360 environmental

Lake Mackay Sulphate of Potash Project

Detailed Flora and Vegetation Assessment at Lake Mackay

Prepared for:
Agrimin Ltd

August 2017

people • planet • professional

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Executive Summary

360 Environmental was commissioned by Agrimin Ltd (Agrimin) to undertake a Detailed Flora and Vegetation Assessment for the Lake Mackay Sulphate of Potash Project.

This assessment was to form the second phase of the Detailed Flora and Vegetation Assessment at Lake Mackay to provide Agrimin with preliminary data to support environmental approvals for the Sulphate of Potash Project.

A total of 253 taxa (including species, subspecies, varieties and forms) from 117 genera and 42 families were identified. The most commonly occurring families were Fabaceae (35 taxa), Poaceae (29 taxa) and Malvaceae (29 taxa). The most frequently recorded genera were *Acacia* (12 taxa), *Tecticornia* (10 taxa) and *Sida* (10 taxa).

No Threatened flora species pursuant to the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and/or gazetted as Threatened pursuant to the *Wildlife Conservation Act 1950* were recorded during the survey.

A review of the Department of Parks and Wildlife (DPaW) threatened flora database and EPBC Protected Matters Search Tool (PMST) did not identify any Threatened/EPBC listed species, however, ten taxa listed as Priority flora were identified as potentially occurring in the Survey Area. Of these ten conservation significant flora, four are considered Likely to occur - *Goodenia virgata* (P2) (recorded during the survey), *Thysanotus sp.* Desert East of Newman (P2), *Dampiera atriplicina* (P3) and *Goodenia modesta* (P3) (recorded during the survey).

Three Priority listed flora were recorded during the survey comprising one Priority 1 taxon (*Tecticornia globulifera*), one Priority 2 taxon (*Goodenia virgata*) and one Priority 3 taxon (*Goodenia modesta*).

One introduced species, **Malvastrum americanum,* was recorded during the survey. No species recorded are listed as Weeds of National Significance (WONS) or Declared under the *Biosecurity and Agriculture Management Act 2007* (BAM Act).

Eighteen vegetation associations were identified during the survey, with the vegetation condition in the proposed infrastructure areas, the proposed track and the surveyed islands assessed as being in Excellent condition.

None of the vegetation associations recorded during the survey are considered to represent any Federal or State listed Threatened Ecological Communities or Priority Listed Ecological Communities.

The landforms and, consequently, the vegetation associations are considered common and widespread in the Survey Area, but also more broadly surrounding Lake Mackay and, more importantly, in the region.

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1 Introduction

1.1 The Project

360 Environmental was commissioned by Agrimin Ltd (Agrimin) to undertake a Detailed Flora and Vegetation Assessment for the Lake Mackay (the lake) Sulphate of Potash Project (SOP). Lake Mackay is a seasonally inundated salt lake located in the Great Sandy Desert on the Western Australian (WA) and Northern Territory (NT) border, with most of the lake located in WA.

A first-phase flora and vegetation assessment was undertaken in September 2016 by Ecologia (Ecologia survey), with this current survey forming the second-phase of the Detailed Flora and Vegetation Assessment. The SOP comprises nine tenements covering the majority of Lake Mackay for a combined area of approximately 297,195 ha (Figure 1). The survey effort focused on two proposed infrastructure development areas (adjacent to the southern boundary of the lake), a proposed track extending south from the proposed eastern-most infrastructure development area (to connect with the existing Gary Junction Road) and three islands located in the lake (outside of the proposed disturbance footprint). The proposed disturbance areas and surveyed islands comprise the Survey Area for this flora and vegetation assessment which forms part of the wider project Study Area (Figure 2).

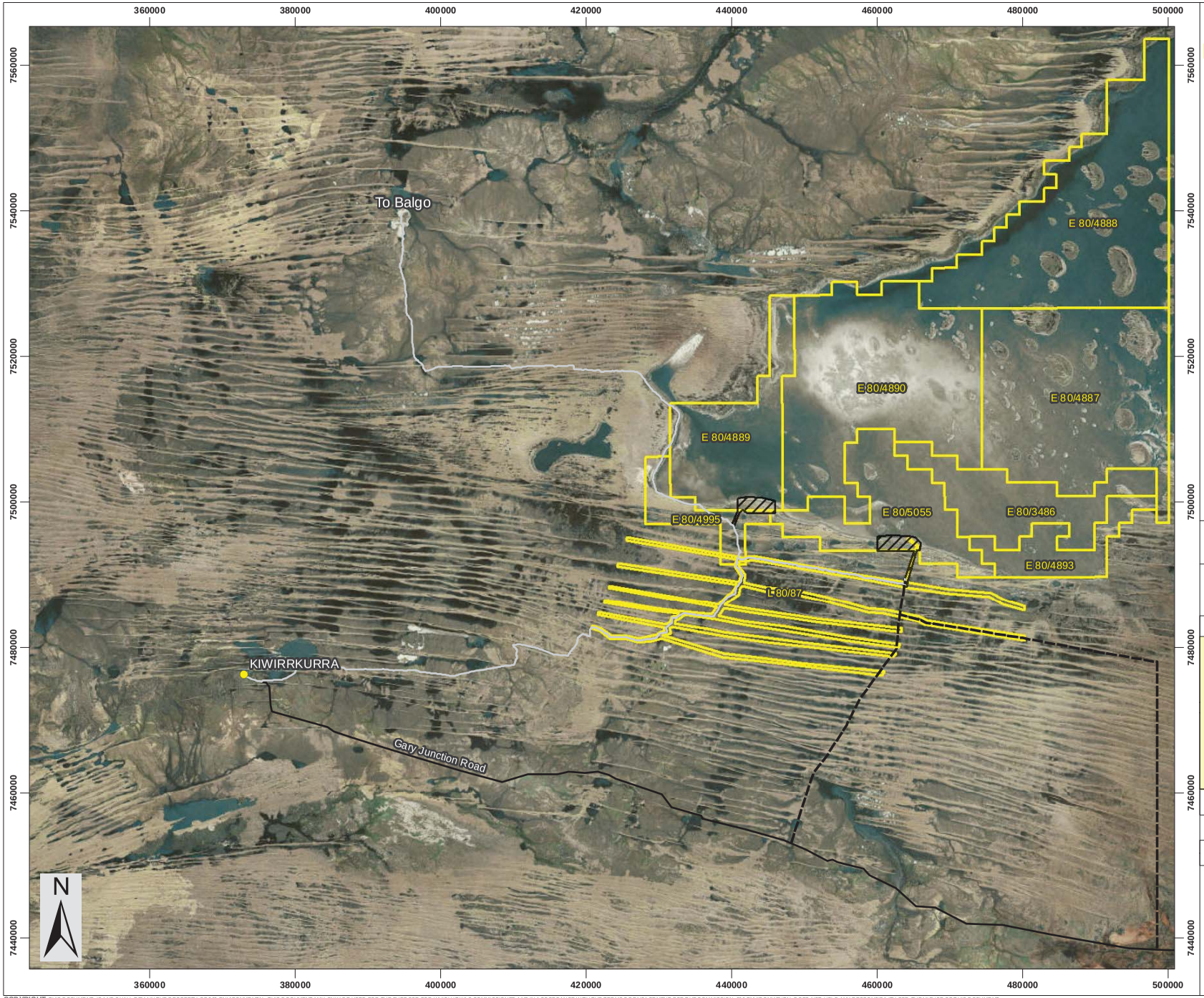
The purpose of this assessment was to provide Agrimin with data to support environmental approvals for the SOP.

1.1.1 Objectives

The objectives of the flora and vegetation assessment were to:

- Conduct a desktop assessment of the Survey Area and wider Study Area prior to the field survey work to identify all floristic constraints which may be in, or nearby, the Survey Area;
- Identify and review any existing and relevant environmental reports;
- Identify broad vegetation types using Beard (1976);
- Undertake a field survey to take the previous survey efforts to a second-phase survey;
- Undertake vegetation condition mapping using the Trudgen (1988) condition scale and ecological community mapping (Environment Protection Authority [EPA] 2016);
- Undertake relevant environmental constraints mapping with GIS software; and

- Asses the Survey Area's plant species diversity, density, composition, structure and weed cover, recording the percentage of each in nominated quadrats.



Legend

- Tenements
- Proposed Infrastructure Boundaries
- Existing Track
- Existing Road
- Proposed Track

- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS
- LOCALITY MAP SOURCED LANDGATE 2006
- TENEMENTS SOURCED FROM AGRIMIN 2017
- RARE AND PRIORITY FLORA SOURCED DPAW 2017
- AERIAL PHOTOGRAPHY SOURCED LANDGATE 2007 AND ADDITIONAL LANGATE COMPOSITE AERIALS (© Western Australian Land Information Authority 2015)

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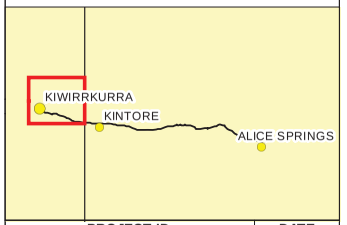

