Native Vegetation Clearing Permit (Purpose): Supporting Documentation

Apollo Hill Pilot Project

Prepared for Saturn Metals Limited

29 July 2024

Project Number: TE24038

DOCUMENT CONTROL

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Approval for Release

Name	Position	File Reference
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1 Introduction

1.1 Background

Talis Consultants have been appointed by Saturn Metals Limited (Saturn) to prepare a Native Vegetation Clearing Permit (NVCP) application for clearing works required for the development of the Apollo Hill Pilot Project (the Project).

The Project is located approximately 650 kilometres (km) north-east of Perth and 50 km south-east of the town of Leonora in the Eastern Goldfields district in Western Australia (WA) (Figure 1-1). The Project includes the proposed development of an open pit (290 metres (m) long and 30 m deep), a waste rock landform (WRL), a run-of-mine (ROM) pad, an ore crushing circuit, a heap leach pad, process ponds and plant, a power plant, topsoil stockpile areas and associated infrastructure areas. All the main Project infrastructure will be located on mining lease M31/486 (Figure 1-2). A borefield to supply process water will also be developed following investigation into groundwater resourcing.

The current pit design allows for variable mining scenarios up to 2 million tonnes (Mt) of ore and waste which will be used to run a stacking height heap leach trial. The life of mine (LoM) for this bulk sample mining and pilot heap leach project will be approximately 2 years, with construction planned to commence in mid 2025, and mining and heap leach commissioning operations in late 2025.

Saturn Metals Limited is the registered tenement holder for the Project tenements. A summary of the relevant project tenement for the NVCP application is listed in Table 1-1. No clearing will be undertaken on tenement L31/93 until it is granted.

Table 1-1: Project Tenements

Tenement	Tenement Area (ha)	Date Granted	Expiry Date	Status
M31/486	410.80	12/03/2015	11/03/2036	Live
M39/296	24.43	30/09/1993	29/09/2035	Live
L31/93	377.00			Pending

Under Section 51C of the *Environmental Protection Act 1986* (EP Act), the clearing of any native vegetation requires an approved clearing permit, unless an exemption applies. Exemptions for mining generally apply to areas of low impact mining and exploration, or for proposals that have already been assessed by the Environmental Protection Authority (EPA), Department of Water and Environmental Regulation (DWER) or Department of Energy, Mines, Industry Regulation and Safety (DEMIRS) through a separate process. Since the vegetation clearing will require a greater area, the exemption for clearing will not apply in this case.

This NVCP application is to clear up to 197 hectares (ha) of native vegetation within the Development Envelope (DE) of approximately 811 ha.

1.2 Purpose of Clearing Permit Application

The purpose of this NVCP supporting document is to present the results of an assessment of the clearing aspects of this proposal against the ten clearing principles as outlined in the (then) Department of Environment Regulation (DER)'s *A guide to the assessment of applications to clear native vegetation* (2014) under Part V Division 2 of the EP Act. This report identifies the potential environmental impacts associated with the proposal based on the best available data. This report and accompanying NVCP Purpose Permit application form will be submitted to DEMIRS for assessment.

1.3 Proposed Timeframe

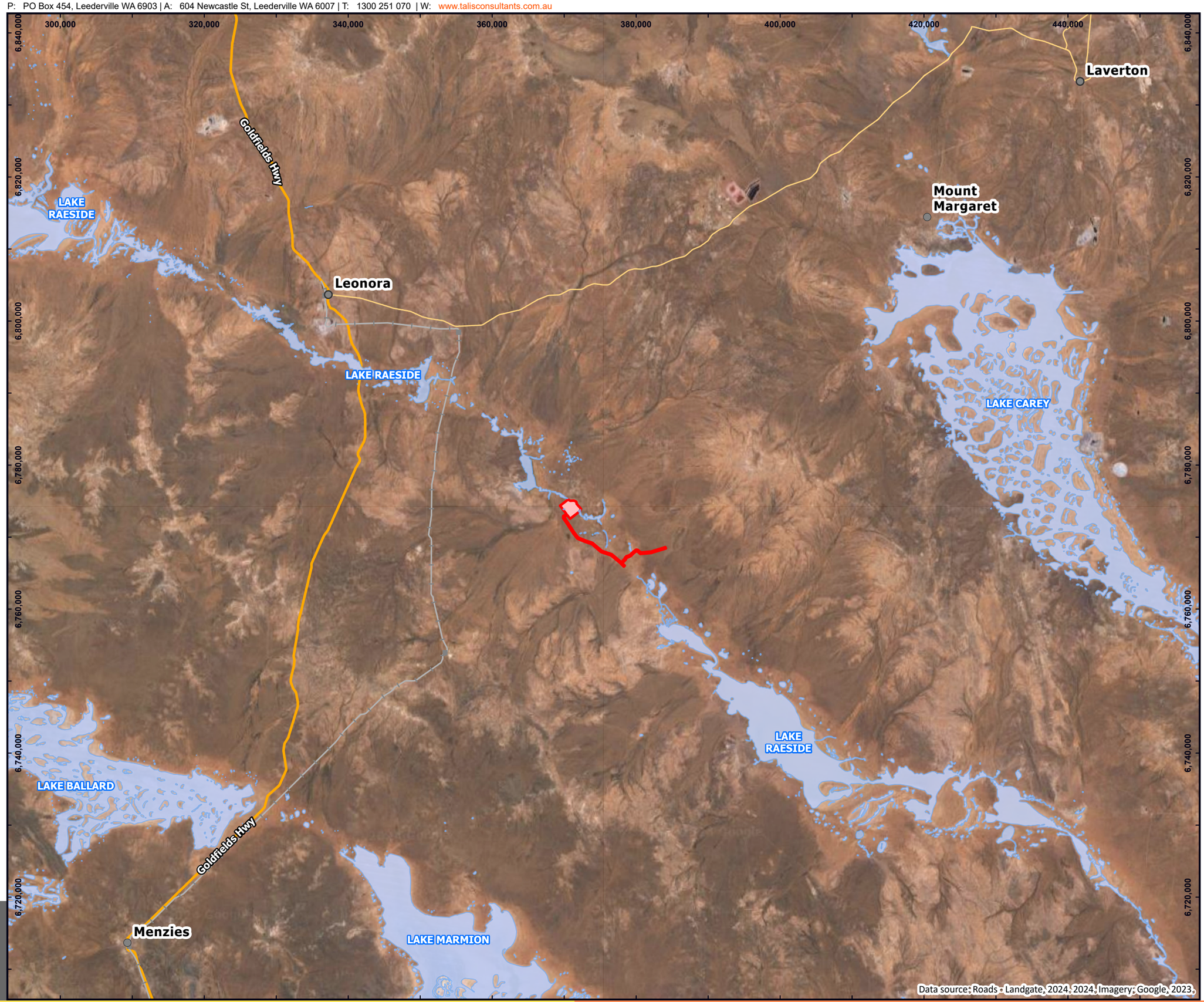
Clearing is proposed to commence in Q3 2024 with clearing and associated works likely to be completed by early 2025.

1.4 Responsible Applicant

Saturn Metals Limited are responsible for the implementation of the clearing described within this report. Correspondence relating to this NVCP application should be addressed to:

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General Manager – Project Development
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sellison@saturnmetals.com.au

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LEGEND

- Development Envelope
- Lakes

Rail Network

- Railway Stations
- Railway Lines

Western Australian Roads

- Freeway / Highway
- Main Road

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LOCALITY



0 500 1,000 1,500 2,000 2,500 km

LOCALITY

Apollo Hill Pilot Project

Native Vegetation
Clearing Permit
Saturn Metals Limited

N

0 5 10 15 20 km

Coordinate System: GDA2020 MGA Zone 51
Scale @ A3: 1:500,000

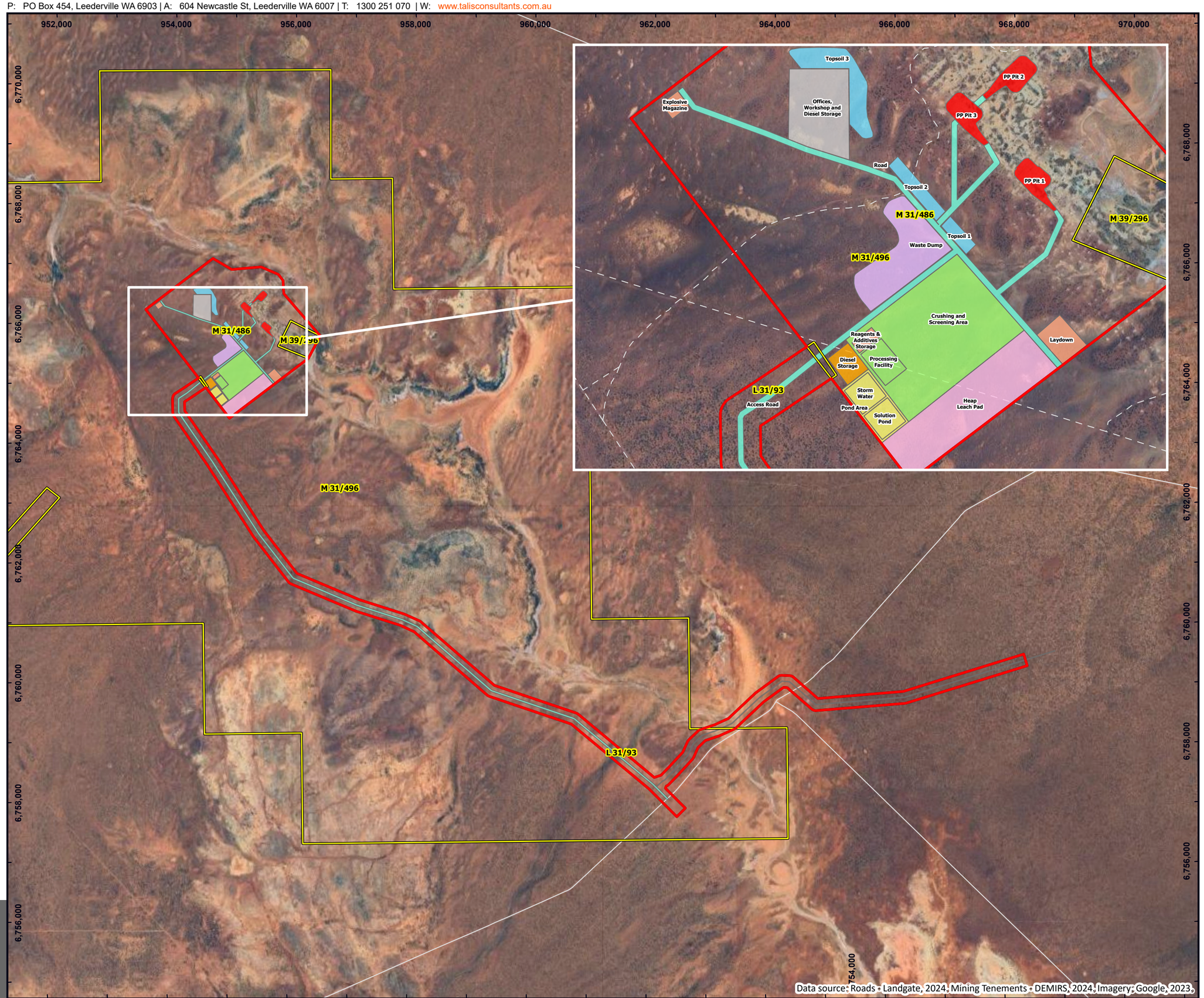
Prepared:	E Jackson	Date:	15/04/2024
Reviewed:	J Kirke	Revision:	A
Project:	TE24038		

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Figure 1-1

Document Path: \\server\talis\SECTIONS\Environment\Projects\TE2024\TE24038 - Apollo Hill Pilot Project Approvals\GIS\Maps\TE24038 - Apollo Hill Mining Proposal\TE24038 - Apollo Hill Mining Proposal.aprx

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LEGEND

- Development Envelope
- Currect Mining Tenements

Site Layout

- Evaporation Pond
- Fuel Storage Facility
- Heap or Vat Leach Facility
- Laydown or Hardstand Area
- Mining Void
- Plant Site
- Topsoil Stockpile
- Transport or Service Infrastructure Corridor
- Waste Dump
- Workshop

Western Australian Roads

- Minor Road

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LOCALITY



0 100 200 300 400 500 km

SITE LAYOUT

Apollo Hill Pilot Project

Native Vegetation Clearing Permit

Saturn Metals Limited

N

0 500 1,000 1,500 2,000 2,500 m

Coordinate System: GDA2020 MGA Zone 51
Scale @ A3: 1:60,000

Prepared:	E Jackson	Date:	15/04/2024
Reviewed:	I Tucakovic	Revision:	A
Project:	TE24038		

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Figure 1-2

Data source: Roads - Landgate, 2024. Mining Tenements - DEMIRS, 2024. Imagery: Google, 2023.

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2 Site Overview

2.1 Climate

The Project occurs in an area with an arid climate, with mainly winter rainfall (Cowan, 2021). The closest weather station to the Project is Leonora Station (012046). Climatic data at this station dates back to the 1980 and has been used to provide an indication of the climatic conditions within the Project area (BoM, 2024) (Figure 2-1). Average annual rainfall recorded at weather station 012046 is 236.4 mm, peaking in the month of February where the maximum monthly average rainfall is 30.9 mm. September and October are the driest months of the year on average, receiving less than 10 mm. The average maximum temperature for the area is 27.9 degrees Celsius (°C), with the hottest months being November through to March, with temperatures consistently above 30°C on average. June through to August represent the coolest months, with average minimum temperatures of 7.3°C, 6.1°C and 7°C, respectively.

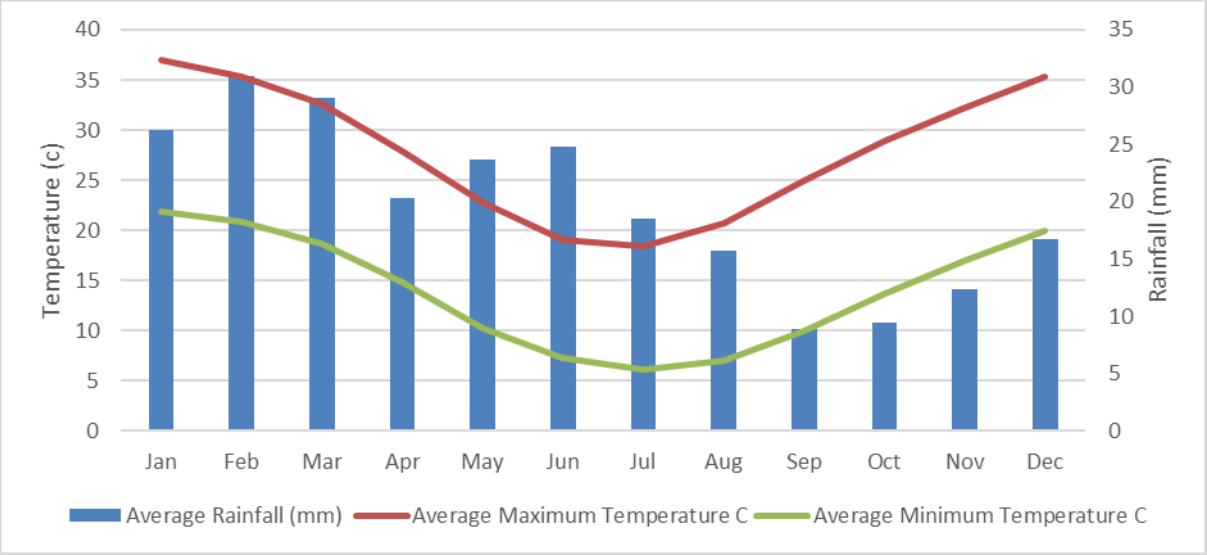


Figure 2-1: Climate Data for Leonora, Station ID 012046 (BoM, 2024)

Morning easterly winds primarily of speeds up to 10 km/hr are typical of the area, shifting to a more southeasterly and sometimes westerly direction in the afternoons (BoM, 2024) (Figure 2-2).

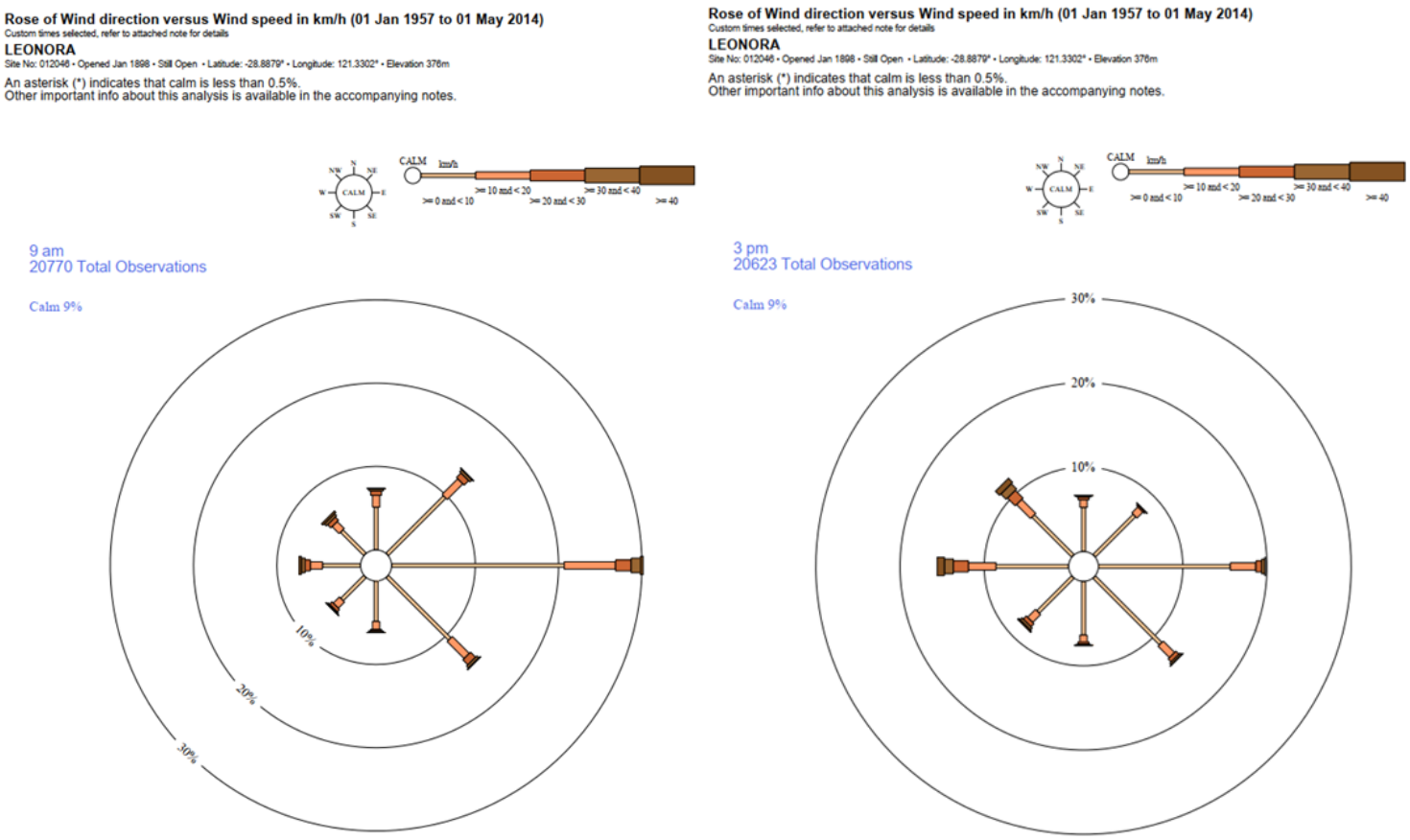


Figure 2-2: Wind Rose for Leonora (9 am and 3 pm) (BoM, 2024)

2.2 Topography

The Project is characterised by a subdued topography, comprising flat hardpan wash plains with scattered mantles of small pebbles and gravels (dominated by quartz). The high-point of the Project site is the Apollo hills to the north-west where the proposed pit development is located (up to 369mAHD), and south-west and southwards from this high point is the flat wash plains (355-357 mAHD) where rainfall runoff and drainage occurs steadily into the soils comprising of sandy clays with pebbles (SES, 2023). Apollo Hill forms the highest point at 374 mAHD, while the lowest point locally is the surface water drainage channel within the wider Lake Raeside drainage system to the west of the proposed pits at 348 mAHD (Pentium, 2023).

2.3 Interim Biogeographic Regionalisation of Australia

The Interim Biogeographic Regionalisation of Australia (IBRA) 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 (Department of Climate Change, Energy, the Environment and Water, 2021).

The Project is located within the Murchison bioregion and East Murchison subregion. The Murchison bioregion is characterised by mulga low woodlands often rich in ephemerals, on outcrop and fine-textured Quaternary alluvial and eluvial surfaces mantling granitic and greenstone strata of the northern part of the Yilgarn Craton (DCCEEW, 2022).

The East Murchison subregion contains the northern parts of the 'Southern Cross' and 'Eastern Goldfields' Terrains of the Yilgarn Craton and is characterised by its internal drainage, and extensive areas of elevated red desert sandplains with minimal dune development (Cowan, 2021). It includes salt lake systems associated with the occluded Paleodrainage system and broad plains of red-brown soils and breakaway complexes, as well as red sandplains (Cowan, 2021). Vegetation is dominated by Mulga Woodlands often rich in ephemerals: hummock grasslands, saltbush shrublands and Halosarcia shrublands (Cowan, 2021).

2.4 Soil Landscape Systems

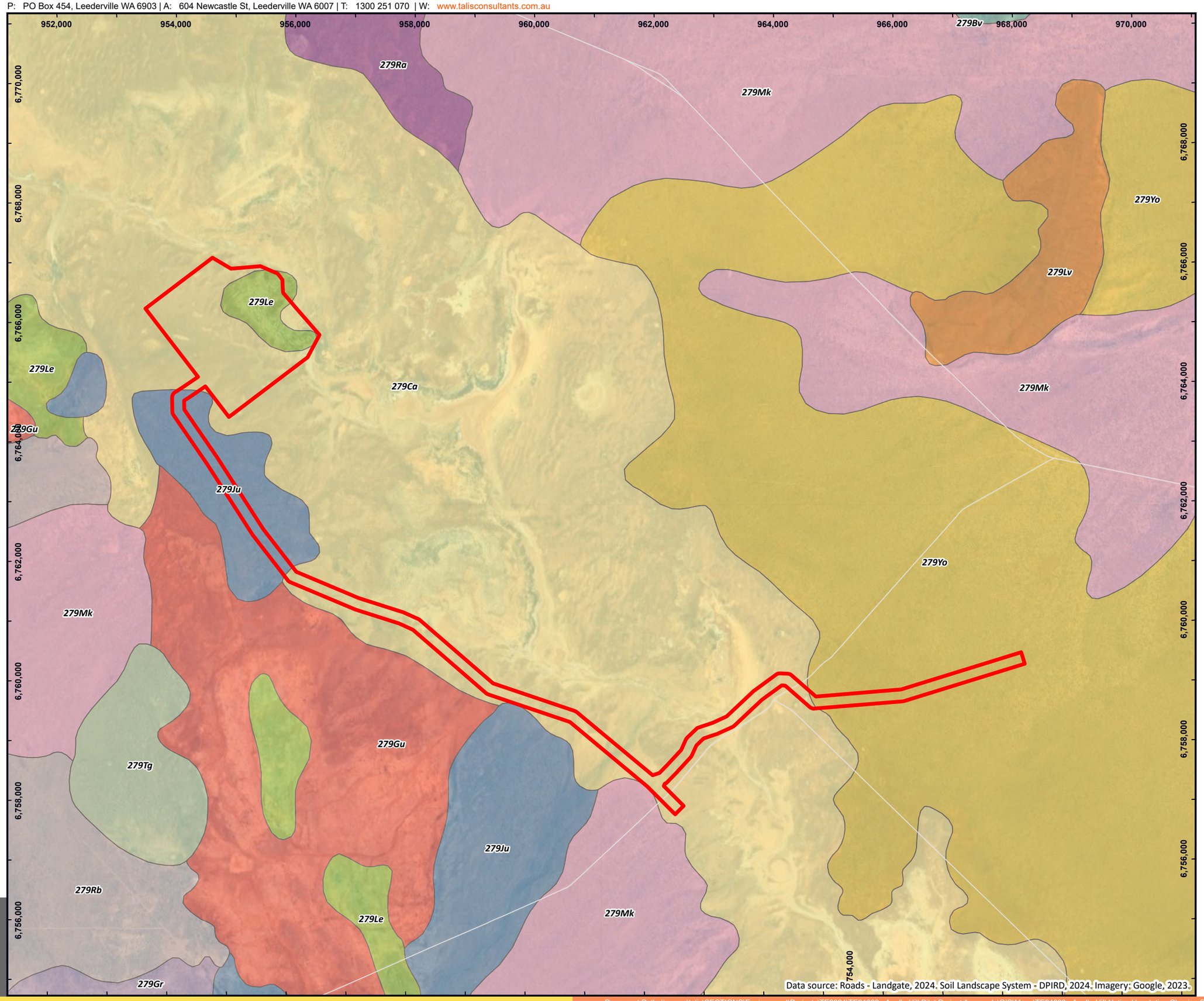
Desktop assessment and data from flora and fauna assessment (Ecoscape, 2024) and data from the Department of Primary Industries and Regional Development (DPIRD, 2022) determined four soil landscape systems are present within the proposed DE (Figure 2-3). These are summarised in Table 2-1 below:

Table 2-1: Soil Landscape Systems

Land System	Description	Area (ha)	% of DE
279Le Leonora	Low greenstone hills and stony plains supporting mixed chenopod shrublands.	113.00	13.93

Land System	Description	Area (ha)	% of DE
279Ca Carnegie	Salt lakes with fringing saline alluvial plains, kopi dunes and sandy banks, supporting halophytic shrublands and acacia tall shrublands.	550.94	67.94
279Ju Jundee	Hardpan plains with variable gravelly mantles and minor sandy banks supporting weakly groved mulga shrublands.	74.16	9.15
279Yo Yowie system	Sandy plains supporting tall shrublands of mulga and bowgada with patchy wanderrie grasses.	72.81	8.98
Total		**810**	**100**

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LEGEND

Development Envelope

Soil Landscape Mapping

- Bevon System (279Bv): Irregular low ironstone hills with stony lower slopes supporting mulga shrublands.
- Carnegie System (279Ca): Salt lakes with fringing saline alluvial plains, kopi dunes and sandy banks, supporting halophytic shrublands and acacia tall shrublands.
- Gransal System (279Gr): Stony plains and low rises based on granite supporting mainly halophytic low shrublands.
- Gundockerta System (279Gu): Extensive, gently undulating calcareous stony plains supporting bluebush shrublands.
- Jundee System (279Ju): Hardpan plains with variable gravelly mantles and minor sandy banks supporting weakly groved mulga shrublands.
- Laverton System (279Lv): Greenstone hills and ridges with acacia shrublands.
- Leonora System (279Le): Low greenstone hills and stony plains supporting mixed chenopod shrublands.
- Monk System (279Mk): Hardpan plains with occasional sandy banks supporting mulga tall shrublands and wanderrie grasses.
- Rainbow System (279Rb): Hardpan plains supporting mulga tall shrublands.
- Ranch System (279Ra): Hardpan plains and prominent broad drainage tracts supporting dense mulga tall shrublands.
- Tiger System (279Tg): Gravelly hardpan plains and sandy banks with mulga shrublands and wanderrie grasses.
- Yowie System (279Yo): Sandy plains supporting tall shrublands of mulga and bowgada with patchy wanderrie grasses.

Western Australian Roads

Minor Road

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LOCALITY



0 100 200 300 400 500 km

SOIL LANDSCAPE SYSTEMS

Apollo Hill Pilot Project

Native Vegetation Clearing Permit

Saturn Metals Limited

N

0 500 1,000 1,500 2,000 2,500 m

Coordinate System: GDA2020 MGA Zone 51
Scale @ A3: 1:60,000

Prepared: E Jackson	Date: 15/04/2024
Reviewed: I Tucakovic	Revision: A
Project: TE24038	

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Figure 2-3

Data source: Roads - Landgate, 2024. Soil Landscape System - DPIRD, 2024. Imagery: Google, 2023.

2.5 Hydrology and Wetlands

2.5.1 Surface Water

2.5.1.1 *Regional Hydrology*

The Project is situated within the central-east region of the DWER Raeside-Ponton catchment of the vast Salt Lake Basin, which extends over much of central WA. No streamflow data are available for the Raeside-Ponton catchment.

2.5.1.2 *Local Surface Hydrology*

A surface water assessment of the proposed Project was completed in June 2024 by Carrick Consulting (Appendix A). The Project is located immediately to the southwest of Lake Raeside, a south-east trending paleodrainage system extending over a length of about 350 km and with a surface area of some 633 km^2. It comprises numerous playa lakes and channels varying in width from several hundred metres to over 8 km wide. Lake Raeside is normally dry except following periods of considerable rainfall-runoff when up to several hundred millimetres of water may be stored in discrete parts of the lake. On rare occasions a single, continuous waterbody may be formed over the entire lake surface, leading to outflow into Ponton Creek at its southern end, as occurred most recently in March 1995 with the passage of Tropical Cyclone (TC) Bobby (Carrick Consulting Pty Ltd, 2024).

Analysis of imagery following TC Bobby indicates a maximum flood elevation of approximately 352.5 mAHD in the vicinity of the proposed Project site. The proposed pits, heap leach pad and processing area is situated above this elevation and would therefore not have been inundated. Impacts from standing water at the site would likely have been limited to loss of access along the proposed haul road between the pits and ROM, in addition to direct rainfall to the pits and process ponds (Carrick Consulting Pty Ltd, 2024).

The Lake Raeside lakebed has a nominal surface elevation of about 350 mAHD in the vicinity of the Project, while the elevation at Mount Kildare, the local topographic high located some 12.5 km east of the Project, has an elevation of 429 mAHD. Surface gradients are very low over the lake (typically less than 0.01%) with land adjoining the lake also relatively flat with average slopes in the order of 0.1%. Although the overall gradient or direction of flow over the lakebed is south-eastwards, the movement of water on the lakebed is controlled at a local scale by the presence of islands, levees and bars and the prevailing wind direction (Carrick Consulting Pty Ltd, 2024).

The Project site slopes gently at about 0.2% west to east towards the Lake Raeside paleodrainage channel. The only exception to this is the presence of a range of low hills of up to about 30-35 m relief along the northeastern flank of the site. The proposed open Pits A and B are located within these hills with the lowest crest elevation at 354 mAHD, some 4 m above the nearby Lake Raeside channel elevation.

There are no major river systems or significant watercourses in the vicinity of the Project. However, inspection of the available topographical data and imagery indicates that there are three catchment areas upstream of the proposed Project facilities, namely Northern, Central and Southern catchments. These catchments have a combined area of approximately 6.0km^2 and drain mostly by overland sheetflow, with channelised flow only becoming established within a few hundred metres of the Lake Raeside channel (Carrick Consulting Pty Ltd, 2024).

The land surfaces in the vicinity of the Project are typical of salt lakes with fringing alluvial plains and dunes of kopi or sand within gently inclined wash plains with mantles of fine ironstone gravel that exist across the region. These irregular plains and low rises support mulga and halophytic shrublands.

2.6 Hydrogeology

The Project area is underlain by variably fractured, weathered Archean bedrock, which is part of the Yilgarn Goldfields fractured rock groundwater province (Pentium, 2023). The bedrock is locally covered by paleochannel deposits of alluvium (Pentium, 2023).

2.6.1 Fractured Rock Aquifer

The Archean rocks found in the Project area do not have any intrinsic permeability and make exceptionally poor aquifers. However, secondary porosity contained in structural defects such as joints, faults, and shears, enhanced by weathering and the development of a saprolite profile, does allow for water storage and transmission (Pentium Water, 2023). This secondary porosity forms the fractured rock aquifer.

A typical saprolite weathering profile developed across the region is depicted in Figure 2-4. The Upper Saprolite refers to the zone immediately beneath the ferruginous hard cap where the rock has undergone complete chemical decomposition into heavy textured clay minerals, which may display remnant rock textures (Pentium Water, 2023). The upper saprolite is mostly unsaturated but can form a slow seepage zone where water is present (Pentium Water, 2023).

The transition into Lower Saprolite (the zone of joint oxidation) is characterised by a change from heavy textured clay to soft, decomposed, friable rock 10-20 cm thick. The lower saprolite zone is typically the most reliable water zone (Pentium Water, 2023).

The Saprock (the zone of broken fresh rock between the lower saprolite and the hard fresh rock) can also contain open water bearing defects, particularly within faults, shears and joints. These defects characteristically act as high permeability groundwater conduits but contain virtually no intrinsic groundwater storage.

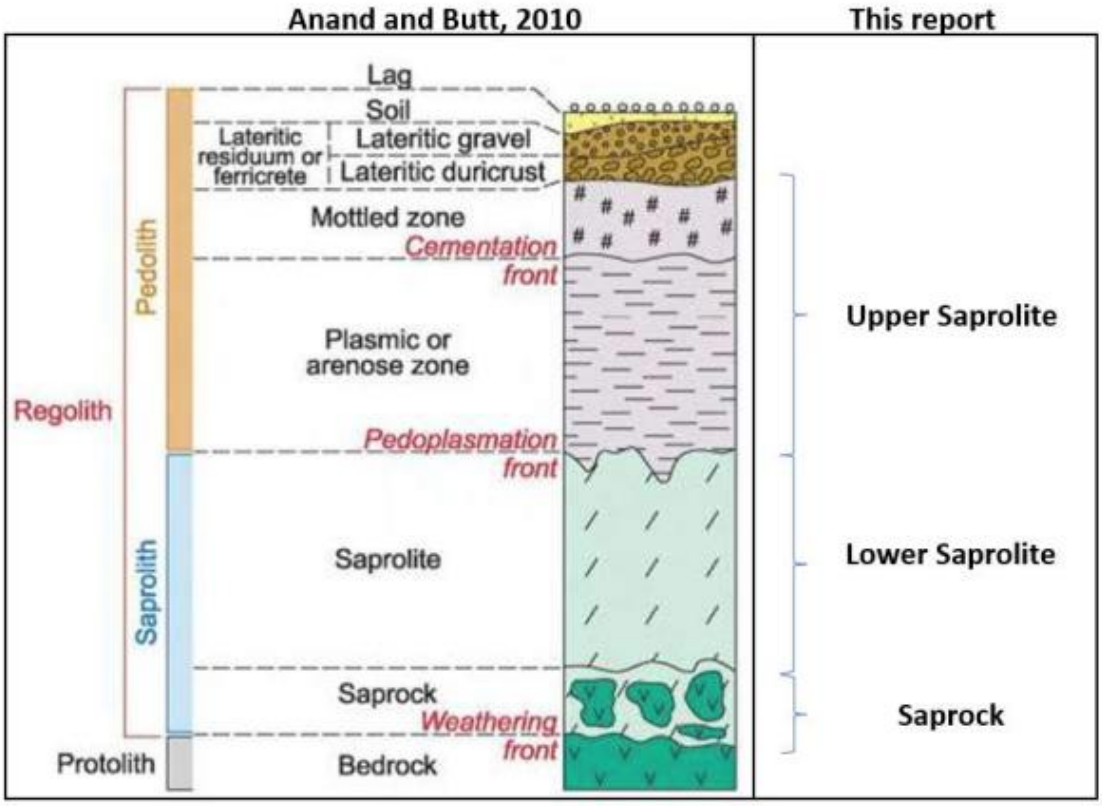


Figure 2-4: Project area geology profile from Anand and Butt, 2010.

