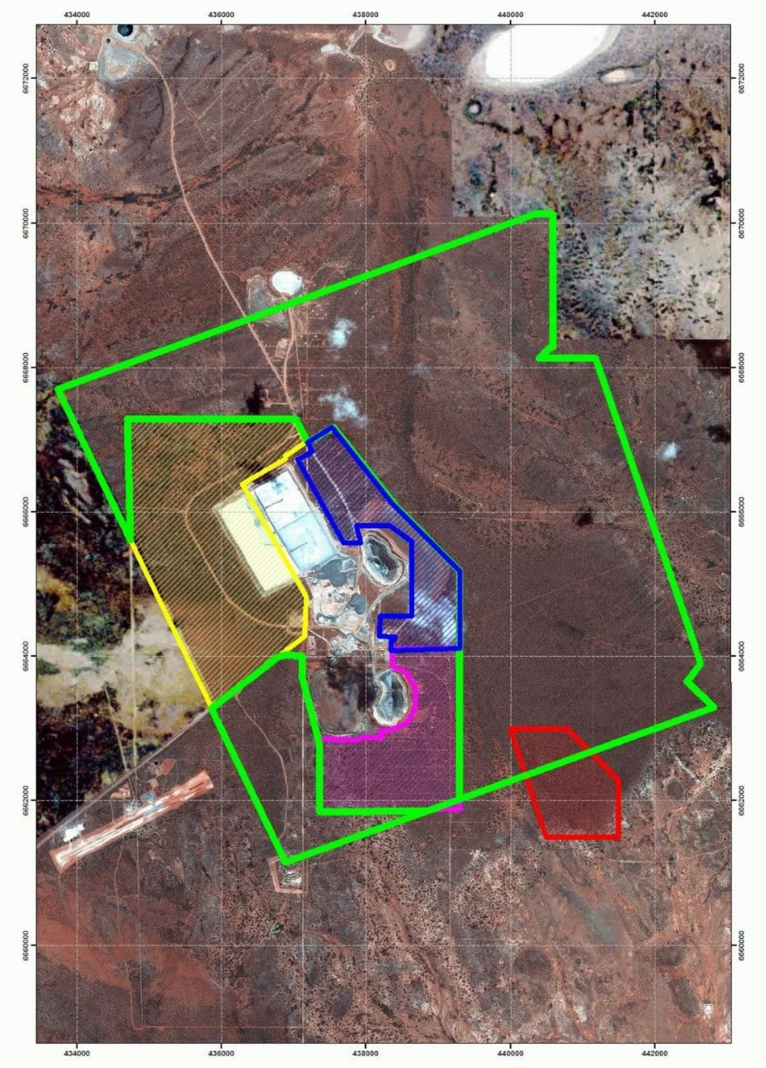
- Digital photographs.
- All flora species within approximately 50 m of a central location and in the same land unit were inventoried and voucher specimens collected of all taxa which were also compiled within a reference field herbarium.
- Vegetation condition were visually estimated using rating scales of Environmental Protection Authority (2016) and soil erosion compared with standard rating scales used for rangeland surveys and described by Pringle *et al*. (2004).
- Vegetation community and land unit descriptions using terminology from Payne et al. (1998).

- Vegetation cover, landform, slope, relief, surface coarse fragment characteristics and surface water flow characteristics (Anon, 2009).
- Soil characteristics (texture, reaction to acid and fragment characteristics) of A horizon to maximum of 30cm (Anon, 2009).

These data were augmented by walking traverses by two surveyors along selected routes. The survey aimed to:

- Locate priority or threatened flora.
- Locate species not previously recorded at inventory sites.

Locations of inventory sites, vehicle traverse (150km) and walking traverses (2.5km) are shown in Figure 4.



Alexander Holm & Associates (2010)
Mattiski (2010)
Mattiski (2010)
Alexander Holm & Associates (2013)

Figure 3: Proposed survey area (green) and locations of existing flora and vegetation surveys.

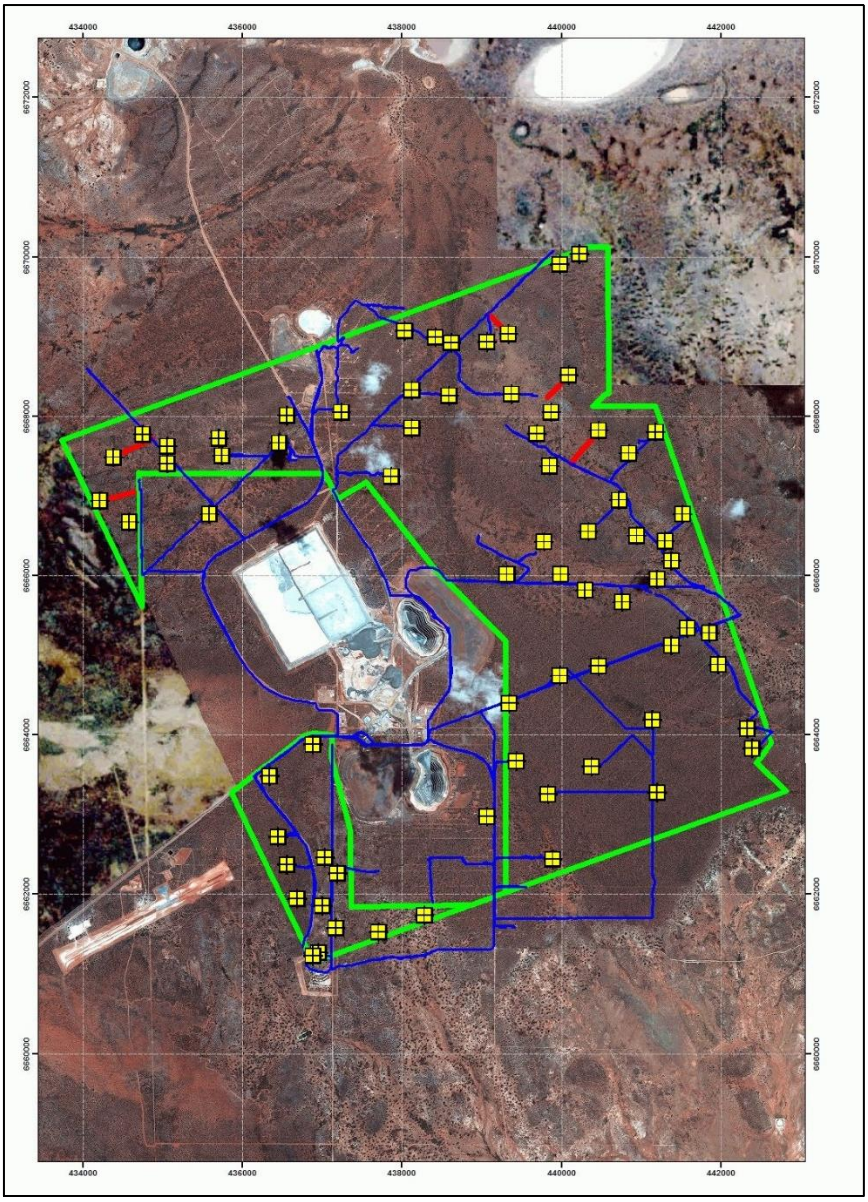


Figure 4: Location of inventory sites (yellow) vehicle traverse (blue) and walking traverses (red) during initial flora survey.

Targeted flora survey

Three main search areas were defined by locations of *Eremophila arachanoides* subsp. *tenura* found during the reconnaissance survey and earlier adjoining surveys: a northern area of about 600ha and southern areas of about 50ha and 40ha. Each area was searched by two operators along previously defined transects approximately 25m apart using GPS guidance to ensure a systematic coverage. Additional opportunistic traverses were done to cover possible habitat outside the pre-defined search area. Total foot-traverse distance was 209km.

Operators concentrated on defining population boundaries. About 40-50% of found plants in the northern area were tagged with tape and located by GPS including all outliers. All found plants in the southern areas were tagged and located by GPS.

Additional areas outside the two main search areas, which were considered as possibilities for occurrence of the target species, were also inspected.

Reconnaissance fauna survey

The site visit involved looking around as much of the project area as possible in daylight; as shown in Figure 5. This enabled environmental descriptions to be prepared and allowed opportunistic observations on fauna. Familiarity with the environment enables interpretation of species lists from databases. Targeted searching was undertaken for two significant species known from the general area: the Malleefowl (searching for nest mounds, foraging signs, tracks and direct observations); and the Brush-tailed Mulgara (searching for burrows, tracks and scats). In general, walks were unstructured and two personnel travelled 20-40m apart, with the track determined by areas of interest and intended to cover as much ground as possible. An exception to this was just north of the accommodation village where systematic transects were walked across a small area to search for Malleefowl mounds. Signs of all species observed, and other notable features of interest were recorded.
On the evening of 14th January, between c.19:30 and 21:10, the surveyors conducted a torch-light search of a rocky breakaway just north of the mine camp for nocturnal fauna. Both surveyors carried head torches and recorded species observed or heard.

Throughout the torch-light survey, bat echolocations and calls were recorded on a hand-held bat detector (Echo Meter Touch 2 Pro (EMT2)(Ser No: E2A00773). The EMT2 was run from a Samsung Galaxy S7 with Echo Meter software version 2.6.5. A Wildlife Acoustics Song Meter 4 BAT Full Spectrum (SM4BAT) was deployed next to three settling ponds that form part of the Mine Camp's sewerage treatment plant on the afternoon of 14th January and retrieved on the morning of 17th January 2019. The settling ponds were located approximately 1km due south of the Survey Area boundary and 0.75km south of the Mine Camp. Recordings from the EMT2 and SM4BAT were viewed in Kaleidoscope Viewer v4.5.4 from Wildlife Acoustics. More than 4,000 audio records were obtained over the three nights of sampling indicating very high levels of bat activity. Only a small sample was assessed to provide a preliminary list of bat fauna supporting the Level 1 survey.

The complete fauna memo report is attached

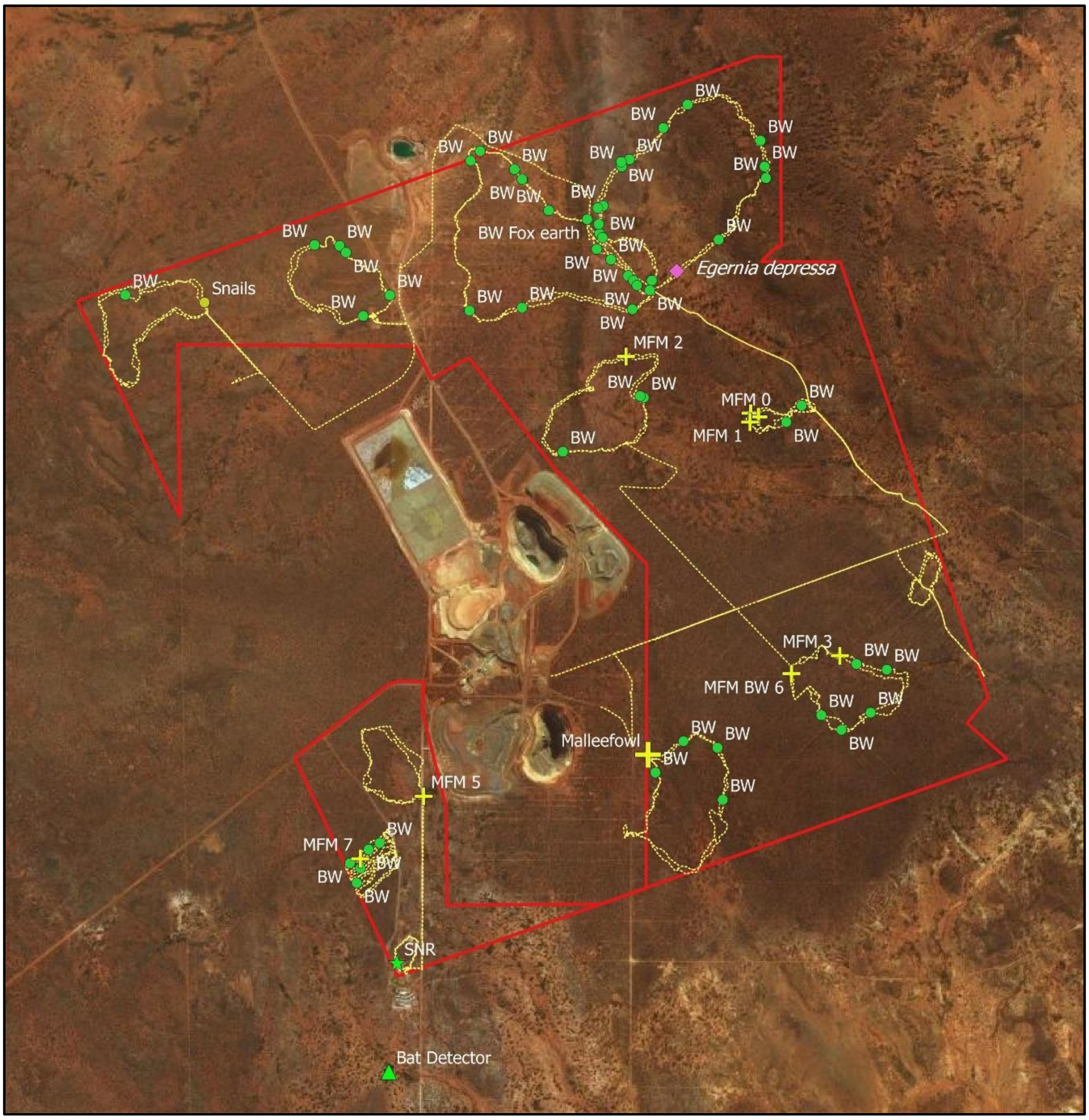


Figure 5: Vehicle traverse and walking traverses (yellow) during fauna survey. Locations of fauna observations are indicated: BW = Boodie warrens, MFM = Malleefowl mound

ENVIRONMENTAL ANALYSIS

Conservation estate

Beard Vegetation Association 20 (Low woodland: mulga mixed with Casuarina obesa and Eucalyptus spp.) is the most common vegetation association in the survey area occupying 83%. Vegetation Association 529 (Succulent steppe with open low woodland; mulga and sheoak over salt bush) occupies 12% and the remaining 5% is Vegetation Association 24 (Low woodland; Casuarina obesa) (Beard 1976).

Vegetation Association 20 occupies approximately 13,000 km^2 in Western Australia of which 16.7% is within conservation reserves and although less than 1% of Vegetation Association 24, which occupies approximately 266 km^2 in Western Australia, is within reserves, both have a low priority for conservation (Table 1). Vegetation Association 529 is very poorly conserved and has a high priority for conservation.

There are no conservation reserves within 50 km of the survey area (Appendix 1). The closest conservation area is Bullock Holes Reserve, approximately 60 km south west.

There are no listed sites of international or national significance or wetlands of International, National or sub-regional significance within the project area (Appendix 1) although Lake Rebecca is considered an ecologically significant component of inter-regional palaeo-channels.

There are no registered sites on State or National heritage registers.

Lake Rebecca is a registered mythological site.

Land systems and landforms

Approximately 55% of the survey area is occupied by plains with eucalypt woodlands with non-halophytic undershrubs of Deadman land system; 14% consists of low greenstone hills and stony plains, supporting chenopod shrublands with patchy eucalypt overstoreys of Moriarty land system; 4% is sandplain of Kirgella land system and the remainder by Leonora, Lawrence, Campsite and Gundockerta (Table 2).

Table 2: Descriptions of land systems within the survey area (Pringle, Van Vreeswyk & Gilligan, 1994 and Department of Agriculture and Food, WA).

Land type	Land system	Description	Soil and land management
Hills and ridges	Lawrence	Low greenstone hills with ironstone ridges, supporting pearl bluebush shrublands with mixed eucalypt overstoreys.	Narrow drainage tracts are susceptible to water erosion.
Erosional surfaces of low relief	Gundockerta	Extensive gently undulating plains on weathered greenstone with stony mantles and lower alluvial tracts	Saline plains and adjacent alluvial tracts are susceptible to water erosion.
Depositional plains with calcareous red earths	Deadman	Level to gently undulating plains with casuarina-acacia shrublands.	Generally not susceptible to soil erosion
	Moriarty	Low greenstone hills and stony plains, supporting chenopod shrublands with patchy eucalypt overstoreys.	Slopes of low rises, alluvial plains and narrow drainage tracts are moderately susceptible to soil erosion.
Sandplain spinifex hummock grasslands	Kirgella	Extensive sandplain with spinifex hummock grasslands and mulga and mallee shrublands	Prone to wildfires which temporarily render sands unstable.
Plains with saline alluvium	Campsite	Alluvial plains and minor gently undulating stony upper plains with groved eucalypt woodlands.	Moderately susceptible to erosion

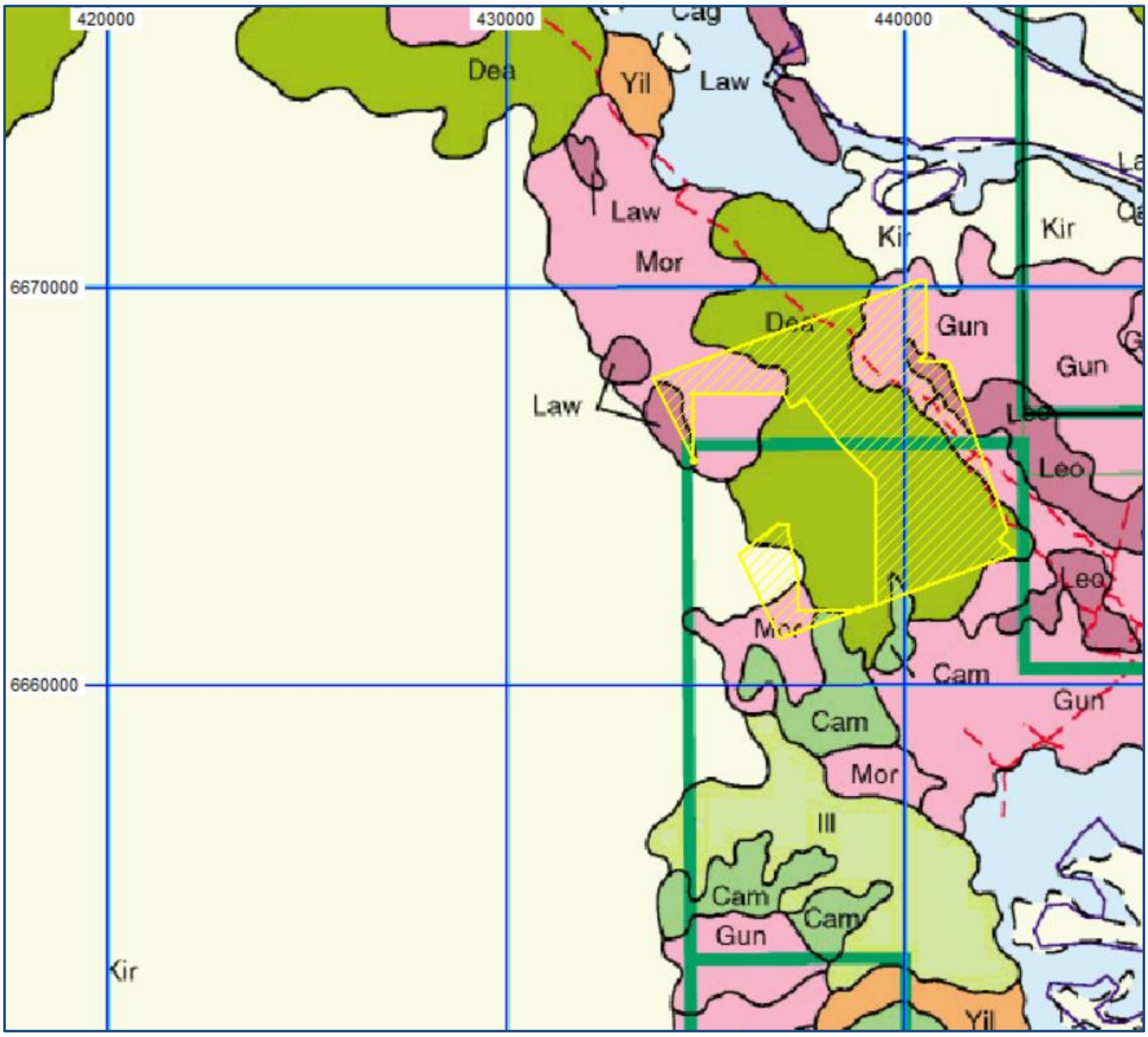


Figure 6: Land systems within the survey area (in yellow)

Land units, soil types and vegetation communities

Land unit descriptions and mapping

Thirteen land units and associated vegetation communities and soil types are described (Table 4).

A map of land units is overlain on an aerial photograph (Figure 7).

Table 3: Land unit descriptions, their soil type, vulnerability to erosion and associated vegetation communities.

Land unit	Land form and soil type	Vegetation community
1a. Lateritic hills		
	Lateritic hills with relief to 20m with slopes up to 8%, very abundant (>90%) surface mantles of ironstone coarse and medium gravel and occasional quartz. Shallow sandy loams or sandy clay loams over calcrete or parent laterite. Run-off source zones, nil vulnerability to erosion.	Open mixed shrubland (PFC 6-15%) dominated by *Acacia stowardii*, *Dodonaea lobulata* and *Ptilotus obovatus* with very sparse overstorey of *Casuarina pauper*, *Eucalyptus* spp and occasional *Acacia incurvaneura.* "Stony ironstone acacia shrubland" (SIAS vegetation community)
1b. Basalt hills		
	Basalt hills with relief to 30m, slopes from 3-10%, abundant (50-90%) surface mantles of coarse gravel and cobbles of basalt and occasional quartz or calcrete. Sandy loams less than 30cm in depth often highly calcareous. Run-off source zones, nil vulnerability to erosion.	Open mixed height shrubland (PFC 25-30%) dominated by *Acacia quadrimarginea, A. burkittii,* and *Dodonaea lobulata* with very sparse overstorey of *Casuarina pauper*. "Greenstone hill acacia shrubland" (GHAS vegetation community)

Land unit	Land form and soil type	Vegetation community
1c. Felsic hills breakaways and footslopes		
	Breakaways with relief of 25m and scarp slopes of 20%, low hills to 12m with slopes of 5% and footslopes with slopes of 2%, Common to very abundant (20->90% surface mantles of medium to coarse gravel and cobbles of felsic rocks and occasional quartz. Skeletal sandy loams less than 15cm. Non-calcareous. Run-off source zones, nil vulnerability to erosion.	Open low or mixed height shrubland (PFC 10-30%) dominated by *Scaevola spinescens, Acacia erinacea, Eremophila scoparia* and *Senna artemisioides* subsp. *filifolia* with very sparse overstorey of Casuarina pauper or *Eucalyptus oleosa* subsp. *oleosa* and occasionally open woodlands of *Eucalyptus lesouefii*. “Breakaway mixed shrubland” (BRXS vegetation community) .
1d. Sandy rises		
	Broad sandy rise to 10m and slopes to 3%. Deep sandy soils. Most rain water inflitrates and in high intensity rainfall sheds water to lower parts of the landscape. Slight vulnerability to erosion.	Sparse woodlands (PFC 5 -10%) dominated by *Acacia incurvaneura* and low mallees (4 -10m) including *Eucalyptus eremicola*, *E.ceratocorys* and *E. oldfieldii* over a diverse sparse (PFC 20 -30%) shrubland (<1.5 m) with spinifex (*Triodia irritans*) often dominated by myrtaceous shrubs. Shrubs include *Eremophila forrestii* subsp. *forrestii*, *Thryptomene kochii*, *Verticordia pritzelii*, *Prostanthera althoferi* subsp. *althoferi* and *Acacia effusifolia* “Sandplain mallee spinifex woodland” (SAMA vegetation community).

Land unit	Land form and soil type	Vegetation community
2a. Low lateritic rises		
	Gentle low rises with slopes to 2%, relief up to 2 – 3 m, common to very abundant (20 - >90%) surface mantles of fine and medium gravel of laterite with occasional calcrete and quartz. Sandy loams to 30cm occasionally highly calcareous at surface and overlaying calcrete. Run-off source zones, nil to slight vulnerability to erosion.	Very sparse to open mid-height shrubland (PFC 10-25%) dominated by *Eremophila forrestii*, *E. scoparia*, *Dodonaea lobulata*, *Senna artemisioides* subsp. *filifolia* and *Acacia colletioides* with sparse overstorey of *Acacia incurvaneura* or isolated *Casuarina pauper* “Calcareous casuarina acacia shrubland” (CCAS vegetation community).
2b. Low rises on basalt		
	Gently rounded hills, rises and gentle slopes to 7%, relief to 5 m, many to abundant mantles (20 –90%) fine to coarse gravels of dolerite, ironstone, shale, quartz and calcrete. Often with abundant cryptogams. Shallow calcareous sandy loams over calcrete. Run –off source zones to lower parts of the landscape occasionally via shallow incised drainage channels. Nil to slight vulnerability to erosion.	Very sparse to open (PFC 10 – 20%) mixed height shrublands dominated by *Dodonaea lobulata*, *Senna artemisioides* subsp. *filifolia*, *Acacia burkittii*, *Ptilotus obovatus* or less frequently, *Maireana sedifolia* and *Atriplex nummularia* subsp. *spathulata* with isolated to very sparse overstorey of *Casuarina pauper* and occasionally *Acacia incurvaneura*, *Grevillea nematophylla* subsp. *nematophylla* and/or *Alectryon oleifolius* “Greenstone hill mixed shrubland” (GHMW vegetation community).

Land unit	Land form and soil type	Vegetation community
4a. Plains supporting acacia shrublands 	Very gently inclined to level plains (slopes <1.5%); mostly few to common (2-20%) mantles of ironstone fine gravel, calcrete nodules and quartz fragments, often abundant cryptogams. Deep sandy loam to sandy clay loams mostly non-calcareous. Broad transfer zones receiving water from upper units and shedding onto lower parts of landscape with occasional sheet and rill erosion. Nil to slight vulnerability to erosion.	Open tall acacia shrublands (PFC 10 - 30%) dominated by *Acacia incurvaneura. A. ayersiana*, *A. burkittii*, *A. hemiteles*, *A.tetragonophylla* and very sparse lower shrubs including *Dodonaea lobulata*, *Senna artemisioides* subsp. *filifolia*, and *Ptilotus obovatus* with overstoreys of isolated *Casuarina pauper* or *Eucalyptus oleosa* subsp. *oleosa.* Plain acacia eucalypt shrubland (PAES)
4b. Plains supporting acacia shrublands on hardpan. 	Gently inclined plains (slopes <1.5%); mostly few to common (2-20%) mantles of ironstone fine to coarse gravel, calcrete nodules and quartz fragments, often abundant cryptogams. Non-calcareous sandy loams over ferruginous hardpan at >30cms. Broad transfer zones receiving water from upper units and shedding onto lower parts of landscape. Not vulnerable to erosion.	Open tall acacia shrublands (PFC 15 - 30%) dominated by *Acacia incurvaneura. A. ayersiana*, *A. burkittii*, *A. ramulosa* and very sparse lower shrubs including *Dodonaea rigida*, *D. lobulata* and *Ptilotus obovatus* with overstoreys of isolated *Casuarina pauper* or *Eucalyptus oleosa* subsp. *oleosa.* "Hardpan plain mulga shrubland" (HPMS vegetation community)

Land unit	Land form and soil type	Vegetation community
4c. Calcareous plains supporting chenopod shrublands		
	Gently inclined plains (slopes 1%); mostly very few to few (<2-10%) mantles of fine to medium ironstone gravel, calcrete nodules and quartz fragments. Calcareous sandy clay loams greater than 30cms. Broad transfer zones receiving water from upper units and shedding onto lower parts of landscape. Nil to slightly vulnerable to erosion with very minor soil surface deflation.	Open, mostly degraded *Maireana sedifolia* shrubland (PFC 10-25%) with colonizing shrubs including *Senna artemisioides* subsp. *filifolia*, *Eremophila scoparia and Acacia burkittii* and with very sparse overstorey of *Acacia incurvaneura or Casuarina pauper.* "Plain mixed halophyte shrubland" (PXHS vegetation community).
4d. Spinifex sandplain		
	Extensive level to gently sloping sand plain (slopes 0 -2%) with sandy or slightly crusted soil surfaces and abundant patchy litter. Deep sandy loam. Moderate vulnerability to wind erosion if cover removed. Fire susceptible.	Fire-climax community. Very sparse (PFC 5%) eucalypt woodland (6 -10m) of *Eucalyptus yilgarnensis* and *Eucalyptus oleosa* subsp. *oleosa* over mixed height (0.5 – 4m), very sparse (PFC 5 -15%) shrubs including, *Acacia colletioides. A. ramulosa*, *A.burkittii*, *Eremophila caperata and Westringia rigida* and variable density (PFC 5-50%) *Triodia irritans.* "Sandplain mallee spinifex woodland" (SAMA vegetation community).

Land unit	Land form and soil type	Vegetation community
5a. Alluvial plains supporting chenopod shrublands.		
	Near level to gently sloping (slopes <1 -1%) plains with very few to common surface mantles (<2 – 20%) of fine and medium gravels of quartz, ironstone and calcrete nodules. Common to abundant cryptogams. Sandy clay loam often calcareous especially at depth. Subject to occasional shallow sheet flow, occasionally more concentrated. Stripped soils surfaces common. Moderate vulnerability to erosion.	Very sparse to open, often degraded (PFC 5 – 30%) chenopod shrublands dominated by *Maireana sedifolia M. georgei*, *M. pyramidata*, *Atriplex vesicaria*, *Ptilotus obovatus* and others or in poor condition dominated by *Senna artemisioides* subsp. *filifolia*, *Eremophila scorparia*, *Dodonaea lobulata*, *Acacia burkittii and A. hemiteles* with isolated, occasionally clumped overstorey of *Acacia incurvaneura*, *Casuarina pauper*, *Eucalyptus brachycorys* or E. *lesouefii* “Plain mixed halophyte shrubland” (PXHS vegetation community).
5b. Alluvial plains supporting chenopod shrublands and salmon gums		
	Gently sloping plains (slopes 1-2%) with very few to few mantles (<2-10%) of fine to medium gravels of ironstone, basalt and quartz fragments. Sandy clay loam, occasionally light clay, often saline. Subject to shallow sheet flow, occasionally more concentrated. Stripped soil surfaces common. Moderate vulnerability to erosion.	Open, often degraded, chenopod shrublands dominated by either *Maireana sedifolia, Atriplex vesicaria, A. nummularia, or Tecticornia disarticulata* and in poor condition dominated by *Senna artemisioides* subsp. *filifolia*, *Eremophila scorparia, Acacia hemiteles, with sparse overstorey, and groves of Eucalyptus salmonophlioia and E. salubris.* “Plain eucalypt chenopod shrubland” (PECW vegetation community).

Land unit	Land form and soil type	Vegetation community
6. Drainage tracts		
	Gently sloping (1%) drainage tracts 50 – 200m wide with occasional minor channels, mostly without surface mantles, and abundant litter trains. Sandy clay loam to sandy clay greater than 30cms. Slight to moderate vulnerability to water erosion.	Open to mid-close (PFC: 20 – 60%), tall acacia shrubland and occasional thickets dominated by *Acacia incurvaneura. A. ayersiana* and *A. burkittii* with isolated *Eucalyptus oleosa* subsp. *oleosa*, *Brachychiton gregorii* or *Casuarina pauper* or less commonly *Bursaria occidentalis. Senna artemisioides* ssp. *filifolia*, *Grevillea nematophylla* subsp. *nematophylla* and *Teucrium teucriiflorum.* “Drainage tract acacia shrubland” (DRAS vegetation community)

* (PFC): Projected foliar cover
** (CCAS etc.) vegetation types see Table 6.

Figure 7: Map of land units

Land unit areas

Approximately 40% of the survey area is occupied by plains supporting acacia shrublands with sparse overstoreys of eucalypts and casuarina (land units 4a and 4b). Chenopod shrublands occur on approximately 25% of the area either on calcareous plains (land unit 4c) or alluvial plains (land units 5a and 5b). Sand plains and sandy rises occupy 4% of the area and typically support spinifex tussock grasslands with sparse eucalypt overstoreys. Low hills and rises on laterite, basalt or felsic rocks occupy the remainder (Table 5).

Table 4: Area of each land unit within the extended survey area

Land unit	Description	Hectares	%
1a.	Lateritic hills	70.08	1.43
1b.	Basalt hills	43.92	0.90
1c.	Felsic hills breakaways and footslopes	166.45	3.40
1d.	Sandy rises	37.85	0.77
2a.	Low lateritic rises	233.41	4.77
2b.	Low rises on basalt	335.56	6.85
4a.	Plains supporting acacia shrublands	1327.78	27.12
4b.	Plains supporting acacia shrublands on hardpan	476.59	9.73
4c.	Calcareous plains supporting chenopod shrublands	411.70	8.41
4d.	Spinifex sandplain	175.69	3.57
5a.	Alluvial plains supporting chenopod shrublands	716.20	14.63
5b.	Alluvial plains supporting chenopod shrublands and salmon gums	127.16	2.60
6.	Drainage tracts	154.11	3.15
MD	Mining disturbance	619.44	12.65
Total		**4895.93**	**100.00**

Vegetation communities

Fire-susceptible ‘Sandplain mallee spinifex grassland’ (SAMA) occupies central western areas (Table 5). Elevated land units on laterite are mostly occupied by ‘Stony ironstone acacia shrubland’ (SIAS) while lower lateritic slopes are occupied by ‘Calcareous casuarina acacia shrubland’ (CCAS). Elevated land unit on basalt are occupied by ‘Greenstone hill shrubland’ (GHAS and GHMW) while those on felsic geology, mostly in the south west, are ‘Breakaway mixed shrubland’ (BRXS).

‘Plain acacia eucalypt shrubland’ (PAES) and ‘Hardpan plain mulga shrubland’ (HPMS) occupy extensive plains throughout the central areas through which pass a significant drainage tract occupied by ‘Drainage tract acacia shrubland’ (DRAS).

‘Plain mixed halophyte low shrublands’ (PXHS) occur on plains in northern areas and on adjacent alluvial plains which are often degraded. The lowest parts of the landscape, discharging overland flows to Lake Rebecca in the south, are occupied with ‘Plain eucalypt chenopod woodland’ (PECW).

Table 5: Vegetation communities, associated land units and vulnerability to disturbance.

Vegetation community	Description	Land unit	Vulnerable
BRXS	Breakaway mixed shrubland (N)	1c	
CCAS	Calcareous casuarina acacia shrubland or woodland (N)	2a	Yes (C)
DRAS	Drainage tract acacia shrubland (S)	6	
GHAS	Greenstone hill acacia shrubland (N)	1b	
GHMW	Greenstone hill mixed shrubland (N)	2b	
HPMS	Hardpan plain mulga shrubland (N)	4b	
PAES	Plain acacia eucalypt shrubland (new)	4a	
PECW	Plain eucalypt chenopod woodland (N)	5b	Yes
PXHS	Plain mixed halophyte low shrublands (N)	4c 5a	Yes (C)
SAMA	Sandplain mallee spinifex woodland (N)	1d 4d	
SIAS	Stony ironstone acacia shrubland (N)	1a	

*(N)(Pringle, Van Vreeswyk & Gilligan, 1994); (S) (Payne, Van Vreeswyk, Pringle, Leighton and Hennig 1998) (C) (Cowan, 2001)

Vegetation and soil condition

The survey area has been disturbed by recent and historic mining activity and is mostly within a pastoral lease and has been grazed. Vehicle tracks, cut lines and pastoral fences cross the area.

Land units supporting chenopod vegetation, preferentially grazed by livestock, are mostly degraded and few areas are in good condition (Table 6). Spinifex communities (SASP) on sandplains and sandy rises are not suitable for grazing and are in excellent condition. Hills on laterite, basalt and felsic geology are mostly in excellent condition. (Table 5) while lower slopes on laterite and basalt are often in poorer condition.

Minor to moderate soil erosion is evident on alluvial plains (land unit 5a and 5b) and these land units are rated as moderately vulnerable to erosion (Table 6). Other land units are mostly rated nil or slight vulnerable to soil erosion and only small areas on these units are slightly eroded (Table 7). Spinifex sand plain and rises are susceptible to wind erosion following fire.

Table 6: Vegetation and soil surface condition ratings for each land unit

Land unit	Vulnerability to erosion	Erosion status	Vegetation condition
1a. Lateritic hills	Nil	100% nil	100% excellent
1b. Basalt hills	Nil	100% nil	100% excellent/v.good
1c. Felsic hills breakaways and footslopes	Nil	100% nil	100% excellent/good
1d. Sandy rises	Slight	100% nil	100% excellent
2a. Low lateritic rises	Nil -slight	100% nil to minor	80% excellent/good 20% poor
2b. Low rises on basalt	Nil -slight	93% nil to minor 7% moderate	50% excellent/good 50% poor
4a. Plains supporting acacia shrublands	Nil -slight	94% nil to minor 6% moderate	75% excellent/good 25% poor
4b. Plains supporting acacia shrublands on hardpan	Nil	100% nil to minor	100% excellent/good
4c. Calcareous plains supporting chenopod shrublands	Nil -slight	83% nil to minor 17% moderate	17% good 17% poor 66% degraded
4d. Spinifex sandplain	Moderate	100% nil to minor	100% excellent/ v.good
5a. Alluvial plains supporting chenopod shrublands	Moderate	71% nil to minor 29% moderate	14% good 29% poor 57% degraded/ completely degraded
5b. Alluvial plains supporting chenopod shrublands and salmon gums	Moderate	67% nil to minor 33% moderate	33% good 29% poor 28% degraded
6. Drainage tracts	Slight to moderate	60% nil 40% minor	60% excellent/good 20% poor 20% degraded

Threatened ecosystems and wetlands.

Threatened and priority ecological communities

There are no identified threatened ecological communities (TECs) on Saracen tenements or in the entire MUR1 biogeographic subregion (Cowan, 2001).

There are no listed priority ecological communities (PECs) in the area.

Ecosystems at risk

Cowan, (2001) lists PXHS vegetation community (Plain mixed halophyte low shrublands) as an ecosystem at risk to disturbance (Table 5). PXHS vegetation community is associated with land unit 5a, 57% of which was degraded through over grazing. This current survey also identifies PECW (Plain eucalypt chenopod woodland) as an ecosystem at risk in that over 50% is in poor or degraded condition. PXHS and PECW occur on land unit 5a and 5b which are moderately vulnerable to erosion and erosion is evident (Table 6).

Significant wetlands

There are no nationally significant wetlands in the area (Appendix 1). Lake Rebecca is a major wetland with local and regional significance.

Riparian vegetation

The survey landscape mainly drains via overland flow to a main drainage tract (land unit 6a) which flows into Lake Rebecca 5 km to the north. Southern areas drain southerly through various drainage systems also to Lake Rebecca.

Flora

General

One hundred and twenty-nine flora taxa representing 26 families were found during the reconaisance survey (Table 7). Chenopodiaceae accounted for 24 taxa, Fabaceae 19 taxa and Scrophulariaceae 17 taxa. There were four sterile specimens which were identified to genera level.

An additional 14 taxa were found on the sandy rises of land unit 1D during the November 2013 survey (Table 7).

A list of species within each family found at each inventory site is presented in Attachment 3. Species typifying the survey area include: *Acacia tetragonophylla, Scaevola spinescens*; *Ptilotus obovatus, Acacia burkittii, Casuarina pauper, Dodonaea lobulata* and *Senna artemisioides* subsp. *filifolia,* all present on at least 70% of sites.

Local endemics

No taxa are considered to be locally endemic.

Range extension

The collection of the following species at this location indicates a significant extension of their known distribution range:

- *Eucalyptus oleosa* subsp. *cylindroidea*
- *Sclerolaena glabra*
- *Thryptomene kochii*

Declared weed species

No alien to Western Australia (weed) species were located during survey although *Carthamus lanatus* (saffron thistle) was noted growing along road verges.

Table 7: List of flora taxa found during field survey in January 2019 and on land unit 1D during field survey in November 2012.

		Land units											
Family	**Taxa**	**1A**	**1B**	**1C**	**1D**	**2A**	**2B**	**4A**	**4B**	**4C**	**5A**	**5B**	**6**
Amaranthaceae	*Ptilotus obovatus*	y	y	y		y	y	y	y	y	y	y	y
Apocynaceae	*Alyxia buxifolia*			y			y	y			y	y	
Apocynaceae	*Marsdenia australis*	y	y			y	y	y	y	y	y	y	y
Asteraceae	*Brachyscome ciliaris*		y					y			y		y
Asteraceae	*Brachyscome trachycarpa*										y		
Asteraceae	*Cratystylis subspinescens*					y				y	y	y	
Asteraceae	*Minuria cunninghammii*									y	y		
Asteraceae	*Olearia exiguifolia*							y					y
Asteraceae	*Olearia muelleri*	y		y		y	y	y	y	y	y	y	
Asteraceae	*Vittadinia eremaea*									y	y		
Boraginaceae	*Halgania cyanea*							y					y
Boraginaceae	*Halgania erecta**				Y								
Casuarinaceae	*Allocasuarina helmsii*												
Casuarinaceae	*Casuarina pauper*	y	y	y		y	y	y	y	y	y	y	
Chenopodiaceae	*Atriplex bunburyana*						y	y	y	y	y	y	
Chenopodiaceae	*Atriplex nummularia* subsp. *spathulata*	y	y	y		y	y	y	y	y	y	y	
Chenopodiaceae	*Atriplex vesicaria*			y			y			y	y	y	
Chenopodiaceae	*Chenopodium gaudichaudianum*		y				y	y		y	y	y	
Chenopodiaceae	*Enchylaena lanata*			y			y	y			y	y	y
Chenopodiaceae	*Enchylaena tomentosa* var. *tomentosa*	y		y			y	y			y	y	y
Chenopodiaceae	*Enchyleana x Maireana* hybrid							y		y	y		y
Chenopodiaceae	*Eriochiton sclerolaenoides*	y											
Chenopodiaceae	*Maireana georgei*	y	y	y			y	y		y	y	y	y
Chenopodiaceae	*Maireana pentatropis*	y	y	y		y	y				y	y	
Chenopodiaceae	*Maireana planifolia*										y	y	
Chenopodiaceae	*Maireana pyramidata*							y		y	y	y	
Chenopodiaceae	*Maireana sedifolia*	y	y	y		y	y	y		y	y	y	
Chenopodiaceae	*Maireana tomentosa*			y							y	y	
Chenopodiaceae	*Maireana triptera*	y		y			y	y		y	y	y	y
Chenopodiaceae	*Rhagodia drummondii*	y	y				y	y		y	y	y	
Chenopodiaceae	*Rhagodia eremaea*	y	y	y		y	y	y			y	y	y
Chenopodiaceae	*Salsola australis*									y		y	
Chenopodiaceae	*Sclerolaena cuneata*											y	

		Land units											
Family	**Taxa**	**1A**	**1B**	**1C**	**1D**	**2A**	**2B**	**4A**	**4B**	**4C**	**5A**	**5B**	**6**
Chenopodiaceae	*Sclerolaena diacantha*	y	y	y		y	y	y		y	y	y	
Chenopodiaceae	*Sclerolaena gardneri*									y	y	y	
Chenopodiaceae	*Sclerolaena glabra*	y										y	
Chenopodiaceae	*Sclerolaena obliquicuspis*										y	y	
Chenopodiaceae	*Tecticornia disarticulata*			y								y	
Convolvulaceae	*Convolvulus clementii*									y			y
Convolvulaceae	*Duperreya commixta**				Y								
Euphorbiaceae	*Bertya dimerostigma**				Y								
Fabaceae	*Acacia aptaneura*			y					y	y	y	y	
Fabaceae	*Acacia ayersiana*	y	y	y		y		y	y				y
Fabaceae	*Acacia burkittii*	y	y	y		y	y	y	y	y	y	y	y
Fabaceae	*Acacia caesaneura*					y		y	y				
Fabaceae	*Acacia effusifolia**				Y								
Fabaceae	*Acacia erinacea*	y		y									
Fabaceae	*Acacia hemiteles*	y	y				y	y	y	y	y	y	y
Fabaceae	*Acacia incurvaneura*	y	y	y	Y	y	y	y	y	y	y		y
Fabaceae	*Acacia kempeana*					y	y		y		y		
Fabaceae	*Acacia ligulata*			y			y	y		y			
Fabaceae	*Acacia nyssophylla*	y	y	y		y	y	y		y	y	y	
Fabaceae	*Acacia oswaldii*		y	y		y	y	y	y	y	y	y	
Fabaceae	*Acacia quadrimarginea*		y										
Fabaceae	*Acacia ramulosa* var. *linophylla*		y	y		y	y	y	y				
Fabaceae	*Acacia sibirica*	y	y			y	y	y	y			y	
Fabaceae	*Acacia tetragonophylla*	y	y	y	Y	y	y	y	y	y	y	y	y
Fabaceae	*Senna artemisioides* subsp. *filifolia*	y	y	y		y	y	y	y	y	y	y	y
Fabaceae	*Senna artemisioides* subsp. x *artemisioides*		y				y	y	y		y	y	y
Fabaceae	*Senna cardiosperma*	y	y										
Fabaceae	*Templetonia incrassata*			y		y		y	y		y		
Frankeniaceae	*Frankenia interioris*			y						y	y	y	
Goodeniaceae	*Scaevola spinescens*	y	y	y		y	y	y	y	y	y	y	y
Lamiaceae	*Physopsis viscida*												
Lamiaceae	*Prostanthera althoferi* subsp. *althoferi*		y		Y	y		y	y		y		y
Lamiaceae	*Teucrium disjunctum*										y		
Lamiaceae	*Teucrium teucriiflorum*					y		y	y		y		y
Lamiaceae	*Westringia rigida*				Y					y			

		Land units											
Family	**Taxa**	**1A**	**1B**	**1C**	**1D**	**2A**	**2B**	**4A**	**4B**	**4C**	**5A**	**5B**	**6**
Loranthaceae	*Amyema fitzgeraldii*							y		y	y		y
Loranthaceae	*Amyema gibberula* var. *gibberula*							y	y				y
Loranthaceae	*Amyema preissii*						y						
Loranthaceae	*Lysiana casuarinae*							y		y	y		
Malvaceae	*Abutilon cryptopetalum*									y			
Malvaceae	*Abutilon otocarpum*										y		
Malvaceae	*Brachychiton gregorii*		y			y		y	y		y		y
Malvaceae	*Sida calyxhymenia*			y				y	y				
Malvaceae	*Sida intricata*						y	y			y		
Malvaceae	*Sida* sp. Excedentifolia (J.L. Egan 1925)					y							
Malvaceae	*Sida spodochroma*									y	y	y	y
Myrtaceae	*Aluta aspera* subsp. *aspera**				Y								
Myrtaceae	*Calytrix* sp.			y									
Myrtaceae	*Enekbatus cryptandroides**				Y								
Myrtaceae	*Eucalyptus ewartiniana*					y							
Myrtaceae	*Eucalyptus ceratocorys**				Y								
Myrtaceae	*Eucalyptus concinna*	y						y	y				
Myrtaceae	*Eucalyptus eremicola**				Y								
Myrtaceae	*Eucalyptus eremicola* subsp *peeneri*			y									
Myrtaceae	*Eucalyptus lesouefii*			y			y					y	
Myrtaceae	*Eucalyptus oldfieldii**				Y								
Myrtaceae	*Eucalyptus oleosa* subsp. *cylindroidea**				Y								
Myrtaceae	*Eucalyptus oleosa* subsp. *oleosa*			y				y	y		y		y
Myrtaceae	*Eucalyptus salmonophloia*			y								y	
Myrtaceae	*Eucalyptus salubris*						y					y	
Myrtaceae	*Eucalyptus yilgarnensis*	y											
Myrtaceae	*Melaleuca hamata*					y							
Myrtaceae	*Thryptomene kochii**				Y								
Myrtaceae	*Verticordia pritzelii**				Y								
Pittosporaceae	*Bursaria occidentalis*				Y			y			y		y
Pittosporaceae	*Marianthus bicolor**				Y								
Pittosporaceae	*Pittosporum angustifolium*										y		
Poaceae	*Aristida contorta*		y							y			
Poaceae	*Astrostipa* sp.	y	y			y	y			y	y		
Poaceae	*Austrostipa elegantissima*	y		y		y	y			y	y	y	

		Land units											
Family	**Taxa**	**1A**	**1B**	**1C**	**1D**	**2A**	**2B**	**4A**	**4B**	**4C**	**5A**	**5B**	**6**
Poaceae	*Austrostipa eremophila*							y					
Poaceae	*Enneapogon avenaceus*						y				y	y	
Poaceae	*Enneapogon caerulescens*									y	y		
Poaceae	*Enneapogon polyphyllus*										y		
Poaceae	*Eragrostis eriopoda*					y		y	y				
Poaceae	*Monachather paradoxus*					y		y					
Poaceae	*Paspalidium constrictum*						y			y	y	y	y
Poaceae	*Thyridolepis* sp								y				
Poaceae	*Triodia irritans*				Y					y			
Proteaceae	*Grevillea juncifolia* subsp. *juncifolia**				Y								
Proteaceae	*Grevillea nematophylla* subsp. *nematophylla*				Y								
Proteaceae	*Hakea preissii*			y							y		
Pteridaceae	*Cheilanthus sieberi* subsp. *sieberi*		y			y							
Rubiaceae	*Psydrax suaveolens*			y	Y	y							
Rutaceae	*Phebalium canaliculatum*	y	y		Y					y	y	y	y
Santalaceae	*Exocarpos aphyllus*			y							y	y	
Santalaceae	*Santalum acuminatum*											y	
Santalaceae	*Santalum spicatum*	y	y	y		y	y	y	y	y	y		y
Sapindaceae	*Alectryon oleifolius* subsp. *canescens*	y	y	y		y	y	y		y	y	y	
Sapindaceae	*Dodonaea amblyophylla**				Y								
Sapindaceae	*Dodonaea lobulata*	y	y	y		y	y	y	y	y	y	y	y
Sapindaceae	*Dodonaea rigida*			y		y		y	y		y		y
Scrophulariaceae	*Eremophila alternifolia*			y				y		y	y		
Scrophulariaceae	*Eremophila arachnoides* subsp. *tenera*										y	y	
Scrophulariaceae	*Eremophila caperata*												
Scrophulariaceae	*Eremophila decipiens* subsp. *decipiens*	y		y	Y	y	y	y	y	y	y	y	y
Scrophulariaceae	*Eremophila eriocalyx*	y	y			y	y	y	y		y		y
Scrophulariaceae	*Eremophila forrestii* subsp. *forrestii*				Y	y		y	y				
Scrophulariaceae	*Eremophila georgei*	y	y	y			y	y	y		y		
Scrophulariaceae	*Eremophila glabra* subsp *glabra*		y			y	y	y	y	y	y		y
Scrophulariaceae	*Eremophila granitica*				Y			y	y				y
Scrophulariaceae	*Eremophila latrobei* subsp. *latrobei*	y	y	y		y	y	y	y				
Scrophulariaceae	*Eremophila longifolia*						y	y	y		y	y	y
Scrophulariaceae	*Eremophila maculata*											y	
Scrophulariaceae	*Eremophila metallicorum*					y		y		y	y		y

		Land units											
Family	**Taxa**	**1A**	**1B**	**1C**	**1D**	**2A**	**2B**	**4A**	**4B**	**4C**	**5A**	**5B**	**6**
Scrophulariaceae	*Eremophila oldfieldii* subsp. *angustifolia*	y	y	y		y	y	y	y	y	y		y
Scrophulariaceae	*Eremophila oppositifolia* subsp. *angustifolia*	y		y			y	y				y	y
Scrophulariaceae	*Eremophila scoparia*	y	y	y		y	y			y	y	y	
Scrophulariaceae	*Eremophila* sp									y	y		
Solanaceae	*Lycium australe*										y		
Solanaceae	*Solanum nummularium*					y		y			y		
Solanaceae	*Solanum lasiophyllum*		y				y	y	y	y	y	y	y
Violaceae	*Hybanthus floribundus* subsp. *curvifolius*	y											
Zygophyllaceae	*Roepera aurantiaca* subsp. *aurantiaca*										y		

* 2013 survey

.