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Figure 1
Site location

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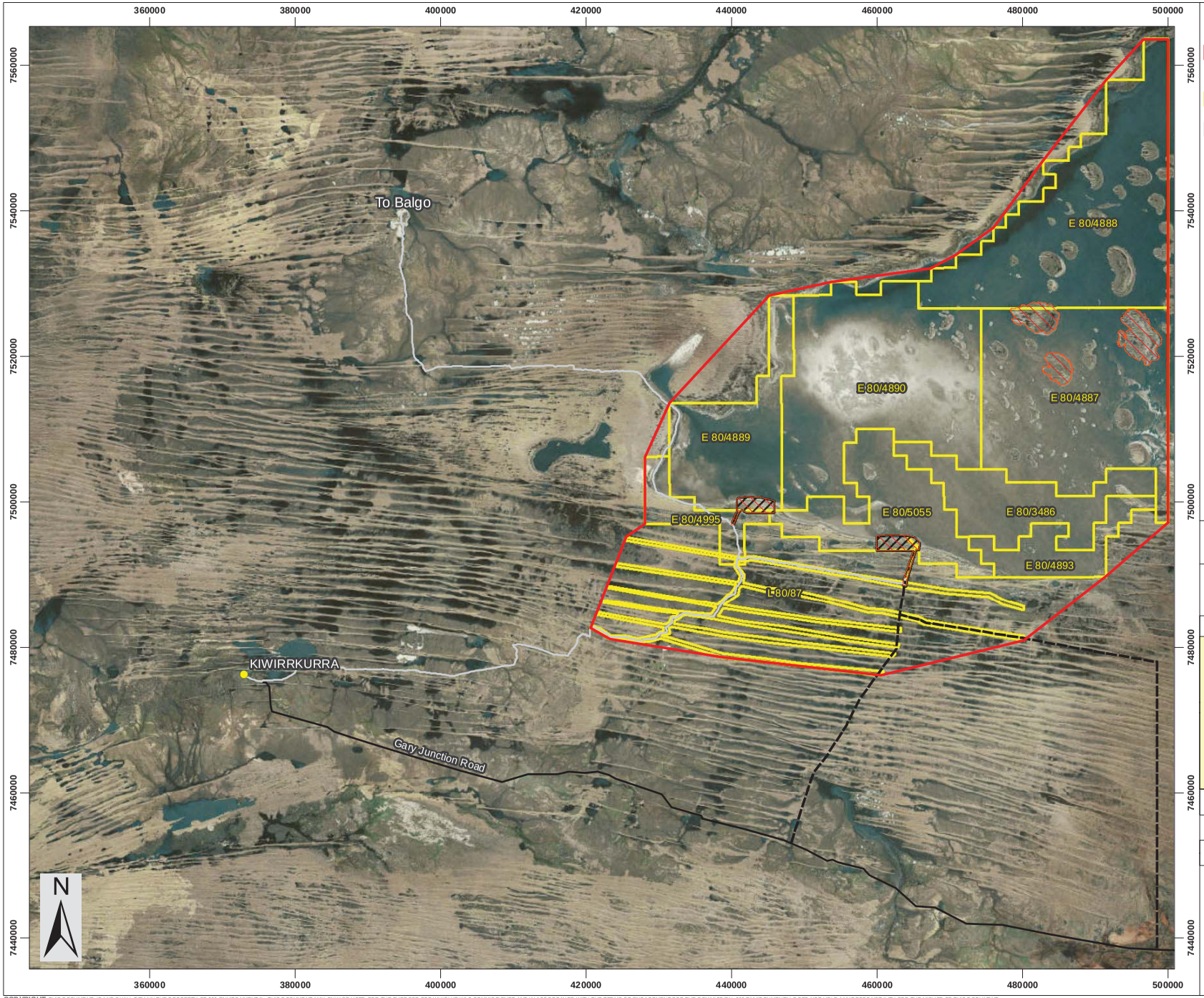

Legend

- Study Area
- Survey Area
- Tenements
- Proposed Infrastructure Boundaries
- Existing Track
- Existing Road
- Proposed Track

- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS
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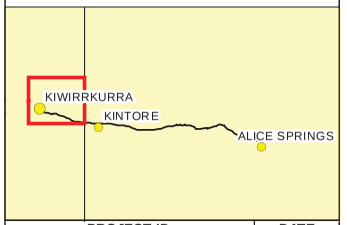

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Figure 2

Survey Area

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1.2 Background to the Protection of Flora and Vegetation

Flora is protected formally and informally by various legislative and non-legislative measures, which are as follows:

Legislative measures:

- *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act);
- *Biodiversity Conservation Act 2016* (BC Act);
- WA *Environmental Protection Act 1986* (EP Act); and
- *Biosecurity and Agriculture Management Act 2007* (BAM Act).

Non-legislative measures:

- WA Department of Parks and Wildlife (DPaW) Priority lists for flora and ecological communities;
- Weeds of National Significance (WONS); and
- Recognition of locally significant populations by DPaW.

A short description of each is given below. Other definitions, including species conservation categories, are provided in Appendix A. Conservation categories for ecological communities are provided in Appendix B.

1.2.1 EPBC Act

The EPBC Act aims to protect matters of national environmental significance (MNES). Under the EPBC Act, the Commonwealth Department of the Environment and Energy (DEE) lists threatened species and communities in categories determined by criteria set out in the EPBC Act (Appendix A and B).

Projects likely to cause a significant impact on MNES should be referred to the DEE for assessment under the EPBC Act.

1.2.2 WC Act

The WA DPaW lists flora under the provisions of the WC Act as protected according to their need for protection (Appendix A).

Flora is given Declared Rare status when populations are geographically restricted or are threatened by local processes. In addition, under the WC Act, by Notice in the WA Government Gazette of 9 October 1987, all native flora (spermatophytes, pteridophytes, bryophytes and thallophytes) is protected throughout the State.

1.2.3 EP Act

Threatened Flora and Threatened Ecological Communities (TECs) are given special consideration in environmental impact assessments and have special status as

Environmentally Sensitive Areas (ESAs) under the EP Act and the *Environmental Protection (Clearing of Native Vegetation) Regulations 2004*. Exemptions for a clearing permit do not apply in an ESA. In addition, habitat necessary for the maintenance of indigenous fauna is considered in the clearing principles and assessed during consideration of applications for a clearing permit.

1.2.4 BAM Act

Plants may be 'Declared' by the Minister for Agriculture and Food under the BAM Act. The Western Australian Organism List contains information on the area(s) in which a plant is declared and the control and keeping categories to which it has been assigned in Western Australia. Details of the definitions of these categories are provided in Appendix C. A declaration may apply to the whole State, to districts, individual properties or even to single paddocks. If a plant is 'Declared', landholders are obliged to control that plant on their properties (Department of Agriculture and Food Western Australia [DAFWA] 2017).

1.2.5 Weeds of National Significance

The Australian Government, along with the State and Territory Governments, has endorsed 32 Weeds of National Significance (WONS). Four major criteria were used in determining WONS:

- The invasiveness of a weed species;
- A weed's impact(s);
- The potential for spread of a weed; and
- Socio-economic and environmental values.

Each WONS has a national strategy and a national coordinator responsible for implementing the strategy. WONS are regarded as priority weeds in Australia because of their invasiveness, potential for spread and economic and environmental impacts (Thorp and Lynch 2000).

1.2.6 DPaW Priority Lists

DPaW lists 'Priority' flora that have not been assigned statutory protection as Declared Rare or 'Scheduled' under the WC Act and are under consideration for declaration as Threatened. Flora assessed as Priority 1-3 are considered to be in urgent need of further survey. Priority 4 flora requires monitoring every 5 -10 years and Priority 5 flora is subject to a specific conservation program (Appendix A).

DPaW maintains a list of Priority Ecological Communities (PECs) which identifies plant communities that require further investigation before possible nomination for TEC status. Once listed, a community becomes a PEC and, when endorsed by the WA Minister of Environment, becomes a TEC and protected as an ESA under *Environmental Protection (Clearing of Native Vegetation) Regulations 2004* (Appendix B).

1.2.7 Informal Recognition of Flora

Certain populations or communities of flora may be of local significance or interest because of their patterns of distribution and abundance. For example, specific locations of flora may be locally significant because they are range extensions to the previously known distribution, or are newly discovered taxa (and have the potential to be of more than local significance). In addition, many species are in decline as a result of threatening processes (land clearing, grazing, and changed fire regimes) and relict populations of such species assume local importance for DPaW. It is not uncommon for DPaW to make comment on these species of interest.

2 Biophysical Environment

2.1 Climate

The Survey Area is located in the Great Sandy Desert bioregion of Western Australia. The Great Sandy Desert experiences an arid tropical climate in the north, grading into a temperate-subtropical climate in the south, where dry conditions with hot summers and mild winters occur. Rainfall is generally variable and unpredictable, but occurs typically in summer (Tille 2006).

The most relevant and reliable Bureau of Meteorology (BoM) weather station for the Survey Area is Walungurru Airport (Site No. 15664), approximately 80 km south-east of the southern boundary of the Study Area. The Walungurru Airport station receives a mean minimum temperature that ranges from 10.4°C to 26°C and mean maximum that ranges from 23.2°C to 39.4°C. The annual average rainfall is 306.1 mm (BoM 2017).

Walungurru Airport station recorded 720 mm of rain in the 12 months prior to survey (April 2016 – March 2017) which is 413.9 mm above the long term average rainfall for the same period (Figure 2). In the three months prior to the survey (January 2017 – March 2017) 108.6 mm of rainfall was recorded which is below the 130.8 mm average rainfall for the same period (BoM 2017).

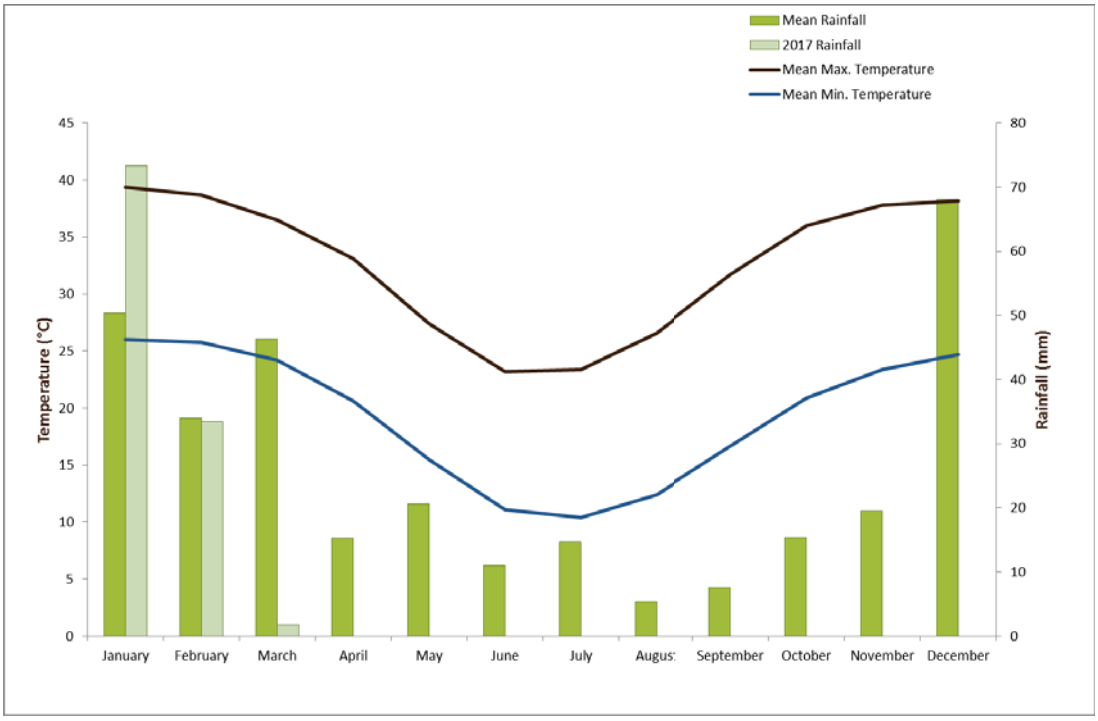

Figure 3: Mean rainfall, 2017 rainfall and mean maximum and minimum temperatures for Walungurru Airport station from 1998 to 2017 (BoM 2017).