The storability and hydraulic conductivity of the fractured rock aquifer is related to the degree of weathering and fracturing of the rock. Greenstones, like those underlying this site, are generally more prospective for groundwater than granitoids (Pentium Water, 2023). The weathered zone in greenstones is generally low yielding for groundwater due to its clay content. However, the transitional zone can have moderate yields. Regional faults and shear zones can have high yields. The project sits on the western edge of the Keith Kilkenny Shear zone, which indicates there may be a high level of fracturing in the area (Pentium Water, 2023).

Underlying the weathered and fractured aquifer, the fresh Archaean rocks in the area are essentially impermeable with limited aquifer storage characteristics (Pentium Water, 2023).

2.6.2 Alluvium and Paleochannels

The site is near the Raeside Paleochannel, which is comprised of a multicoloured, plastic clay with minor sand and pisolite beds with an overall thickness of approximately 120 m (Pentium Water, 2023). The paleochannel sand is highly permeable and contains large amounts of groundwater which is brackish in the tributaries and saline in the main drainages (Figure 2-5). The sand has limited groundwater storage with most of the water abstracted being the result of leakage from overlying sediments and surround fractured-rock aquifers (Pentium Water, 2023).

While the location of the overlying modern drainage channel can be easily determined from satellite images, the exact position of the underlying paleochannel is likely further to the northeast of the Project based on the bedrock outcrops (Pentium Water, 2023).

As the proposed pits occur in outcrop and only reach a depth of 30 mbgl, there is unlikely to be any influence on the Raeside Paleochannel (Pentium Water, 2023).

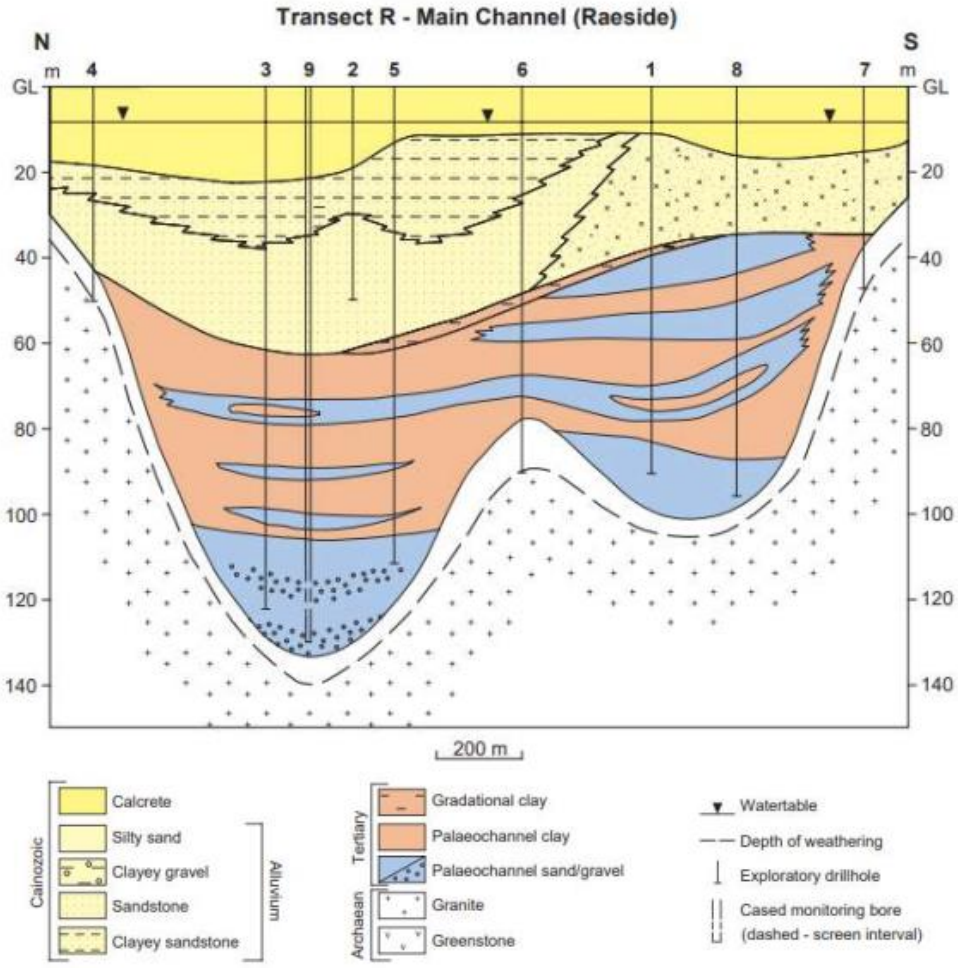


Figure 2-5: A hydrogeological cross section of the Raeside Channel from Johnson et al. 1999

2.6.3 Baseline Conditions

Saturn have retrofitted 22 exploration holes with PVC casing to create a wide array of new monitoring bores. All the monitoring bores were dipped and sampled during November 2022 as part of the Pentium hydrogeology study. The resultant data were used to inform baseline conditions for the site.

Groundwater quality data collected from the bores across site indicate the Total Dissolved Solids (TDS) ranged from 44,000 milligrams per litre (mg/L) to 120,000 mg/L, indicating the groundwater in the area is hypersaline (Pentium Water, 2023). Groundwater salinity contours were drafted based on the monitoring data and indicate salinity increases towards and along drainage lines to the northeast (Pentium Water, 2023).

Other than the high salinity, no other analytes appear to be elevated above the ranges typical of the Goldfields region (Pentium Water, 2023). Appendix B contains the full dataset of water quality results.

Groundwater levels sampled in November 2022 indicate the water level ranges from 1.24-16.36 mbgl, with deeper levels generally seen in the higher relief areas (Pentium Water, 2023). The local water table ranges from 450-355 mAHD and is likely to have an eastern to southeastern

gradient with groundwater predominantly flowing into the drainage channel to the east of the Project (Pentium Water, 2023).

2.6.4 Other Groundwater Users

There are two other groundwater licences within 10 km of the Project. Groundwater Licence (GWL) 167938 held by GME Resources Ltd and allows the extraction of 2 GL of groundwater approximately 400 m to the north of the Project. The second licence (GWL 173529) is held by Ulysses Mining Pty Ltd and authorises the abstraction of 1.2 GL of groundwater, 4.5 km to the southeast of the Project (Pentium Water, 2023).

2.6.5 Dewatering Assessment

A high-level assessment of potential dewatering volumes and associated impacts was undertaken using an analytical model (Pentium, 2023). No test pumping has been conducted on site, so hydraulic parameters were estimated based on other studies in the goldfields and textbook values (Pentium Water, 2023). The Dupuit-Thiem analytical model generated indicates the maximum extent of drawdown to be 0.26 km under a base case scenario. This extends to a radius of 0.49 km under a high hydraulic conductivity scenario (Pentium Water, 2023).

All identified potential groundwater dependent ecosystems and groundwater users lie beyond this distance.

2.7 Conservation Features

The survey area intersects the Lake Carey and Raeside-Ponton catchments (Landgate 2021). Thirteen nonperennial streams are identified within this area, with four classed as major and nine as minor. Among these creeks, only Bullock Hole Creek is specifically named. Additionally, small non-perennial lakes forming part of the upstream tributaries of Lake Raeside, located approximately 20 km south, are located within the survey area (Ecoscape, 2024) (Figure 2-6).

The Groundwater Dependent Ecosystems Atlas (GDEs) indicates that the survey area does not intersect any mapped GDEs (Ecoscape, 2024).

No National Parks, Nature Reserves or other conservation estates occur near the survey area. The nearest conservation estate is Goongarrie National Park, located approximately 67 km south of the survey area (Ecoscape, 2024).

The survey area does not intersect or occur within proximity to any mapped Environmentally Sensitive Areas (ESAs). Survey by Ecoscape (2024) identified the following ESAs nearby:

- Lake Marmion located 42 km to the south;
- Lake Ballard, located 47 km southwest; and
- Goongarrie National Park, located 67 km to the south.

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754,000

Data source: Roads - Landgate, 2024. Hydrology - Geoscience Australia, 2024. Imagery: Google, 2023.

LEGEND

Development Envelope

Hydrography

Lakes

Western Australian Roads

Minor Road

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LOCALITY



0 100 200 300 400 500 km

HYDROGRAPHY

Apollo Hill Pilot Project

Native Vegetation Clearing Permit

Saturn Metals Limited

N

0 500 1,000 1,500 2,000 2,500 m

Coordinate System: GDA2020 MGA Zone 51
Scale @ A3: 1:60,000

Prepared:	E Jackson	Date:	15/04/2024
Reviewed:	I Tucakovic	Revision:	A
Project:	TE24038		

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Figure 2-6

Document Path: \\server\talis\SECTIONS\Environment\Projects\TE2024\TE24038 - Apollo Hill Pilot Project Approvals\GIS\Maps\TE24038 - Apollo Hill Native Vegetation Clearing Permit\TE24038 - Apollo Hill Native Vegetation Clearing Permit.aprx

3 Flora and Vegetation Assessment

Ecoscape Australia Pty Ltd (Ecoscape) was commissioned by Saturn to undertake a detailed flora and vegetation survey and basic terrestrial vertebrate fauna survey for the Project in 2023 (Appendix C). This survey was conducted over an area within mining lease M31/496 encompassing the proposed disturbance footprints and comprising a total survey area of 12,678.83 ha. Both a desktop and field assessment were completed, with the results of the desktop assessment directing targeted searches during the field portion of the survey.

Ecoscape also undertook a detailed flora and vegetation survey and a basic terrestrial vertebrate fauna survey in 2024. Targeted searches for conservation-listed flora, fauna and ecological communities were also undertaken. The second survey was over a smaller area of approximately 822.50 ha, focussing on the proposed DE and access corridors for the Project on tenements M31/486, M39/296 and L31/93.

3.1 Desktop Assessment

The desktop assessment of the flora and vegetation survey involved a search of the available online databases from the Department of Biodiversity Conservation and Attractions (DBCA), using a 100 km buffer, and using a Protected Matters Search Tool (PMST) from Department of Climate Change, Energy, the Environment and Water (DCCEEW), using a 50 km buffer. The Department of Water and Environmental Regulation's (DWER) Index of Biodiversity Surveys for Assessments (IBSA) portal was also searched for any recent studies conducted within or in the vicinity of the Pilot Project area.

3.1.1 Flora Assessment

The PMST search did not identify any *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)-listed Threatened Flora (TF) within the 50 km search buffer area. The results of the DBCA database search identified 56 conservation-listed flora taxa consisting of no Threatened Flora, 15 Priority 1 (P1), four P2, 30 P3 and six P4 species (Ecoscape, 2024).

3.1.2 Vegetation Assessment

3.1.2.1 *Broad Vegetation Types*

Beard vegetation mapping indicates that the survey area intersects three pre-European vegetation units (Figure 3-1):

- Association 18: Mulga *Acacia aneura* and associated species;
- Association 125: Salt lake; and
- Association 389: Mulga, other wattle, Casuarina, Atriplex spp., Maireana spp, with Acacia aneura, A. papyrocarpa, Allocasuarina cristata.

None of the identified vegetation units are below the EPA's Guidance Statement No. 33 minimum threshold of retention of 30% of pre-European extent at the State, bioregion, subregion or local government level (Ecoscape, 2024).

Table 3-1 details the remaining proportion of the vegetation units that lie within the proposed clearing footprint.

Table 3-1: Remaining Extents of Vegetation Associations (DPIRD, 2019)

Vegetation Association	WA	IBRA Murchison region	IBRA East Murchison subregion	LGA (Shire of Leonora)
18	99.75%	99.68%	99.66%	99.62%
125	90.27%	99.83%	99.83%	99.52%
389	99.71%	99.62%	99.62%	99.46%

3.1.2.2 *Ecological Communities*

A search for Threatened and Priority Ecological Communities (TECs and PECs) within the survey area using the DCCEEW Protected Matters Search Tool and DBCA database found there to be no Commonwealth-listed TECs or PECs within the survey area (Ecoscape, 2023). Field surveys confirmed these results with no mapped vegetation types considered representative of any currently described TEC or PEC (Ecoscape, 2023).

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6,770,000 6,768,000 6,766,000 6,764,000 6,762,000 6,760,000 6,758,000 6,756,000 6,754,000

LEGEND

Development Envelope

Pre-European Vegetation

- 125: Salt lake, lagoon, clay pan
- 18: Low woodland, open low woodland or sparse woodland
- 389: Saltbush and/or bluebush with scattered low trees
- 39: Scrub, open scrub or sparse scrub
- 676: Samphire

Western Australian Roads

- Minor Road

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LOCALITY



0 100 200 300 400 500 km

PRE-EUROPEAN VEGETATION

Apollo Hill Pilot Project

Native Vegetation Clearing Permit

Saturn Metals Limited

N

0 500 1,000 1,500 2,000 2,500 m

Coordinate System: GDA2020 MGA Zone 51
Scale @ A3: 1:60,000

Prepared: E Jackson	Date: 15/04/2024
Reviewed: I Tucakovic	Revision: A
Project: TE24038	

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Figure 3-1

Data source: Roads - Landgate, 2024. Pre-European Vegetation - DPIRD, 2024. Imagery: Google, 2023.

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3.2 Field Survey Assessment

The flora and vegetation field survey was conducted as a single-phase Detailed survey according to the Flora and Vegetation Technical Guidance (EPA 2016a) by Ecoscape in 2023 (Appendix C). The field survey was conducted during March/April, within the optimal period for a primary survey within the Eremaean Botanical Province, according to the Flora and Vegetation Technical Guidance (EPA 2016a). Supplementary surveys were conducted during August 2023 (Ecoscape, 2024).

The surveys were undertaken using the floristic quadrat method, where locations were selected using aerial photography, environmental values, and field observations to represent the vegetation values existing at the site. The unmarked quadrats were 20 m × 20 m in dimension, as required according to the Flora and Vegetation Technical Guidance (EPA 2016a). Where the vegetation consisted of a narrow linear corridor, quadrats were linear but of the same overall size, i.e. 400 m^2 (Ecoscape, 2024). At least three quadrats per vegetation type were recorded for the Detailed survey where there was sufficient extent (Ecoscape, 2024).

Targeted searches were conducted in potentially suitable habitats of target species, with the remainder of the site opportunistically searched during site traverses. The central Pilot Plant and Bulk Sample area were extensively traversed at 200 m or less intervals whilst the entire length of the access corridor was also traversed. The locations of all targeted taxa collected were recorded using a handheld GPS (Ecoscape, 2024).

3.2.1 Flora

A total of 166 vascular flora were recorded during the field survey and of these, two were introduced and 25 could not be identified due to the species level. The most represented families were Chenopodiaceae (440 taxa), Fabaceae (26 taxa) and Scrophulariaceae (17 taxa) (Ecoscape, 2024).

3.2.1.1 *Threatened and Priority Flora*

None of the identified species were listed threatened flora and no taxa that were identified resembled any currently described threatened flora (Ecoscape, 2024). Two Priority flora were recorded during the field survey (Figure 3-2Error! Reference source not found.):

- *Tecticornia globulifera* (P1); and
- *Hemigenia exilis* (P4).

These two species are described in more detail in Table 3-2.

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Data source: Roads - Landgate, 2024. Imagery: Google, 2023.

LEGEND

Development Envelope

Threated & Priority Flora

Priority 1

- Tecticornia globulifera
- Tecticornia sp. Christmas Creek (K.A. Shepherd & T. Colmer et al. KS 1063)

Priority 4

- Hemigenia exilis

Conservation Status Not Listed

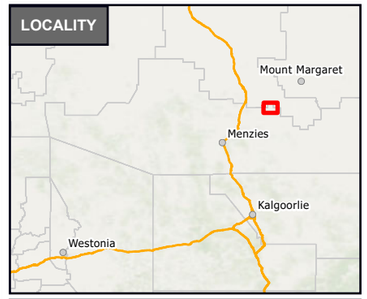
- Multiple Species

Western Australian Roads

- Minor Road

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LOCALITY



0 100 200 300 400 500 km

THREATENED & PRIORITY FLORA

Apollo Hill Pilot Project

Native Vegetation Clearing Permit

Saturn Metals Limited

N

0 500 1,000 1,500 2,000 2,500 m

Coordinate System: GDA2020 MGA Zone 51
Scale @ A3: 1:60,000

Prepared:	E Jackson	Date:	29/04/2024
Reviewed:	I Tucakovic	Revision:	A
Project:	TE24038		

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Figure 3-2

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Table 3-2: Priority Flora Recorded During the Field Survey

Species	Description
Tectricornia globulifera (P1)	**Habitat:** recorded from a samphire dominated saltmarsh **Location:** following the non-perennial creeks from the northeast through to the southwest of the survey area. One population is close to the proposed pits. **Survey results:** 3,342 plants identified within the survey area. **Populations:** Ecoscape suggest four populations within the survey area.
Hemigenia exilis (P4)	**Habitat:** recorded from sandy drainage line. **Location:** along the southeastern corridor section of the survey area. **Survey results:** 45 plants identified within the survey area. **Populations:** One population.

Two introduced flora species (weeds) were recorded during the survey. Neither are Declared Pest Plants or Weeds of National Significance (Ecoscape, 2024).

3.2.2 Vegetation

3.2.2.1 *Vegetation Condition*

Vegetation condition was assessed broadly and continuously throughout the survey area and at each quadrat using the Vegetation Condition Scale for the Eremaean Botanical Province (EPA 2016a) (Ecoscape, 2024). The vegetation condition within the survey area ranged from Completely Degraded to Very Good condition, with the majority in Very Good condition (Ecoscape, 2024). The main factors affecting vegetation condition were clearing and grazing. The vegetation of Apollo Hill was typically of lower condition rating than elsewhere within the survey area due to the impacts of historical clearing (Ecoscape, 2024). Details of the vegetation condition within the survey area are provided in Table 3-3 and Figure 3-3.

Table 3-3: Vegetation Condition Summary

Vegetation Condition	Extent of survey area (ha) (%)
Very Good	698.41 (84.91)
Good	33.68 (4.09)
Poor	34.04 (4.14)
Degraded	46.50 (5.65)
Completely Degraded	2.75 (0.33)
Not vegetated or cleared	7.14 (0.87)

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Data source: Roads - Landgate, 2024. Imagery: Google, 2023.

LEGEND

- Development Envelope
- Site Layout

Vegetation Condition

- Completely Degraded
- Degraded
- Poor
- Good
- Very Good
- Excellent

Western Australian Roads

- Minor Road

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LOCALITY



0 100 200 300 400 500 km

VEGETATION CONDITION

Apollo Hill Pilot Project

Native Vegetation Clearing Permit

Saturn Metals Limited

N

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Coordinate System: GDA2020 MGA Zone 51
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Prepared:	E Jackson	Date:	15/04/2024
Reviewed:	I Tucakovic	Revision:	A
Project:	TE24038		

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Figure 3-3

3.2.2.2 *Vegetation Types*

Twelve vegetation types were recorded from the survey area from a variety of landforms, including drainage lines, dunes, flats/plains, rocky hills and wetlands (Ecoscape, 2024). Details of the mapped vegetation types are provided in Table 3-4 and Figure 3-4**.**

Table 3-4: Vegetation Types and Description

Vegetation Type	Landform	Description	Total Area within the DE (ha)(%)
AaAePo: *Acacia aneura*	Rocky hills	*A. pteraneura* low open woodland over *A. effusifolia, A. tetragonophylla* and *A. ramulosa var. ramulosa* mid sparse shrubland over *Ptilotus obovatus* and *Sclerolaena obliquicuspis* low sparse shrubland/chenopod shrubland	64.26 (7.81)
AaEmRd	Low dunes	*Acacia aneura, A. incurvaneura* and *A. caesaneura* low woodland over *Eremophila miniata, Hakea preissii* and *Scaevola spinescens* mid sparse shrubland over *Rhagodia drummondii* and *Maireana pyramidata* low sparse chenopod shrubland.	120.04 (14.59)
AcEfPo	Flat	*Acacia caesaneura*, *A. incurvaneura* and *A. aneura* low woodland over *Eremophila forrestii* subsp. *forrestii* and *A. tetragonophylla* mid sparse shrubland over *Ptilotus obovatus*, *Teucrium teucriiflorum* and *Eragrostis eriopoda* low sparse shrubland/tussock grassland	188.40 (22.91)
AdMsMt	Flat	*Acacia duriuscula* low open woodland over *aireana sedifolia*, *Senna artemisioides* subsp. *filifolia* and *Scaevola spinescens* mid sparse shrubland over *Maireana triptera*, *Ptilotus obovatus* and *Roepera ovata* low sparse chenopod shrubland/forbland.	29.82 (3.63)
AkLs	Flat	*Acacia kalgoorliensis* mid-sparse shrubland over *Lawrencia squamata, Scaevola spinescens* and *Maireana triptera* low sparse shrubland.	42.83 (5.21)
AlAb	Flat	*Acacia ligulata* and A*. victoriae* subsp. *victoriae* tall open shrubland over *Atriplex bunburyana* and *Scaevola spinescens* low sparse chenopod shrubland/shrubland.	10.57 (1.28)
AmFs	Flat	*Acacia masliniana* and *Cratystylis subspinescens* mid-sparse shrubland over *Frankenia setosa* and *Lawrenciasquamata* low sparse shrubland	96.17 (11.69)
CsLs	Flat	*Hakea preissii*, *Maireana platycarpa*, *Scaevola spinescens*, *Sclerolaena cuneata*, *Senna* sp. *Meekatharra* (E. Bailey 1-26)	142.19 (17.29)

Vegetation Type	Landform	Description	Total Area within the DE (ha)(%)
EcAbPd	Drainage lines	*Eucalyptus camaldulensis* subsp. *Arida* mid woodland over *Acacia burkittii* tall sparse shrubland over *Pluchea dentex* low sparse forbland	2.65 (0.32)
Mp	Flats	*Maireana pyramidata* and *Lawrencia squamata* low open chenopod shrubland/shrubland	25.48 (3.10)
PaHpCs	Flats	*Pittosporum angustifolium* low sparse woodland over *Hakea preissii* and *Acacia tetragonophylla* tall open shrubland over *Cratystylis subspinescens* low sparse shrubland.	1.52 (0.19)
Tspp	Flat, saline drainage	*Tecticornia spp.* low samphire shrubland	91.43 (11.12)

3.2.2.3 *Groundwater Dependent Vegetation (GDV)*

Eucalyptus camaldulensis sens. lat. may be a groundwater dependant species; therefore, vegetation with this species included is considered representative of GDV (Eamus et al. 2006a; Grierson 2010). *Eucalyptus camaldulensis subsp*. arida was the dominant species of one vegetation type (EcAbPd). The EcAbPd vegetation type corresponds with a single drainage line that intersects the corridor section and occupies 2.65 ha or 0.19 % of the survey area (Ecoscape, 2024). Given the minimal area of this vegetation type proposed to be impacted by the Project, impacts to GDV are expected to be minimal.

3.2.2.4 *Sheet Flow Dependent Vegetation (SFDV)*

There were numerous Mulga species recorded from the survey area, including *Acacia aneura*, *A. caesaneura*, *A. craspedocarpa*, *A. fuscaneura*, *A. incurvaneura* and *A pteraneura*. Within the survey area, these Mulga species formed the dominant vegetation stratum of three vegetation types (AaAePo, AaEmRd and AcEfPo). However, none of the vegetation types dominated by Mulga displayed the characteristic grove-intergrove formation considered to be representative of (SFDV). Therefore, SFDV is unlikely to occur within the survey area (Ecoscape, 2024).

3.2.2.5 *Vegetation of Conservation Significance*

No vegetation recorded from the survey area was assessed as representative of any currently described TEC or PEC (Ecoscape, 2024). There were no vegetation types with either dominant or characteristic flora that are conservation-listed.

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Vegetation Types

- Acacia aneura and A. caesaneura low woodland over Acacia tetragonophylla and Eremophila forrestii subsp. forrestii mid sparse shrubland
- Acacia aneura, A. incurvaneura and A. caesaneura low woodland over Eremophila miniata, Hakea preissii and Scaevola spinescens mid sparse shrubland over Rhagodia drummondii and Maireana pyramidata low sparse chenopod shrubland
- Acacia aneura, A. pteraneura low open woodland over A. effusifolia, A. tetragonophylla and A. ramulosa var. ramulosa mid sparse shrubland over Ptilotus obovatus and Scleroloena obliquicuspis low sparse shrubland/ chenopod shrubland
- Acacia burkittii and A. victoriae subsp. victoriae tall open shrubland
- Acacia burkittii, A. tetragonophylla and Hakea preissii tall shrubland over Maireana pyramidata, Ptilotus obovatus and Enchylaena tomentosa low open chenopod shrubland/shrubland
- Acacia caesaneura, A. incurvaneura and A. aneura low woodland over Eremophila forrestii subsp. Forrestii and A. tetragonophylla mid sparse shrubland over Ptilotus obovatus, Teucrium teucriiflorum and Eragrostis eriopoda low sparse shrubland/tussock grass
- Acacia duriuscula low open woodland over A. tetragonophylla and A. ramulosa var. ramulosa mid sparse shrubland over Sida ectogama and Scaevola spinescens low isolated shrubs
- Acacia duriuscula low open woodland over Maireana sedifolia, Senna artemisioides subsp. filifolia and Scaevola spinescens mid sparse shrubland over Maireana triptera, Ptilotus obovatus and Roepera ovata low sparse chenopod shrubland/forbland
- Acacia incurvaneura and A. caesaneura low woodland over A. tetragonophylla mid sparse shrubland over Ptilotus divaricatus low isolated shrubs
- Acacia incurvaneura low open woodland over A. victoriae subsp. victoriae tall sparse shrubland over Senna sp. Meekatharra (E. Bailey 1-26) low sparse shrubland
- Acacia kalgoorliensis mid sparse shrubland over Lawrencia squamata, Scaevola spinescens and Maireana triptera low sparse shrubland
- Acacia ligulata and A. victoriae subsp. victoriae tall open shrubland over Atriplex bunburyana and Scaevola spinescens low sparse chenopod shrubland/shrubland
- Acacia ligulata mid open shrubland over Salsola australis low sparse chenopod shrubland
- Acacia masliniana and Cratystylis subspinescens mid sparse shrubland over Frankenia setosa and Lawrencia squamata low sparse shrubland
- Acacia victoriae subsp. victoriae mid isolated shrubs
- Cratystylis subspinescens and Eremophila miniata mid sparse shrubland over Lawrencia squamata and Frankenia setosa low open shrubland
- Duma florulenta and Cratystylis subspinescens mid sparse shrubland over Chenopodiaceae sp. low isolated chenopod shrubs
- Eucalyptus camaldulensis subsp. arida mid open woodland
- Eucalyptus camaldulensis subsp. arida mid woodland over Acacia burkittii tall sparse shrubland over Pluchea dentex low sparse forbland
- Grevillea nematophylla subsp. supraplana, Acacia aneura and A. pteraneura low woodland over A. tetragonophylla mid sparse shrubland over Scaevola spinescens low sparse shrubland
- Hakea preissii and Acacia victoriae subsp. victoriae tall sparse shrubland over Maireana sedifolia, M. pyrimidata and Senna artemisioides subsp. filifolia low open chenopod shrubland/shrubland
- Hakea preissii and Eremophila miniata mid sparse shrubland over Cratystylis subspinescens, Maireana pyramidata and Atriplex sp. low open shrubland/ chenopod shrubland
- Maireana pyramidata, Lawrencia squamata low open chenopod shrubland/ shrubland
- Melaleuca interioris tall sparse shrubland over Duma florulenta low sparse shrubland
- Melaleuca xerophila tall open shrubland
- Pittosporum angustifolium low sparse woodland over Hakea preissii and Acacia tetragonophylla tall open shrubland over Cratystylis subspinescens low sparse shrubland
- Sporobolus ramigerus mid sparse tussock grassland
- Tecticornia sp. 5 low open samphire shrubland
- Tecticornia spp. low samphire shrubland
- No vegetation/cleared

Data source: Roads - Landgate, 2024. Imagery: Google, 2023.

LEGEND

- Development Envelope
- Site Layout
- **Western Australian Roads**
- Minor Road

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LOCALITY



0 100 200 300 400 500 km

VEGETATION TYPES

Apollo Hill Pilot Project

Native Vegetation Clearing Permit

Saturn Metals Limited

N

0 500 1,000 1,500 2,000 2,500 m

Coordinate System: GDA2020 MGA Zone 51
Scale @ A3: 1:60,000

Prepared:	E Jackson	Date:	15/04/2024
Reviewed:	I Tucakovic	Revision:	A
Project:	TE24038		

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Figure 3-4

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4 Terrestrial Fauna Assessment

A Basic terrestrial vertebrate fauna survey has been conducted by Ecoscape in 2023 (Appendix C), as well as targeted significant fauna survey in accordance with *Technical Guidance – Terrestrial vertebrate fauna surveys for environmental impact assessment*, known herein as the Fauna Technical Guidance (EPA, 2020), and *Environmental Factor Guideline – Terrestrial Fauna* EPA (2016c). The survey area encompasses the proposed disturbance footprint for the Project comprising a total area of 822.50 hectares (ha).

4.1 Desktop Assessment

The desktop portion of the fauna survey involved a search of the available online databases from DBCA and DCCEEW. DWER's IBSA portal was also searched for any recent studies conducted within or in the vicinity of the Project area. A total of 18 surveys within 100 km of the Project area were identified on the portal.

4.1.1 Vertebrate Fauna

A search of DBCA databases was conducted using a 90 km buffer around the survey area. Twenty-one conservation listed fauna were identified as having been previously recorded within the search area buffer, consisting of three mammals, 13 birds, one reptile and four invertebrates (Ecoscape, 2023). A likelihood of occurrence assessment was undertaken of the recorded fauna, with three species assessed as being 'Likely' to occur within the search area:

- *Leipo ocellata* (Malleefowl) – Vulnerable (VU) EPBC status, VU BC status;
- *Falco peregrinus* (Peregrine Falcon) – Other specially protected species (OS) BC status, DBCA status; and
- Chalcites osculans (Black-eared Cuckoo) – Marine/Migratory (MA/MI) EPBC status.

Targeted searches for these species were undertaken during the field portion of the fauna survey. Additional conservation significant species that may be found within the proposed Project area include:

- *Sminthopsis longicaudata (*Long-tailed dunnart) – P4 DBCA Status*;*
- *Aphelocephala leucopsis* (Southern Whiteface) – VU EPBC status;
- *Polytelis alexandrae* (Princess parrot) – VU EPBC status, P4 DBCA status;
- *Actitis hypoleucos* (Common sandpiper) – MI EPBC status; and
- *Tringa nebularia* (Common greenshank) – MI EPBC status.

Likelihood of occurrence does not consider factors such as the frequency that a species occurs (or may occur), the duration that such species occupies (or may occupy) the survey area, or dependence on habitat or resources within the survey area. Highly mobile species potentially only occur within (or for birds, overflying) the survey area for very brief periods and/or on very infrequent intervals. If a previous observation included in the database search records corresponds with this event it is listed as 'Recorded'; if such a transient visitation is possible in the future the likelihood of such species occurring is likely listed as 'Likely' (Ecoscape, 2024).

4.2 Field Survey Assessment

The Basic fauna survey incorporated several survey techniques as per the Terrestrial Fauna Technical Guidance (EPA, 2020), including habitat assessment, active searches (day and night-time), raking of spoil heaps and leaf litter, searches for secondary evidence such as scats and tracks, as well as opportunistic searches (Ecoscape, 2024). The field survey was conducted by Ecoscape in 2023 from March to April and then again in September. The survey area was extensively traversed on foot, and all habitats were assessed for quality and capability of supporting both locally common and significant fauna species (Ecoscape, 2024).

4.2.1 Habitat Types

The fauna habitats present within the survey areas were identified and mapped. Seven fauna habitat types were recorded within the survey area and are detailed in Table 4-1 and Figure 4-1**.**

Mulga woodland was the predominant fauna habitat, representing 535 ha of the 810 ha survey area (Ecoscape, 2024). The habitats recorded are typical for the local area and representative of the Eastern Murchison subregion. The recorded habitats provide resources for the generalist fauna assemblage, however, high levels of degradation from grazing may have reduced the suitability of the survey area for ground-dwelling or fossorial species in some areas (Ecoscape, 2024).

Some of the habitats (Flood plain, Chenopod shrubland and Drainage lines) are likely to experience seasonal variability in their fauna assemblage due to inundation, with the inclusion of waterbirds and amphibians during the wetter months (Ecoscape, 2024).