Threatened and priority flora

There are three threatened flora taxa (WA Wildlife Conservation Act 1950 – Wildlife Conservation (Rare Flora) Notice 2010(2) likely to occur in the general area: *Thryptomene wittweri*, *Eucalyptus articulata* and *Gastrolobium graniticum* which is also an endangered species under the Commonwealth EPBC Act (Table 2).

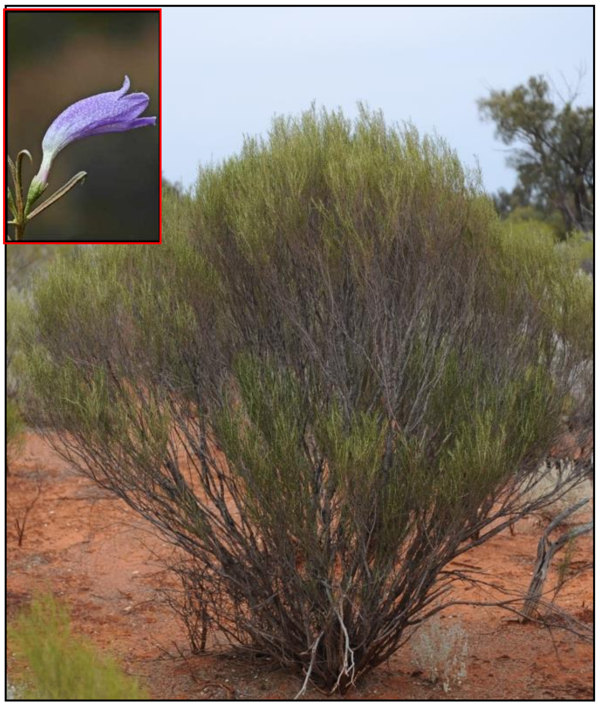
No threatened (rare) or endangered flora taxa were found during reconaissance or targetted surveys.

Eremophila arachnoides subsp. *tenera (*P1) was located at:

- Northern area of approximately 125ha containing about 2500, mostly adult, plants (Figure 8). The vast majority of these are located on land unit 5a: Alluvial plains supporting chenopod shrublands.
- A southern area of approximately 3.4ha containing 28 adult plants.
- A southern area of approximately 3.4ha containing 13 adult plants.
- A southern area of approximately 1.2ha containing 5 adult plants
- Two singletons in the southern area.

Southern areas shown in Figure 9 and all occuring on land unit 5b: Alluvial plains supporting chenopod shrublands and salmon gums.

It is likely that other populations exist in similar land units to the south of the survey area.



Eremophila arachnoides subsp. *tenera* P1

Figure 8: Location of *Eremophila arachnoides* subsp. *tenera* (yellow dots) and search traverses (black lines) in the northern area.

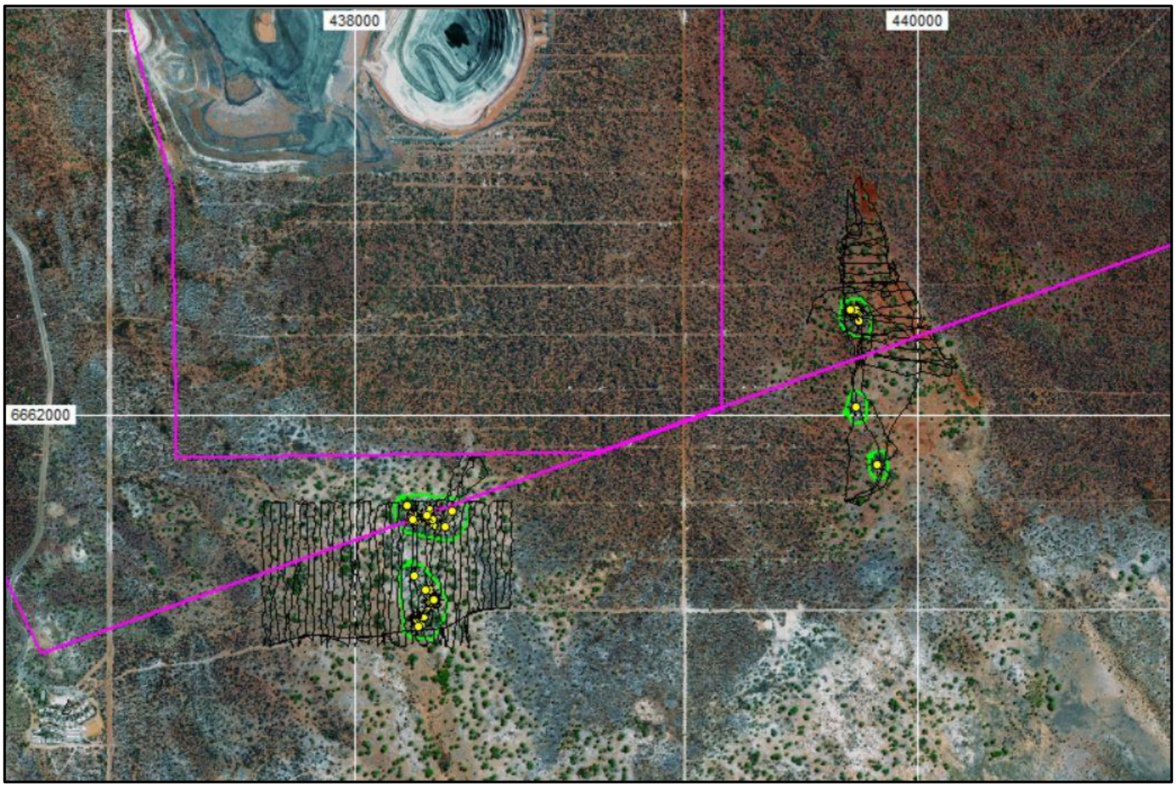


Figure 9: Location of *Eremophila arachnoides* subsp. *tenera* (yellow dots) and search traverses (black lines) in the southern area.

Fauna

Conservation significant fauna

Malleefowl

Malleefowl are active in the survey area. There were three sightings of birds during field work for this survey and active mounds have been found in previous studies (Coffey Environment 2010, Alexander Holm and Associtès 2012d), and in the airport area just to the west. Several Malleefowl mounds were found during this survey but most were long-inactive (Figure 5). The species is therefore clearly resident, but density of mounds is low. Furthermore, several mounds were very small, little more than small pits with a slightly raised edge of excavated soil, and it is unlikely they had ever been used for breeding; possibly they were dug by young males. These tended to be in heavy loamy-clay soils which are not usually the preferred substrate, with sands and gravels generally favoured. Malleefowl is probably more abundant to the west where there are extensive sandy soils associated with land unit 1d and 4d together occupying about 4.5% of the survey area. They may also be more abundant in rocky hills and low rises (land unit 1a, 1b, 1c 2a and 2b) collectively occupying 17% of the survey area.

Peregrine Falcon

Peregrine Falcon were not observed but are a widespread species and considered likely to be a regular visitor if not resident. It could also breed in tall eucalypts in the area, probably by utilising old nests of the Australian Raven.

Rainbow Bee-eater.

This species is only considered of local significance but was formerly listed as Migratory under legislation. It is still considered locally significant as it is a true migrant and breeds in burrows in the area, making it vulnerable to disturbance and predation. It will also often nest along tracks, increasing its vulnerability.

Habitat

The sandy soils supporting spinifex and mallee in the south-west (land units 1d and 4d) are likely to be rich in reptiles as the soils allow for burrowing and the spinifex provides abundant cover. Such areas are also likely to be rich in shrubland-dependent birds and some small mammals. During the site inspection, it was noted that the transition between eucalypt woodland and acacia shrublands appeared to be rich in birds; south of the current operations this is where species such as the Red-capped Robin, White-eared and Brown-headed Honeyeaters and White-browed Babblers were observed. It was also where a Malleefowl was seen. Tall shrublands of acacia with little understorey, found across large areas of loamy-clay soils (land unit 4a and 4b), are probably less rich in species. The low rocky hills (land units 1a, 1b, 1c) have potential for short range endemic invertebrates and appeared to be floristically rich, so may be seasonally important for nectar-dependent birds and invertebrates.

Impacting processes on fauna

Habitat loss leading to population decline.

Habitat loss from clearing 3m wide drill-lines at 90m intervals will affect about 3% of the landscape, and there will inevitably be some mortality during this clearing. Note that the habitat loss will be temporary except where lines are maintained as access tracks, and therefore populations should recover from this loss eventually. The effect of habitat loss can be reduced by avoiding sensitive environmental features such as Malleefowl mounds.

Habitat loss leading to population fragmentation.
This is unlikely to be a concern with the proposal as the clearing is in narrow lines through otherwise more or less continuous vegetation.

Ongoing mortality from operations.
Main sources of ongoing mortality will be from vehicle strike and entrapment in drilling sumps. There are standard procedures for minimising these risks.

Species interactions including feral and overabundant native species.
Feral predators are present and affect fauna assemblage. Creation of multiple tracks will improve their access into areas where currently tracks are few. The presence of personnel in these areas can also lead to an increase in activity of feral species.

Hydrological change.
There may be some disruption of surface flow especially on the lower slopes of hills. Wastewater from drilling is usually contained in lined sumps so should have no impact.

Altered fire regimes.
Drilling activities and the presence of personnel will increase the risk of unplanned bushfire.

Disturbance (dust, light, noise).
Some level of disturbance during drilling is inevitable but temporary. If drilling occurs at night, lighting may be a source of mortality for insects. While only a temporary effect there are means by which this sort of mortality can be reduced. It is not known if the specially protected jewel beetles known from the general area are present, or how they might be affected by light.

Hydrological summary

The survey landscape mainly drains via overland flow to a main drainage tract (land unit 6) which flows into Lake Rebecca 5 km to the north. Southern areas drain southerly through various drainage systems again to Lake Rebecca.

Groundwater within the in the vicinity of the existing tailings facility is hypersaline (30,000 to 120,000 mg/l TDS) and between 15 and 60m below ground level (Saracen annual ground water report). Groundwater beneath the sandplain and sandy rise to the west of the survey area is likely to be less saline however no data exists for this aquifer.

ASSESSMENT IN RELATION TO CLEARING PRINCIPLES

Results of this survey are used to assess clearing within the survey area in relation to ten clearing principles prescribed in Schedule 5 under amendments in 2004 to the Environmental Protection Act (1986):

(a) Native vegetation should not be cleared if it comprises a high level of biological diversity.

The survey area is in the south-east of Eastern Murchison (MUR 1) bio-geographic subregion and adjacent to Shield and Eastern Goldfields bio-geographic sub-regions. Lake Ballard/Lake Rebecca form a major vegetation divide with characteristic *Acacia aneura* (mulga) low woodlands associated with red loams over siliceous hard pan to the north and low woodlands of mixed mulga and casuarina (black oak) and *Eucalyptus* species on alkaline and calcareous soils to the south. The survey area straddles this vegetation divide.

Beard Vegetation Association 20 (Low woodland: mulga mixed with Casuarina obesa and Eucalyptus spp.) is the most common vegetation association in the survey area occupying 83%. Vegetation Association 529 (Succulent steppe with open low woodland; mulga and sheoak over salt bush) occupies 12% and the remaining 5% is Vegetation Association 24 (Low woodland; Casuarina obesa) (Beard 1976).

One hundred and twenty nine flora taxa representing 26 families were found during the reconaisance survey. An additional 14 taxa were found on the sandy rises of land unit 1D during the November 2013 survey.

Vegetation associations and species composition are typical of the area and most are not unusually diverse.

Proposal is not at variance to this 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.

Malleefowl are active in the survey area. Malleefowl mounds are of importance for the birds, whether or not they are active or recently-used, while active mounds (containing eggs) are of special value. Even very old mounds have been found to be re-used, possibly after an interval of several decades (M. Bamford pers. obs; Mt Jackson area). Malleefowl is probably more abundant to the west where there are extensive sandy soils associated with land unit 1d and 4d together occupying about 4.5% of the survey area. They may also be more abundant in rocky hills and low rises (land unit 1a, 1b, 1c 2a and 2b) collectively occupying 17% of the survey area.

Large Eucalypt trees, common in land unit 5b, may support nesting by the Peregrine Falcon (and other birds).

Proposal is at variance to this principle

(c) Native vegetation should not be cleared if it includes, or is necessary for the continued existence of, rare flora.

No listed species of rare or critically endangered flora were found during this survey.

A search of the Department of Environment and Conservation's Rare and Priority Flora Database revealed no records of Declared Rare Flora (DRF) in or nearby the survey area.

Three populations consisting of over 2500 plants of *Eremophila arachnoides* subsp. *tenera,* a Priority 1 listed taxa (P1) were located within the survey envelope. Priority flora are under consideration for listing as threatened species and as such require protection until their status is decided.

The proposal is likely to be at variance to this principle.

(d) Native vegetation should not be cleared if it comprises the whole or part of, or is necessary for the maintenance of a threatened ecological community.

There are no Threatened Ecological Communities (TECs) within the north east Goldfields subregion (Cowan, 2001).

There are no Priority Ecological Communities within or adjacent to the survey area.

The proposal is not at variance to this principle.

(e) Native vegetation should not be cleared if it is significant as a remnant of native vegetation in an area that has been extensively cleared.

Beard Vegetation Association 20 (Low woodland: mulga mixed with Casuarina obesa and Eucalyptus spp.) is the most common vegetation association in the survey area occupying 83%. Vegetation Association 529 (Succulent steppe with open low woodland; mulga and sheoak over salt bush) occupies 12% and the remaining 5% is Vegetation Association 24 (Low woodland; Casuarina obesa) (Beard 1976).

Vegetation Association 20 occupies approximately 13,000 km^2 in Western Australia of which 16.7% is within conservation reserves and although less than 1% of Vegetation Association 24, which occupies approximately 266 km^2 in Western Australia, is within reserves, both have a low priority for conservation (Table 1). Vegetation Association 529 is very poorly conserved and has a high priority for conservation.

Vegetation Association 529 has not been extensively cleared and clearing within this survey area will have minimal effect on extent of this vegetation community.

Proposal is not at variance to this 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.

The survey landscape mainly drains via overland flow to a main drainage tract (land unit 6) which flows into Lake Rebecca 5 km to the north. Southern areas drain southerly through various drainage systems again to Lake Rebecca. Lake Rebecca is a major wetland with local and regional significance.

Survey lines will intercept these watercourses.

Proposal is at variance with this principle.

(g) Native vegetation should not be cleared if the clearing of the vegetation is likely to cause appreciable land degradation.

The survey area has been disturbed by recent mining activity, is mostly within a pastoral lease and has been grazed. Vehicle tracks and pastoral fences cross the area.

Land units supporting chenopod vegetation, preferentially grazed by livestock, are mostly degraded and few areas are in good condition. Spinifex communities (SASP) on sandplains and sandy rises are not suitable for grazing and are in excellent condition. Hills on laterite, basalt and felsic geology are mostly in excellent condition while lower slopes on laterite and basalt are often in poorer condition.

Minor to moderate soil erosion is evident on alluvial plains (land unit 5a and 5b) and these land units are rated as moderately vulnerable to erosion. Other land units are mostly rated nil or slight vulnerable to soil erosion and only small areas on these units are slightly eroded. Spinifex sand plain and rises are susceptible to wind erosion following fire.

Extensive clearing within alluvial land units 5a and 5b are likely to lead to further soil erosion. Limited strip clearing, as proposed, is unlikely to cause extensive land degradation.

Water tables are a) below the rooting depth of vegetation growing in these areas and b) hypersaline. Extensive clearing of vegetation at catchment-scale or artificial recharge of the water table may raise saline water tables and lead to secondary salinity in surrounding landscapes.

Clearing of vegetation at local scales will have minimal, if any, effect on water tables and associated risk of secondary salinity.

Proposal is unlikely to be at variance to this 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.

No conservation areas are nearby.

Proposal is not at variance to this principle.

(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.

Approximately 17% of the survey area is occupied by alluvial plains supporting halophytic low shrubland with sparse overstoreys of eucalypts and casuarina (land units 5a and 5b). Minor to moderate soil erosion is evident on alluvial plains and these land units are rated as moderately vulnerable to erosion. Other land units are mostly rated nil or slightly vulnerable to soil erosion.

While, disturbance to land units 5a and 5b has the potential to increase sediment discharge to drainage tracts down-slope and ultimately, and through extreme events, to Lake Rebecca, the proposed strip clearing is unlikely to result in significant increases in sediment discharge.

Proposal is unlikely to be at variance with this principle.

(j) Native vegetation should not be cleared if clearing the vegetation is likely to cause, or exacerbate, the incidence or intensity of flooding.

The climate is arid to semi-arid with about 230 mm of annual rainfall. Rain falls on an average of 43 days a year.

Most rainfall events will cause little runoff, however extreme rainfall events such as those recorded in summers of 1984 and 1967, will result in runoff.

Clearing in this proposal will have negligible effect on the volume of runoff discharged.

Proposal is unlikely to be at variance with this principle.

DISCUSSION AND RECOMMENDATIONS

Saracen operates the Carosue Gold Mine and is proposing intensive exploration around its existing mine. A seismic survey is proposed over a 4300ha area requiring clearing of 3m wide access-lines at 90m spacing. Parts of this area have been covered by earlier environmental assessments. The current environmental assessment envelope covers the balance of 3136ha.

Flora composition and vegetation associations are typical of the region and not considered unusually diverse. There are no Threatened Ecological Communities (TECs) and no Priority Ecological Communities within or adjacent to the survey area.

No listed species of rare or critically endangered flora were found during this survey and no records of Declared Rare Flora (DRF) found in or nearby the survey area. Three populations consisting of over 2500 plants of *Eremophila arachnoides* subsp. *tenera,* a Priority 1 listed taxa (P1), were located within the survey envelope. Priority flora are under consideration for listing as threatened species and as such require protection until their status is decided.

No alien to Western Australia (weed) species were located during survey although *Carthamus lanatus* (saffron thistle) was noted growing along road verges.

Approximately 17% of the survey area is occupied by alluvial plains (land units 5a and 5b) where moderate soil erosion is evident, and these land units are rated as moderately vulnerable to erosion. These alluvial systems support PXHS vegetation community (Plain mixed halophyte low shrublands) and PECW (Plain eucalypt chenopod woodland) which are degraded through over grazing. While, disturbance to land units 5a and 5b has the potential to increase sediment discharge to drainage tracts down-slope and ultimately, and through extreme events, to Lake Rebecca, the proposed strip clearing is unlikely to result in significant increases in sediment discharge.

The survey landscape mainly drains via overland flow to a main drainage tract (land unit 6) which flows into Lake Rebecca 5 km to the north. Southern areas drain southerly through various drainage systems again to Lake Rebecca. Lake Rebecca is a major wetland with local and regional significance. Survey lines will intercept these watercourses.

Malleefowl are active in the survey area. There were three sightings of birds during field work for this survey and active mounds have been found in previous studies. Malleefowl is probably more abundant to the west where there are extensive sandy soils associated with land unit 1d and 4d together occupying about 4.5% of the survey area. They may also be more abundant in rocky hills and low rises (land unit 1a, 1b, 1c 2a and 2b) collectively occupying 17% of the survey area. Malleefowl mounds are of importance for the birds, whether or not they are active or recently-used. Malleefowl mounds are active from about May to December and depending on rainfall into January. Active mounds containing eggs are of special value.

Large Eucalypt trees, common in land unit 5b, may support nesting by the Peregrine Falcon (and other birds).

It is recommended that, in planning and implementing seismic operations within the survey area, the proponent:

1. **Avoids disturbance to *Eremophila arachnoides* subsp. *tenera*.**

2. **Undertakes a Malleefowl survey especially within land units 1a, 1b, 1c, 1d, 2a and 2b and avoids disturbance within 50m of active Malleefowl nests during nesting and incubation.**

3. **Installs signage on access roads to the exploration area if Malleefowl are seen or suspected.**

4. **Avoids destruction of mature Eucalyptus trees with nesting hollows.**

5. **Takes measures to minimise erosion through soil disturbance and concentration of overland water flows on vulnerable land units, especially alluvial plains (land unit 5a and 5b).**

6. **Avoids disturbance to watercourses within land unit 6.**

REFERENCES

Alexander Holm & Associates (2010). Environmental assessment: Proposed expansion of Whirling Dervish mine. Perth, Western Australia, Unpublished report for Saracen Gold Mines**:** 45.

Alexander Holm & Associates (2012a). Environmental assessment: Montys' dewatering pipeline to Lake Rebecca. Perth, Western Australia, Unpublished report for Saracen Gold Mines**:** 100.

Alexander Holm & Associates (2012b). Environmental assessment: Old Plough Dam. Perth, Western Australia, Unpublished report for Saracen Gold Mines**:** 96.

Alexander Holm & Associates (2012c). Environmental assessment: Pinnacles. Perth, Western Australia, Unpublished report for Saracen Gold Mines**:** 82.

Alexander Holm & Associates (2012d). Environmental assessment: Tailings storage facility expansion. Perth, Western Australia, Unpublished report for Saracen Gold Mines**:** 81.

Beard, J. S. (1976). Vegetation Survey of Western Australia - Sheet 6. Murchison. Nedlands, Western Australia, University of Western Australia Press.

Brown, A. and B. Buirchell (2011). A field guide to the Eremophilas of Western Australia, Simon Nevill Publications.

Cowan, M. (2001). Murchison 1 (MUR1 - East Murchison subregion). A biodiversity audit of Western Australia's 53 biogeographical subregions in 2002. N. L. McKenzie and J. E. May. Perth, The Department of Conservation and Land Management**:** 466-479.

Desmond, A., M. Cowan and A. Chant (2003). Murchison 2 (MUR2 - Western Murchison subregion). A Biodiversity Audit of Western Australia’s 53 Biogeographical Subregions in 2002. N. L. McKenzie and J. E. May. Perth The Department of Conservation and Land Management**:** 480-496.

Environmental Protection Authority (2016). Technical guidance. Flora and Vegetation Surveys for Environmental Impact Assessment. Perth Western Australia**:** 42.

Mitchell, A. A. and D. G. Wilcox (1994). Arid Shrubland Plants of Western Australia. Perth, University of Western Australia Press.

Payne, A. L., A. M. E. Van Vreeswyk, H. J. R. Pringle, K. A. Leighton and P. Hennig (1998). An inventory and condition survey of the Sandstone-Yalgoo- Paynes Find area, Western Australia. South Perth, Agriculture Western Australia**:** 372.

Disclaimer

While Alexander Holm & Associates has carried out some enquiries concerning data, assumptions and information supplied to it, those enquiries were limited and Alexander Holm & Associates does not accept responsibility for their accuracy. Accordingly, Alexander Holm & Associates does not accept any legal responsibility to any person, organisation or company for any loss or damage suffered by them resulting from their use of the report however caused, and whether by breach of contract, negligence or otherwise

Within the limitation imposed by the scope of review, the data assessment and preparation of the report have been undertaken in a professional manner and in accordance with generally accepted practices using a degree of care ordinarily exercised by professional environmental consultants. No other warranty, expressed or implied, is made.

ATTACHMENTS

Attachment 1: ‘NatureMap’ report

NatureMap Species Report

Created By Alexander Holm on 18/01/2019

Conservation Status	Conservation Taxon (T, X, IA, S, P1-P5)
Current Names Only	Yes
Core Datasets Only	Yes
Method	'By Circle'
Centre	122° 21' 56'' E,30° 08' 16'' S
Buffer	40km
Group By	Kingdom

Kingdom	Species	Records
Animalia	1	54
Plantae	1	4
TOTAL	**2**	**58**

	Name ID	Species Name	Naturalised	Conservation Code	[1]Endemic To Query Area
Animalia					
1.	24557	*Leipoa ocellata (Malleefowl)*		T	
Plantae					
2.	19695	*Thryptomene eremaea*		P2	

Conservation Codes
T - Rare or likely to become extinct
X - Presumed extinct
IA - Protected under international agreement
S - Other specially protected fauna
1 - Priority 1
2 - Priority 2
3 - Priority 3
4 - Priority 4
5 - Priority 5

[1] For NatureMap's purposes, species flagged as endemic are those whose records are wholely contained within the search area. Note that only those records complying with the search criterion are included in the calculation. For example, if you limit records to those from a specific datasource, only records from that datasource are used to determine if a species is restricted to the query area.

Attachment 2: ‘Protected matters’ search tool output

Australian Government
Department of the Environment and Energy

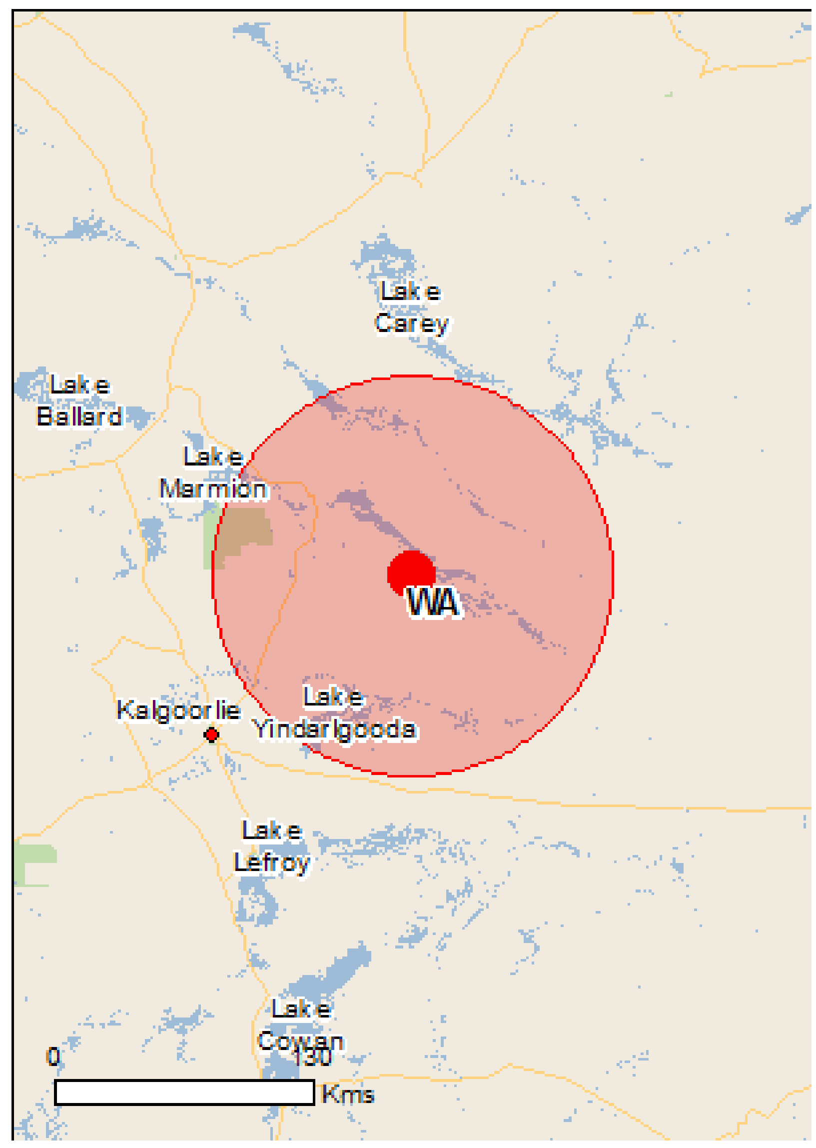
EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

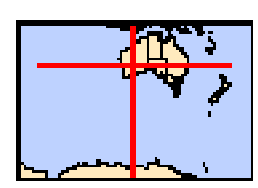
Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 18/01/19 21:08:05



Coordinates
Buffer: 100.0Km



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	10
Listed Migratory Species:	9

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	14
Whales and Other Cetaceans:	None
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	6
Regional Forest Agreements:	None
Invasive Species:	15
Nationally Important Wetlands:	1
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

Listed Threatened Species		[Resource Information]
Name	Status	Type of Presence
Birds		
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat likely to occur within area
Leipoa ocellata Malleefowl [934]	Vulnerable	Species or species habitat known to occur within area
Pezoporus occidentalis Night Parrot [59350]	Endangered	Species or species habitat may occur within area
Polytelis alexandrae Princess Parrot, Alexandra's Parrot [758]	Vulnerable	Species or species habitat may occur within area
Mammals		
Dasyurus geoffroii Chuditch, Western Quoll [330]	Vulnerable	Species or species habitat may occur within area
Sminthopsis psammophila Sandhill Dunnart [291]	Endangered	Species or species habitat likely to occur within area
Plants		
Eucalyptus articulata Ponton Creek Mallee [56772]	Vulnerable	Species or species habitat likely to occur within area
Gastrolobium graniticum Granite Poison [14872]	Endangered	Species or species habitat likely to occur within area
Hibbertia crispula Ooldea Guinea-flower [15222]	Vulnerable	Species or species habitat may occur within area
Tecticornia flabelliformis Bead Glasswort [82664]	Vulnerable	Species or species habitat known to occur within area

Listed Migratory Species		[Resource Information]
* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.		
Name	Threatened	Type of Presence
Migratory Marine Birds		
Apus pacificus Fork-tailed Swift [678]		Species or species

Name	Threatened	Type of Presence
		habitat likely to occur within area
Migratory Terrestrial Species		
[Motacilla cinerea](#) Grey Wagtail [642]		Species or species habitat may occur within area
[Motacilla flava](#) Yellow Wagtail [644]		Species or species habitat may occur within area
Migratory Wetlands Species		
[Actitis hypoleucos](#) Common Sandpiper [59309]		Species or species habitat may occur within area
[Calidris acuminata](#) Sharp-tailed Sandpiper [874]		Species or species habitat likely to occur within area
[Calidris ferruginea](#) Curlew Sandpiper [856]	Critically Endangered	Species or species habitat likely to occur within area
[Calidris melanotos](#) Pectoral Sandpiper [858]		Species or species habitat may occur within area
[Charadrius veredus](#) Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
[Tringa nebularia](#) Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
[Actitis hypoleucos](#) Common Sandpiper [59309]		Species or species habitat may occur within area
[Apus pacificus](#) Fork-tailed Swift [678]		Species or species habitat likely to occur within area
[Ardea alba](#) Great Egret, White Egret [59541]		Species or species habitat likely to occur within area
[Ardea ibis](#) Cattle Egret [59542]		Species or species habitat may occur within area
[Calidris acuminata](#) Sharp-tailed Sandpiper [874]		Species or species habitat likely to occur within area
[Calidris ferruginea](#) Curlew Sandpiper [856]	Critically Endangered	Species or species habitat likely to occur within area

Name	Threatened	Type of Presence
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
Chrysococcyx osculans Black-eared Cuckoo [705]		Species or species habitat known to occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area
Thinornis rubricollis Hooded Plover [59510]		Species or species habitat known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area

Extra Information

State and Territory Reserves [Resource Information]

Name	State
Bullock Holes Timber Reserve	WA
Cardunia Rocks	WA
Coonana Timber Reserve	WA
Goongarrie	WA
Queen Victoria Spring	WA
Wallaby Rocks Timber Reserve	WA

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Streptopelia chinensis Spotted Turtle-Dove [780]		Species or species habitat likely to occur within area

Name	Status	Type of Presence
Streptopelia senegalensis Laughing Turtle-dove, Laughing Dove [781]		Species or species habitat likely to occur within area
Mammals		
Camelus dromedarius Dromedary, Camel [7]		Species or species habitat likely to occur within area
Canis lupus familiaris Domestic Dog [82654]		Species or species habitat likely to occur within area
Capra hircus Goat [2]		Species or species habitat likely to occur within area
Equus asinus Donkey, Ass [4]		Species or species habitat likely to occur within area
Equus caballus Horse [5]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Oryctolagus cuniculus Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Vulpes vulpes Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Carrichtera annua Ward's Weed [9511]		Species or species habitat likely to occur within area
Cenchrus ciliaris Buffel-grass, Black Buffel-grass [20213]		Species or species habitat may occur within area
Lycium ferocissimum African Boxthorn, Boxthorn [19235]		Species or species habitat likely to occur within area

Nationally Important Wetlands

[Resource Information]

Name	State
Lake Marmion	WA

Caveat
The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-30.13825 122.36587

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

- -Office of Environment and Heritage, New South Wales
- -Department of Environment and Primary Industries, Victoria
- -Department of Primary Industries, Parks, Water and Environment, Tasmania
- -Department of Environment, Water and Natural Resources, South Australia
- -Department of Land and Resource Management, Northern Territory
- -Department of Environmental and Heritage Protection, Queensland
- -Department of Parks and Wildlife, Western Australia
- -Environment and Planning Directorate, ACT
- -Birdlife Australia
- -Australian Bird and Bat Banding Scheme
- -Australian National Wildlife Collection
- -Natural history museums of Australia
- -Museum Victoria
- -Australian Museum
- -South Australian Museum
- -Queensland Museum
- -Online Zoological Collections of Australian Museums
- -Queensland Herbarium
- -National Herbarium of NSW
- -Royal Botanic Gardens and National Herbarium of Victoria
- -Tasmanian Herbarium
- -State Herbarium of South Australia
- -Northern Territory Herbarium
- -Western Australian Herbarium
- -Australian National Herbarium, Canberra
- -University of New England
- -Ocean Biogeographic Information System
- -Australian Government, Department of Defence
- Forestry Corporation, NSW
- -Geoscience Australia
- -CSIRO
- -Australian Tropical Herbarium, Cairns
- -eBird Australia
- -Australian Government – Australian Antarctic Data Centre
- -Museum and Art Gallery of the Northern Territory
- -Australian Government National Environmental Science Program
- -Australian Institute of Marine Science
- -Reef Life Survey Australia
- -American Museum of Natural History
- -Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
- -Tasmanian Museum and Art Gallery, Hobart, Tasmania
- -Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

Department of the Environment
GPO Box 787
Canberra ACT 2601 Australia
+61 2 6274 1111

Attachment 3: List of flora taxa found at each inventory site

Family	**Taxa**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**
Amaranthaceae	*Ptilotus obovatus*	y		y	y	y	y		y	y	y	y		y		y
Apocynaceae	*Alyxia buxifolia*															
Apocynaceae	*Marsdenia australis*	y				y	y	y	y		y	y	y	y	y	y
Asteraceae	*Brachyscome ciliaris*						y									
Asteraceae	*Brachyscome trachycarpa*															
Asteraceae	*Cratystylis subspinescens*		y													
Asteraceae	*Minuria cunninghammii*															
Asteraceae	*Olearia exiguifolia*										y	y				
Asteraceae	*Olearia muelleri*				y	y					y			y		y
Asteraceae	*Vittadinia eremaea*															
Boraginaceae	*Halgania cyanea*															
Casuarinaceae	*Allocasuarina helmsii*															
Casuarinaceae	*Casuarina pauper*				y			y		y	y			y		y
Chenopodiaceae	*Atriplex bunburyana*		y											y		
Chenopodiaceae	*Atriplex nummularia* subsp. *spathulata*		y		y									y		
Chenopodiaceae	*Atriplex vesicaria*		y											y		
Chenopodiaceae	*Chenopodium gaudichaudianum*															
Chenopodiaceae	*Enchylaena lanata*									y				y		
Chenopodiaceae	*Enchylaena tomentosa* var. *tomentosa*													y		
Chenopodiaceae	*Enchyleana x Maireana* hybrid															
Chenopodiaceae	*Eriochiton sclerolaenoides*															
Chenopodiaceae	*Maireana georgei*				y					y	y			y		
Chenopodiaceae	*Maireana pentatropis*															y
Chenopodiaceae	*Maireana planifolia*															
Chenopodiaceae	*Maireana pyramidata*															
Chenopodiaceae	*Maireana sedifolia*		y		y											
Chenopodiaceae	*Maireana tomentosa*															
Chenopodiaceae	*Maireana triptera*		y		y									y		
Chenopodiaceae	*Rhagodia drummondii*															
Chenopodiaceae	*Rhagodia eremaea*		y				y	y			y	y		y		y
Chenopodiaceae	*Salsola australis*															
Chenopodiaceae	*Sclerolaena cuneata*															
Chenopodiaceae	*Sclerolaena diacantha*		y											y		y
Chenopodiaceae	*Sclerolaena gardneri*															
Chenopodiaceae	*Sclerolaena glabra*															
Chenopodiaceae	*Sclerolaena obliquicuspis*															
Chenopodiaceae	*Tecticornia disarticulata*															
Convolvulaceae	*Convolvulus clementii*															
Fabaceae	*Acacia aptaneura*															
Fabaceae	*Acacia ayersiana*	y		y		y			y		y	y				
Fabaceae	*Acacia burkittii*	y		y	y	y	y	y	y	y	y	y				y
Fabaceae	*Acacia caesaneura*												y		y	
Fabaceae	*Acacia erinacea*															

Family	Taxa	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
Fabaceae	*Acacia hemiteles*	y	y		y	y					y					
Fabaceae	*Acacia incurvaneura*	y		y	y	y	y	y	y	y	y	y	y	y	y	y
Fabaceae	*Acacia kempeana*								y					y		y
Fabaceae	*Acacia ligulata*															
Fabaceae	*Acacia nyssophylla*															
Fabaceae	*Acacia oswaldii*												y	y		y
Fabaceae	*Acacia quadrimarginea*															
Fabaceae	*Acacia ramulosa* var. *linophylla*			y		y		y	y		y		y	y	y	
Fabaceae	*Acacia sibirica*			y		y		y	y	y						y
Fabaceae	*Acacia tetragonophylla*	y	y	y	y	y	y	y	y	y	y	y		y		y
Fabaceae	*Senna artemisioides* subsp. *filifolia*				y	y			y		y	y		y		y
Fabaceae	*Senna artemisioides* subsp. *x artemisioides*	y	y	y		y	y	y	y	y	y			y		
Fabaceae	*Senna cardiosperma*															
Fabaceae	*Templetonia incrassata*															
Frankeniaceae	*Frankenia interioris*															
Goodeniaceae	*Scaevola spinescens*			y		y	y		y	y	y		y	y	y	y
Lamiaceae	*Physopsis viscida*															
Lamiaceae	*Prostanthera althoferi* subsp. *althoferi*	y		y		y	y	y	y			y	y		y	
Lamiaceae	*Teucrium disjunctum*															
Lamiaceae	*Teucrium teucriiflorum*						y	y					y			
Lamiaceae	*Westringia rigida*															
Loranthaceae	*Amyema fitzgeraldii*															
Loranthaceae	*Amyema gibberula* var. *gibberula*					y		y				y				
Loranthaceae	*Amyema preissii*															
Loranthaceae	*Lysiana casuarinae*															
Malvaceae	*Abutilon cryptopetalum*															
Malvaceae	*Abutilon otocarpum*															
Malvaceae	*Brachychiton gregorii*			y			y		y				y			
Malvaceae	*Sida calyxhymenia*			y					y							
Malvaceae	*Sida intricata*															
Malvaceae	*Sida* sp. Excedentifolia (J.L. Egan 1925)												y		y	
Malvaceae	*Sida spodochroma*															
Myrtaceae	*Calytrix* sp.															
Myrtaceae	*Eucalyptus ewartiniana*												y			
Myrtaceae	*Eucalyptus concinna*															
Myrtaceae	*Eucalyptus eremicola* subsp *peeneri*															
Myrtaceae	*Eucalyptus lesouefii*													y		
Myrtaceae	*Eucalyptus oleosa* subsp. *oleosa*	y		y	y	y		y		y		y				
Myrtaceae	*Eucalyptus salmonophloia*		y													
Myrtaceae	*Eucalyptus salubris*													y		
Myrtaceae	*Eucalyptus yilgarnensis*															
Myrtaceae	*Melaleuca hamata*														y	
Pittosporaceae	*Bursaria occidentalis*						y									

Family	Taxa	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
Pittosporaceae	*Pittosporum angustifolium*															
Poaceae	*Aristida contorta*															
Poaceae	*Astrostipa* sp.												y			
Poaceae	*Austrostipa elegantissima*													y		
Poaceae	*Austrostipa eremophila*							y								
Poaceae	*Enneapogon avenaceus*															
Poaceae	*Enneapogon caerulescens*															
Poaceae	*Enneapogon polyphyllus*															
Poaceae	*Eragrostis eriopoda*			y									y		y	
Poaceae	*Monachather paradoxus*												y		y	
Poaceae	*Paspalidium constrictum*															
Poaceae	*Thyridolepis sp*															
Poaceae	*Triodia irritans*															
Proteaceae	*Grevillea nematophylla* subsp. *nematophylla*															
Proteaceae	*Hakea preissii*															
Pteridaceae	*Cheilanthus sieberi* subsp. *sieberi*														y	
Rubiaceae	*Psydrax suaveolens*														y	
Rutaceae	*Phebalium canaliculatum*											y				
Santalaceae	*Exocarpos aphyllus*															
Santalaceae	*Santalum acuminatum*															
Santalaceae	*Santalum spicatum*						y		y		y	y		y		y
Sapindaceae	*Alectryon oleifolius* subsp. *canescens*		y		y						y			y		y
Sapindaceae	*Dodonaea lobulata*	y		y		y	y		y	y	y	y		y		y
Sapindaceae	*Dodonaea rigida*			y		y	y	y	y	y	y		y		y	
Scrophulariaceae	*Eremophila alternifolia*															
Scrophulariaceae	*Eremophila arachnoides* subsp. *tenera*															
Scrophulariaceae	*Eremophila caperata*															
Scrophulariaceae	*Eremophila decipiens* subsp. *decipiens*		y					y				y		y		
Scrophulariaceae	*Eremophila eriocalyx*	y		y	y	y			y	y	y		y	y		
Scrophulariaceae	*Eremophila forrestii* subsp. *forrestii*								y				y		y	
Scrophulariaceae	*Eremophila georgei*			y					y					y		
Scrophulariaceae	*Eremophila glabra* subsp *glabra*															
Scrophulariaceae	*Eremophila granitica*	y			y	y	y	y		y						
Scrophulariaceae	*Eremophila latrobei* subsp. *latrobei*								y				y	y	y	
Scrophulariaceae	*Eremophila longifolia*		y				y							y		
Scrophulariaceae	*Eremophila maculata*		y													
Scrophulariaceae	*Eremophila metallicorum*											y				
Scrophulariaceae	*Eremophila oldfieldii* subsp. *angustifolia*						y		y		y			y		y
Scrophulariaceae	*Eremophila oppositifolia* subsp. *angustifolia*						y				y			y		
Scrophulariaceae	*Eremophila scoparia*		y													
Scrophulariaceae	*Eremophila* sp															
Solanaceae	*Lycium australe*															
Solanaceae	*Solanum nummularium*										y		y			

Family	Taxa	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
Solanaceae	*Solanum lasiophyllum*										y					
Violaceae	*Hybanthus floribundus* subsp. *curvifolius*															
Zygophyllaceae	*Roepera aurantiaca* subsp. *aurantiaca*															