2.2 Soils

The dominant soils of the Great Sandy Desert dunefields and sandplains are red deep sands and red sandy earths, with some red loamy earths and shallow gravels in depressions between dunes (Tille 2006). Hilly areas typically comprise red loamy earths, with red shallow loams, red shallow sands, stony soils and shallow gravels (Tille 2006).

Four soil units have been mapped within the proposed disturbance areas and the surveyed islands, using the Digital Atlas of Australian soils (Bureau of Rural Sciences 2009). These are described in Table 1 and mapped in Figure 4. The proposed disturbance areas and the surveyed islands are mostly dominated by the SV12 unit (Figure 4).

Table 1: Soil units and their occurrence in the Survey Area.

SOILS	DESCRIPTION	EXTENT IN PROPOSED DISTURBANCE AREAS (HA)	EXTENT IN SURVEYED ISLANDS (HA)
AB39	Gently undulating plain dominated by longitudinal dunes of varying frequency; some exposures of ironstone gravels on low rises occur in the dune swales	20.26	-
AB56	Plains extensively covered with longitudinal dunes; some hilly residuals with rock outcrops	2102.35	-
AB55	Broad, very gently undulating upland (tableland) elevated above adjacent dune fields; some low laterite-capped residuals showing exposures of sedimentary rocks; some dunes, some salt lakes and pans	82.57	-
SV12	Plains studded with salt pans, seasonal lakes; calcrete (kunkar) platforms; and fringing dunes	1334.23	5864.74
MY110	Plains with some longitudinal dunes; some stony residuals of sedimentary rocks which are sometimes capped with a lateritic dust	99.26	-

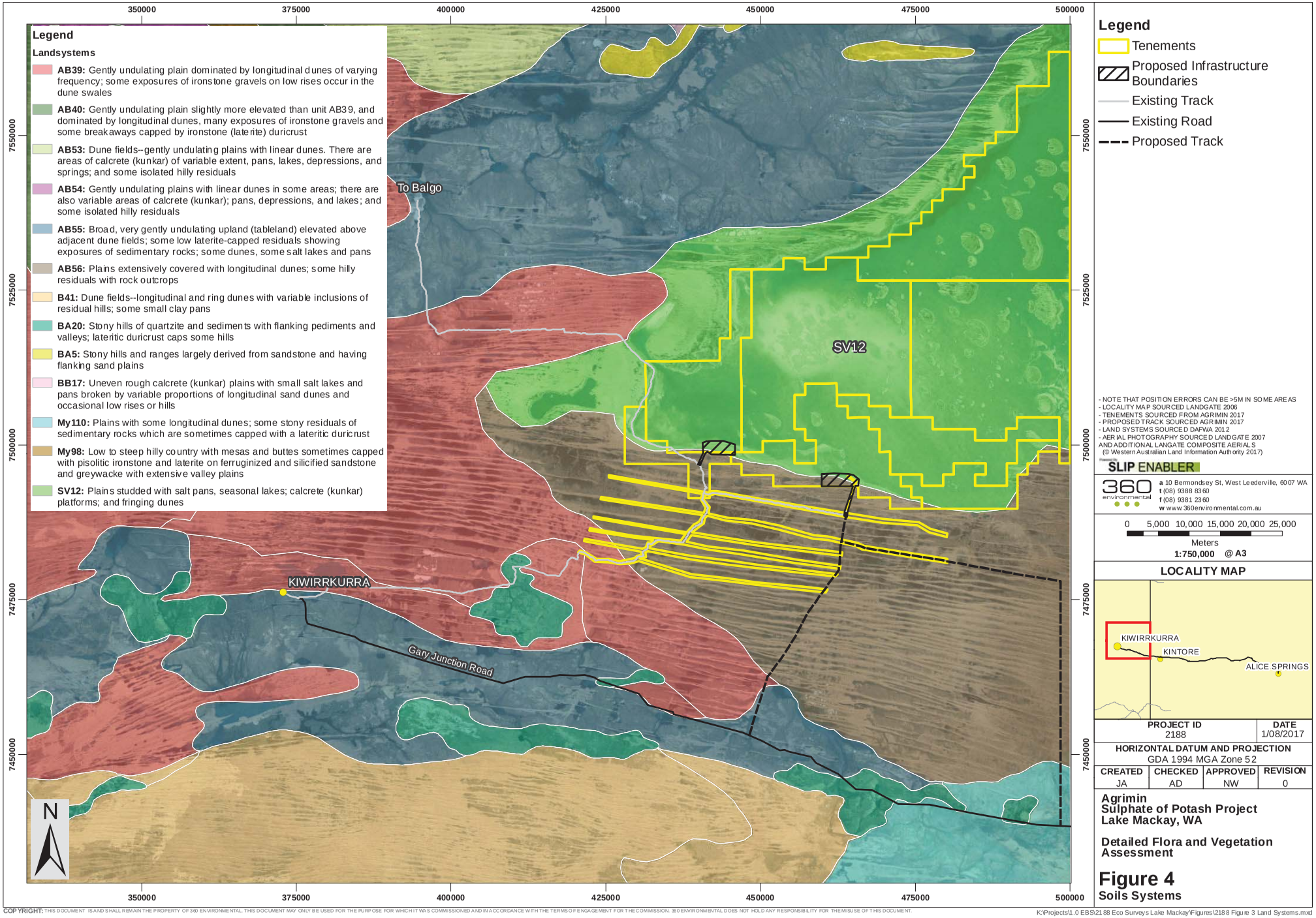

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Figure 4
Soils Systems

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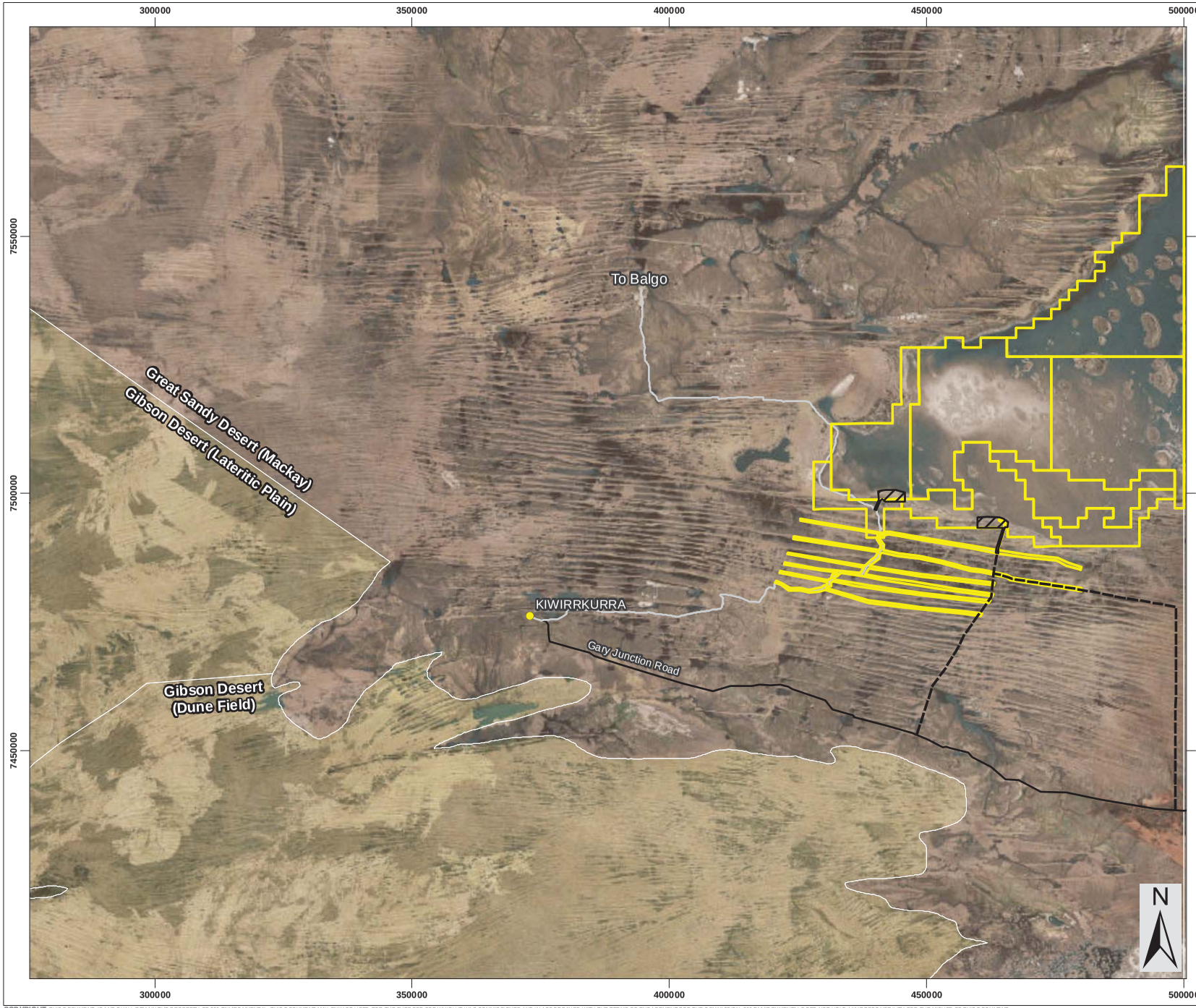
2.3 Biogeographic Regionalisation for Australia

The Biogeographic Regionalisation of Australia (IBRA7) divides Australia into 89 bioregions based on major biological, geographical and geological attributes. These bioregions are subdivided into 419 subregions as part of a refinement of the IBRA framework (DEE 2016a).