Table 4-1: Fauna Habitat Types

Habitat Type	Description	Extent within survey area (ha) (%)
Mulga woodland	Open mulga woodland over mixed shrubs and bare ground. Soil variable, loam, sand, sandy-clay, clayey-sand. Litter cover 1–20 %. Disturbance low to high.	535.38 (65.09)
Mixed shrubland	Open mixed shrublands dominated by Acacia, Hakea and Melaleuca species with smaller mixed shrubs. Soil sandy-clay to clayey-sand. Litter cover is low, 0– 1 %. Disturbance is low to moderate. Fire age: >10 yrs.	96.17 (11.69)
Chenopod shrubland	Low flat areas with low chenopod shrubs and occasional herbs. The soil was clay, sandy-clay, loamyclay or loam. Litter cover is low, 0–1%. Disturbance variable. Fire age: >10 yrs.	116.91 (14.21)
Rocky escarpment	Rocky escarpment that makes up Apollo Hill. Soils are rocky, vegetation is sparse, and litter cover is absent. Disturbance high. Fire age: >10 yrs.	64.26 (7.81)

Habitat Type	Description	Extent within survey area (ha) (%)
Flood plain	Low lying area of clay to clayloam, vegetation absent or occasional scattered chenopod. Litter cover absent. Disturbance low. Fire age: >10 yrs.	7.14 (0.87)
Drainage line	Shallow drainage lines, 5–20 m in width. Seasonally inundated. They were fringed with Eucalypt and Acacia species. The soil was sandy-clay. The litter cover was 5 %. Disturbance low. Fire age: >10 yrs.	2.65 (0.32)
Mineshaft/cave	A mineshaft and several small caves were located on and around Apollo Hill. Disturbance high. Possible habitat for bat species.	Too small to be mapped

4.2.2 Recorded Species

Thirty-three vertebrate fauna species were recorded during the survey (Ecoscape, 2024), consisting of:

- 13 mammals (one introduced)
- 18 birds
- two reptiles.

One of the fauna species recorded was the conservation-listed *Chalcites osculans* (Black-eared Cuckoo), with a MA/MI EPBC status (Ecoscape, 2024), but due to the extent of the fauna habitat outside of the DE, it is unlikely that it is dependable solely on the Project area. All species recorded were expected to occur within the survey area and were considered typical for the region and the habitat surveyed (Ecoscape, 2024).

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6,770,000 6,768,000 6,766,000 6,764,000 6,762,000 6,760,000 6,758,000 6,756,000 6,754,000

Data source: Roads - Landgate, 2024. Imagery: Google, 2023.

LEGEND

- Development Envelope
- Site Layout

Fauna Habitats

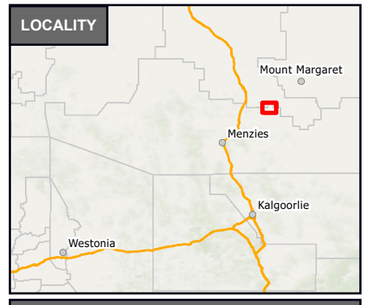
- Chenopod shrubland
- Claypan
- Drainage line
- Flood plain
- Mixed shrubland
- Mulga woodland
- Rocky escarpment

Western Australian Roads

- Minor Road

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LOCALITY



0 100 200 300 400 500 km

FAUNA HABITATS

Apollo Hill Pilot Project

Native Vegetation Clearing Permit

Saturn Metals Limited

N

0 500 1,000 1,500 2,000 2,500 m

Coordinate System: GDA2020 MGA Zone 51
Scale @ A3: 1:60,000

Prepared:	E Jackson	Date:	15/04/2024
Reviewed:	I Tucakovic	Revision:	A
Project:	TE24038		

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Figure 4-1

4.2.3 Conservation Significant Species

Following the field survey, re-evaluation of the likelihood of occurrence of the three conservation listed vertebrate fauna species identified as likely to occur in the desktop study was undertaken. One of the species was confirmed to be occurring within the DE (Black-eared cuckoo), with the Peregrine Falcon remaining likely to occur within the Project area. The likelihood of Malleefowl occurrence was updated as following field survey thery are considered unlikely to occur in the Project area due to the lack of suitable habitat noted.

Table 4-2 shows the conservation species identified within the Project area and the post field survey likelihood of the presence within the development envelope. Figure 4-2 shows conservation significant fauna recorded during the field assessment.

Table 4-2: Conservation Significant Fauna

Species (Common Name)	EPBC Act	BC Act/ DBCA	Likelihood of occurrence
Leipoa ocellata (Malleefowl)	VU	VU	Unlikely
Falco peregrinus (Peregrine Falcon)	-	OS	Likely
Chalcites osculans (Black-eared Cuckoo)	MA/MI	-	Recorded
Sminthopsis longicaudata (Long-tailed dunnart)	-	P4	May occur
Aphelocephala leucopsis (Southern Whiteface)	VU	-	May occur
Polytelis alexandrae (Princess parrot)	VU	P4	Unlikely
Actitis hypoleucos (Common sandpiper)	MI	-	May occur
Tringa glareola (Wood Sandpiper)	MI	-	May occur
Tringa nebularia (Common greenshank)	MI	-	May occur

4.2.3.1 *Black-eared Cuckoo*

The Black-eared Cuckoo is a medium-sized species identified by its brown-grey underparts, pale rump, dark tail with white tip, dark eye stripe, and distinctive mournful descending whistle (Higgins, Handbook of Australian, New Zealand and Antarctic Birds. Vol. 4. Parrots to Dollarbird, 1999). This cuckoo is distributed across mainland Australia and occasionally in Papua New Guinea (Higgins, Handbook of Australian, New Zealand and Antarctic Birds. Vol. 4. Parrots to Dollarbird, 1999). The Black-eared Cuckoo travels large distances to find suitable densities of its host species, primarily the Redthroat *Pyrrholaemus brunneus* in W.A., to lay its egg in their nests (Higgins 1999). Both the cuckoo and its host are threatened by impacts such as habitat damage caused by introduced herbivores, habitat fragmentation, and predation by introduced predators (Hope, 2020) (Ecoscape, 2024).

The Mulga Woodland and Mixed Shrubland habitat types are considered suitable habitat for this species, and it was recorded as present during field surveys. However, due to the high mobility of this species, it is unlikely that the Black-eared Cuckoo is dependent upon the survey area (Ecoscape, 2024).

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6,770,000 6,768,000 6,766,000 6,764,000 6,762,000 6,760,000 6,758,000 6,756,000 6,754,000

Data source: Roads - Landgate, 2024. Pre-European Vegetation - DPIRD, 2024. Imagery: Google, 2023.

LEGEND

Development Envelope

Threatened & Priority Fauna

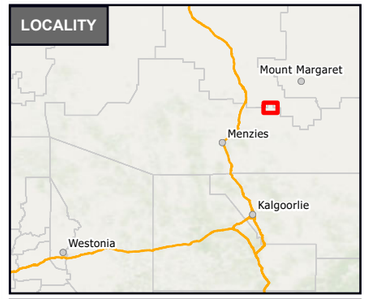
Migratory Marine (Chalcites osculans (Black-Eared Cuckoo)

Western Australian Roads

Minor Road

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LOCALITY



0 100 200 300 400 500 km

THREATENED & PRIORITY FAUNA

Apollo Hill Pilot Project

Native Vegetation Clearing Permit

Saturn Metals Limited

N

0 500 1,000 1,500 2,000 2,500 m

Coordinate System: GDA2020 MGA Zone 51
Scale @ A3: 1:60,000

Prepared: E Jackson	Date: 15/04/2024
Reviewed: I Tucakovic	Revision: A
Project: TE24038	

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Figure 4-2

Document Path: \\server\talis\SECTIONS\Environment\Projects\TE2024\TE24038 - Apollo Hill Pilot Project Approvals\GIS\Maps\TE24038 - Apollo Hill Native Vegetation Clearing Permit\TE24038 - Apollo Hill Native Vegetation Clearing Permit.aprx

4.2.3.2 *Malleefowl*

The DBCA database records show 40 records from within the 90 km survey area buffer, four of which are within 45 km of the survey area. No suitable Malleefowl habitat or evidence of Malleefowl or their mounds was found within the survey area. The habitat types within the survey area had only sparse leaf litter, making them unsuitable for Malleefowl to build mounds. High levels of disturbance due to pastoral grazing further reduce the likelihood that Malleefowl are present in the survey area (Ecoscape, 2024).

The post-survey likelihood of occurrence of this species is 'Unlikely'.

4.2.3.3 *Peregrine Falcon*

No Peregrine Falcons were recorded in the survey area. Nine recent (<25 years) DBCA records indicate that this species occurs within the survey area search buffer, with four records from within 45 km of the survey area. Foraging habitat for this species occurs throughout the survey area. However, suitable breeding habitat is limited. Peregrine Falcon would likely only be transient and not dependent on any resources in the survey area (Ecoscape, 2024).

The post-survey likelihood of the species occurring remains as 'Likely'.

4.2.3.4 *Long-tailed Dunnart*

The Long-tailed Dunnart is a small, nocturnal, insectivorous Dasyurid, and can be distinguished from other *Sminthopsis* species by its tail being more than twice the length of the head and body (Van Dyck & Strahan 2008). This species is rare but can sometimes be locally common when resources are abundant. It is found in rocky scree and plateau areas with little vegetation or spinifex hummock grassland, shrubs, and/or open woodland (Van Dyck & Strahan, 2008); (Gibson & McKenzie, 2009).

There appear to be no major naturally occurring threats to this species. In the range within central Australia, this species is affected by the spread of exotic buffel grass (*Cenchrus spp*.), which increases the frequency and intensity of fires. This is also likely to be an issue in some areas in Western Australia (Pavey, 2002).

A DBCA record of this species is within 20 km of the survey area. Suitable habitat exists within the survey area; therefore, there is potential for this species to occur locally despite it not being recorded during surveys within the area (Ecoscape, 2024). The post-survey likelihood remains as "may occur".

4.2.3.5 *Southern Whiteface*

The Southern Whiteface is a small (10–11.5 cm) bird with a brown body, white belly, and distinctive white band with black edging across the forehead (Simpson & Day, 2010).

This species has recently been listed as Vulnerable (March 2023), due to a population decline of an estimated 30–50% every ten years since 1999. The likely cause of this decline is habitat loss and fragmentation, particularly where habitat has been completely removed for intensive agriculture. The Southern Whiteface is predominately sedentary, preferring open woodlands and shrublands, usually dominated by eucalypts or acacias, with an understorey of grasses and/or shrubs (Ehmke, Antos, Bennett, & Ford, 2021). The Southern Whiteface favours habitat where the tree density is low and there is an herbaceous understorey with leaf litter, where they can forage for insects, spiders, and seeds. Trees with hollows and crevices are also essential for

roosting and nesting, although they will also nest in low bushes (Ehmke et al. 2021). A large portion (7023.59 ha, 55.43 %) of the survey area constitutes a habitat for this species (Ecoscape, 2024). However, this habitat is also characteristic of the local region, thus having no specific significance. The post-survey likelihood remains as “may occur”.

4.2.3.6 *Princess Parrot*

The Princess Parrot is restricted to arid regions of Western Australia, southern Northern Territory and northwestern South Australia, with all records being far inland except where the Great Sandy Desert reaches the coast south of Broome. It occurs only sparsely within its distribution, and sightings are rare except in the Great Sandy, Gibson, Tanami and Great Victoria Deserts and central ranges; the Great Sandy Desert is the ‘core range’. Recorded habitats include sand dunes and flats with open savannah woodlands (scattered stands of *Eucalyptus gongylocarpa, E. chippendalei* and mallee species, *Casuarina* or *Allocasuarina*) over *Acacia*, *Eremophila, Grevillea, Hakea* and *Senna* shrublands, over *Triodia* hummock grassland (DCCEEW 2023).

The Princess Parrot feeds on seeds of grasses and shrubs, as well as some flowers, nectar, and leaves. They nest in hollows of Eucalypts close to watercourses, or occasionally in Allocasuarina away from water. Their movements are poorly known but are described as nomadic, irruptive, or both. No threatening processes have been demonstrated for this species. Still, populations may have been impacted by changes in vegetation due to grazing, altered fire regimes, and competition from more water-dependent species following the provision of artificial water sources (DCCEEW 2023).

Suitable habitat exists within the survey area in the Mulga Woodland and Drainage Line habitat types. The PMST search found that the “species or species habitat is known to occur within the area”; however, it was not recorded during the field survey, and there are no historical records of the Princess Parrot from within the 90 km survey area buffer. It is unlikely that this species is dependent upon the habitat within the survey area. Therefore, this species' likelihood has been re-evaluated and is considered “Unlikely” to occur within the survey area (Ecoscape, 2024).

4.2.3.7 *Common Sandpiper*

The Common Sandpiper is mainly found in coastal areas such as intertidal mudflats, estuaries, and inlets. They are also recorded inland, although less commonly, around ephemeral and permanent lakes, dams and waterholes (Higgins & Davies 1996).

Common Sandpipers migrate to Australia in August and leave in March, coinciding with the survey's timing from late March to April and in September. Within the survey area, suitable habitat occurs in the Chenopod Shrubland habitat type, when flooded, although this habitat is not preferred by these species. However, the lack of any recent rainfall events prior to the survey meant that there was no habitat available for these species if they did occur. No Common Sandpipers were recorded during the survey, however, historical records occur in the survey area buffer. Therefore, the post-likelihood assessment of these species is that they “May” occur in the survey area.

4.2.3.8 *Wood Sandpiper*

The Wood Sandpiper prefers habitat containing shallow freshwater wetlands (DCCEEW 2024). Migration to Australia is from August to March, and suitable habitat is available within the survey area, consisting of the Chenopod Shrubland habitat type, when flooded. The lack of any recent

rainfall events prior to the survey meant that there was no habitat available for these species if they did occur. No Wood Sandpipers were recorded during the survey, however, historical records occur in the survey area buffer. Therefore, the post-likelihood assessment of these species is that they "May" occur in the survey area.

4.2.3.9 *Common Greenshank*

The Common Greenshank is mainly found in coastal areas such as intertidal mudflats, estuaries, and inlets. They are also recorded inland, although less commonly, around ephemeral and permanent lakes, dams and waterholes (Higgins & Davies, 1996)

Common Greenshanks also migrate to Australia in August and leave in March. Within the survey area, suitable habitat occurs in the Chenopod Shrubland habitat type when flooded, although this habitat is not preferred. The lack of any recent rainfall events prior to the survey meant that there was no habitat available for this species if they did occur. No Common Greenshanks were recorded during the survey, however, historical records occur in the survey area buffer. Therefore, the post-likelihood assessment of these species is that they "May" occur.

4.3 Short-Range Endemic (SRE)

Bennolongia (2023b) completed a SRE survey of the Project area, reviewing available information on potential habitats and previous biological records to appraise the likelihood of SRE invertebrate fauna occurring within and in the vicinity of the Project. The survey was conducted in accordance with the relevant EPA guidelines for SRE fauna assessment.

A square of 100 km x 100 km around the Project was defined as the search area. Database searches recovered 585 records of animals belong to SRE groups attributable to at least 66 species-level taxa within the defined search area (Bennelogia, 2023a). In total, 76 samples belonging to SRE groups and representing 12 identifiable species were collected from the Project area, including:

- Mygalomorph spiders;
- Scorpions;
- Pseudoscorpions;
- Isopods;
- Millipedes; and
- Land snails.

Of these species, five were categorised as widespread and seven were categorised as potential SREs:

- The mygalomorphs:
  - *Aname* 'BMYG218' '*mellosa* group' – Unlikely Potential SRE;
  - *Idiosoma* 'BMYG168' – Unlikely Potential SRE; and
  - *Kwonkan* 'BMYG219' – Data Deficient SRE.
- The pseudoscorpions:
  - *Beirolpium* 8/4 'BPS499' – Unlikely Potential SRE;
  - *Beierolpium* 8/4 'BPS520' – Data Deficient SRE;

- *Indolpium* 'BPS500' – Unlikely Potential SRE; and
- *Garypinidae* 'BPS519' – Data Deficient SRE.

All the Potential SREs identified belong to taxa that have not been formally described but which were identified by either molecular or morphological characters as distinct species (Bennelongia, 2023). Although most of the Potential SREs are currently known only from the Project area, it is not expected that any of the identified species will have a distribution restricted to the Project area as they were all collected from habitats that are also abundant outside the survey area (Bennelongia, 2023).

The Project includes habitat likely to host species belonging to SRE groups, but most of these have been historically disturbed. Moreover, all habitats identified within the survey area are also found outside of it. Therefore, it is not expected that any potential impacts arising from the Project will impact any of the SRE populations (Bennelongia, 2023).

5 Environmental Management Measures

5.1 Risk Assessment Strategy

A risk assessment was undertaken to identify risk, risk pathways and likely impacts which may arise from the proposed clearing. Environmental risk was based on an understanding of the existing environment at the Apollo Hill Project.

Saturn has established a risk assessment utilising the as Low as Reasonably Practicable (ALARP) principle. The following definition is to be used to determine whether a risk has been lowered to ALARP:

The ALARP Principle in relation to risk levels is show in Figure 5-1.

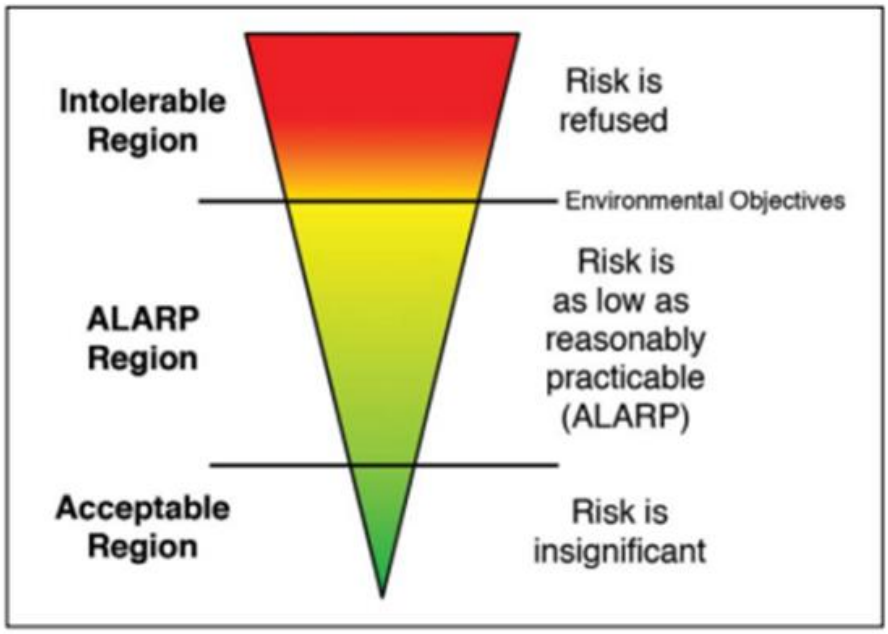


Figure 5-1: ALARP and Risk

This allows for proactive risk management strategies to be developed during planning and operation. A standard risk matrix (AS/NZS ISO 31000:2009) was utilised to evaluate the likelihood and consequence of potential risks:

- Likelihood - The likelihood of an impact on the surrounding environment or other receptors; and
- Consequence - The scale or magnitude of the potential impact (i.e., severity/extent) if it were to occur.

The likelihood and consequence tables are provided in Table 5-1 and Table 5-2, respectively. Table 5-3 provides the risk ratings associated with each of the potential environmental impacts for each Project area before and after management strategies have been implemented. Table 5-3 also provides the risk ranking criteria tables used to determine these ratings.

Table 5-1: Likelihood of Risk Occurring

Likelihood of Risk Occurring		
Level	**Likelihood**	**Description**
A.	Almost Certain	The event is common or frequent occurrence or an ongoing impact (e.g. daily)
B.	Likely	The event is expected to occur under some conditions or has occurred more than once
C.	Possible	The event will probably occur, or has occurred under some conditions (e.g. yearly)
D.	Unlikely	Known to have occurred but not often
E.	Rare	Very unlikely/may occur in exceptional circumstances

Table 5-2: Consequence of a Risk Occurring

Consequence of a Risk Occurring		
Level	**Likelihood**	**Description**
1.	Catastrophic	Severe environmental impact, extensive clean up and recovery period, requires internal and external resources
2.	Major	Major environmental impact, extends beyond mine, considerable clean up using internal and external resource
3.	Moderate	Impact confined to the mine, clean up may require external assistance, moderate environmental damage
4.	Minor	Confined to an isolated area, rapid clean up using internal resources, minimal environmental damage
5.	Insignificant	Confined to the immediate area, rapid clean up, no environmental damage

The risk matrix detailed in

Table 5-3 combines the level of likelihood and consequence to determine the associated level of risk. The impact of each identified risk is then categorised as extreme (red), high (orange), medium (yellow) and low (green). Management measures for each identified risk is then included and the risk rating re-categorised.

A risk priority is assigned to each of the 25 possible outcomes.

Table 5-3: Risk Matrix and Rankings

Risk Matrix		Consequence				
		5. Insignificant	4. Minor	3. Moderate	2. Major	1. Catastrophic
Likelihood	A. Almost Certain	Medium 14	High 19	Extreme 22	Extreme 24	Extreme 25
	B. Likely	Medium 10	Medium 13	High 18	Extreme 21	Extreme 23
	C. Possible	Low 6	Medium 9	Medium 12	High 17	Extreme 20
	D. Unlikely	Low 3	Low 5	Medium 8	Medium 11	High 16
	E. Rare	Low 1	Low 2	Low 4	Medium 7	High 15

20-25 Extreme risk; immediate action required

15-19 High risk; senior management attention needed

7-14 Medium risk; management responsibility must be specified

1-6 Low risk; manage by routine procedures

5.1.1 Risk Treatment

The risk assessment conducted for the proposed Project documents measures applied to each risk, documenting the raw and residual risks. The residual risk is then evaluated to ensure it is meeting the ALARP principle and is consistent with identified environmental objectives.

Risk treatment options may consult relevant Australian Standards, Guidance Notes, Codes of Practice, and other established industry best practice to assess and determine appropriate outcomes.

The following hierarchy is used for treating residual risk with each chosen method adaptable to the type of risk being controlled:

1. **Elimination** – Where practicable, the risk is eliminated completely;
2. **Substitution** – The original activity, substance or equipment may be substituted for a different activity, substance or equipment that lowers the risk;
3. **Isolation** – The risk is isolated;
4. **Engineering controls** – The risk may be mitigated using engineering controls to reduce the risk; and
5. **Administrative controls** – Include training, implementation of policies, procedures, and introduction of behavioural expectations to reduce risk.

5.2 Risk Assessment

A risk assessment was completed to consider those activities conducted as part of the proposed Project elements and the relevant controls and management practices that are utilised to minimise the associated environmental risks. The risks are outlined in Table 5-4 and discussed in detail in the Section 6 Assessment Against the Ten Clearing Principles.

Table 5-4: Risk Assessment

ASPECT	IMPACT	LIKELIHOOD	CONSEQUENCE	RAW RISK	TREATMENT	LIKELIHOOD	CONSEQUENCE	TREATED RISK
Native flora and vegetation	Clearing of threatened and/or Priority flora	Unlikely	Minor	Low 5	• Minimise clearing; • Design of project to avoid known areas of Priority Flora species occurrence where possible; • Induction of personnel to cover any potential Priority flora species within the work areas.	Rare	Minor	Low 2
Native flora and vegetation	Potential for spread of weeds within the Project area	Unlikely	Minor	Low 5	• Personnel to undertake an environmental induction which will include threats of Weeds of National Significance to environmental values; • Inspection of vehicles prior to entry into the Project area; • Ensure vehicles are clean of plant materials before entering undisturbed areas on site; and • Undertake weed removal where required.	Rare	Insignificant	Low 1
Native flora and vegetation	Inadvertent clearing outside of approved DE	Possible	Minor	Medium 9	• Demarcation of the area to be cleared; • Demarcated area to be inspected prior to commencement of clearing by a qualified environmental practitioner; and • Annual reconciliation of clearing undertaken and comparison against approved areas.	Unlikely	Minor	Low 5
Native flora and vegetation	Fugitive dust from cleared areas degrading adjacent native vegetation	Possible	Minor	Medium 9	• Minimise clearing to only areas required for operations; • Dust suppression activities to be undertaken when required; • Limit the clearing activities during high wind conditions; and • Water trucks to be available for dust suppression.	Unlikely	Minor	Low 5
Native vegetation/ surface water	Diversion of surface water flows impacting conservation of native vegetation	Unlikely	Low	Low 3	• Surface water assessment undertaken by qualified personnel; • Project design avoids all surface water drainage lines and is outside likely flood impact zones; • Haul road design includes installation of 900 mm culverts to allow maintenance of surface water flows; • Diversion channel and drain to be installed around the proposed Processing area, mine yard and magazine to pass the 10% AEP flow; and • Progressive rehabilitation of cleared areas where possible.	Rare	Insignificant	Low 1
Native vegetation	Clearing of pre-European vegetation below the minimum threshold of retention of 30% of pre-European extent set in EPA's Guidance Statement No. 33	Rare	Minor	Low 2	• Environmental consultant has undertaken the vegetation type assessment for the proposed clearing area; • Clearing area was compared to the results of the original mapping by Beard and Burns (976); No clearing outside of NVCP boundary.	Rare	Minor	Low 2

ASPECT	IMPACT	LIKELIHOOD	CONSEQUENCE	RAW RISK	TREATMENT	LIKELIHOOD	CONSEQUENCE	TREATED RISK
Native vegetation/ soils	Spills of contaminated water impacting native vegetation causing degraded vegetation health or death.	Possible	Major	High 17	• All ponds containing process water to be triple lined; • Heap leach facility to be lined with clay, and a HDPE liner; • All pipelines will be within bunded areas and designed to drain to the Stormwater pond; • Sufficient freeboard to be maintained for 1% AEP rainfall; • Leak detection to be installed for all process water ponds and heap leach facility; • Monitoring bores to be installed around ponds and heap leach facility; and • Triggers for seepage recovery to be developed.	Unlikely	Major	Medium 11
Native vegetation/ soils	Hydrocarbon spills	Possible	Minor	Medium 9	• Roofed and bunded storage to be utilised for all hydrocarbons on site; • Clean-up procedure to be implemented and included in site inductions; • All contaminated material to be removed from site.	Unlikely	Minor	Low 5
Fauna	Clearing of native vegetation results in removal of significant habitat for the threatened species such as Malleefowl and Black-eared Cuckoo.	Possible	Moderate	Medium 12	• Habitat has been assessed for potential foraging and roosting habitat for the Malleefowl, Ecoscape (2024) survey concluded that is unlikely for the occurrence of the species. • Topsoil retained with any felled vegetation to promote any habitat for the species within the close proximity of the Project area. • Pre clearance survey to be undertaken by site environmental staff to ensure no malleefowl mounds are present. • No clearing outside of approved clearing boundary.	Unlikely	Minor	Low 5
Fauna	Entrapment of fauna in containment facilities	Possible	Minor	Medium 9	• Daily inspections of water containment infrastructure; • Water storage areas to be fenced to prevent fauna access; • Egress matting to be placed in all water containment infrastructure.	Unlikely	Minor	Low 5
Rehabilitation	Unsuccessful rehabilitation delays reestablishment of native vegetation communities	Possible	Moderate	Medium 12	• Rehabilitation to be conducted according to the Mine Closure Plan (as assessed and approved by DEMIRS).	Unlikely	Moderate	Medium 8

5.3 Avoid

Saturn will ensure that clearing of the DE for the Project area will adhere to the demarcated areas, and will avoid any potential areas where the habitat or any significant flora and fauna may be present. Existing roads will be utilised to further minimise the disturbance.

5.4 Minimisation

Saturn will implement the following controls in order to minimise the clearing impact:

- All personnel and contractors will undertake inductions to understand obligations in regard to site clearing permits and other relevant approval instruments;
- Personnel involved in undertaking clearing activities will undergo additional training to ensure adherence with internal procedures and NVCP conditions;
- Clearing areas will be demarcated prior to the commencement of the clearing activities and inspected by site environmental personnel;
- Only areas necessary for the operation of the Project will be cleared;
- Where possible, infrastructure will be located in degraded or already cleared areas;
- All vehicles will be inspected prior to entry to the Project area and on exit for soils and vegetation; and
- Dust suppression will be conducted in accordance with the internal management practices and Saturn will avoid conducting clearing in high wind conditions.

6 Assessment Against the Ten Clearing Principles

The proposed clearing activities have been assessed against the ten clearing principles as defined in the Department of Environment Regulation (DER) Guide to Assessment: Clearing of Native Vegetation under the EP Act, considering the current extent and condition of the native vegetation on the site. This assessment is presented in Table 6-1.

Table 6-1: Assessment Against Clearing Principles

Principle	Assessment
Principle (a) – Native vegetation should not be cleared if it comprises a high level of biological diversity.	The proposed clearing will not affect any Priority Ecological Communities or Threatened flora. Ecoscape (2024) found 166 flora taxa recorded from the survey area. While the field survey was undertaken following periods of below-average rainfall, flora diversity is considered low to moderate. The 166 flora taxa recorded and vegetation types are considered likely to be present in the wider area outside the Project area. Within the Project area, there is no remnant vegetation that exclusively supports all or most of the significant species. The proposed clearing is unlikely to be at variance with this clearing Principle.
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.	Ecoscape (2024) has recorded seven fauna habitats within the Proposed area, none of which are considered to be significant. Thirty-one vertebrate fauna species were documented in field surveys, one of which is the migratory Black-eared Cuckoo (*Chalcites osculans*). Ecoscape (2024) found that even though this species utilises habitat types represented in the area, due to the high mobility of this species, it is unlikely that the Black-eared Cuckoo is dependent upon this habitat. The Peregrine Falcon (*Falco peregrinus*) is also considered likely to occur within the proposed area, although no individuals have been recorded. Individuals are likely to be transient and not dependent on any resources in the survey area. Malleefowl (*Leipoa ocellata*) were identified as likely to occur during desktop surveys, however were reclassified as being unlikely to be present in the proposed clearing area following field surveys. Several other species of significance were noted as potentially occurring within the proposed clearing area, however none are considered to be dependent on habitat within the area. The proposed Project area includes habitat likely to host species belonging to SRE Groups, but most of the habitat has been historically disturbed and is also found to be widespread outside the DE. It's not expected that there will be a significant impact on the SRE's resulting from the Project development. Given the low impact on species of conservation significance, the proposed clearing is not likely to be at variance with this Principle.

Principle	Assessment
Principle (c) – Native vegetation should not be cleared if it includes, or is necessary for the continued existence of rare flora.	No Threatened Flora were recorded within the survey area, and none are considered likely to occur. Two Priority Flora (*Tecticornia globulifera* [P1] and *Hemigenia exilis* [P4]) were recorded, each from a single location. Based on the proposed disturbance footprints, there will be no direct impacts on *Tecticornia globulifera*. A small number of *Hemigenia exilis* plants (<10) may be impacted by the proposed access road. Ecoscape identified 59 records of the species located within the Murchinson bioregion, all of the records were to the north of the survey area. Considering the distribution of the species and the numbers that were identified during the survey impact of clearing to the species is considered negligible. Habitat with the potential to support these species (salt lakes, saline drainage plains) is extensive outside the survey area (Ecoscape, 2024). Considering the area that is being cleared will only impact a small number of individual conservation significant plants, and the vegetation type supporting the priority flora is found to be widespread outside the proposed clearing area, the proposed clearing is not considered to be at variance with this Principle.
Principle (d) – Native vegetation should not be cleared if it comprises the whole or a part of or is necessary for the maintenance of a Threatened Ecological Community (TEC).	No TECs or PECs were recorded from the survey area (Ecoscape, 2024). The proposed clearing is not at variance with this Principle.
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.	Pre-European vegetation association mapping indicates that all vegetation types have greater than 90% statewide distribution remaining (Ecoscape, 2024). The EPA's Guidance Statement No. 33 has identified a minimum threshold of retention of 30% of pre-European extent of each community (Environmental Protection Authority, 2008). All the vegetation types that are within the DE are well above this threshold. The proposed clearing is therefore not at variance with this Principle.

Principle	Assessment
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.	No significant watercourses, wetlands or groundwater areas will be affected by the native vegetation clearing. The Project is not located within a surface water proclaimed area. All major project infrastructure has been located to avoid drainage lines and designed to minimise impacts to surface water flows. The Project is located immediately south of Lake Raeside which is part of a salt lake drainage system, however the proposed location of Project infrastructure is outside the likely flood extent and is not likely to be affected by rising surface water. Vegetation type EcAbPd represents an ephemeral drainage line. The drainage line will intersect with the proposed access road, representing a minor disturbance, and culverts will be installed to maintain water flow. Vegetation type Tspp represents wetland vegetation type, and partially intersects proposed development footprints. The impact to this vegetation type is likely negligible due to the widespread distribution of this vegetation type outside the survey area (Ecoscape, 2024). Considering that the proposed disturbance of vegetation associated with watercourses and wetlands is only minor and that these vegetation types are widespread within the vicinity of the Project area, it can be concluded that the proposed clearing is unlikely to be at variance with this Principle.
Principle (g) – Native vegetation should not be cleared if the clearing of the vegetation is likely to cause appreciable land degradation.	Clearing vegetation within the survey area is unlikely to cause appreciable land degradation in areas adjacent to the clearing (Ecoscape, 2024). Clearing to be undertaken will be minimised to only include that necessary for the operation of the Project. As the land belongs to an arid climate zone, and the rainfall runoff and drainage occurs steadily into the soils (SignificantENV, 2023) there will be no waterlogging on or off the site. Dust impacts are not expected to be significant, and mitigation strategies will be employed to minimise fugitive dust emissions outside the site boundaries. Additionally, at the conclusion of the Project the land will be rehabilitated in accordance with an approved Mine Closure Plan. Given the low likelihood of impacts to adjacent soils, vegetation or water catchment areas, the proposed clearing is unlikely to cause appreciable land degradation outside of the direct clearing footprint. The clearing footprint will be rehabilitated at the conclusion of the Project, and as such the proposed clearing is not considered to be at variance with this Principle.