Family	Taxa	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Amaranthaceae	*Ptilotus obovatus*	y	y	y	y	y	y	y		y	y	y	y	y	y	y
Apocynaceae	*Alyxia buxifolia*															
Apocynaceae	*Marsdenia australis*		y	y		y	y			y		y	y			y
Asteraceae	*Brachyscome ciliaris*															
Asteraceae	*Brachyscome trachycarpa*															
Asteraceae	*Cratystylis subspinescens*															
Asteraceae	*Minuria cunninghammii*															
Asteraceae	*Olearia exiguifolia*															
Asteraceae	*Olearia muelleri*			y		y	y				y	y			y	
Asteraceae	*Vittadinia eremaea*							y								
Boraginaceae	*Halgania cyanea*															
Casuarinaceae	*Allocasuarina helmsii*															
Casuarinaceae	*Casuarina pauper*	y	y	y		y	y		y	y	y	y	y		y	y
Chenopodiaceae	*Atriplex bunburyana*			y	y	y		y				y				
Chenopodiaceae	*Atriplex nummularia* subsp. *spathulata*			y		y			y	y	y	y	y		y	
Chenopodiaceae	*Atriplex vesicaria*								y	y		y				
Chenopodiaceae	*Chenopodium gaudichaudianum*				y											
Chenopodiaceae	*Enchylaena lanata*							y	y			y				
Chenopodiaceae	*Enchylaena tomentosa* var. *tomentosa*			y	y			y	y							y
Chenopodiaceae	*Enchyleana x Maireana* hybrid															
Chenopodiaceae	*Eriochiton sclerolaenoides*										y					
Chenopodiaceae	*Maireana georgei*				y			y	y		y	y			y	y
Chenopodiaceae	*Maireana pentatropis*				y							y			y	y
Chenopodiaceae	*Maireana planifolia*									y						
Chenopodiaceae	*Maireana pyramidata*			y				y	y							
Chenopodiaceae	*Maireana sedifolia*		y	y	y		y		y	y		y	y			
Chenopodiaceae	*Maireana tomentosa*			y					y							
Chenopodiaceae	*Maireana triptera*			y				y	y	y		y				y
Chenopodiaceae	*Rhagodia drummondii*								y			y	y			y
Chenopodiaceae	*Rhagodia eremaea*			y	y			y								y
Chenopodiaceae	*Salsola australis*									y		y				
Chenopodiaceae	*Sclerolaena cuneata*															
Chenopodiaceae	*Sclerolaena diacantha*			y	y			y	y	y		y			y	
Chenopodiaceae	*Sclerolaena gardneri*								y							
Chenopodiaceae	*Sclerolaena glabra*								y						y	
Chenopodiaceae	*Sclerolaena obliquicuspis*								y	y		y				
Chenopodiaceae	*Tecticornia disarticulata*															
Convolvulaceae	*Convolvulus clementii*															
Fabaceae	*Acacia aptaneura*		y			y		y	y							
Fabaceae	*Acacia ayersiana*													y		y
Fabaceae	*Acacia burkittii*		y	y	y	y		y	y	y		y	y			
Fabaceae	*Acacia caesaneura*	y												y		
Fabaceae	*Acacia erinacea*														y	

Family	*Taxa*	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Fabaceae	*Acacia hemiteles*		y	y	y	y	y	y	y	y		y				y
Fabaceae	*Acacia incurvaneura*	y			y	y	y	y						y		y
Fabaceae	*Acacia kempeana*	y					y	y								
Fabaceae	*Acacia ligulata*															
Fabaceae	*Acacia nyssophylla*								y			y			y	
Fabaceae	*Acacia oswaldii*			y		y						y				
Fabaceae	*Acacia quadrimarginea*															
Fabaceae	*Acacia ramulosa* var. *linophylla*	y					y									
Fabaceae	*Acacia sibirica*									y	y	y	y		y	y
Fabaceae	*Acacia tetragonophylla*	y	y	y	y			y	y			y	y		y	y
Fabaceae	*Senna artemisioides* subsp. *filifolia*		y	y	y	y	y	y	y	y		y	y	y		y
Fabaceae	*Senna artemisioides* subsp. *x artemisioides*									y						
Fabaceae	*Senna cardiosperma*										y					
Fabaceae	*Templetonia incrassata*			y		y										
Frankeniaceae	*Frankenia interioris*															
Goodeniaceae	*Scaevola spinescens*	y		y		y	y		y	y	y	y		y	y	y
Lamiaceae	*Physopsis viscida*															
Lamiaceae	*Prostanthera althoferi* subsp. *althoferi*	y														
Lamiaceae	*Teucrium disjunctum*															
Lamiaceae	*Teucrium teucriiflorum*	y												y		
Lamiaceae	*Westringia rigida*															
Loranthaceae	*Amyema fitzgeraldii*				y			y								
Loranthaceae	*Amyema gibberula* var. *gibberula*															
Loranthaceae	*Amyema preissii*															
Loranthaceae	*Lysiana casuarinae*			y												
Malvaceae	*Abutilon cryptopetalum*															
Malvaceae	*Abutilon otocarpum*				y											
Malvaceae	*Brachychiton gregorii*	y												y		
Malvaceae	*Sida calyxhymenia*	y														
Malvaceae	*Sida intricata*											y	y	y		
Malvaceae	*Sida* sp. Excedentifolia (J.L. Egan 1925)															
Malvaceae	*Sida spodochroma*							y	y							
Myrtaceae	*Calytrix* sp.															
Myrtaceae	*Eucalyptus ewartiniana*															
Myrtaceae	*Eucalyptus concinna*	y									y			y		
Myrtaceae	*Eucalyptus eremicola* subsp *peeneri*															
Myrtaceae	*Eucalyptus lesouefii*															
Myrtaceae	*Eucalyptus oleosa* subsp. *oleosa*				y			y								
Myrtaceae	*Eucalyptus salmonophloia*		y						y	y		y				
Myrtaceae	*Eucalyptus salubris*								y							
Myrtaceae	*Eucalyptus yilgarnensis*														y	
Myrtaceae	*Melaleuca hamata*															
Pittosporaceae	*Bursaria occidentalis*							y								

Family	Taxa	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Pittosporaceae	*Pittosporum angustifolium*															
Poaceae	*Aristida contorta*															
Poaceae	*Astrostipa* sp.											y	y			y
Poaceae	*Austrostipa elegantissima*			y					y	y		y	y		y	
Poaceae	*Austrostipa eremophila*															
Poaceae	*Enneapogon avenaceus*															
Poaceae	*Enneapogon caerulescens*															
Poaceae	*Enneapogon polyphyllus*															
Poaceae	*Eragrostis eriopoda*													y		
Poaceae	*Monachather paradoxus*													y		
Poaceae	*Paspalidium constrictum*									y						
Poaceae	*Thyridolepis sp*	y														
Poaceae	*Triodia irritans*															
Proteaceae	*Grevillea nematophylla* subsp. *nematophylla*															
Proteaceae	*Hakea preissii*															
Pteridaceae	*Cheilanthus sieberi* subsp. *sieberi*															
Rubiaceae	*Psydrax suaveolens*															
Rutaceae	*Phebalium canaliculatum*								y							y
Santalaceae	*Exocarpos aphyllus*		y													
Santalaceae	*Santalum acuminatum*															
Santalaceae	*Santalum spicatum*			y							y	y	y		y	
Sapindaceae	*Alectryon oleifolius* subsp. *canescens*		y	y	y					y						y
Sapindaceae	*Dodonaea lobulata*		y		y	y	y	y			y	y	y		y	y
Sapindaceae	*Dodonaea rigida*	y												y		
Scrophulariaceae	*Eremophila alternifolia*															
Scrophulariaceae	*Eremophila arachnoides* subsp. *tenera*															
Scrophulariaceae	*Eremophila caperata*															
Scrophulariaceae	*Eremophila decipiens* subsp. *decipiens*					y	y					y	y		y	y
Scrophulariaceae	*Eremophila eriocalyx*						y									
Scrophulariaceae	*Eremophila forrestii* subsp. *forrestii*													y		
Scrophulariaceae	*Eremophila georgei*	y			y							y	y			y
Scrophulariaceae	*Eremophila glabra* subsp *glabra*			y		y										
Scrophulariaceae	*Eremophila granitica*															
Scrophulariaceae	*Eremophila latrobei* subsp. *latrobei*					y										
Scrophulariaceae	*Eremophila longifolia*		y	y	y	y		y						y		
Scrophulariaceae	*Eremophila maculata*															
Scrophulariaceae	*Eremophila metallicorum*															
Scrophulariaceae	*Eremophila oldfieldii* subsp. *angustifolia*					y	y				y	y	y		y	y
Scrophulariaceae	*Eremophila oppositifolia* subsp. *angustifolia*														y	
Scrophulariaceae	*Eremophila scoparia*		y	y			y		y	y	y	y			y	
Scrophulariaceae	*Eremophila* sp															
Solanaceae	*Lycium australe*															
Solanaceae	*Solanum nummularium*															

Family	*Taxa*	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Solanaceae	*Solanum lasiophyllum*	y			y			y	y	y		y	y	y		
Violaceae	*Hybanthus floribundus* subsp. *curvifolius*															
Zygophyllaceae	*Roepera aurantiaca* subsp. *aurantiaca*															

Family	Taxa	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Amaranthaceae	*Ptilotus obovatus*	y	y	y	y	y	y	y	y	y		y	y	y	y	y
Apocynaceae	*Alyxia buxifolia*															
Apocynaceae	*Marsdenia australis*		y			y		y	y	y			y	y	y	
Asteraceae	*Brachyscome ciliaris*				y		y								y	
Asteraceae	*Brachyscome trachycarpa*															
Asteraceae	*Cratystylis subspinescens*										y	y				
Asteraceae	*Minuria cunninghammii*															y
Asteraceae	*Olearia exiguifolia*															
Asteraceae	*Olearia muelleri*		y			y	y			y		y			y	
Asteraceae	*Vittadinia eremaea*					y										y
Boraginaceae	*Halgania cyanea*						y							y		
Casuarinaceae	*Allocasuarina helmsii*															
Casuarinaceae	*Casuarina pauper*	y	y		y	y	y		y	y	y	y				
Chenopodiaceae	*Atriplex bunburyana*		y	y			y			y						y
Chenopodiaceae	*Atriplex nummularia* subsp. *spathulata*		y	y					y	y		y				y
Chenopodiaceae	*Atriplex vesicaria*		y	y							y					y
Chenopodiaceae	*Chenopodium gaudichaudianum*								y		y					y
Chenopodiaceae	*Enchylaena lanata*			y				y		y						
Chenopodiaceae	*Enchylaena tomentosa* var. *tomentosa*							y						y		
Chenopodiaceae	*Enchyleana x Maireana* hybrid									y				y		y
Chenopodiaceae	*Eriochiton sclerolaenoides*															
Chenopodiaceae	*Maireana georgei*		y	y			y		y	y			y	y		
Chenopodiaceae	*Maireana pentatropis*								y							
Chenopodiaceae	*Maireana planifolia*															
Chenopodiaceae	*Maireana pyramidata*										y					
Chenopodiaceae	*Maireana sedifolia*	y	y	y	y	y	y		y		y	y			y	y
Chenopodiaceae	*Maireana tomentosa*															
Chenopodiaceae	*Maireana triptera*						y			y			y	y	y	y
Chenopodiaceae	*Rhagodia drummondii*								y	y					y	y
Chenopodiaceae	*Rhagodia eremaea*				y			y						y		
Chenopodiaceae	*Salsola australis*					y							y			
Chenopodiaceae	*Sclerolaena cuneata*															
Chenopodiaceae	*Sclerolaena diacantha*			y			y		y				y			y
Chenopodiaceae	*Sclerolaena gardneri*															y
Chenopodiaceae	*Sclerolaena glabra*															
Chenopodiaceae	*Sclerolaena obliquicuspis*															
Chenopodiaceae	*Tecticornia disarticulata*															
Convolvulaceae	*Convolvulus clementii*					y		y					y			y
Fabaceae	*Acacia aptaneura*			y		y				y			y			y
Fabaceae	*Acacia ayersiana*	y			y		y					y			y	
Fabaceae	*Acacia burkittii*	y	y	y	y	y	y	y	y	y		y		y	y	y
Fabaceae	*Acacia caesaneura*	y														
Fabaceae	*Acacia erinacea*															

Family	Taxa	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Fabaceae	*Acacia hemiteles*										y				y	
Fabaceae	*Acacia incurvaneura*	y	y		y	y	y	y				y	y	y	y	y
Fabaceae	*Acacia kempeana*															
Fabaceae	*Acacia ligulata*															
Fabaceae	*Acacia nyssophylla*								y		y	y				
Fabaceae	*Acacia oswaldii*		y		y							y				y
Fabaceae	*Acacia quadrimarginea*				y											
Fabaceae	*Acacia ramulosa* var. *linophylla*	y			y											
Fabaceae	*Acacia sibirica*		y		y				y							
Fabaceae	*Acacia tetragonophylla*	y	y	y	y	y	y	y		y		y		y	y	y
Fabaceae	*Senna artemisioides* subsp. *filifolia*		y	y		y	y	y	y	y	y	y	y	y	y	y
Fabaceae	*Senna artemisioides* subsp. *x artemisioides*	y			y			y		y				y		
Fabaceae	*Senna cardiosperma*				y											
Fabaceae	*Templetonia incrassata*						y			y		y				
Frankeniaceae	*Frankenia interioris*										y					
Goodeniaceae	*Scaevola spinescens*	y	y		y	y	y		y	y	y	y	y	y		
Lamiaceae	*Physopsis viscida*															
Lamiaceae	*Prostanthera althoferi* subsp. *althoferi*	y			y		y									
Lamiaceae	*Teucrium disjunctum*															
Lamiaceae	*Teucrium teucriiflorum*														y	
Lamiaceae	*Westringia rigida*															
Loranthaceae	*Amyema fitzgeraldii*					y	y	y					y	y	y	y
Loranthaceae	*Amyema gibberula* var. *gibberula*															
Loranthaceae	*Amyema preissii*															
Loranthaceae	*Lysiana casuarinae*						y						y			
Malvaceae	*Abutilon cryptopetalum*															y
Malvaceae	*Abutilon otocarpum*															
Malvaceae	*Brachychiton gregorii*				y		y									
Malvaceae	*Sida calyxhymenia*															
Malvaceae	*Sida intricata*															
Malvaceae	*Sida* sp. Excedentifolia (J.L. Egan 1925)															
Malvaceae	*Sida spodochroma*					y		y					y			y
Myrtaceae	*Calytrix* sp.															
Myrtaceae	*Eucalyptus ewartiniana*															
Myrtaceae	*Eucalyptus concinna*															
Myrtaceae	*Eucalyptus eremicola* subsp *peeneri*															
Myrtaceae	*Eucalyptus lesouefii*															
Myrtaceae	*Eucalyptus oleosa* subsp. *oleosa*	y					y	y						y		
Myrtaceae	*Eucalyptus salmonophloia*															
Myrtaceae	*Eucalyptus salubris*															
Myrtaceae	*Eucalyptus yilgarnensis*															
Myrtaceae	*Melaleuca hamata*															
Pittosporaceae	*Bursaria occidentalis*														y	

Family	Taxa	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Pittosporaceae	*Pittosporum angustifolium*			y												
Poaceae	*Aristida contorta*				y											
Poaceae	*Astrostipa* sp.				y	y				y			y			
Poaceae	*Austrostipa elegantissima*		y			y					y	y	y			
Poaceae	*Austrostipa eremophila*															
Poaceae	*Enneapogon avenaceus*			y												
Poaceae	*Enneapogon caerulescens*					y										y
Poaceae	*Enneapogon polyphyllus*			y												
Poaceae	*Eragrostis eriopoda*	y														
Poaceae	*Monachather paradoxus*															
Poaceae	*Paspalidium constrictum*		y					y								y
Poaceae	*Thyridolepis sp*															
Poaceae	*Triodia irritans*												y			
Proteaceae	*Grevillea nematophylla* subsp. *nematophylla*															
Proteaceae	*Hakea preissii*															
Pteridaceae	*Cheilanthus sieberi* subsp. *sieberi*															
Rubiaceae	*Psydrax suaveolens*															
Rutaceae	*Phebalium canaliculatum*			y	y				y	y				y		y
Santalaceae	*Exocarpos aphyllus*															
Santalaceae	*Santalum acuminatum*															
Santalaceae	*Santalum spicatum*			y	y			y		y		y		y	y	
Sapindaceae	*Alectryon oleifolius* subsp. *canescens*		y	y			y		y	y		y				
Sapindaceae	*Dodonaea lobulata*		y		y	y			y	y	y	y			y	y
Sapindaceae	*Dodonaea rigida*	y		y								y				
Scrophulariaceae	*Eremophila alternifolia*			y			y			y			y			y
Scrophulariaceae	*Eremophila arachnoides* subsp. *tenera*															
Scrophulariaceae	*Eremophila caperata*															
Scrophulariaceae	*Eremophila decipiens* subsp. *decipiens*		y			y	y					y				
Scrophulariaceae	*Eremophila eriocalyx*						y					y			y	
Scrophulariaceae	*Eremophila forrestii* subsp. *forrestii*											y				
Scrophulariaceae	*Eremophila georgei*		y		y											
Scrophulariaceae	*Eremophila glabra* subsp *glabra*								y		y	y	y	y	y	y
Scrophulariaceae	*Eremophila granitica*															
Scrophulariaceae	*Eremophila latrobei* subsp. *latrobei*				y							y				
Scrophulariaceae	*Eremophila longifolia*		y							y				y		
Scrophulariaceae	*Eremophila maculata*															
Scrophulariaceae	*Eremophila metallicorum*					y	y	y				y		y	y	y
Scrophulariaceae	*Eremophila oldfieldii* subsp. *angustifolia*		y		y										y	
Scrophulariaceae	*Eremophila oppositifolia* subsp. *angustifolia*															
Scrophulariaceae	*Eremophila scoparia*		y	y					y		y	y				y
Scrophulariaceae	*Eremophila* sp			y		y										
Solanaceae	*Lycium australe*															
Solanaceae	*Solanum nummularium*															

Family	*Taxa*	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Solanaceae	*Solanum lasiophyllum*	y	y		y	y	y	y		y			y	y	y	y
Violaceae	*Hybanthus floribundus* subsp. *curvifolius*															
Zygophyllaceae	*Roepera aurantiaca* subsp. *aurantiaca*															

Family	Taxa	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Amaranthaceae	*Ptilotus obovatus*	y	y	y	y	y		y	y	y	y	y	y	y	y	y
Apocynaceae	*Alyxia buxifolia*							y		y	y			y		
Apocynaceae	*Marsdenia australis*		y	y	y		y	y	y		y	y			y	
Asteraceae	*Brachyscome ciliaris*			y				y		y					y	
Asteraceae	*Brachyscome trachycarpa*							y								
Asteraceae	*Cratystylis subspinescens*						y									
Asteraceae	*Minuria cunninghammii*				y			y								
Asteraceae	*Olearia exiguifolia*															
Asteraceae	*Olearia muelleri*	y	y			y	y				y	y	y			y
Asteraceae	*Vittadinia eremaea*															
Boraginaceae	*Halgania cyanea*															
Casuarinaceae	*Allocasuarina helmsii*															
Casuarinaceae	*Casuarina pauper*	y	y		y	y	y	y	y	y	y	y	y	y	y	
Chenopodiaceae	*Atriplex bunburyana*															
Chenopodiaceae	*Atriplex nummularia* subsp. *spathulata*	y					y		y	y	y	y	y			y
Chenopodiaceae	*Atriplex vesicaria*							y				y	y			y
Chenopodiaceae	*Chenopodium gaudichaudianum*								y	y	y	y	y			
Chenopodiaceae	*Enchylaena lanata*								y		y	y				
Chenopodiaceae	*Enchylaena tomentosa* var. *tomentosa*						y		y	y		y				
Chenopodiaceae	*Enchyleana x Maireana* hybrid				y	y						y				
Chenopodiaceae	*Eriochiton sclerolaenoides*															
Chenopodiaceae	*Maireana georgei*			y		y			y			y				y
Chenopodiaceae	*Maireana pentatropis*													y		
Chenopodiaceae	*Maireana planifolia*											y				
Chenopodiaceae	*Maireana pyramidata*								y							y
Chenopodiaceae	*Maireana sedifolia*	y			y	y	y	y	y	y	y	y	y	y	y	y
Chenopodiaceae	*Maireana tomentosa*															y
Chenopodiaceae	*Maireana triptera*	y	y	y		y										y
Chenopodiaceae	*Rhagodia drummondii*		y							y						
Chenopodiaceae	*Rhagodia eremaea*															
Chenopodiaceae	*Salsola australis*				y	y										
Chenopodiaceae	*Sclerolaena cuneata*															y
Chenopodiaceae	*Sclerolaena diacantha*			y			y		y	y		y				y
Chenopodiaceae	*Sclerolaena gardneri*								y							y
Chenopodiaceae	*Sclerolaena glabra*															
Chenopodiaceae	*Sclerolaena obliquicuspis*							y								
Chenopodiaceae	*Tecticornia disarticulata*															y
Convolvulaceae	*Convolvulus clementii*															
Fabaceae	*Acacia aptaneura*			y	y		y			y		y				
Fabaceae	*Acacia ayersiana*		y													
Fabaceae	*Acacia burkittii*	y	y	y	y	y	y	y	y	y	y	y	y	y	y	
Fabaceae	*Acacia caesaneura*															
Fabaceae	*Acacia erinacea*															

Fabaceae	*Acacia hemiteles*						y				y				y	
Fabaceae	*Acacia incurvaneura*	y	y	y	y	y		y	y							
Fabaceae	*Acacia kempeana*															
Fabaceae	*Acacia ligulata*				y									y		
Fabaceae	*Acacia nyssophylla*										y	y		y		
Fabaceae	*Acacia oswaldii*					y						y		y	y	
Fabaceae	*Acacia quadrimarginea*														y	
Fabaceae	*Acacia ramulosa* var. *linophylla*															
Fabaceae	*Acacia sibirica*	y													y	
Fabaceae	*Acacia tetragonophylla*	y	y	y	y		y		y	y	y	y	y	y	y	
Fabaceae	*Senna artemisioides* subsp. *filifolia*	y	y	y	y	y	y	y		y		y	y	y	y	y
Fabaceae	*Senna artemisioides* subsp. *x artemisioides*							y	y							
Fabaceae	*Senna cardiosperma*															
Fabaceae	*Templetonia incrassata*										y	y				
Frankeniaceae	*Frankenia interioris*							y								y
Goodeniaceae	*Scaevola spinescens*	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
Lamiaceae	*Physopsis viscida*															
Lamiaceae	*Prostanthera althoferi* subsp. *althoferi*		y	y												
Lamiaceae	*Teucrium disjunctum*						y					y				
Lamiaceae	*Teucrium teucriiflorum*		y	y					y							
Lamiaceae	*Westringia rigida*															
Loranthaceae	*Amyema fitzgeraldii*									y						
Loranthaceae	*Amyema gibberula* var. *gibberula*															
Loranthaceae	*Amyema preissii*												y			
Loranthaceae	*Lysiana casuarinae*			y					y	y						
Malvaceae	*Abutilon cryptopetalum*															
Malvaceae	*Abutilon otocarpum*															
Malvaceae	*Brachychiton gregorii*								y	y						
Malvaceae	*Sida calyxhymenia*															
Malvaceae	*Sida intricata*						y			y	y					
Malvaceae	*Sida* sp. Excedentifolia (J.L. Egan 1925)															
Malvaceae	*Sida spodochroma*				y											
Myrtaceae	*Calytrix* sp.															
Myrtaceae	*Eucalyptus ewartiniana*															
Myrtaceae	*Eucalyptus concinna*															
Myrtaceae	*Eucalyptus eremicola* subsp *peeneri*															
Myrtaceae	*Eucalyptus lesouefii*															y
Myrtaceae	*Eucalyptus oleosa* subsp. *oleosa*		y					y								
Myrtaceae	*Eucalyptus salmonophloia*															y
Myrtaceae	*Eucalyptus salubris*															y
Myrtaceae	*Eucalyptus yilgarnensis*															
Myrtaceae	*Melaleuca hamata*															
Pittosporaceae	*Bursaria occidentalis*															
Pittosporaceae	*Pittosporum angustifolium*															

Poaceae	*Aristida contorta*				y											
Poaceae	*Astrostipa* sp.			y	y				y				y			
Poaceae	*Austrostipa elegantissima*					y	y	y		y	y	y	y	y		
Poaceae	*Austrostipa eremophila*															
Poaceae	*Enneapogon avenaceus*												y			
Poaceae	*Enneapogon caerulescens*				y			y								
Poaceae	*Enneapogon polyphyllus*															
Poaceae	*Eragrostis eriopoda*															
Poaceae	*Monachather paradoxus*															
Poaceae	*Paspalidium constrictum*							y								
Poaceae	*Thyridolepis sp*															
Poaceae	*Triodia irritans*															
Proteaceae	*Grevillea nematophylla* subsp. *nematophylla*															
Proteaceae	*Hakea preissii*							y								
Pteridaceae	*Cheilanthus sieberi* subsp. *sieberi*														y	
Rubiaceae	*Psydrax suaveolens*															
Rutaceae	*Phebalium canaliculatum*	y		y		y										
Santalaceae	*Exocarpos aphyllus*						y	y		y		y				
Santalaceae	*Santalum acuminatum*															
Santalaceae	*Santalum spicatum*				y					y						
Sapindaceae	*Alectryon oleifolius* subsp. *canescens*					y	y	y		y	y	y		y	y	
Sapindaceae	*Dodonaea lobulata*	y	y	y		y	y	y	y	y	y	y	y	y	y	
Sapindaceae	*Dodonaea rigida*		y													
Scrophulariaceae	*Eremophila alternifolia*			y						y	y	y				
Scrophulariaceae	*Eremophila arachnoides* subsp. *tenera*						y					y				
Scrophulariaceae	*Eremophila caperata*															
Scrophulariaceae	*Eremophila decipiens* subsp. *decipiens*		y				y	y		y		y				
Scrophulariaceae	*Eremophila eriocalyx*	y	y						y	y					y	
Scrophulariaceae	*Eremophila forrestii* subsp. *forrestii*															
Scrophulariaceae	*Eremophila georgei*	y					y		y	y						
Scrophulariaceae	*Eremophila glabra* subsp *glabra*		y	y	y	y	y	y			y	y	y		y	
Scrophulariaceae	*Eremophila granitica*															
Scrophulariaceae	*Eremophila latrobei* subsp. *latrobei*	y											y			
Scrophulariaceae	*Eremophila longifolia*						y			y	y					
Scrophulariaceae	*Eremophila maculata*															
Scrophulariaceae	*Eremophila metallicorum*		y					y	y	y	y	y				
Scrophulariaceae	*Eremophila oldfieldii* subsp. *angustifolia*	y		y		y	y			y	y	y	y	y	y	
Scrophulariaceae	*Eremophila oppositifolia* subsp. *angustifolia*	y														
Scrophulariaceae	*Eremophila scoparia*	y						y								y
Scrophulariaceae	*Eremophila* sp															
Solanaceae	*Lycium australe*										y	y				
Solanaceae	*Solanum nummularium*									y						
Solanaceae	*Solanum lasiophyllum*			y	y	y	y		y	y	y					y
Violaceae	*Hybanthus floribundus* subsp. *curvifolius*	y														

Zygophyllaceae	*Roepera aurantiaca* subsp. *aurantiaca*	y

Family	*Taxa*	61	62	63	64	65	66	67	68	69	70	71	72	Counts
Amaranthaceae	*Ptilotus obovatus*	y		y	y	y	y	y	y	y	y	y	y	64
Apocynaceae	*Alyxia buxifolia*	y						y	y	y	y	y	y	11
Apocynaceae	*Marsdenia australis*										y			37
Asteraceae	*Brachyscome ciliaris*													8
Asteraceae	*Brachyscome trachycarpa*													1
Asteraceae	*Cratystylis subspinescens*	y												5
Asteraceae	*Minuria cunninghammii*													3
Asteraceae	*Olearia exiguifolia*													2
Asteraceae	*Olearia muelleri*	y						y		y		y		29
Asteraceae	*Vittadinia eremaea*													3
Boraginaceae	*Halgania cyanea*													2
Casuarinaceae	*Allocasuarina helmsii*			y										1
Casuarinaceae	*Casuarina pauper*	y					y	y	y	y	y	y		47
Chenopodiaceae	*Atriplex bunburyana*	y									y			14
Chenopodiaceae	*Atriplex nummularia* subsp. *spathulata*	y						y	y				y	29
Chenopodiaceae	*Atriplex vesicaria*	y						y						15
Chenopodiaceae	*Chenopodium gaudichaudianum*	y									y			11
Chenopodiaceae	*Enchylaena lanata*										y		y	13
Chenopodiaceae	*Enchylaena tomentosa* var. *tomentosa*	y						y			y		y	16
Chenopodiaceae	*Enchyleana x Maireana* hybrid										y			7
Chenopodiaceae	*Eriochiton sclerolaenoides*													1
Chenopodiaceae	*Maireana georgei*							y			y			25
Chenopodiaceae	*Maireana pentatropis*							y						8
Chenopodiaceae	*Maireana planifolia*													2
Chenopodiaceae	*Maireana pyramidata*										y			7
Chenopodiaceae	*Maireana sedifolia*	y						y		y	y	y		39
Chenopodiaceae	*Maireana tomentosa*							y						4
Chenopodiaceae	*Maireana triptera*							y		y	y		y	24
Chenopodiaceae	*Rhagodia drummondii*	y									y			12
Chenopodiaceae	*Rhagodia eremaea*												y	15
Chenopodiaceae	*Salsola australis*													6
Chenopodiaceae	*Sclerolaena cuneata*													1
Chenopodiaceae	*Sclerolaena diacantha*	y						y			y			24
Chenopodiaceae	*Sclerolaena gardneri*	y												5
Chenopodiaceae	*Sclerolaena glabra*													2
Chenopodiaceae	*Sclerolaena obliquicuspis*													4
Chenopodiaceae	*Tecticornia disarticulata*	y						y					y	4
Convolvulaceae	*Convolvulus clementii*													4
Fabaceae	*Acacia aptaneura*												y	15
Fabaceae	*Acacia ayersiana*		y		y	y	y			y				19
Fabaceae	*Acacia burkittii*		y	y	y	y	y		y		y		y	55
Fabaceae	*Acacia caesaneura*													5
Fabaceae	*Acacia erinacea*								y					2

Family	*Taxa*	61	62	63	64	65	66	67	68	69	70	71	72	Counts
Fabaceae	*Acacia hemiteles*			y			y							22
Fabaceae	*Acacia incurvaneura*		y		y	y	y			y		y	y	46
Fabaceae	*Acacia kempeana*													6
Fabaceae	*Acacia ligulata*		y		y					y		y	y	7
Fabaceae	*Acacia nyssophylla*		y	y				y	y	y	y			15
Fabaceae	*Acacia oswaldii*									y	y			16
Fabaceae	*Acacia quadrimarginea*													2
Fabaceae	*Acacia ramulosa* var. *linophylla*		y		y		y		y				y	17
Fabaceae	*Acacia sibirica*													17
Fabaceae	*Acacia tetragonophylla*		y	y		y	y	y		y	y	y	y	56
Fabaceae	*Senna artemisioides* subsp. *filifolia*	y	y			y			y	y	y	y		52
Fabaceae	*Senna artemisioides* subsp. *x artemisioides*	y		y	y	y								22
Fabaceae	*Senna cardiosperma*													2
Fabaceae	*Templetonia incrassata*									y	y	y		10
Frankeniaceae	*Frankenia interioris*	y						y					y	6
Goodeniaceae	*Scaevola spinescens*	y	y	y	y	y	y	y	y			y	y	57
Lamiaceae	*Physopsis viscida*		y											1
Lamiaceae	*Prostanthera althoferi* subsp. *althoferi*						y							16
Lamiaceae	*Teucrium disjunctum*													2
Lamiaceae	*Teucrium teucriiflorum*				y		y							11
Lamiaceae	*Westringia rigida*			y										1
Loranthaceae	*Amyema fitzgeraldii*													10
Loranthaceae	*Amyema gibberula* var. *gibberula*					y					y			5
Loranthaceae	*Amyema preissii*													1
Loranthaceae	*Lysiana casuarinae*													6
Malvaceae	*Abutilon cryptopetalum*													1
Malvaceae	*Abutilon otocarpum*													1
Malvaceae	*Brachychiton gregorii*				y		y							12
Malvaceae	*Sida calyxhymenia*					y	y				y		y	7
Malvaceae	*Sida intricata*													6
Malvaceae	*Sida* sp. Excedentifolia (J.L. Egan 1925)													2
Malvaceae	*Sida spodochroma*													7
Myrtaceae	*Calytrix* sp.												y	1
Myrtaceae	*Eucalyptus ewartiniana*													1
Myrtaceae	*Eucalyptus concinna*													3
Myrtaceae	*Eucalyptus eremicola* subsp *peeneri*			y				y						2
Myrtaceae	*Eucalyptus lesouefii*								y					3
Myrtaceae	*Eucalyptus oleosa* subsp. *oleosa*		y	y	y	y	y	y			y		y	23
Myrtaceae	*Eucalyptus salmonophloia*	y										y		8
Myrtaceae	*Eucalyptus salubris*	y												4
Myrtaceae	*Eucalyptus yilgarnensis*													1
Myrtaceae	*Melaleuca hamata*													1
Pittosporaceae	*Bursaria occidentalis*													3

Family	*Taxa*	61	62	63	64	65	66	67	68	69	70	71	72	Counts
Pittosporaceae	*Pittosporum angustifolium*													1
Poaceae	*Aristida contorta*													2
Poaceae	*Astrostipa* sp.													12
Poaceae	*Austrostipa elegantissima*								y	y				22
Poaceae	*Austrostipa eremophila*													1
Poaceae	*Enneapogon avenaceus*	y												3
Poaceae	*Enneapogon caerulescens*													4
Poaceae	*Enneapogon polyphyllus*													1
Poaceae	*Eragrostis eriopoda*													5
Poaceae	*Monachather paradoxus*													3
Poaceae	*Paspalidium constrictum*													5
Poaceae	*Thyridolepis sp*													1
Poaceae	*Triodia irritans*		y	y										3
Proteaceae	*Grevillea nematophylla* subsp. *nematophylla*													0
Proteaceae	*Hakea preissii*												y	2
Pteridaceae	*Cheilanthus sieberi* subsp. *sieberi*													2
Rubiaceae	*Psydrax suaveolens*		y										y	3
Rutaceae	*Phebalium canaliculatum*	y												13
Santalaceae	*Exocarpos aphyllus*	y						y	y			y		9
Santalaceae	*Santalum acuminatum*	y												1
Santalaceae	*Santalum spicatum*			y				y	y			y		24
Sapindaceae	*Alectryon oleifolius* subsp. *canescens*										y	y		26
Sapindaceae	*Dodonaea lobulata*	y	y		y	y		y	y	y	y	y		51
Sapindaceae	*Dodonaea rigida*		y		y	y	y						y	20
Scrophulariaceae	*Eremophila alternifolia*											y		10
Scrophulariaceae	*Eremophila arachnoides* subsp. *tenera*	y												3
Scrophulariaceae	*Eremophila caperata*			y										1
Scrophulariaceae	*Eremophila decipiens* subsp. *decipiens*	y							y	y		y		23
Scrophulariaceae	*Eremophila eriocalyx*		y		y	y	y							22
Scrophulariaceae	*Eremophila forrestii* subsp. *forrestii*		y		y									7
Scrophulariaceae	*Eremophila georgei*				y		y					y	y	18
Scrophulariaceae	*Eremophila glabra* subsp *glabra*													19
Scrophulariaceae	*Eremophila granitica*													6
Scrophulariaceae	*Eremophila latrobei* subsp. *latrobei*						y						y	11
Scrophulariaceae	*Eremophila longifolia*													15
Scrophulariaceae	*Eremophila maculata*													1
Scrophulariaceae	*Eremophila metallicorum*		y											15
Scrophulariaceae	*Eremophila oldfieldii* subsp. *angustifolia*				y		y	y	y	y		y	y	32
Scrophulariaceae	*Eremophila oppositifolia* subsp. *angustifolia*	y						y	y	y		y	y	11
Scrophulariaceae	*Eremophila scoparia*	y						y	y	y		y	y	24
Scrophulariaceae	*Eremophila* sp													2
Solanaceae	*Lycium australe*													2
Solanaceae	*Solanum nummularium*		y											4

Family	*Taxa*	61	62	63	64	65	66	67	68	69	70	71	72	Counts
Solanaceae	*Solanum lasiophyllum*													28
Violaceae	*Hybanthus floribundus* subsp. *curvifolius*													1
Zygophyllaceae	*Roepera aurantiaca* subsp. *aurantiaca*													1

Attachment 4: Inventory site data on landform, soil type and erosion.

Site	LU code	Land system	Geology	Land unit	Slope %	Relief	Landform	Soil texture	Erosion score	Vulnerability to erosion
SE01	6	Deadman	CZc	PLO	0%	0m	Flat	Sandy clay loam	nil	slightly
SE02	5b	Campsite	CZc	PLA	0%	0m	Flat	Light clay	nil	moderately
SE03	4b	Deadman	Sit	PLO	1%	1m	Flat	Sandy loam	nil	nil
SE04	4a	Deadman	CZc	PLO	1%	1m	Flat	sandy loam	nil	nil
SE05	4b	Deadman	CZc	PLO	0%	0m	Flat	Sandy loam	nil	nil
SE06	6	Deadman	CZc	CHM	1%	1m	Flat	Sandy loam	nil	slightly
SE07	4a	Deadman	CZc	PLO	0%	0m	Flat	Sandy loam	nil	nil
SE08	4b	Deadman	CZl	PLC	3%	3m	Upper slope	Sandy loam	nil	nil
SE09	4a	Deadman	CZc	PLO	1%	1m	Flat	Sandy loam	nil	nil
SE10	4a	Deadman	CZc	PLC	1%	1m	Flat	Sandy loam	nil	nil
SE11	6	Deadman	CZc	CHM	1%	1m	Flowline	Sandy clay loam	nil	nil
SE12	2a	Deadman	CZl	RIL	2%	10m	Crest	Sandy loam	nil	nil
SE13	2b	Moriarty	CZc	PLC	2%	3m	Lower slope	Sandy loam	nil	nil
SE14	2a	Deadman	CZc	RIL	1%	1m	Upper slope	Sandy loam	nil	nil
SE15	2a	Deadman	CZl	RIL	2%	1m	Lower slope	Sandy loam	nil	nil
SE16	4b	Deadman	CZl	PLO	1%	0m	Flat	Sandy loam	nil	nil
SE17	5b	Deadman	CZc	CHM	2%	1m	Broad wash	Sandy clay loam	minor	moderately
SE18	5a	Deadman	CZc	PLC	1%	0m	Flat	Sandy clay loam	minor	slightly
SE19	5a	Deadman	CZc	PLC	1%	1m	Flat	Sandy clay loam	minor	slightly
SE20	4b	Deadman	CZc	PLC	1%	0m	Flat	Sandy clay loam	minor	slightly
SE21	2b	Deadman	CZc	HIL	3%	2 -3m	Upper slope	Sandy loam	nil	nil
SE22	5a	Deadman	CZc	PLS	2%	0m	Flat	Sandy clay loam	moderate	moderately
SE23	5b	Moriarty	CZc	PLS	2%	0m	Flat	Sandy clay loam	moderate	moderately
SE24	5b	Moriarty	CZc	PLC	1%	1m	Flat	Sandy clay loam	nil	nil
SE25	1a	Leonora	Czu	HIL	5%	6m	Upper slope	Sandy loam	nil	nil
SE26	5b	Moriarty	CZc	PLO	1%	0m	Flat	Sandy clay loam	nil	slightly
SE27	2b	Moriarty	CZc	HIL	5%	5m	Upper slope	Sandy loam	nil	nil
SE28	4a	Deadman	CZc	PLO	0%	0m	Flat	loamy sand	nil	nil
SE29	1a	Leonora	Ab	HIL	8%	10m	Upper slope	Sandy clay loam	nil	nil
SE30	1a	Leonora	CZc	PLC	1%	1m	Flat	Sandy loam	nil	nil
SE31	4a	Deadman	CZc	PLO	0%	om	Flat	Sandy loam	nil	nil
SE32	2b	Moriarty	CZc	PLC	1%	1m	Low rise	Sandy loam	nil	nil
SE33	5a	Moriarty	CZc	PLA	1%	1m	Flat	Sandy clay	minor	moderately
SE34	1b	Leonora	Ab	HIL	10%	17m	Lower slope	Sandy loam	nil	nil
SE35	4c	Deadman	CZc	PLC	1%	0m	Flat	Sandy clay loam	nil	nil
SE36	4a	Deadman	CZc	PLO	1%	1m	Flat	Sandy clay loam	nil	nil
SE37	6	Deadman	CZc	CHM	1%	1m	Flat	sandy clay	minor	slightly
SE38	1b	Gunadocketa	CZc	HIL	3%	3 - 4m	Lower slope	Sandy loam	nil	nil

Site	LU code	Land system	Geology	Land unit	Slope %	Relief	Landform	Soil texture	Erosion score	Vulnerability to erosion
SE39	5a	Gunadocketa	CZc	PLO	1%	1m	Flat	Sandy clay loam	minor	slightly
SE40	4c	Gunadocketa	CZc	PLC	1%	1m	Broad flowline	Sandy clay loam	moderate	moderately
SE41	2a	Gunadocketa	CZc	HIL	2%	2m	Low rise	Sandy loam	minor	slightly
SE42	4c	Deadman	CZc	PLC	1%	1m	Flat	Sandy clay loam	nil	nil
SE43	6	Deadman	CZc	PLO	1%	1m	Flat	Sandy clay loam	minor	slightly
SE44	4a	Deadman	CZc	PLC	1%	1m	Flat	Sandy clay loam	minor	slightly
SE45	4c	Gunadocketa	CZc	PLC	1%	1m	Flat	Sandy clay loam	minor	slightly
SE46	1a	Leonora	Ab	HIL	8%	17 - 20m	Crest	Sandy loam	nil	nil
SE47	4a	Deadman	CZc	PLC	1%	1m	Flat	Sandy clay loam	nil	nil
SE48	5a	Deadman	CZc	PLO	1%	1m	Flat	Sandy clay loam	minor	slightly
SE49	4c	Deadman	CZc	PLC	1%	1m	Flat	Sandy clay loam	minor	slightly
SE50	4c	Moriarty	CZc	PLC	1%	1m	Flat	Sandy clay loam	minor	slightly
SE51	5a	Moriarty	CZc	PLC	1%	1m	Flat	Sandy clay loam	minor	slightly
SE52	5a	Moriarty	CZc	PLC	2%	2m	Flat	Sandy clay loam	moderate	moderately
SE53	5a	Moriarty	CZc	PLH	1%	1m,	Flat	Sandy loam	moderate	moderately
SE54	5a	Moriarty	CZc	PLH	1%	1m	Flat	Sandy clay loam	moderate	moderately
SE55	5a	Moriarty	CZc	PLC	1%	1m	Flat	Sandy clay loam	minor	slightly
SE56	5a	Moriarty	CZc	PLC	2%	2m	Flat	Sandy clay loam	moderate	moderately
SE57	2b	Moriarty	CZc	PLC	2%	2m	Lower slope	Sandy loam	moderate	moderate
SE58	2b	Moriarty	CZc	PLC	3%	3m	Lower slope	Sandy loam	nil	nil
SE59	1b	Lawrance	Ab	HIL	8%	30m	Upper slope	Sandy loam	nil	nil
SE60	5b	Campsite	CZc	PLA	2%	2m	Flat	Sandy clay loam	moderate	moderately
SE61	5b	Campsite	CZc	PLA	1%	1m	Flat	Sandy clay loam	moderate	moderately
SE62	4d	Deadman	CZc	SSH/PLO	0%	0m	Flat	Sandy loam	minor	slightly
SE63	4d	Deadman	CZc	SSH/PLO	0%	0m	Flat	Sandy loam	minor	slightly
SE64	4a	Kirgella	CZc	PLO	0%	0	Flat	Sandy loam	nil	nil
SE65	4a	Kirgella	CZc	PLC	0%	0m	Flat	Sandy loam	minor	slightly
SE66	4a	Moriarty	CZc	PLO	0%	0m	Flat	Sandy loam	nil	nil
SE67	1c	Moriarty	CZc	HIL	6%	25m	Upper slope	Sandy loam	nil	nil
SE68	1c	Moriarty	CZc	HIL	5%	12m	Upper slope	Sandy loam	nil	nil
SE69	1c	Kirgella	CZc	HIL	2%	6m	Mid slope	Sandy loam	nil	nil
SE70	4a	Moriarty	CZc	PLC	2%	2m	Broad drainage plain	Sandy loam	moderate	moderately
SE71	1c	Moriarty	CZc	PLO	2%	2m	Mid slope	Sandy clay loam	nil	nil
SE72	1c	Moriarty	CZc	PTX	20%	25m	Crest	Durey crust	nil	nil

Attachment 5: Inventory site data on dominant flora vegetation cover and condition.