The Survey Area is located in the Great Sandy Desert Bioregion and in the Great Sandy Desert Mackay subregion (Figure 5). This region includes tropical inland 'red-centre' desert. It includes 'Percival' and 'Auld' palaeoriver systems. It mainly comprises tree steppe grading to shrub steppe in the south, with open hummock grassand of *Triodia pungens* and *Triodia schinzii* with scattered trees of *Owenia reticulata* and Bloodwood (*Corymbia spp.*), and shrubs of *Acacia spp.*, *Grevillea wickenhamii* and *G. refracta*, on Quaternary red longitudinal sand dune fields overlying Jurassic and Cretaceous sandstones of the Canning and Armadeus Basins. *Casuarina decaisneana* (Desert Oak) occurs in the south and east of the region. Gently undulating, lateritised uplands support shrub steppe such as *Acacia pachycarpa* shrublands over *Triodia pungens* hummock grass. Calcrete and evaporate surfaces are associated with occluded palaeo-drainage systems that traverse the desert. These include extensive salt lake chains with samphire low shrublands and *Melaleuca glomerata* to *M. lasiandra* shrublands. The climate is arid tropical with summer rainfall (Kendrick 2001).



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IBRA 7 Sub-regions

- Gibson Desert
- Great Sandy Desert

- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS
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- TENEMENTS SOURCED FROM AGRIMIN 2017
- ROADS AND TRACKS SOURCED AGRIMIN 2017
- PROPOSED TRACK SOURCED AGRIMIN 2017
- IBRA 7 SUB REGIONS SOURCED DOE 2015
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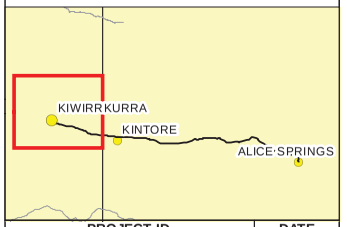

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Figure 5
IBRA 7 Regions and Sub-regions

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2.4 Geology

The Survey Area lies in the Canning Province of the Great Sandy Desert bioregion as described by Tille (2006). The inland landforms of the Great Sandy Desert are predominantly east to west running linear dunes with swales opening locally onto sandplains. Some undulating plains and uplands occur. Among the dunes are areas of small claypans and isolated residual sandstone hills as well as areas of ironstone gravels and some breakaways capped by laterite duricrust (Tille 2006).

Seven geological units have been mapped in the proposed disturbance areas and the surveyed islands as part of the Geological Series of WA. These are presented in Table 2.

Table 2: Geology in the Survey Area.

GEOLOGICAL CODE	DESCRIPTION	EXTENT IN PROPOSED DISTURBANCE AREAS (HA)	EXTENT IN SURVEYED ISLANDS (HA)
Sandplain 38499	Sandplain may include some residual alluvium; sand dominant; gravel, clay.	18.81	3444.13
Lake Deposits 38492	Lake and swamp deposits; mud, silt, evaporates, limestone and minor sand.	483.98	-
Lunette Dunes 72955	Quartz and gypsum dunes and mounds (kopi); may include minor silt, sand, gravel, and clay flats adjacent to playas; locally includes some playa sediments.	-	702.39
Alluvium 74331	Reworked or incised sandy alluvium in older stream channels; lateritised alluvial terraces above younger alluvium; alluvial and colluvial outwash deposits not in defined channel systems; sand, silt, gravel, clay, evaporates.	896.78	-
Calcrete 38497	Pisolitic, nodular or massive calcrete; ferruginous inclusions; calcerous cementing of bedrock and transported materials; locally with intercalated chalecony; as low mounds, in playa lakes, or as valley calcrete; locally dissected and karstified.	6831.51	702.88
Dunes 38496	Dunes, sandplain with dunes and swales; may include numerous interdune claypans; residual and aeolian sand with minor silt and clay; aeolian red quartz sand, clay and silt, in places gypsiferous; yellow hummocky sand.	1483.65	-

GEOLOGICAL CODE	DESCRIPTION	EXTENT IN PROPOSED DISTURBANCE AREAS (HA)	EXTENT IN SURVEYED ISLANDS (HA)
Colluvium 38491	Colluvium, sheetwash, talus; gravel piedmonts and aprons over and around bedrock; clay-silt-sand with sheet and nodular kankar; alluvial and aeolian sand-silt-gravel in depressions and broad valleys in Canning Basin; local calcrete, reworked laterite.	52.55	-

2.5 Broad Vegetation Types

Mapping of the vegetation of the Great Sandy Desert region of WA was completed on a broad scale (1:1,000,000) by Beard (1976). These vegetation types were later re-assessed by Shepherd *et al.* (2001) to account for clearing in the intensive land use zones, dividing some larger vegetation units into smaller units. The current pre-European vegetation mapping dataset of WA is an output of a joint project between DAFWA and DPaW (Beard *et al.* 2013).

This mapping forms the basis of the vegetation extent statistics released annually by DPaW. Four Shepherd vegetation associations occur in the proposed disturbance area and the surveyed islands. The Shepherd *et al.* (2001) vegetation types are described, along with their representation, in the Survey Area (Table 3).

Table 3: Broad vegetation types in the Survey Area.

SHEPHERD VEGETATION UNIT	DESCRIPTION	EXTENT IN PROPOSED DISTURBANCE AREAS (HA)	EXTENT IN SURVEYED ISLANDS (HA)
125-Great Sandy Desert	Bare areas; salt lakes.	602.80	-
134-Great Sandy Desert	Mosaic: Hummock grasslands, open low tree steppe, desert bloodwood and feathertop spinifex on sandhills/hummockgrasslands, shrub steppe; mixed shrubs over spinifex between sandhills.	1077.74	-
174-Great Sandy Desert	Hummock grasslands, shrub steppe; mixed shrubs over soft spinifex.	199.82	-

SHEPHERD VEGETATION UNIT	DESCRIPTION	EXTENT IN PROPOSED DISTURBANCE AREAS (HA)	EXTENT IN SURVEYED ISLANDS (HA)
2041-Great Sandy Desert	Succulent steppe with scrub; teatree over saltflats.	1758.33	4763.28

2.6 Environmentally Sensitive Areas (ESAs)

There are no mapped Environmentally Sensitive Areas occurring in or nearby to the Survey Area (DEC 2013).

3 Methods

3.1 Background

The flora and vegetation assessment was consistent with a detailed survey as per the Environmental Protection Authority (EPA) requirements for environmental surveying and reporting for flora and vegetation in WA, where practicable and relevant, as set out in the following documents:

- Environmental Protection of Native Vegetation in WA: Clearing of Native Vegetation with Particular Reference to Agricultural Areas. Position Statement No.2 (EPA 2000);
- EPA Guidance for the Assessment of Environmental Factors: Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia No. 51 (EPA 2004); and
- Technical Guidance – Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment (EPA 2016).

3.1.1 Permits

This flora survey was conducted under the following licences issued by DPaW:

- Licence to take flora for scientific or other prescribed purposes - SL010733 issued to Brian Morgan and SL011882 issued to Amy Dalton.

3.2 Flora and Vegetation Survey Methods

3.2.1 Flora and Vegetation Database Review

The desktop study provided background information on the flora and vegetation of the Survey Area. This included information from database searches and previous surveys in the surrounding area.

A database search of the DPaW Threatened and Priority flora database (60 km radial buffer around the Survey Area) was undertaken to identify the potential for Declared Rare/Threatened and Priority flora species to occur in the Survey Area (DPaW 2017a). A search of the DPaW Threatened and Priority Ecological Communities database (TECs and PECs) was also undertaken to identify the potential for them to occur in the Survey Area (2017b). An additional EPBC Protected Matters Search (60 km buffer around the Survey Area) was undertaken to identify the potential for MNES (DEE 2017).

A limited number of publically available flora and vegetation surveys are available for the Lake Mackay area, therefore, only a small number of relevant botanical surveys were

considered suitable for the desktop assessment. These relevant botanical surveys include:

- Level 1 Fauna and Single Phase Level 2 Flora and Vegetation Assessment (Ecologia 2017);
- Level 1 Flora and Vegetation Assessment – Theseus Project (Outback Ecology 2012); and
- Traditional Owner Survey, Biological Resources of the Kiwirrkurra Region (Desert Wildlife Services 2010).

All of these sources were used to compile a list of expected Threatened or Priority flora species and TECs or PECs that may occur in the Survey Area.

3.2.2 Flora and Vegetation Field Survey

The field survey was undertaken by Brian Morgan and Amy Dalton from the 14th– 23rd April 2017 with a total field survey effort of 20 person days. The field survey included an assessment of 34 (50 x 50 m) quadrats (6 quadrats were re-surveyed Ecologia quadrats from 2016, 4 transects (1 transect was a re-surveyed Ecologia transect from 2016), 24 (3 x 3 m) quadrats (6 quadrats were re-surveyed Ecologia quadrats), 11 relevés, mapping notes, targeted searches and opportunistic collections. Surveyed sites are illustrated in Figures 6a and 6b.