Principle	Assessment
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 National Parks, Nature Reserves or other conservation estates occur near the survey area. The nearest conservation estate is Goongarrie National Park, located approximately 67 km south of the survey area. Due to the distance of the Project from significant conservation areas, the proposed clearing is not likely to be considered at variance with this Principle.
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.	The proposed pits are unlikely to result in any impact on the local groundwater from the Raeside Paleochannel as they are not anticipated to intersect the water table. (Pentium, 2023). No surface water quality data from the Project area is currently available given the ephemeral nature of the flow. The survey area intersects one drainage line along the corridor section, with deterioration in surface water volume or quality considered unlikely, as culverts will be installed to allow flow and sedimentation control will be installed if determined to be required. The drainage line vegetation is also potentially groundwater-dependant, however the proposed clearing of this vegetation is unlikely to impact the groundwater as the area to be cleared is minor and the vegetation type extends outside the proposed clearing area. Surface water quality of Lake Raeside is also unlikely to be impacted from Project implementation as discussed above. Clearing of vegetation within the survey area is also considered unlikely to cause deterioration in groundwater quality (Ecoscape, 2024). The proposed clearing is unlikely to be at variance with this Principle.
Principle (j) – Native vegetation should not be cleared if clearing the vegetation is likely to cause, or exacerbate, the incidence of flooding.	The proposed clearing should be considered unlikely to exacerbate the incidence of flooding (Ecoscape, 2024). The majority of Project infrastructure has been located away from natural drainage lines, and culverts will be installed to maintain flow where intersections with drainage lines occurs. The Project is also located outside the predicted extent of flooding of Lake Raeside (Carrick Consulting Pty Ltd, 2024). Diversion channels and bunds will be installed to maintain surface water flow around constructed infrastructure, to minimise risk of flooding. As the proposed clearing is unlikely to affect the incidence of flooding, it is unlikely to be at variance with this Principle.

7 Summary of Assessment

This assessment report covers approximately 197 ha of proposed native vegetation clearing for development of the Project. A risk assessment was completed for the proposed clearing and incorporates proposed avoidance, mitigation and management measures to be implemented as part of the Project to minimise environmental impacts.

The proposal will not cause any disturbance to conservation significant flora or fauna species or their habitat, or any other significant conservation areas. There are no significant surface water features within the DE, which indicates that there will be minimal impact to surface water quality or flow. Significant impacts to groundwater resulting from Project implementation are also not anticipated.

As such, assessment of the proposed clearing in regard to the 10 clearing principles determined that the Project is unlikely to be at variance with any of the principles.

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APPENDIX A
Surface Water Assessment

REPORT ON

APOLLO HILL PILOT PROJECT
BASELINE HYDRO-METEOROLOGY
&
SURFACE WATER MANAGEMENT

Prepared for

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EXECUTIVE SUMMARY

Saturn Metals Limited (STN) proposes to develop the Apollo Hill Pilot Project (AHPP), located approximately 45 km southeast of Leonora in the Goldfields region of Western Australia.

STN engaged Carrick Consulting (WA) Pty Ltd to complete a baseline hydro-meteorological study and hydrological assessment to identify and ameliorate potential flood risks and develop preliminary engineering designs for the required surface water management measures. This report presents the findings from the subsequent desktop study.

The following key *hydro-meteorological* findings were made:

- The regional climate is one of extremes and droughts and major floods can occur in the same area within a few years of each other. The climate in this region is highly variable, both spatially and temporally, and this can make hydrologic analysis and the design of water management measures difficult.
- Regional climatic conditions are arid with mean annual rainfalls of less than 250 mm. The rainfall that occurs during the early winter months of June and July tends to be more reliable and generally of a greater total amount than the less dependable, but more intense, summer rainfalls from January to March.
- Although remnant tropical cyclones and associated depressions may bring heavy rains to the region, they are erratic in nature and occur relatively infrequently. An analysis of cyclone data for the last 52 years shows that, on average, a cyclone will pass within 200 km of the AHPP approximately once every five years. Four cyclones have passed within 100 km of the AHPP in the last 52 years, which included the significant Tropical Cyclone (TC) Bobby in late February 1995.
- The Bureau of Meteorology (BoM) Leonora rainfall station (No. 12046) is located approximately 45 km northwest of the AHPP and daily data are available from January 1907 to the present. Analysis of 107 complete years of data yield mean and median annual rainfalls of 238 and 221 mm. These values are considered to be representative of conditions at the AHPP and their use is recommended for design purposes.
- Locally, maximum and minimum annual rainfalls of 612.1 mm and 57.4 mm have been recorded at Yundamindra in 1995 and at Nambi in 1962 respectively. The 1995 maximum rainfall has an annual exceedance probability (AEP in the order of 0.5% (1 in 200) and was largely due to Tropical Cyclone (TC) Bobby which crossed the region in late February that year, delivering three-day rainfalls in the order of 225.0 mm. The 1962 minimum rainfall is representative of 100 year drought conditions.
- Typically there are in the order of 38 rain days each year, although this may be as low as 9 days and as high as 81 days. The longest period without rain was 173 days and was recorded at Yundamindra between 17 Nov 1955 and 7 May 1956.
- Locally the wettest day on record occurred on 17 February 2011, when 126 mm was recorded at Yundamindra (Laverton recorded 120.2 mm on the same day). This rainfall was the result of a rain bearing system associated with TC Dianne/Carlos and had an AEP in the order of 1.5%.
- A rainfall intensity-frequency-duration (IFD) relationship was developed for the AHPP using the latest BoM 2016 dataset. In summary, the 1% AEP intensities for 1, 3, 12, 24

and 72 hr duration events are 52.7, 24.3, 9.3, 5.9 and 2.75 mm/hr respectively (yielding equivalent storm depths of approximately 53, 73, 111, 141 and 198 mm).

- The AHPP is situated within the central-east region of the DWER Raeside-Ponton catchment of the vast Salt Lake Basin, which extends over much of central WA. No streamflow data are available for the Raeside-Ponton catchment. Therefore, it was not possible to scale or benchmark peak flow estimates for on-site catchments with those from similar, local off-site catchments.
- The AHPP is located immediately south of Lake Raeside paleodrainage which has a direct catchment area in excess of 28,000 km^2 measured to its southern outlet. Lake Raeside is typically dry and only conveys surface water flow following periods of significant rainfall with standing water of several hundred millimetres occasionally present over discrete parts of the lakebed. A review of satellite imagery from March 1972 to the present indicates that only on one occasion, following TC Bobby in late February 1995, did the various parts of Lake Raeside link-up and form a continuous water body with flow discharge onto the Nullarbor Plain through Ponton Creek.
- TC Bobby was a very significant event and for preliminary planning purposes can be considered to be the "design event". Inspection of satellite imagery over the AHPP site following TC Bobby indicate a maximum flood elevation of approximately 352.5 mAHD in the vicinity of the proposed AHPP site. It should be noted that the proposed pits, heap leach pad and processing area is situated above this elevation and would therefore not have been inundated.

The following key *surface water management* findings were made:

- The fact that the key project facilities are largely situated above the TC Bobby design event maximum flood elevation (~352.5 mAHD) and the upstream catchment area is fairly modest (6.0 km^2) the resulting surface water management measures at the proposed AHPP site are relatively limited and will comprise the following:
- Approximately 732 m long raised Pit 1 to ROM haul road raised to a nominal minimum elevation 353.0 mAHD and requiring in the order of 2,160 m^3 of cut and 16,950 m^3 of fill for a 28 m wide road with 2H:1V sideslopes. Culverts should be constructed below the proposed raised haul road in order to permit the passage of runoff from the upstream catchment area. In order to pass the 10% AEP peak flow 3 No. 900 mm diameter corrugated metal pipe culverts should be used with flap gates installed at the outlet of each of the culvert barrels to prevent backwatering in the event of high flows along the Lake Raeside.
- Approximately 515 m long diversion channel and parallel flood bund which will divert runoff from the upstream sub-catchment area around the proposed Processing Area. A channel with a 4 m basewidth, 1.2 m depth and 2H:1V sideslopes will be required to pass the 1% AEP peak flow.
- Approximately 435 m and 150 m long lengths of diversion channel for the proposed Mine Yard and Magazine respectively. A 3 m basewidth dozer cut channel with 2H:1V sideslopes will suffice in both cases cut to depths of 0.75 m for the Mine Yard and 0.65 m for the Magazine in order to pass the 10% AEP peak flow.

GLOSSARY OF HYDROLOGICAL TERMS

Annual Exceedance Probability (AEP)	The probability that a given rainfall total accumulated over a given duration will be exceeded in any one year.
Antecedent Soil Moisture	Water present in the soil prior to a rainfall event.
Average Recurrence Interval (ARI)	The average or expected value of the periods between exceedances of a given rainfall total accumulated over a given duration. It is implicit in this definition that the periods between exceedances are generally random.
Australian Rainfall and Runoff (ARR)	National guideline document, data and software suite that can be used for the estimation of design flood characteristics in Australia. Currently in its 4th edition it is commonly referred to as ARR2016.
Backwater	Water backed-up or retarded in its course as compared with its normal or natural condition of flow
Baseflow	The component of streamflow supplied by groundwater discharge
Basin	A tract of country, generally larger catchment areas, drained by a river and its tributaries.
Catchment	The land area draining to a point of interest, such as a water storage or monitoring site on a watercourse.
Channel	An artificial or constructed waterway designed to convey water. Often described as open channels to distinguish them from pipes.
Control	Physical properties of a cross-section or a reach of an open channel, either natural or artificial, that govern the relation between stage and discharge at a location in the open channel.
Dead Storage	In a water storage, the volume of water stored below the level of the lowest outlet (the minimum supply level). This water cannot be accessed under normal operating conditions.
Discharge	Volume of liquid flowing through a cross-section in a unit time.
Drainage Division	Representation of the catchments of the 12-major surface water drainage systems across Australia, generally comprising a number of river basins.
Endorheic Basin	A closed surface water drainage basin that retains water and has no outflow to the sea.
Environmental Flow	The streamflow required to maintain appropriate environmental conditions in a waterway or water body.
Ephemeral	Something which only lasts for a short time. Typically used to describe rivers, lakes and wetlands that are intermittently dry.
Evapotranspiration (ET)	The sum of evaporation and plant transpiration from the earth's land surface to the atmosphere.
Evaporation	A process that occurs at a liquid surface, resulting in a change of state from liquid to vapour.
Floodplain	Flat or nearly flat land adjacent to a stream or river that experiences occasional or periodic flooding
Full Supply Level (FSL)	The normal maximum operating water level of a water storage when not affected by floods. This water level corresponds to 100% capacity.
Generalised Short-Duration Method (GSDM)	Appropriate for estimating probable maximum precipitation for durations up to six hours and for an area of less than 1000 square kilometres.
Generalised Tropical Storm Method – Revised (GTSMR)	Appropriate for estimating probable maximum precipitation in regions of Australia affected by tropical storms.

Intensity-Frequency-Duration (IFD)	Design rainfall intensities (mm/h) or design rainfall depths (mm) corresponding to selected standard probabilities, based on the statistical analysis of historical rainfall.
Minimum Supply Level (MSL)	The lowest water level to which a water storage can be drawn down (0% full) with existing outlet infrastructure; typically, equal to the level of the lowest outlet, the lower limit of accessible storage capacity.
Precipitation	All forms in which water falls on the land surface and open water bodies as rain, sleet, snow, hail, or drizzle.
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation (PMP, and coupled with the worst flood producing catchment conditions.
Probable Maximum Precipitation (PMP)	The theoretically greatest depth of precipitation for a given duration under modern meteorological conditions for a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends.
Rainfall	The total liquid product of precipitation or condensation from the atmosphere, as received and measured in a rain gauge
Riparian	An area or zone within or along the banks of a stream or adjacent to a watercourse or wetland; relating to a riverbank and its environment, particularly to the vegetation.
Stage	The water level, typically measured at a water monitoring site
Storage	A pond, lake or basin, whether natural or artificial, for the storage, regulation and control of water.
Surface Runoff	Water from precipitation or other sources that flows over the land surface. Surface runoff is the fraction of precipitation that does not infiltrate at the land surface and may be retained at the surface or result in overland flow toward depressions, streams and other surface water bodies
Sustainable Yield	The level of water extraction from a particular system that would compromise key environmental assets, or ecosystem functions and the productive base of the resource, if it were exceeded.
Total Suspended Solids (TSS)	The sum of all particulate material suspended (i.e. not dissolved) in water. Usually expressed in terms of milligrams per litre (mg/L). It can be measured by filtering and comparing the filter weight before and after filtration.
Transpiration	Evaporative loss of water from the leaves of plants through the stomata; the flow of water through plants from soil to atmosphere.
Watercourse	A river, creek or other natural watercourse (whether modified or not) in which water is contained or flows (whether permanently or from time to time).
Wind Run	The product of the average wind speed and the period over which that average speed was measured

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1.0 INTRODUCTION

Saturn Metals Limited (STN) proposes to develop the Apollo Hill Pilot Project (AHPP), located approximately 45 km southeast of Leonora in the Goldfields region of Western Australia.

STN proposes to develop the project over several stages and this report deals solely with the initial or "pilot" stage of the project with mining commencing in mid-2025 and expected to take approximately two years. Gold bearing ore will be mined from two starter open pits, which will be crushed and agglomerated prior to being conveyed to an on-site heap leach pad. Process solutions will report to lined ponds with gold absorbed from the pregnant leach solution using activated carbon. STN plans to process ore at between 1 and 2 Mtpa and recover approximately 24,000 oz of gold during the pilot stage of the project. The results of pilot stage will be used to inform a definitive feasibility study (DFS) that will be completed concurrently, prior to STN's final investment decision to proceed with the full scale development of the project.

STN engaged Carrick Consulting (WA) Pty Ltd to complete a baseline hydro-meteorological study and hydrological assessment to identify and ameliorate potential flood risks and develop preliminary engineering designs for the required surface water management works. This report presents the findings from a desktop study of regional hydro-meteorological data that has been used in the preliminary design of surface water management measures at the AHPP.

The following tasks were completed as part of the assessment:

- *Hydrological/meteorological Desktop Study* – we obtained hydro-meteorological data and mapping information from the relevant WA and Federal government bodies and completed a desktop review to define catchment areas and determine key catchment characteristics and regional and local meteorological conditions. This study yielded pertinent meteorological information e.g. rainfall intensity-frequency-duration (IFD), maximum daily rainfalls, tropical cyclone risk, critical historical wet/dry periods etc. and can be used in the future detailed design of surface water management works.
- *Feasibility Level Surface Water Management Measure Design* - we have developed feasibility level designs for the surface water management works required at the AHPP including diversion channels, bunds, raised haul roads, floodways etc. The designs are summarised in the text and shown on preliminary design figures to a level consistent with a Feasibility Study (FS).

The study findings and preliminary engineering designs are presented in the following sections.

2.0 HYDRO-METEOROLOGICAL STUDY

2.1 Data Sources

The key data used in the study have been analysed and the results discussed in the following sections and summarised in Appendix A.

2.1.1 Bureau of Meteorology (BoM) Data:

The BoM data summarised in Tables 1 and 2 were obtained and used in the completion of the desktop study (refer to Figures 1 and 2 for station locations). It should be noted that all stations remain open unless noted otherwise and all distances have been measured from the approximate centre of the proposed Apollo Hill mining area (6,774,300 mN and 371,250 mE GDA94/MGA Zone 51):

Table 1: Climate Summaries for Regional BoM Stations

BoM Station Name	Station No.	Data Period[note 1]	Distance from Site (km)
Leonora	12046	Jan 1898 - Jun 2024	45 NW
Menzies	12052	Jan 1896 - Jun 2024	87 SW
Laverton	12045	Jan 1899 - Jun 2024	92 NE
Laverton Aero	12305	Aug 1991 - Jun 2024	94 NE
Leinster Aero	12314	Jul 1994 - Jun 2024	174 NW
Kalgoorlie Airport	12038	Mar 1939 - Jun 2024	182 S
Yamarna [closed]	12219	Jan 1967 - Aug 1998	222 NE
Yeelirrie	12090	Jun 1928 - Jun 2024	259 NW

Note 1: Record length and quality varies depending on climate parameter under consideration.

Table 2: Daily Rainfall Records for Local BoM Stations

BoM Station Name	Station No.	Data Period[1,2]	% Complete[3]	Distance from Site (km)
Glenorn	12032	Feb 1932 - Dec 2003	92.8	7 N
Minara [closed]	12061	Jan 1907 - May 2014	92.6	29 NNE
Yundamindra	12093	Jan 1907 - Feb 2015	97.9	43 ESE
Leonora	12046	Jan 1907 - Jul 2020	99.9	45 NW
Nambi	12062	Mar 1922 - Dec 2013	64.5	85 N

Note 1: Data prior to January 1907 discarded due to frequency and length of gaps.
Note 2: Data after end date shown unavailable or discarded due to frequency and length of gaps.
Note 3: % Complete = No. of Daily Observations ÷ (End Date of Record - Start Date of Record)

Swept path data from the BoM's Southern Hemisphere Tropical Cyclone Data Portal for Australian cyclones from 1969/1970 season to 2021/2022 season were also used in the study.

2.1.2 Department of Water & Environmental Regulation (DWER):

A request was made to the DWER for mean and maximum flow monitoring data. However, currently the Department has no flow gauging stations within the Raeside-Ponton catchment of the Salt Lake Basin (Basin No. 024).

2.1.3 Department of Agriculture (DoA):

Data presented in the Department's Evaporation Data for Western Australia, Resource Management Technical Report No. 65, October 1987 were used as part of the hydro-meteorological study.

Reference was also made to the Department's Technical Bulletin No. 87 "An Inventory and Condition Survey of Rangelands in the North-Eastern Goldfields, Western Australia" (Pringle et al).

2.1.4 Mapping Data

The following mapping data were used in the completion of the desktop study:

- 1:250,000 scale electronic topographic mapping from Geoscience Australia.
- 1-second Hydro-Enforced SRTM data from Geoscience Australia.
- ESRI World Imagery.
- Stereo satellite topographic survey and imagery (both at 50 cm resolution) for Apollo Hill mining area captured 18 May 2023, supplied by STN.
- Preliminary infrastructure shapes supplied by STN in June 2024.

2.2 Desktop Study Findings – Hydro-Meteorological Conditions

2.2.1 Regional Climate

The AHPP straddles the Shire of Leonora/Shire of Menzies boundary within the North-Eastern Goldfields of Western Australia (see Figure 1). The regional climate is arid[1] and can be characterised by its relatively low annual rainfall and large temperature range. The regional bioclimatic zone can be categorised as "*Desert: Summer and Winter Rainfall*"[2] and, as such, none of the months of the year are reliably wet, and zero rainfall can be recorded in any month.

The mean annual rainfall is typically ranges between 225 mm and 240 mm, but may vary annually from less than one third to almost three times that amount. The rainfall that occurs during the autumn and early winter months of May to July tends to be more reliable though generally of a lesser total amount than the less dependable, but more intense summer cyclonic rainfall from December to March.

Temperature ranges of over 45°C have been recorded between summer maxima and winter minima. Annual pan evaporation rates typically exceed 2,500 mm/year and surpass rainfall by an order of magnitude.

[1] In the temperate zones of Australia the classification of aridity generally refers to areas with a mean annual rainfall of less than 250 mm.

[2] "Plant Life of Western Australia", J. S. Beard, 1990.

2.2.2 Regional Summer Climate

During the warmer months between November and April the region is influenced by anti-cyclonic systems to the southeast. The area is also occasionally influenced by southern extensions of the Inter Tropic Convergence Zone (ITCZ) which may bring thunderstorm activity. Significant summer features include almost stationary heat lows over the region, which occur during fine, hot to very hot days, with little or no cloud, and easterly winds. Evenings typically bring only slight decreases in temperature with an easing in wind velocity and direction change to the south-east.

Occasionally, remnant tropical cyclones, which have crossed the Pilbara coast, pass over the Goldfields region. These proceed in a south-easterly direction weakening as they progress to become rain-bearing troughs or depressions between the usual anti-cyclone patterns. Strong wind gusts can be associated with these depressions that can occasionally cause wind erosion and dust storms. During March to April, the surface winds become lighter and more variable. Typically by April, the northward movement of the anti-cyclone belt has become very noticeable and the probability of tropical depression rain decreases.

Summer maximum temperatures commonly exceed 40°C. Evaporation levels are very high during the summer months, with Kalgoorlie averaging in excess of 300 mm/month. Humidity levels are low and dews are rare except during and immediately following periods of rain.

2.2.3 Regional Winter Climate

Anti-cyclone systems reach their northern limit over Western Australia during the cooler half of the year, between May and October. Winter in the region is then characterised by a continuous sequence of anti-cyclones moving from west to east, which distribute westerly winds and on occasion, north-westerly winds to the area.

Associated with these sequences of anti-cyclones are depressions bringing rain-bearing frontal systems through the region. Winds are usually moderate but occasionally westerly gales can extend into the area. Winter rains most often occur between late May and early August. When anti-cyclones are centred over the area, winds are frequently light and variable. Minimum temperatures may occasionally fall below freezing point for several successive days.

During September-October the re-establishment of stable anti-cyclonic conditions is characterised by little to no rain in the region. Also during October, because of the southward movement of the ITCZ and the anti-cyclonic belt, the easterlies in the north and the westerlies in the south of the region both weaken, and light variable winds are characteristic.

Regional minimum winter temperatures of -5.0°C have been recorded. Evaporation levels are greatly reduced during the winter months with a mean monthly evaporation at Kalgoorlie of less than 100 mm/month. Generally the average rainfall during the wettest months of July to August still does not exceed the evaporation rate. Humidity levels are generally higher in winter than in summer, except during, and immediately following, summer rainfalls.

2.2.4 Local Rainfall

In order to analyse local rainfall conditions daily rainfall data were obtained for five BoM rainfall stations, all of which are located within an 85 km radius of the AHPP (see Figure 2). All the stations are still active and have at least 70 years of record with varying degrees of

completeness. Key local rainfall parameters for these records are summarised as follows (refer to Appendix A for charts):

Annual Rainfall

An analysis of annual rainfall data for the five local stations was carried out using only complete years of data. Table 3 gives the minimum, maximum, mean and median annual rainfalls, while Table 4 gives the minimum, maximum and mean number of rain days per year and maximum duration without rain.

The annual rainfall data for all local stations demonstrate right-handed or positive skewness typical of the region (annual skewness values ranged from +0.61 to +0.86). Median annual rainfall is generally considered to be a more representative reflection of rainfall central tendency for areas with skewed rainfall data than mean annual rainfall. This is the case for locations where exposure to a few, or even a single, extreme cyclonic rainfall event can have a disproportionate effect on the mean, but has much less effect on the median, given that it is based on ranked data.

Table 3: Local Rainfall Stations Annual Rainfall

Station Name	Maximum Annual Rainfall and Year (mm)	Minimum Annual Rainfall and Year (mm)	Mean Annual Rainfall (mm)	Median Annual Rainfall (mm)	No. of Complete Years of Data
Leonora	552.2 (1975)	57.8 (1936)	239.1	221.2	107
Glenorn	564.0 (1942)	58.4 (1936)	232.6	198.6	60
Minara [closed]	494.5 (2001)	88.6 (1969)	225.4	211.9	84
Yundamindra	612.1 (1995)	72.7 (1961)	236.1	219.6	99
Nambi	541.4 (2000)	57.4 (1962)	229.3	204.0	51

Note 1. Data prior to 1907 discarded due to gaps, along with all incomplete years.

Table 4: Local Rainfall Stations Annual Rain Days and Duration Without Rainfall

Station Name	No. of Rain Days per Year			Period Without Rainfall		
	Min.	Max.	Mean	Maximum Duration	From	To
Leonora	16	81	44.8	127	22 Jan 1940	27 May 1940
Glenorn	15	71	37.9	150	3 Oct 1952	1 Mar 1953
Minara [closed]	14	74	38.7	149	19 Jul 1938	14 Dec 1938
Yundamindra	9	64	34.3	173	17 Nov 1955	7 May 1956
Nambi	17	76	35.4	129	9 Sep 1924	15 Jan 1925

Note 1: All Annual Rainfall values above calculated using complete years of data only.

Table 3 shows that the mean annual rainfall for the local stations range from approximately 225 to 239 mm, while the median values range from some 199 to 221 mm. However, given that the Leonora station remains open, is located some 45 km northwest of the AHPP and has

107 years of complete data, its mean and median annual rainfall of 239 and 221 mm respectively are considered suitable for use in the design of the project.

Points of note from the analysis of the complete annual rainfall data sets for Leonora and the other local stations are as follows:

- Local annual rainfalls are highly variable with typically a one order of magnitude range between maximum and minimum values. Minimum and maximum annual rainfalls of 57.4 mm and 612.1 mm were recorded at Nambi in 1962 and at Yundamindra in 1995 respectively.
- Local annual rainfalls are also highly temporally variable and significantly wet and dry years can occur in consecutive years. This temporal variation is reflected in the data for Nambi with annual rainfalls of 447.1 mm in 1975, followed by 57.5 mm in 1976 i.e. a near eightfold year-on-year decrease. Nambi also recorded an annual rainfall of 57.4 mm in 1962, followed by 299.7 mm in 1963 i.e. greater than a fivefold year-on-year increase.
- Frequency analyses of the annual rainfall data for the local stations indicates that the 612.1 mm recorded at Yundamindra in 1995 had an annual exceedance probability (AEP) of less than 0.5% (1 in 200). The 57.4 mm recorded in 1962 at Nambi was approximately equal to 1% AEP annual drought for the local area.
- The local annual maximum of 612.1 mm recorded at Yundamindra in 1995 was due largely to heavy rainfalls associated with Tropical Cyclone (TC) Bobby which delivered a three-day rainfall total of 225.0 mm locally. It should be noted that 1995 was a significantly wet year and ranked seventh or higher at all of the local stations that were open at the time.
- Significantly wet years also occurred locally in 1975 and 2000 with several of the local stations recording their highest or second highest annual rainfalls. Rainfalls in 1975 were attributable to TC Trixie in late February and to depressions related to TC's Beverley, Clara and Joan later that year. In March 2000 TC Steve re-crossed the WA coast at Carnarvon and continued in a south-easterly direction bringing rainfalls of between 50 and 100 mm to inland parts from the West Gascoyne to the South Coast near Esperance.
- The local minimum annual rainfall of 57.4 mm, which was recorded at Nambi in 1962 was as a result of only 17 days of rainfall that year. It is interesting to note that Yundamindra recorded fewer days of rain (9 days) in 1961, but recorded a total annual rainfall of 72.7 mm that year.
- The longest continuously dry period was 173 days long and was recorded at Yundamindra between 17 Nov 1955 and 7 May 1956 inclusive. This event was due to the absence of Tropical Cyclone or depression related rainfall for that entire summer.
- The average number of rain days per year recorded locally ranges from between 34 and 44 days, with an overall average of some 38 days. However as many as 81 rain days per year (Leonora in 1992) and as few as 9 rain days per year (Yundamindra in 1961) have been recorded locally

Monthly Rainfall

Mean, median, maximum and minimum monthly rainfall values were determined for all five local rainfall stations using only complete months of data (refer to Appendix A for results). The monthly values for Leonora using all 1,301 complete months within the data set are shown in Table 5.

Table 5: Leonora Monthly Rainfall

Month	Mean Monthly Rainfall (mm)	Median Monthly Rainfall (mm)	Maximum Monthly Rainfall and Year (mm)	Minimum Monthly Rainfall (mm)	No. of Complete Months
January	26.2	11.4	172.0	0.0	108
February	31.0	12.8	284.6	0.0	109
March	30.6	12.5	273.9	0.0	109
April	20.5	14.1	135.4	0.0	109
May	23.5	17.8	158.6	0.0	107
June	24.1	19.4	144.0	0.0	108
July	18.7	15.3	101.6	0.0	109
August	15.5	11.0	85.2	0.0	108
September	8.5	5.1	49.9	0.0	108
October	9.5	3.8	73.0	0.0	109
December	12.4	7.1	61.2	0.0	108
December	17.5	10.8	94.0	0.0	109
Total No. of complete months in data set					**1,301**

Note data for all months are positively skewed. Average skewness = +2.1 and ranges between +3.9 (Nov) and +1.4 (Apr).

Table 5 shows that the six months of the year between January and June are the wettest based on mean monthly values and from February to July are the wettest based on median monthly values. The wettest month at Leonora based on mean monthly values is February with 31.0 mm. However, June has the maximum median monthly value of 19.4 mm. This bi-modal distribution is caused in late summer by tropical cyclones and associated depressions, while the increase in rainfall in early winter tends to be due to low-pressure trough systems acting in conjunction with large southerly frontal systems.

The results show the positive skewing effect that extreme cyclonic rainfall events can have on the mean rainfall values compared to median values, especially during the summer months. The difference between the mean and median monthly rainfall amounts is significantly less during the drier winter months. September and October are the driest months of the year based on both mean and median values.

The maximum monthly rainfall for each of the local stations are presented in Table 6. Clearly TC Bobby was a very significant event in the vicinity of the AHPP as it gave rise to the wettest month on record at all five of the local rainfall stations. Yundamindra recorded the local maximum monthly rainfall of 346.6 mm, with over 306 mm being recorded over an eight day period between 25 February and 4 March 1995. (The frequency of cyclones in the local area is discussed later in this report).

Table 6: Local Rainfall Stations Maximum Monthly Rainfall

Station Name	Maximum Monthly Rainfall (mm)	Date	Event (if known)
Leonora	284.6	Feb 1995	TC Bobby
Glenorn	282.4	Feb 1995	TC Bobby
Minara [closed]	256.1	Feb 1995	TC Bobby
Yundamindra	346.6	Feb 1995	TC Bobby
Nambi	213.0	Feb 1995	TC Bobby

Note: Only months with complete data were used in the analysis.

Zero precipitation or dry months have been recorded at Leonora (and all of the other local rainfall stations considered) throughout the year, with up to approximately 10% of the usually wetter months of February, May and June recording no rainfall.

A plot of the mean and median monthly rainfall data for the Leonora station is included in Appendix A, along with those for the other four local BoM rainfall stations.

Daily Rainfall

A frequency analysis was carried out using Leonora daily data to assess the typical duration of local rainfall events. As only daily data were available, a multiple day duration event was assumed to comprise two or more consecutive days of rainfall, resulting in 3,048 discrete rainfall events during the approximately 114 year span of the Leonora rainfall dataset. The results of the frequency analysis are presented in Table 7.

Table 7: Rainfall Duration Frequency Analysis for Leonora

Event Duration (days)	Frequency (No. of Events)	Frequency (%)	Cumulative Frequency (%)
1	1,898	62.27%	62.27%
2	748	24.54%	86.81%
3	243	7.97%	94.78%
4	106	3.48%	98.26%
5	38	1.25%	99.51%
6	10	0.33%	99.84%
7	4	0.13%	99.97%
8	0	0.00%	99.97%
9	1	0.03%	100.00%
Total	**3,048**	**100%**	**-**

A review of the results of the rainfall duration frequency analysis shows that by far the greatest amount (about 62%) of rainfall events are discrete, single-day events. As expected two and three-day events represent some 25% and 8% of all rainfall events. The longest period of consecutive daily rainfall was found to be 9 days and occurred between 19 and 27 February

1975 and was likely related to the remnant TC Trixie which was active in the NE Goldfields at that time.

An analysis of maximum daily rainfall data was carried out for all five local BoM stations. The top ten wettest days are shown in Table 8 along with the recording station, date and tropical cyclone name where related. It should be noted that the highest daily events are more than double the minimum annual rainfall at some of the local stations.

Table 8: Local Rainfall Stations Maximum Daily Rainfall

Station Name	Date	Daily Precipitation to 9 am (mm)	Rank	Event Name note1
Yundamindra	17 Feb 2011	126.0	1st	TC Dianne/Carlos
Glenorn	22 Feb 1975	109.2	2nd	TC Trixie
Leonora	23 Jan 2014	109.2	= 2nd	Tropical Low 06U
Leonora	27 Feb 1995	105.9	4th	TC Bobby
Leonora	21 Mar 1927	103.4	5th	TC Unnamed #4 1926
Yundamindra	1 Jan 1955	101.6	6th	TC Unnamed #2 1954
Minara closed	1 Jan 1955	100.6	7th	TC Unnamed #2 1954
Yundamindra	29 Jan 1942	100.6	8th	TC Unnamed #2 1941
Leonora	10 Jan 2006	98.2	9th	TC Clare
Yundamindra	16 Mar 1907	96.5	10th	Unknown

Note 1: Prior to 1964 Tropical Cyclones were unnamed and were instead assigned a sequential number by BoM according to the season of their occurrence.

Frequency analyses were carried out on the annual daily maxima for the local BoM rainfall stations. The analyses showed that the 126 mm event recorded at Yundamindra on 17 February 2011 as a result of a rain bearing system associated with TC Dianne/Carlos had an AEP in the order of 1.5%. The equal second highest rainfall of 109 mm recorded at Glenorn on 22 February 1975 and at Leonora on 23 January 2014 had an AEP of approximately 2%.

A listing of the ten wettest days at each of the local stations is provided in Appendix A and is presented by individual station, by total rainfall depth and chronologically.

Maximum two and three day rainfalls recorded at each of the local rainfall stations are shown in Table 9. The maximum two-day rainfall depth of 173.5 mm recorded at Leonora at 9.00 am on 22 March 1927 was as a result of rainfall associated with TC Unnamed #4 1926. The maximum three-day rainfall depth of 173.5 mm recorded at Yundamindra at 9.00 am on 28 February 1995 was as a result of rainfall associated with TC Bobby.

Table 9: Local Stations Maximum Two and Three Day Rainfalls

Station Name	Maximum Two-Day Rainfall (mm)	Date of Maximum Two-Day Rainfall	Maximum Three-Day Rainfall (mm)	Date of Maximum Three-Day Rainfall
Leonora	173.5	21-22 Mar 1927	216.2	26-28 Feb 1995
Glenorn	170.2	21-22 Feb 1975	214.6	21-23 Feb 1975
Minara [closed]	128.5	1-2 Jan 1955	134.2	21-23 Feb 1975
Yundamindra	153.0	25-26 Feb 1995	225.0	26-28 Feb 1995
Nambi	113.2	22-23 Feb 1975	152.2	21-23 Feb 1975

Intensity-Frequency-Duration Relationship

Table 10 shows the point rainfall depth-frequency-duration (IFD) relationship developed for the proposed Apollo Hill mining area using the most recent data set (updated by BoM in 2016). The full intensity-frequency-duration relationship is presented in Appendix B.