	Upper storey		Mid storey		Lower storey			
Site	US % cover	US Dominant	MS cover	MS Dominant	LS Cover	LS Dominant	Total cover	Veg condition
SE01	20%	acaaye[4]	5%	acabur	0%		20%	2
SE02	10%	eucsalmon	0%		2%	eremac	10%	3
SE03	5%	eucole	10%	acaaye	2%	scvspi	15%	2
SE04	5%	eucole	5%	acabur	0%		10%	3
SE05	10%	eucole	10%	acabur	0%		20%	3
SE06	10%	acainc	15%	acabur	0%		25%	3
SE07	2%	eucole	25%	acainc	5%	dodrig	30%	2
SE08	2%	eucole	15%	acalin	0%		15%	3
SE09	5%	eucole	20%	acainc	0%		20%	2
SE10	2%	caspau	10%	acainc	2%	ptiobo	10%	2
SE11	20%	eucole	40%	acainc	1%	ptiobo	60%	2
SE12	5%	acainc	20%	erefor	0%		25%	2
SE13	2%	caspau	5%	ereold	3%	ptiobo	10%	2
SE14	5%	acainc	15%	erefor	0%		20%	3
SE15	2%	caspau	10%	acainc	3%	ptiobo	15%	3
SE16	10%	acainc	4%	acalin	1%	ptiobo	15%	3
SE17	10%	eucsalmon	20%	acahem	0%		25%	5
SE18	1%	caspau	10%	acahem	0%		10%	6
SE19	2%	eucole	5%	acabur	0%		5%	6
SE20	5%	caspau	10%	snnfil	5%	ptiobo	15%	3
SE21	1%	caspau	20%	dodlob	2%	ptiobo	20%	4
SE22	1%	acainc	5%	acahem	1%	ptiobo	5%	6
SE23	5%	eucsalmon	5%	atrnum	10%	atrves	20%	3
SE24	1%	caspau	15%	eresco	1%	ptiobo	15%	4
SE25	2%	caspau	15%	acasib	1%	ptiobo	15%	2
SE26	2%	eucsalmon	15%	atrnum	10%	atrves	25%	4
SE27	5%	caspau	4%	dodlob	1%	ptiobo	10%	4
SE28	30%	acainc	1%	erefor	0%		30%	3
SE29	4%	euccon	4%	eresco	2%	ptiobo	10%	2
SE30	2%	caspau	10%	acasib	3%	ptiobo	15%	2
SE31	8%	acainc	2%	scvspi	0%		10%	2
SE32	2%	caspau	3%	acabur	15%	maigeo	20%	3
SE33	2%	acainc	5%	maised	0%		7%	5
SE34	1%	acainc	30%	acaqua	0%		30%	2
SE35	2%	acainc	3%	acabur	5%	maised	10%	3
SE36	1%	acainc	15%	acabur	5%	eremet	20%	4

[4] Field codes see following table for taxa

	Upper storey		Mid storey		Lower storey			
Site	US % cover	US Dominant	MS cover	MS Dominant	LS Cover	LS Dominant	Total cover	Veg condition
SE37	1%	eucole	60%	acabur	1%	snnart	60%	4
SE38	3%	caspau	20%	acabur	2%	ptiobo	25%	3
SE39	1%	caspau	25%	acabur	0%		25%	4
SE40	1%	caspau	25%	maised	0%		25%	5
SE41	3%	caspau	5%	eresco	5%	ptiobo	10%	4
SE42	4%	acainc	5%	snnfil	2%	maised	10%	5
SE43	5%	acainc	10%	acabur	1%	ptiobo	15%	5
SE44	1%	acainc	20%	acabur	0%		20%	5
SE45	1%	acainc	10%	snnfil	15%	maised	25%	4
SE46	2%	acainc	6%	acasib	2%	scvspi	10%	2
SE47	2%	eucole	5%	acabur	3%	olemue	10%	4
SE48	4%	acainc	5%	snnfil	2%	maised	10%	4
SE49	1%	acaapt	15%	snnfil	1%	maised	15%	5
SE50	5%	caspau	5%	snnfil	1%	ptiobo	10%	5
SE51	2%	caspau	4%	snnfil	15%	maised	20%	3
SE52	1%	caspau	4%	snnfil	10%	maised	15%	4
SE53	1%	acainc	10%	acabur	2%	maised	10%	5
SE54	1%	caspau	15%	acabur	1%	maised	15%	5
SE55	1%	caspau	4%	acabur	15%	maised	20%	3
SE56	5%	caspau	20%	snnfil	5%	maised	30%	4
SE57	1%	caspau	10%	snnfil	5%	maised	15%	4
SE58	2%	caspau	15%	dodlob	2%	ptiobo	15%	3
SE59	2%	caspau	25%	acaqua	0%		25%	2
SE60	5%	eucsalmon	5%	eresco	10%	maised	20%	3
SE61	2%	eucsalmon	0%		15%	maised	15%	4
SE62	5%	eucole	15%	acabur	5%	spinifex	25%	2
SE63	18%	eucole	12%	acahem	20%	wesrig	50%	2
SE64	4%	eucole	30%	acabur	0%		35%	2
SE65	4%	eucole	10%	acabur	0%		15%	3
SE66	2%	eucole	30%	acabur	3%	scvspi	35%	2
SE67	4%	eucole	1%	eresco	10%	scvspi	15%	3
SE68	20%	eucles	2%	eresco	5%	acaeri	25%	1
SE69	4%	caspau	30%	acacol	5%	scvspi	35%	1
SE70	1%	caspau	40%	dodlob	2%	ptiobo	40%	3
SE71	5%	caspau	2%	dodlob	3%	scvspi	10%	2
SE72	1%	caspau	2%	acajen	2%	sidcal	5%	3

Fieldcode	Taxa
acaapt	*Acacia aptaneura*
acaaye	*Acacia ayersiana*
acaaye	*Acacia ayersiana*
acabur	*Acacia burkittii*
acacol	*Acacia nyssophylla*
acaeri	*Acacia erinacea*
acahem	*Acacia hemiteles*
acainc	*Acacia incurvaneura*
acainc	*Acacia incurvaneura*
acajen	*Acacia ligulata*
acalin	*Acacia ramulosa* var. *linophylla*
acaqua	*Acacia quadrimarginea*
acasib	*Acacia sibirica*
atrnum	*Atriplex nummularia* subsp. *spathulata*
atrves	*Atriplex vesicaria*
caspau	*Casuarina pauper*
dodlob	*Dodonaea lobulata*
dodrig	*Dodonaea rigida*
erefor	*Eremophila forrestii* subsp. *forrestii*
eremac	*Eremophila maculata*
eremet	*Eremophila metallicorum*
ereold	*Eremophila oldfieldii* subsp. *angustifolia*
eresco	*Eremophila scoparia*
euccon	*Eucalyptus concinna*
eucles	*Eucalyptus lesouefii*
eucole	*Eucalyptus oleosa* subsp. *oleosa*
eucsalmon	*Eucalyptus salmonophloia*
maigeo	*Maireana georgei*
maised	*Maireana sedifolia*
maised	*Maireana sedifolia*
olemue	*Olearia muelleri*
ptiobo	*Ptilotus obovatus*
scvspi	*Scaevola spinescens*
scvspi	*Scaevola spinescens*
sidcal	*Sida calyxhymenia*
snnart	*Senna artemisioides* subsp. x *artemisioides*
snnfil	*Senna artemisioides* subsp. *filifolia*
spinifex	*Triodia irritans*
wesrig	*Westringia rigida*

Attachment 6: Location of inventory sites

Site			Zone	Easting	Northing
SE01	UTM	GDA94	51J	439437	6663669
SE02	UTM	GDA94	51J	439895	6662441
SE03	UTM	GDA94	51J	441203	6663268
SE04	UTM	GDA94	51J	439847	6663259
SE05	UTM	GDA94	51J	440379	6663600
SE06	UTM	GDA94	51J	441148	6664178
SE07	UTM	GDA94	51J	440474	6664857
SE08	UTM	GDA94	51J	441383	6665118
SE09	UTM	GDA94	51J	439979	6664741
SE10	UTM	GDA94	51J	439072	6662978
SE11	UTM	GDA94	51J	439349	6664400
SE12	UTM	GDA94	51J	441592	6665331
SE13	UTM	GDA94	51J	441870	6665276
SE14	UTM	GDA94	51J	441973	6664879
SE15	UTM	GDA94	51J	442345	6664079
SE16	UTM	GDA94	51J	442396	6663827
SE17	UTM	GDA94	51J	439324	6666014
SE18	UTM	GDA94	51J	439997	6666014
SE19	UTM	GDA94	51J	440303	6665814
SE20	UTM	GDA94	51J	440763	6665669
SE21	UTM	GDA94	51J	441206	6665957
SE22	UTM	GDA94	51J	439781	6666421
SE23	UTM	GDA94	51J	441383	6666174
SE24	UTM	GDA94	51J	441311	6666433
SE25	UTM	GDA94	51J	441518	6666766
SE26	UTM	GDA94	51J	440951	6666503
SE27	UTM	GDA94	51J	440727	6666945
SE28	UTM	GDA94	51J	440335	6666555
SE29	UTM	GDA94	51J	440838	6667523
SE30	UTM	GDA94	51J	441184	6667793
SE31	UTM	GDA94	51J	439852	6667376
SE32	UTM	GDA94	51J	439875	6668046
SE33	UTM	GDA94	51J	439689	6667781
SE34	UTM	GDA94	51J	440466	6667821
SE35	UTM	GDA94	51J	438025	6669069
SE36	UTM	GDA94	51J	438417	6668982
SE37	UTM	GDA94	51J	438607	6668926
SE38	UTM	GDA94	51J	440221	6670024
SE39	UTM	GDA94	51J	439973	6669890
SE40	UTM	GDA94	51J	439322	6669020
SE41	UTM	GDA94	51J	439061	6668928
SE42	UTM	GDA94	51J	438122	6668327
SE43	UTM	GDA94	51J	438585	6668258
SE44	UTM	GDA94	51J	438125	6667846
SE45	UTM	GDA94	51J	439373	6668271
SE46	UTM	GDA94	51J	440081	6668511
SE47	UTM	GDA94	51J	437857	6667239
SE48	UTM	GDA94	51J	437236	6668045
SE49	UTM	GDA94	51J	436547	6668009

Site			Zone	Easting	Northing
SE50	UTM	GDA94	51J	436454	6667663
SE51	UTM	GDA94	51J	435737	6667504
SE52	UTM	GDA94	51J	435701	6667722
SE53	UTM	GDA94	51J	435584	6666770
SE54	UTM	GDA94	51J	435056	6667408
SE55	UTM	GDA94	51J	435051	6667626
SE56	UTM	GDA94	51J	434747	6667777
SE57	UTM	GDA94	51J	434371	6667489
SE58	UTM	GDA94	51J	434570	6666681
SE59	UTM	GDA94	51J	434206	6666935
SE60	UTM	GDA94	51J	437709	6661531
SE61	UTM	GDA94	51J	438287	6661738
SE62	UTM	GDA94	51J	436884	6663887
SE63	UTM	GDA94	51J	436344	6663481
SE64	UTM	GDA94	51J	436447	6662715
SE65	UTM	GDA94	51J	436552	6662378
SE66	UTM	GDA94	51J	436693	6661952
SE67	UTM	GDA94	51J	436958	6661272
SE68	UTM	GDA94	51J	437001	6661861
SE69	UTM	GDA94	51J	437035	6662469
SE70	UTM	GDA94	51J	437188	6662265
SE71	UTM	GDA94	51J	437176	6661585
SE72	UTM	GDA94	51J	436884	6661238

Attachment 7: Fauna memo report

M.J. & A.R. Bamford
CONSULTING ECOLOGISTS
23 Plover Way,
Kingsley, WA, 6026
ph: 08 9309 3671
em:
bamford.consulting@iinet.net.au
ABN 84 926 103 081

4th February 2019

Saracen Carosue Project
Fauna assessment of proposed exploration drilling program

M. Bamford, B. Shepherd and K. Chuk

Background

Saracen operates the Carosue Gold Mine and is proposing intensive exploration around its existing mine, with a spread of 3m cleared drill-lines at 90m spacing. Environmental Impact Assessment for this proposal is being prepared by Alexander Holm and Assoc. (AHA), and Bamford Consulting Ecoogists (BCE) has been asked to provide information on the fauna component of this assessment.

BCE uses a ‘values and impacts’ assessment process with the following components:

- The identification of fauna values:
  - Assemblage characteristics: uniqueness, completeness and richness;
  - Species of conservation significance;
  - Recognition of ecotypes or vegetation/substrate associations (VSAs) that provide habitat for fauna, particularly those that are rare, unusual and/or support significant fauna;
  - Patterns of biodiversity across the landscape;
  - Ecological processes upon which the fauna depend.
- The review of impacting processes such as:
  - Habitat loss leading to population decline;
  - Habitat loss leading to population fragmentation;
  - Degradation of habitat due to weed invasion leading to population decline;
  - Ongoing mortality from operations;
  - Species interactions including feral and overabundant native species;
  - Hydrological change;
  - Altered fire regimes; and
  - Disturbance (dust, light, noise).

The following memo provides information on the approach to the assessment, the fauna values and reviews impacting processes in relation to these values and the proposed exploration program.

Methods

Desktop Assessment

Sources of information

Information on the fauna assemblage of the survey area was drawn from a wide range of sources. These included state and federal government databases and results of regional studies. Databases accessed were the Atlas of Living Australia (ALA), Department of Biodiversity, Conservation and Attractions (DBCA) NatureMap (incorporating the Western Australian Museum's FaunaBase and the DBCA Threatened and Priority Fauna Database), BirdLife Australia's Atlas Database (BA) and the EPBC Protected Matters Search Tool of the Department of Energy and the Environment (DEE) (Table). Information from the above sources was supplemented with species expected in the area based on general patterns of distribution. Sources of information used for these general patterns were:

Frogs: Tyler *et al.* (2009) and Anstis (2013);

Reptiles: Storr *et al.* (1983, 1990, 1999 and 2002) and Wilson and Swan (2017);

Birds: Johnstone and Storr (1998, 2005) and Barrett *et al.* (2003); and

Mammals: Menkhorst & Knight (2004); Armstrong (2011); Churchill (2008); and Van Dyck and Strahan (2008).

Table 1. Sources of information used for the desktop assessment.

Database	Type of records held on database	Area searched
Atlas of Living Australia.	Records of biodiversity data from multiple sources across Australia.	Point search: 30° 10' 05"S, 122° 22' 20"E plus 40 km buffer. Searched: January 2019.
NatureMap (DBCA)	Records in the WAM and DBCA databases. Includes historical data and records on Threatened and Priority species in WA.	Point search: 30° 10' 05"S, 122° 22' 20"E plus 40 km buffer. Searched: January 2019.
BirdLife Australia Atlas Database (Birdlife Australia)	Records of bird observations in Australia, 1998-2019.	Point search: 30° 10' 05"S, 122° 22' 20"E plus 40 km buffer. Searched: January 2019.
EPBC Protected Matters (DEE)	Records on matters of national environmental significance protected under the EPBC Act.	Point search: 30° 10' 05"S, 122° 22' 20"E plus 40 km buffer. Searched: January 2019.

In addition, information on fauna was available from a number of previous studies in the area. These included:

- Alexander Holm and Assoc. (2017). Malleefowl survey of proposed airstrip. Saracen Gold Mines.
- Coffey environments (2010). Level 1 vertebrate fauna survey for the Carosue Dam Project, Saracen Gold.

- Biologic. (2010). Level 1 survey for a proposed pipeline from GGT to Carosue Dam and powerline from Black Swan to Carosue Dam. Tropicana JV and Saracen Gold Mine Pty Ltd.
- Henry-Hall *et al.* (1990). Report on survey of Goongarrie Nature Reserve.
- ABRS (2013). Bush Blitz; Biological survey of Credo Station Reserve WA.

Nomenclature and taxonomy

As per the recommendations of EPA (2004), the nomenclature and taxonomic order presented in this report are based on the Western Australian Museum's (WAM) Checklist of the Fauna of Western Australia 2016. The authorities used for each vertebrate group were: amphibians (Doughty *et al.* 2016a), reptiles (Doughty *et al*. 2016b), birds (Johnstone and Darnell 2016), and mammals (Travouillon 2016). In some cases, more widely-recognised names and naming conventions have been followed, particularly for birds where there are national and international naming conventions in place (e.g. the BirdLife Australia working list of names for Australian Birds). This includes the use of capital letters in English names. English names of species where available are used throughout the text; Latin species names are presented with corresponding English names in tables in the appendices.

Interpretation of species lists

Species lists generated from the review of sources of information are generous as they include records drawn from a large region and possibly from environments not represented in the survey area. Therefore, some species that were returned by one or more of the data searches have been excluded because their ecology, or the environment within the survey area, meant that it is highly unlikely that these species will be present. Such species can include, for example, seabirds that might occur as extremely rare vagrants at a terrestrial, inland site, but for which the project area is of no importance. Similarly, waterbirds were generally excluded even though they could over-fly the site, since the site provides little habitat for them. The only exceptions were species that might use the water treatment wetlands near the village. Species returned from databases but excluded from species lists due to lack of suitable habitat (and some database errors) are not presented.

Species returned from the databases and not excluded on the basis of ecology or environment are therefore considered potentially present or expected to be present in the survey area at least occasionally, whether or not they were recorded during field surveys, and whether or not the survey area is likely to be important for them. This list of expected species is therefore subject to interpretation by assigning each a predicted status in the survey area.

The status categories used are:

Resident: species with a population permanently present in the survey area;

Migrant or regular visitor: species that occur within the project area regularly in at least moderate numbers, such as part of annual cycle;

Irregular Visitor: species that occur within the survey area irregularly such as nomadic and irruptive species. The length of time between visitations could be decades but when the species is present, it uses the project area in at least moderate numbers and for some time;

Vagrant: species that occur within the project area unpredictably, in small numbers and/or for very brief periods. Therefore, the project area is unlikely to be of importance for the species; and

Locally extinct: species that would have been present but has not been recently recorded in the local area and therefore is almost certainly no longer present in the project area.

These status categories make it possible to distinguish between vagrant species, which may be recorded at any time but for which the site is not important in a conservation context, and species which use the site in other ways but for which the site is important at least occasionally. This is particularly useful for birds that may naturally be migratory or nomadic, and for some mammals that can also be mobile or irruptive, and further recognises that even the most detailed field survey can fail to record species which will be present at times, or may have been previously confirmed as present. The status categories are assigned conservatively. For example, a lizard known from the general area is assumed to be a resident unless there is very good evidence that the site will not support it, and even then it may be classed as a vagrant rather than assumed to be absent if the site might support dispersing individuals. It must be stressed that these status categories are predictions only and that often very intensive sampling would be required to confirm a species' status.

Field Investigation and Personnel

The project area was visited between 14th and 17th January 2019 by Drs Mike Bamford (B.Sc. Hons. Ph.D. Biol.) and Barry Shepherd (B.Sc. Hons. Env. Biol., Ph.D. Ecol.). The site visit involved looking around as much of the project area as possible in daylight; tracks and effort of this search are shown in Figure 1. This enabled environmental descriptions to be prepared and some opportunistic observations on fauna to be made. Familiarity with the environment enables interpretation of species lists from databases. Targeted searching was undertaken for two significant species known from the general area: the Malleefowl (searching for nest mounds, foraging signs, tracks and direct observations); and the Brush-tailed Mulgara (searching for burrows, tracks and scats). In general, walks were unstructured and two personnel travelled 20-40m apart, with the track determined by areas of interest and intended to cover as much ground as possible. An exception to this was just north of the accommodation village where systematic transects were walked across a small area to search for Malleefowl mounds. Signs of all species observed, and other notable features of interest were recorded.

On the evening of 14th January, between c.19:30 and 21:10, the surveyors conducted a torch-light search of a rocky breakaway just north of the mine camp for nocturnal fauna. Both surveyors carried head torches and recorded species observed or heard.

Throughout the torch-light survey, bat echolocations and calls were recorded on a hand-held bat detector (Echo Meter Touch 2 Pro (EMT2)(Ser No: E2A00773). The EMT2 was run from a Samsung Galaxy S7 with Echo Meter software version 2.6.5. A Wildlife Acoustics Song Meter 4 BAT Full Spectrum (SM4BAT) was deployed next to three settling ponds that form part of the Mine Camp's sewerage treatment plant on the afternoon of 14th January and retrieved on the morning of 17th January 2019. The settling ponds were located approximately 1 km due south of the Survey Area boundary and 0.75 km south of the Mine Camp. Recordings from the EMT2 and SM4BAT were viewed in Kaleidoscope Viewer v4.5.4 from Wildlife Acoustics. More than 4,000 audio records were obtained over the three nights of sampling indicating very high levels of bat activity. Only a small sample was assessed to provide a preliminary list of bat fauna supporting the Level 1 survey.

Vegetation and Substrate Associations

Vegetation and Substrate Associations (VSAs) in the project area were assessed during the desktop review and as part of the field investigations. Within the project area, all major VSAs were visited to develop an understanding of major fauna habitat types present and to assess the likelihood of conservation significant species being present in the area. VSAs correspond to the Land Units described by AHA.

Survey Limitations

The EPA Guidance Statement 56 (EPA 2004) outlines a number of limitations that may arise during surveying. These survey limitations are discussed in the context of the BCE investigation of the survey area in Table 2.

Table 2. Survey limitations as outlined by EPA.

EPA Limitation	BCE Comment
Level of survey.	Level 1 (desktop study and site inspection). Survey intensity was deemed adequate for the various habitat types viewable from aerial photograph, scale of the project and the amount of data records available in the region. The entire area was not searched for Malleefowl mounds and though the survey results are deemed representative for the Project Area as a whole, only a small percentage of the habitats inside the Project Area boundary was surveyed.
Competency/experience of the consultant(s) carrying out the survey.	The ecologists have had extensive experience in conducting fauna surveys and have conducted several fauna studies in the region (over three decades).
Scope. (What faunal groups were sampled and were some sampling methods not able to be employed because of constraints?)	The survey focussed on vertebrate fauna and fauna values.
Proportion of fauna identified, recorded and/or collected.	All vertebrate fauna observed were identified.
Sources of information e.g. previously available information (whether historic or recent) as distinct from new data.	Abundant information from databases and previous studies.
The proportion of the task achieved and further work which might be needed.	The survey was completed and the report provides fauna values for the project area.
Timing/weather/season/cycle.	Timing is not of great importance for level 1 investigations.

EPA Limitation	BCE Comment
Disturbances (e.g. fire, flood, accidental human intervention etc.) that affected results of survey.	None
Intensity. (In retrospect, was the intensity adequate?)	The survey area is approximately 3135 ha and was traversed by vehicle and on foot and thus was adequately comprehensive to assess fauna and fauna values.
Completeness (e.g. was relevant area fully surveyed).	Site was fully surveyed to the level appropriate for a level 1 assessment. Fauna database searches covered a 10 to 20 km radius beyond the survey area boundary.
Resources (e.g. degree of expertise available in animal identification to taxon level).	Field personnel have extensive experience with fauna and habitat in the region.
Remoteness and/or access problems.	There were no remoteness/access problems encountered.
Availability of contextual (e.g. bio-geographic) information on the region.	Extensive regional information was available and was consulted.

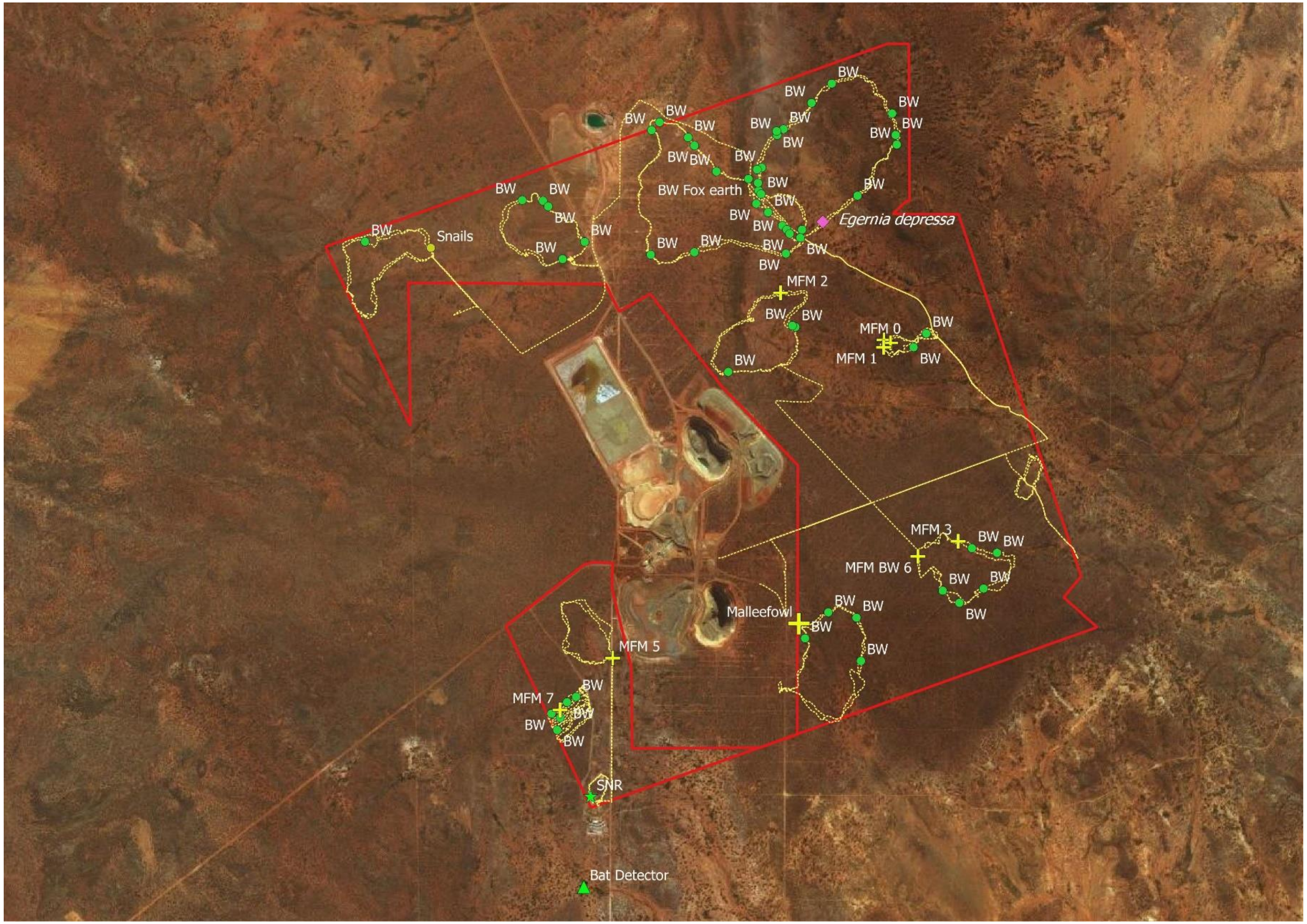


Figure 1. Areas of the project area visited by vehicle and on foot, indicating tracks taken. Locations of fauna observations are indicated: BW = Boodie warrens, MFW = Malleefowl mound.

Fauna assemblage

The vertebrate fauna assemblage potentially includes 285 species, with a further six species considered locally extinct (Table 3). A complete list of all species appears in Appendix 1, indicating those of conservation significance and assigning each species a status category in the area. Appendix 1 includes a list of jewel beetles known from the general area but no other information on invertebrates is available. Appendix 2 provides notes on fauna observations made during the January 2019 site inspection.

- Assemblage characteristics. A rich assemblage which reflects the fairly complex environment ranging from low rocky hills to shrublands on gravelly loams and open woodland on clayey-loams. Broadly typical of the eastern goldfields with some southern elements present. The extinct species are those that have disappeared from vast areas of Australia, due largely to predation by feral species. The Boodie was clearly abundant in the region (see Figure 1).
- Species of conservation significance. Numbers of conservation significant species are summarised in Table 4. The 11 invertebrates are all jewel beetles that have special protection, primarily to prevent over-collection by entomologists. The remaining significant species include one reptile, 19 birds and two mammals. The single reptile is a Priority 2 skink that may occur under leaf-litter around trees and mallee. The majority (9) of the birds are waterbirds that are either vagrants or irregular visitors, and would not utilise the actual project area due to the lack of wetlands. Most other significant birds are expected only as vagrants but three species may use the site regularly: Malleefowl (CS1), Peregrine Falcon (CS1) and Rainbow Bee-eater (CS3). These are discussed below. Only two significant mammals are expected, with the Central Long-eared Bat (CS2) potentially roosting in large trees in the area, and the Brush-tailed Mulgara (CS2) probably being locally extinct or possibly being a vagrant, as much of the project area lacked suitable habitat (sandy soil with spinifex), and there was no evidence of the species.
- Vegetation and Substrate Associations (VSAs). These provide habitat for fauna and are represented by the land units described by AHA. Notable features of the landscape are low rocky hills in the north-west, north-east and south-east, a broad area of loam-clay soils that are part of a broad drainage system through the centre of the area, and sandy soils in the far west. The drainage system soils support tall eucalypts and the sandy soils support mallee over spinifex. Other areas support a range of shrublands largely dominated by acacia. These have some significance to patterns of biodiversity.
- Patterns of biodiversity across the landscape. Massive sample efforts are required to determine patterns of biodiversity, but some can be surmised from the landscape and VSAs. The sandy soils supporting spinifex and mallee in the south-west are likely to be rich in reptiles as the soils allow for burrowing and the spinifex provides abundant cover. Such areas are also likely to be rich in shrubland-dependent birds and some small mammals. During the site inspection, it was noted that the transition between eucalypt woodland and acacia shrublands appeared to be rich in birds; south of the current operations this is where species such as the Red-capped Robin, White-eared and Brown-headed Honeyeaters and White-browed Babblers were observed. It was also where a Malleefowl was seen. Tall shrublands of acacia with little understorey,

found across large areas of loamy-clay soils, are probably less rich in species. The low rocky hills have potential for short range endemic invertebrates and appeared to be floristically rich, so may be seasonally important for nectar-dependent birds and invertebrates.

- Ecological processes upon which the fauna depend. A range of ecological processes can be important for fauna, but a major feature of the project area is surface hydrology/drainage. There is extensive drainage via small ephemeral watercourses from the low rocky hills, as well as broad drainage through the centre of the area. These patterns of drainage affect productivity for both flora and fauna. Introduced species (in particular the European Fox and Feral Cat) have probably led to local extinction of several species, and may be suppressing the populations of some species that are still present. Some of the vegetation, notably mallee over spinifex and shrublands on low rocky hills, are likely to be fire-prone and this can have both negative and positive effects on fauna.

Malleefowl

Several Malleefowl mounds were found (Figure 1) but all were long-inactive. Mounds have been found in previous studies (Coffey Environment 2010, Alexander Holm and Assoc. 2017), and in the airport area just to the west some of these were active or recently active. There was also one sighting of a bird in January 2019. Malleefowl mounds are active from about May to December, even into January depending on rainfall.

The species is clearly resident but from past experience the density of mounds is low. Furthermore, several of the mounds were very small, little more than small pits with a slightly raised edge of excavated soil, and it is unlikely they had ever been used for breeding; possibly they were dug by young males. These tended to be in heavy loamy-clay soils which are not usually the preferred substrate, with sands and gravels generally favoured. The Malleefowl is probably more abundant to the west where there are extensive sandy soils.

Peregrine Falcon

Not observed but a widespread species and considered likely to be a regular visitor if not resident. It could also breed in tall eucalypts in the area, probably by utilising old nests of the Australian Raven.

Rainbow Bee-eater.

This species is only considered of local significance but was formerly listed as Migratory under legislation. It is still considered locally significant as it is a true migrant and breeds in burrows in the area, making it vulnerable to disturbance and predation. It will also often nest along tracks, increasing its vulnerability.

Table 3. Composition of the vertebrate fauna of the project area.

Taxon	Number of species expected	Number of species in each status category				
		Resident	Regular visitor or migrant	Irregular visitor	Vagrant	Locally extinct
frogs	5	4	-	1	-	-
reptiles	74	67	5	1	1	-
birds	165	64	43	36	22	-
mammals	41	28	3	2	2	6
Total	**285** **(including 9 int.)**	**163**	**51**	**40**	**25**	**6**

Table 4. Numbers of species of conservation significance in each major taxon (excluding locally extinct species).

Taxon	Conservation Significant (CS) fauna		
	CS1	CS2	CS3
Invertebrates	11	-	-
Frogs	-	-	-
Reptiles	-	1	-
Birds	15	3	1
Mammals	-	2	-

CS1 = listed under legislation
CS2 = listed as priority by DBCA
CS3 = locally significant

Impacts

Impacts are a result of the interaction of the proposed development and the fauna values, and can be interpreted from the nature of both. For example, the assessment of fauna values identifies minor drainage lines, Malleefowl mounds and large trees as notable features for biodiversity. Impacting processes are discussed below.

- Habitat loss leading to population decline. Habitat loss from clearing 3m wide drill-lines at 90m intervals will affect about 3% of the landscape, and there will inevitably be some mortality during this clearing. Note that the habitat loss will be temporary except where lines are maintained as access tracks, and therefore populations should recover from this loss eventually. The effect of habitat loss can be reduced by avoiding sensitive environmental features (such as Malleefowl mounds; see recommendations below).
- Habitat loss leading to population fragmentation. This is unlikely to be a concern with the proposal as the clearing is in narrow lines through otherwise more or less continuous vegetation.

- Degradation of habitat due to weed invasion leading to population decline. The native vegetation in the area appears to have very low levels of weed invasion currently. There are standard procedures for minimising the risk of introducing weeds (discussed in recommendations below).
- Ongoing mortality from operations. Main sources of ongoing mortality will be from vehicle strike and entrapment in drilling sumps. There are standard procedures for minimising these risks (discussed in recommendations below).
- Species interactions including feral and overabundant native species. Feral predators are already present and affecting the fauna assemblage, but the creation of multiple tracks will improve their access into areas where currently tracks are few. The presence of personnel in these areas can also lead to an increase in activity of feral species. Recommendations to limit these affects are discussed below.
- Hydrological change. There may be some disruption of surface flow especially on the lower slopes of hills. Wastewater from drilling is usually contained in lined sumps so should have no impact.
- Altered fire regimes. Drilling activities and the presence of personnel will increase the risk of unplanned bushfire.
- Disturbance (dust, light, noise). Some level of disturbance during drilling is inevitable but temporary. If drilling occurs at night, lighting may be a source of mortality for insects. While only a temporary effect there are means by which this sort of mortality can be reduced. It is not known if the specially protected jewel beetles known from the general area are actually present, or how they might be affected by light.

Recommendations

Impacts outlined above clearly indicate a range of recommendations to ensure that adverse effects are minimised.

- Habitat loss leading to population decline.
    - Malleefowl mounds are of importance for the birds, whether or not they are active or recently-used, while active mounds (containing eggs) are of special value. Even very old mounds have been found to be re-used, possibly after an interval of several decades (M. Bamford pers. obs; Mt Jackson area). Therefore, no mounds should be damaged or otherwise disturbed if this is possible. If this is not possible, then it should be ensured that mounds are not active or disturbance should be delayed until breeding is complete. This requires a mound survey along all areas to be cleared, but given the apparent low density of mounds it is suggested that this could be carried out by exploration personnel with guidance from an experienced zoologist. For example, exploration personnel could be shown known mounds and could take photographs of suspected mounds for confirmation and interpretation by a zoologist. The protocol for searching for mounds needs to be discussed with government agencies, but in similar projects searching involves walking the alignment and ensuring that mounds can be avoided, while in areas of dense vegetation with poor visibility, searching needs to extend 50m from the centreline. This is to avoid clearing activity within c. 50m of an active mound.

  This sort of detailed searching involves a small team of 3-4 people, but would only be needed in areas most likely to have mounds such as in the sandy soils in the west, and amongst the low rocky hills, particularly of the north-west and north-east.
  - Large trees may support nesting by the Peregrine Falcon (and other birds) but it is assumed that clearing for exploration lines will go around trees wherever possible. Clearing should also avoid, if possible, mallee and tall shrubs with extensive beds of leaf-litter as these are important for some fauna.
  - In general, the clearing footprint should be minimised and vegetation retained where possible. Even tall shrubs and small trees can harbour colonies of lizards and bats that can survive if the vegetation is pushed over slowly and is not roughly wind-rowed. Clearing from mid winter to mid spring runs the risk of destroying nests of small birds. While this may be unavoidable, retaining shrubs will reduce the risk. Consideration could be given to having a 'spotter' present during clearing, especially in areas of dense vegetation.
  - To encourage regeneration, drill-lines should be ripped. Large branches and logs can be moved back over the drill-line, but there is a risk of killing fauna that may have colonised pushed-over vegetation.
- <u>Degradation of habitat due to weed invasion leading to population decline</u>. There are standard equipment hygiene practices to minimise the risk of introducing weeds, and these should be practiced.
- <u>Ongoing mortality from operations</u>.
  - Vehicle strike. There are existing speed limits and signage where Malleefowl have been seen near roads. These need to be installed on access roads to the exploration area if birds are seen or suspected.
  - Entrapment in drilling sumps. It is standard practice to create a ramp in drilling sumps, but plastic linings (required to prevent drill wastewater from soaking into the ground) can render such ramps more or less useless. Rope ladders, heavy rope mesh and even branches can be placed into sumps to assist egress by small animals. Drilling sumps should be filled as soon as they are no longer required. Capping drill-holes is standard practice but should be reiterated in inductions.
- <u>Species interactions including feral and overabundant native species</u>. Personnel should be encouraged not to feed feral fauna and to report Foxes and Cats. Rapid rehabilitation of drill-lines will reduce their attractiveness to these feral species.
- <u>Hydrological change</u>. Where drill lines cross minor drainage lines, soil should not cause damming of the drainage line, and should not form an alternative route for water flow.
- <u>Altered fire regimes</u>. Personnel should be educated on the need to avoid bushfire. Spinifex areas in particular can readily be set alight so special care may be needed.
- <u>Disturbance</u> (dust, light, noise). Dust and noise should be suppressed where possible. Lighting should not be left on overnight unless needed.

References

ABRS (2013). Credo Station Reserve WA, 2011. A Bush Blitz survey report. Australian Biological Resources Study: Canberra. Accessed online at: http://bushblitz.org.au/credo-station-reserve-wa-2011/

Alexander Holm and Assoc. (2017). Malleefowl survey of proposed airstrip. Saracen Gold Mines Pty Ltd.

Anstis, M. (2013). Tadpoles and Frogs of Australia. New Holland Publishers, Sydney.

Armstrong, K.N. (2011). The current status of bats in Western Australia. In Law *et al*. (2011). *The Biology and Conservation of Australiasian Bats.* Royal Zoological Society of NSW, Mosman, NSW, Australia.

Barrett, G., Silcocks, A., Barry, S., Cunningham, R. and Poulter, R. (2003). *The New Atlas of Australian Birds*. Royal Australasian Ornithologists Union, Hawthorn East, Victoria.

Biologic. (2010). Level 1 survey for a proposed pipeline from GGT to Carosue Dam and powerline from Black Swan to Carosue Dam. Tropicana JV and Saracen Gold Mine Pty Ltd.

Churchill, S. (2008) *Australian Bats.* 2nd Edition. Jacana Books, Allen & Unwin. Crows Nest NSW.

Coffey environments (2010). Level 1 vertebrate fauna survey for the Carosue Dam Project, Saracen Gold.

Henry-Hall, N.J., Hopper, S.D., McKenzie, N.L. and Keighery, G.J. (1990). Report on survey of Goongarrie Nature Reserve.

Johnstone, R. E. and Storr, G. M. (1998). *Handbook of Western Australian birds. Volume 1: Non-passerines (Emu to Dollarbird)*. Western Australian Museum, Perth, Western Australia.

Johnstone, R. E. and Storr, G. M. (2005). *Handbook of Western Australian birds. Volume 2: Passerines (Blue-winged Pitta to Goldfinch)*. Western Australian Museum, Perth, Western Australia.

Menkhorst, P. and Knight, F. (2011). *A Field Guide to the Mammals of Australia*. Oxford University Press, Melbourne, Victoria.

Storr, G. M., Smith, L. A. and Johnstone, R. E. (1983). *Lizards of Western Australia. II. Dragons and Monitors*. Western Australian Museum, Perth, Western Australia.

Storr, G. M., Smith, L. A. and Johnstone, R. E. (1990). *Lizards of Western Australia. III. Geckos and Pygopods*. Western Australian Museum, Perth, Western Australia.

Storr, G. M., Smith, L. A. and Johnstone, R. E. (1999). *Lizards of Western Australia. I. Skinks*. Western Australian Museum, Perth, Western Australia.

Storr, G. M., Smith, L. A. and Johnstone, R. E. (2002). *Snakes of Western Australia*. Western Australian Museum, Perth, Western Australia.

Tyler, M. J. and Doughty, P. (2009). *Field Guide to Frogs of Western Australia*. Western Australian Museum, Welshpool, Western Australia.

Van Dyck, S. and Strahan, R. (Eds.) (2008). *Mammals of Australia.*3rd Edition. Australian Museum, Sydney.

Wilson, S. and Swan, G. (2017). *A Complete Guide to Reptiles of Australia*. Fifth Ed. New Holland, Australia.

Appendix 1. Vertebrate fauna assemblage of the project area, based upon database and literature searches and the January 2019 site inspection. Sources of information are:

- ALA = Atlas of Living Australia, searched January 2019;
- N = Naturemap Database, searched January 2019;
- EPBC = EPBC Protected Matters, searched January 2019;
- BA = Birdlife Australia's Birdata database, searched January 2019;
- GNP 1990 = fauna survey of Goongarrie nature reserve (Henry-Hall *et al.* 1990);
- BB 2011 = fauna survey of Credo Station (ABRS 2013).
- BCE 2018 = species observed in the project area in January 2019;

Conservation significance (CS) codes:

- CS1, CS2, CS3 = (summary) levels of conservation significance. See Appendix 4 for full explanation.
- EPBC Act listings: Cr = Critically Endangered, E = Endangered, V = Vulnerable, Mig = Migratory (see Appendix 3).
- Biodiversity Conservation Act listings: for all CS1 species S1 to 7 = Schedules 1 to 7 respectively, (see Appendix 3).
- DBCA Priority species: P1 to P4 = Priority 1 to 4 (see Appendix 4).

Expected status as outlined in Methods.

FROGS		**CS**	**ALA**	**N**	**GNP 1990**	**BB 2011**	**BCE 2018**	**Expected status in area**
HYLIDAE								
Water-holding Frog	*Cyclorana platycephala*		X	X				Resident
Desert Tree Frog	*Litoria rubella*							Irregular visitor
LIMNODYNASTIDAE								
Kunapalari Frog	*Neobatrachus kunapalari*		X	X		X		Resident
Shoemaker Frog	*Neobatrachus sutor*		X	X				Resident
MYOBATRACHIDAE								
Western Toadlet	*Pseudophryne occidentalis*					X		Resident

REPTILES		**CS**	**ALA**	**N**	**GNP 1990**	**BB 2011**	**BCE 2018**	**Expected status in area**
AGAMIDAE								
Bicycle Dragon	*Ctenophorus cristatus*		X	X	X	X	X	Resident
Mallee Sand Dragon	*Ctenophorus fordi*		X	X				Resident
Military Dragon	*Ctenophorus isolepis*					X		Resident
Central Netted Dragon	*Ctenophorus nuchalis*							Resident
Western Netted Dragon	*Ctenophorus reticulatus*		X	X	X	X	X	Resident
Lozenge-marked Dragon	*Ctenophorus scutulatus*		X	X	X	X	X	Resident
Mulga Dragon	*Diporiphora amphiboluroides*		X					Resident
Thorny Devil	*Moloch horridus*		X	X				Resident

REPTILES		**CS**	**ALA**	**N**	**GNP 1990**	**BB 2011**	**BCE 2018**	**Expected status in area**
Western Bearded Dragon	*Pogona minor*		X	X	X			Resident
DIPLODACTYLIDAE								
Fat-tailed Gecko	*Diplodactylus conspicillatus*						X	Resident
Goldfields Stone Gecko	*Diplodactylus granariensis*					X		Resident
Western Saddled Ground Gecko	*Diplodactylus pulcher*		X	X	X	X		Resident
Reticulated Velvet Gecko	*Hesperoedura reticulata*					X		Resident
Main's Ground Gecko	*Lucasium maini*				X			Resident
Beaked Gecko	*Rhynchoedura ornata*		X	X	X	X		Resident
Thorn-tailed Gecko	*Strophurus assimilis*							Resident
Jewelled Gecko	*Strophurus elderi*							Resident
Western Ring-tailed Gecko	*Strophurus strophurus*				X			Resident
Western Shield Spiny-tailed Gecko	*Strophurus wellingtonae*					X		Resident
CARPHODACTYLIDAE								
Knob-tailed Gecko	*Nephrurus vertebralis*							Resident
Barking Gecko	*Underwoodisaurus milii*		X	X		X		Resident
GEKKONIDAE								
Purple Arid Dtella	*Gehyra purpurascens*		X	X	X	X		Resident
Variegated Dtella	*Gehyra variegata*		X	X	X	X		Resident
Bynoe's Gecko	*Heteronotia binoei*		X	X	X	X		Resident
PYGOPODIDAE								
Marble-faced Delma	*Delma australis*					X		Resident
Unbanded Delma	*Delma butleri*		X	X				Resident
Burton's Legless Lizard	*Lialis burtonis*		X	X		X		Resident
Western Hooded Scaly-foot	*Pygopus nigriceps*		X					Resident
SCINCIDAE								
	Cryptoblepharus australis		X	X				Resident
Buchanan’s Snake-eyed Skink	*Cryptoblepharus buchananii*					X		Resident
Peron’s Fence Skink	*Cryptoblepharus plagiocephalus*				X			Resident
	Ctenotus atlas		X	X	X			Resident
Leonhardi’s Ctenotus	*Ctenotus leonhardii*		X	X	X	X	X	Resident
	Ctenotus mimetes						X	Resident
Leopard Skink	*Ctenotus pantherinus*							Resident
Barred Wedge-snout Ctenotus	*Ctenotus schomburgkii*		X	X	X	X		Resident
Spotted Ctenotus	*Ctenotus uber*		X	X	X	X		Resident
Wide-striped Ctenotus	*Ctenotus xenopleura*					X		Resident
Slender Blue-tongue	*Cyclodomorphus melanops*		X	X				Resident

REPTILES		CS	ALA	N	GNP 1990	BB 2011	BCE 2018	Expected status in area
Pygmy Spiny-tailed Skink	*Egernia depressa*		X	X		X	X	Resident
Goldfields Crevice Skink	*Egernia formosa*		X	X		X		Resident
South-Western Crevice-Skink	*Egernia napoliensis*		X					Resident
Broad-banded Sand-swimmer	*Eremiascincus richardsonii*					X	X	Resident
	Lerista desertorum							Resident
	Lerista kingi		X	X				Resident
Unpatterned Robust Slider	*Lerista macropisthopus*	P2				X		Resident
Southern Robust Slider	*Lerista picturata*					X		Resident
Timid Slider	*Lerista timida*		X	X		X		Resident
Desert Skink	*Liopholis inornata*		X	X		X	X	Resident
Common Dwarf Skink	*Menetia greyii*		X	X	X	X	X	Resident
Saltbush Morethia Skink	*Morethia adelaidensis*					X	X	Resident
Woodland Dark-flecked Morethia	*Morethia butleri*		X	X	X	X		Resident
Western Blue-tongue	*Tiliqua occipitalis*		X	X		X		Resident
Bobtail	*Tiliqua rugosa*		X	X		X		Resident
VARANIDAE								
Stripe-tailed Monitor	*Varanus caudolineatus*		X	X	X	X		Resident
Perentie	*Varanus giganteus*					X		Resident
Sand Goanna	*Varanus gouldii*		X	X		X	X	Resident
Black-headed Monitor	*Varanus tristis*			X				Resident
TYPHLOPIDAE								
Southern Blind Snake	*Anilios australis*					X		Resident
Dark-spined blind snake	*Anilios bicolor*							Resident
Prong-snouted Blind Snake	*Anilios bituberculatus*					X		Resident
Northern Hook-snouted Blind Snake	*Anilios hamatus*						X	Resident
Beaked Blind Snake	*Anilios waitii*							Resident
ELAPIDAE								
Desert Death Adder	*Acanthophis pyrrhus*		X	X				Resident
Southern Shovel-nosed Snake	*Brachyurophis semifasciata*							Resident
Yellow-faced Whipsnake	*Demansia psammophis*							Resident
Moon Snake	*Furina ornata*					X		Resident
Monk Snake	*Parasuta monachus*		X	X		X		Resident
Mulga Snake	*Pseudechis australis*		X	X		X		Resident
Ringed Brown Snake	*Pseudonaja modesta*		X	X	X			Resident
Gwardar	*Pseudonaja mengdeni*							Resident
Jan's Banded Snake	*Simoselaps bertholdi*		X	X		X	X	Resident
Rosen's Snake	*Suta fasciata*							Resident

BIRDS		**CS**	**ALA**	**N**	**EPBC**	**BA**	**GNP 1990**	**BB 2011**	**BCE 2018**	**Expected status in area**
CASUARIIDAE										
Emu	*Dromaius novaehollandiae*		X	X		X		X	X	Resident
MEGAPODIIDAE										
Malleefowl	*Leipoa ocellata*	V S3	X	X	X			X	X	Resident
OTIDIDAE										
Australian Bustard	*Ardeotis australis*		X					X		Regular visitor
BURHINIDAE										
Bush Stone-curlew	*Burhinus grallarius*									Vagrant
PHASIANIDAE										
Stubble Quail	*Coturnix pectoralis*									Irregular visitor
TURNICIDAE										
Little Button-quail	*Turnix velox*							X		Regular visitor
ANATIDAE										
Grey Teal	*Anas gracilis*		X			X		X	X	Regular visitor
Australasian Shoveler	*Anas rhynchotis*							X		Irregular visitor
Pacific Black Duck	*Anas superciliosa*					X		X		Regular visitor
Hardhead	*Aythya australis*					X		X		Regular visitor
Musk Duck	*Biziura lobata*					X		X		Irregular visitor
Australian Wood Duck	*Chenonetta jubata*		X			X		X		Irregular visitor
Black Swan	*Cygnus atratus*					X		X		Irregular visitor
Pink-eared Duck	*Malacorhynchus membranaceus*			X		X		X	X	Regular visitor
Blue-billed Duck	*Oxyura australis*	P4						X		Irregular visitor
Freckled Duck	*Stictonetta naevosa*							X		Vagrant
Australian Shelduck	*Tadorna tadornoides*		X	X		X				Irregular visitor
PODICIPEDIDAE										
Great Crested Grebe	*Podiceps cristatus*							X		Vagrant
Hoary-headed Grebe	*Poliocephalus poliocephalus*					X		X		Regular visitor
Australasian Grebe	*Tachybaptus novaehollandiae*							X	X	Regular visitor
COLUMBIDAE										
Diamond Dove	*Geopelia cuneata*									Irregular visitor

BIRDS		**CS**	**ALA**	**N**	**EPBC**	**BA**	**GNP 1990**	**BB 2011**	**BCE 2018**	**Expected status in area**
Crested Pigeon	*Ocyphaps lophotes*		X	X		X		X	X	Resident
Common Bronzewing	*Phaps chalcoptera*		X	X		X		X		Resident
CUCULIDAE										
Fan-tailed Cuckoo	*Cacomantis flabelliformi*							X		Irregular visitor
Horsfield's Bronze-Cuckoo	*Chalcites basalis*		X	X		X		X		Regular migrant
Black-eared Cuckoo	*Chalcites osculans*		X	X	X	X		X		Regular migrant
Pallid Cuckoo	*Cuculus pallidus*		X			X		X		Regular migrant
APODIDAE										
Fork-tailed Swift	*Apus pacificus*	M S5			X			X		Regular migrant
RALLIDAE										
Eurasian Coot	*Fulica atra*					X		X	X	Regular visitor
Australian Spotted Crake	*Porzana fluminea*							X		Irregular visitor
Black-tailed Native-hen	*Gallinula ventralis*							X		Irregular visitor
RECURVIROSTRIDAE										
Banded Stilt	*Cladorhynchus leucocephalus*							X		Vagrant
Black-winged Stilt	*Himantopus himantopus*					X		X		Irregular visitor
Red-necked Avocet	*Recurvirostra novaehollandiae*					X		X		Vagrant
CHARADRIIDAE										
Inland Dotterel	*Charadrius australis*									Irregular visitor
Black-fronted Dotterel	*Charadrius melanops*							X		Irregular visitor
Red-capped Plover	*Charadrius ruficapillus*							X		Irregular visitor
Red-kneed Dotterel	*Erythrogonys cinctus*							X		Regular visitor
Hooded Plover	*Thinornis rubricollis*	P4			X					Vagrant
Banded Lapwing	*Vanellus tricolor*			X				X		Regular visitor
SCOLOPACIDAE										
Sharp-tailed Sandpiper	*Calidris acuminata*	M S5			X					Irregular visitor
Curlew Sandpiper	*Calidris ferruginea*	Cr M S1 S5			X					Vagrant
Pectoral Sandpiper	*Calidris melanotos*	M S5			X					Vagrant