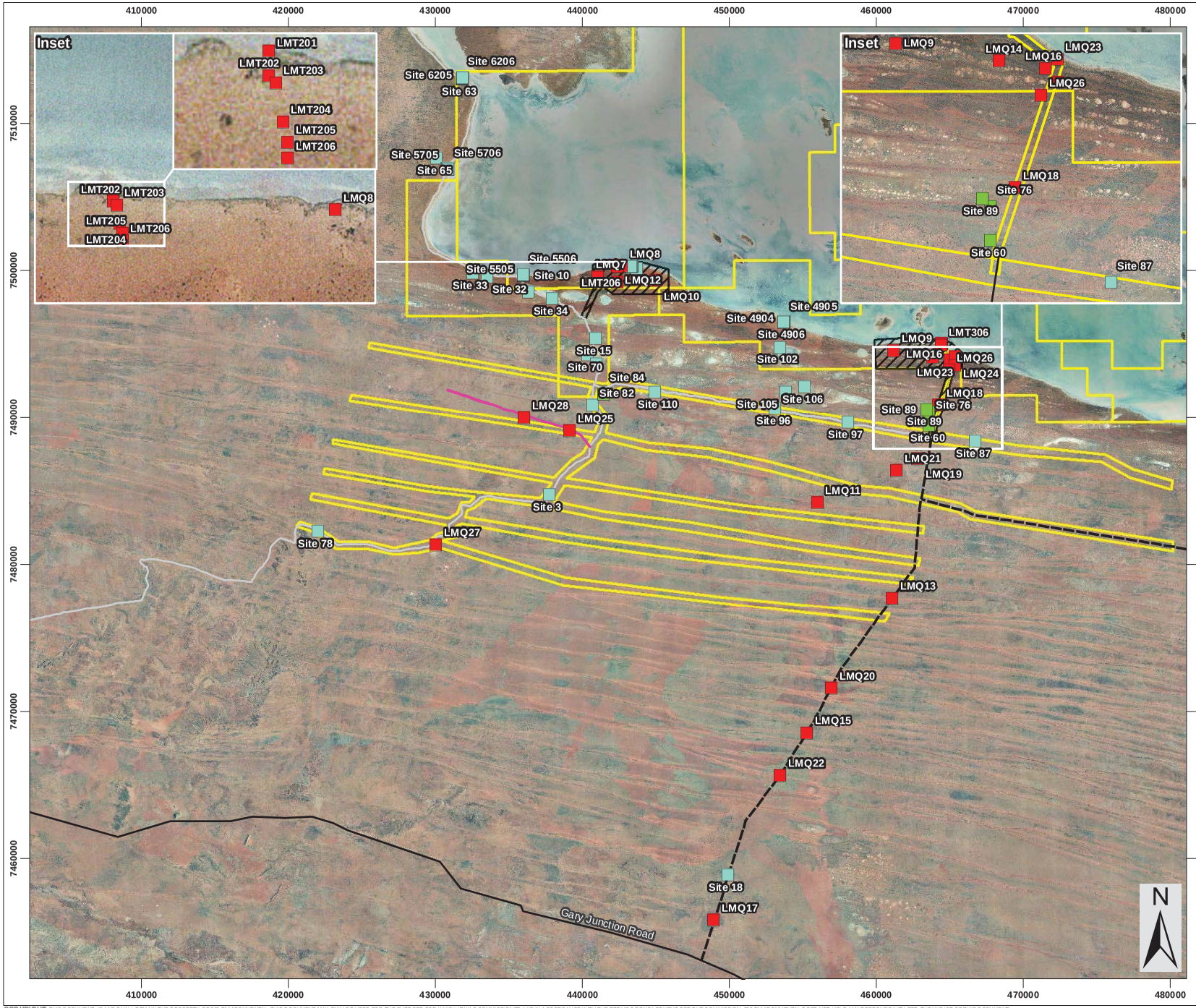
Quadrats are vegetation survey plots which are accurately measured out with each corner demarcated with a steel stake, with the northwest (NW) stake a permanent marker. The NW corner of each plot was recorded using a handheld Garmin GPS unit. The quadrat size consisted of 50 x 50 m (or an area equivalent to 400 m^2); this is considered the standard for the region (EPA 2016).

Additionally, transects consisting of 3 x 3 m quadrats were established in transitional vegetation associated with the lake margin in order to describe the changes in vegetation from the upper lake margin profile to the edge of the playa. Along transects, two 3 x 3 m quadrats were placed in each of the lake lower, mid and upper zones to capture the changes in vegetation. This approach is consistent with the recommended survey intensity for salt lakes as described in the Flora Technical Guidance (EPA 2016).

Each species of plant at each quadrat was recorded, including information on height and percentage cover. Additional information recorded at each quadrat included landscape features, surface soil colour and texture, bare ground, litter cover, disturbance, fire age, aspect and vegetation condition.

Relevés are unbounded vegetation survey plots with each species of dominant plant at each relevé being recorded. Additional information recorded included landscape features, surface soil colour and texture and vegetation condition.

During this survey, a focus was given to vegetation associations considered not adequately surveyed during the 2016 assessment, sampling Islands and revisiting some 2016 sites including those where taxa had only been identified to the genus level.



Legend

- Tenements
- Proposed Infrastructure Boundaries
- Proposed Track
- Existing Track
- Existing Road
- Survey Track (360 Survey 2017)
- 360 Re-Surveyed Quadrat Locations (Ecologia Survey 2016)
- Quadrat Locations (Ecologia Survey 2016)
- Quadrat Locations (360 Survey 2017)

- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS
- LOCALITY MAP SOURCED LANDGATE 2006
- TENEMENTS SOURCED FROM AGRIMIN 2017
- AERIAL PHOTOGRAPHY SOURCED LANDGATE 2007 AND ADDITIONAL LANGATE COMPOSITE AERIALS (© Western Australian Land Information Authority 2017)

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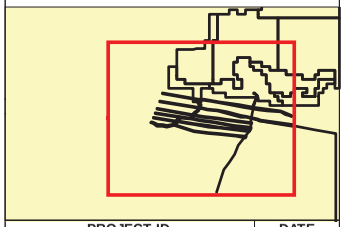
LOCALITY MAP



PROJECT ID	DATE
2188	1/08/2017

HORIZONTAL DATUM AND PROJECTION
GDA 1994 MGA Zone 52

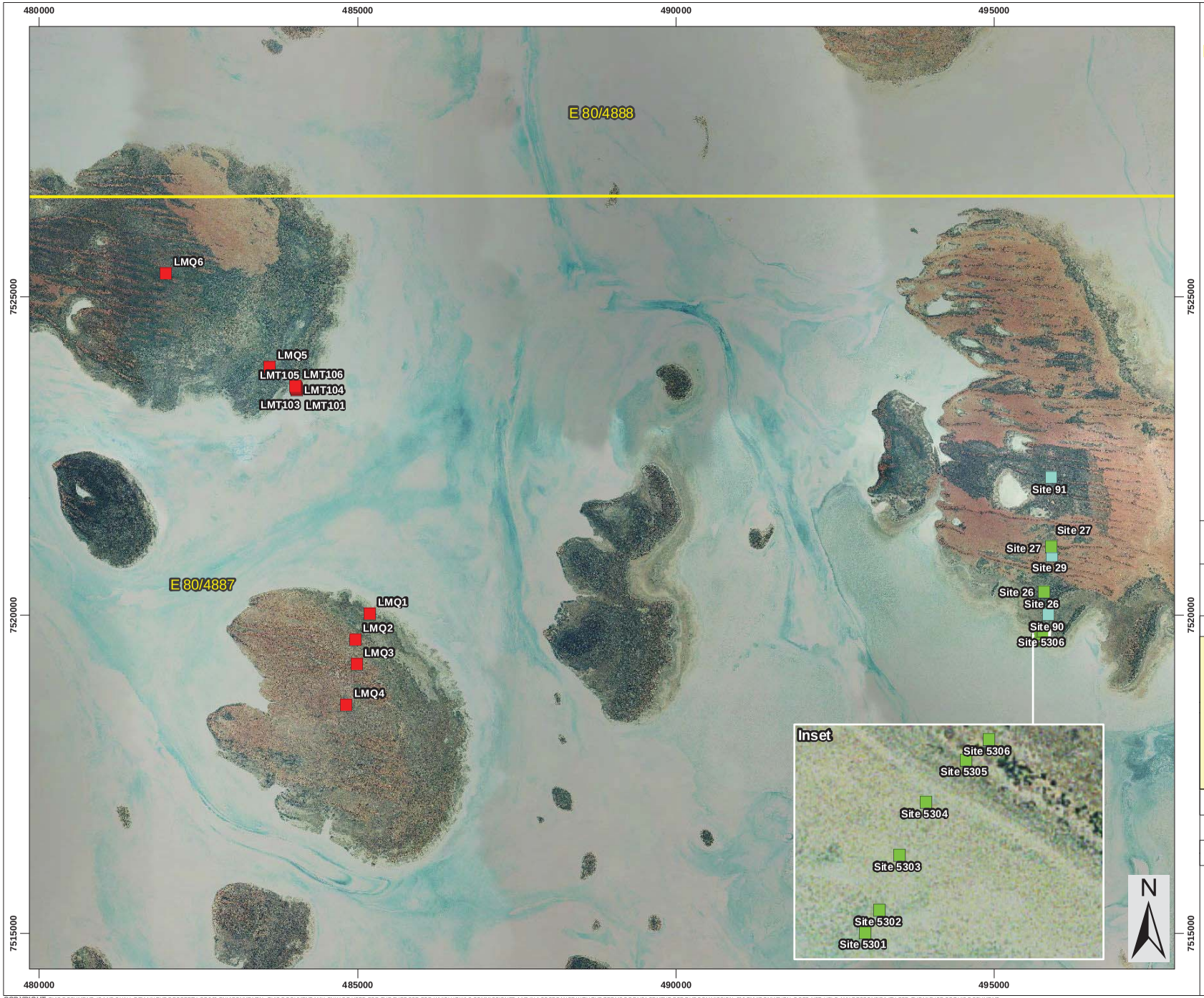
CREATED	CHECKED	APPROVED	REVISION
JA	AD	NW	0

Agrimin
Sulphate of Potash Project
Lake Mackay, WA

Detailed Flora and Vegetation Assessment

Figure 6a
Survey Locations (2016/2017)

K:\Projects\1.0 EBS\2188 Eco Surveys Lake Mackay\Figures\2188 Figure 5b Quadrat Survey Locations (2016-2017).mxd



Legend

- Tenements
- 360 Re-Surveyed Quadrat Locations (Ecologia 2016)
- Quadrat Locations (Ecologia Survey 2016)
- Quadrat Locations (360 Survey 2017)

- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS
- LOCALITY MAP SOURCED LANDGATE 2006
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LOCALITY MAP

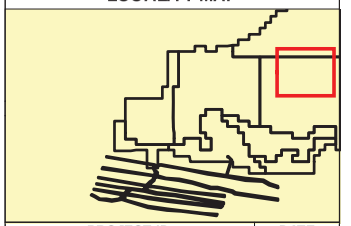

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Figure 6b
Survey Locations (2016/2017)

K:\Projects\1.0 EBS\2188 Eco Surveys Lake Mackay\Figures\2188 Figure 5b Quadrat Survey Locations (2016-2017).mxd

3.2.4 Systematic Searches

In addition to the information collected from the quadrats and relevés, traverses on foot targeting suitable habitat likely to support significant flora were undertaken. Known populations of conservation significant flora in the Survey Area identified during the desktop assessment were also visited to confirm their occurrence. For each population of conservation significant flora identified during the field survey, the following were recorded:

- Co-ordinate locations (using handheld GPS units);
- Abundance/population size;
- Date, time and name of botanist (including flora licence details);
- Reproductive condition and any interesting features (i.e. health); and
- Brief vegetation association description.