Table 10: AHPP Point Rainfall Depth-Frequency-Duration Relationship

AEP	10%	5%	2%	1%
Duration	**Rainfall Intensity (mm/hr)**			
5 mins	107.0	133.0	172.0	205.0
30 mins	43.4	54.0	69.6	82.9
1 hr	27.3	34.0	44.0	52.7
2 hrs	16.8	20.9	27.1	32.5
3 hrs	12.70	15.70	20.30	24.3
6 hrs	7.85	9.73	12.50	14.9
12 hrs	4.92	6.10	7.82	9.29
24 hrs	3.08	3.84	4.93	5.87
48 hrs	1.88	2.36	3.07	3.68
72 hrs	1.36	1.73	2.28	2.75

Cyclone Swept Path Analysis

As discussed earlier, the AHPP is located within part of the eastern Goldfields that is occasionally subject to tropical cyclones, thunderstorms and related events. Of particular note was TC Bobby which crossed the western Pilbara coast near Onslow on 25 February 1995 as a Category 4 event, before continuing southwards across the Gascoyne as a Category 2 event and then the Goldfields as a rain bearing depression. Intense rainfall accompanied Bobby, with Onslow recording more than 400 mm over the duration of the cyclone. Many centres in the Goldfields recorded their maximum daily, monthly and annual rainfalls as presented in the preceding sections. Yundamindra and Leonora recorded some 287 mm and 233 mm of rainfall respectively in the four days to 28 February 1995, and a daily rainfall of

some 106 mm at Leonora on 27 February. The resulting runoff closed roads and flooded many open pits and underground mines across the region. It was estimated to have caused more than a $50 million loss in gold output alone[3].

In more recent times, Tropical Low 06U crossed the Northern Territory coast east of Darwin on 14 January 2014 and moved inland causing significant rainfall across vast swathes of inland Australia including the Kimberley, Pilbara, Mid-West and Goldfields regions of Western Australia. Kalgoorlie recorded 103.0 mm during a 24 hour period on 23-24 January and Laverton and Cowarna Downs received some 127 mm and 121 mm respectively to 9 a.m. on 23 January (these amounts are equivalent to approximately the 50 year-24 hour duration rainfall amount). Parts of the arid Nullarbor Plain received more than an entire summer's worth of rain in 24 hours, with Eyre receiving over 106 mm. While this event brought much needed rainfall and alleviated drought conditions over north-west Australia, it also caused widespread flooding and inundation of mines and cattle stations in the Goldfields.

In order to estimate the frequency that cyclones might be expected in the region, the swept paths of all Australian cyclones from the 1969/70 season to the 2021/22 season were examined and those that passed within a 200 km radius of the AHPP were noted. This radius of influence was arbitrarily chosen as the distance within which a cyclone would result in significant rainfalls and runoff in the vicinity of the AHPP.

This initial assessment showed that some ten tropical cyclones entered the 200 km radius during the approximately 52-year period of record, or that the long-term regional average is approximately one cyclone within 200 km every five years or so.

A second assessment was carried out to determine the number of cyclones crossing closer to or within 100 km of the AHPP site. It was considered that cyclones crossing within this tighter radius would result in even more significant rainfall-runoff in the vicinity of the AHPP, likely leading to lost time and possible asset damage or loss. This assessment showed that four cyclones (TC's Mavis in March 1971, Connie in January 1987, Orson in April 1989 and Bobby in February 1995) crossed within a 100 km radius over the approximately 52-year period of record, or one every thirteen years or so.

A final assessment showed that two cyclones (TC Connie in January 1987 and TC Orson in April 1989) crossed within a 50 km radius of the AHPP site over the approximately 52-year period of record.

The results of the cyclone swept path analyses are provided in Appendix C.

It should be noted that the above analyses are somewhat subjective as it only considers the cyclone frequency and not its intensity or resulting rainfall. Cyclone intensity varies from a gale force category 1 with wind speeds up to 125 km/hr to severe category 5 cyclones with gusts of more than 280 km/hr. Obviously a more intense cyclone passing further away may result in more significant rainfall and/or cause greater damage than a less intense cyclone in the immediate vicinity of the project site.

[3] "Report on a Survey of the Effects of Cyclone Bobby on Western Australian Mines", Dept. of Minerals and Energy, October 1995.

2.2.5 Evaporation

The mean monthly Class A bird-guarded pan evaporation records for Yamarna and Kalgoorlie are listed in Table 11 (these are the closest BoM evaporation gauging sites, with the former located some 222 km northeast and the latter located some 178 km south of the AHPP).

Table 11: Mean Monthly Pan Evaporation

Month	Mean Monthly Pan Evaporation (mm)		
	Yamarna note 1	Kalgoorlie Airport note 1	AHPP Estimated note 3
January	434	388	411
February	342	305	323
March	313	267	290
April	213	174	194
May	136	112	124
June	96	78	87
July	99	87	93
August	133	118	126
September	204	174	189
October	288	260	274
December	345	309	327
December	406	372	389
Mean Annual Pan Evaporation (mm)	**3,010**	**2,643**	**2,827**

Notes:
1. Yamarna values based on BoM's analysis of 24 years of data collected between 1968 and 1997.
2. Kalgoorlie Airport values based on BoM's analysis of 48 years of data collected between 1966 and 2015.
3. Assumed mean pan evaporation based on average of other two stations

The mean annual pan evaporation measured at Yamarna and Kalgoorlie Airport is 3,010 mm and 2,643 mm respectively, both of which are one order of magnitude greater than the mean annual rainfall for the region. It should also be noted that mean monthly evaporation exceeds mean monthly rainfall throughout the year. The evaporation data show that evaporation is highest in the summer months from December to February, with January having the highest values.

Given that the AHPP is located approximately midway between the Yamarna and Kalgoorlie Airport stations and in the absence of any local evaporation data, the average of pan evaporation data for both stations shown in the table above is considered suitable for current design purposes for the project. This indicates that the annual evaporation rates at the AHPP will be in the order of 2,827 mm/year.

The Department of Agriculture's (DoA) Technical Report No. 65 referenced earlier states that a 7% coefficient of variation can be applied to mean annual evaporation rates in WA. Applying this coefficient to the project mean annual evaporation of 2,827 mm gives a standard

deviation of 198 mm. Assuming that evaporation data are normally distributed, estimates of annual pan evaporation with 10%, 2% and 1% AEP will be in the order of 3,155, 3,225 and 3,425 mm respectively.

The DoA report also states that a "pan to dam" coefficient in the order of 65-70% is appropriate for use for shallow dams and ponds (less than 4 m deep) storing freshwater in the Northeast Goldfields. Consequently mean annual evaporative rates in the order of 1,840 mm to 1,980 mm might be expected from freshwater storage ponds at the AHPP.

2.2.6 Temperature

The climate summary data for the Leonora station, situated some 45 km northwest of the AHPP are shown in Table 12 below.

Table 12: Leonora Monthly Temperature

Month	Mean daily maximum Temp (°C)	Mean daily minimum Temp (°C)	Highest daily Max Temp (°C)	Lowest daily Min Temp (°C)	Mean no. of days where Max Temp ≥ 40.0 °C	Mean no. of days where Min Temp ≤ 2.0 °C
Jan	37.0	21.8	49.0	12.6	9.9	0
Feb	35.3	20.9	46.7	10.6	5.6	0
Mar	32.6	18.6	45.2	8.4	2.2	0
Apr	27.9	14.8	41.7	3.1	0.1	0
May	22.8	10.2	35.6	0.7	0	0.2
Jun	19.0	7.3	30.2	-2.8	0	1.3
Jul	18.4	6.1	28.9	-1.7	0	3.2
Aug	20.7	7.0	33.0	0.3	0	1.3
Sep	24.9	10.0	37.7	1.8	0	0.1
Oct	28.9	13.7	40.8	3.6	0.2	0
Nov	32.3	17.0	44.4	4.0	1.9	0
Dec	35.3	20.0	47.8	9.5	5.2	0

Note: Leonora mean maximum and minimum temperature values based on approximately 64 years of data recorded between 1900 and 2014. All other values based on approximately 57 years of data recorded between 1957 and 2014.

The monthly temperature data for Leonora provided the following information:

- Mean daily maximum temperatures range from 37.0°C in January to 18.4°C in July.
- Mean daily minimum temperatures range from 21.8°C in January to 6.1°C in July.
- Highest and lowest daily temperatures of 49.0°C and -2.8°C have been recorded in January (2013) and June (1981) respectively.
- Typically there will be in the order of 25 days each year with daily maximum temperatures in excess of 40°C, approximately 21 of which will occur in December, January and February.

- On average 6 days each year can be expected when minimum temperatures will be 2°C or less and light ground frosts are possible. The bulk of such days will occur in June, July and August.

2.2.7 Wind Speed and Direction

Wind speed and direction data are available for Leonora, situated 45 km northwest of the AHPP and Kalgoorlie Airport, some 178 km south. Although the Leonora station is closer, the Kalgoorlie Airport station has the advantage of not only recording wind speed and direction at three-hourly intervals, but also records the instantaneous wind gust speed. The 9 am and 3 pm mean monthly wind speeds for both stations and maximum wind gusts for Kalgoorlie Airport are shown in Table 13 and annual wind roses are provided in Appendix A.

Table 13: Mean Monthly 9 am and 3 pm Wind Speed for Kalgoorlie Airport and Leonora Stations and Maximum Wind Gusts for Kalgoorlie Airport

Month and Station Name	Mean 9 am Wind Speed (kph)		Mean 3 pm Wind Speed (kph)		Highest Recorded Wind Gust (kph)	
	Kalgoorlie	Leonora	Kalgoorlie	Leonora	Kalgoorlie	
Jan	16.6	10.8	15.1	8.6	141	14-Jan-94
Feb	16.4	10.2	15.1	8.7	118	16-Feb-70
Mar	15.7	10.3	14.2	8.6	118	28-Mar-71
Apr	14.4	8.8	13.7	8.1	104	24-Apr-73
May	11.8	7.6	14.1	8.1	122	5-May-75
Jun	11.8	7.5	15.7	9.6	102	4-Jun-74
Jul	12.4	8.1	16.6	10.4	97	30-Jul-48
Aug	14.3	9.1	17.2	11.1	108	12-Aug-64
Sep	16.2	10.7	17.8	11.2	109	13-Sep-65
Oct	17.1	11.8	17.6	11.7	117	3-Oct-50
Nov	17.1	12.1	17.2	11.5	139	7-Nov-79
Dec	16.3	10.7	16.0	9.6	122	10-Dec-46

Note: Leonora mean wind values based on approximately 53 years of data (1957-2010). Kalgoorlie Airport mean wind and gust values based on approximately 72 years of data (1939-2010) and 84 years (1939-2023) respectively.

Mean wind speeds at Leonora are consistently lower than those at Kalgoorlie Airport in both the mornings and afternoons. Given the AHPP's location, it is likely that it will encounter mean wind speeds similar to those shown above for Leonora.

The highest instantaneous wind gust recorded at Kalgoorlie Airport was 141 kph which occurred on 14 January 1994 and may have been associated with TC Pearl which was passing along the Pilbara coast at that time. Inspection of the wind roses for both the Leonora and Kalgoorlie Airport stations show that easterly's of up to 30 kph predominate in the morning, but by the afternoon somewhat weaker westerly's are equally likely to occur. Calm conditions are roughly similar with morning and afternoon calms recorded at Leonora about 9% of the year, compared to 7% calm mornings and 5% calm afternoons for Kalgoorlie.

2.3 Hydrological Conditions

2.3.1 Regional Hydrological Setting

The AHPP is located in the central-east part of the Department of Water and Environmental Regulation's (DWER's) Raeside-Ponton Catchment (approximate area = 116,000 km^2), about 30 km southwest of the regional watershed divide with DWER's Lake Carey Catchment (approximate area = 114,000 km^2), as shown in Figure 3. Both of these catchments form part of the much larger Salt Lake Basin (approximate area = 441,000 km^2) which extends across much of central Western Australia.

The AHPP is situated immediately south of Lake Raeside, within the Raeside paleochannel, one of several large and broad, sub-parallel, southeast trending salt-lake drainage systems within the Salt Lake Basin that extend from the regional divide to the west of Wiluna/Sandstone and either drain into Ponton Creek (Raeside and Rebecca system) or terminate at the edge of sand plains (Carey/Minigwal system). These drainages typically have very low gradients and contain small to very large playa lakes such as Lake Raeside with surface areas in excess of 500 km^2.

Although catchment delineation is difficult, given the low-relief of the terrain and inter-connected salt lakes, Lake Raeside is estimated to have a direct catchment area in excess of 28,000 km^2 measured to its southern outlet. However, it may be considerably larger if other inter-connected upstream salt lakes such as Lake Mason, Lake Noondie and Lake Barlee are taken into consideration.

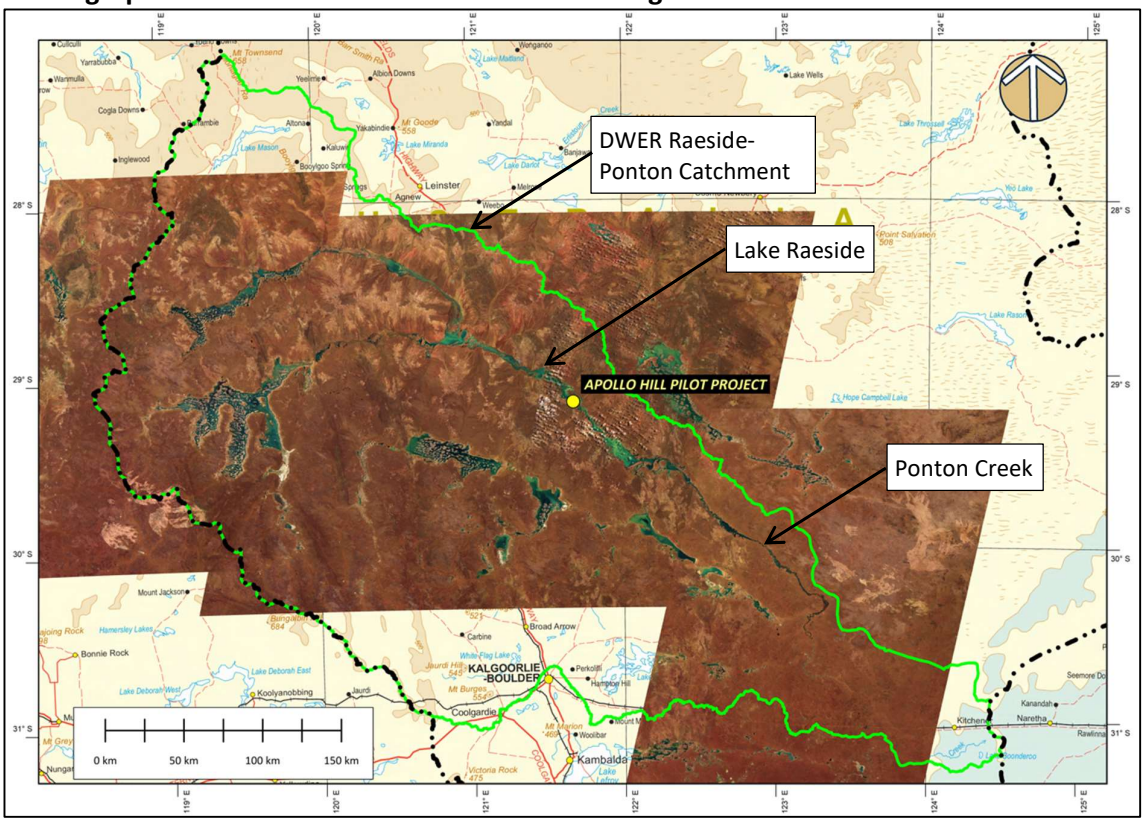
Ponton Creek originates at the southern end of Lake Raeside, some 150 km south of the AHPP. Ponton Creek continues for approximately 250 km in a generally southerly/south-easterly direction before terminating in a number of poorly defined soaks near Lake Boonderoo on the south side of the Trans Australian Railway. It is similar to all regional watercourses, in that it is ephemeral and only carries flow following prolonged periods of heavy rainfall. Currently no streamflow data are collected by DWER along Ponton Creek or any regional watercourses within the Raeside-Ponton catchment. It was therefore not possible to review local or regional flow data.

In order to gauge how frequently the various parts of Lake Raeside and the interconnecting channels link up and overflow southwards into Ponton Creek a review of public domain satellite imagery[4] was completed. A review of imagery from March 1972 to the present indicates that only on one occasion, following TC Bobby in late February 1995, were the various parts of Lake Raeside found to link up and form a continuous water body with flow discharge onto the Nullarbor Plain through Ponton Creek. Mosaics of Landsat False Colour and NDWI[5] images are shown as Photograph Nos. 1 and 2 on the following page for the period from 6 to 20 March 1995. Inspection of imagery for subsequent periods indicates that discrete pools of standing water remained at various sections of Lake Raeside for several months after TC Bobby.

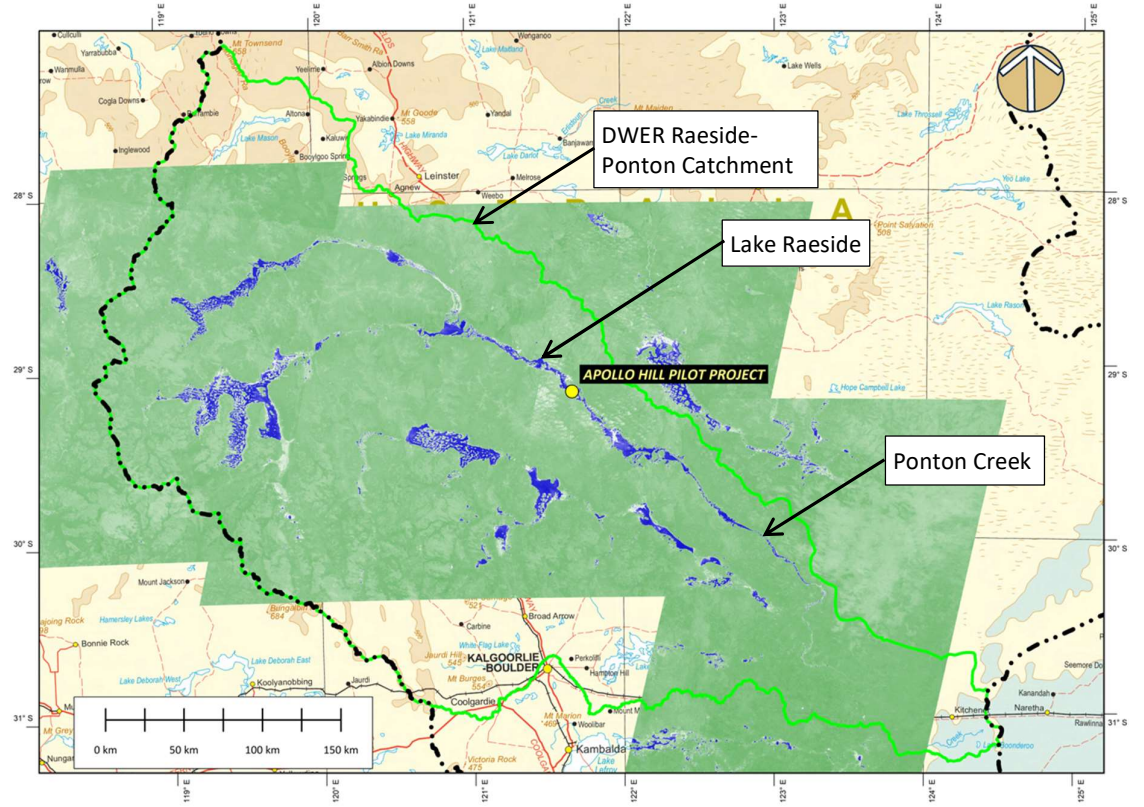
[4] Landsat 4-5 TM L2 imagery from Sentinel Hub (https://www.sentinel-hub.com/). It should be noted that images are non-continuous and gaps of several weeks may exist between images due to availability of satellites, cloud cover, technical problems etc.

[5] In Near Difference Water Index (NDWI) blue shading is used to differentiate water bodies from dry land based on their lower radiation and stronger absorbability in the visible infra-red wavelengths range.

Photograph 1: Landsat 4-5 False Colour Mosaic Image over Lake Raeside 6-20 March 1995



Photograph 2: Landsat 4-5 NDWI Mosaic Image over Lake Raeside 6-20 March 1995



2.3.2 Local Hydrological Setting

The AHPP is located immediately to the southwest of Lake Raeside, a south-east trending paleodrainage system extending over a length of about 350 km and with a surface area of some 633 km^2. It comprises numerous playa lakes and channels varying in width from several hundred metres to over 8 km wide. Lake Raeside is normally dry except following periods of considerable rainfall-runoff when up to several hundred millimetres of water may be stored in discrete parts of the lake. As discussed earlier, on rare occasions a single, continuous waterbody may be formed over the entire lake surface, leading to outflow into Ponton Creek at its southern end, as occurred most recently in March 1995 with the passage of TC Bobby.

TC Bobby was a very significant event and for preliminary planning purposes can be considered to be the "design event". Inspection of satellite imagery over the AHPP site following TC Bobby are shown on Photographs 3 and 4 on the following page. These indicate a maximum flood elevation of approximately 352.5 mAHD in the vicinity of the proposed AHPP site as shown in Figure 4. The proposed pits, heap leach pad and processing area is situated above this elevation and would therefore not have been inundated. Impacts from standing water at the site would likely have been limited to loss of access along the proposed haul road between the pits and ROM, in addition to direct rainfall to the pits and process ponds.

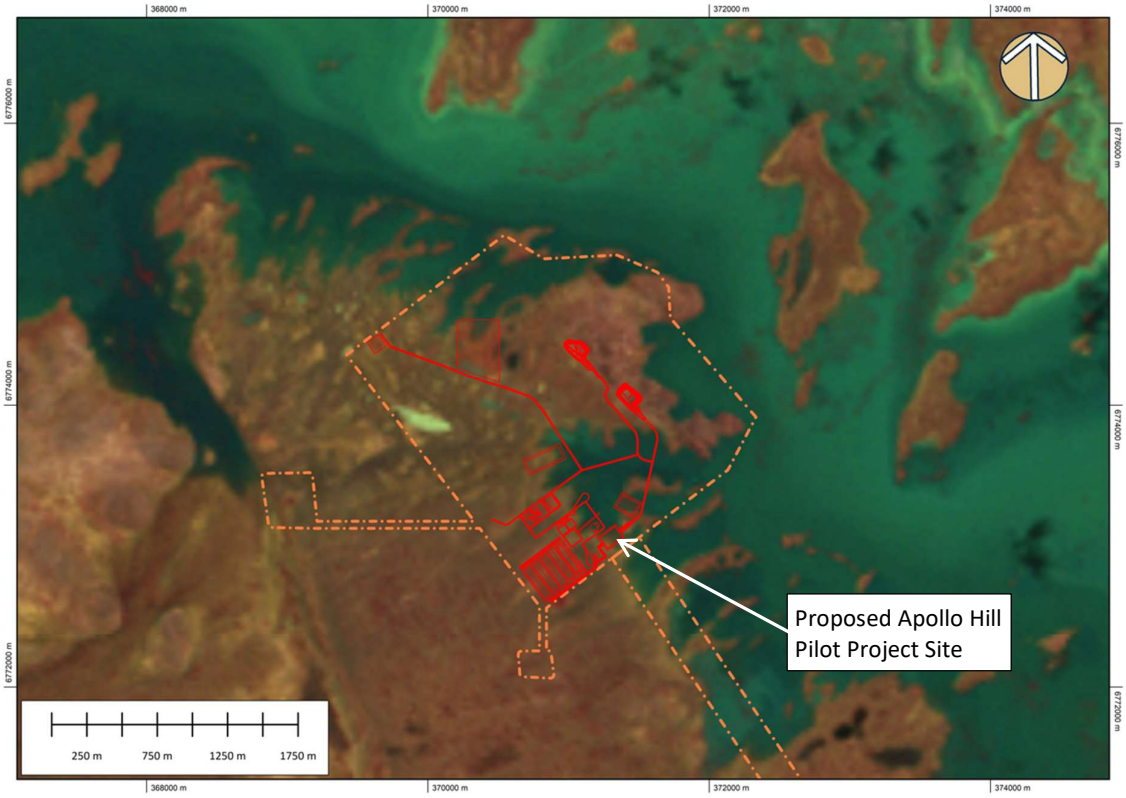
The Lake Raeside lakebed has a nominal surface elevation of about 350 mAHD in the vicinity of the AHPP, while the elevation at Mount Kildare, the local topographic high located some 12.5 km east of the AHPP, has an elevation of 429 mAHD. Surface gradients are very low over the lake (typically less than 0.01%) with land adjoining the lake also relatively flat with average slopes in the order of 0.1%. Although the overall gradient or direction of flow over the lakebed is south-eastwards, the movement of water on the lakebed is controlled at a local scale by the presence of islands, levees and bars and the prevailing wind direction.

The AHPP site slopes gently at about 0.2% west to east towards the Lake Raeside paleodrainage channel. The only exception to this is the presence of a range of low hills of up to about 30-35 m relief along the northeastern flank of the site. The proposed open Pits 1 and 2 are located within these hills with the lowest crest elevation at 354 mAHD, some 4 m above the nearby Lake Raeside channel elevation.

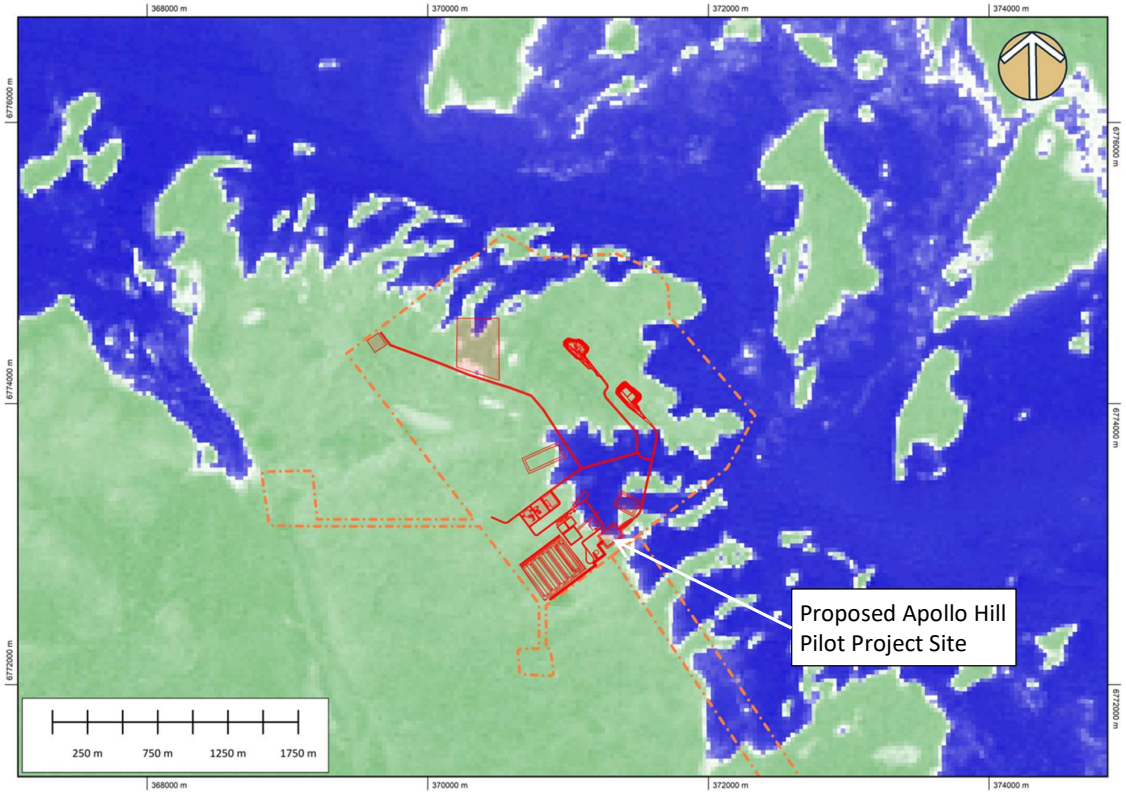
There are no major river systems or significant watercourses in the vicinity of the AHPP. However, inspection of the available topographical data and imagery indicates that there are three catchment areas upstream of the proposed AHPP facilities, namely Northern, Central and Southern catchments, as shown in Figure 5. These catchments have a combined area of approximately 6.0km^2 and drain mostly by overland sheetflow, with channelised flow only becoming established within a few hundred metres of the Lake Raeside channel. These catchments are delineated further and peak flow estimates are developed in the following section.

A selection of photographs showing typical catchment conditions at the AHPP is shown on the following pages (a complete set of site photographs is provided in Appendix D – to come). Inspection of the photographs show that the land surfaces in the vicinity of the AHPP are typical of salt lakes with fringing alluvial plains and dunes of kopi or sand within gently inclined wash plains with mantles of fine ironstone gravel that exist across the region. These irregular plains and low rises support mulga and halophytic shrublands.

Photograph 3: Landsat 4-5 False Colour Image over AHPP Site 6 March 1995



Photograph 4: Landsat 4-5 NDWI Image over AHPP Site 6 March 1995



Photograph 5: View at outlet from Central Drainage towards Lake Raeside Paleochannel



Photograph 6: View from Central Area Northeast towards low hills that host Pits 1 & 2



Photograph 7: View towards low hills that host Pits 1 & 2



Photograph 8: Typical catchment conditions



2.3.3 Local Catchment Delineation

As shown earlier in Figure 5 the proposed AHPP site has a total upstream catchment area of approximately 6.0 km^2 comprising the following areas:

- Northern Catchment = 0.825 km^2;
- Central Catchment = 1.316 km^2; and,
- Southern Catchment = 3.864 km^2.

The various proposed mine facilities will be located within these catchment areas and their upstream sub-catchment areas were delineated as shown in Figure 6 and summarized in Table 14.

Table 14: Proposed Mine Facility Sub-Catchments

Sub-Catchment ID	Area (km^2)	Perimeter (km)	Max. Stream Length (km)	Slope (m/km)
Haul Road Crossing	2.715	13.422	3.290	1.7
Processing Area	1.149	7.211	1.668	1.5
Mine Yard Area	0.568	7.068	1,735	0.8
Magazine	0.246	3.617	1,118	1.0

Peak flow estimates are developed for these sub-catchments below.

2.3.4 Peak Flow Estimate

Given the non-availability of site or regional streamflow data, hydrological calculations were completed using the calculation methods presented in ARR[6].

The AHPP is located at approximately 29.154° South and 121.676° East and so the ARR "*Zone 4 – Arid Interior: Mean Annual Rainfall < 255 mm*" Rational method was applied to the upstream catchment areas to give the 10, 5, 2 and 1% AEP peak flows presented in Table 15 (calculation worksheets are presented in Appendix E).

Table 25: Peak Flow Estimates for Proposed Mine Facilities

Catchment ID	Peak Flow Estimate (m^3/s)					
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
Haul Road Crossing	0.7	2.2	4.1	6.5	10.6	14.5
Processing Area	0.5	1.6	2.9	4.6	7.5	10.0
Mine Yard Area	0.3	0.9	1.7	2.7	4.4	6.0
Magazine	0.2	0.6	1.1	1.7	2.7	3.8

These peak flow estimates are used in the preliminary design of the required surface water management measures presented later in this report.

[6] Australian Rainfall and Runoff, Engineers Australia, 1997.

3.0 SURFACE WATER MANAGEMENT

3.1 Surface Water Management Objectives

The surface water management objectives for the AHPP are as follows:

Reduce Potential Risk of Loss of Life, Health Hazards or Property Damage:

- provide protection for life, livelihood, and property;
- control the incidence of nuisance or damage related to flooding, poor drainage and sedimentation to an acceptable level; and,
- protect project infrastructure.

Preserve the Environment:

- minimise the potential project impacts such as changes in the stream-flow regime, alteration of habitat, pollution or increased erosion and sedimentation;
- where feasible, maintain the shape and composition (geomorphology) of the natural watercourse geometry, natural biological indicator conditions and flow conditions;
- employ protection measures to prevent adverse hydrological and water quality impacts for all recognised watercourses within the site limits;
- promote sound development that respects the natural environment; and,
- rehabilitate any watercourses that are impacted as soon as practicable.

Conserve Social and Financial Resources:

- treat water as a resource, ensuring that water management facilities are functional and integrate multi-use objectives where possible;
- provide a system of infrastructure that enhances site personnel convenience and safety, and allows development to proceed according to the mine plan;
- sustain future mine development, support orderly and managed development of resources and integration of land uses within the site limits;
- use best management water and sediment practices where feasible; and,
- encourage economic design of drainage systems.

These objectives are intended to ensure a consistent approach to:

- planning and analyses required for surface water management;
- constructing new operational phase surface water management works; and,
- installing future closure phase surface water management works.

The design philosophy and design criteria for floodwater protection and surface water management is presented in the following sections. The PFS level design of the various water management facilities is presented in Section 4.0.

3.2 Flood risk

The AHPP site is located immediately adjacent to the Lake Raeside paleodrainage channel which, although normally dry, can convey runoff from its large upstream catchment area (~28,000 km^2) following significant rainfall-runoff events. However, as discussed earlier, a review of historical satellite imagery shows that the various parts of Lake Raeside seldom link-up to form a continuous water body and runoff is more often stored temporarily in discrete parts of the lake prior to loss by infiltration and evaporation.

Furthermore a review of satellite imagery for TC Bobby, which is considered to be the local design event, shows that the maximum flood elevation at the AHPP site is approximately 352.5 mAHD and that the proposed pits, heap leach pad or processing areas would not have been impacted by this event. As described later in this report (refer to Section 4.0), flood bunding in the form of a raised haul road between the Pit 1 and the ROM can be used to prevent flows from Lake Raeside reporting to the AHPP site.

The proposed open Pits 1 and 2 are located within a range of low hills of up to about 35 m relief along the northeastern flank of the site, which provides a high level of flood immunity to the mining area. The lowest crest elevation at the southern limit of Pit 1 daylights natural ground at an elevation of 354 mAHD i.e. some 4 m above the nearby Lake Raeside channel elevation. Flooding of the proposed open pits from flow along Lake Raeside is therefore not considered to be credible.

As shown earlier the proposed AHPP site has relatively modest upstream catchment areas with approximately 1.1 and 2.7 km^2 reporting to the Processing Area and Pit 1 to ROM Haul Road haul respectively (in addition about 0.6 and 0.2 km^2 reporting to the Mine Yard and Magazine respectively). As such the AHPP is considered to be at relatively low risk from large flood events and on-site surface water management measures are likely to be fairly modest (refer to Section 4.0 for preliminary design of surface water management measures).