BIRDS		**CS**	**ALA**	**N**	**EPBC**	**BA**	**GNP 1990**	**BB 2011**	**BCE 2018**	**Expected status in area**
Red-necked Stint	*Calidris ruficollis*	M S5						X		Irregular visitor
Wood Sandpiper	*Tringa glareola*	M S5								Vagrant
Common Sandpiper	*Tringa hypoleucos*	M S5			X					Irregular visitor
Common Greenshank	*Tringa nebularia*	M S5								Irregular visitor
Marsh Sandpiper	*Tringa stagnatalis*	M S5								Irregular visitor
ARDEIDAE										
White-faced Heron	*Egretta novaehollandiae*					X		X		Irregular visitor
White-necked Heron	*Ardea pacifica*					X		X		Irregular visitor
Eastern Great Egret	*Ardea modesta*				X					Vagrant
Nankeen Night Heron	*Nycticorax caledonicus*									Vagrant
THRESKIORNITHIDAE										
Yellow-billed Spoonbill	*Platalea flavipes*							X		Vagrant
Glossy Ibis	*Plegadis falcinellus*	M S5						X		Vagrant
Australian White Ibis	*Threskiornis molucca*							X		Vagrant
Straw-necked Ibis	*Threskiornis spinicollis*							X		Vagrant
PHALACROCORACIDAE										
Little Pied Cormorant	*Phalacrocorax melanoleucos*					X		X		Irregular visitor
Little Black Cormorant	*Phalacrocorax sulcirostris*									Vagrant
ACCIPITRIDAE										
Collared Sparrowhawk	*Accipiter cirrhocephalus*									Resident
Brown Goshawk	*Accipiter fasciatus*		X			X		X		Regular visitor
Wedge-tailed Eagle	*Aquila audax*		X	X		X		X		Resident
Spotted Harrier	*Circus assimilis*		X					X		Regular visitor
Black-shouldered Kite	*Elanus axillaris*									Regular visitor
Letter-winged Kite	*Elanus scriptus*	P4								Irregular visitor
Whistling Kite	*Haliastur sphenurus*		X			X		X		Regular visitor
Black-breasted Buzzard	*Hamirostra melanosternon*					X				Regular visitor
Little Eagle	*Hieraaetus morphnoides*					X		X		Regular visitor
Square-tailed Kite	*Lophoictinia isura*							X		Irregular visitor

BIRDS		**CS**	**ALA**	**N**	**EPBC**	**BA**	**GNP 1990**	**BB 2011**	**BCE 2018**	**Expected status in area**
Black Kite	*Milvus migrans*									Irregular visitor
FALCONIDAE										
Brown Falcon	*Falco berigora*		X	X		X		X		Regular visitor
Nankeen Kestrel	*Falco cenchroides*		X	X		X		X	X	Regular visitor
Grey Falcon	*Falco hypoleucos*	S3								Vagrant
Australian Hobby	*Falco longipennis*		X			X		X	X	Regular visitor
Peregrine Falcon	*Falco peregrinus*	S7						X		Regular visitor
Black Falcon	*Falco subniger*									Irregular visitor
STRIGIDAE										
Southern Boobook	*Ninox novaeseelandiae*		X			X		X		Resident
TYTONIDAE										
Barn Owl	*Tyto alba*			X				X		Resident
PODARGIDAE										
Tawny Frogmouth	*Podargus strigoides*			X		X		X		Resident
CAPRIMULGIDAE										
Spotted Nightjar	*Eurostopodus argus*			X		X				Regular visitor
AEGOTHELIDAE										
Australian Owlet-nightjar	*Aegotheles cristatus*		X	X		X				Resident
MEROPIDAE										
Rainbow Bee-eater	*Merops ornatus*	CS3	X	X	X	X		X	X	Regular migrant
ALCEDINIDAE										
Red-backed Kingfisher	*Todiramphus pyrrhopygia*		X					X		Resident
Sacred Kingfisher	*Todiramphus sanctus*							X		Regular visitor
CACATUIDAE										
Major Mitchell's Cockatoo	*Cacatua leadbeateri*									Irregular visitor
Little Corella	*Cacatua sanguinea*									Vagrant
Galah	*Eolophus roseicapilla*		X	X		X		X		Regular visitor
Cockatiel	*Nymphicus hollandicus*		X					X		Regular visitor
PSITTACIDAE										
Australian Ringneck	*Barnardius zonarius*		X	X		X		X	X	Resident
Purple-crowned Lorikeet	*Glossopsitta porphyrocephala*		X			X		X		Regular visitor

BIRDS		**CS**	**ALA**	**N**	**EPBC**	**BA**	**GNP 1990**	**BB 2011**	**BCE 2018**	**Expected status in area**
Budgerigar	*Melopsittacus undulatus*							X		Regular visitor
Scarlet-chested Parrot	*Neophema splendida*					X				Irregular visitor
Night Parrot	*Pezoporus occidentalis*	E S1			X					Vagrant
Princess Parrot	*Polytelis alexandrae*	V P4			X					Vagrant
Regent Parrot	*Polytelis anthopeplus*		X					X		Regular visitor
Mulga Parrot	*Psephotus varius*		X	X		X		X	X	Resident
CLIMACTERIDAE										
White-browed Treecreeper	*Climacteris affinis*		X	X				X		Resident
Rufous Treecreeper	*Climacteris rufa*							X		Resident
PTILONORHYNCHIDAE										
Western Bowerbird	*Ptilonorhynchus guttatus*			X		X				Resident
MALURIDAE										
White-winged Fairy-wren	*Malurus leucopterus*		X	X		X	X	X		Resident
Splendid Fairy-wren	*Malurus splendens*		X	X		X	X	X	X	Resident
MELIPHAGIDAE										
Spiny-cheeked Honeyeater	*Acanthagenys rufogularis*		X	X		X		X	X	Resident
Red Wattlebird	*Anthochaera carunculata*		X	X		X		X		Regular visitor
Pied Honeyeater	*Certhionyx variegatus*									Regular visitor
White-fronted Chat	*Epthianura albifrons*		X	X				X		Regular visitor
Orange Chat	*Epthianura aurifrons*		X							Irregular visitor
Crimson Chat	*Epthianura tricolor*		X	X		X		X		Regular visitor
Grey-fronted Honeyeater	*Lichenostomus plumulus*		X							Irregular visitor
Singing Honeyeater	*Lichenostomus virescens*		X			X		X	X	Resident
Brown Honeyeater	*Lichmera indistincta*		X	X		X		X		Resident
Yellow-throated Miner	*Manorina flavigula*		X	X		X		X	X	Resident
Brown-headed Honeyeater	*Melithreptus brevirostris*		X	X		X		X	X	Resident
White-eared Honeyeater	*Nesoptilotis leucotis*		X	X		X		X	X	Resident
White-fronted Honeyeater	*Phylidonyris albifrons*		X	X		X		X		Regular visitor
Yellow-plumed Honeyeater	*Ptilotula ornata*		X			X		X		Regular visitor

BIRDS		**CS**	**ALA**	**N**	**EPBC**	**BA**	**GNP 1990**	**BB 2011**	**BCE 2018**	**Expected status in area**
Black Honeyeater	*Sugomel niger*							X		Irregular visitor
PARDALOTIDAE										
Striated Pardalote	*Pardalotus striatus*		X	X		X		X		Resident
ACANTHIZIDAE										
Inland Thornbill	*Acanthiza apicalis*		X	X		X		X	X	Resident
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*		X	X		X		X	X	Resident
Slender-billed Thornbill	*Acanthiza iredalei*									Vagrant
Slaty-backed Thornbill	*Acanthiza robustirostris*		X	X		X				Resident
Chestnut-rumped Thornbill	*Acanthiza uropygialis*		X	X		X		X	X	Resident
Southern Whiteface	*Aphelocephala leucopsis*		X	X		X		X		Resident
Rufous Fieldwren	*Calamanthus campestris*									Regular visitor
Western Gerygone	*Gerygone fusca*							X		Resident
Redthroat	*Pyrrholaemus brunneus*		X	X		X		X	X	Resident
Weebill	*Smicrornis brevirostris*		X	X		X		X	X	Resident
NEOSITTIDAE										
Varied Sittella	*Daphoenositta chrysoptera*		X			X		X		Resident
POMATOSTOMIDAE										
White-browed Babbler	*Pomatostomus superciliosus*		X	X		X		X	X	Resident
CINCLOSOMATIDAE										
Chestnut Quail-thrush	*Cinclosoma castanotum*		X			X		X		Regular visitor
Copper-backed Quail-thrush	*Cinclosoma casteneothorax*									Irregular visitor
Chiming Wedgebill	*Psophodes occidentalis*									Vagrant
CAMPEPHAGIDAE										
Ground Cuckoo-shrike	*Coracina maxima*		X	X		X		X		Resident
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*		X	X		X		X		Resident
White-winged Triller	*Lalage tricolor*		X	X		X		X		Resident
PACHYCEPHALIDAE										
Grey Shrike-thrush	*Colluricincla harmonica*		X	X		X	X	X	X	Resident
Crested Bellbird	*Oreoica gutturalis*		X	X		X	X	X	X	Resident
Gilbert’s Whistler	*Pachycephala inornata*							X		Irregular visitor

BIRDS		CS	ALA	N	EPBC	BA	GNP 1990	BB 2011	BCE 2018	Expected status in area
Rufous Whistler	*Pachycephala rufiventris*		X	X		X		X	X	Resident
ARTAMIDAE										
Black-faced Woodswallow	*Artamus cinereus*		X	X		X		X	X	Resident
Dusky Woodswallow	*Artamus cyanopterus*		X					X		Resident
Little Woodswallow	*Artamus minor*									Irregular visitor
Masked Woodswallow	*Artamus personatus*		X	X				X	X	Resident
Pied Butcherbird	*Cracticus nigrogularis*		X	X		X		X	X	Resident
Australian Magpie	*Cracticus tibicen*		X	X		X		X	X	Resident
Grey Butcherbird	*Cracticus torquatus*		X	X		X		X	X	Resident
Grey Currawong	*Strepera versicolor*		X	X		X		X	X	Resident
RHIPIDURIDAE										
White-tailed Grey Fantail	*Rhipidura albiscapa albicauda*							X	X	Resident
Willie Wagtail	*Rhipidura leucophrys*		X	X		X		X	X	Resident
CORVIDAE										
Little Crow	*Corvus bennetti*		X	X		X		X	X	Resident
Australian Raven	*Corvus coronoides*		X	X		X		X	X	Resident
Torresian Crow	*Corvus orru*		X	X						Resident
MONARCHIDAE										
Magpie-lark	*Grallina cyanoleuca*		X	X		X		X	X	Resident
PETROICIDAE										
Southern Scrub-robin	*Drymodes brunneopygia*		X			X		X		Resident
Hooded Robin	*Melanodryas cucullata*		X			X		X		Resident
Jacky Winter	*Microeca leucophaea*		X	X		X	X	X		Resident
Red-capped Robin	*Petroica goodenovii*		X	X		X		X	X	Resident
NECTARINIIDAE										
Mistletoebird	*Dicaeum hirundinaceum*		X	X		X		X	X	Regular visitor
ESTRILDIDAE										
Zebra Finch	*Taeniopygia guttata*		X	X		X		X		Resident
MOTACILLIDAE										
Australasian Pipit	*Anthus australis*		X	X		X		X	X	Resident
LOCUSTELLIDAE										

BIRDS		**CS**	**ALA**	**N**	**EPBC**	**BA**	**GNP 1990**	**BB 2011**	**BCE 2018**	**Expected status in area**
Brown Songlark	*Cinclorhamphus cruralis*		X					X		Resident
Rufous Songlark	*Cinclorhamphus mathewsi*							X		Resident
HIRUNDINIDAE										
White-backed Swallow	*Cheramoeca leucosternum*		X			X		X	X	Resident
Welcome Swallow	*Hirundo neoxena*		X	X		X		X	X	Resident
Fairy Martin	*Petrochelidon ariel*									Irregular visitor
Tree Martin	*Petrochelidon nigricans*		X	X		X		X		Resident

MAMMALS		**CS**	**ALA**	**N**	**EPBC**	**GNP 1990**	**BB 2011**	**BCE 2018**	**Expected status in area**
TACHYGLOSSIDAE									
Echidna	*Tachyglossus aculeatus*			X			X	X	Resident
DASYURIDAE									
Kultarr	*Antechinomys laniger*								Resident
Brush-tailed Mulgara	*Dasycercus blythi*	P4							Vagrant
Chuditch	*Dasyurus geoffroii*	V S3			X				Locally extinct
Wongai Ningaui	*Ningaui ridei*		X	X					Resident
Southern Ningaui	*Ningaui yvonneae*						X		Resident
Woolley's Pseudantechinus	*Pseudantechinus woolleyae*						X		Resident
Fat-tailed Dunnart	*Sminthopsis crassicaudata*		X	X			X		Resident
Little Long-tailed Dunnart	*Sminthopsis dolichura*		X	X			X		Resident
Hairy-footed Dunnart	*Sminthopsis hirtipes*								Resident
Ooldea Dunnart	*Sminthopsis ooldea*						X		Resident
THYLACOMYIDAE									
Greater Bilby	*Macrotis lagotis*	V S3							Locally extinct
BURRAMYIDAE									
Western Pygmy Possum	*Cercartetus concinnus*						X		Resident
POTOROIDAE									
Boodie	*Bettongia lesueur*	Ex S4						*	Locally extinct
PERAMELIDAE									

MAMMALS		**CS**	**ALA**	**N**	**EPBC**	**GNP 1990**	**BB 2011**	**BCE 2018**	**Expected status in area**
Pig-footed Bandicoot	*Chaeropus ecaudatus*	Ex S4							Extinct
Golden Bandicoot	*Isoodon auratus*	V S3							Locally extinct
Western Barred Bandicoot	*Perameles bougainville*	E S3	X						Locally extinct
MACROPODIDAE									
Rufous Hare-Wallaby	*Lagorchestes hirsutus*	Ex S4							Locally extinct
Western Grey Kangaroo	*Macropus fuliginosus*		X	X		X	X		Resident
Euro, Biggada	*Macropus robustus*			X			X	X	Resident
Red Kangaroo, Marlu	*Macropus rufus*		X	X		X	X		Resident
MOLOSSIDAE									
White-striped Freetail-Bat	*Austronomus australis*						X	X	Resident
Southern Freetail-Bat	*Mormopterus planiceps*						X		Resident
VESPERTILIONIDAE									
Gould's Wattled Bat	*Chalinolobus gouldii*						X	X	Resident
Lesser Long-eared Bat	*Nyctophilus geoffroyi*						X		Resident
Central Long-eared Bat	*Nyctophilus major tor*	P3							Resident
Inland Broad-nosed Bat	*Scotorepens balstoni*								Resident
Inland Forest Bat	*Vespadelus baverstocki*								Regular visitor
Southern Forest Bat	*Vespadelus regulus*								Irregular visitor
MURIDAE									
Stick-nest Rat	Leporillus sp	Ex S4						*	Extinct
Spinifex Hopping-Mouse	*Notomys alexis*								Irregular visitor
Mitchell's Hopping-Mouse	*Notomys mitchellii*						X	X	Resident
Bolam's Mouse	*Pseudomys bolami*		X	X			X		Resident
Sandy Inland Mouse	*Pseudomys hermannsburgensis*		X	X					Resident
INTRODUCED MAMMALS									
European Cattle	Bos taurus	Int.		X				X	Regular visitor
Camel	*Camelus dromedarius*	Int.			X		X	X	Regular visitor

MAMMALS		**CS**	**ALA**	**N**	**EPBC**	**GNP 1990**	**BB 2011**	**BCE 2018**	**Expected status in area**
Dog, Dingo	*Canis lupus*	Int.	X		X		X	X	Resident
Goat	*Capra hircus*	Int.		X	X		X	X	Resident
Horse	*Equus caballus*	Int.			X				Vagrant
Cat	*Felis catus*	Int.		X	X		X	X	Resident
House Mouse	*Mus musculus*	Int.	X	X	X		X		Resident
Rabbit	*Oryctolagus cuniculus*	Int.		X	X		X	X	Resident
Red Fox	*Vulpes vulpes*	Int.			X		X	X	Resident

CS INVERTEBRATES		CS	BB 2011
BUPRESTIDAE			
jewel beetle	*Castiarina acuticeps*	SP	X
jewel beetle	*Castiarina aeraticollis*	SP	X
jewel beetle	*Castiarina bakeri*	SP	X
jewel beetle	*Castiarina pallidiventris*	SP	X
jewel beetle	*Castiarina recta*	SP	X
jewel beetle	*Castiarina rufolimbata*	SP	X
jewel beetle	*Castiarina subacuticeps*	SP	X
jewel beetle	*Chalcophorotaenia martinii*	SP	X
jewel beetle	*Diadoxus regius*	SP	X
jewel beetle	*Pseudotaenia gigas*	SP	X
jewel beetle	*Temognatha pascoei*	SP	X

SP = special protection under the WA Biodiversity Conservation Act.

Appendix 2. Annotated species list from site inspection, 16-17 January 2019.

1. *Diplodactylus conspicillatus*. One dead in drill pit in north.
2. *Strophurus* sp.. Several dead in drill pit in north. Very spiny tail with spines apparently not in clear lines.
3. *Lucasium* sp.. One dead in drill pit in north.
4. *Ctenophorus scutulatus*. Seen regularly in mixed shrubland on loam and gravelly loam flats.
5. *Ctenophorus reticulatus.* One seen in south-east.
6. *Ctenophorus cristatus*. One seen in woodland in east.
7. *Varanus gouldii*. Young animal (year 2?) on track in east, and a slightly larger animal seen in south-east. Also one record in north-east.
8. *Ctenotus mimetes*. One seen in north-west.
9. *Ctenotus leonhardi.* Hatchling seen in south.
10. *Eremiascincus richardsonii*. Adult and neonate at base of dead tree; seen head-torching at breakaway near camp. Also one dead animal in pit in south of area.
11. *Liopholis inornata*. Burrow systems probably this species throughout. Several dead specimens in drill-pits.
12. *Menetia greyii*. Several seen active.
13. *Morethia ?adelaidensis*. One seen in shrubland in north-west. Appeared strongly-marked but could be *M. obscura.*
14. *Anilios hamatus*. One removed from pit near drilling site in south.
15. *Simoselaps bertholdi*. Two in pit in south; one dead and one rescued.

1. Emu. Dropping near camp wastewater treatment ponds. Droppings also found around Sandalwood in north-west. Fresh tracks across soft ground in south. Old nest (scattered eggshell) in south-west.
2. Malleefowl. Reported near camp and three fairly old mounds found in east. All are quite small (3, 3.5m and 1.5-2m across) with clear central crater but no plant material in crater. One had possible scratch marks from Malleefowl in clay and raised soil still a bit loose, so maybe only 5-10 years since last used. The very small one also looked like it had been excavated within the last few years and uncertain if it had ever been filled with vegetation. Perhaps an experimental mound started by a young animal? One flushed from eucalypts and scrub in south at about 51J 439316E, 6663325N.
3. Australasian Grebe. Four adults and a juvenile on treatment ponds.
4. Grey Teal. Flock of 45 on treatment ponds.
5. Pink-eared Duck. One on treatment ponds.
6. Eurasian Coot. One on treatment ponds (17/01; had not been present on 14/01).
7. Australian Hobby. One seen in north.
8. Nankeen Kestrel. One over east.
9. Crested Pigeon. One in camp.
10. Australian Ringneck. Several around camp regularly and occasionally in woodlands.
11. Mulga Parrot. Pair in north-west and pair in north-east.
12. Rainbow Bee-eater. Seen occasionally; group of about five in east might be a pre-migratory gathering. Similar group seen in south.
13. Splendid Fairy-wren. Parties throughout and coloured males present.
14. Redthroat. Calling from thickets and few seen throughout.
15. Inland Thornbill. Few parties throughout.
16. Chestnut-rumped Thornbill. Few parties throughout.

17. Yellow-rumped Thornbill. Party in north-east.
18. Weebill. Common among eucalypts.
19. Singing Honeyeater. Small numbers throughout.
20. Yellow-throated Miner. Parties throughout.
21. Spiny-cheeked Honeyeater. Seen and heard throughout.
22. White-eared Honeyeater. Several seen and heard in tall eucalypts in south.
23. Brown-headed Honeyeater. Party in tall shrubs and eucalypts in south.
24. Mistletoebird. Several seen and heard in south.
25. Red-capped Robin. At least two pairs in south.
26. Rufous Whistler. Occasional birds seen and heard throughout.
27. Grey Shrike-thrush. Calling in dense thickets and one sheltering from heat in small cave.
28. Crested Bellbird. Calling throughout.
29. Quail-thrush. Species not determined. Heard in north-west area.
30. White-browed Babbler. Parties throughout.
31. Willie Wagtail. One in north-west and one in south.
32. White-tailed Fantail. One in south and one in north-east. Pale tail very prominent.
33. White-backed Swallow. Seen occasionally.
34. Welcome Swallow. Several over south.
35. Magpie-lark. One in camp.
36. Masked Woodswallow. Group of five over east and similar group seen in north-east; included juveniles.
37. Black-faced Woodswalllow. Several on powerlines near offices.
38. Australian Raven. Small numbers throughout.
39. Little Crow. Two in north-west area and also small group in north-east.
40. Grey Currawong. Several in south-west area and one seen in north-west area. Juvenile seen in south-west.
41. Pied Butcherbird. Adults and a juvenile in south-west. Juvenile also seen in north.
42. Grey Butcherbird. Several seen and heard in south.
43. Australian Magpie. Single bird seen in north.
44. Australian Pipit. Few along roads.

1. Echidna. Diggings throughout and scats in small caves in breakaway.
2. Boodie. Old warrens widespread (56 recorded) especially in areas where calcrete present. Extinct on the mainland (except for translocated populations).
3. Stick-nest Rat. Old nests in breakaway overhangs. Coordinates for a large nest in good condition: 51J 436877E, 6661282N. Uncertain if *Leporillus conditor* or *L. apicalis*. Both extinct on the mainland; *L. conditor* survives on one island and some translocated populations.
4. Euro. Scats in breakaways.
5. White-striped Bat *Austronomus australis*. Detected near camp and almost constant activity over settling ponds late into evenings.
6. Gould's Wattled Bat *Chalinolobus gouldii*. Detected near camp and almost constant activity over settling ponds late into evenings.
7. Chocolate Wattled Bat *Chalinolobus morio*. Occasional records at settling ponds in morning.
8. Southern Forest Bat *Vespadelus regulus.* Almost constant activity through all nights over settling ponds. Active until 04:43.

9. Inland Freetail Bat *Ozimops planiceps*. Occasional records from settling ponds in early morning.
10. Long-eared Bat *Nyctophilus* sp. Probable; could not be identified to species.
11. Mitchell's Hopping-Mouse *Notomys ?mitchelli*. Burrows in old Boodie warrens.
12. Rabbit. Scats and diggings throughout.
13. Goat. Scats in breakaway caves.
14. Cow. Old scats and tracks seen at several locations.
15. Camel. Old scats in north-west.
16. Red Fox. Scats fund at a few locations.
17. Feral Cat. Tracks at one location in south.
18. Dingo. Fresh tracks in north.

Appendix 3. Locations and descriptions of fauna records.

Eastings	Northings	Date_Time	Notes
436804	6660228	17/01/19	Bat detector
439104	6669114	17/01/2019 8:06	Boodie warren
439029	6669044	17/01/2019 8:08	Boodie warren
438849	6668661	17/01/2019 8:19	Boodie warren
438815	6668391	17/01/2019 8:27	Boodie warren
438844	6668352	17/01/2019 8:28	Boodie warren
439328	6667937	17/01/2019 8:46	Boodie warren
439140	6667656	17/01/2019 9:15	Boodie warren
437549	6667634	17/01/2019 10:00	Boodie warren
437644	6669186	17/01/2019 11:15	Boodie warren
437981	6669010	17/01/2019 11:22	Boodie warren
438056	6668915	17/01/2019 11:25	Boodie warren
438317	6668613	17/01/2019 11:32	Boodie warren
438694	6668529	17/01/2019 11:40	Boodie warren and Fox earth
439309	6667842	17/01/2019 12:07	Boodie warren
439979	6668338	17/01/2019 6:40	Boodie warren
440424	6669052	17/01/2019 7:13	Boodie warren
439096	6667982	17/01/2019 11:59	Boodie warren
436411	6662253	16/01/2019 15:49	Boodie warren
439390	6663152	16/01/2019 8:07	Boodie warren
441348	6664218	16/01/2019 10:03	Boodie warren
441644	6664165	16/01/2019 10:11	Boodie warren
441204	6663577	16/01/2019 10:48	Boodie warren
441007	6663719	16/01/2019 10:56	Boodie warren
436700	6662452	16/01/2019 15:36	Boodie warren
436594	6662388	16/01/2019 15:39	Boodie warren
434185	6667767	15/01/2019 7:56	Boodie warren
436511	6667576	15/01/2019 9:09	Boodie warren
439256	6666797	15/01/2019 17:12	Boodie warren
436032	6668264	15/01/2019 9:51	Boodie warren
436276	6668258	15/01/2019 10:08	Boodie warren
436339	6668192	15/01/2019 10:11	Boodie warren
436770	6667779	15/01/2019 10:32	Boodie warren
440649	6666567	15/01/2019 12:19	Boodie warren
440798	6666729	15/01/2019 12:24	Boodie warren
438469	6666267	15/01/2019 15:59	Boodie warren
439220	6666812	15/01/2019 17:11	Boodie warren
440049	6662891	16/01/2019 7:01	Boodie warren
439994	6663397	16/01/2019 7:19	Boodie warren
439662	6663458	16/01/2019 7:28	Boodie warren
441488	6663746	16/01/2019 10:36	Boodie warren
436514	6662206	16/01/2019 15:55	Boodie warren
436480	6662062	16/01/2019 16:27	Boodie warren

Eastings	Northings	Date_Time	Notes
440438	6668940	17/01/2019 7:10	Boodie warren
440382	6669304	17/01/2019 7:19	Boodie warren
438928	6668138	17/01/2019 11:55	Boodie warren
439149	6667936	17/01/2019 12:00	Boodie warren
439184	6667889	17/01/2019 12:02	Boodie warren
439668	6669650	17/01/2019 7:43	Boodie warren
439432	6669422	17/01/2019 7:54	Boodie warren
439022	6669090	17/01/2019 8:07	Boodie warren
438795	6668639	17/01/2019 8:18	Boodie warren
438806	6668482	17/01/2019 8:22	Boodie warren
438062	6667666	17/01/2019 9:43	Boodie warren
437551	6669093	17/01/2019 11:12	Boodie warren
438788	6668239	17/01/2019 11:51	Boodie warren
439571	6668030	17/01/2019 6:22	*Egernia depressa* colony
440300	6666651	14/01/2019 11:59	Malleefowl mound
437128	6662908	14/01/2019 11:29	Malleefowl mound
439316	6663325	16/01/2019 7:46	Malleefowl
440713	6664119	16/01/2019 11:15	Malleefowl mound and Boodie warren
436512	6662297	16/01/2019 15:43	Malleefowl mound
440377	6666617	15/01/2019 11:50	Malleefowl mound
440296	6666565	15/01/2019 11:57	Malleefowl mound
439080	6667196	15/01/2019 16:47	Malleefowl mound
441185	6664298	16/01/2019 9:55	Malleefowl Mound
436877	6661282	14/01/2019 14:49	old Stick-nest Rat nest in cave
434960	6667699	15/01/2019 8:30	Land snails

Appendix 4. Categories used for the assessment of conservation significance.
IUCN categories (based on review by Mace and Stuart 1994) as used for the Environment Protection and Biodiversity Conservation Act 1999 and the Western Australian Biodiversity Conservation Act 2018.

Extinct	Taxa not definitely located in the wild during the past 50 years.
Extinct in the Wild (Ex)	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 (E)	Taxa facing a very high risk of extinction in the wild in the near future.
Vulnerable (V)	Taxa facing a high risk of extinction in the wild in the medium-term future.
Near Threatened	Taxa that risk becoming Vulnerable in the wild.
Conservation Dependent	Taxa whose survival depends upon ongoing conservation measures. Without these measures, a conservation dependent taxon would be classed as Vulnerable or more severely threatened.
Data Deficient (Insufficiently Known)	Taxa suspected of being Rare, Vulnerable or Endangered, but whose true status cannot be determined without more information.
Least Concern.	Taxa that are not Threatened.

Schedules used in the WA Biodiversity Conservation Act 2018

Schedule 1 (S1)	Critically Endangered fauna.
Schedule 2 (S2)	Endangered fauna
Schedule 3 (S3)	Vulnerable Migratory species listed under international treaties.
Schedule 4 (S4)	Presumed extinct fauna
Schedule 5 (S5)	Migratory birds under international agreement
Schedule 6 (S6)	Conservation dependant fauna
Schedule 7 (S7)	Other specially protected fauna

WA Department of Biodiversity, Conservation and Attractions Priority species (species not listed under the Biodiversity Conservation Act 2018, but for which there is some concern).

Priority 1 (P1)	Taxa with few, poorly known populations on threatened lands.
Priority 2 (P2)	Taxa with few, poorly known populations on conservation lands; or taxa with several, poorly known populations not on conservation lands.
Priority 3 (P3)	Taxa with several, poorly known populations, some on conservation lands.
Priority 4. (P4)	Taxa in need of monitoring. Taxa which are considered to have been adequately surveyed, or for which sufficient knowledge is available, and which are considered not currently threatened or in need of special protection, but could be if present circumstances change.

Appendix D: Solar Farm Malleefowl Assessment

Malleefowl Activity and Habitat Assessment Within Proposed Expansion of Carosue Dam Solar Farm

Northern Star Resources Limited

Alexander Holm & Associates

Natural Resource Management Services

December 12, 2023

Table of Contents

List of Figures

List of Tables

Summary

Alexander Holm & Associates was contracted by Northern Star Resources Ltd (Northern Star) in November 2023 to undertake a targeted survey of Malleefowl activity and habitat within a 28ha potential impact area (IA) for development of a third solar farm adjacent to the existing Carosue Dam Operations' Solar Farm. Malleefowl activity was also assessed within a 200m buffer around the IA creating an assessment envelope (AE) of 68ha.

Malleefowl are active in the AE, utilising the southern areas for foraging, with minor excursions elsewhere.

While the tall acacia shrublands which dominate the AE have been rated in adjoining areas as critical habitat for breeding and survival, an underlying shallow basement geology and proximity to active mining operations renders the AE suitable habitat for foraging but not critical habitat for breeding and survival.

1 Introduction

Northern Star operates the Carosue Dam Gold Mine (Carosue Dam Operations), located 110km north-east of Kalgoorlie.

To reduce carbon emissions by 35% by 2030 and progress towards net zero emissions by 2050, Northern Star is planning implementation of a series of renewable energy projects.

There are currently two solar farms at Carosue Dam Operations and a third Solar Farm is being planned. A site next to the existing solar farm near Karari pit is being considered for the solar farm expansion.

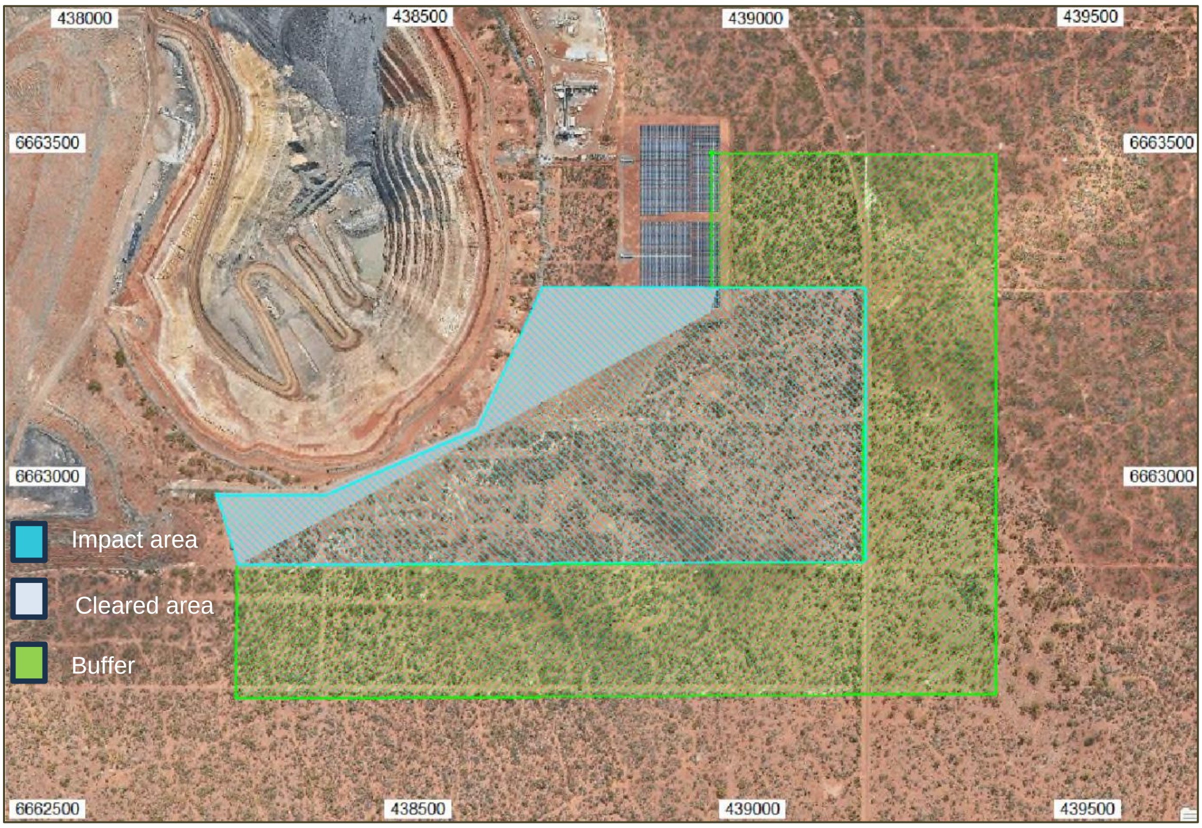


Figure 1: Solar farm assessment envelope in relation to Karari Pit and existing solar farm.

2 Scope of Works

To support planning and approvals, Alexander Holm & Associates were contracted by Northern Star in November 2023 to undertake a survey of Malleefowl activity within the assessment envelope (AE) and to relate these findings to habitat suitability for Malleefowl within the IA. The Malleefowl activity requires foot traverse at nominal 20m spacings to locate and record nesting mounds, visible Malleefowl tracks or any other evidence of recent Malleefowl activity. The habitat assessment is to define areas within a 28ha potential impact area (IA) as either a) critical for breeding and survival, b) suitable for foraging and dispersal or c) unsuitable Malleefowl habitat. A memo report is required to present results.

3 Background

3.1 Conservation Status

Malleefowl is a Threatened fauna species listed as Vulnerable under the State Biodiversity Conservation Act 2016 and Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) whereby approval may be required for a proposed activity that significantly adversely affects their wellbeing.

3.2 Nesting Mound Characterisation

The nesting mound categories used in this report are:

- **Active**: any Malleefowl mound nest that is currently being used as an incubator for eggs and is likely to contain eggs
- **Inactive recent**: Potentially used within the last 5 years. Mound well-formed, litter often still present, no evidence of inner crusting or growth of annual herbs or grasses.
- **Inactive abandoned**: Likely unused for more than 5-10 years and possibly abandoned. Mound somewhat degraded, often crusted, annual herbs or grasses may be present.
- **Long unused**: Evidence of an extended period of inactivity such as shrubs or trees growing from hollow or mound very degraded/poorly formed. Highly unlikely to become active in the future.
- **Failed:** Evidence of an attempt to prepare a nesting mound resulting in a small, abandoned hole with no evidence of subsequent use.

3.3 Vegetation and Habitat

'Plains supporting acacia shrublands' is the dominant habitat type within the AE and described in Alexander Holm & Associates (2019) as very gently inclined to level plains with sandy loam to sandy clay loam soils supporting open tall acacia shrublands dominated by *Acacia incurvaneura. A. ayersiana, A. burkittii, A. hemiteles, A.tetragonophylla* and very sparse lower shrubs including *Dodonaea lobulata*, *Senna artemisioides* subsp. *filifolia*, and *Ptilotus obovatus* with overstoreys of isolated *Casuarina pauper* or *Eucalyptus oleosa* subsp. *oleosa.*

The AE also includes a small area of near level plain with light clay soil supporting a sparse woodland dominated by *Eucalyptus salmonophloia* with patchy *Acacia hemiteles* understorey.

Plains supporting acacia shrublands have been classified as critical habitat for Malleefowl breeding and survival (Alexander Holm & Associates 2022), while *E. salmonophloia* woodlands are classified unsuitable habitat (Alexander Holm & Associates 2023).

4 Assessment Methodology

4.1 Assessment Personnel

The November 2023 survey was conducted and managed on site by Alexander Holm assisted by Philip Smyth.

Dr Holm is an ecologist with over 35 years-experience in arid environments and Goldfield regions and an accredited environmental consultant with the Environmental Consultants Association of Western Australia.

Mr Philip Smyth has over 30 years-experience with the Western Australian Lands and Surveys Department specialising in characterising and mapping of vegetation and land resources. He assisted in previous malleefowl surveys for Northern Star.

This memo report was prepared by Dr Alexander Holm (Alexander Holm & Associates).

4.2 Timing of Survey

The Malleefowl survey was conducted on November 5, 2023, during the breeding season of Malleefowl in accordance with the National Malleefowl Monitoring Manual (2020) and is therefore considered suitable timing to determine mound status.

4.3 Targeted Malleefowl Survey

The 28ha site proposed for the solar farm expansion included cleared land, most of which was not traversed, and the AE was expanded to include a 200m buffer of mostly undisturbed surrounding vegetation bringing the searched area to 62ha (Figure 1).

Personnel surveyed the AE along gridlines 20m apart using GPS devices to maintain position (Figure 2). A total of 39km was traversed. It is estimated that the search procedures were sufficient to locate 100% of newly established nesting mounds.

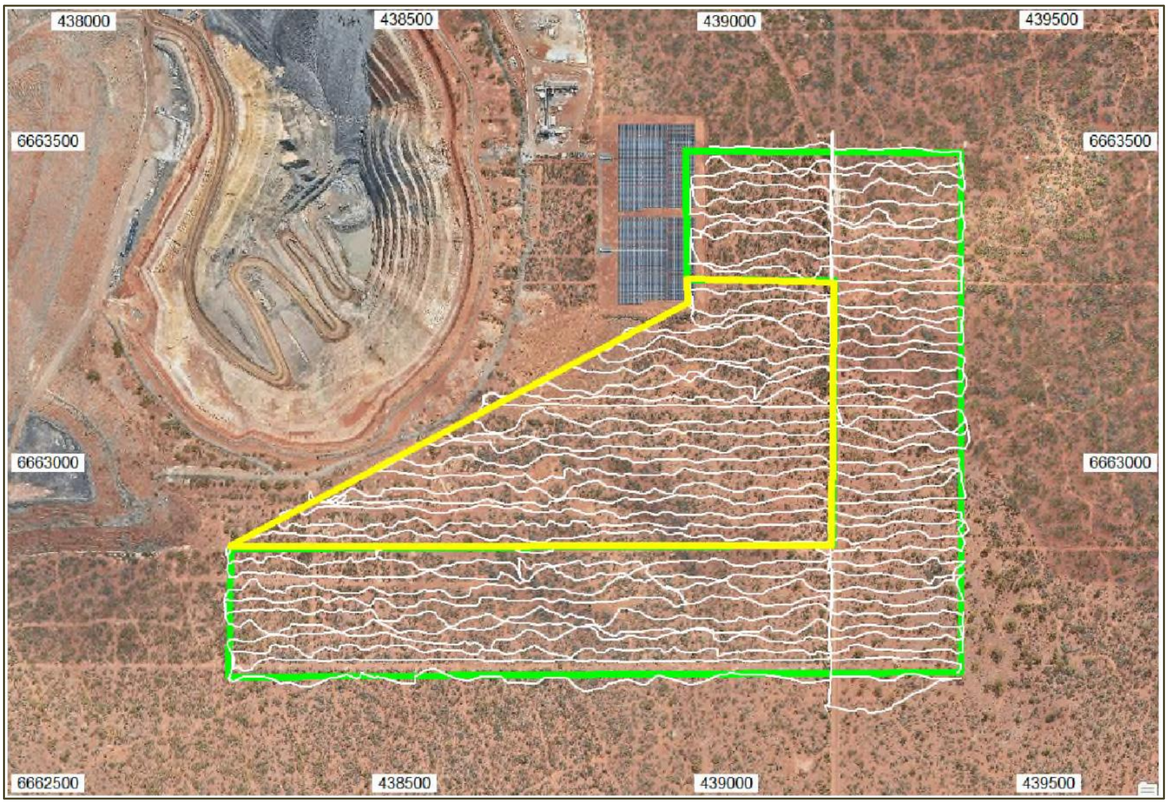


Figure 2: Assessment envelope with 200m buffer in green and foot traverse in November 2023.

Other evidence of Malleefowl activity, disturbance of litter, tracks and sightings, was noted if present and GPS-located during traverse.

4.4 Habitat assessment

Critical Malleefowl breeding habitat within the 28ha IA, proposed for expansion of the solar farm, was assessed by reference to 1) land unit (habitat) mapping of the AE from Alexander Holm & Associates (2019) and 2) breeding habitat described in the Malleefowl Recovery Plan (Alexander Holm & Associates 2022), and by 3) a survey-informed update of the set of environmental variables, as informed by the National Malleefowl Recovery Plan (Benshemesh 2007), which consisted of an analysis of site suitability, site context and Malleefowl activity.

5 Results

5.1 Malleefowl Activity Survey

Malleefowl are active in parts of the AE as evidenced by tracks and litter disturbance.

Malleefowl foraging activity was particularly evident by their tracks and litter disturbance in the southwest, with only limited excursions elsewhere (Figure 3).

No nesting mounds were found. One failed attempt was found in the buffer zone where an excavation encountered the shallow weathered bedrock. A Long Unused nesting mound (MFM039) is located a few meters south of the AE buffer.

5.2 Habitat Assessment

Approximately 6.3ha within the 28ha is 95-100% cleared land and is classed as unsuitable Malleefowl habitat.

The remaining 21.7ha is ‘Plains supporting acacia shrublands’ previously classified as critical habitat for Malleefowl breeding and survival (Alexander Holm & Associates 2022). In comparison to the Holm 2022 ratings for Plains supporting acacia shrublands the IA rated poorly for depth to intractable soil layer and less favourably for Malleefowl activity as no nesting mounds were present. Otherwise, the ratings for other criteria were similar (Table 1).

It is unlikely that habitat within the IA represents breeding habitat critical for survival of the species if the soil depth is unsuitable for nest construction as evidenced by the failure to build critical nesting mounds nesting mounds for breeding due to shallow expression of the underlying geology. Accordingly, the remaining 21.7ha is rated as suitable habitat for foraging and dispersal.

Table 1: Habitat rating comparison between the IA and previous assessment of acacia shrublands habitat.

Criteria	IA rating*	Holm 2022 rating
Site suitability		
Depth to intractable soil layer	-	+
Litter abundance	+	+
Canopy cover	0	0
Favourable vegetation	+	+
Vegetation condition	0	0
Site context		
Constraints to movement	+	+
Malleefowl activity	0	+
Overall rating	**Foraging habitat**	**Critical breeding habitat**

* +/- positive or negative rating for criteria.
0 neutral rating for criteria

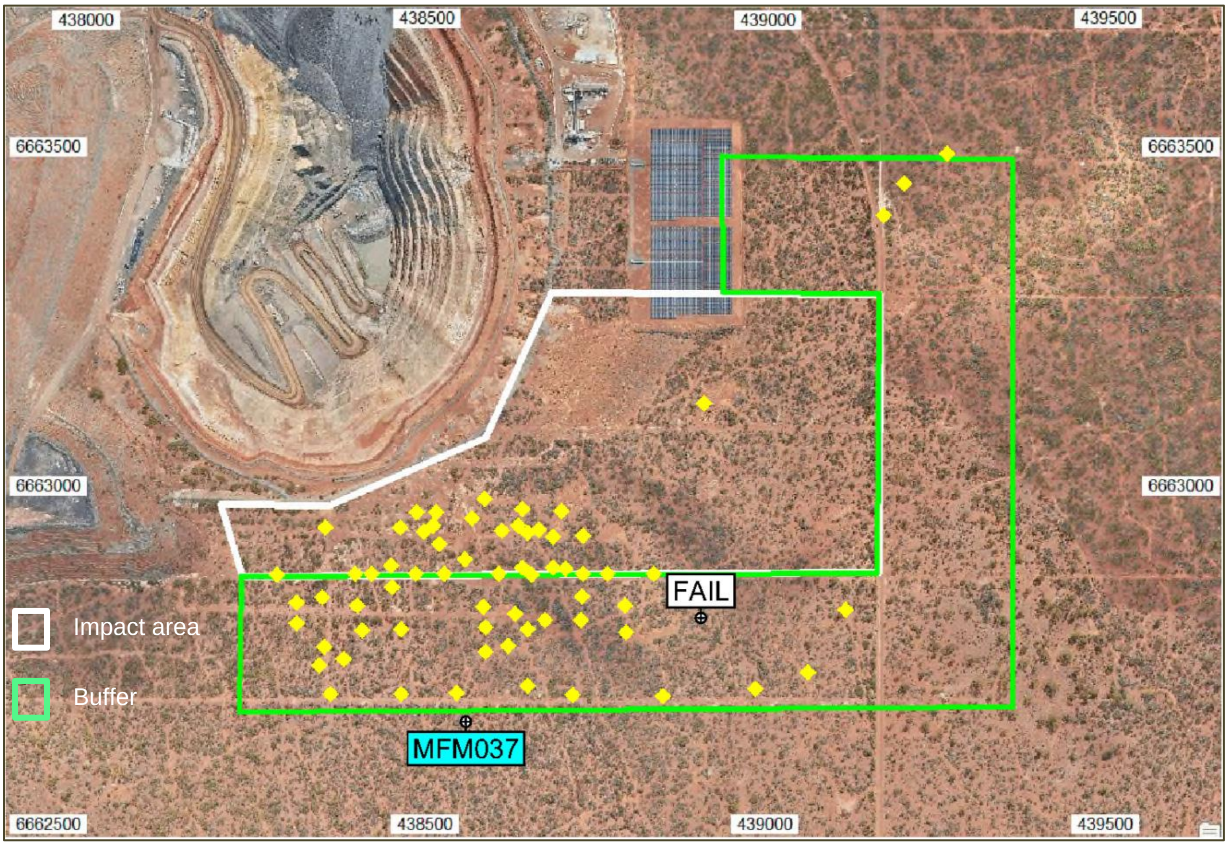


Figure 3: Malleefowl activity showing tracks (yellow) failed nesting attempt and long unused mound (MFM037).

6 Discussion

Malleefowl are actively foraging in the AE and IA, particularly in the southwest, with only minor exploratory excursions elsewhere. There was one attempt to create a nesting mound in the buffer area which failed due to contact with the underlying shallow decomposed basement.

Vegetation over most of the 28ha IA is tall acacia shrublands which was habitat described in the Malleefowl Recovery Plan as critical habitat for Malleefowl breeding and survival (Alexander Holm & Associates 2022).

Approximately 6.7ha of the IA has been cleared and is considered unsuitable habitat for Malleefowl.