For each new population of significant flora recorded during the survey, a suitable reference specimen was taken and lodged at the Western Australian Herbarium (WAH) and Threatened (Declared Rare) Flora Report forms were completed.

3.2.5 Taxonomy and Nomenclature

Where field identification of plant taxa was not possible, specimens were collected systematically for later identification using resources of the WAH. The majority of the taxonomy was completed by experienced taxonomist Brian Morgan, with assistance from other taxonomist specialists (Mike Hislop and Kelly Shepherd).

The species list was checked against FloraBase (WAH 2017) to determine the species' conservation status. Threatened and Priority flora were verified against the EPBC Act listing of threatened species to determine Commonwealth listing.

Introduced species were checked against the BAM Act Declared Plants list to determine if any are Declared Plants, as with the WONS list (Thorp and Lynch 2000).

3.2.6 Vegetation Mapping and Statistical Analysis

The vegetation communities were described based on a combination of their structure and species composition, as defined by quadrat, relevé data and field observations. Vegetation boundaries were mapped in the field using handheld GPS (Garmin) units and high-resolution aerial photographs which, in the office, were then digitised using GIS software.

Vegetation condition was mapped in the field using handheld GPS (Garmin) units and high-resolution aerial photographs. Vegetation condition was based on the Trudgen vegetation condition scale (Trudgen 1998) (Appendix D).

All statistics were carried out using Primer-E version 6.1.5 (Clarke and Gorley 2006). Quadrats were classified on the basis of similarity in species composition. Quadrat cover

data was pre-treated with square root transformation and a Dendrogram was then computed using hierarchical agglomerative cluster analysis. Using the results of the observations made in the field, boundaries of the vegetation communities were finalised on aerial photographs at a scale of 1:20,000 with the aid of GPS coordinates taken during the field survey. The vegetation communities were digitised and reproduced as electronic mapping data using GIS software.

In order to assess the adequacy of the field survey, a species accumulation curve was generated (note that this was undertaken using only systematic site data [quadrat data]). The species accumulation curve analyses accumulation rates of new species added during the survey period. That is, as the number of quadrats increases, the number of newly recorded species should increase until the accumulation of new species declines (the graph reaches an asymptote). This indicates that the majority of species have been recorded and that the area has been adequately surveyed (species accumulation curves can be useful in estimating total species richness). The accumulation curve generated was based on presence / absence data and the sample order being random with a maximum 999 permutations. Four estimator curves (Chao2, Jacknife 1, Jacknife 2 and Bootstrap) were also generated using Primer-E version 6.1.5 (Clarke and Gorley 2006). These estimator curves help predict the true total number of species that would be observed as the number of sites tends to infinity.

4 Results

4.1 Flora and Vegetation Survey Limitations and Constraints

Survey constraints are often difficult to predict, as is the extent to which they influence survey effort. Survey limitations and constraints of the flora and vegetation survey are detailed in Table 4.

Table 4: Limitations and constraints associated with the survey.

VARIABLE	IMPACT ON SURVEY OUTCOMES
Access	Due to the vast size and remoteness of the Study Area, it was not possible for it to be surveyed and accessed in its entirety. Further to this, access was constrained as a result of limited tracks for vehicles (one primary track and no off track driving is permitted as a part of an agreement with the Kiwirrkurra People). In addition, the larger Islands of Lake Mackay that were sampled are approximately 40 km from the end of the nearest track or about 35 km from the lakes edge. Consequently, access for the most part was limited to the use of a helicopter and walking between sites, with the survey effort primarily focussing on the proposed infrastructure areas, a proposed track option and three islands (Survey Area).
Experience	The personnel who executed the survey were practitioners suitably qualified in their respective fields: • Coordinating Botanists: Brian Morgan (Senior Botanist) and Amy Dalton (Botanist); • Field Staff: Brian Morgan and Amy Dalton; • Taxonomy: Brian Morgan (with assistance from other taxonomic specialists); • Data Interpretation and Reporting: Amy Dalton and Narelle Whittington (Principal Botanist); • Report Review: Dr Ron Firth (Principal Zoologist)
Timing, weather, season	The survey was undertaken during April 2017 which is the recommended survey period for the Eremaean zone, where the primary survey is recommended from March to June (6-8 weeks post wet season) (EPA 2016). The survey was conducted after three months of below

VARIABLE	IMPACT ON SURVEY OUTCOMES
	average rainfall (refer to Section 2.1). Flora composition changes with time, particularly across the seasons and with seasonal conditions. Fire history also affects the composition of flora. Therefore, botanical surveys completed at different times of the year will have varying results.
Scope: Life forms sampled	The survey was consistent with a Detailed Flora and Vegetation Assessment and included high level sampling of vascular flora and vegetation.
Sources of information	Relevant DPaW and EPBC searches were undertaken for the Survey Area. Relevant publically available reports from the region were also reviewed.
Completeness	All broad vegetation communities were sufficiently surveyed, with 68 sites surveyed. This comprised 28 (50 x 50 m quadrats), 10 relevés, 3 transects (total of 18 [3 x 3 m] quadrats), six revisits to 50 x 50 m quadrats and one revisit to one transect (transect consisted of six 3 x 3 m quadrats) along with mapping notes. The number of sites is considered adequate for a Detailed Flora and Vegetation Assessment.
Current land use and disturbances	There was very little pre-existing disturbance in the Survey Area and wider Study Area. What disturbance there was is considered minor and included animal tracks and some signs of browsing by camels, recent fire (particularly in the western proposed infrastructure area) and some evidence of relatively recent historic mining activity such as tracks and some rubbish.

4.2 Flora Results

4.2.1 Database Results

The DPaW Threatened and Priority Flora database and EPBC search listed ten Priority flora taxa as potentially occurring in the Survey Area. No Threatened/EPBC listed species were present in the database search (Appendix E [Figure 7]). A likelihood assessment based on preferred habitat and distance to records was undertaken for these ten conservation significant flora, with four taxa being considered Likely to occur (two of these species *Goodenia virgata* (P2) and *Goodenia modesta* (P3) were recorded during the survey) and six taxa considered Unlikely to occur based on their closest recorded distance and the lack of suitable habitat in the Survey Area.

The likelihood assessment of these ten conservation significant flora occurring in the Survey Area and wider Study Area is outlined in Appendix E.

A DPaW TEC and PEC database search did not return any results for TECs or PECs occurring in or adjacent to the Survey Area and wider Study Area.

4.2.2 Desktop Survey Results

There have been few detailed botanical studies in this area of the Great Sandy Desert Region. Previous botanical surveys have mostly been conducted by biological consulting companies. This includes a first-phase Level 2 Flora and Vegetation Assessment (Ecologia 2017), a Level 1 Flora and Vegetation Assessment (Outback Ecology 2012) and a Traditional Owner Flora Survey (Desert Wildlife Services 2010). The results of these surveys area summarised below.

Single Phase Level 2 Flora and Vegetation Assessment (Ecologia 2017)

Ecologia conducted a single phase Level 2 Flora and Vegetation Assessment in 2016. The objective of the survey was to provide preliminary data to support the approval of the Sulphate of Potash mine at Lake Mackay for Agrimin.

A total of 31 (50 x 50 m) quadrats, along with six transects of six 3 x 3 m quadrats (36 quadrats), were used to define vegetation communities. A total of 214 subgeneric taxa were recorded. Four Priority flora taxa were recorded in the Study Area: *Tecticornia globulifera* (P1), *Goodenia virgata* (P2), *Thysanotus* sp. Desert East of Newman (P2), and *Stackhousia clementii* (P3).

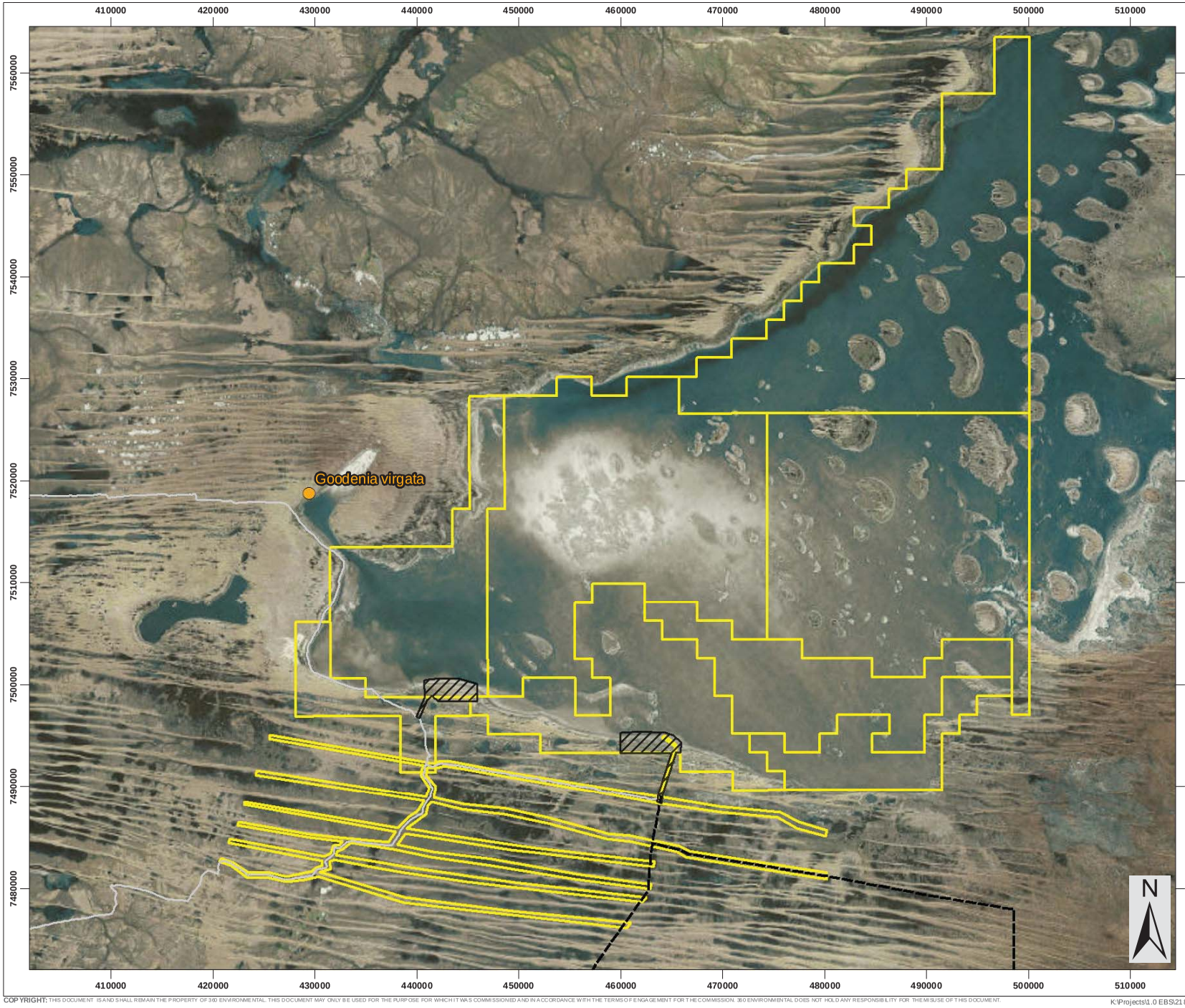
Level 1 Flora and Vegetation Assessment – Lake Mackay Theseus Project (Outback Ecology 2012)