Runoff will only occur following significant rainfall events, particularly during the summer months from January to March, when the potential exposure to high intensity rainfall is greatest. The hazard that such events pose to on-site facilities depends, amongst other things, on the following:

- the magnitude of the flood event;
- the proximity of the facility to the watercourse in flood;
- the sensitivity of the facility to flooding; and,
- the level of protective flood measures provided to the facility.

While the latter three factors can be controlled or engineered to some degree, the magnitude of the naturally occurring rainfall-runoff events may lead to flooding that cannot be controlled.

Although significant rainfall-runoff events do not occur cyclically, especially in a climatic region as variable as this, their probability of occurrence within any given period can be estimated. This probability is typically expressed as an AEP.

Table 16 shows the percentage probability for a range of different AEP flood events that could occur during an assumed two year operational life of the AHPP.

Table 16: Probability of Rainfall Events Occurring During Two Year Operational Life

Annual Exceedance probability (AEP)	~20%	~10%	5%	2%	1%
Probability of Occurrence	33.0%	18.1%	9.5%	3.9%	2.0%

It is recommended that a 1% AEP (100 year) design criterion is applied to the Mining and Processing areas flood protection measures during operations, while a 10% AEP (10 year) criterion be adopted for the design of all other on-site drainage measures.

3.3 Pit Flood Protection Design Philosophy

Inspection and review of the available topographical mapping and aerial photography indicates that the flood risks to the proposed AHPP open Pits 1 and 2 can be ameliorated and flood protection provided by a combination of the following measures:

- Pit crest/safety bunding placed as close as geotechnically possible to the pit crests to minimise runoff from adjacent areas;
- Road "hump" at the top of the pit ramps; and,
- Haul road grading and drainage to direct runoff away from the pits as required.

3.4 In-Pit Runoff Volume Estimate

Even with the provision of the surface water management measures identified above some runoff will report in-pit from direct precipitation within Pit 1 and Pit 2 crests and limited runoff from adjacent minor catchment areas within the pit bunds. This rainfall-runoff will report to in-pit sump pumps before being pumped back to surface.

The proposed Pit 1 and Pit 2 crest areas of 26,215 m^2 and 23,975m^2 respectively were measured directly from the pit shells provided by STN. A 10% allowance was added to this area for the surface area between the pit crests and the adjacent pit bund. The rainfall depths for a range of 72 hour duration hydrological events of interest are as follows (refer to Rainfall IFD values in Appendix B):

- 50%AEP-72 hour duration = 46 mm;
- 20%AEP-72 hour duration = 75 mm
- 10%AEP-72 hour duration = 98 mm
- 5%AEP-72 hour duration = 125 mm
- 2%AEP-72 hour duration = 164 mm
- 1%AEP-72 hour duration = 198 mm

Applying these rainfall depths to the ultimate crest areas assuming a conservative 100% runoff factor results in the total in-pit runoff volumes shown in Table 17.

Table 17: In-Pit Runoff Volume Estimates

Rainfall Event	Pit 1 In-Pit Volume (m^3)	Pit 2 In-Pit Volume (m^3)
50%AEP-72 hour	1,326	1,213
20%AEP-72 hour	2,163	1,978
10%AEP-72 hour	2,826	2,585
5%AEP-72 hour	3,605	3,297
2%AEP-72 hour	4,729	4,325
1%AEP-72 hour	5,710	5,222

Note: 100% runoff coefficient assumed and pit crest area increased by 10% to allow for area between crest and safety bund.

3.5 Stormwater and Sediment Management Philosophy

Suitable management of runoff from more common rainfall events will also be required in order to protect project infrastructure, minimise erosion and reduce the potential loss of sediment laden or other contaminated runoff from the AHPP site. This should include the segregation of the various project facilities as follows:

- Processing Area;
- Mine Yard/Laydown Area.
- Hazardous Material Storage Areas.
- Disturbed Mine Areas.
- Undisturbed Mine Areas.

3.5.1 Processing Area

Rain falling within wet processing areas (outside of the Heap Leach Pad and Solution Ponds) will be collected within bunded areas and returned to the process. Provision should be made for the return of such flows to the process by means of drains, launders, sumps, pumps etc. Alternatively such water may be used for dust suppression within the process area if of acceptable quality.

3.5.2 Mine Yard/Laydown Area

The Mine Yard/Laydown area should comprise surface water runoff and wash down water drainage and recovery systems. Rainfall runoff from the Mine Yard/Laydown area including roads, building roofs, laydown yards etc. should be captured in open drains, prior to pumping to a water management pond for re-use.

Mine Yard/Laydown area drains should be sized for the peak of the 10% AEP event as a minimum with a freeboard of at least 250 mm. Flow velocities along such drains should be limited to minimise erosion and the generation of sediment.

3.5.3 Disturbed Areas

Outside the Processing and Mine Yard/Laydown areas the proposed facilities will comprise the open pits, ROM pad, WRD, access and haul roads and various stockpiles. Source controls should be used to improve the quality of runoff from these facilities. Runoff from these facilities should be directed to a water management pond prior to re-use.

For runoff within the proposed open pits, source controls should comprise practices such as mining from upper benches or processing stockpiled material following significant rainfall events. In-pit sumps should be used to settle out sediment from collected runoff prior to pumping to surface for re-use.

3.5.4 Undisturbed Areas

Run-off from undisturbed areas within the project boundaries should be diverted around proposed project facilities into existing natural watercourses or drainage lines by providing diversion drains typically sized for the 10% AEP event with a minimum 250 mm freeboard. Flow velocities along all diversion drains should be limited to minimise erosion and the generation of sediment.

Where active mining and processing areas or other sensitive facilities require protection from runoff from undisturbed areas the 1% AEP event should typically be used for the design of flood protection bunds.

3.6 Drainage and Sediment Control Design Criteria

The following design criteria will be applied to drainage measures for the project facilities:

3.6.1 Peak Flow Estimation

Peak discharges from catchment areas of less than 10 hectares will be estimated using the Rational Method (i.e. Q = CIA). The average run-off coefficient (C) will be based on the values presented in Table 18.

Table 18: Run-off Coefficients

Catchment Type	Run-off Coefficient
Undisturbed areas	0.20
Gravel roads and yard areas	0.50
Asphalt, concrete and roof areas	0.90

Rainfall intensity (I) for the event duration will be interpolated from the rainfall Intensity Duration Frequency (IDF) relationship developed for the AHPP provided in Appendix B. The time of concentration of each catchment area will be determined in accordance with the Kirpich Equation as follows:

$T_c = 0.00032 \times L^{0.77} \div S^{0.385}$

Where:

T_c = Time of concentration (hours).
L = Maximum length of water travel (m).
S = Average Slope (m/m).

The minimum time of concentration to be used for design purposes will be 5 minutes. Catchment areas (A) will either be measured directly in the field or calculated using CAD tools and the latest field survey data.

Peak discharge estimates from areas larger than 10 hectares will be obtained by using hydrologic modelling methods such as those presented in ARR19.

3.6.2 Channel Design

Channel design parameters will be determined using Manning's Equation as follows:

$Q = (A\ R^{2/3}\ S^{1/2})/n$

Where:

Q = flow rate (m^3/sec).
A = cross-sectional area of channel (m^2).
n = roughness coefficient, as per values presented below (dimensionless).
R = hydraulic radius, i.e. cross-sectional area, A, divided by wetted perimeter, P (m)
S = channel slope (m/m).

Roughness coefficients will be based on the values presented in Table 19 below:

Table 19: Roughness Coefficients

Channel Type	Roughness Coefficient
Unlined Earth, Clean, recently completed	0.016-0.018
Unlined Earth, With short grass, few weeds	0.022-0.027
Unlined Rock, Smooth and uniform	0.035-0.040
Unlined Rock, Jagged and irregular	0.040-0.045
Lined, Formed concrete	0.017-0.020
Lined, Random stone mortar	0.020-0.023
Lined, Dry rubble (rip-rap)	0.023-0.033

3.6.3 Drainage Design

Open Drain Construction

Open drain construction will be based upon the following criteria:

- Minimum self-cleansing velocity of 0.7 m/sec for a 50% AEP event;
- Maximum velocity of 1.0 m/sec for a 10% AEP event for unlined earth channels with no specific erosion protection;
- Minimum 250 mm freeboard on open drains; and,
- Channel erosion control protection in the form of appropriate drop structures, rock check dams, rock-lined channels or concrete lined channels.

Culvert Installation

The minimum culvert diameter will be 450 mm. Culverts and underground stormwater pipes will be installed at slopes that provide self-cleansing minimum velocities of 0.7 m/s for one-third depth of full-flow wherever possible.

Hardstand Area Drainage

Hardstand area drainage will be designed with a minimum surface grade of 0.5% in open yard areas and a minimum grade of 2% for a distance of 25 m away from structures. Hardstand areas with finished elevations 1 m or greater above natural surface elevations will have a safety bund constructed along their outside edge. Suitably spaced breaks will be placed along the bund to allow runoff to escape. Rock or geomembrane lined slope drains will be constructed at these breaks to minimise erosion of fill material.

3.6.4 Water Management/Sedimentation Pond Design

For preliminary design purposes water management/sedimentation ponds will be designed to store runoff from the 10% AEP-24-hour rainfall event i.e. 74 mm rainfall, without discharge.

The detailed design of sedimentation ponds will be based on removing the settleable fraction down to a selected minimum design particle size based on an analysis of the sediment particle size distribution reporting to the pond. The adopted design particle size will correspond to 25% of the sample passing by weight or an absolute minimum particle size of 20 micron (unless chemical coagulant dosing is used). The required pond surface area will be estimated using the peak inflow rate and design particle settling velocity according to Stokes Law and applying published sedimentation efficiency factors[7].

Sedimentation ponds will have a minimum live settling depth of 1 m and an aspect ratio (length: width) of not less than 3:1 and preferably 5:1. Sufficient provision for dead (sediment) storage and freeboard will also be made.

3.6.5 Oily Water Separator Design

All potentially hydrocarbon impacted water from wash-down and re-fueling facilities will be directed to a suitable gravity type OWS prior to collection and re-use.

[7] *The Constructed Wetlands Manual (Vols 1 & 2)*, Dept of Land and Water Conservation, NSW, 1998.

4.0 PRELIMINARY ENGINEERING DESIGN

The preliminary design of the surface water management measures is described in the following sections and shown on the accompanying figures. The layout of the measures has been based on the project topographic data and aerial imagery and the mine landform design shapes provided by STN on 20 June 2024.

4.1 Raised Pit 1 to ROM Haul Road

As discussed earlier, the AHPP site is located immediately adjacent to the Lake Raeside paleodrainage channel which, although normally dry, can convey runoff from its large upstream catchment area following significant rainfall-runoff events. A review of satellite imagery for TC Bobby, which is considered to be the local design event, shows that the maximum flood elevation at the AHPP site is approximately 352.5 mAHD, as shown earlier in Figure 4.

Despite the fact that the proposed pits, heap leach pad or processing areas are largely situated above this elevation, it is recommended that the Pit 1 to ROM haul road is raised to a nominal minimum elevation 353.0 mAHD along its length of 732 m to prevent Lake Raeside flows reporting to the AHPP site. A plan and profile showing the preliminary design of the raised Pit 1 to ROM haul road is provided in Figure 7.

Assuming an overall haul road width of 25 m (safety bunding would be constructed within this width) and 2H:1V cut and fill sideslopes it is estimated that approximately 2,160 m^3 of cut and 16,950 m^3 of fill earthworks will be required to raise the haul road to the required elevation. Maximum cut and fill depths of some 1.3 m and 2.5 m respectively will be required. It has been assumed that the road fill can be constructed from waste rock won from the development of the nearby open pits, placed in controlled layers and traffic compacted.

In order to permit the passage of runoff from the approximately 2.7 km^2 sub-catchment area upstream of the haul road (delineated earlier) it is recommended that culverts are constructed below the proposed raised haul road at about Ch 420 m. The 10% AEP peak flow at this location was estimated earlier to be about 4.1 m^3/s and so an preliminary culvert selection of 3 No. 900 mm diameter corrugated metal pipe culverts has been made. This is based on passing 1.4 m^3/s per barrel with headwater/depth ratio of 1.5 i.e. a 1.35 m depth of water at the inlet, as shown on the design chart in Appendix E.

In order to prevent backwatering in the event of high flows along the Lake Raeside channel it is recommended that a flap gate is installed at the outlet of each of the culvert barrels. These can either be mounted on the end of the culvert pipe itself, or preferably mounted on a reinforced concrete headwall las shown in Photograph No. 9 on the following page.

A rock lined apron should be installed at the outlet from culvert crossing where it reports to the existing creekline to minimise potential erosion. For preliminary design purposes this should be approximately 12 m long and flare out from 7 to 15 m wide. It should be lined with a 1,250 mm thick layer of broken rock (riprap) with a median rock size (D_{50}) of 700 mm and a maximum rock size (D100) of 1,050 mm. The riprap should be manufactured from fresh (non-PAF), hard, angular rock and installed over a heavy-duty non-woven geotextile layer.

Photograph 9: Typical Flap Gate Installation of Reinforced Concrete Headwall



4.2 Processing Area Upstream Diversion

In order to divert runoff from the approximately 1.2 km^2 catchment area (identified earlier) upstream of the Processing Area it will be necessary to construct an approximately 515 m long diversion channel and parallel flood bund, as shown in Figure 8. This will be offset from the southern limit of the Heap Leach Pad by about 15 m and be aligned in a southeasterly direction.

The 10% and 1% AEP peak flow estimates developed earlier for the Processing Area sub-catchment were used in the preliminary design with the diversion channel designed to pass the 10% AEP peak flow with 0.3 m freeboard and checked for the 1% AEP peak flow with zero freeboard. A 2.0 m minimum high diversion bund should be constructed along the downstream side of the channel to provide protection for events of greater magnitude.

The preliminary design parameters for the modified Processing Area Diversion have been summarised in Table 20 (channel sizing calculations have been provided in Appendix E). Preliminary earthworks modelling indicates that in the order of 4,000 m^3 of cut will be required for the channel and approximately 7,200 m^3 of fill will be required for the bund.

The diversion bund should not be constructed by end dumping of waste materials in piles, but instead the bund footprint should be cleared and should be built from select clayey-oxide waste (300 mm maximum size) material placed and compacted in layers (500 mm maximum thickness) and dozer-compacted. The bund should have 2H:1V sideslopes and a 3 m crest.

Table 20: Processing Area Upstream Diversion Preliminary Design Parameters

Design Parameter	Units	Value
Length	m	515
Average Gradient[1]	%	0.20
Base Width	m	4.0
Side Slopes	H:V	2H:1V
Channel Design Top Width	m	8.8
10% AEP Peak Flow	m^3/sec	2.9
10% AEP Peak Flow Depth[1]	m	0.6
1% AEP Peak Flow	m^3/sec	10.0
1% AEP Peak Flow Depth[1]	m	1.2
Minimum Bund Height	m	2.0
Minimum Bund Crest Width	m	3.0
Minimum Bund Base Width	m	11.0

Notes 1: Hydraulic design assumes Manning Roughness "n" = 0.030.

4.3 Surface Water Management Ancillary Works

In addition to the measures outlined above, the following ancillary works will also be required:

- *Mine Yard Diversion* - an approximately 435 m long diversion channel should be constructed along the southern limit of the proposed Mine Yard to direct runoff from the upstream catchment area to the west of the proposed facility. In order to pass the peak 10%AEP flow of 1.7 m^3/s with 250 mm freeboard a dozer cut channel with a 3 m base width, 0.75 m depth and 2H:1V sideslopes should be sufficient assuming a 0.20% gradient and Manning's roughness of 0.030 (refer to channel sizing calculation in Appendix E).
- *Magazine Diversion* - an approximately 150 m long diversion channel should be constructed along the southwestern limit of the proposed Magazine to direct runoff from the upstream catchment area to the west of the proposed facility. In order to pass the peak 10%AEP flow of 1.1 m^3/s with 250 mm freeboard a dozer cut channel with a 3 m base width, 0.65 m depth and 2H:1V sideslopes should be sufficient assuming a 0.20% gradient and Manning's roughness of 0.030 (refer to channel sizing calculation in Appendix E).

A rock (riprap) lined apron should be installed at the outlet from both the Mine Yard and Magazine diversions in order to minimise potential erosion of the drainage line downstream.

5.0 CLOSING REMARKS

A desktop study was completed to develop hydro-meteorological information that was then used in the preliminary design of surface water management measures at the proposed Apollo Hill Pilot Project.

The fact that the key project facilities are largely situated above the TC Bobby design event maximum flood elevation (~352.5 mAHD) and the upstream catchment area is fairly modest (6.0 km^2) the resulting surface water management measures at the proposed AHPP site are relatively limited.

Key measures will comprise the following:

- Approximately 732 m long raised Pit 1 to ROM haul road raised to a nominal minimum elevation 353.0 mAHD and requiring in the order of 2,160 m^3 of cut and 16,950 m^3 of fill for a 28 m wide road with 2H:1V sideslopes. Culverts should be constructed below the proposed raised haul road in order to permit the passage of runoff from the upstream catchment area. In order to pass the 10% AEP peak flow 3 No. 900 mm diameter corrugated metal pipe culverts should be used with flap gates installed at the outlet of each of the culvert barrels to prevent backwatering in the event of high flows along the Lake Raeside.
- Approximately 515 m long diversion channel and parallel flood bund which will divert runoff from the upstream sub-catchment area around the proposed Processing Area. A channel with a 4 m basewidth, 1.2 m depth and 2H:1V sideslopes will be required to pass the 1% AEP peak flow.
- Approximately 435 m and 150 m long lengths of diversion channel for the proposed Mine Yard and Magazine respectively. A 3 m basewidth dozer cut channel with 2H:1V sideslopes will suffice in both cases cut to depths of 0.75 m for the Mine Yard and 0.65 m for the Magazine in order to pass the 10% AEP peak flow.

We trust that this report satisfies STN's current requirements and we look forward to discussing the future development of the project with you.

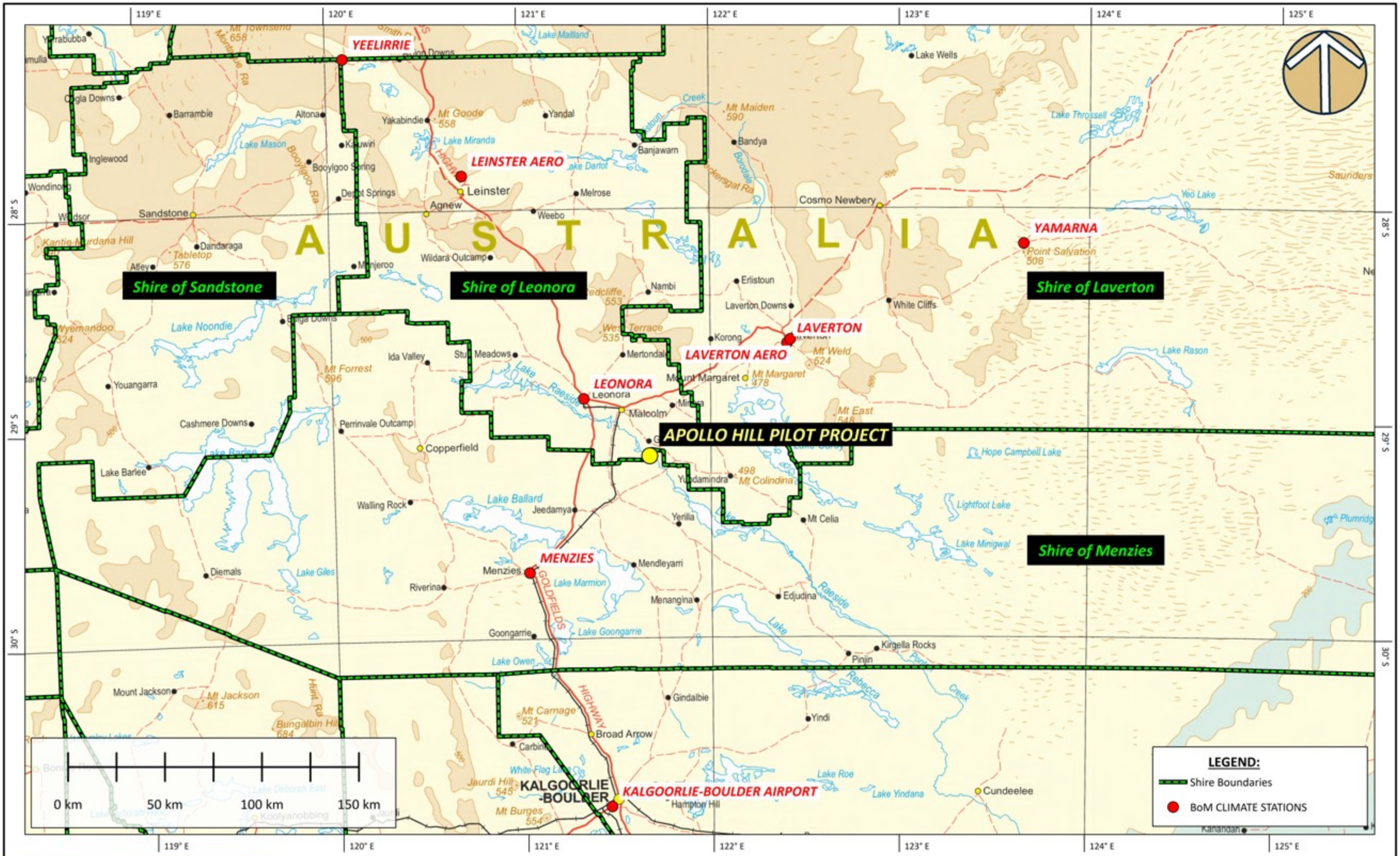
Carrick Consulting (WA) Pty Ltd



Alistair R. Lowry MSc, MIEAust, CPEng

Civil Engineering Hydrologist

C:\\2209 - SATURN APOLLO HILL\04 REPORTING\J2209-R01 SATURN METALS APOLLO HILL SURFACE WATER MANGT FINAL 240731.DOCX



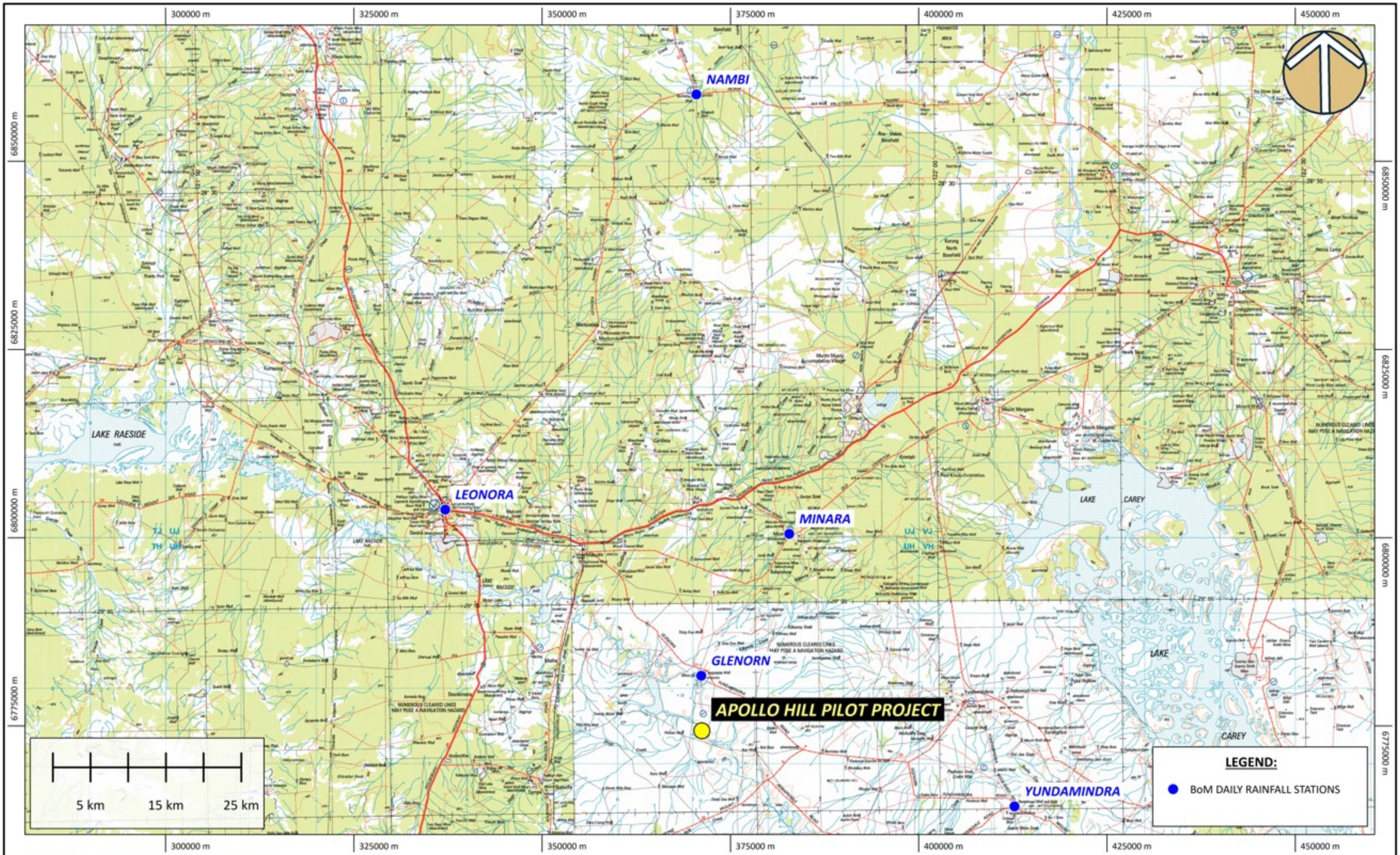
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FIGURE 1
APOLLO HILL PILOT PROJECT
LOCATION PLAN WITH
REGIONAL BoM CLIMATE STATIONS

Date: June 2024
Client: Saturn Metals Ltd
Project: Apollo Hill Pilot Project
Document: J2209R01

Notes
1. Figure scale = 1:1,750,000 @ A3.
2. Coordinates to WGS84/Lat-Lon.

Sources
1. Climate stations from BoM www.bom.gov.au/climate/data/
2. Topo mapping Geoscience Australia https://ecat.ga.gov.au/geonetwork



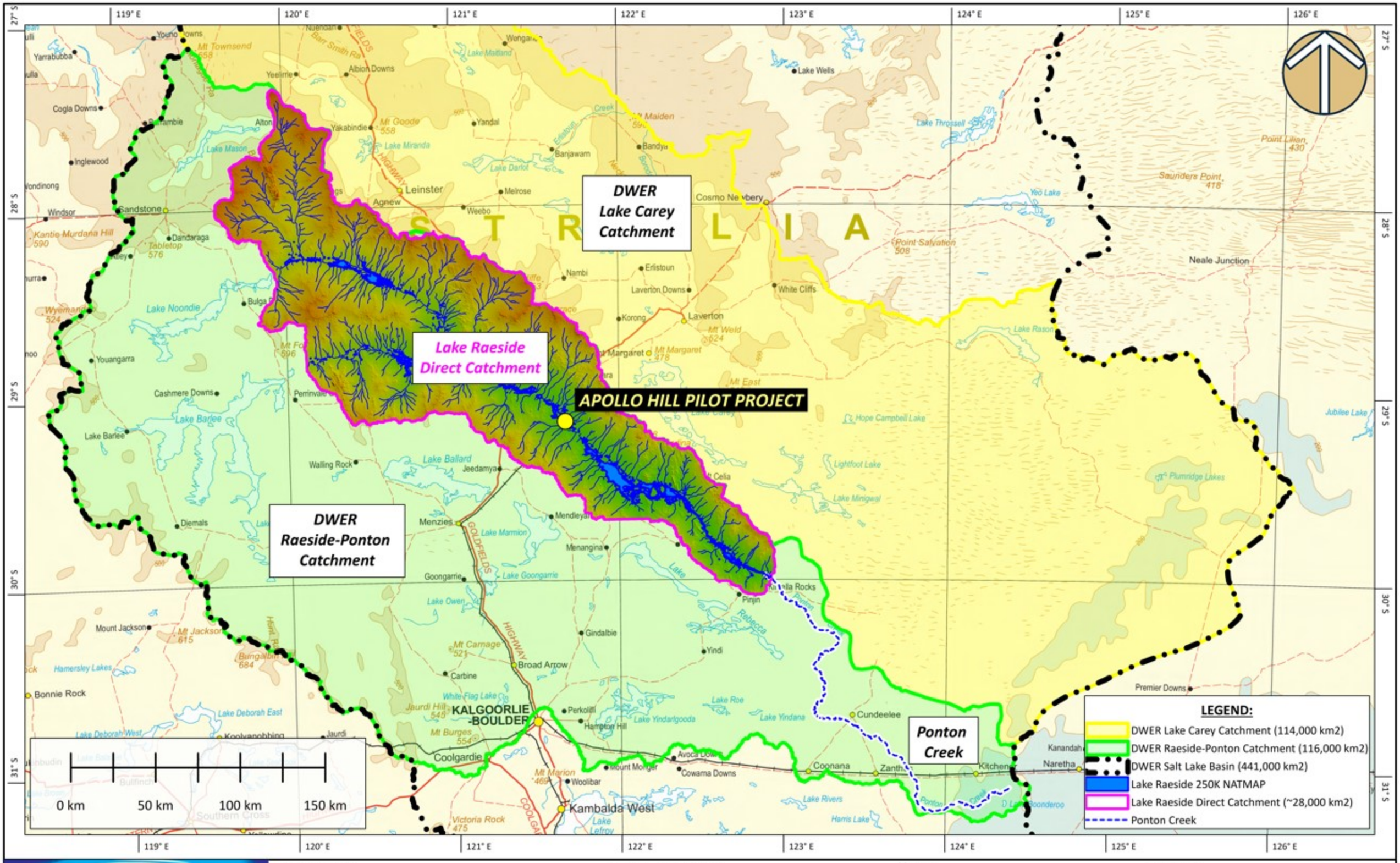
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FIGURE 2
APOLLO HILL PILOT PROJECT
LOCATION PLAN WITH
LOCAL BoM RAINFALL STATIONS

Date: June 2024
Client: Saturn Metals Ltd
Project: Apollo Hill Pilot Project
Document: J2209R01

Notes
1. Figure scale = 1:450,000 @ A3.
2. Coordinates to GDA94-MGA51.

Sources
1. Climate stations from BoM www.bom.gov.au/climate/data/
2. Topo mapping Geoscience Australia https://ecat.ga.gov.au/geonetwork



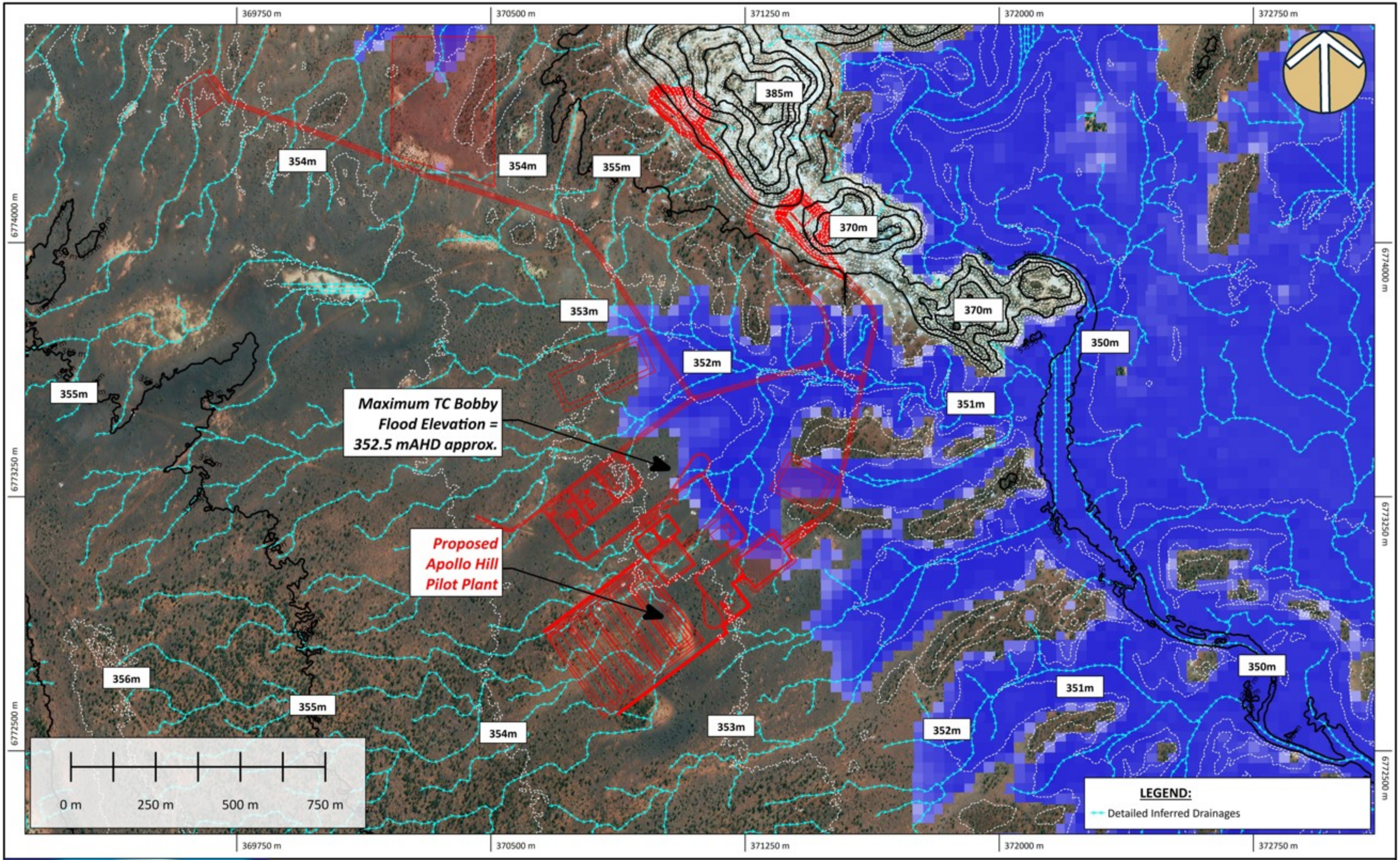
CARRICK CONSULTING (WA) PTY LTD

FIGURE 3
APOLLO HILL PILOT PROJECT
LOCATION PLAN WITH
REGIONAL CATCHMENT DELINEATION

Date: June 2024
Client: Saturn Metals Ltd
Project: Apollo Hill Pilot Project
Document: J2209R01

Notes
1. Figure scale = 1:2,000,000 @ A3.
2. Coordinates to WGS84/Lat-Lon.