Malleefowl have failed to establish critical nesting mounds for breeding within the remaining 21.7ha of the IA due to shallow basement geology and, possibly, proximity to mining operations. It can be concluded that the balance of the IA provides habitat for foraging but is not critical habitat for breeding and survival of the species.

7 References

Alexander Holm & Associates (2019). Environmental assessment: Proposed Seismic Survey pp 136.

Alexander Holm & Associates (2022). Assessment of impacts on Malleefowl of proposed expansion of Carosue Dam Tailings Storage Facility pp 36.

Alexander Holm & Associates (2023). Assessment of malleefowl activity and habitat for the Fimiston South Project. Kalgoorlie Consolidated Gold Mines Pty Ltd pp. 40.

Benshemesh, J. (2007). National Recovery Plan for Malleefowl.: pp 121.

Disclaimer

Within the limitation imposed by the scope of review, the data assessment and preparation of the report have been undertaken in a professional manner and in accordance with generally accepted practices using a degree of care ordinarily exercised by professional environmental consultants. No other warranty, expressed or implied, is made.

Appendix E: Soil and Landform Assessment

CAROSUE DAM OPERATIONS
QENA PROJECT
SOIL AND LANDFORM ASSESSMENT

PREPARED FOR:

NORTHERN STAR RESOURCES LIMITED

FEBRUARY 2024

PREPARED BY:

Martinick Bosch Sell Pty Ltd
4 Cook Street
West Perth WA 6005
Ph: (08) 9226 3166
Email: info@mbsenvironmental.com.au
Web: www.mbsenvironmental.com.au

CAROSUE DAM OPERATIONS - QENA PROJECT
SOIL AND LANDFORM ASSESSMENT

Distribution List:

Company	Contact name	Copies	Date
Northern Star Resources Limited	Cliff Bennison - Senior Environmental Advisor	1	8 February 2024
Northern Star Resources Limited	Dane Vincent - Environmental Advisor	1	8 February 2024

Document Control for Job Number: NSRQMSL

Document Status	Prepared By	Authorised By	Date
Draft Report	Louise Crawley/ Patrick James	David Allen	13 December 2023
Final Report	Elliott Duncan	David Allen	8 February 2024

TABLE OF CONTENTS

TABLES

FIGURES

PLATES

APPENDICES

1. INTRODUCTION

1.1 BACKGROUND

Northern Star Resources (Northern Star) operate the Carosue Dam operations located within the South Laverton gold field, situated 120 km northeast of Kalgoorlie, Western Australia (Figure 1). Carosue Dam operations includes numerous operations spread across three Environmental Group Sites (EGS), including: Porphyry, Carosue Dam and Safarir Bore and Deep South (Mt Celia).

Northern Star intend to develop the existing Qena gold Project adjacent to the Luvironza gold mine, situated in the Carosue Dam Operations EGS. The proposed development will include:

- The expansion of the current open pit mine and development of underground mine.
- Waste rock dump for approximately 51 Mm^3 of waste rock.
- Paste plant - potentially utilising tailings currently stored in the Luvironza pit.
- Run of Mine (ROM) pad.
- Associated infrastructure such as power supply, workshops, laydown areas and office buildings.

In order to gain approvals for the Qena Project, MBS Environmental (MBS) was engaged by Northern Star to undertake a soil and landform assessment across the proposed development and disturbance areas. Soil and landform studies are typically conducted in order to understand soils from a structural and physiochemical basis to assist in mine development, approvals and closure planning. It is beneficial if the presence of soil with adverse characteristics is identified in the early stages of the Project (i.e. acidic, saline, dispersive, phytotoxic, and contaminated soils), as appropriate soil resources are important in Project planning (construction/engineering purposes), rehabilitation, and ultimately, Project closure. These assessments are typically conducted to align with the criteria set out in the DMIRS (2020) guidelines for mining proposals.

1.2 SCOPE OF WORK

The scope of work performed by MBS included:

- Liaising with the Northern Star environmental team to ensure the latest proposed site layout plan for the Project was used to identify locations for proposed areas of disturbance including open pit voids, waste rock dumps, haul roads, material stockpiles, access roads and other supporting infrastructure.
- Completing a desktop assessment/sampling and analysis plan (SAP) which outlined the common soil types within the region, preliminary sampling locations and methodologies required to profile soils and subsoils and collect representative samples for analysis.
- Conducting a two-day site visit by an experienced MBS Environmental Scientist and involving soil profiling and sampling from pre-excavated test pits through the area.
- Liaising with the relevant NATA (National Association of Testing Authorities) accredited laboratory to select appropriate chemical analyses for soils and subsoils. This included preparing all relevant chain of custody documentation.
- Compiling all laboratory results, including:
  - An assessment of key physical (moisture, particle sizing, Emerson Class) and chemical (pH, salinity, cation exchange capacity, plant available nutrients and metals) characteristics of surface soils and subsoils.
  - Identification of soil types suitable for rehabilitation of mine waste landforms and other disturbed areas at mine closure.

- Estimation (high-level calculation) of the volume of surface soils that may reasonably be harvested and stockpiled prior to mining in areas of disturbance for mine closure planning (materials balance).

- Preparing a Soils and Landform Assessment Report (this report) which includes:
  - Descriptions of the natural landforms and soil types at the Project focusing on the proposed expansion areas.
  - Collation of analytical data.
  - An assessment of key physical and chemical characteristics of surface soils and subsoils from field notes and laboratory results.
  - Identification of soil types suitable for rehabilitation of mine waste landforms and other disturbed areas at mine closure.
  - An indication of the volume of surface soils that may reasonably be harvested and stockpiled prior to mining in areas of disturbance for mine closure planning.

Scale: 1:1500000 Original Size: A4 Image: Copernicus Sentinel Data 2020 Grid: GDA94 / MGA zone 51 0 25 50 km	Northern Star Resources Ltd Carosue Dam	**Figure 1** **Project Location**	Martinick Bosch Sell Pty Ltd 4 Cook St West Perth WA 6005 Australia t: +61 8 9226 3166 info@mbsenvironmental.com.au www.mbsenvironmental.com.au MBS ENVIRONMENTAL

W:\Northern Star\Carosue Dam\GIS Common\Northern Star Carosue Dam_Location Plan.qgz 06/02/2024

2. PROJECT DESCRIPTION

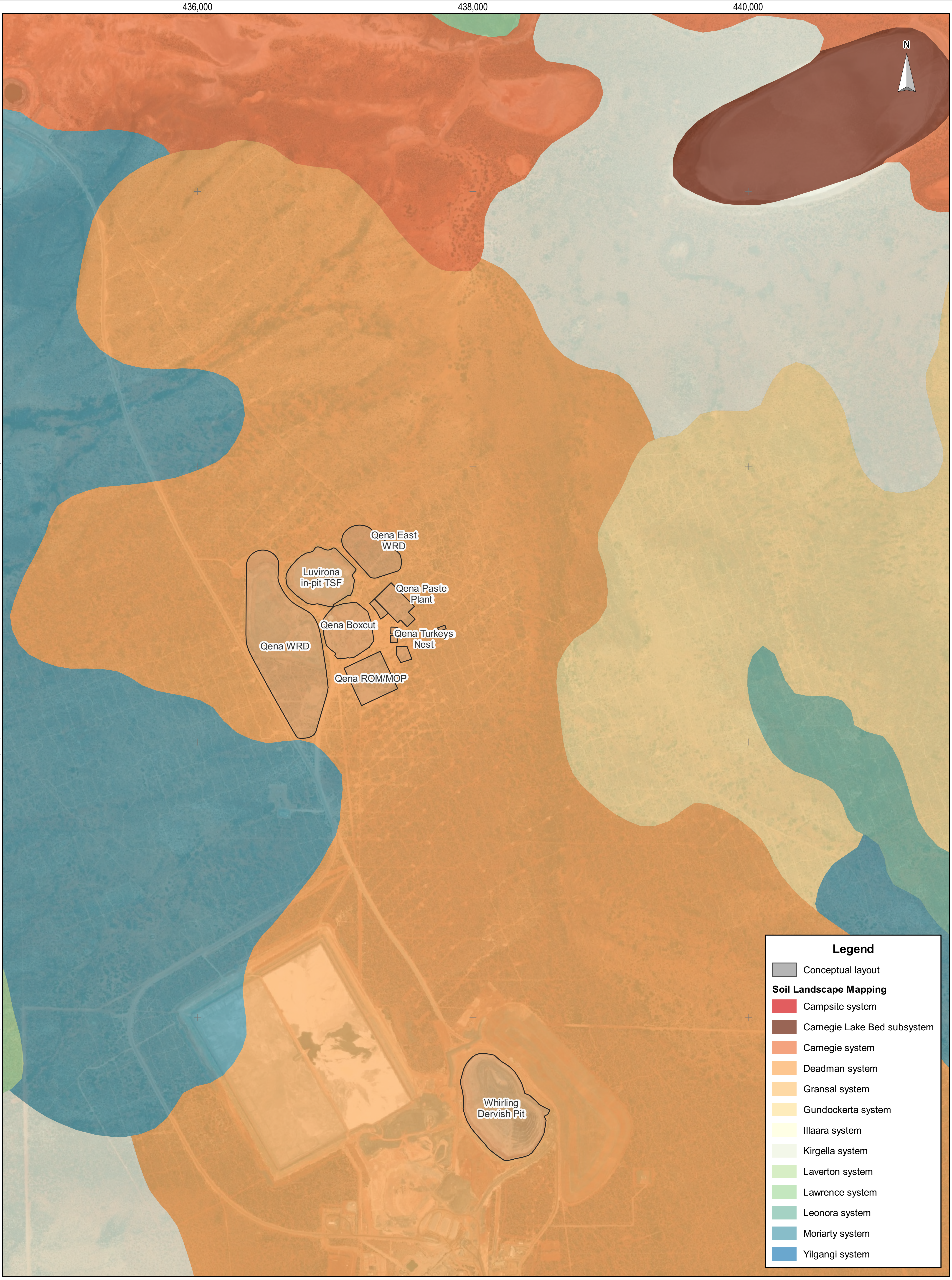
The Qena Project principally comprises development of an underground mine with access to mine via a portal in the in a pit or boxcut that will be developed adjacent to the existing Luvironza in-pit tailings facility. Supporting infrastructure will be installed in surrounding areas (Figure 2). Existing infrastructure such as the Luvironza pit will be retained. It is anticipated an additional lift will be constructed on the existing Luvironza waste rock landform.

The Qena deposit comprises three main lithologies — monzonite (granite), intermediate volcaniclastic sandstone/tuff and intermediate volcaniclastic conglomerate. Very minor portions of an intrusive dyke will also be encountered.

Mining the open pit option for Qena would result in mining approximately 50,767,901 t of waste rock. However, it is anticipated a much smaller boxcut option will be mined, which would produce about 3,768,661 t of waste rock. Ore extracted from the Project will be processed at the Carosue Dam Operations mill.

The Qena Project is expected to require the following infrastructure (Figure 2):

- Development of a pit or boxcut (approximately 12 ha).
- Expansion of the Luvironza in pit tailings storage facility - approximately 16 ha.
- Expansion of the Qena waste rock landform - approximately 49 ha.
- Construction of an additional waste rock landform - approximately 11 ha.
- Run of mine pad - approximately 9 ha.
- Supporting infrastructure - approximately 7.1 ha.



Scale: 1: 25,000
Original Size: A3
Grid: GDA94 / MGA zone 51 (EPSG:28351)
0 0.5 1 km

Northern Star Resources Ltd
Carosue Dam

Figure 2

Conceptual Layout of Disturbance Area and Land Systems

Martinick Bosch Sell Pty Ltd
4 Cook St
West Perth WA 6005
Australia
t: +61 8 9226 3166
info@mbsenvironmental.com.au
www.mbsenvironmental.com.au

MBS ENVIRONMENTAL

W:\Northern Star\Carosue Dam\Studies\Qena Soil 2023\GIS Common\NS Qena Common Map.qgz 06/02/2024 Fig_2_Layout_LS

3. PROJECT ENVIRONMENT

3.1 CLIMATE

The Goldfields-Esperance Region experiences an arid climatic regime, which experiences generally low and intermittent rainfall with hot summers. The closest Bureau of Meteorology (BoM) weather station to the Project is Leonora (012046) which recorded long-term rainfall averaging 236.4 mm with approximately 80% of the annual rainfall experienced between the months January and June (Chart 1).

Diurnal maximum temperatures frequently exceed 30°C between December and March. Average January maximum and minimum temperatures are 37°C and 21.8°C, respectively. The July average range is 18.4°C to 6.1°C (BoM 2023).

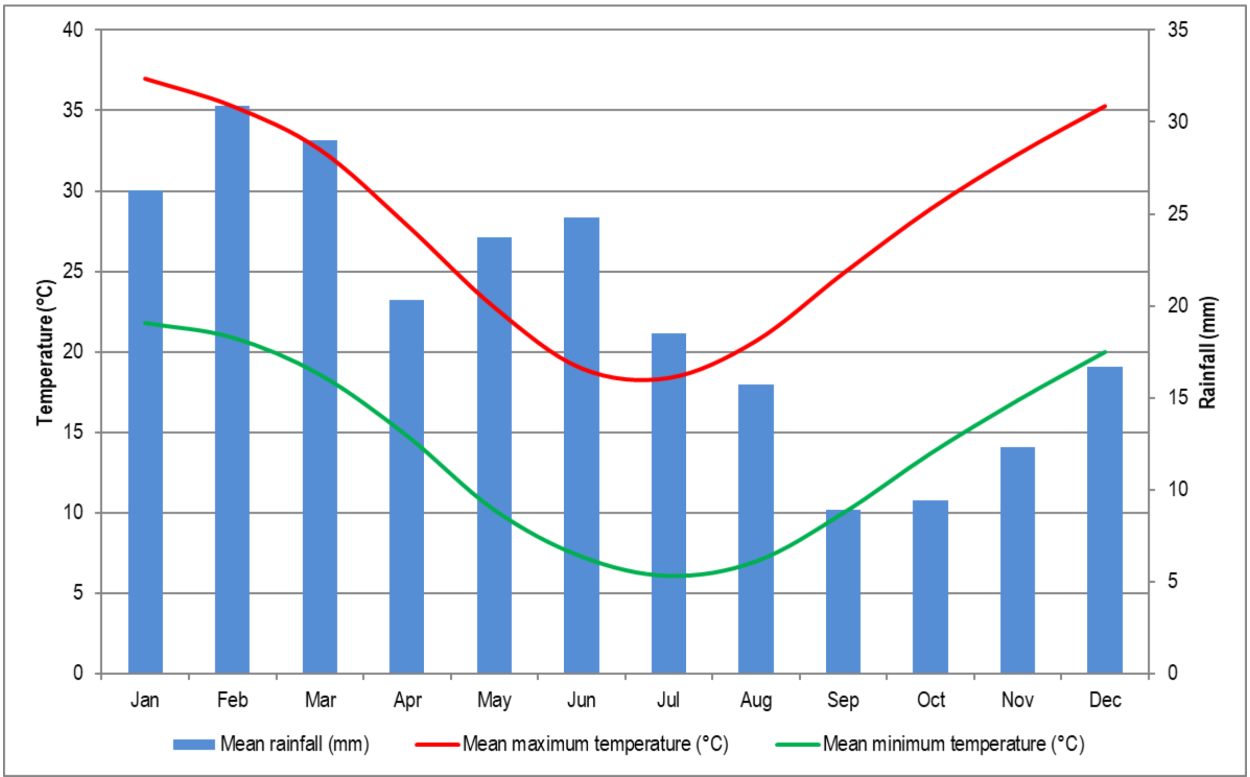


Chart 1: Leonora Weather Station Rainfall and Temperature Data

3.2 GEOLOGICAL SETTING

3.2.1 Regional Geology

The geology in the northeastern Goldfields region of the Yilgarn craton is characterised by arcuate to linear belts of meta-mafic volcanic and associated intrusives, commonly described as “greenstone belts” separated by larger expanses of granitoid rocks. Associated with the predominantly mafic and ultramafic sequences of these greenstone belts are felsic to intermediate volcanics and clastic sedimentary rocks. According to McCullough et al. (1983), the greenstone-granitoid sequences formed between 2,800 and 2,600 million years ago during the late Archaean period.

The Archaean granites are usually expressed as low, rounded tors surrounded by gritty surfaced plains. Surface features developed on the greenstone belts tend to be more variable in elevation and structure, ranging from low rounded features with broad, stony, calcareous slopes to higher, less weathered hills with narrow, incised drainage lines (McCullough et al.; 1983).

3.2.2 Project Area Geology

The Qena deposit forms part of the Carouse Dam Basin, an approximately 2,500-m-thick sequence consisting of intermediate volcanoclastic siltstones, sandstones and conglomerates. The sequence is a mineralised material that gradually transitions east, developing into a hanging wall sequence composed of tuffs overlain by chloritic schists.

Over time, this stratigraphic sequence has been intruded by various rock types including monzonite, dolerites, syenite, and lamprophyre. West of the formation, the footwall of the sequence is composed of interleaving tuffs and porphyries. Marking the transition between the footwall of Qena and the margin of the Atbara Monzonite is the Qena Shear. This geological feature in the rock is a steeply dipping shear zone mirroring the hanging wall contact of the nearby Atbara Monzonite.

3.3 HYDROLOGY, HYDROGEOLOGY AND GROUNDWATER QUALITY

Groundwater occurs throughout the northeastern Goldfields as a regional water table sub-parallel to the topography with an ill-defined surface ranging in depth from approximately 30–100 m. The groundwater is usually located in fracture controlled aquifers within fresh basement rocks, within the weathered rock zone close to the fresh rock interface and in alluvial sediments, particularly those associated with ancient paleochannel drainage systems (Pringle et al., 1994).

Recharge to groundwater occurs mainly from intense, but infrequent rainfall events. Groundwater flow is controlled by gravity through fractures within basement rocks, through the weathered rock zone and through surficial alluvial sediments particularly those associated with ancient paleochannel drainage systems, all of which are in hydraulic continuity. Depending on position within these flow systems and local geological settings, aquifers may be either confined, or unconfined with localised artesian areas (Pringle et al., 1994). Localised perched aquifers may form following rainfall events, mainly in surficial sediments overlying weathered rocks of lower permeability.

Groundwater quality varies from almost fresh to moderately saline, dependent on the position within the landscape with almost fresh water normally in elevated intake areas and more saline water in discharge areas associated with salt lake systems along the ancient paleochannel drainage lines. In addition, a relatively thin, almost freshwater zone often occurs within that portion of the aquifer that is closest to the surface.

3.4 VEGETATION

The region lies within the Eremaean botanical province near the southern boundary of the Austin botanical district (Beard, 1990). The Eremaean Botanical Province is typified by plants from the families Fabaceae (*Acacia* spp., *Senna* spp.), Scrophulariaceae (*Eremophila* spp.), Chenopodiaceae (Samphires, Bluebushes, Saltbushes), Asteraceae (Daisies) and Poaceae (grasses). The Austin Botanical District is essentially the Mulga (*Acacia aneura*) region of Western Australia. *Acacia aneura* is a dominant or a significant component in most plant communities in this District. The region is often rich in ephemerals, which reduce to scrub on hills. The Austin Botanical District is also characterised by hummock grasslands, saltbush shrublands and *Tecticornia* shrublands (Beard, 1990; Cowan 2001).

Vegetation of the Carosue Dam area consists of low open *Eucalyptus* woodland over *Acacia* and other mixed shrubs to *Casuarina* and *Acacia* woodland. Toward Lake Rebecca the vegetation becomes more halophytic and the overstorey disappears, leaving low halophytic shrubs with occasional sandy banks and drainage zones which support a wide range of species. A number of flora and vegetation surveys have been undertaken throughout the Carosue Dam Project area (Northern Star Resources Ltd, 2022).

A vegetation, flora and fauna survey was conducted for the Qena Project and surrounds in October 2023 (Alexander Holm & Associates, 2023). Nine vegetation communities were recorded within a 2,100-ha area encompassing the project. Vegetation within the project area is typical of the goldfields region and dominated by two vegetation communities: calcareous casuarina acacia shrublands and woodland (CCAS) and plain acacia casuarina shrublands (PACS).

4. LAND SYSTEMS AND LANDFORMS

4.1 LAND SYSTEMS AND SOILS

A desktop review of soil and landform mapping units was undertaken using the spatial data made available by the Department of Primary Industries and Regional Development (DPIRD, 2018) which shows the regional land system mapping units in relation to the proposed Project plan disturbance envelope.

The proposed disturbance area is primarily located in the Deadman Land System with the proposed explosive magazine location in the Moriarty Land System (Figure 2). Characteristics of the units, including landforms and soil types are summarised in Table 1 as outlined in Van Vreeswyk et al, 2004 and Pringle et al, 1994.

Table 1: Soil and Landform Units Within Project Disturbance Area

Land System	Geology	Landforms	Major Soil Types (DAFWA Soil Group)	Infrastructure Within Land System
Deadman (265De)	Quaternary alluvium, some Tertiary calcrete	• Level to gently undulating plains • Sandplains	• Calcareous loamy earth • Red loamy earth • Red deep sands • Calcareous shallow loam • Red deep sandy duplex • Red sandy earth	Boxcut, WRDs, ROM, Supporting infrastructure.
Moriarty (265Mo)	Archaean greenstone, minor granite, Tertiary ferruginous duricrust, Quaternary colluvium and alluvium	• Low rises • gently inclined lower plains • level alluvial plains	• Red shallow loam • Calcareous loamy earth • Red shallow sand • Red shallow sandy duplex • Red/brown non-cracking clay	Supporting infrastructure
Gundockerta (265Gu)	Extensive Quaternary colluvium, eluvium and alluvium, minor Archaean greenstone and Tertiary limonite	• Gently undulating plains • Lower alluvial plains	• Calcareous loamy earth • Red shallow sandy duplex • Stony soil • Red/brown hardpan shallow loam • Red/brown non-cracking clay	Adjacent system (Reference sample only)
Kirgella (266Ki)	Quaternary sand and cemented alluvium with scattered Archaean granite exposures locally with Tertiary siliceous, calcareous or ferruginous duricrust.	• Undulating sandplains • Weathered granite exposures	• Calcareous loamy earth • Red loamy earth • Red deep sand • Red shallow sand	Adjacent system (Reference sample only)

4.2 LANDFORMS

Landforms can be described as "The distinctive, recognisable physical features of the earth's surface having a characteristic shape produced by natural processes. A landform is defined by the combination of its geology (composition) and morphology (form)" (EPA 2018).

The following sections describe the regional landform context of the surrounding Carouse Dam area as well as the landforms identified within the Project area and an assessment of their potential significance (refer Section 4.2.3).

4.2.1 Regional Landform Context

The Project area lies within the Kambalda soil landscape zone within the Kalgoorlie Province of the Western Region (Tille et al., 2006). This zone is characterised as having flat to undulating plains (with hills, ranges and some salt lakes and stony plains) on greenstone and granitic rocks of the Yilgarn Craton. The Project area lies within the Gascoyne biodiversity area.

4.2.2 Project Area Landforms

Based on the findings of the desktop assessment, the following landforms are likely to occur within the Project area:

- Undulating plains.
- Sandplains.
- Alluvial plains.

Specific landmarks within the Project and surrounding areas included (DPRID, 2018):

- Three Aboriginal heritage sites are present within the Carouse Dam heritage area. No sites are located within the Qena Project area.
- Aboriginal heritage site, Lake Rebecca is located approximately 11 km east and 10 km south of the Project area.
- No geoheritage sites (Brocx and Semeniuk, 2007) are located within 50 km of Carosue Dam.
- No National Heritage Areas are located within 50 km of Carosue Dam.
- Goongarrie National Park is located approximately 61 km west of Carosue Dam and Queen Victoria Spring National Park is located approximately 74 km east of Carosue Dam.

4.2.3 Assessment of Landform Significance

The Environmental Protection Authority (EPA) nominates the following six criteria to determine whether landforms are significant (EPA 2018):

- **Variety:** The landform is a particularly good or important example of its type. The landform is not well represented over the local, regional or national scale or differs from other examples at these scales, either naturally or as a result of cumulative impacts from existing and reasonably foreseeable activities, developments and land uses.
- **Integrity:** The landform is intact, being largely complete or whole and in good condition.
- **Ecological importance:** The landform has a distinctive or exclusive role in maintaining existing ecological and physical processes; for example, by providing a unique microclimate, source of water flow, or shade. The landform supports endemic or highly restricted plants or animals.

- **Scientific importance:** The landform provides evidence of past ecological processes or is an important geomorphological or geological site. The landform is of recognised scientific interest as a reference site, or an example of where important natural processes are operating.
- **Rarity:** The landform is rare or relatively rare, being one of the few of its type at a national, regional or local level.
- **Social importance:** The landform supports significant amenity, cultural or heritage values linked to its defining physical features.

Table 2 assesses landforms within the Project area against these criteria.

From the desktop and field assessments a single landform was observed within the Project area and in wider surrounding region: level plains.

From both the field and desktop assessments the level plains landform was considered to be a good example of the landform and was also considered to have sufficient integrity (i.e. are in good condition). This landform was, however, not considered to be significant in the context of ecology or scientific importance given that they are widely distributed across the region and to our knowledge do not contain significant scientific or evolutionary values such as geoheritage sites or reserves (DMIRS GeoVIEW database, 2021). The widespread nature of the landforms means that they have no significance in terms of rarity and thus based on these criteria it is unlikely that the Project will be disturbing landforms that would be considered significant in the context of the EPA 2018 guidelines.

Table 2: Assessment of Landform Significance

Landform	Variety	Integrity	Ecological Importance	Scientific Importance	Rarity	Social Importance
Level plains	Typical examples of common landform in region.	Appear in good condition.	No sites of ecological importance identified.	No sites of scientific importance identified.	Widespread	To our knowledge there are no significant heritage sites within the Project area.

5. DETAILED FIELD INVESTIGATION

5.1 SAMPLING LOCATIONS

Approximate sampling locations were determined for field sampling using soil and landform data in conjunction with the proposed site layout. Test pits were prepared for all 18 locations (Table 3) which resulted in a total of 23 samples collected and analysed (Figure 3).

Table 3: Details of Samples Collected in this Assessment.

Test Pit ID	Proposed Disturbance Type	Land System
NSQPIT4	Pit / Boxcut	Deadman
NSQPIT2		
NSQPIT3	Supporting Infrastructure	Deadman
NSQPIT5		
NSQWRD5		
NSQPIT1	ROM	Deadman
NSQWRD2	Reference Sites - Deadman	Deadman
NSQWRD1		
NSQWRD4		
NSQDMREF1		
NSQDMREF2		
NSQDMREF3		
NSQWS1		
NSQOFF2		
NSQEXM1	Reference Sites - Gundockerta	Gundockerta
NSQGUREF1		
NSQKIREF1	Reference Sites - Kirgella	Kirgella
NSQMOREF1	Reference Sites - Moriarty	Moriarty

Scale: 1: 25,000 Original Size: A3 Grid: GDA94 / MGA zone 51 (EPSG:28351) 0 0.5 1 km	Northern Star Resources Ltd Carosue Dam	**Figure 3** **Soil Sampling Locations**	Martinick Bosch Sell Pty Ltd 4 Cook St West Perth WA 6005 Australia t: +61 8 9226 3166 info@mbsenvironmental.com.au www.mbsenvironmental.com.au MBS ENVIRONMENTAL

W:\Northern Star\Carosue Dam\Studies\Qena Soil 2023\GIS Common\NS Qena Common Map.qgz 06/02/2024 Fig_3_SoilSampleLocs

5.2 SOIL PROFILE CHARACTERISATION

In order to ensure an appropriate characterisation of topsoil and subsoil resources within the disturbance area, soil profiles were logged at each sampling location. Test pits were generated using excavators prior to field sampling taking place, whereby soils were removed from the profile in 200- to 250-mm-deep layers, with the removed soil placed in separate piles to ensure that changes in characteristics could be documented accurately.

Soil profiles were logged using the MBS template (Appendix 2) which records the following details of both the site and soil sample:

- Sample location — including coordinates (from a Global Positioning Device (GPS)) and characteristics of the proposed disturbance (i.e. pit, WRD, camp etc).
- Vegetation and landscape characteristics (including slope and elevation).
- Details of observable soil characteristics (i.e. texture, colour, gravel content) throughout the profile.
- Sample identification numbers, and photographic records of exposed soil profiles, collected soil samples, and the surrounding environment (i.e. vegetation and landscape).

For each trench or test pit that was evaluated, the profile by depth was classified and paired with a description of the dominant soil type based off the descriptions in Schoknecht and Pathan (2013). The characteristics of soils can change throughout the profile and thus profiles are described across different horizons (layers) as follows:

- ‘O Horizons’. Partly decomposed organic matter accumulated at the surface of the topsoil and overlies the A horizon. O-horizons are noted, when present, but not generally sampled.
- ‘A Horizons’: topsoil or first horizon. Can also be sub-classified (A1, A2, etc.) if multiple types of different soils occur within the same horizon. Soils in the A horizon are typically enriched in organic matter content (plant debris and humus) and more coarse texture (less clay) compared to underlying horizons.
- ‘B Horizons’: second horizon (subsoil). Clay, soluble salts, gravel and/or iron staining are commonly found in this horizon as a result of illuviation. It is common for more than one B horizon to be present — these are sequentially identified as B1, B2, etc. when present.
- ‘C Horizons’: third horizon (substratum). Underlies horizon B before fresh bedrock is found. Typically, characteristic of weathered bedrock (saprock). Depth to C horizon if found should be noted but does not require sampling.
- ‘E Horizons’. If present, this is a distinctive layer (usually pale/white) formed between A and B horizons as a result of heavy leaching, leaving only resistant minerals behind (i.e. quartz).
- ‘R Layer’. Hard bedrock.

Along with the soil profile classification and description, photographs were taken and included in the log:

- One photograph of the bagged and labelled soil sample(s) for the location to help indicate the sequence of photographs by location.
- One photograph of the soil profile (e.g. Plate 1).
- At least one photograph of the surrounding landscape and vegetation.
- Site and field profile descriptions were recorded as per the Australian Soil and Land Survey Handbook (McDonald and Isbell 2009) with the following recorded for all samples:
  - Horizon depth and boundary type (transitional or abrupt).
  - Soil colour (grey, grey-brown, dark brown, red-brown, yellow-brown, yellow, etc.).
  - Field texture description (e.g. sand, light clay, gravelly loam, silty gravel).

— Moisture content (dry, damp, moist or saturated).

— Presence, depth, and types of plant roots (fine, medium, coarse).

— Presence and characteristics of coarse fragments such as pisolitic gravels, rock fragments, and charcoal (proportions of total matrix, rounded or angular, composition/possible source of fragments).

— Presence or absence of pedogenic features (terrace gravels, mottles, hardpans — silcrete, calcrete, ferricrete, nodular calcrete, ferruginous pisoliths, etc).

— Underlying bedrock or saprock geology, where observable.

Plate 1: Example of Soil Profile Photograph

5.3 LABORATORY TESTS

A laboratory analysis program was undertaken by a NATA accredited laboratory to characterise physical and chemical properties of the soils to assess any risks associated with the disturbance of soils (i.e. acidity; metal/metalloid contamination; susceptibility to erosion, etc) and their suitability for use as cover materials for rehabilitation. For this reason, the test program focused on parameters relating to physical stability, plant nutrition, and contamination.

The following tests were undertaken by ChemCentre (Bentley, Western Australia), generally using in-house modifications of standard soil tests described by Rayment and Lyons (2011):

- pH and electrical conductivity (EC).
- Exchangeable cations (calcium, sodium, potassium, and sodium) and exchangeable sodium percentage (ESP%).
- Organic carbon and total nitrogen.
- Particle size (sand, silt, clay, and gravel contents).
- Potential for clay dispersion (Emerson Class, AS 1289 3.8.1 2006).
- Nutrients and plant-available heavy metals (Mehlich-3 extract, Mehlich, 1984).
- Aqua-regia digestible concentrations of eight metals and metalloids to establish a baseline for future contaminated site assessments in accordance with NEPC (2013) guidelines.

5.4 INTERPRETATION OF RESULTS

The following sources of information were used to assess the significance of laboratory test results:

- Soil Analysis: An Interpretation Manual (Peverill et al. 1999).
- Interpreting Soil Test Results. What do all the numbers mean? (Hazelton and Murphy, 2007).
- Soil Groups of Western Australia. In Resource Management Technical Report 380, Soil Physical Measurement and Interpretation for Land Evaluation, Australian Soil and Land Survey Handbooks Series 5 (4th ed). DAFWA, Perth (Schoknecht and Pathan, 2013).
- Soil Guide. A handbook for understanding and managing agricultural soils. DAFWA Bulletin 4343 (DAFWA, 1998).
- Soil-Landscapes of Western Australia's Rangelands and Arid Interior. Resource Management Technical Report 313 (Tille, 2006).

A summary of the information sources and ratings tables used for this assessment is presented in Appendix 1. Collated laboratory results and laboratory reports are provided in Appendix 3 and Appendix 4 respectively.

6. SOIL PROFILE DESCRIPTIONS

Test pit photographs, soil profile descriptions, laboratory sample details and general descriptions for each soil test pit and sampling location are presented in Appendix 2. All soils in the Project area were calcareous with two main groups identified: calcareous loamy earths (DAFWA Soil Group 542) and calcareous shallow loams (DAFWA Soil Group 521). The distribution of different soil types across the Project area is summarised in Figure 4.

6.1 CALCAREOUS LOAMY EARTHS

Calcareous loamy earths (DAFWA Soil Group 542) typically consisted of a shallow red-brown loamy sand topsoil layer (<10 cm) which trended into a gravelly/sand/clay subsoil (to approximately 1 m) which in turn overlay indurated calcretes (Plate 2).

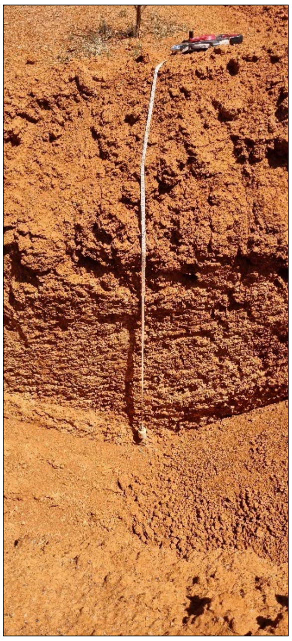
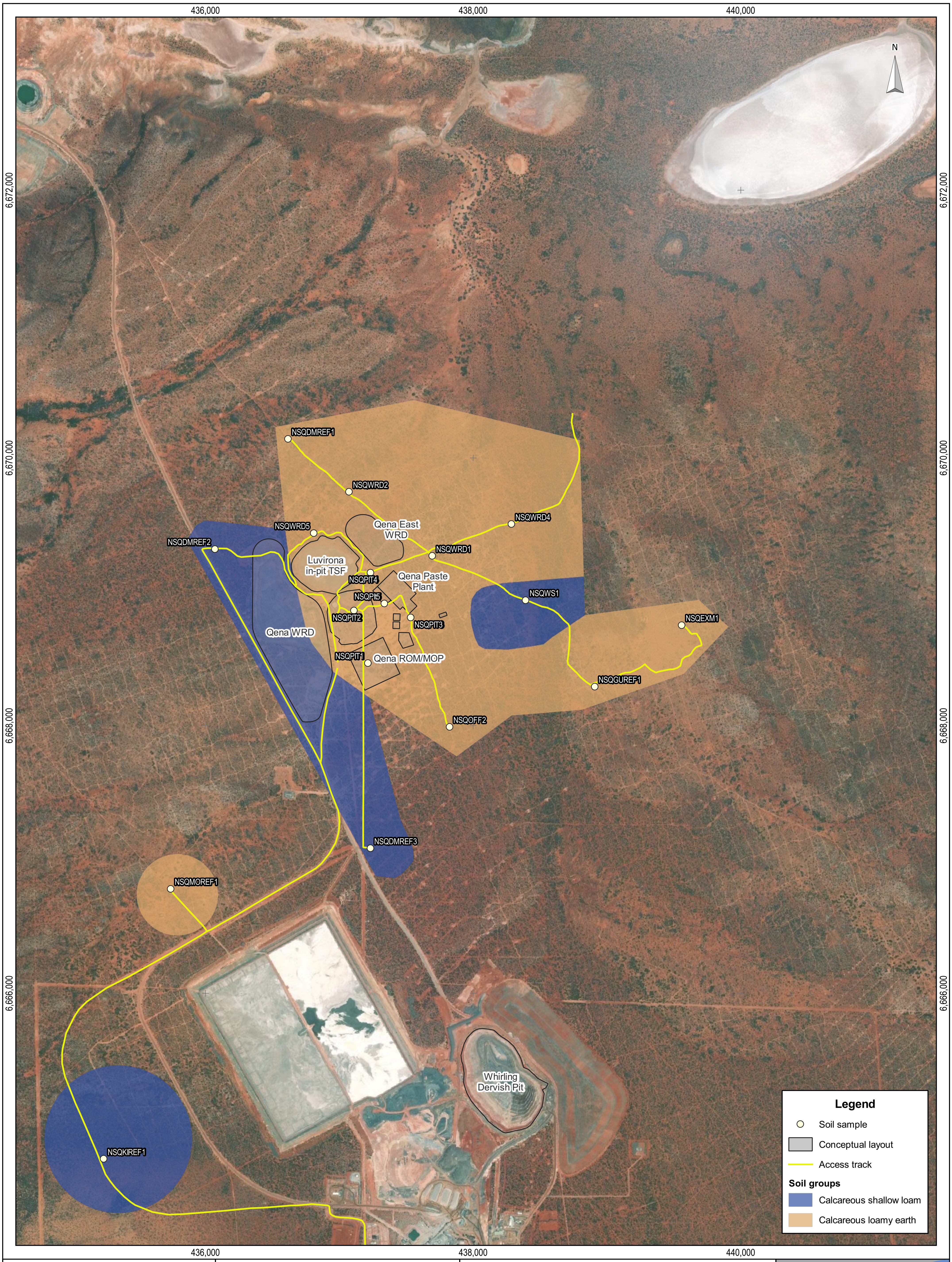


Plate 2: Example of Calcareous Loamy Earth (DAFWA Soil Group 542) — NSQWRD4

6.2 CALCAREOUS SHALLOW LOAMS

In some areas the calcareous soils were classified as calcareous shallow loams due to having a much shallower profile (<0.5 m), and lower clay content than the Calcareous loamy earths (Plate 3).

Plate 3: Example of Calcareous Shallow Loam (DAFWA Soil Group 521) — NSQWS1



Scale: 1: 25,000
Original Size: A3

Grid: GDA94 / MGA zone 51 (EPSG:28351)

0 0.5 1 km

Northern Star Resources Ltd
Carosue Dam

Figure 4

Distribution of Soil Groups Across the Project Area

Martinick Bosch Sell Pty Ltd
4 Cook St
West Perth WA 6005
Australia
t: +61 8 9226 3166
info@mbsenvironmental.com.au
www.mbsenvironmental.com.au

MBS ENVIRONMENTAL

W:\Northern Star\Carosue Dam\Studies\Qena Soil 2023\GIS Common\NS Qena Common Map.qgz 07/02/2024 Fig_4_SoilGroups

7. PHYSICAL PROPERTIES

7.1 GRAVEL CONTENT

The average gravel content by proposed disturbance area is presented in Table 4 and in detail in Appendix 3 Particles greater than 2 mm in diameter (i.e. gravels) are often a useful resource within mining area soils that can be utilised for infrastructure development (i.e. haul roads or to limit erosion on waste landforms).

Table 4: Average Gravel Content of Soils

Soil Group	Horizon	No of Samples	Gravel Content % (>2 mm)		
			Average	Minimum	Maximum
Calcareous shallow loams (521)	Surface	5	4.5	0.6	12.5
Calcareous loamy earths (542)	Surface	13	2.9	0.5	5.6
	Subsoil	5	11.7	4.8	16.1

The following key points are noted:

- Gravel contents were generally low, containing between 0% and 16% by mass, with the majority of samples containing <5%.
- Gravel contents in the two identified soil types (calcareous loamy earths (DAFWA Soil Group 542) and calcareous shallow loams (DAFWA Soil Group 521) were on average similar (approximately 5%).
- Average gravel contents in subsoils (11.7%) were typically higher than those in surface soils (2.7%) for calcareous loamy earths.

7.2 PARTICLE SIZE DISTRIBUTION AND DISPERSIVITY (EMERSON CLASS)

The textural classification of selected soil samples (<2 mm fraction) is presented in Table 5 and in detail in Appendix 3. Textural classifications are important in highlighting areas that could be utilised as a resource (i.e. high clay content for TSF basement, gravels for haul road generation, sands for plant growth mediums etc.). Data for Emerson Class number can be used to estimate the likelihood of clay dispersion under different environmental conditions. An Emerson Class value of <2 is an indication of the presence of spontaneously dispersive clay materials, whilst ratings of 3–6 are an indication that dispersion is increasingly less likely.

Table 5: Average Particle Size Distribution and Emerson Class Rating

Soil Group	Horizon	No of Samples	<2 mm Soil Fraction			Texture	Emerson Class Rating
			Sand %	Silt %	Clay %		
Calcareous shallow loams (521)	Surface	1	71	10	19	Sandy Loam	3
Calcareous loamy earths (542)	Surface	7	64	14	22	Sandy Clay Loam	2 - 4
	Subsoil	2	51	17	32	Sandy Clay Loam	-

The following key points are noted:

- Most samples were classified as sandy clay loams on a textural basis due to the presence of >20% clay (by mass).
- Two samples (NSQDMREF2 and NSQWRD1) contained <20% clay and were thus classed as sandy loams.
- All but one sample (NSQOFF2) had Emerson Class ratings of either 3 or 4, indicating that the spontaneous dispersion of clay materials is unlikely.

8. CHEMICAL PROPERTIES

8.1 PH AND SALINITY

Soil pH and salinity (EC) are used in assessing the re-use potential of soil materials. Summary data for soil pH and salinity is presented in Table 6 and in detail in Appendix 3: Collated Analytical Results

Table 6: pH and EC (Salinity) Data for Selected Soils

Soil Group	Horizon	No of Samples	pH			EC (mS/m)		
			Mean	Min	Max	Mean	Min	Max
Calcareous shallow loams (521)	Surface	5	7.4	6.8	8.8	10	3	20
Calcareous loamy earths (542)	Surface	13	8.7	8.1	9.2	30	4	210
	Subsoil	5	9.0	8.9	9.2	73	13	280
Criteria			<6.6	6.6 - 7.8	>7.8	<25	25–100	>100
			Acidic	Neutral – Alkaline	Moderate – Strongly Alkaline	Non-saline	Moderately Saline	High – Extremely Saline

The following key points are noted:

- All assessed soils had pH values >6.8 and were therefore categorised as circum-neutral to strongly alkaline.
- The soils surrounding the proposed disturbance area were typically very strongly alkaline with average soil pH values of >8.5.
- Calcareous loamy earth soils (542) were on average more alkaline than the calcareous shallow loams (521).
- Nearly all samples were considered non-saline having average EC values <25 mS/m.
- The exception to this was the sample from the reference site NSQEXM1 had an average EC value of 245 mS/m and was therefore considered high to extremely saline.

8.2 EFFECTIVE CATION EXCHANGE CAPACITY (ECEC)

Characteristics of effective cation exchange capacity (ECEC) (cmol(+)/kg) and ESP for selected soils are presented in detail in Table 7. ECEC is an important parameter in describing the ability of soils to retain nutrients derived from fertilisers or organic matter. In addition, the exchangeable sodium percentage (ESP) is a measure of soil sodicity, which informs on the risk of instability and erosion potential.

Table 7: Average Cation Exchange Characteristics

Soil Group	Horizon	No of Samples	Exchangeable (cmol(+)/kg)					%
			Ca	K	Mg	Na	ECEC	ESP
Calcareous shallow loams (521)	Surface	5	4.7	0.4	1.1	0.3	6.5	4.8
Calcareous loamy earths (542)	Surface	3	12.8	0.9	1.9	0.3	15.9	1.6
	Subsoil	3	6.7	0.5	2.9	0.4	10.4	3.4
Low			<5	<0.5	<1	<0.3	<5	<6
Moderate/Typical			5–10	0.5–2	1–5	0.3–1	5–15	6–15
High			>10	>2	>5	>1	>15	>15

The following key observations are noted:

- Calcareous loamy earth (542) surface soils typically contained exchangeable calcium concentrations that are considered high for WA soils (i.e. >10 cmol(+)/kg). This is to be expected given the calcareous nature of soils in the area.
- For nearly all samples concentrations of exchangeable potassium, magnesium and sodium were in the low to typical range for WA soils.
- The low exchangeable sodium concentrations resulted in all samples having ESP values of 6% or less. This indicates that all assessed soils are of low sodicity.

8.3 MAJOR NUTRIENTS

Results for organic carbon and total nitrogen concentrations in selected soils are presented in Table 8 and in detail in Appendix 2.

Table 8: Average Organic Carbon and Total Nitrogen Concentrations in Selected Surface Soils

Soil Group	Horizon	No of Samples	Organic C (%)	Total N (%)	C:N
Calcareous shallow loams (521)	Surface	1	0.20	0.021	10
Calcareous loamy earths (542)	Surface	7	0.46	0.045	10
Low			<0.5	<0.05	<10
Typical			0.5–1.5	0.05–0.3	10–16
High			>1.5	>0.3	>16

Major observations included:

- Most of the assessed samples contained organic C and total N concentrations that are considered low by WA standards.
- C:N ratios are typically in the low to moderate range and thus soils are likely to release mineralised nitrogen if organic matter is added.

8.4 PLANT AVAILABLE NUTRIENTS, TRACE ELEMENTS AND CONTAMINANTS

Results for a suite of Mehlich-3 extractable nutrients and trace elements in selected soils are presented in Table 9 and in detail in Appendix 3. The Mehlich-3 extraction provides an estimate of the availability of a range of trace elements, metals and metalloids to plants, which can inform both the ability of the soils to provide nutrition and also risks related to contaminant exposure.

Major observations were:

- The majority of nutrients and trace element concentrations were within typical WA standards for plant availability for the assessed soils. There were, however, some exceptions.
- Plant available calcium, potassium and manganese concentrations were considered high for WA standards in most calcareous loamy earth samples.
- Selected samples also contained plant available concentrations of elements such as aluminium, boron, copper, magnesium and sodium that are considered high. In the case of the explosives magazine sample the elevated boron and sodium concentrations are consistent with the high salinity values reported in Table 6.
- Plant available molybdenum concentrations were lower than typically observed (in WA) in all samples, whilst selected samples also contained low plant available cobalt, phosphorus and/or sulfur concentrations.
- Common metal(loid) contaminants (As, Cd, Pb and Se) were all present in low concentrations and are thus unlikely to have any environmental significance.

8.5 METALS AND METALLOIDS

To establish site-specific background concentrations of selected metals and metalloids, aqua regia digests were performed on selected soils as outlined in Table 10 and Appendix 3.

The National Environmental Protection Council (NEPC) (2013) guidelines (Public Open Spaces) was used as environmental criteria for comparison purposes. Elements including cadmium, mercury and manganese are not provided in the NEPC framework and thus the Department of Environment and Conservation (DEC) default soil investigation guidelines (DEC 2010) were used in their absence.