Outback Ecology conducted a Level 1 Flora and Vegetation Assessment at Lake Mackay, near the southern boundary of the Study Area.

The survey included nine quadrats and 11 releves which were used to define seven community types. A total of 141 taxa were recorded, all of which were native. Of these taxa, *Goodenia anfracta* is currently listed as a Priority 1 species.

Traditional Owner Flora Survey, Biological Resources of the Kiwirrkurra Region (Desert Wildlife Services 2010)

Desert Wildlife Services also conducted a flora survey in the current Study Area. The survey identified 117 taxa. Three priority species were identified which included *Goodenia virgata* (P2), *Goodenia modesta* (P3) and *Dampiera atriplicina* (P3).



Legend

- Tenements
- Proposed Infrastructure Boundaries
- Existing Track
- Proposed Track

Rare and Priority Flora

- Priority 2

- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS
- LOCALITY MAP SOURCED LANDGATE 2006
- TENEMENTS SOURCED FROM AGRIMIN 2017
- RARE AND PRIORITY FLORA SOURCED DPAW 2017
- AERIAL PHOTOGRAPHY SOURCED LANDGATE 2007 AND ADDITIONAL LANGATE COMPOSITE AERIALS (© Western Australian Land Information Authority 2015)

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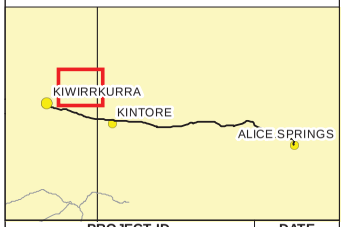

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Sulphate of Potash Project
Lake Mackay, WA

Detailed Flora and Vegetation Assessment

Figure 7
Rare and Priority Flora

K:\Projects\1.0 EBS\2188 Eco Surveys Lake Mackay\Figures\2188 Figure 6 Rare and Priority Flora.mxd

4.2.3 Overview of Flora Survey Results

A total of 253 taxa (including species, subspecies, varieties and forms) from 117 genera and 42 families were identified from quadrats, relevés and opportunistic collections in the Survey Area and wider Study Area, with the taxa inventory presented in Appendix F. The most commonly occurring families were Fabaceae (35 taxa), Poaceae (29 taxa) and Malvaceae (21 taxa). The most frequently recorded genera were *Acacia* (12 taxa), *Tecticornia* (10 taxa) *and Sida* (10 taxa). The site data sheets are presented in Appendix G

Due to poor material, eight specimens could only be identified to the genus level. None are considered to represent conservation significant species.

A species accumulation curve was generated using quadrat data and is illustrated below in Figure 8. The species accumulation tool routine plots (and lists) the increasing total number of different species oberserved as sites are successively pooled (Sobs [number of species observed curve] curve in Figure 8). Four extrapolators were plotted to help predict the true total number of species that would be observed as the number of sites tends to infinity (the asymptote of the species accumulation curve). A total of 231 taxa were recorded from the quadrat sites (Sobs curve) while the four species extrapolator curves gave an estimated range of 260 to 340 taxa.

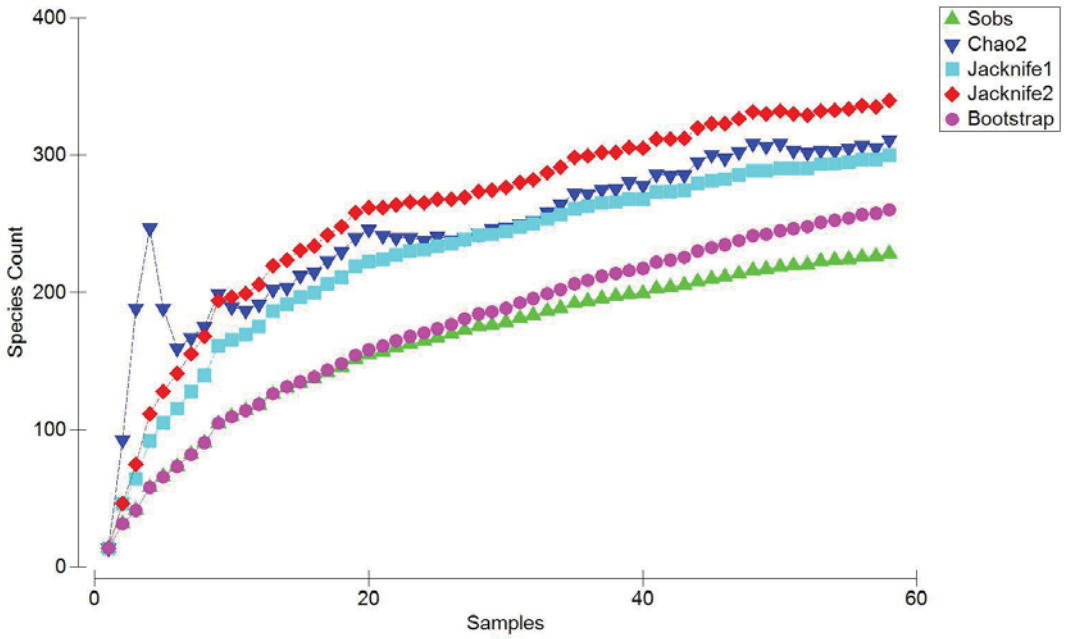


Figure 8: Species Accumulation Curve and Extrapolator Curves based on quadrat data.

4.2.4 Flora of Conservation Significance

No Threatened species listed under the EPBC Act and/or gazetted as Threatened under the WC Act were recorded during the survey.

Three priority-listed flora were recorded during the survey. These taxa, together with their corresponding priority status, are listed in Table 5 and their locations are presented in Figure 9.

Table 5: Conservation Significant Taxa Recorded During the Survey.

CONSERVATION STATUS	TAXON
Priority 1	*Tecticornia globulifera*
Priority 2	*Goodenia virgata*
Priority 3	*Goodenia modesta*

Tecticornia globulifera (P1)

Tecticornia globulifera is a low shrub reaching 0.5 m (Plate 1). This species is known from 11 collections at the WAH, with the collections including specimens observed on saline flats and lake margins. *Tecticornia globulifera* was recorded from one location in vegetation association 'LakeLower'.

Plate 1. *Tecticornia globulifera* (P1) recorded in the Survey Area (Ecologia 2017)

Goodenia virgata (P2)

Goodenia virgata is a herb reaching 0.4 m high (Plate 2). It is known from 5 collections at the WAH. The WAH collections include specimens observed on red sandy loam near saltpans. *Goodenia virgata* was recorded from one location in vegetation association 'Ep' (Figure 9).

Plate 2. *Goodenia virgata* (P2) recorded in Study Area (Ecologia 2017).

Goodenia modesta (P3)

Goodenia modesta is a herb reaching 0.5 m (Plate 3). It is known from 21 collections at the WAH. WAH collections include specimens collected on red loam and sand on plains or swales between dunes. *Goodenia modesta* was recorded from two locations in vegetation associations 'EgCo'and 'Ep' (Figure 9).

Plate 3. *Goodenia modesta* (P3) recorded in Study Area (WAH 2017).

4.2.5 Flora of Interest

Several flora of interest were recorded during the survey and are discussed below:

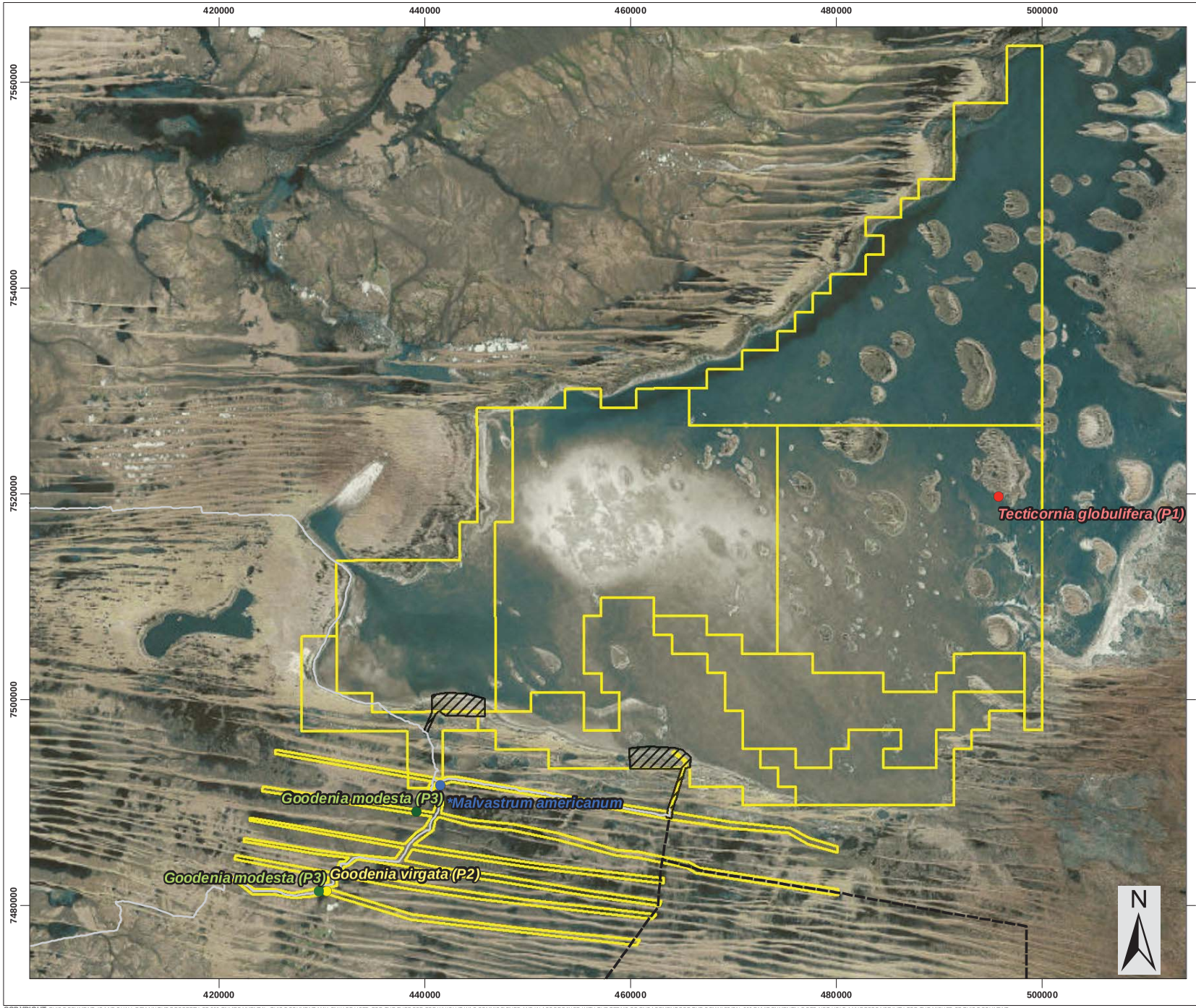
- *Tephrosia* sp. deserts (J.R. Maconochie 1403) – considered to be poorly collected and was submitted to the WAH at the request of Ryonen Butcher (Technical officer at the WAH);
- *Stemodia* sp. Tanami (P.K Latz 8218) – considered to be poorly collected and was submitted to the WAH at the request of Mike Hislop (Technical officer at the WAH);
- *Sclerolaena recurvicuspis* – considered to be poorly collected and submitted to WAH at the request of Rob Davies (Technical officer at the WAH);
- *Tecticornia tenuis* – considered to be poorly collected and submitted to the WAH at the request of Kelly Shepherd (Technical officer at the WAH);
- *Tecticornia* aff. *calyptrata* – considered to be poorly collected and submitted to the WAH at the request of Kelly Shepherd;
- *Tecticornia* aff. *halocnemoides* – considered to be poorly collected and submitted to the WAH at the request of Kelly Shepherd;
- *Fimbrostylis oxystachya* – was a significant range extension for its known recorded distribution and was submitted to the WAH; and
- *Sida* sp. – could not be identified to species level and has been submitted to the WAH at request of Mike Hislop.

4.2.6 Introduced Flora

One introduced species was recorded during the survey. This introduced species is not listed as WONS or Declared under the BAM Act.

**Malvastrum americanum* (Spiked Malvastrum) was recorded in one location 19 times in quadrat LMRQ84 (Plate 4) (Figure 9). This location was dominated by *Eucalyptus victrix* in a clay depression. This species is a weed of river and creek margins, wasteland and many arid zone habitats from the Kimberley to the Pilbara and Gascoyne regions (Hussey *et al*. 2007).

Plate 4. **Malvastrum americanum* recorded in the Study Area.



Legend

- Tenements
- Proposed Infrastructure Boundaries
- Existing Track
- Proposed Track

Surveyed Priority Flora

- *Tecticornia globulifera* (P1)
- *Goodenia virgata* (P2)
- *Goodenia modesta* (P3)
- **Malvastrum americanum*

- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS
- LOCALITY MAP SOURCED LANDGATE 2006
- TENEMENTS SOURCED FROM AGRIMIN 2017
- RARE AND PRIORITY FLORA SOURCED DPAW 2017
- AERIAL PHOTOGRAPHY SOURCED LANDGATE 2007 AND ADDITIONAL LANGATE COMPOSITE AERIALS (© Western Australian Land Information Authority 2015)

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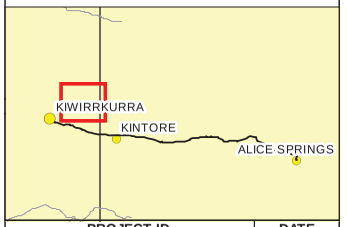

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Figure 9
Surveyed Priority Flora

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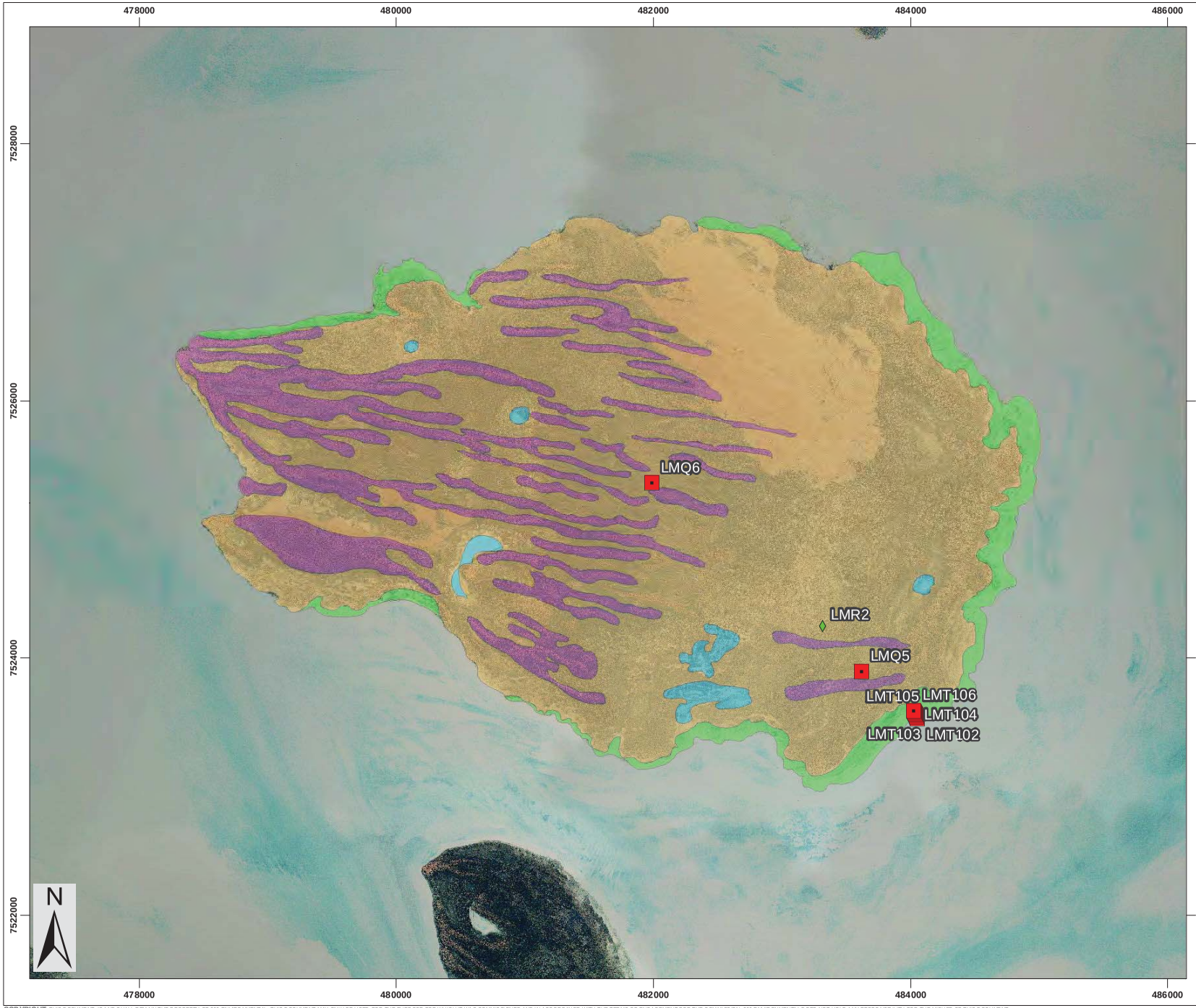
4.2.7 Vegetation Associations

Nineteen vegetation associations from seven landforms or broad vegetation complexes were identified in the Survey Area (Figure 10a-k). The vegetation associations are summarised in Table 6 and the results of the multivariate analysis are presented in Appendix H.



Legend

- 2017 Quadrats
- 2017 Releve

Vegetation Complexes

- Island Dune Complex (359.43 ha)
- Island Swales (1493.68 ha)
- Lake Margin (141.2 ha)
- Saline Flats and Depressions (29.29 ha)

- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS
- LOCALITY MAP SOURCED LANDGATE 2006
- CADASTRE SOURCED FROM LANDGATE 22 DEC 2015
- AERIAL PHOTOGRAPHY SOURCED LANDGATE SEPT 2015
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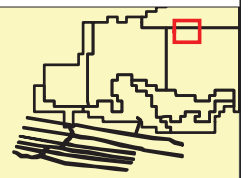
LOCALITY MAP



PROJECT ID	DATE
2188	1/08/2017

HORIZONTAL DATUM AND PROJECTION
GDA 1994 MGA Zone 52

CREATED	CHECKED	APPROVED	REVISION
JA	AD	NW	0

Agrimin
Sulphate of Potash Project
Lake Mackay, WA

Detailed Flora and Vegetation Assessment

Figure 10a:
Vegetation Complexes - Island 1

K:\Projects\1.0 EBS\2188 Eco Surveys Lake Mackay\Figures\2188 Figure 9a Vegetation Complex Island1.mxd