Sources
1. Topo mapping Geoscience Australia https://ecat.ga.gov.au/geonetwork



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FIGURE 4
APOLLO HILL PILOT PROJECT
TROPICAL CYCLONE BOBBY
(FEB/MAR 1995) FLOOD EXTENTS

Date: June 2024
Client: Saturn Metals Ltd
Project: Apollo Hill Pilot Project
Document: J2209R01

Notes
1. Figure scale = 1:10,000 @ A3.
2. Coordinates to GDA94-MGA51.
3. Major/minor contour interval is 5m/1m.
4. Inferred drainages developed using GIS spatial analysis tools applied to client supplied DTM.

Sources
1. Aerial iamgery and topographical data from Sentinel.
2. Satellite imagery from Sentinel Hub (www.sentinel-hub.com)

368000 m | 369000 m | 370000 m | 371000 m | 372000 m | 373000 m

6775000 m

6774000 m

6773000 m

6772000 m

Magazine

Mine Services Area

Pilot Pit B

Pilot Pit A

Lake Raeside Paleodrainage Channel

Waste Rock Dump

Temporary Stockpile

Processing Offices & Facilities

ROM

Process & Water Storage Ponds

Crushing & Conveying Plant

Heap Leach Pad

0 m | 500 m | 1000 m

LEGEND:

- Central Catchment (1.316 km2)
- Northern Catchment (0.825 km2)
- Southern Catchment (3.864 km2)
- Detailed Inferred Drainages

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FIGURE 5
APOLLO HILL PILOT PROJECT
LOCAL CATCHMENT DELINEATION

Date: June 2024
Client: Saturn Metals Ltd
Project: Apollo Hill Pilot Project
Document: J2209R01

Notes
1. Figure scale = 1:15,000 @ A3.
2. Coordinates to GDA94-MGA51.
3. Major/minor contour interval is 5m/1m.
4. Inferred drainages developed using GIS spatial analysis tools applied to client supplied DTM.

Sources
1. Aerial iamgery and topographical data from Sentinel.

368000 m
369000 m
370000 m
371000 m
372000 m
373000 m
6775000 m
6774000 m
6773000 m
6772000 m
Magazine
Mine Services Area
Pilot Pit 1
Pilot Pit 2
Waste Rock Dump
Temporary Stockpile
Processing Offices & Facilities
Process & Water Storage Ponds
ROM
Crushing & Conveying Plant
Heap Leach Pad
Lake Raeside Paleodrainage Channel
0 m
500 m
1000 m
LEGEND:
Haul Road Crossing Sub-Catchment (2.715 km2)
Magazine Sub-Catchment (0.246 km2)
Mine Yard Sub-Catchment (0.568 km2)
Processing Area Sub-Catchment (1.149 km2)
Detailed Inferred Drainages

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FIGURE 6
APOLLO HILL PILOT PROJECT
MINE FACILITY
UPSTREAM CATCHMENT AREAS

Date: June 2024
Client: Saturn Metals Ltd
Project: Apollo Hill Pilot Project
Document: J2209R01

Notes
1. Figure scale = 1:15,000 @ A3.
2. Coordinates to GDA94-MGA51.
3. Major/minor contour interval is 5m/1m.
4. Inferred drainages developed using GIS spatial analysis tools applied to client supplied DTM.

Sources
1. Aerial iamgery and topographical data from Sentinel.

371250 m

ROM

Temporary Stockpile

PIT A

3 No. 900 mm Dia. CMP
Culverts with Flap Gates

CH 0m
CH 100m
CH 200m
CH 300m
CH 400m
CH 500m
CH 600m
CH 700m
CH 732.8m

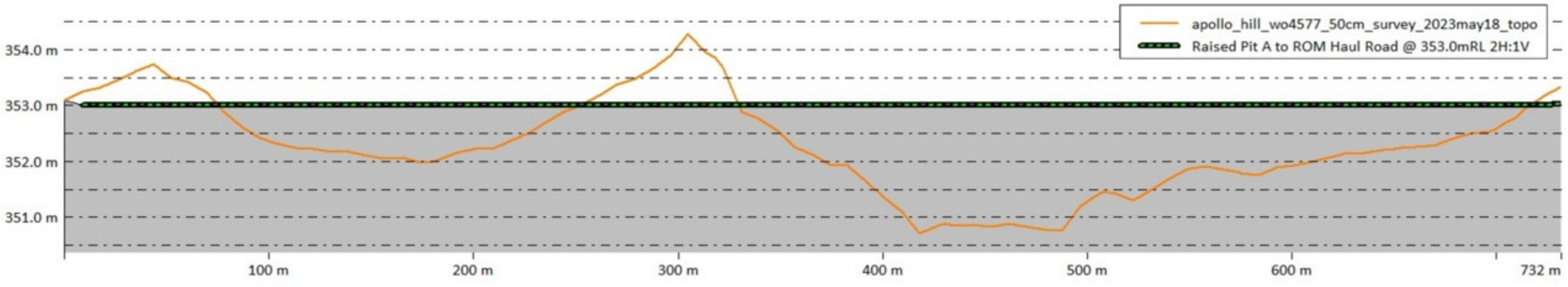
PIT A to ROM Haul Road
Raised to 353.0mAHD Min. Elev.

25 m 75 m 125 m 175 m

6773000 m

6774000 m

371750 m



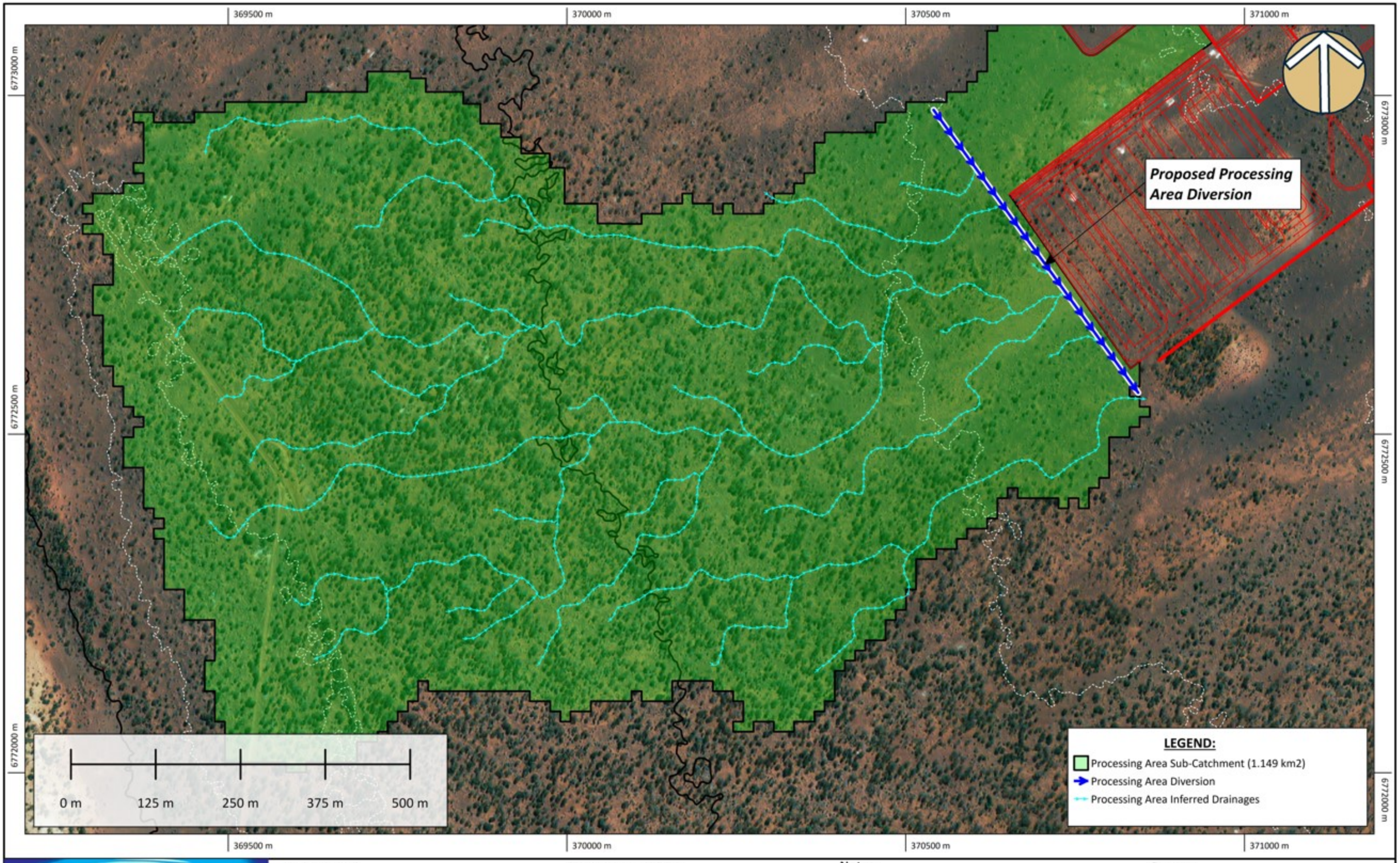
CARRICK CONSULTING (WA) PTY LTD

FIGURE 7
APOLLO HILL PILOT PROJECT
RAISED PIT A TO ROM HAUL ROAD
PRELIMINARY DESIGN
PLAN & PROFILE

Date: June 2024
Client: Saturn Metals Ltd
Project: Apollo Hill Pilot Project
Document: J2209R01

Notes
1. Figure scale = 1:2,500 @ A3.
2. Coordinates to GDA94-MGA51.
3. Major/minor contour interval is 5m/1m.

Sources
1. Aerial iamgery and topographical data from Sentinel.



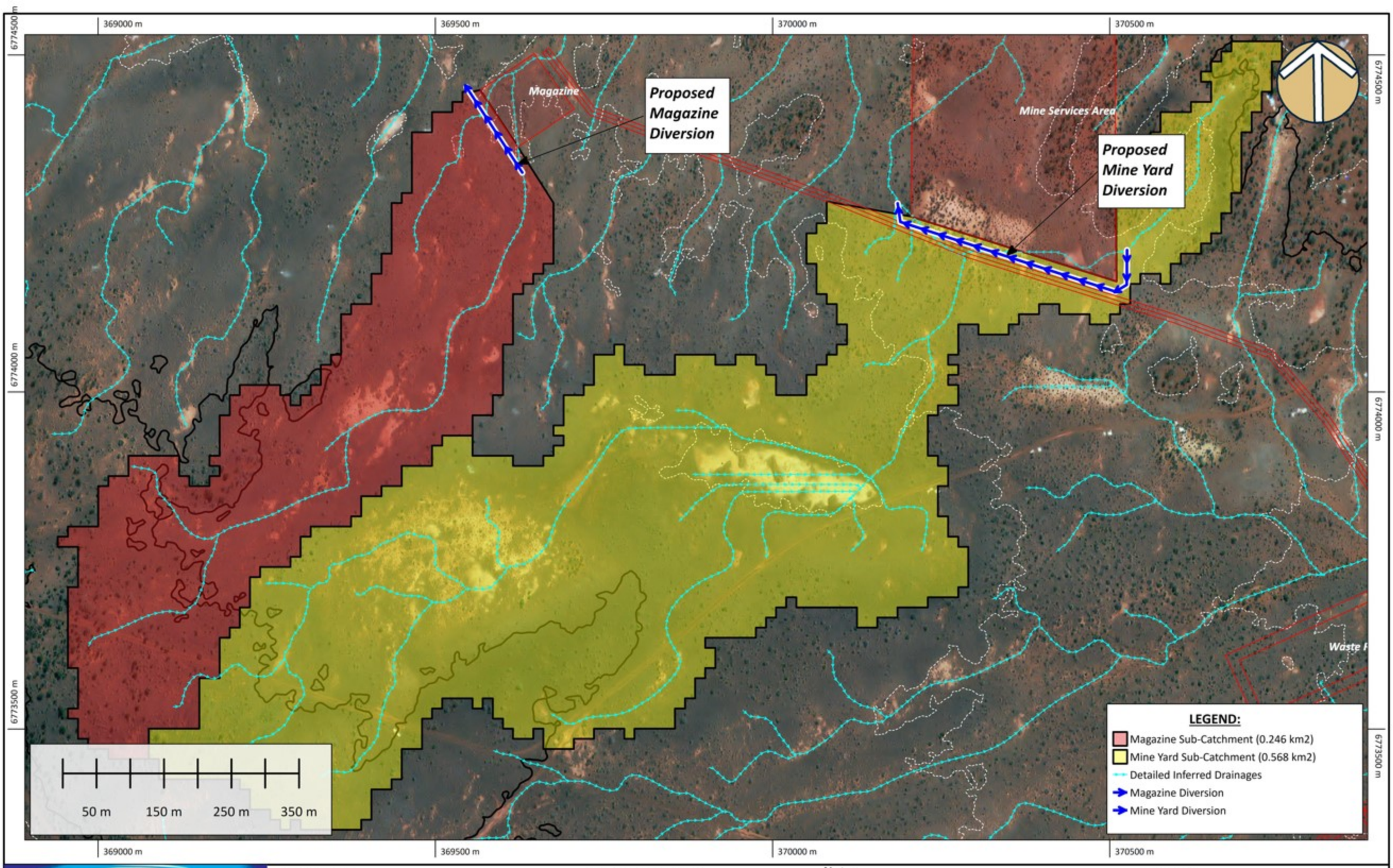
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FIGURE 8
APOLLO HILL PILOT PROJECT
PROPOSED PROCESSING AREA
UPSTREAM DIVERSION

Date: June 2024
Client: Saturn Metals Ltd
Project: Apollo Hill Pilot Project
Document: J2209R01

Notes
1. Figure scale = 1:5,000 @ A3.
2. Coordinates to GDA94-MGA51.
3. Major/minor contour interval is 5m/1m.
4. Inferred drainages developed using GIS spatial analysis tools applied to client supplied DTM.

Sources
1. Aerial imagery and topographical data from Sentinel.



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FIGURE 9
APOLLO HILL PILOT PROJECT
PROPOSED MINE YARD & MAGAZINE UPSTREAM DIVERSIONS

Date: June 2024
Client: Saturn Metals Ltd
Project: Apollo Hill Pilot Project
Document: J2209R01

Notes
1. Figure scale = 1:5,000 @ A3.
2. Coordinates to GDA94-MGA51.
3. Major/minor contour interval is 5m/1m.
4. Inferred drainages developed using GIS spatial analysis tools applied to client supplied DTM.

Sources
1. Aerial imagery and topographical data from Sentinel.

APPENDIX A

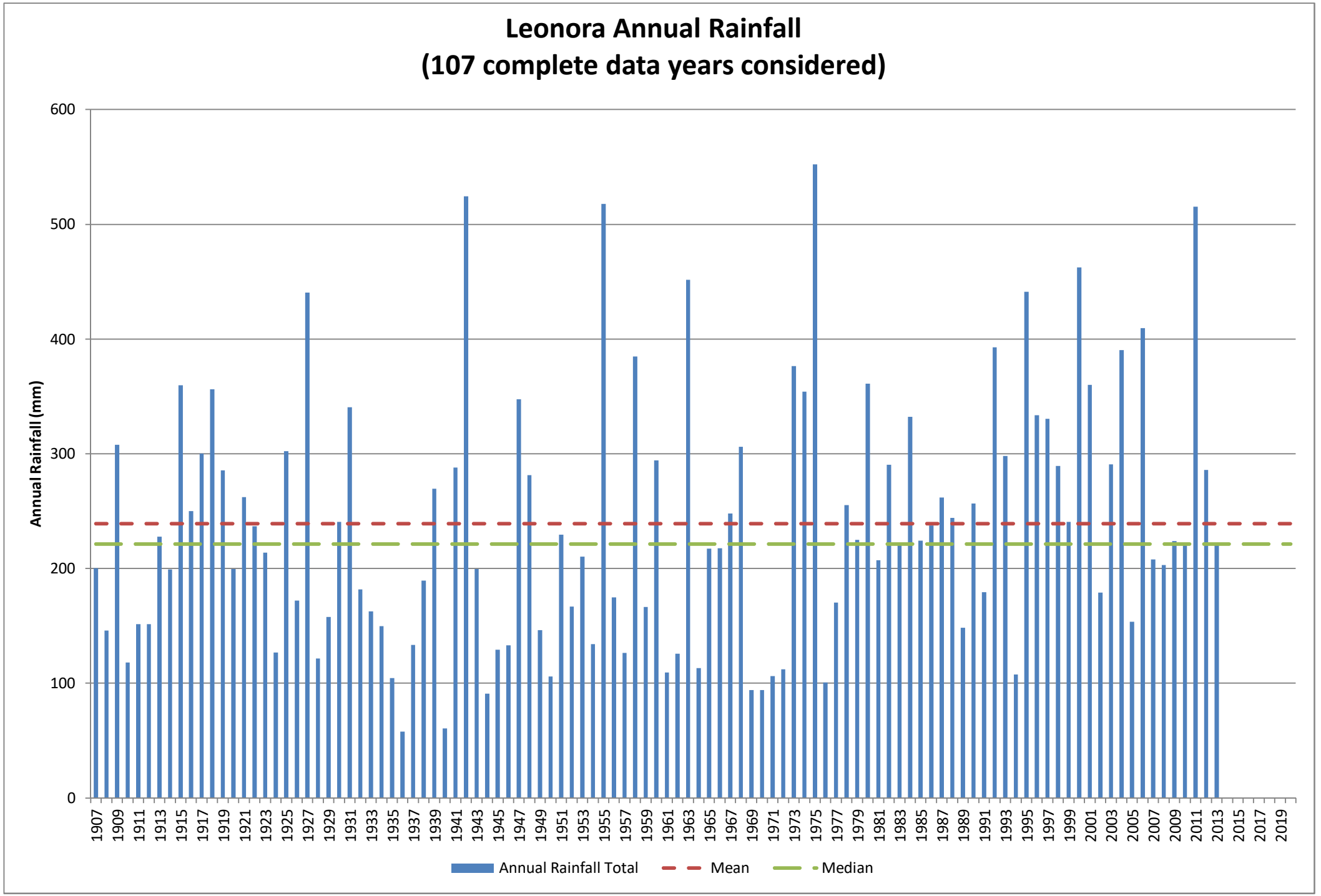
HYDRO-METEOROLOGICAL DATA

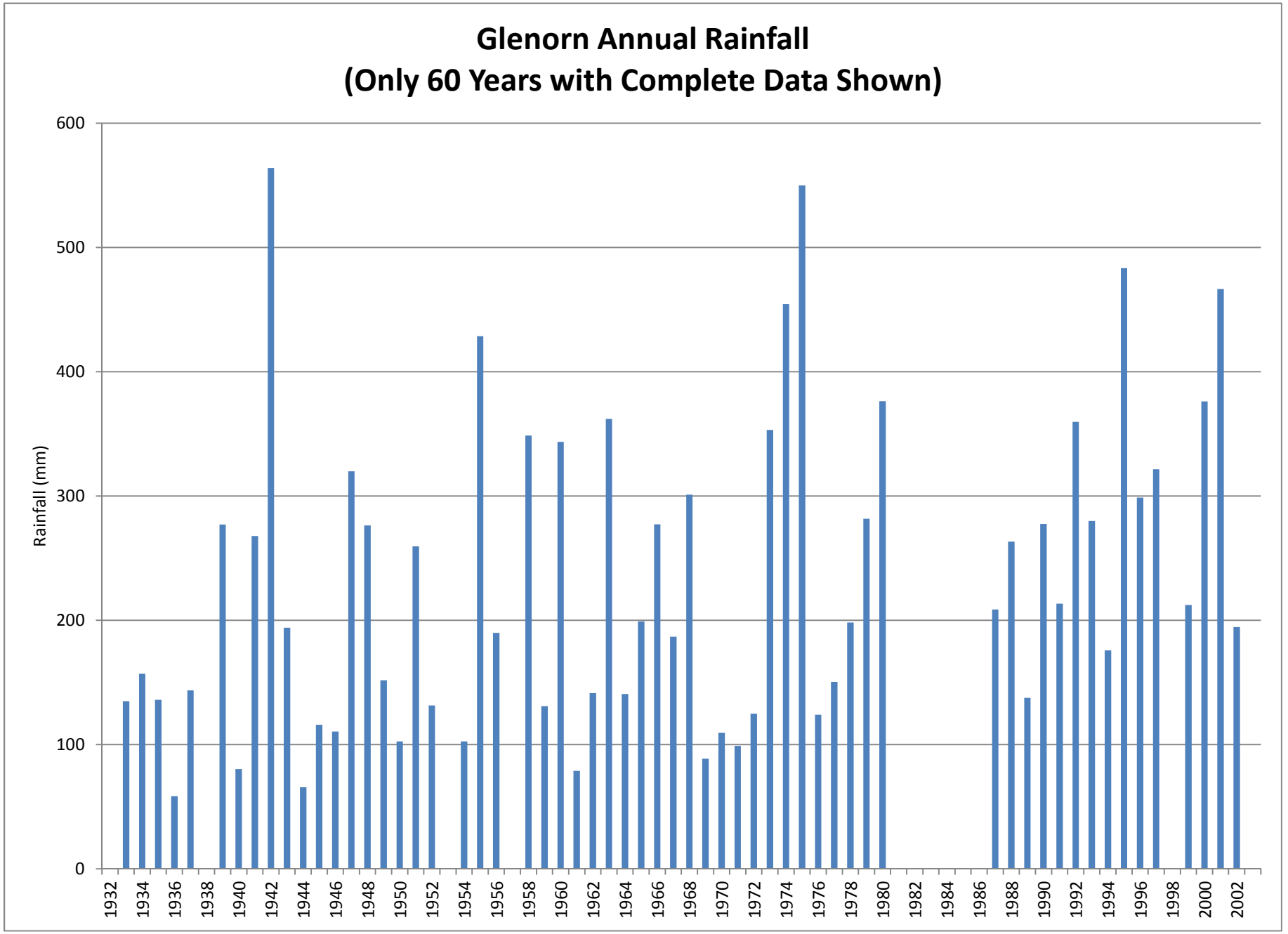
Monthly and Annual Rainfall Values
for Local Rainfall stations (all within 85 km of Apollo Hill Pilot Project Site)

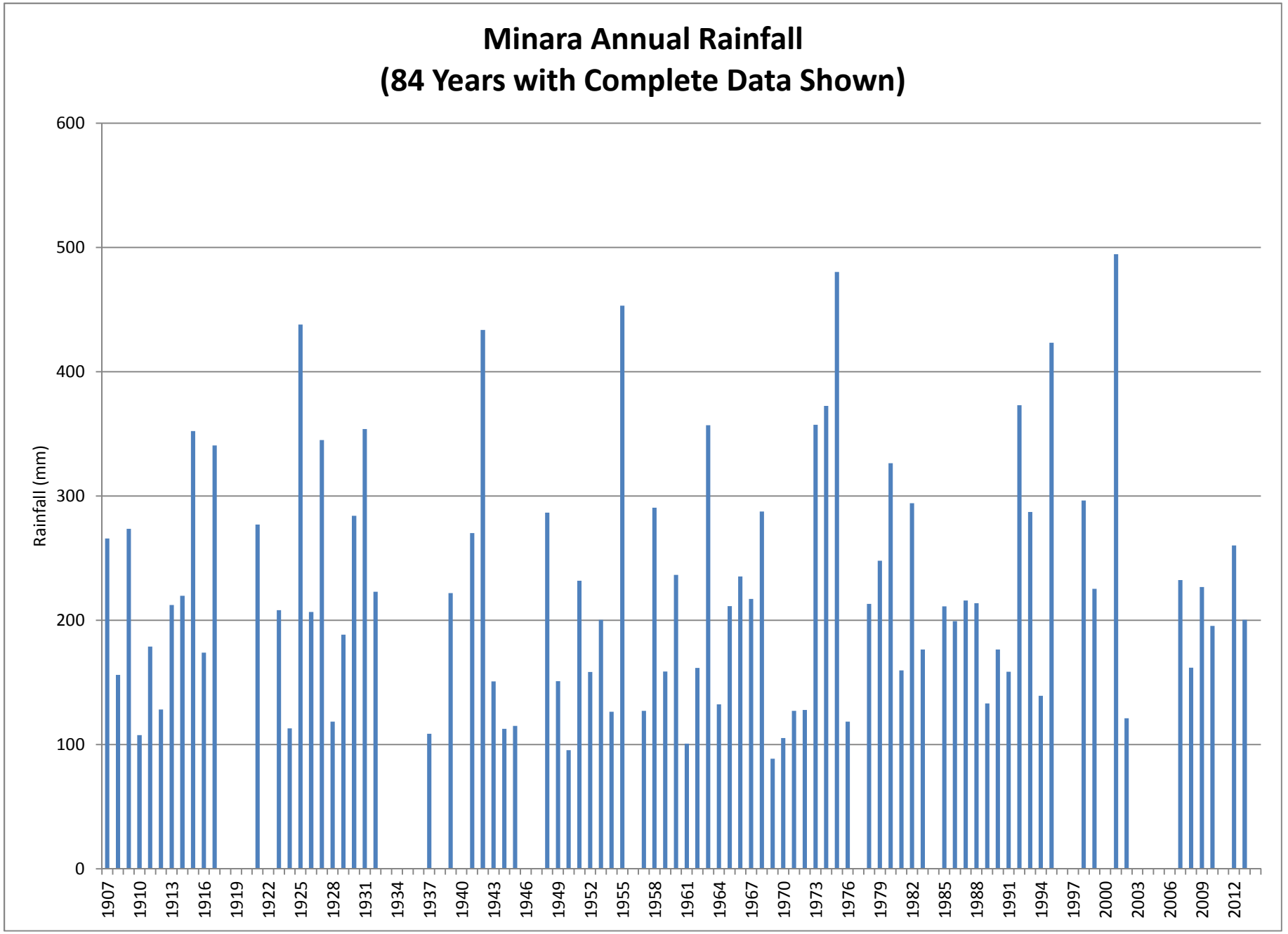
	Local BoM Rainfall Stations[1,2]																			
	Leonora				**Glenorn**				**Minara**				**Yundamindra**				**Nambi**			
	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median	Max	Min	Mean	Median
Jan	172.0	0.0	26.2	11.4	173.7	0.0	24.6	9.4	152.1	0.0	23.3	9.6	171.9	0.0	26.0	10.6	173.1	0.0	33.0	12.8
Feb	284.6	0.0	31.0	12.8	282.4	0.0	31.9	9.4	256.1	0.0	26.2	10.2	346.6	0.0	27.8	9.8	213.0	0.0	30.7	14.0
Mar	273.9	0.0	30.6	12.5	119.0	0.0	24.5	9.8	175.8	0.0	30.9	12.9	189.3	0.0	30.7	17.5	123.2	0.0	27.2	9.5
Apr	135.4	0.0	20.5	14.1	88.2	0.0	22.0	15.2	94.0	0.0	21.4	13.2	104.5	0.0	20.4	13.4	129.6	0.0	23.1	14.1
May	158.6	0.0	23.5	17.8	99.4	0.0	21.7	14.6	174.6	0.0	23.0	14.2	176.8	0.0	21.9	15.9	113.4	0.0	24.9	20.6
Jun	144.0	0.0	24.1	19.4	116.3	0.0	24.5	17.1	107.6	0.0	23.3	18.5	121.2	0.0	23.9	17.8	121.2	0.0	24.2	14.0
Jul	101.6	0.0	18.7	15.3	92.2	0.0	18.1	12.4	72.6	0.0	14.8	12.0	84.0	0.0	17.5	13.6	84.8	0.0	16.9	10.3
Aug	85.2	0.0	15.5	11.0	71.5	0.0	15.4	9.0	59.7	0.0	14.3	9.3	80.1	0.0	15.3	10.5	62.2	0.0	12.8	6.6
Sep	49.9	0.0	8.5	5.1	52.8	0.0	9.0	3.8	58.5	0.0	7.8	3.8	61.7	0.0	8.2	4.8	38.4	0.0	8.4	5.8
Oct	73.0	0.0	9.5	3.8	56.4	0.0	9.8	4.9	76.4	0.0	9.3	3.8	95.5	0.0	12.1	5.2	51.0	0.0	8.8	3.0
Nov	61.2	0.0	12.4	7.1	58.3	0.0	11.0	6.4	109.1	0.0	14.4	9.1	112.9	0.0	14.4	9.7	71.1	0.0	11.7	10.5
Dec	94.0	0.0	17.5	10.8	114.3	0.0	15.1	7.2	104.1	0.0	17.5	11.2	124.2	0.0	18.5	9.1	103.8	0.0	16.3	9.7
Max Annual	552.2				564.0				494.5				612.1				541.1			
Min Annual	57.8				58.4				88.6				72.7				57.4			
Mean Annual	239.1				232.6				225.4				236.1				229.3			
Median Annual	221.2				198.6				211.9				219.6				204.0			

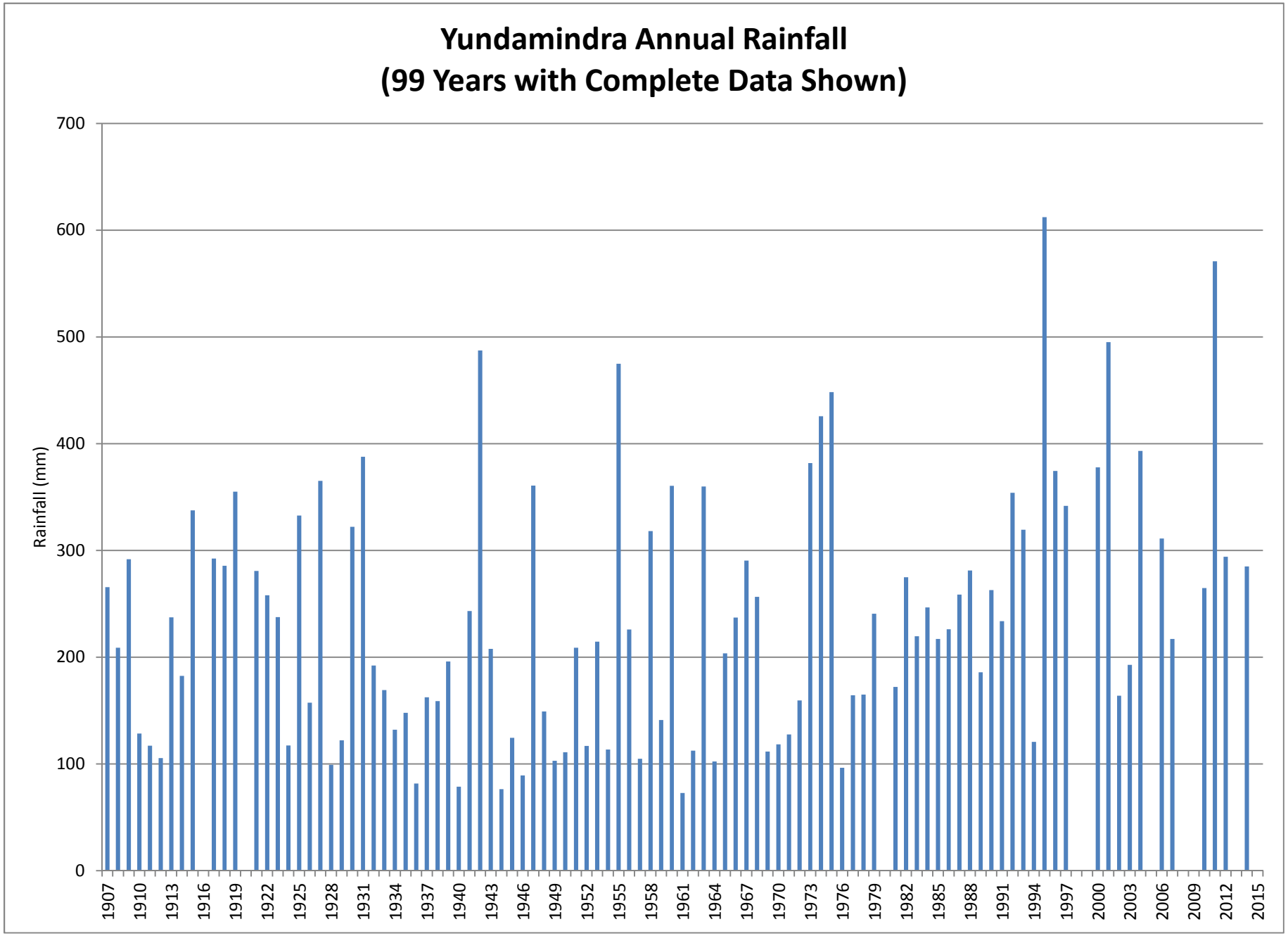
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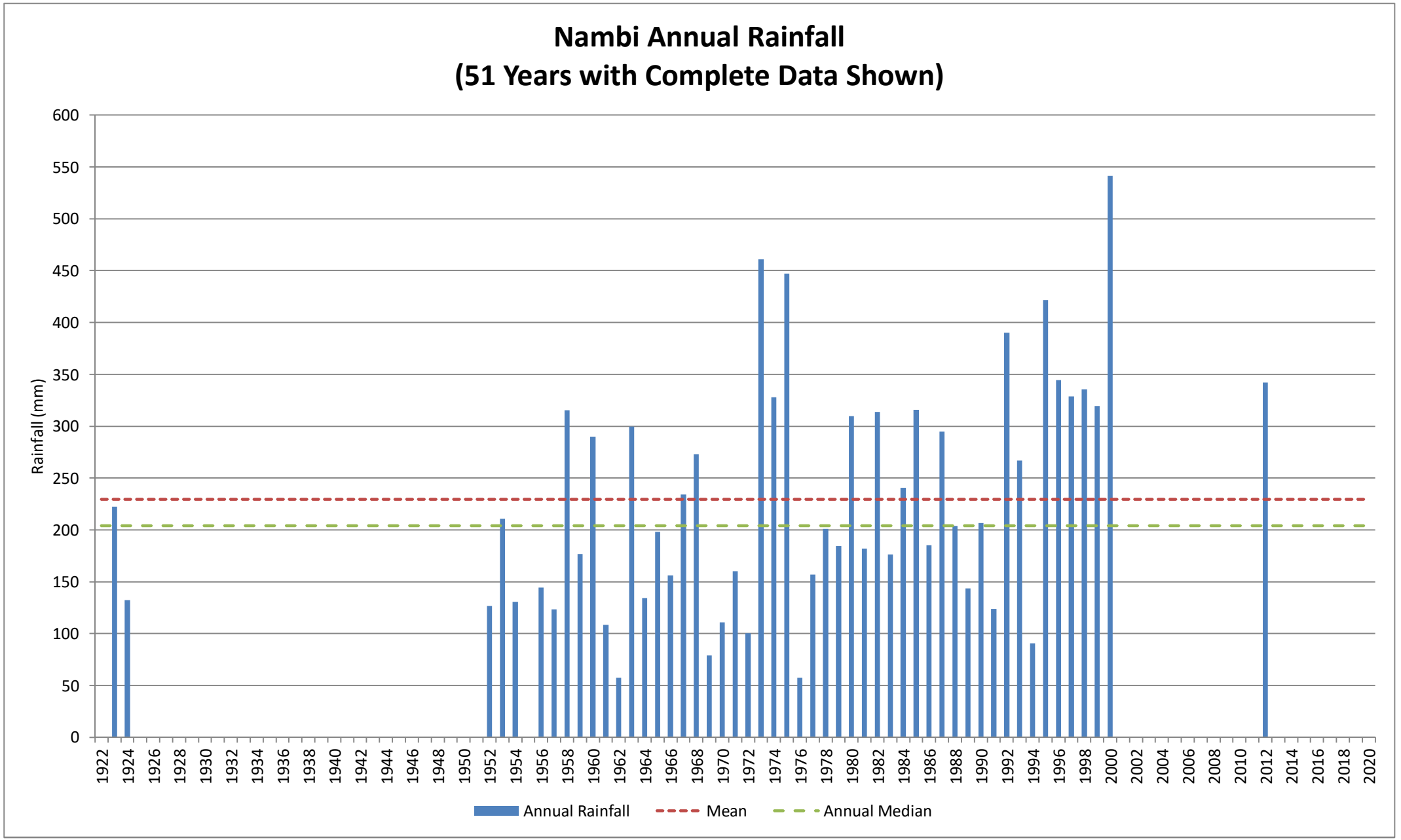
1. Monthly values based on complete months only.
2. Annual values based on complete years only.