Table 9: Concentrations of Plant Available Nutrients and Trace Elements in Selected Samples

Soil Group (DAFWA ID)	Horizon	No of Samples	Plant Available Elements (mg/kg)																		
			Al	As	B	Ca	Cd	Co	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Se	Zn
Calcareous shallow loams (521)	Surface	1	>550	<0.1	0.4	2900	<0.01	3.2	3.2	29	280	500	150	<0.01	49	3.3	1	0.9	2	<0.1	0.2
Calcareous loamy earths (542)	Surface	7	370	0.1	1.3	5500	0.03	1.7	4.4	21	366	393	70	<0.01	227	1.5	7	0.8	32	0.1	0.5
Low			-	-	<0.1	<50	-	<1	<0.1	<10	<10	<20	<5	<0.01	-	<1	<2	-	<5	-	<0.2
Typical			-	-	0.1-2	50–5,000	-	1–10	0.1–5	10–200	10–300	20–2,000	5–100	0.01–0.05	-	1–20	2–10	-	5–200	-	0.2–5
High			>550	>5	>2	>5,000	>1	>10	>5	>200	>300	>2000	>100	>0.05	>180	>20	>10	>35	>200	>1.5	>5

Table 10: Aqua-Regia Digestible Metal and Metalloid Concentrations in Selected Samples

Soil Group (DAFWA ID)	Horizon	Number of Samples	Aqua Regia Digestible Concentrations (mg/kg)											
			Ag	As	Cd	Cr	Cu	Hg	Mn	Ni	Pb	Sb	Se	Zn
Calcareous shallow loams (521)	Surface	3	<0.05	3	0.03	119	13	<0.02	149	22	6	0.05	0.2	13
Calcareous loamy earths (542)	Surface	10	<0.05	6	0.06	225	32	<0.02	361	68	11	0.08	0.2	33
	Subsoil	1	<0.05	10	0.06	240	29	<0.02	190	81	6	0.03	0.2	21
NEPM (2013)			N/G	100	3*	550	220	1*	500*	210	1,100	N/G	N/G	550
Ambient background concentration (80th percentile)			<0.05	9	0.1	276	33	<0.02	346	88	10	0.1	0.3	35

*Note — * indicates the DEC (2010) guidelines were used in the absence of NEPM (2013) guideline values.*

Major observations were:

- Sporadic exceedances of Cr, Mn and Ni were observed across the dataset, which is consistent with mafic derived soils.
- On average, however, project area soils contained total metal(loid) concentrations well below that of the NEPM (2013) criteria.

9. DISCUSSION AND RECOMMENDATIONS

9.1 LANDFORMS

From the desktop and field assessments the only landform present in the Project area was level plains. The proposed disturbance area is comprised of landforms that are widespread, in good condition and do not contain site of ecological or scientific importance. Consequently, any development is unlikely to impact this landform at the local or regional scale.

9.2 IDENTIFIED SOIL GROUPS

Two soil groups were identified within the Project area which included:

- Calcareous loamy earths (DAFWA Soil Group 542).
- Calcareous shallow loams (DAFWA Soil Group 521).

Calcareous loamy earths were more common and typically had a deeper profile and contained more clay than the calcareous shallow loams. The similarities between both soil groups physically and chemically means that both soils can be managed as one single unit with no need for separate stockpiling.

9.3 PHYSICAL PROPERTIES OF PROJECT SOILS

The main physical properties of Project area soils included:

- Most surface soil samples contained low gravel contents of <5%. Subsoil samples of calcareous loamy earths contained slightly higher gravel contents (average 12%).
- Most samples were classified as sandy clay loams on a textural basis due to the presence of >20% clay (by mass).
- All but one sample (NSQOFF2) had Emerson Class ratings of 3 or 4, indicating that the spontaneous dispersion of clay materials is unlikely.

9.4 CHEMICAL PROPERTIES OF PROJECT SOILS

The main chemical properties of soils included:

- All soils had pH values >6.8 and are therefore categorised as circum-neutral to strongly alkaline.
- The vast majority of soils are non-saline (EC <25mS/m), with samples taken from a reference location within the Gundockerta system a clear outlier (average EC = 245 mS/m).
- Most calcareous loamy earth samples contained exchangeable calcium concentrations that are considered high for WA soils (i.e. >10 cmol(+)/kg). This is to be expected given the calcareous nature of soils in the area. As a result most samples had high ECEC values (>15 cmol(+)/kg).
- For nearly all samples concentrations of exchangeable potassium, magnesium and sodium were in the low to typical range for WA soils.
- The low exchangeable sodium concentrations resulted in all samples having ESP values of 6% or less. This indicates that all assessed soils are non-sodic and are thus not dispersion prone.
- Most of the assessed samples contained organic C and total N concentrations that are considered low by WA standards whilst concentrations of most plant available nutrients and trace elements were within typical WA standards for plant availability for the assessed soils.

- Exceptions to this included that many samples plant-available calcium, potassium and manganese concentrations which were considered high by WA standards whilst plant-available molybdenum, was low in most samples.
- Plant-available concentrations of metal(loid) contaminants (As, Cd, Pb and Se) were low in all samples and are thus unlikely to have any environmental significance.
- Manganese, nickel and total chromium concentrations sporadically exceeded relevant EILs but are likely to be typical of concentrations in local environments. There was no exceedance of NEPM criteria at the Project scale.

9.5 IMPLICATIONS FOR SOIL MANAGEMENT

The following sections outline the key factors for the management of topsoil and subsoils during operations and post closure. Characteristics of project are soil are summarised below in Table 11.

Based on the results of the field survey a volume of approximately 2.4 million m^3 of surface soil material is available to harvest to a depth of 30 cm from the survey area as outlined in Figure 4. Based on the physical and chemical data generated in this assessment surface soils should be suitable for re-use.

In order to ensure soils are managed appropriately stockpiles should be capped at a height of 2 m to avoid excessive dust generation and maintain seed/nutrient viability. Given the similarity in surface soils between the two major soil groups (calcareous loamy earths and calcareous shallow loams) stockpiles of both soil types can be combined as required (i.e. soils do not need to be stockpiled separately).

Table 11: Chemical Characteristics and Rehabilitation Potential of Soils from Across the Project Area

Parameter	WA Soil Groups
	Calcareous Loamy Earths/Calcareous Shallow Loams (DAFWA Soil Group 542/521)
Estimated Area (ha)	804.5
Harvestable Volume (m^3) — assumed 30cm harvest depth	2,413,510
Gravel	Low in surface soils (<5%). Higher in subsoils (up to 15%)
Texture	Sandy loam to sandy-clay loam
Clay dispersion	Unlikely
pH	Circum neutral to strongly alkaline
Salinity	Disturbance area is non-saline. Saline pockets do exist in wider area.
ECEC	Variable across the project area
Sodicity	Low risk
Al Toxicity	No risk — alkaline soils
Major Nutrients	C and N both low
Plant available nutrients	Calcium, potassium and manganese high in most samples Molybdenum low in most samples
Total metal(oids)	Generally below NEPM (2013) criteria
Comments for management and re-use	• Likely to support plant growth for rehabilitation purposes as non-saline and non-acidic. • High ECEC in calcareous loamy earths indicates that soils should hold nutrients (fertilisers) if applied. • Highly alkaline soils could result in trace metal (e.g. Cu, Zn, Ni and Mn) deficiencies. • Low risk of dispersion and/or sodicity thus can be used on sloping surfaces as required. • Localised areas of salinity.

10. REFERENCES

Alexander Holm & Associates. 2023. Vegetation, Flora and Fauna Survey M31/219, M31/210, M31/220 and M31/285. Unpublished report prepared for Northern Star Resources Ltd.

Beard, J. S. 1990. Plant Life of Western Australia. Kangaroo Press, Kenthurst, NSW.

Brocx, M, and Semeniuk, V. 2007. Geoheritage and Geoconservation – history, definition, scope, and scale. Journal of the Royal Society of Western Australia 90: 53-87.

Bureau of Meteorology (BoM). 2023. Climate Statistics for Australian Locations – Leonora (Station Number 012046). Australian Government, Bureau of Meteorology. Available from http://www.bom.gov.au/climate/data/ (accessed 20 October 2023).

Cowan, M. (2001). Murchison 1 (MUR1 - East Murchison subregion). Pp 466-479 in N. L. McKenzie and J. E. May, (ed.) *A biodiversity audit of Western Australia's 53 biogeographical subregions in 2002.* Department of Conservation and Land Management, Perth, Western Australia.

Department of Agriculture and Food, Western Australia (DAFWA). 1998. Soil Guide - A Handbook for Understanding and Managing Agricultural Soils. Bulletin No. 4343. Ed. G. Moore. Government of Western Australia: Department of Agriculture and Food Western Australia.

Department of Environment and Conservation (DEC). 2010. *Assessment Levels for Soil, Sediment and Water.* Contaminated Sites Management Series. Department of Environment and Conservation. Perth, Western Australia.

Department of Mines Industry Regulation and Safety (DMIRS). 2021. GeoVIEW WA Interactive Geological Map. Available from https://www.dmp.wa.gov.au/GeoView-WA-Interactive-1467.aspx (accessed 20 October 2023).

Department of Primary Industries and Regional Development (DPIRD). 2018. Soil-landscape mapping – Best Available (DPIRD-027). Government of Western Australia, Department of Primary Industries and Regional Development. Available from https://dpird.maps.arcgis.com/apps/webappviewer/index.html?id=662e8cbf2def492381fc915aaf3c6a0f (accessed 20 October 2023).

DMIRS 2020. Mining Proposal Guidance — How to prepare in accordance with Part 1 of the Statutory Guidelines for Mining Proposals. Effective from 3 March 2020.

Environmental Protection Authority (EPA). 2018. Environmental Factor Guideline: Landforms. Government of Western Australia Environmental Protection Authority (EPA). Available from http://www.epa.wa.gov.au/sites/default/files/Policies_and_Guidance/Guideline-Landforms-29062018.pdf (accessed 20 September 2022).

Hazelton, P. and Murphy, B. 2007. Interpreting Soil Test Results, What Do All the Numbers Mean? CSIRO Publishing, Collingwood.

McCullough, M.J., Compston, W. and Froude, D., 1983. *Sm-Nd and Rb-Sr dating of Archaen gneisses, eastern Yilgarn block, Western Australia*. Journal of the Geological Society of Western Australia, **30:** 149-153.

McDonald, R.C. and Isbell, R.F. 2009. Soil Profile. In Australian Soil and Land Survey Handbook, 3rd ed. CSIRO Publishing, Collingwood.

Mehlich, A. 1984. Mehlich 3 Soil Test Extractant: A Modification of Mehlich 2. Communications of Soil Science and Plant Analysis 15: 1409-1416.

National Environmental Protection Council (NEPC). 2013. Schedule B1 - Guideline on Investigation Levels for Soil and Groundwater. In National Environment Protection (Assessment of Site Contamination) Measure 1999 (Amended 2013). Australian Government: National Environmental Protection Council. Canberra: ACT.

Northern Star Resources Ltd. (2022). Carosue Dam Environmental Group Site S0018887 Mining Proposal - JO2241, Mineral Fields 27, 28 & 31. January 2022.

Peverill, K.I., Sparrow, L.A., and Reuter, D.J. 1999. Soil Analysis: An Interpretation Manual. CSIRO Publishing, Collingwood.

Pringle, H.J.R., Van Vreeswyk, A.M.E. and Gilligan, S.A., 1994. *An Inventory and Condition Survey of the North-Eastern Goldfields, Western Australian*. Technical Bulletin No. 87, WA Department of Agriculture, December 1994.

Rayment, G. and Lyons, D. 2011. Soil Chemical Methods – Australasia. CSIRO Publishing, Collingwood.

Schoknecht, N. and Pathan, S. 2013. Soil Groups of Western Australia. In Resource Management Technical Report 380, Soil Physical Measurement and Interpretation for Land Evaluation, Australian Soil and Land Survey Handbooks Series 5 (4th ed). DAFWA, Perth.

Standards Australia. 2006. AS 1289 3.8.1: Determination of Emerson Class Number of a Soil. Strathfield:

Tille, P. 2006. Soil-landscapes of Western Australia's Rangelands and Arid Interior. Resource Management Technical Report 313. Government of Western Australia, Department of Agriculture and Food.

Van Vreeswyk, A M, Leighton, K A, Payne, A L, and Hennig, P. (2004). An inventory and condition survey of the Pilbara region, Western Australia. Department of Agriculture and Food, Western Australia, Perth. Technical Bulletin 92.

APPENDICES

APPENDIX 1: SOIL ASSESSMENT METHODOLOGY

1. INTRODUCTION

1.1 SOIL TEST METHODOLOGY

Understanding the physical, chemical and biological properties of soils is dependent on the ability of scientists and land managers to critically evaluate and assess data provided by meaningful soil tests. A multitude of different soil tests, often intended to measure the same soil quality parameter, have been developed over many years for various reasons, including:

- Characterisation of the diversity of soil types around the world with widely different physical and chemical properties.
- Cost - market forces by land managers, especially farmers, have driven development of soil tests that are simple, rapid and cheap to form, even though technically superior procedures exist.
- Speed of assessment: Rapid advances in laboratory automation, technical capabilities of modern instruments and data management systems.
- Increasing demands to deal with emerging issues of natural resource management including sustainability issues, environmental protection, soil health and food safety.

Unlike water and geological analysis, total elemental composition of soils generally provides will little predictive capacity for assessing the ability of soil to provide necessary levels of nutrients for good plant growth. For this reason, different soil tests for specific nutrients have been developed using extracting solutions that mimic the role of plant roots for taking up nutrients from soil.

In recent times, there have been attempts by various organisations to standardise laboratory methods throughout Australia. Most government and commercial soil testing laboratories in Australia now use standard methods, or validated variations derived from the following sources:

- Chemical analysis for agriculture and land management: Soil Chemical Methods – Australian (Rayment and Lyons 2011).
- Environmental assessment: NEPC. 2013. National Environment Protection (Assessment of Site Contamination) Measure. Guideline on Laboratory Analysis of Potentially Contaminated Soil. Schedule B3. National Environment Protection Council.
- Physical and engineering properties of soil: Australian Standard AS 1289.0-2000.

MBS Environmental provides soil characterisation assessments, mainly for the mining industry in WA and other Australian states, to inform pre-feasibility studies, mining proposals and closure planning to meet regulators' requirements. Soil test data and interpretation is provided to meet the following objectives:

- Properties of regional and project areas soils in terms of:
  - Physicochemical attributes including acidity, alkalinity, salinity, sodicity, texture, fertility and structural stability.
  - An indication of the volumes of suitable topsoils and subsoils that can be harvested and stockpiled for rehabilitation activities.
  - Ability to assimilate potential environmental contaminants such as hydrocarbons, metals, metalloids, nutrients, salts, acidity and pathogens.
- Achieving acceptable mine closure outcomes to provide a land surface that is:
  - Structurally stable and safe.
  - Non-polluting (surface water run-off, groundwater and air quality).
  - Compatible with post-mineral land use requirements.

Note that MBS Environmental does not offer geophysical and geotechnical soil assessment for engineering purposes such as constructions of roads, structures and water storages.

1.2 INFORMATION SOURCES

Interpretation of laboratory and field soil testing results and observations requires not only accurate data, but also a "Decision Support System" that provides meaningful predictions of soil properties and behaviour. A reliable Decision Support System needs to be:

- Developed and validated for local conditions including soil types, climate and land use.
- Able to predict soil constraints that may limit productivity and health of vegetation including:
  - Crop plants for agricultural land use on different soil types and environmental settings.
  - Pasture and feed value for pastoral land use.
  - Native plants for rehabilitation of degraded or disturbed areas, especially for WA plant species that are specially adapted to low nutrient and poorly structured soils.
- Able to quantify the risk of ecological and human health impacts for a specific location relating to:
  - Heavy metals and metalloids.
  - Nutrient runoff and leaching.
  - Petroleum hydrocarbons.
  - Agro-chemicals including insecticides and herbicides.

There is an enormous volume of interpretative soil test information available in response to the diversity of soil test methods and differences in soil types throughout the world. However, it is important that the information used be validated against local conditions and for this reason, much of the information published by reputable authorities in overseas countries is not applicable to Australian conditions.

The following sources of information are used by MBS Environmental to assess the significance of laboratory test results:

- Soil Analysis: An Interpretation Manual (Peverill *et al.* 1999). This reference was compiled by specialists from CSIRO and State Government agricultural research agencies. It is biased towards agricultural production, mainly in the eastern states, although it does reference large volumes of research provided by WA researchers between 1960 and 1998.
- Interpreting Soil Test Results. What do all the numbers mean? (Hazelton and Murphy 2007). This document was written specifically for officers in the former Soil Conservation Service of NSW, but is now used widely by soil professionals in other Australian States.
- Soil Guide. A handbook for understanding and managing agricultural soils. DAFWA Bulletin 4343 (DAFWA 2001). This document was prepared specifically for WA agricultural land use.
- Land Evaluation Standards for Land Resource Mapping (assessing land qualities and determining land capability in south-western Australia). DAFWA Resource Management Technical Report 298 (DAFWA 2005). This report describes the standard method for attributing and evaluating conventional land resource survey maps in the south-west agriculture region of Western Australia so that strategic decisions about the management, development and conservation of land resources can be based on the best information available.
- Understanding soil analysis data. DAFWA Resource Management Technical Report 327 (DAFWA 2008). The aim of this report is to help people who are interested in soil science, but are not specialists in this area, to better understand soil analysis reports in particular, and soil data in general.
- Soilquality.org.au website, with contributions from the University of Western Australia, DAFWA, Wheatbelt Natural Resource Management, Grains Research & Development Corporation, South Coast Natural Resource Management and the Grower Group Alliance.

MBS Environmental also draws upon the author's experience from coordinating physical and chemical laboratory analysis for DAFWA and DPaw soil and biological surveys conducted between 1988 and 2008. These include:

- Reference soils of south-western Australia (McArthur 1991). This publication presents soil profile descriptions and laboratory analysis of samples from the O, A and B soil horizons from 161 locations between Geraldton and Esperance in south-western Australia.
- Laboratory soil test results for about 10,000 soil samples from soil surveys of WA conducted by DAFWA between 1989 and 2007. Details of these surveys are presented in DAFWA Resource Management Technical Report 280, Soil-Landscape Mapping in South-Western Australia, Overview of methodology and outputs (DAFWA 2004).
- Soil analysis data to support the following biological surveys conducted by the Department of Parks and Wildlife (DPaW):
    - Pilbara region biological survey, 2002-2007 (George *et al*. 2009).
    - Floristic surveys of the banded iron formation ranges of the Yilgarn, 2005 to 2008 (Meissner and Caruso, 2008).
    - Wetland flora and vegetation of the WA wheatbelt, 2004.

2. PHYSICAL PROPERTIES

2.1 PARTICLE SIZE AND TEXTURE

2.1.1 Field Measurements

Soil texture describes the proportions of sand, silt and clay particles; the particle size distribution. Sands are mineral particles with an effective diameter between 0.02 and 2 mm, silt from 0.002 to 0.02 mm and clay less than 0.002 mm.

The field (or hand texture) of soil can be assigned by describing the behaviour of a sample of field sieved (<2 mm) soil when moistened to field capacity and kneaded into a ball or bolus and then pressed out between the thumb and forefinger to form a ribbon (bolus) (McDonald *et al.* 1990). The behaviour of the soil during bolus formation and the length of the ribbon define the field texture grade, as summarised in Table A1-1.

Table A1-1: Field Texture Grades

Texture Grade	Behaviour of Moist Bolus	Approximate Clay Content
Sand	Nil to very slight coherence; cannot be moulded; single sand grains adhere to fingers	<5%
Loamy sand	Slight coherence; can be sheared between thumb and forefinger to give a small ribbon (~5 mm)	About 5%
Clayey sand	Slight coherence; sticky when wet; many sand grains stick to fingers, discolours fingers with stain; ribbon 5 to 15 mm	5-10%
Sandy loam	Coherent bolus but very gritty; dominant sand grains of medium size and readily visible; ribbon of 15 to 25 mm	10-20%
Loam	Bolus coherent and spongy; no obvious grittiness or silkiness; ribbon about 25 mm	About 25%
Sandy clay loam	Strongly coherent bolus; sandy to touch; ribbon of 25 to 40 mm	20-30%
Clay loam	Coherent plastic bolus; smooth to manipulate; ribbon of 40 to 50 mm	30-35%
Clay loam, sandy	Coherent plastic bolus; sand grains visible in finer matrix; ribbon of 40 to 50 mm	30-35%
Light clay	Plastic bolus; smooth to touch; slight resistance to shearing; ribbon of 50 to 75 mm	35-40%
Light medium clay	Ribbon of about 75 mm; slight to moderate resistance to ribboning shear	40-45%
Medium clay	Smooth plastic bolus; can be moulded into rods without fracture; moderate resistance to ribboning shear; ribbons 75 mm of longer	45-55%
Medium heavy clay	Ribbons of 75 mm or longer; moderate to firm resistance to ribboning shear	≥50%
Heavy clay	Extremely plastic; firm resistance to ribboning shear; ribbons of 75 mm or longer	≥50%

2.1.2 Laboratory Measurements

Soil texture assessment can be undertaken by two distinct laboratory methodologies:

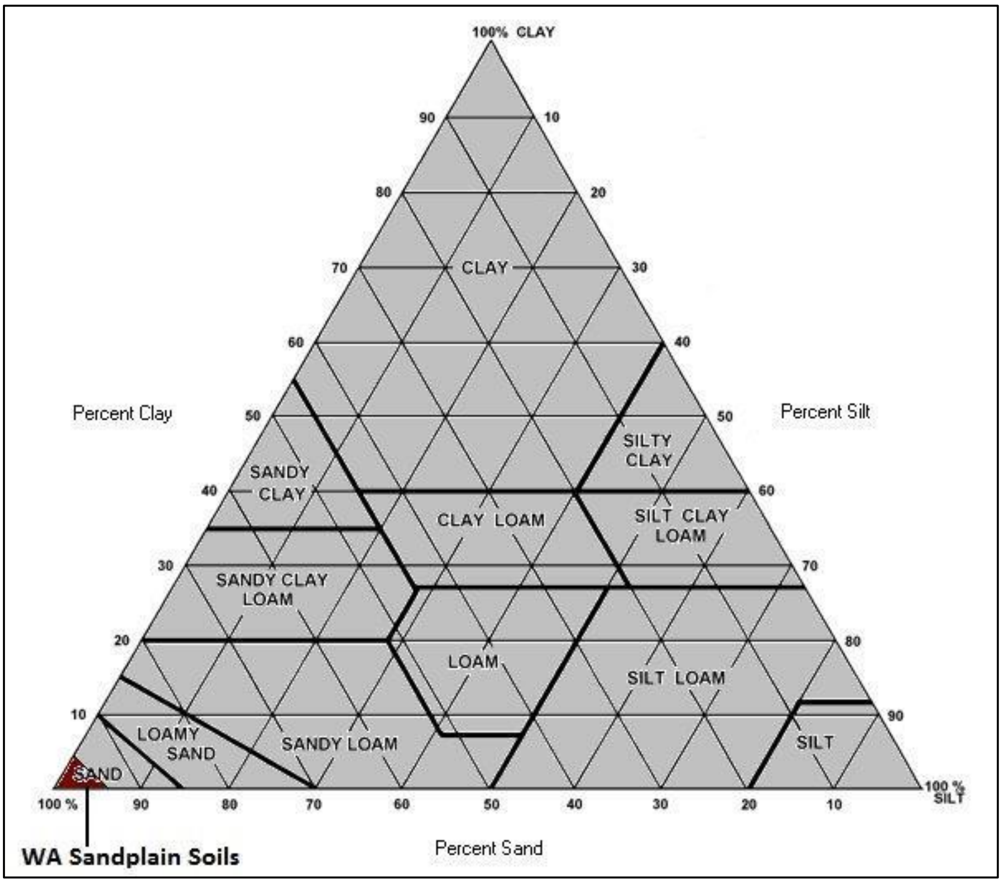
- Particle size determination. This method involves determination of the relative proportions of and, silt and clay sized particles, usually by a combination of sedimentation (hydrometer measurements) and sieving, and classifying the sol texture using the "soil texture triangle" (Figure 1). The method is preferred by land capability and land management professionals.
- Atterberg limits. This methodology, favoured by engineers, classifies soil on the basis of measurements for:
  - Plastic limit, defined as the amount of water added to dry soil to reach a plastic state.
  - Liquid limit, defined as the amount of water added to dry soil to reach a fluid state.
  - Plasticity Index, defined as the difference between the liquid limit (% by weight, dry soil basis) and plastic limit ((% by weight, dry soil basis).

In most cases, field texture grades align well with laboratory based classifications. Poor correlation is occasionally observed for unusual soil types, especially highly saline soils and compacted ferruginous soils (plinthites).

Soil texture information based on laboratory particle size measurements is often used to predict other soil physical characteristics such as hydraulic permeability and water holding capacity (DAFWA 2004). Although laboratory tests are available for direct measurement of these properties, the methodology is comparatively expensive and requires specific sample collection and preservation techniques.

The southwest and arid interior of WA is represented by vast tracts of sandplain, especially dune fields in the Great Sandy and Great Victoria Deserts and coastal plains between Geraldton and Esperance. The sandy nature of these soils in indicated in Figure 1.

Figure 1: Soil Texture Triangle



2.2 DISPERSION POTENTIAL

The structural stability of loams and clay soils can be assessed by a simple field test referred to as the Emerson aggregate test (AS 1289 C8.1 1980). The test involves observation of the behaviour of natural soil aggregates (peds) and subsamples of soil remoulded at field capacity when placed in deionised water. Poorly structured soils, often containing sodic clays (Section 3.3), exhibit low strength when wet, resulting in rapid slaking of aggregates and dispersion of fine clays, resulting in a cloudy halo when placed in deionised water.

The Emerson Aggregate Test provides an Emerson class number ranging from 1 to 8, with Emerson class number 1 indicating soils with weak structure and high potential for clay dispersion, while Emerson class number 8 indicating soils that do not slake, swell or disperse when placed in water. Soil aggregates that slake and disperse readily (Emerson class numbers 1, 2 and 3) indicate weak structure that is easily disrupted by raindrop impact or mechanical disturbance and therefore prone to water erosion, especially on sloping landforms.

The Emerson aggregate test requires submission of a field sample in which natural aggregates have been preserved and not destroyed by crushing and grinding. For this reason, samples provided by reverse circulation drilling are not suitable.

Description of Emersion class numbers are presented in Table A1:2.

Table A1:2: Emerson Aggregate Test Class Numbers

Class Number	Description
Class 1	Dry aggregates slake and completely disperse within several hours.
Class 2	Dry aggregates slake and partly disperse after 24 hours.
Class 3a	Dry aggregates slake but do not disperse. Remoulded soil disperses completely.
Class 3b	Dry aggregates slake but do not disperse. Remoulded soil partly disperses.
Class 4	Dry aggregates slake but do not disperse. Remoulded soil does not disperse. Soil contains free carbonate minerals and / or gypsum.
Class 5	Dry aggregates slake but do not disperse. Remoulded soil does not disperse. No carbonates or gypsum present. 1:5 suspension in water remains dispersed
Class 6	Dry aggregates slake but do not disperse. Remoulded soil does not disperse. No carbonates or gypsum present. 1:5 suspension in water flocculates.
Class 7	Dry aggregates do not slake. Aggregates swell.
Class 8	Dry aggregates do not slake. Aggregates do not swell.

2.3 SOIL WATER RELATIONSHIPS

Physical characteristics of soil, especially drainage and water storage, play critically important roles in the ability of soils to support sustainable plant growth. Well drained soils with low water holding capacity, such as those with deep sandy profiles, retain relatively little water from rainfall, and therefore require a deep profile to support plant growth. Conversely, poorly drained clay soils are subject to water-logging as a consequence of very slow infiltration rates. Many plant species perform poorly in water-logged soils as a consequence of low oxygen availability, or high risk of fungal disease (especially *Phytophora*).

Providing meaningful laboratory results for hydraulic conductivity and water holding capacity in the laboratory is complicated by the nature of the sample submitted for analysis. These tests require an undisturbed core sample to reflect physical characteristics of soil in its natural environment. Other physical and chemical soil tests are usually conducted on a homogenised sample that has been crushed and sieved to break down natural structure and allow removal of coarse fragments. The inherent structure of undisturbed soil, which comprises various micro, meso and macropores determines drainage and water storage characteristics. During a mining project, soil required for waste landform rehabilitation is disturbed at regular intervals by processes including compaction, vegetation clearing, soil harvesting, stockpiling, re-spreading, blending with waste rock and contour ripping – all of which changes these physical soil characteristics.

MBS Environmental does not recommend laboratory testing for these soil properties for reason discussed above (and high costs). Useful information relating to assessment of these soil properties is better provided by field observations by an experienced soil scientist, and by correlation with more easily measured soil properties such as particle size distribution.

2.3.1 Hydraulic Permeability

The rate at which the water moves through a soil profile depends on the soil's permeability (the ease with which water can be transmitted). The permeability of a soil to water is described by its hydraulic conductivity (K), which is usually measured on an intact soil core sample to reflect field conditions. Darcy's Law combines the effects of gradient and hydraulic conductivity to calculate the quantity of water (flux) flowing in a saturated system:

$$\text{Flux rate in a saturated system (mm/h)} = -K_s * (\Delta\psi/\Delta z)$$

where K_s is the saturated hydraulic conductivity,
$\Delta\psi$ is the change in matric potential, and
Δz is the change in distance.

Hydraulic conductivity is highest in soils with a porous structure and where the pores are interconnected (i.e. coarse sands, gravels and structured loam and clay soils). Common values for K_s for soils of different texture are presented in Table A1-3. In general, K_s values greater than 1 x 10^{-6} m/sec (0.1 m/day) represent freely draining conditions, while soils where K_s is less than 1 x 10^{-9} (0.0001 m/day) are almost impermeable.

Table A1-3: K_s Values of Soils of Different Texture Classes

Texture / Soil Type	K_s (m/sec)
Gravel	10^{-2} to 10^{-3}
Coarse sand	10^{-3}
Medium sand	10^{-4}
Fine sand	10^{-5}
Loam	10^{-5} to 10^{-6}
Clay soils	10^{-6} to 10^{-7}
Compacted clays	10^{-7} to 10^{-12}

Provided soils are well graded, contain mainly spherical particles and Low Activity Clays (LAC) clay minerals, it is possible to estimate the K_s of compacted soil using Hazen's formula, which states that K_s (m/s) is related to the 10th percentile particle diameter (d_{10} expressed as mm) by the equation:

$$K_s = C\,(d_{10})^2\text{, where C is a constant between 0.4 and 1.2 (typically 1.0).}$$

2.3.2 Water Holding Capacity

Pore space is that fraction of the soil with potential to be occupied by air and/or water. The *matric potential* (ψ) is the potential produced by capillary and surface forces, or alternatively, the suction pressure by which water is held by the soil. Most soil water is stored in capillaries (or pores) of varying diameter and connectivity. Water stored in very fine (micro) capillaries requires a very high suction force to drain the water. For this reason, water stored in these pores may not be available for plant uptake. On the other hand, water stored in large diameter pores may drain from the soil profile by gravitational forces, and therefore drains beyond the root zone before it can be accessed by plant roots. The amount of water stored in "mesopores", i.e. water that is not tightly by bound in soil, but does not drain rapidly, is termed "Available Water capacity" (AWC).

AWC is defined as the difference between the upper storage limit (USL) and lower storage limit (LSL) per unit depth (v/v) or mass (w/w). AWC is a capacity measure (e.g. 200 mm/m) while *available water* (or available water storage) is a mass or volume measure related to water extraction by plants or to a specified depth (e.g. 75 mm to a depth of 0.5 m). Values of AWC range from 20 mm/m in very coarse sands to more than 250 mm/m in finer textured soils, with the typical range being 50 to 150 mm/m for WA soils. Typical values for soils of different texture classes are presented in Table A1-4 (adapted from DAFWA 2001).

Table A1-4: AWC Values of Soils of Different Texture Classes

Texture / Soil Type	Clay Content (%)	Sand Size Fraction	AWC (mm/m)
Sand	<5	Coarse	~20
		Medium	30-50
		Fine	50-70
Loamy/clayey sands	5-10	Coarse	50-60
		Medium	60-90
		Fine	80-100
Sandy loam	15-20	Coarse	50-220
		Medium	60-170
		Fine	140-220
Light sandy clay loam	15-20	Coarse	50-150
		Medium	90-220
		Fine	100-180
Loam	25	-	100-240
Sandy clay loam	20-30	-	100-190
Clay loam	30-35	-	100-210
Sandy clay	35-40	-	80-150
Clay (non-cracking)	>35	-	90-140
Clay (cracking)	>35	-	~210

3. CHEMICAL PROPERTIES

3.1 PH

As with many measurements on soil, pH values vary with the procedure used. Being a solution measurement, pH of dry soil is effectively meaningless. Soil pH estimates are undertaken in the laboratory by shaking a sample of dry, sieved soil with a standard volume of either deionised water or a dilute salt solution, followed by pH measurement with a calibrated pH meter. pH measurements using deionised water at a sample : solution ratio of 1:5 are widely used for land capability assessment, while use of 0.01 M calcium chloride as the equilibrating solution is preferred for agricultural purposes as this method has been shown by researchers as a superior indicator of phytotoxicity of soil.

The soil pH rating Table adopted for use by MBS Environmental is presented in Table A1-5. The rating table applies to measurements using the 1:5 deionised water extraction method.

Table A1-5: Soil pH Rating Table

pH Range	Rating
1.8 - 3.4	Ultra acid
3.5 - 4.4	Extremely acid
4.5 - 5.0	Very strongly acid
5.1 - 5.5	Strongly acid
5.6 - 6.0	Moderately acid
6.1 - 6.5	Slightly acid
6.6 - 7.3	Circum-neutral
7.4 - 7.8	Slightly alkaline
7.9 - 8.4	Moderately alkaline
8.5 - 9.0	Strongly alkaline
9.1 - 10	Very strongly alkaline
>10	Ultra alkaline

From Rayment and Lyons (2011), adapted from Bruce and Rayment 1982 and USDA 2004.

3.2 ELECTRICAL CONDUCTIVITY AND SALINITY

Measurement of electrical conductivity (EC) of recovered soil porewater, or more commonly either porewater recovered after wetting the sample to saturation or using the 1:5 soil:water extract from pH measurement. EC of the saturation extract is referred to as ECe, while EC of the 1:5 soil:water extract is referred to as EC (1:5).

ECe is considered to be the superior indication of salinity; values of <200 mS/m indicate very low salinity, while values >1,600 indicate high salinity, regardless of the soil type. However, measurement of ECe involves a labour intensive test method and therefore not commonly requested. Salinity risk assessment based on EC (1:5) measurements need to consider the soil type. Table A1-6 presents soil salinity rating classes used by MBS Environmental for sand, loam and clay soil types.

Table A1-6: Salinity Rating Table

Soil Type	Salinity Rating Based on EC (1:5) (mS/m)				
	Nil	Slight	Moderate	High	Extreme
Sand	0 – 15	15 - 25	25 – 50	50 – 100	>100
Loam	0 – 20	20 – 35	35 – 70	70 – 150	>150
Clay	0 - 25	25 - 50	50 - 100	100 - 200	>200

3.3 EXCHANGEABLE CATIONS

The ability of soil to behave as a cation exchange material has been known for more than a century. The major soil cations fall into two distinct groups:

- Basic soil cations comprising Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}.
- Acidic cations comprising H^{+}, Al^{3+} and Mn^{2+}. The sum of these cations is referred to as either "exchangeable" or "titratable" acidity.

At a fixed pH, the sum of all soil cations (when expressed in units of centimoles of positive charge per kilogram, cmol(+)/kg) is constant. This value is referred to as the Cation Exchange Capacity (CEC), which is measured at either pH 7 for circum-neutral soils or pH 8.5 for soils containing free calcium carbonate.

The main soil components contributing to CEC are organic matter and clay minerals. CEC values typically range from <2 cmol(+)/kg) for highly weathered siliceous sands, to 10 cmol(+)/kg) for clay loam soils containing kaolinite as the dominant clay mineral, to greater than 50 cmol(+)/kg) for soils containing clay minerals belonging to the smectite (montmorillonite) or illite group. CEC is an important property for productive agricultural soils as it plays a major role in retention of essential plant nutrients and influencing the physical structure of clay rich soil types.

While most laboratories provide cost-effective methods for measuring soil CEC, it is more common to measure the individual soil cations after extraction with ammonium chloride solution (at either pH 7 or pH 8.5). These procedures are effective at extracting the basic soil cations, but the acidic soil cations are not extracted. For circum-neutral and alkaline soil types, the sum of the concentrations of basic soil cations is very close to the measured CEC. In such cases, the sum of the basic soil cations (expressed in units of cmol(+)/kg)) is referred to as Effective CEC (ECEC).

For acidic soils, the contribution of the acidic soil cations becomes increasingly significant. In such cases, ECEC calculation requires inclusion of the 'exchangeable acidity" component. Alternatively, use of unbuffered 0.1 M barium chloride as the cation displacing extractant allows for measurement of extraction aluminium and manganese, in addition to the basic soil cations. Although exchangeable hydrogen has not been measured, this sum of the basic cations plus exchangeable aluminium and manganese provides an acceptable estimate of ECEC.

The relative proportions of the four basic cations play a major role on the structure of clay rich soil type. Calcium, magnesium and potassium are essential plant nutrients and contribute to good soil structure by allowing effective exchange of air and water into the soil matrix during both wetting and drying cycles. Exchangeable sodium, however, is not conducive to good soil structure and sodium rich (sodic) clays are prone to spontaneous dispersion (Section 2.2), resulting in hard-setting soils when dry and highly erodible soils when saturated.

The acidic soil cations are also undesirable components of a healthy soil, particularly the aluminium component as soluble aluminium is phytotoxic to plants. Elevated concentrations of soluble manganese, which is associated with high concentrations of exchangeable manganese in acidic soils, may also be phytotoxic.

Two important derived parameters from exchangeable cation soil measurements are Base Saturation Percentage (BS%) and Exchangeable Sodium Percentage (ESP). BS% is the sum of the basic soil cations divided by the measured CEC (or ECEC if exchangeable acidity has been measured) and expressed as a percentage. Circum-neutral and alkaline soils have very high BS% values, while acidic soils may have much lower BS% values. BS% provides a better indication of potential soil acidity problems than pH measurements. For example, a soil with a pH of 4.5 and BS% of 30% is likely to be toxic to plants, while a soil with pH of 4.5 and BS% of 80% may not be toxic.

ESP is the exchangeable sodium concentration divided by the measured CEC (or ECEC for circum-neutral and alkaline soils) and expressed as a percentage. ESP values as low as 6% can be responsible for poor structure. ESP values greater than 6% identify sodic soils (Northcote and Skene 1972), which are highly susceptible to structural degradation and erosion.

Table A1-7: Ratings for Exchangeable Cations and Related Parameters

Parameter	Units	Rating		
		Low	Medium	High
CEC	cmol(+)/kg	<5	5 - 15	>15
Calcium	cmol(+)/kg	<5	5 - 10	>10
Magnesium	cmol(+)/kg	<1	1 - 5	>5
Sodium	cmol(+)/kg	<0.3	0.3 – 1.0	>1.0
Potassium	cmol(+)/kg	<0.5	0.5 -2.0	>2.0
Aluminium	cmol(+)/kg	<0.1	0.1 – 1.0	>1.0
Manganese	cmol(+)/kg	<0.02	0.02 – 1.0	>1.0
BS%	%	<20	20 - 60	>60
ESP	%	<6 (non-sodic)	6 – 15 (moderately sodic)	>15 (highly sodic)

Adapted from DAFWA 2004.

3.4 ORGANIC CARBON AND SOIL NITROGEN

Soil organic matter is a critical component of a healthy soil. It plays a major role in maintaining good soil structure, retaining moisture and nutrients and a source of food and energy for soil microbial activity.

Soil organic matter contains 45% to 55% carbon, with most of the balance being oxygen, hydrogen and nitrogen, with lower but still important concentrations of phosphorus and sulfur. There are two reliable laboratory methods for measuring soil organic carbon, which is a very good indicator of soil organic matter content:

- Wet oxidation, with the Walkley and Black method (Walkley and Black 1934) being the most common variation.
- Combustion, occasionally referred to as LECO® Total Organic Carbon.

By international standards, WA soils contain low concentrations of organic carbon. Organic carbon content is dependent upon soil texture and climate, with sandy soils and soil from tropical northern WA and arid central WA containing lower carbon contents (typically <1% in topsoil) compared to clay and loam soils from the temperature southwest corner of WA.

Soil organic matter is also responsible for most of the total nitrogen content of soil, with the remainder (typically <5% of total nitrogen) being in the mineral ammonium (NH_4^+) and nitrate (NO_3^-) forms. Mineralisation of soil organic matter by microbial activity can convert some of this organic nitrogen into mineral nitrogen, which is then available for uptake by plants. However, the amount of nitrogen that can be released by mineralisation is variable and determined largely by the ratio of organic carbon to nitrogen (C/N ratio). For soils with low C/N ratios, mineralisation of soil organic matter releases substantial amounts of mineral nitrogen. Alternatively, microbes breaking down carbon rich soil organic matter require more nitrogen than is available from organic matter, resulting in removal of mineral forms of nitrogen naturally present in soil. This is known as "nitrogen drawdown" and is common when carbon rich woody mulch or leaf litter is added to soil as a soil conditioner or water retentive mulch. Ratings descriptions for organic carbon, total nitrogen and C/N ratio are presented in Table A1-8.

Table A1-8: Ratings Table for Organic Carbon, Total Nitrogen and C/N Ratio

Parameter	Rating		
	Low	Medium	High
Organic carbon, A1 horizon, northern and eastern WA	<0.5%	0.5 – 1.5%	>1.5%
Organic carbon, A2 and B horizon, northern and eastern WA	<0.05%	0.05 – 0.3%	>0.3%
Organic carbon, A1 horizon, southwest WA	<1%	1 – 2%	>2%
Organic carbon, A2 and B horizon, southwest WA	<0.1%	0.1 – 0.5%	>0.5%
Total nitrogen, A1 horizon, northern and eastern WA	<0.05%	0.05 – 0.3%	>0.3%
Total nitrogen, A1 horizon, southwest WA	<0.1	0.1 – 0.5%	>0.5%
Total nitrogen, A2 and B horizons	Generally not measured		
C/N ratio	<10	10 - 16	>16

Adapted from DAFWA 2004.

3.5 BIOAVAILABLE NUTRIENTS

Soil testing is widely used for diagnosing potential nutrient deficiencies and imbalances in soils used for agriculture. Large fertiliser companies often provide cost-effective soil testing packages that provide fertiliser recommendations based on soil test results.

The decision support systems required for provision of reliable fertiliser recommendations based on soil test require a large volume of calibration data based on field trials conducted over many years for different crop plants and on different soil types. The soil tests used also vary for different nutrients as summarised below:

- Phosphorus and potassium use 0.5 M sodium bicarbonate.
- Sulfur uses 0.25 M potassium chloride.
- Boron uses extraction with hot 0.01 M calcium chloride solution.
- Multi-element test for micro-nutrients (Cu, Fe, Mn and Zn) uses 0.005 M DTPA solution.

With the exception of phosphorus (Handreck 1997a and 1997b), there is very little published information available that relates nutrient soil test results with the health of Australian native plants. Also, native plant establishment on disturbed WA soil types is considered to be limited mainly of constraints such as low water holding capacity, salinity or elevated acidity/alkalinity rather than nutrient deficiencies or imbalances. Even in circumstances where nutrient deficiency has been identified as a potential limitation for rehabilitating disturbed sites with WA native plants, land managers are often reluctant to apply additional nutrients in the form of organic or chemical fertilisers on the potential for promoting weed establishment.

MBS Environmental has adopted the Mehlich 3 multi-element soil test methodology (Mehlich 1984) as a cost-effective alternative method to the suite of nutrient soil tests listed above to assess mine site soils for potential nutrient deficiencies, toxicity or imbalance that may affect revegetation outcomes. Concentrations assigned to low, typical and elevated ranges presented in Table A1-9 were derived from the following information:

- Correlations between calibrated single nutrient soil test values (specific for each nutrient) and plant response, typically crop plants under glasshouse or controlled field experiments (Peverill et al. 1999).
- Correlations between Mehlich 3 and calibrated single nutrient soil test results (Walton and Allen 2004). Most of the single nutrient tests correlate well the Mehlich 3 test for acidic, neutral and slightly alkaline (but non-calcareous) WA soil types.
- Results for surface samples analysed from DAFWA and DPaW soil surveys (Section 1.2) and previous mine site surveys conducted by MBS Environmental.

The "Low" rating corresponds approximately to the lowest fifth percentile of unfertilised WA surface soil types and indicates conditions that may result in deficiency to plants not adapted to very low nutrient concentrations in soils. These soil types are often highly weathered siliceous sands in moderate to high rainfall areas in the southwest of WA.

The "Elevated" rating corresponds approximately to the 95th percentile of unfertilised WA surface soil types and may indicate conditions resulting in either nutrient imbalances or toxicities to plant not adapted to high nutrient (especially micronutrients such as boron) concentrations.

Table A1-9: Ratings Table for Bio-available Nutrients (mg/kg), Mehlich 3 Test

Nutrient	Rating		
	Low	Typical Range	Elevated
Phosphorus	<2	2 - 10	>10
Potassium	<10	10 - 300	>300
Calcium	<50	50 – 5,000	>5,000
Magnesium	<20	20 – 2,000	>2,000
Sulfur	<5	5 - 200	>200
Boron	<0.1	0.1 - 2	>2
Copper	<0.1	0.1 - 5	>5
Iron	<10	10 – 200	>200
Manganese	<5	5 - 100	>100
Molybdenum	<0.01	0.01 – 0.05	>0.05
Zinc	<0.2	0.2 - 5	>5

4. REFERENCES

Bruce, R. C. and Rayment, G. E. 1982. *Analytical methods and interpretations used by the Agricultural Chemistry Branch for soil and land use surveys. Bulletin QB 82004.* Brisbane: Queensland Department of Primary Industries.

Department of Agriculture and Food Western Australia (DAFWA). 2001. *Soil Guide - A Handbook for Understanding and Managing Agricultural Soils.* Bulletin No. 4343. Ed. G. Moore. Perth: DAFWA.

Department of Agriculture and Food Western Australia (DAFWA). 2004. *Soil-Landscape Mapping in South-Western Australia, Overview of Methodology and Outputs. Resource Management Technical Report 280.* Perth: DAFWA.

Department of Agriculture and Food Western Australia (DAFWA). 2005. *Land Evaluation Standards for Land Resource Mapping (assessing land qualities and determining land capability in south-western Australia*. *Resource Management Technical Report 298.* Perth: DAFWA.

Department of Agriculture and Food Western Australia (DAFWA). 2008. *Understanding Soil Analysis. Resource Management Technical Report 327.* Perth: DAFWA.

George, A. S., McKenzie, N. L. and Doughty, P. 2009. *A Biodiversity Survey of the Pilbara Region of Western Australia, 2002-2007. Records of the Western Australian Museum, Supplement No 78.* Perth: Western Australian Museum.

Handreck, K. A. 1997a. Phosphorus requirements of Australian native plants. *Australian Journal of Soil Research* 35(2): 241 – 290.

Handreck, K. 1997b. Phosphorus needs of some Australian native plants. *Society for growing Australian Plants Journal* 14: 8-14.

Hazelton, P. and Murphy, B. 2007. *Interpreting Soil Test Results, What Do All the Numbers Mean?* Collingwood: CSIRO Publishing.

McArthur, W. M. 1991. *Reference soils of south-western Australia*. Perth: WA Department of Agriculture on behalf of the Australian Society of Soil Science Incorporated (WA Branch).

McDonald, R. C., Isbell, R. F., Speight, J. G., Walker, J. and Hopkins, M. S. 1990. *Australian soil and land survey field handbook*, 2nd ed. Melbourne: Inkata Press.

Mehlich, A. 1984. Mehlich 3 Soil Test Extractant: A Modification of Mehlich 2. *Communications of Soil Science and Plant Analysis* 15: 1409-1416.

Meissner, R and Caruso, Y. 2008. Flora and vegetation of banded iron formations of the Yilgarn Craton: Koolanooka and Perenjori Hills. *Conservation Science W. Aust.* 7(1): 73-88.

National Environment Protection Council (NEPC). 2013. *National Environment Protection (Assessment of Site Contamination) Measure*. *Guideline on Laboratory Analysis of Potentially Contaminated Soil. Schedule B3.* Canberra: NEPC.

Northcote, K. H. and Skene, J. K. M. 1972. *Australian soils with saline and sodic properties. CSIRO Australia Soil Publication No. 27*. Melbourne: CSIRO.

Peverill, K.I., Sparrow, L.A. and Reuter, D.J. 1999. *Soil Analysis: An Interpretation Manual.* Melbourne: CSIRO Publishing.

Rayment, G. and Lyons, D. 2011. *Soil Chemical Methods – Australasia.* Collingwood: CSIRO Publishing.

Soilquality. 2016. http://www.soilquality.org.au/ (accessed 10 June 2015).

Standards Australia. 1980. *AS 1289 C8.1: Determination of Emerson Class Number of a Soil.* Strathfield: Standards Australia International.

Standards Australia. 2000. *AS 1289.0-2000: Methods for testing soils for engineering purposes*. 2nd ed. Strathfield: Standards Australia International.

US Department of Agriculture (USDA). 2004. Reaction, Soil (pH) (618.47). In *Soil survey Investigations Report No 42, Soil Survey Methods Manual,* Version 4.0. Lincoln: USDA.

Walkley, A. and Black, I.M. 1934. *An Examination of the Degtjareff Method for Determining Soil Organic Matter, and a Proposed Modification of the Chromic Acid Titration Method*. Soil Science. 37: 29-38.

Walton, K and Allen, D. 2004. *Mehlich No. 3 Soil Test - The Western Australian Experience*. SuperSoil 2004: 3rd Australian New Zealand Soils Conference, 5 – 9 December 2004, University of Sydney, Australia.

APPENDIX 2: SOIL PROFILE DESCRIPTIONS

Sample Location and Details

Site	NSQPIT1	**GPS Coordinates**	51	437213.08	mE	Page 1 of 18
				6668467.98	mN	
Locality	Pit	**Date**	9-Oct-23		**Time**	13:50

Vegetation and Landscape

Slope & Elevation	Flat
Landscape	Flat plains

Soil / Soil Profile Annotation

Profile	Description
0 - 0.2 m	LOAMY SAND. Red/Brown. Some pebbles.
0.2 - 1.2 m	SANDY GRAVEL. Compacted calcrete with some brown sand.
Sample Register	NSQPIT1-1

Photographs

Photo 1:

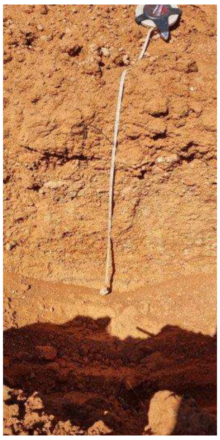


Photo 2:

<table>
<tr><th colspan="7">Sample Location and Details</th></tr>
<tr><td rowspan="2">Site</td><td rowspan="2">NSQPIT2</td><td rowspan="2">GPS Coordinates</td><td rowspan="2">51</td><td>437109</td><td>mE</td><td rowspan="2">Page 2 of 18</td></tr>
<tr><td>6668861</td><td>mN</td></tr>
<tr><td>Locality</td><td>Pit</td><td>Date</td><td colspan="2">9-Oct-23</td><td>Time</td><td>13:10</td></tr>
</table>

<table>
<tr><th colspan="2">Vegetation and Landscape</th></tr>
<tr><td>Slope & Elevation</td><td>Flat</td></tr>
<tr><td>Landscape</td><td>Flat plains</td></tr>
<tr><th colspan="2">Soil / Soil Profile Annotation</th></tr>
<tr><td>Profile</td><td>Description</td></tr>
<tr><td>0 - 0.1 m</td><td>LOAMY SAND. Yellow/Brown. Some pebbles and gravels</td></tr>
<tr><td>0.1 - 1.2 m</td><td>Compacted GRAVEL. Calcrete gravels with some iron stained (siderite) calcrete and brown sand.</td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td>Sample Register</td><td>NSQPIT2-1</td></tr>
</table>

Photographs

Photo 1:

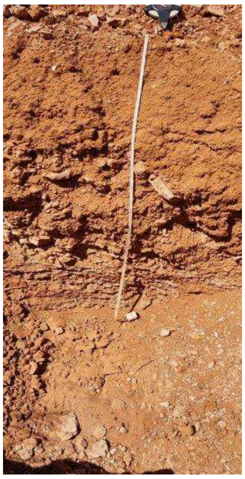


Photo 2:

<table>
<tr><th colspan="8">Sample Location and Details</th></tr>
<tr><td rowspan="2">Site</td><td rowspan="2">NSQPIT3</td><td rowspan="2">GPS Coordinates</td><td rowspan="2">51</td><td>437532.758</td><td>mE</td><td rowspan="2" colspan="2"></td></tr>
<tr><td>6668808.7</td><td>mN</td></tr>
<tr><td>Locality</td><td>Pit</td><td>Date</td><td colspan="3">9-Oct-23</td><td>Time</td><td>13:30</td></tr>
<tr><th colspan="8">Vegetation and Landscape</th></tr>
<tr><td colspan="2">Slope & Elevation</td><td colspan="6">Flat</td></tr>
<tr><td colspan="2">Landscape</td><td colspan="6">Flat plains</td></tr>
<tr><th colspan="8">Soil / Soil Profile Annotation</th></tr>
<tr><td colspan="2">Profile</td><td colspan="6">Description</td></tr>
<tr><td colspan="2">0 - 0.3 m</td><td colspan="6">LOAMY SAND. Red/Brown. Some gravels.</td></tr>
<tr><td colspan="2">0.3 - 2 m</td><td colspan="6">SANDY GRAVEL. Compacted gravels of calcrete and iron stained (siderite) calcrete with some brown sand.</td></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td colspan="2">Sample Register</td><td colspan="6">NSQPIT3-1</td></tr>
<tr><th colspan="8">Photographs</th></tr>
</table>

Photo 1:

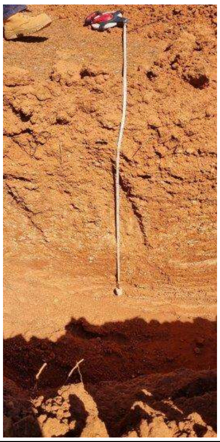


Photo 2:

Sample Location and Details						
Site	NSQPIT4	**GPS Coordinates**	51	437232.3	mE	Page 4 of 18
				6669143	mN	
Locality	Pit	**Date**	9-Oct-23		**Time**	12:20

Vegetation and Landscape	
Slope & Elevation	Flat
Landscape	Flat plains

Soil / Soil Profile Annotation	
Profile	Description
0 - 0.1 m	LOAMY SAND. Red/Brown. Some pebbles and cobbles
0.1 - 1.3 m	Compacted GRAVELLY SAND. Brown and white. Compacted calcrete and some iron stained (siderite) calcrete
Sample Register	NSQPIT4-1

Photographs

Photo 1:

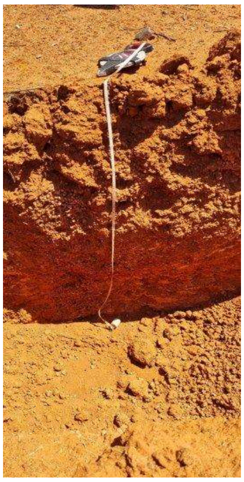


Photo 2:

Sample Location and Details							
Site	NSQPIT5	**GPS Coordinates**	0	437335.856	mE	Page 5 of 18
				6668913.296	mN	
Locality	Pit	**Date**	10-Oct-23		**Time**	13:20

Vegetation and Landscape	
Slope & Elevation	Flat
Landscape	Flat plains

Soil / Soil Profile Annotation	
Profile	Description
0 - 0.1	LOAMY SAND. Red/Brown. Some gravels and pebbles
0.1 - 0.7	Compacted GRAVEL. Calcrete with some brown sand.
Sample Register	NSQPIT5-1

Photographs

Photo 1:

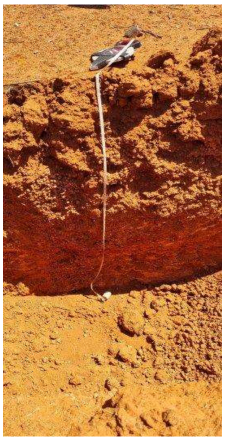


Photo 2:

Sample Location and Details							
Site	NSQWRD1	**GPS Coordinates**	51	437693.5	mE		Page 6 of 18
				6669269	mN		
Locality	WRD	**Date**	9-Oct-23			**Time**	11:30

Vegetation and Landscape	
Slope & Elevation	Flat
Landscape	Flat plains

Soil / Soil Profile Annotation	
Profile	Description
0 - 0.1 m	LOAMY SAND. Red/Brown. Some gravels.
0.1 - 0.6 m	GRAVELLY SAND. Light brown. Calcrete gravels.
0.6 - 1.2 m	Compacted calcrete and iron stained (siderite) calcrete layers. White / Red.
Sample Register	NSQWRD1-1 , NSQWRD1-2

Photographs

Photo 1:

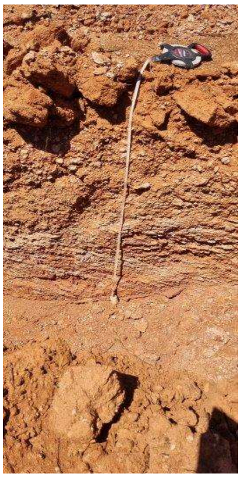


Photo 2:

Sample Location and Details

Site	NSQWRD2	**GPS Coordinates**	51	437071.6	mE	Page 7 of 18
				6669748	mN	
Locality	WRD	**Date**	9-Oct-23		**Time**	12:00

Vegetation and Landscape

Slope & Elevation	Flat
Landscape	Flat plains

Soil / Soil Profile Annotation

Profile	Description
0 - 0.25 m	LOAMY SAND. Red/Brown. Some gravels and pebbles
0.25 - 1 m	GRAVELLY SAND. Brown. Some compacted gravels and boulders
Sample Register	NSQWRD2-1 , NSQWRD2-2

Photographs

Photo 1:

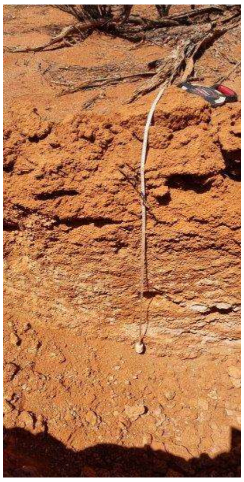


Photo 2:

Sample Location and Details							
Site	NSQWRD4	**GPS Coordinates**	51	438285.2	mE		Page 8 of 18
				6669507	mN		
Locality	WRD	**Date**	9-Oct-23		**Time**		11:40

Vegetation and Landscape	
Slope & Elevation	Flat
Landscape	Flat plains

Soil / Soil Profile Annotation	
Profile	Description
0 - 0.4 m	LOAMY SAND. Red/Brown. Some small pebbles
0.4 - 1.4 m	GRAVELLY SAND. Brown. Compacted calcrete and iron stained (siderite) calcrete.
Sample Register	NSQWRD4-1 , NSQWRD4-2

Photographs

Photo 1:

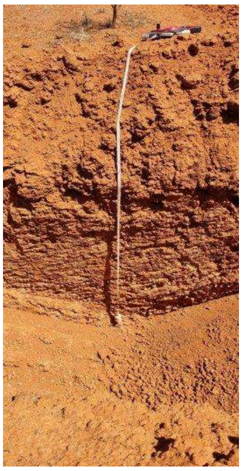


Photo 2:

Sample Location and Details							
Site	NSQWRD5	**GPS Coordinates**	51	436808.4	mE		Page 9 of 18
				6669439	mN		
Locality	WRD	**Date**	9-Oct-23		**Time**	Not Provided	

Vegetation and Landscape	
Slope & Elevation	Flat
Landscape	Flat plains

Soil / Soil Profile Annotation	
Profile	Description
0 - 0.3 m	LOAMY SAND. Red/Brown. Some pebbles
0.3 - 1 m	SANDY GRAVEL. Calcrete with brown sand.
Sample Register	NSQWRD5-1

Photographs

Photo 1:

Photo 2:

Sample Location and Details							
Site	NSQWS1	**GPS Coordinates**	51	438390.9	mE	Page 10 of 18	
				6668938	mN		
Locality	Workshop	**Date**	9-Oct-23		**Time**	11:20	

Vegetation and Landscape	
Slope & Elevation	Flat
Landscape	Flat Plains

Soil / Soil Profile Annotation	
Profile	Description
0 - 0.3 m	LOAMY SAND. Red/Brown. Some small pebbles
Sample Register	NSQWS1-1

Photographs

Photo 1:

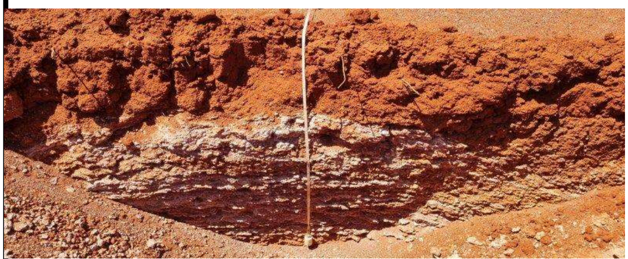


Photo 2:

Sample Location and Details							
Site	NSQOFF2	**GPS Coordinates**	51	437823.2	mE		Page 11 of 18
				6667991	mN		
Locality	Office	**Date**	9-Oct-23		**Time**		13:40

Vegetation and Landscape	
Slope & Elevation	Flat
Landscape	Flat plains

Soil / Soil Profile Annotation	
Profile	Description
0 - 0.4 m	LOAMY SAND. Red/Brown. Some pebbles.
Sample Register	NSQOFF2-1

Photographs

Photo 1:

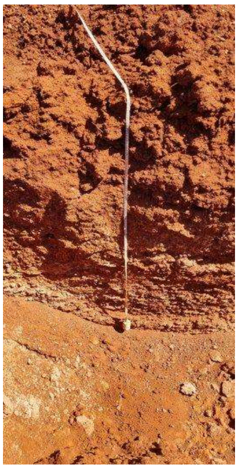


Photo 2:

Sample Location and Details							
Site	NSQEXM1	**GPS Coordinates**	51	439557.2	mE		Page 12 of 18
				6668751	mN		
Locality	Explosives Magazine	**Date**	9-Oct-23		**Time**	10:50	

Vegetation and Landscape	
Slope & Elevation	Flat
Landscape	Flat plains

Soil / Soil Profile Annotation	
Profile	Description
0 - 0.2 m	LOAMY SAND. Red/Brown. Some gravels.
0.2 - 1 m	SANDY GRAVEL. White / Brown. Calcrete and sand.
1 - 2 m	CLAYEY SAND. Brown. Compacted.
Sample Register	NSQEXM-1 , NSQEXM-2

Photographs

Photo 1:

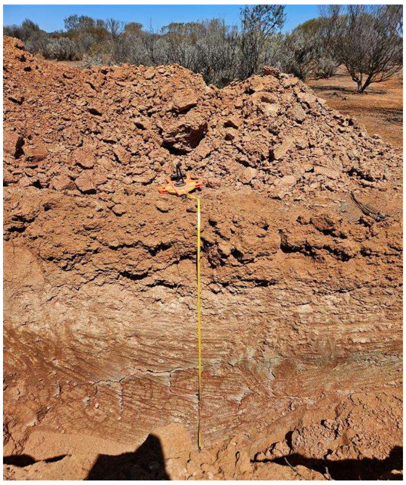


Photo 2:

Sample Location and Details							
Site	NSQDMREF1	**GPS Coordinates**	51	436616	mE	Page 13 of 18	
				6670143	mN		
Locality	Reference	**Date**	9-Oct-23		**Time**	12:10	

Vegetation and Landscape	
Slope & Elevation	Flat
Landscape	Flat plains

Soil / Soil Profile Annotation	
Profile	Description
0 - 0.3 m	LOAMY SAND. Red/Brown. Some cobbles
0.3 - 1.2 m	Compacted calcrete and iron stained (siderite) calcrete layers
Sample Register	NSQDMREF1-1

Photographs

Photo 1:

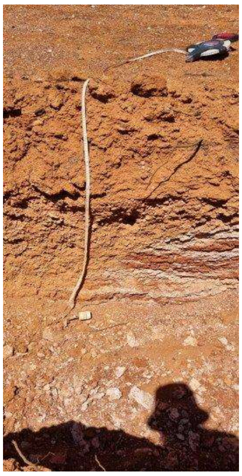


Photo 2:

Sample Location and Details							
Site	NSQDMREF2	**GPS Coordinates**	51	436069.9	mE		Page 14 of 18
				6669319	mN		
Locality	Reference	**Date**	9-Oct-23		**Time**	14:00	

Vegetation and Landscape	
Slope & Elevation	Flat
Landscape	Flat plains

Soil / Soil Profile Annotation	
Profile	Description
0 - 0.3 m	LOAMY SAND. Dark Red/brown. Some pebbles.
Sample Register	NSQDMREF2-1

Photographs

Photo 1:

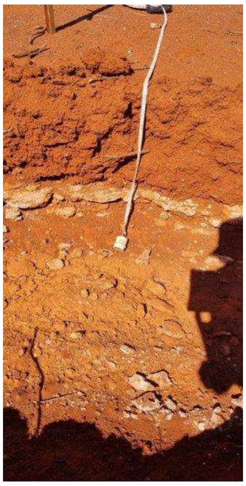


Photo 2:

Sample Location and Details						
Site	NSQDMREF3	**GPS Coordinates**	51	437232.2	mE	Page 15 of 18
				6667085	mN	
Locality	Reference	**Date**	9-Oct-23		**Time**	13:55

Vegetation and Landscape	
Slope & Elevation	Flat
Landscape	Flat plains

Soil / Soil Profile Annotation	
Profile	Description
0 - 0.5 m	LOAMY SAND. Red/Brown. Some pebbles
0.5 m +	Refusal - Calcrete
Sample Register	NSQDMREF3-1

Photographs

Photo 1:

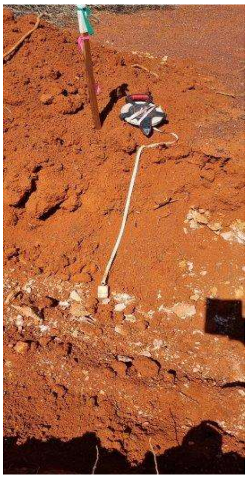


Photo 2:

Sample Location and Details						
Site	NSQMOREF1	**GPS Coordinates**	51	435739.5	mE	Page 16 of 18
				6666781	mN	
Locality	Reference	**Date**	9-Oct-23		**Time**	14:20

Vegetation and Landscape	
Slope & Elevation	Flat
Landscape	Flat plains

Soil / Soil Profile Annotation	
Profile	Description
0 - 0.5 m	LOAMY SAND. Red/Brown. Semi-compacted. Some pebbles.
0.5 - 2 m	Compacted GRAVEL. Laterite with some brown sand.
Sample Register	NSQMOREF1

Photographs

Photo 1:

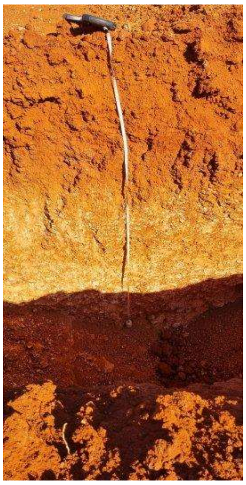


Photo 2:

Sample Location and Details								
Site	NSQGUREF1	**GPS Coordinates**	51	438907.895	mE		Page 17 of 18	
				6668291.878	mN			
Locality	Reference	**Date**	9-Oct-23			**Time**	11:10	

Vegetation and Landscape	
Slope & Elevation	Flat
Landscape	Flat plains

Soil / Soil Profile Annotation	
Profile	Description
0 - 0.3 m	LOAMY SAND. Red/Brown.
0.3 - 1.6 m	SAND. Brown. Compacted with calcrete gravels.
Sample Register	NSQGUREF1-1 , NSQGUREF1-2

Photographs

Photo 1:

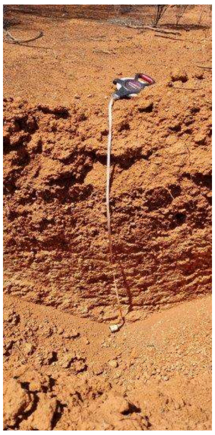


Photo 2:

Sample Location and Details							
Site	NSQKIREF1	**GPS Coordinates**	51	435238.561	mE	Page 18 of 18
				6664765.288	mN	
Locality	Reference	**Date**	10-Oct-23		**Time**	10:00

Vegetation and Landscape	
Slope & Elevation	Flat
Landscape	Flat plains

Soil / Soil Profile Annotation	
Profile	Description
0 - 0.4 m	LOAMY SAND. Red/Brown. Some pebbles
0.4 - 0.8 m	Compacted calcrete.
Sample Register	NSQKIREF1-1

Photographs

Photo 1:

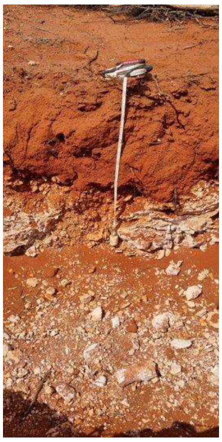


Photo 2:

APPENDIX 3: COLLATED ANALYTICAL RESULTS

Table A3-1: Gravel Content (%)

Sample ID	Stones (>2mm)
	%
NSQWRD2-1	2.9
NSQWRD2-2	13.1
NSQDMREF1-1	3.4
NSQPIT4-1	3.3
NSQPIT2-1	1.9
NSQPIT5-1	5.6
NSQEXM-1	3.4
NSQEXM-2	4.8
NSQGUREF1-1	2.9
NSQGUREF1-2	16.1
NSQWS1-1	3.5
NSQWRD1-1	4.8
NSQWRD1-2	15.5
NSQWRD4-1	3.1
NSQWRD4-2	8.8
NSQPIT3-1	2.1
NSQOFF2-1	3.2
NSQPIT1-1	1.7
NSQDMREF3-1	12.5
NSQDMREF2-1	2.5
NSQKIREF1-1	0.6
NSQWRD5-1	0.5
NSQMOREF1	2

Table A3-2: Particle Size Distribution (%) and Emerson Class

Sample ID	Sand.	Silt.	Clay.	Emerson Class
	%			
NSQWRD2-1	64	13	23	4
NSQPIT4-1	63.5	13.5	23	4
NSQPIT2-1	57	17	26	4
NSQEXM-1	64	15	21	4
NSQEXM-2	43.5	19	37.5	-
NSQWRD1-1	69	14	17	4
NSQWRD1-2	59	15	26	-
NSQWRD4-1	66	13	21	4
NSQOFF2-1	61	15	24	2
NSQDMREF2-1	71	10	19	3

Table A3-3: pH and EC

Sample ID	EC	pH
	mS/m	SU
NSQWRD2-1	11	8.6
NSQWRD2-2	13	8.9
NSQDMREF1-1	20	8.8
NSQPIT4-1	13	8.8
NSQPIT2-1	63	8.3
NSQPIT5-1	10	9.1
NSQEXM-1	210	8.5
NSQEXM-2	280	8.9
NSQGUREF1-1	14	8.7
NSQGUREF1-2	23	9.1
NSQWS1-1	3	7.7
NSQWRD1-1	10	8.8
NSQWRD1-2	13	8.9
NSQWRD4-1	10	8.8
NSQWRD4-2	36	9.2
NSQPIT3-1	12	8.8
NSQOFF2-1	14	8.8
NSQPIT1-1	13	9.2
NSQDMREF3-1	3	6.9
NSQDMREF2-1	20	7.0
NSQKIREF1-1	3	6.8
NSQWRD5-1	9	8.3
NSQMOREF1	4	8.1

Table A3-4: Effective Cation Exchange Capacity

Sample ID	Ca	K	Mg	Na	ECEC	ESP
	cmol(+)/kg					%
NSQWRD2-1	13	0.5	1.4	0.2	15	1
NSQDMREF1-1	13	0.9	1.5	0.5	16	3
NSQPIT4-1	12	1.0	1.2	0.3	14	2
NSQPIT2-1	19	1.2	1.3	0.3	22	1
NSQEXM-1	7	0.9	3.8	0.2	12	2
NSQEXM-2	3	0.4	2.9	0.2	6	4
NSQGUREF1-1	13	1.1	2.4	0.2	17	1
NSQGUREF1-2	7	0.7	3.8	0.2	11	2
NSQWRD1-1	13	1.0	1.5	0.2	16	1
NSQWRD1-2	11	0.4	1.9	0.6	14	4
NSQWRD4-1	12	1.0	1.9	0.2	15	1
NSQOFF2-1	18	1.2	1.8	0.5	21	2
NSQDMREF3-1	4	0.4	1.2	0.2	6	3
NSQDMREF2-1	7	0.6	1.3	0.6	10	6
NSQKIREF1-1	3	0.3	0.7	0.2	4	4
NSQMOREF1	8	0.7	1.8	0.2	11	1
Low	<5	<0.5	<1	<0.3	<5	<6
Typical	5-10	0.5-2	1-5	0.3-1	5-15	6-15
High	>10	>2	>5	>1	>15	>15

Table A3-5: Nutrient Content

Sample ID	OrgC	N	C:N
	%		Ratio
NSQWRD2-1	0.48	0.045	11
NSQPIT4-1	0.28	0.034	8
NSQPIT2-1	0.54	0.051	11
NSQEXM-1	0.45	0.045	10
NSQWS1-1	0.2	0.021	10
NSQWRD1-1	0.83	0.071	12
NSQWRD4-1	0.29	0.032	9
NSQOFF2-1	0.32	0.038	8
Low	<0.5	<0.05	<10
Typical	0.5-1.5	0.05-0.3	10-16
High	>1.5	>0.3	>16

Table A3-6: Mehlich Extractable Nutrients, Trace Elements and Contaminants

Sample ID	Al	As	B	Ca	Cd	Co	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Se	Zn
	mg/kg																		
NSQWRD2-1	250	0.1	0.9	>5500	0.02	1.5	5.2	17	200	260	65	<0.01	44	1.3	6	0.9	11	0.1	0.4
NSQPIT4-1	210	0.2	0.8	>5500	0.02	1.1	5.2	13	380	230	49	<0.01	65	1.0	7	0.9	18	<0.1	0.3
NSQPIT2-1	380	<0.1	1.3	>5500	0.02	1.5	5.4	17	270	270	69	<0.01	280	1.2	8	0.9	96	0.2	0.3
NSQEXM-1	260	<0.1	2.8	>5500	0.05	0.7	2.8	32	490	>1000	27	<0.01	>1000	2.4	8	0.5	69	<0.1	0.6
NSQWS1-1	>550	<0.1	0.4	2900	<0.01	3.2	3.2	29	280	500	150	<0.01	49	3.3	1	0.9	2	<0.1	0.2
NSQWRD1-1	>550	<0.1	1.4	>5500	0.02	1.4	3.4	25	390	310	78	<0.01	40	0.7	16	0.7	11	0.1	1.2
NSQWRD4-1	390	0.2	1	>5500	<0.01	2.4	4.8	20	400	370	81	<0.01	53	2.1	4	0.9	7	<0.1	0.2
NSQOFF2-1	>550	0.1	1.1	>5500	0.01	3.5	4.3	21	430	310	120	<0.01	110	1.8	3	0.9	9	<0.1	0.4
Low	-	-	<0.1	<50	-	<1	<0.1	<10	<10	<20	<5	<0.01	-	<1	<2	-	<5	-	<0.2
Typical	-	-	0.1-2	50-5000	-	1-10	0.1-5	10-200	10-300	20-2000	5-100	0.01 - 0.05	-	1-20	2-10	-	5-200	-	0.2-5
High	>500	>5	>2	>5000	>1	>10	>5	>200	>300	>2000	>100	>0.05	180	>20	>10	>35	>200	>1.5	>5

Table A3-7: Baseline Metals and Metalloid Concentrations

Sample ID	Ag	As	Cd	Cr	Cu	Hg	Mn	Ni	Pb	Sb	Se	Zn
	mg/kg											
NSQWRD2-1	<0.05	4	0.07	120	30	0.02	280	36	10	0.08	0.2	27
NSQDMREF1-1	<0.05	4	0.08	130	28	<0.02	280	33	12	0.09	0.2	28
NSQPIT4-1	<0.05	4	0.07	110	31	<0.02	310	36	10	0.09	0.2	29
NSQPIT2-1	<0.05	4	0.07	120	35	<0.02	330	45	9	0.10	0.2	36
NSQEXM-1	<0.05	14	0.07	690	32	<0.02	560	210	9	0.13	0.4	41
NSQGUREF1-1	<0.05	9	0.07	330	36	<0.02	370	120	10	0.11	0.2	34
NSQGUREF1-2	<0.05	10	0.06	240	29	<0.02	190	81	6	<0.05	0.2	21
NSQWRD1-1	<0.05	4	0.06	120	24	<0.02	290	39	8	<0.05	0.1	34
NSQWRD4-1	0.06	10	0.10	330	60	<0.02	650	98	21	0.06	0.3	61
NSQOFF2-1	<0.05	5	<0.05	180	21	<0.02	310	34	11	0.05	0.4	21
NSQDMREF3-1	<0.05	4	<0.05	160	19	<0.02	290	33	10	<0.05	0.3	21
NSQDMREF2-1	<0.05	3	<0.05	98	10	<0.02	75	15	5	0.07	0.2	8
NSQKIREF1-1	<0.05	3	<0.05	100	11	<0.02	82	19	5	0.06	0.2	10
NSQMOREF1	<0.05	3	<0.05	120	19	<0.02	230	31	9	0.06	0.2	20
NEPM (2013)	N/G	100	3*	470	150	1*	500*	80	1,100	N/G	N/G	200
Ambient background concentration (80th percentile)	0.06	9	0.07	276	33	0.02	346	88	10	0.10	0.3	35

* DEC 2010 concentration used in the absence of NEPM 2013 data

APPENDIX 4: LABORATORY REPORTS

GOVERNMENT OF
WESTERN AUSTRALIA

ChemCentre
Scientific Services Division
Report of Examination

Resources and Chemistry Precinct
Cnr Manning Road and Townsing Drive
Bentley
WA 6102
T +61 8 9422 9800
F +61 8 9422 9801
www.chemcentre.wa.gov.au
ABN 40 991 885 705

Purchase Order: NSRQMS
Your Reference:
ChemCentre Reference: 23S1363 R0

MBS Environmental
4 Cook St
West Perth WA 6005

Attention: Louise Crawley

Final Report on 23 samples of soil received on 13/10/2023

LAB ID	Client ID and Description
23S1363 / 001	NSQWRD2-1
23S1363 / 002	NSQWRD2-2
23S1363 / 003	NSQDMREF1-1
23S1363 / 004	NSQPIT4-1
23S1363 / 005	NSQPIT2-1
23S1363 / 006	NSQPIT5-1
23S1363 / 007	NSQEXM-1
23S1363 / 008	NSQEXM-2
23S1363 / 009	NSQGUREF1-1
23S1363 / 010	NSQGUREF1-2
23S1363 / 011	NSQWS1-1
23S1363 / 012	NSQWRD1-1
23S1363 / 013	NSQWRD1-2
23S1363 / 014	NSQWRD4-1
23S1363 / 015	NSQWRD4-2
23S1363 / 016	NSQPIT3-1
23S1363 / 017	NSQOFF2-1
23S1363 / 018	NSQPIT1-1
23S1363 / 019	NSQDMREF3-1
23S1363 / 020	NSQDMREF2-1
23S1363 / 021	NSQKIREF1-1
23S1363 / 022	NSQWRD5-1
23S1363 / 023	NSQMOREF1

Analyte		Ag	As	Cd	Cr	Cu	Hg
Method		iMET2SAMS	iMET2SAMS	iMET2SAMS	iMET2SAICP	iMET2SAMS	iMET2SAMS
Unit		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Lab ID	Client ID						
23S1363/001	NSQWRD2-1	<0.05	4.3	0.07	120	30	0.02
23S1363/003	NSQDMREF1-1	<0.05	4.0	0.08	130	28	<0.02
23S1363/004	NSQPIT4-1	<0.05	4.0	0.07	110	31	<0.02
23S1363/005	NSQPIT2-1	<0.05	4.0	0.07	120	35	<0.02
23S1363/007	NSQEXM-1	<0.05	14	0.07	690	32	<0.02
23S1363/009	NSQGUREF1-1	<0.05	8.7	0.07	330	36	<0.02
23S1363/010	NSQGUREF1-2	<0.05	9.9	0.06	240	29	<0.02
23S1363/012	NSQWRD1-1	<0.05	3.5	0.06	120	24	<0.02
23S1363/014	NSQWRD4-1	0.06	10	0.10	330	60	<0.02
23S1363/017	NSQOFF2-1	<0.05	4.6	<0.05	180	21	<0.02
23S1363/019	NSQDMREF3-1	<0.05	4.0	<0.05	160	19	<0.02
23S1363/020	NSQDMREF2-1	<0.05	2.8	<0.05	98	9.5	<0.02
23S1363/021	NSQKIREF1-1	<0.05	2.9	<0.05	100	11	<0.02
23S1363/023	NSQMOREF1	<0.05	3.4	<0.05	120	19	<0.02

Analyte		Mn	Ni	Ni	Pb	Sb	Se
Method		iMET2SAICP	iMET2SAICP	iMET2SAMS	iMET2SAMS	iMET2SAMS	iMET2SAMS
Unit		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Lab ID	Client ID						
23S1363/001	NSQWRD2-1	280		36	9.7	0.08	0.19
23S1363/003	NSQDMREF1-1	280		33	12	0.09	0.19
23S1363/004	NSQPIT4-1	310		36	9.6	0.09	0.16
23S1363/005	NSQPIT2-1	330		45	8.8	0.10	0.17
23S1363/007	NSQEXM-1	560	210		9.2	0.13	0.37
23S1363/009	NSQGUREF1-1	370		120	9.7	0.11	0.19
23S1363/010	NSQGUREF1-2	190		81	5.8	<0.05	0.21
23S1363/012	NSQWRD1-1	290		39	8.3	<0.05	0.14
23S1363/014	NSQWRD4-1	650		98	21	0.06	0.32
23S1363/017	NSQOFF2-1	310		34	11	0.05	0.36
23S1363/019	NSQDMREF3-1	290		33	9.7	<0.05	0.32
23S1363/020	NSQDMREF2-1	75		15	4.6	0.07	0.18
23S1363/021	NSQKIREF1-1	82		19	4.9	0.06	0.18
23S1363/023	NSQMOREF1	230		31	9.1	0.06	0.18

Analyte		Stones *	Zn	EC	pH	Sand.	Silt.
Method		(>2mm)	iMET2SAMS	(1:5)	(H2O)	fraction	fraction
Unit		%	mg/kg	mS/m		%	%
Lab ID	Client ID						
23S1363/001	NSQWRD2-1	2.9	27	11	8.6	64.0	13.0
23S1363/002	NSQWRD2-2	13.1		13	8.9		
23S1363/003	NSQDMREF1-1	3.4	28	20	8.8		
23S1363/004	NSQPIT4-1	3.3	29	13	8.8	63.5	13.5
23S1363/005	NSQPIT2-1	1.9	36	63	8.3	57.0	17.0
23S1363/006	NSQPIT5-1	5.6		10	9.1		
23S1363/007	NSQEXM-1	3.4	41	210	8.5	64.0	15.0
23S1363/008	NSQEXM-2	4.8		280	8.9	43.5	19.0
23S1363/009	NSQGUREF1-1	2.9	34	14	8.7		
23S1363/010	NSQGUREF1-2	16.1	21	23	9.1		
23S1363/011	NSQWS1-1	3.5		3	7.7		

Analyte		Stones *	Zn	EC	pH	Sand.	Silt.
Method		(>2mm)	iMET2SAMS	(1:5)	(H2O)	fraction	fraction
Unit		%	mg/kg	mS/m		%	%
Lab ID	Client ID						
23S1363/012	NSQWRD1-1	4.8	34	10	8.8	69.0	14.0
23S1363/013	NSQWRD1-2	15.5		13	8.9	59.0	15.0
23S1363/014	NSQWRD4-1	3.1	61	10	8.8	66.0	13.0
23S1363/015	NSQWRD4-2	8.8		36	9.2		
23S1363/016	NSQPIT3-1	2.1		12	8.8		
23S1363/017	NSQOFF2-1	3.2	21	14	8.8	61.0	15.0
23S1363/018	NSQPIT1-1	1.7		13	9.2		
23S1363/019	NSQDMREF3-1	12.5	21	3	6.9		
23S1363/020	NSQDMREF2-1	2.5	8.0	20	7.0	71.0	10.0
23S1363/021	NSQKIREF1-1	0.6	9.7	3	6.8		
23S1363/022	NSQWRD5-1	0.5		9	8.3		
23S1363/023	NSQMOREF1	2.0	20	4	8.1		

Analyte		Clay.	OrgC	Emerson *	ESP *	N	Ca
Method		fraction	(W/B)	Class	(calc)	(total)	(exch)
Unit		%	%		%	%	cmol(+)/kg
Lab ID	Client ID						
23S1363/001	NSQWRD2-1	23.0	0.48	4	1.1	0.045	13
23S1363/003	NSQDMREF1-1				3.2		13
23S1363/004	NSQPIT4-1	23.0	0.28	4	1.8	0.034	12
23S1363/005	NSQPIT2-1	26.0	0.54	4	1.2	0.051	19
23S1363/007	NSQEXM-1	21.0	0.45	4	1.8	0.045	6.9
23S1363/008	NSQEXM-2	37.5			3.6		2.7
23S1363/009	NSQGUREF1-1				1.0		13
23S1363/010	NSQGUREF1-2				2.0		6.5
23S1363/011	NSQWS1-1		0.20			0.021	
23S1363/012	NSQWRD1-1	17.0	0.83	4	1.1	0.071	13
23S1363/013	NSQWRD1-2	26.0			4.4		11
23S1363/014	NSQWRD4-1	21.0	0.29	4	1.4	0.032	12
23S1363/017	NSQOFF2-1	24.0	0.32	2	2.3	0.038	18
23S1363/019	NSQDMREF3-1				3.2		4.1
23S1363/020	NSQDMREF2-1	19.0		3	6.3		7.1
23S1363/021	NSQKIREF1-1				3.7		3.0
23S1363/023	NSQMOREF1				1.4		8.0

Analyte		K	Mg	Na	Al *	B *	Ca *
Method		(exch)	(exch)	(exch)	(M3)	(M3)	(M3)
Unit		cmol(+)/kg	cmol(+)/kg	cmol(+)/kg	mg/kg	mg/kg	mg/kg
Lab ID	Client ID						
23S1363/001	NSQWRD2-1	0.53	1.4	0.17	250	0.9	>5500
23S1363/003	NSQDMREF1-1	0.90	1.5	0.49			
23S1363/004	NSQPIT4-1	0.99	1.2	0.26	210	0.8	>5500
23S1363/005	NSQPIT2-1	1.2	1.3	0.25	380	1.3	>5500
23S1363/007	NSQEXM-1	0.92	3.8	0.21	260	2.8	>5500
23S1363/008	NSQEXM-2	0.41	2.9	0.22			
23S1363/009	NSQGUREF1-1	1.1	2.4	0.17			
23S1363/010	NSQGUREF1-2	0.69	3.8	0.22			
23S1363/011	NSQWS1-1				>550	0.4	2900
23S1363/012	NSQWRD1-1	0.97	1.5	0.17	>550	1.4	>5500

Analyte Method Unit		K (exch) cmol(+)/kg	Mg (exch) cmol(+)/kg	Na (exch) cmol(+)/kg	Al * (M3) mg/kg	B * (M3) mg/kg	Ca * (M3) mg/kg
Lab ID	**Client ID**						
23S1363/013	NSQWRD1-2	0.35	1.9	0.61			
23S1363/014	NSQWRD4-1	1.0	1.9	0.22	390	1.0	>5500
23S1363/017	NSQOFF2-1	1.2	1.8	0.49	>550	1.1	>5500
23S1363/019	NSQDMREF3-1	0.41	1.2	0.19			
23S1363/020	NSQDMREF2-1	0.55	1.3	0.60			
23S1363/021	NSQKIREF1-1	0.26	0.68	0.15			
23S1363/023	NSQMOREF1	0.65	1.8	0.15			

Analyte Method Unit		Cd * (M3) mg/kg	Co * (M3) mg/kg	Cu * (M3) mg/kg	Fe * (M3) mg/kg	K * (M3) mg/kg	Mg * (M3) mg/kg
Lab ID	**Client ID**						
23S1363/001	NSQWRD2-1	0.02	1.5	5.2	17	200	260
23S1363/004	NSQPIT4-1	0.02	1.1	5.2	13	380	230
23S1363/005	NSQPIT2-1	0.02	1.5	5.4	17	270	270
23S1363/007	NSQEXM-1	0.05	0.68	2.8	32	490	>1000
23S1363/011	NSQWS1-1	<0.01	3.2	3.2	29	280	500
23S1363/012	NSQWRD1-1	0.02	1.4	3.4	25	390	310
23S1363/014	NSQWRD4-1	<0.01	2.4	4.8	20	400	370
23S1363/017	NSQOFF2-1	0.01	3.5	4.3	21	430	310

Analyte Method Unit		Mn * (M3) mg/kg	Mo * (M3) mg/kg	Na * (M3) mg/kg	Ni * (M3) mg/kg	P * (M3) mg/kg	S * (M3) mg/kg
Lab ID	**Client ID**						
23S1363/001	NSQWRD2-1	65	<0.01	44	1.3	6	11
23S1363/004	NSQPIT4-1	49	<0.01	65	1.0	7	18
23S1363/005	NSQPIT2-1	69	<0.01	280	1.2	8	96
23S1363/007	NSQEXM-1	27	<0.01	>1000	2.4	8	69
23S1363/011	NSQWS1-1	150	<0.01	49	3.3	1	2
23S1363/012	NSQWRD1-1	78	<0.01	40	0.7	16	11
23S1363/014	NSQWRD4-1	81	<0.01	53	2.1	4	7
23S1363/017	NSQOFF2-1	120	<0.01	110	1.8	3	9

Analyte Method Unit		Zn * (M3) mg/kg	As * (M3) mg/kg	Pb * (M3) mg/kg	Se * (M3) mg/kg
Lab ID	**Client ID**				
23S1363/001	NSQWRD2-1	0.4	0.1	0.9	0.1
23S1363/004	NSQPIT4-1	0.3	0.2	0.9	<0.1
23S1363/005	NSQPIT2-1	0.3	<0.1	0.9	0.2
23S1363/007	NSQEXM-1	0.6	<0.1	0.5	<0.1
23S1363/011	NSQWS1-1	0.2	<0.1	0.9	<0.1
23S1363/012	NSQWRD1-1	1.2	<0.1	0.7	0.1
23S1363/014	NSQWRD4-1	0.2	0.2	0.9	<0.1
23S1363/017	NSQOFF2-1	0.4	0.1	0.9	<0.1

Analyte	Method	Description
Stones *	(>2mm)	Stones - sieved particles greater than 2 mm (sample preparation method manual 3.3.2)
EC	(1:5)	Electrical conductivity of 1:5 soil extract at 25 C by in-house method S02
ESP *	(calc)	Exchangeable Sodium Percentage (calculated)
K	(exch)	Potassium, K exchangeable (ref. Rayment & Lyons 2011)
Mg	(exch)	Magnesium, Mg exchangeable (ref. Rayment & Lyons 2011)
Na	(exch)	Sodium, Na exchangeable (ref. Rayment & Lyons 2011)
Ca	(exch)	Calcium, Ca exchangeable (ref. Rayment & Lyons 2011)
pH	(H2O)	pH of 1:5 soil extract in water by in-house method S01
S *	(M3)	Sulphur, S extracted by Mehlich No 3 - method S42
P *	(M3)	Phosphorus, P extracted by Mehlich No 3 - method S42
Pb *	(M3)	Lead, Pb extracted by Mehlich No 3 - method S42
Mo *	(M3)	Molybdenum, Mo extracted by Mehlich No 3 - method S42
Na *	(M3)	Sodium, Na extracted by Mehlich No 3 - method S42
Ni *	(M3)	Nickel, Ni extracted by Mehlich No 3 - method S42
Mg *	(M3)	Magnesium, Mg extracted by Mehlich No 3 - method S42
Mn *	(M3)	Manganese, Mn extracted by Mehlich No 3 - method S42
K *	(M3)	Potassium, K extracted by Mehlich No 3 - method S42
Fe *	(M3)	Iron, Fe extracted by Mehlich No 3 - method S42
Ca *	(M3)	Calcium,Ca extracted by Mehlich No 3 - method S42
Cd *	(M3)	Cadmium,Cd extracted by Mehlich No 3 - method S42
B *	(M3)	Boron,B extracted by Mehlich No 3 - method S42
Co *	(M3)	Cobalt,Co extracted by Mehlich No 3 - method S42
Cu *	(M3)	Copper,Cu extracted by Mehlich No 3 - method S42
Zn *	(M3)	Zinc, Zn extracted by Mehlich No 3 - method S42
Al *	(M3)	Aluminium,Al extracted by Mehlich No 3 - method S42
As *	(M3)	Arsenic, As extracted by Mehlich No 3 - method S42
Se *	(M3)	Selenium, Se extracted by Mehlich No 3 - method S42
N	(total)	Nitrogen N, total by method S10
OrgC	(W/B)	Organic Carbon C, Walkley and Black method S09.
Emerson *	Class	Emerson class number by AS 1289 C.8.1
Sand.	fraction	Sand, 0.02 to 2.0mm by method S06. ref. Australian Standard AS1289.C6.3
Clay.	fraction	Clay, less than 0.002mm by method S06. ref. Australian Standard AS1289.C6.3
Silt.	fraction	Silt, 0.02 to 0.002mm by method S06. ref. Australian Standard AS1289.C6.3
Cr	iMET2SAICP	Chromium, dry basis
Mn	iMET2SAICP	Manganese, dry basis
Ni	iMET2SAICP	Nickel, dry basis
Ni	iMET2SAMS	Nickel, dry basis
Pb	iMET2SAMS	Lead, dry basis
Hg	iMET2SAMS	Mercury, dry basis
Cd	iMET2SAMS	Cadmium, dry basis
Zn	iMET2SAMS	Zn, dry basis Zinc has not been validated HB 28.12
Cu	iMET2SAMS	Copper, dry basis
Sb	iMET2SAMS	Antimony, dry basis
As	iMET2SAMS	Arsenic, dry basis
Ag	iMET2SAMS	Silver, dry basis
Se	iMET2SAMS	Selenium, dry basis

Results are based on a air-dry (40C) , < 2 mm basis. Stones (>2mm) if present are reported on an air dry whole sample basis.The results apply only to samples as received. This report may only be reproduced in full. Unless otherwise advised, the samples in this job will be disposed of after a holding period of 30 days from the report date shown below.

EMERSON CLASS CLASSIFICATION

The swelling and dispersive properties of the soils were tested by placing natural peds and samples re-moulded at or near field capacity moisture content in deionised water. Based on their slaking and dispersive behaviour, the samples were classified into one of 8 classes according to the Emerson Classification scheme as described in Australian Standard AS 1289.C8.1-1980.

Summary of classification scheme:

Class 1 Soil slakes, air-dried crumbs are strongly dispersive
Class 2 Soil slakes, air-dried crumbs show slight to moderate dispersion
Class 3 Soil slakes, air-dried crumbs do not disperse, re-moulded soil disperses
Class 4 Soil slakes, air-dried crumbs do not disperse, calcium carbonate or calcium sulphate are present.
Class 5 Soil slakes, air-dried and re-moulded soil do not disperse, 1:5 soil:water extract remains dispersed after 5 minutes.
Class 6 Soil slakes, air-dried and re-moulded soil do not disperse, 1:5 soil:water extract begins to flocculate within 5 minutes
Class 7 Soil does not slake, air-dried crumbs remain coherent and swell.
Class 8 Soil does not slake, air-dried crumbs remain coherent, but do not swell.

A sample with a result of 0, indicates the sample was not suitable for the test, i.e air-dried sample did not contain soil peds between 4.75 - 2.36mm diameter.

Exchangeable Sodium Percentage (ESP)

The ESP is a measure of sodicity (i.e exchangeable Na+) based on a soils exchange complex . High levels of sodium can adversley effect plant growth and soil structure.
The table below (categorised by Northcote and Skene, 1972) relates % ESP to soil sodicity. This table should only be used as a guide as it tolerance can vary on soil type and plant species.

ESP<6 non-sodic
ESP6-15 sodic
ESP>15 strongly sodic

*Analysis not covered by scope of ChemCentre's NATA accreditation.

Barry Price
Senior Scientist
Scientific Services Division
8-Nov-2023