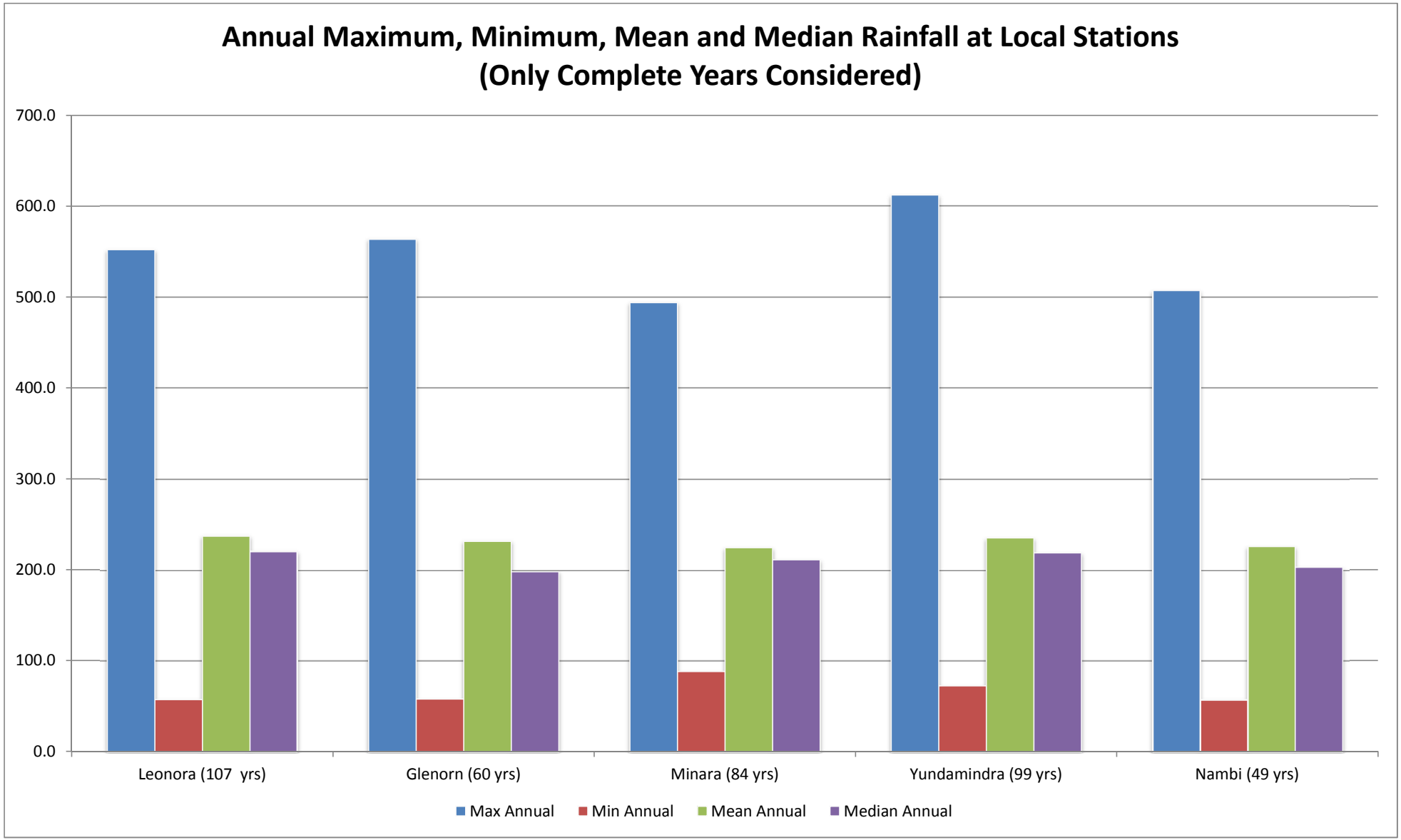

Leonora Annual Rainfall
(107 complete data years considered)
Annual Rainfall (mm)
600
500
400
300
200
100
0
1907
1909
1911
1913
1915
1917
1919
1921
1923
1925
1927
1929
1931
1933
1935
1937
1939
1941
1943
1945
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
Annual Rainfall Total
Mean
Median


Glenorn Annual Rainfall
(Only 60 Years with Complete Data Shown)
Rainfall (mm)
600
500
400
300
200
100
0
1932
1934
1936
1938
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002

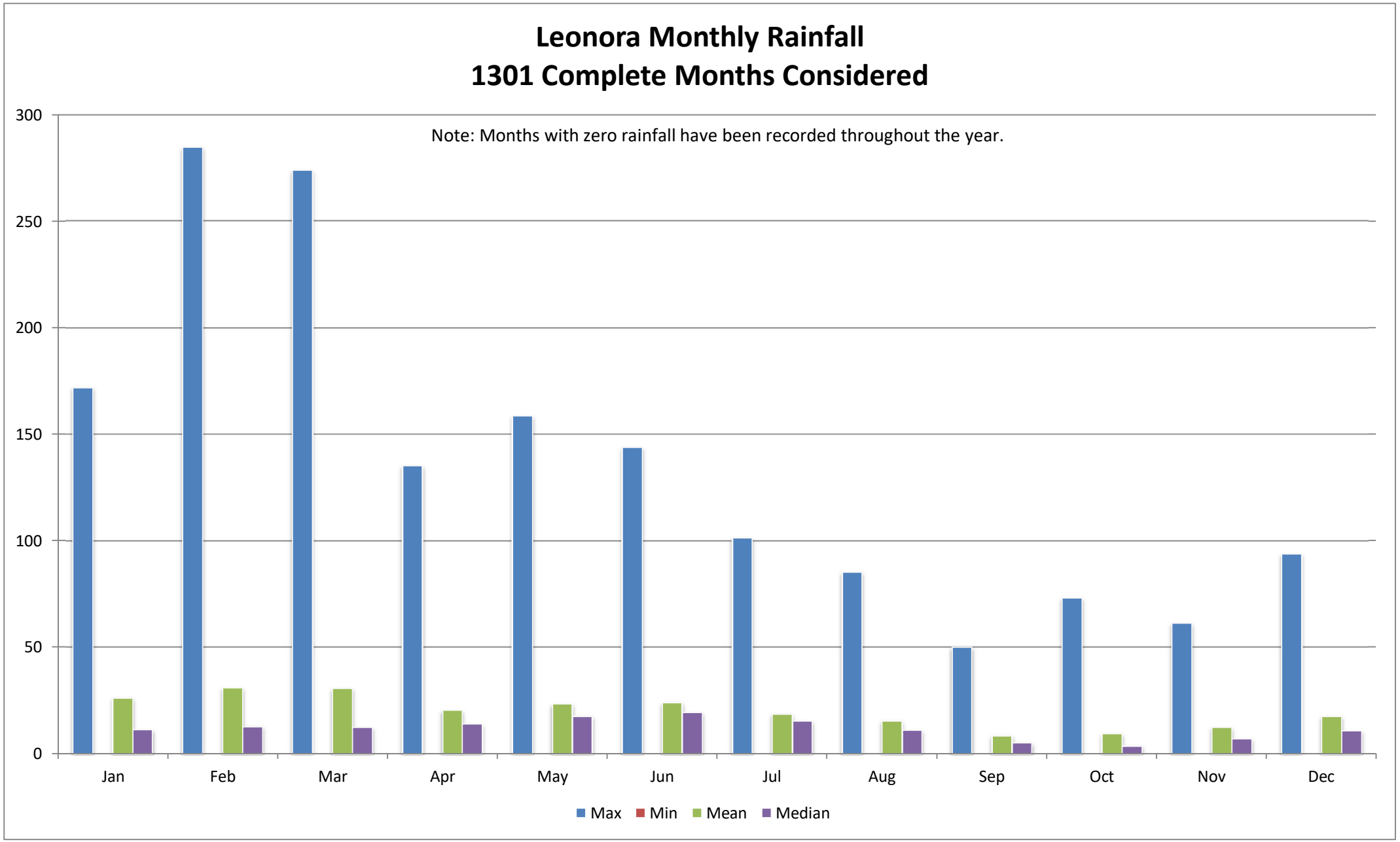

Minara Annual Rainfall
(84 Years with Complete Data Shown)
Rainfall (mm)
600
500
400
300
200
100
0
1907
1910
1913
1916
1919
1922
1925
1928
1931
1934
1937
1940
1943
1946
1949
1952
1955
1958
1961
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1997
2000
2003
2006
2009
2012

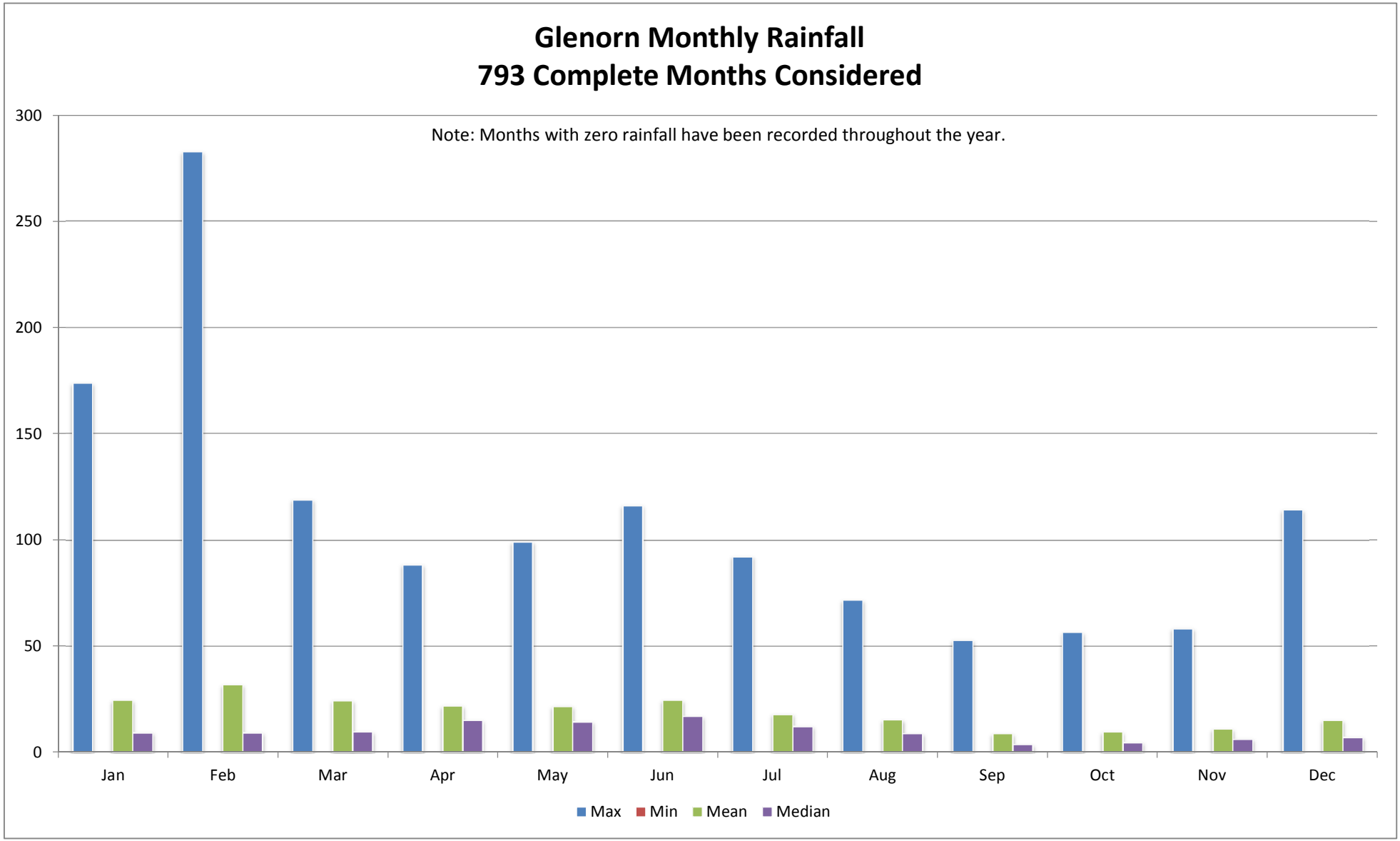

Yundamindra Annual Rainfall
(99 Years with Complete Data Shown)
Rainfall (mm)
0
100
200
300
400
500
600
700
1907
1910
1913
1916
1919
1922
1925
1928
1931
1934
1937
1940
1943
1946
1949
1952
1955
1958
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2000
2003
2006
2009
2012
2015

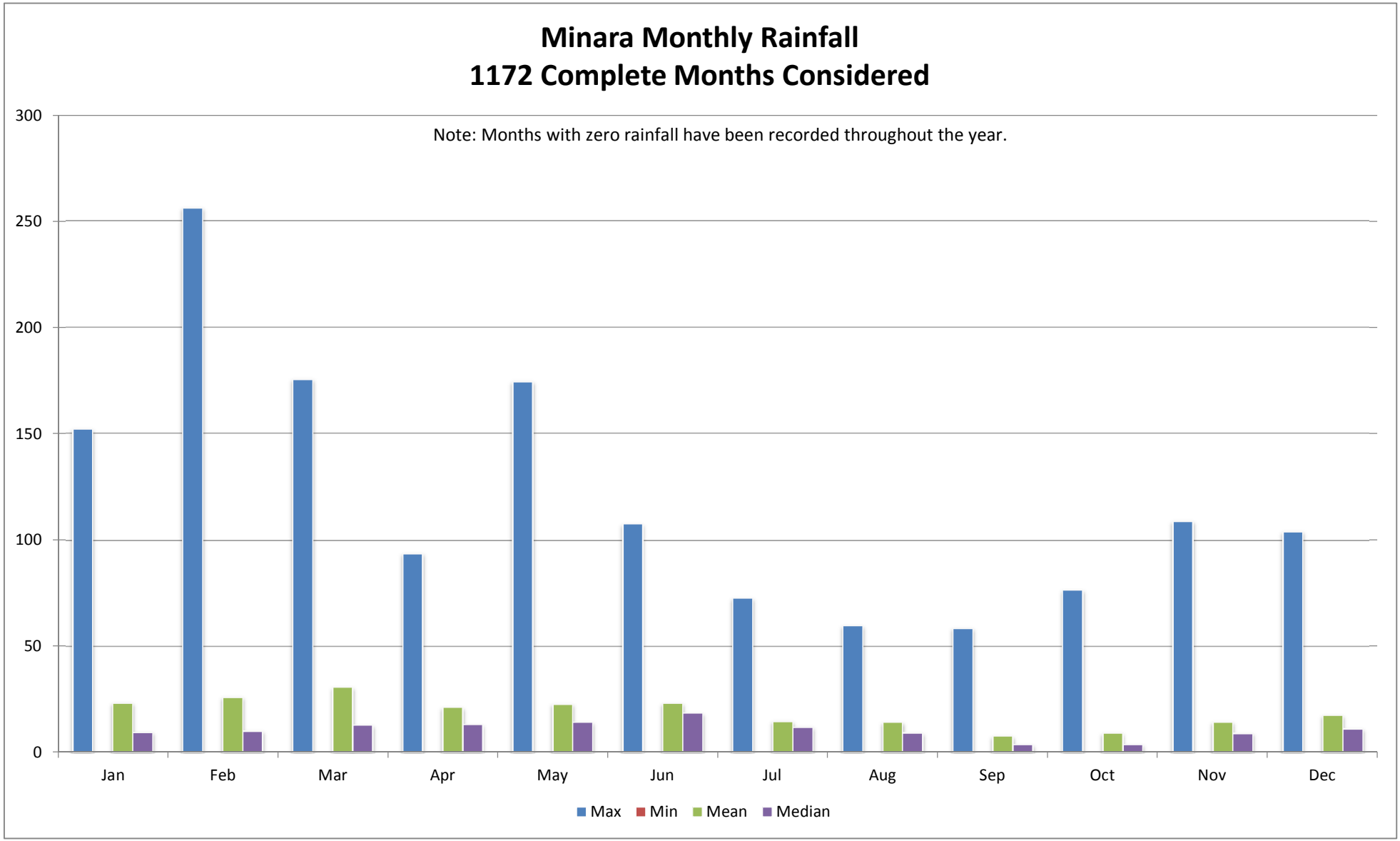

Nambi Annual Rainfall
(51 Years with Complete Data Shown)
Rainfall (mm)
600
550
500
450
400
350
300
250
200
150
100
50
0
1922
1924
1926
1928
1930
1932
1934
1936
1938
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
Annual Rainfall
Mean
Annual Median

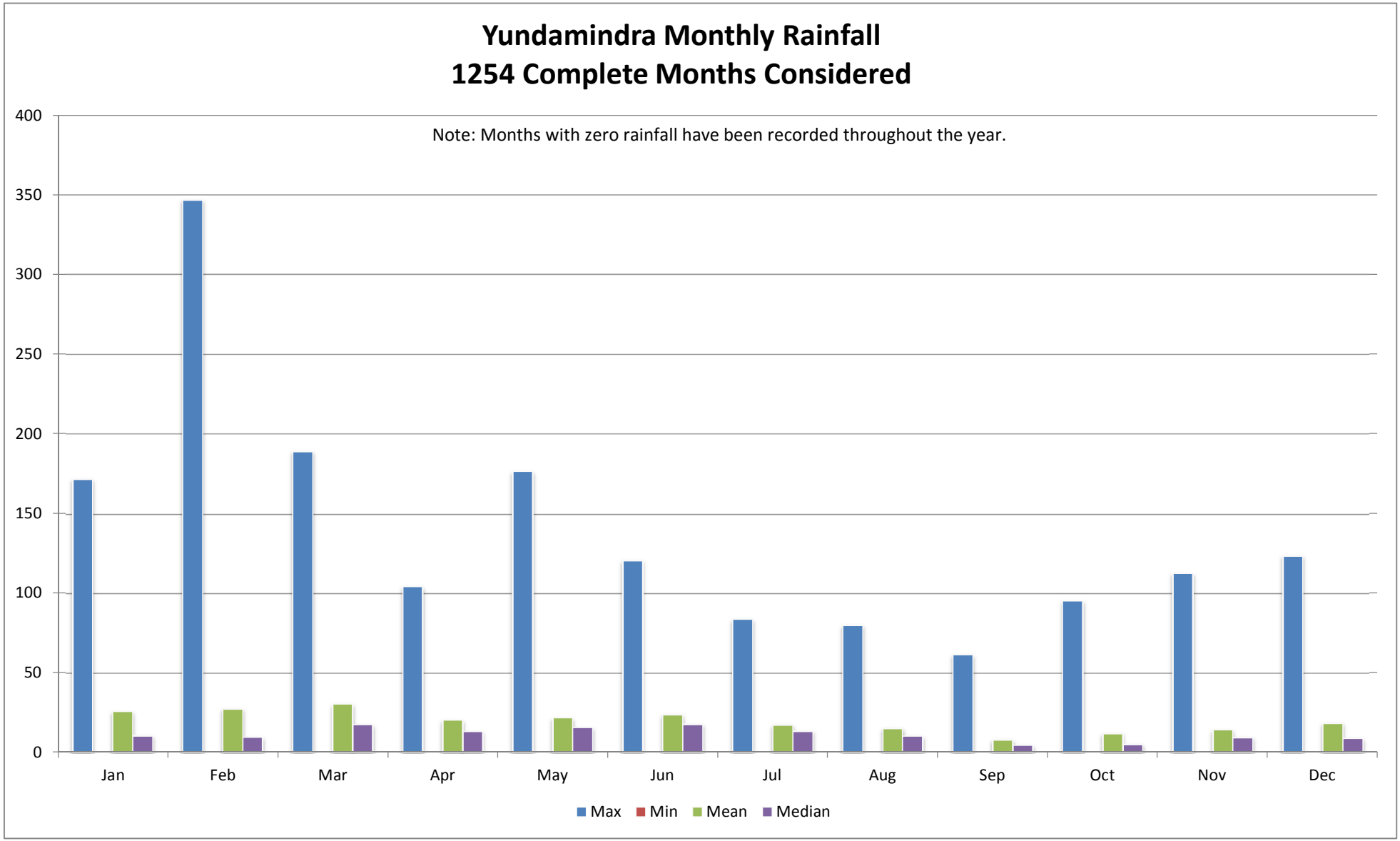

Annual Maximum, Minimum, Mean and Median Rainfall at Local Stations
(Only Complete Years Considered)
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
Leonora (107 yrs)
Glenorn (60 yrs)
Minara (84 yrs)
Yundamindra (99 yrs)
Nambi (49 yrs)
Max Annual
Min Annual
Mean Annual
Median Annual

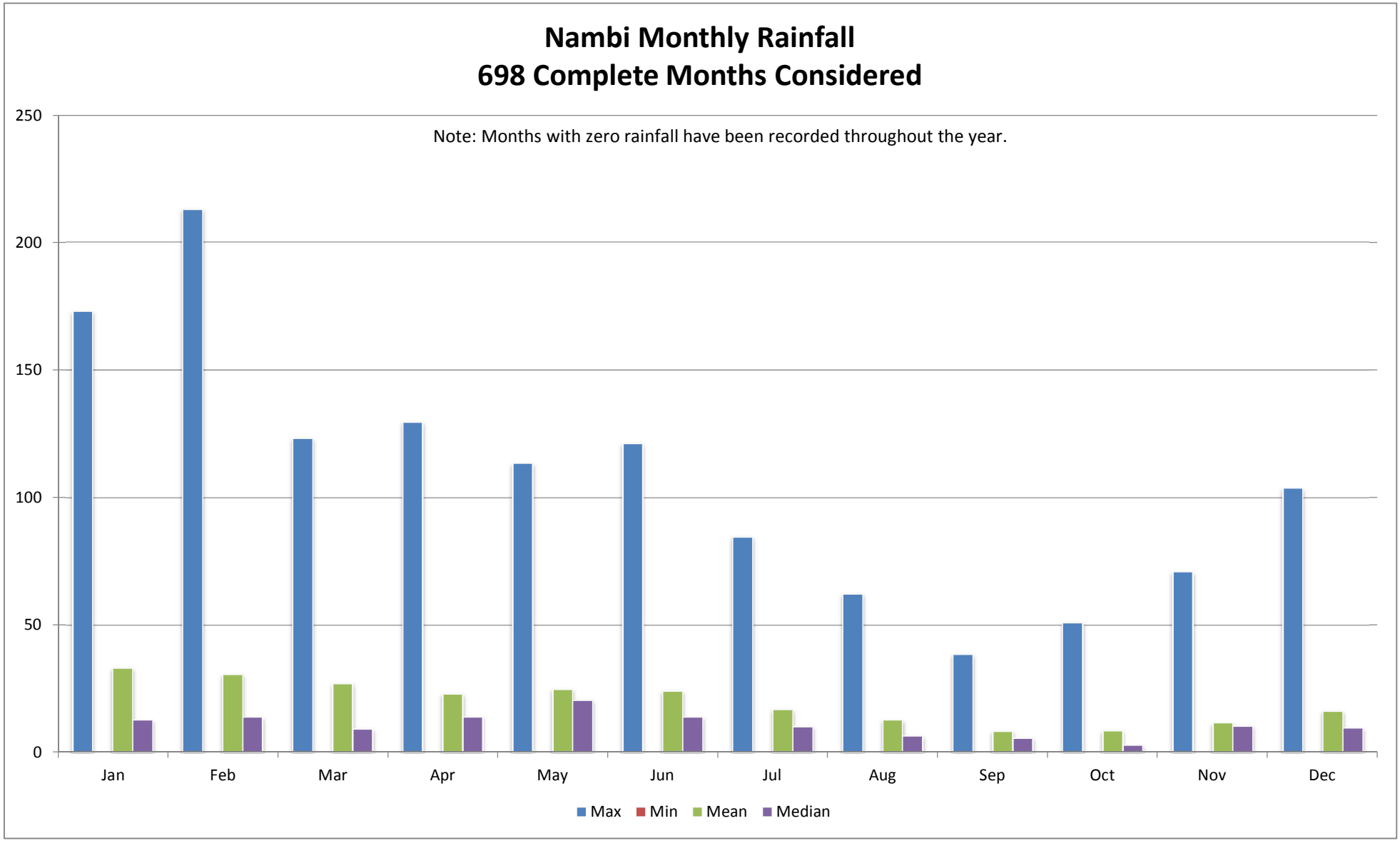
Leonora Monthly Rainfall
1301 Complete Months Considered




Glenorn Monthly Rainfall
793 Complete Months Considered
Note: Months with zero rainfall have been recorded throughout the year.
300
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Max
Min
Mean
Median


Minara Monthly Rainfall
1172 Complete Months Considered
Note: Months with zero rainfall have been recorded throughout the year.
300
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Max
Min
Mean
Median


Yundamindra Monthly Rainfall
1254 Complete Months Considered
Note: Months with zero rainfall have been recorded throughout the year.
400
350
300
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Max
Min
Mean
Median


Nambi Monthly Rainfall
698 Complete Months Considered
Note: Months with zero rainfall have been recorded throughout the year.
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Max
Min
Mean
Median

Top 10 Wettest Days at Each Local BoM Station

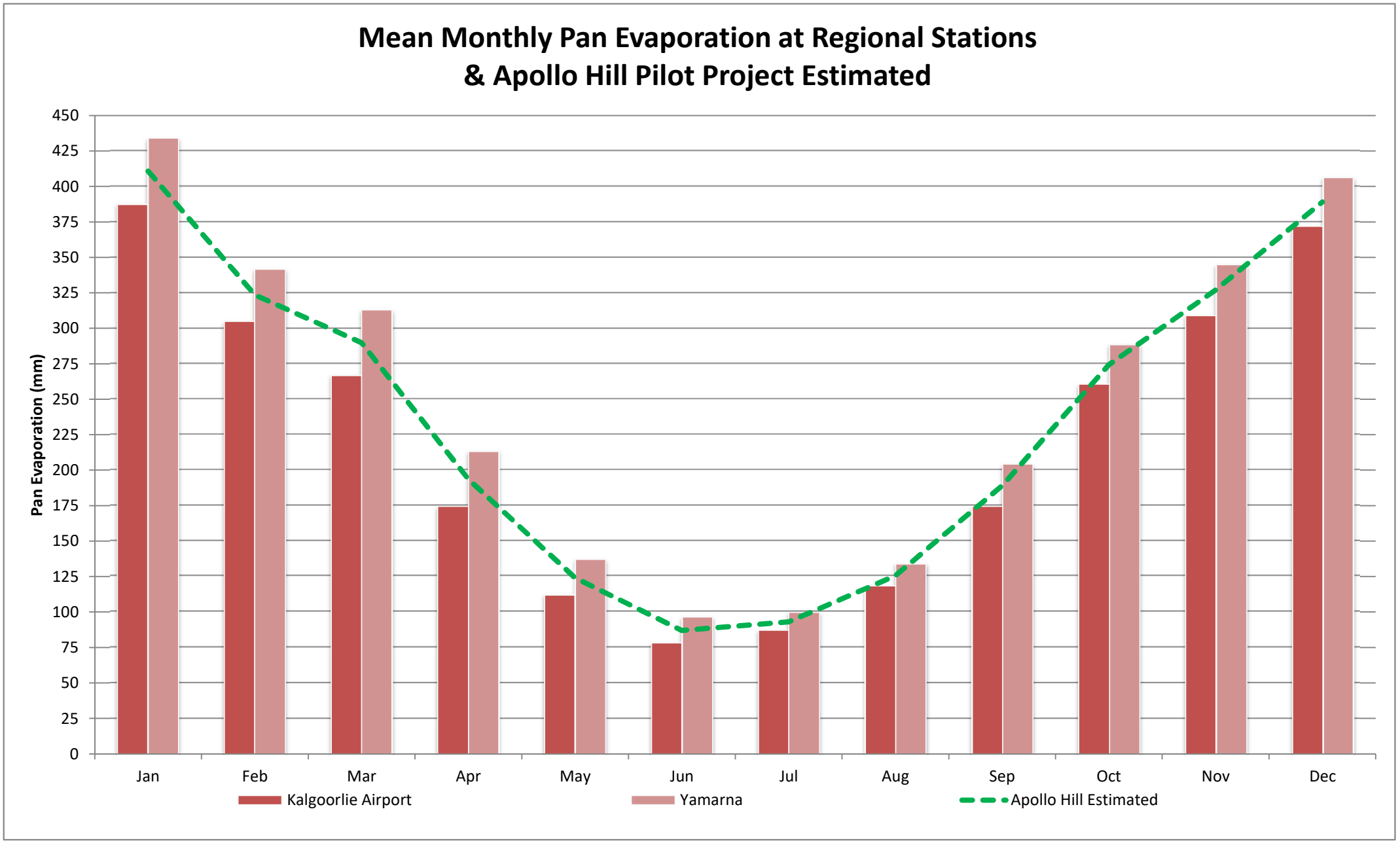
Station No.	Rainfall Station	Year	Month	Day	Precipitation to 9am (mm)	Rank
12032	Glenorn	1975	2	22	109.2	1
12032	Glenorn	1979	2	13	93.4	2
12032	Glenorn	1994	2	27	88.0	3
12032	Glenorn	1942	1	29	87.4	4
12032	Glenorn	1995	2	27	79.8	5
12032	Glenorn	1974	3	2	75.6	6
12032	Glenorn	1995	2	28	74.4	7
12032	Glenorn	1955	1	1	72.1	8
12032	Glenorn	1942	12	22	68.6	9
12032	Glenorn	1952	1	23	62.0	10
12046	Leonora	2014	1	23	109.2	1
12046	Leonora	1995	2	27	105.9	2
12046	Leonora	1927	3	21	103.4	3
12046	Leonora	2006	1	10	98.2	4
12046	Leonora	1909	1	22	84.6	5
12046	Leonora	1942	1	29	82.8	6
12046	Leonora	1939	1	14	82.6	7
12046	Leonora	1975	2	21	75.6	8
12046	Leonora	1975	2	22	75.6	9
12046	Leonora	2000	3	26	75.6	10
12061	Minara	1955	1	1	100.6	1
12061	Minara	1948	2	22	90.9	2
12061	Minara	1925	2	17	86.4	3
12061	Minara	1927	3	22	86.4	4
12061	Minara	1907	3	16	82.6	5
12061	Minara	1942	1	29	78.7	6
12061	Minara	1995	2	1	76.4	7
12061	Minara	1942	3	17	63.5	8
12061	Minara	1919	12	10	62.2	9
12061	Minara	1979	2	13	60.0	10
12062	Nambi	2000	1	23	94.6	1
12062	Nambi	1923	4	9	93.2	2
12062	Nambi	1925	2	26	79.5	3
12062	Nambi	1997	1	10	76.0	4
12062	Nambi	1987	1	22	70.6	5
12062	Nambi	2013	3	1	66.0	6
12062	Nambi	1987	1	20	63.0	7
12062	Nambi	1975	2	23	62.0	8
12062	Nambi	1927	3	22	61.0	9
12062	Nambi	2001	2	17	60.2	10
12093	Yundamindra	2011	2	17	126.0	1
12093	Yundamindra	1955	1	1	101.6	2
12093	Yundamindra	1942	1	29	100.6	3
12093	Yundamindra	1907	3	16	96.5	4
12093	Yundamindra	1960	1	31	96.3	5
12093	Yundamindra	1995	2	26	91.0	6
12093	Yundamindra	1975	2	22	86.0	7
12093	Yundamindra	1995	2	28	84.0	8
12093	Yundamindra	1997	1	10	78.6	9
12093	Yundamindra	2007	1	4	76.0	10

Top 50 Wettest Days at Local BoM Stations

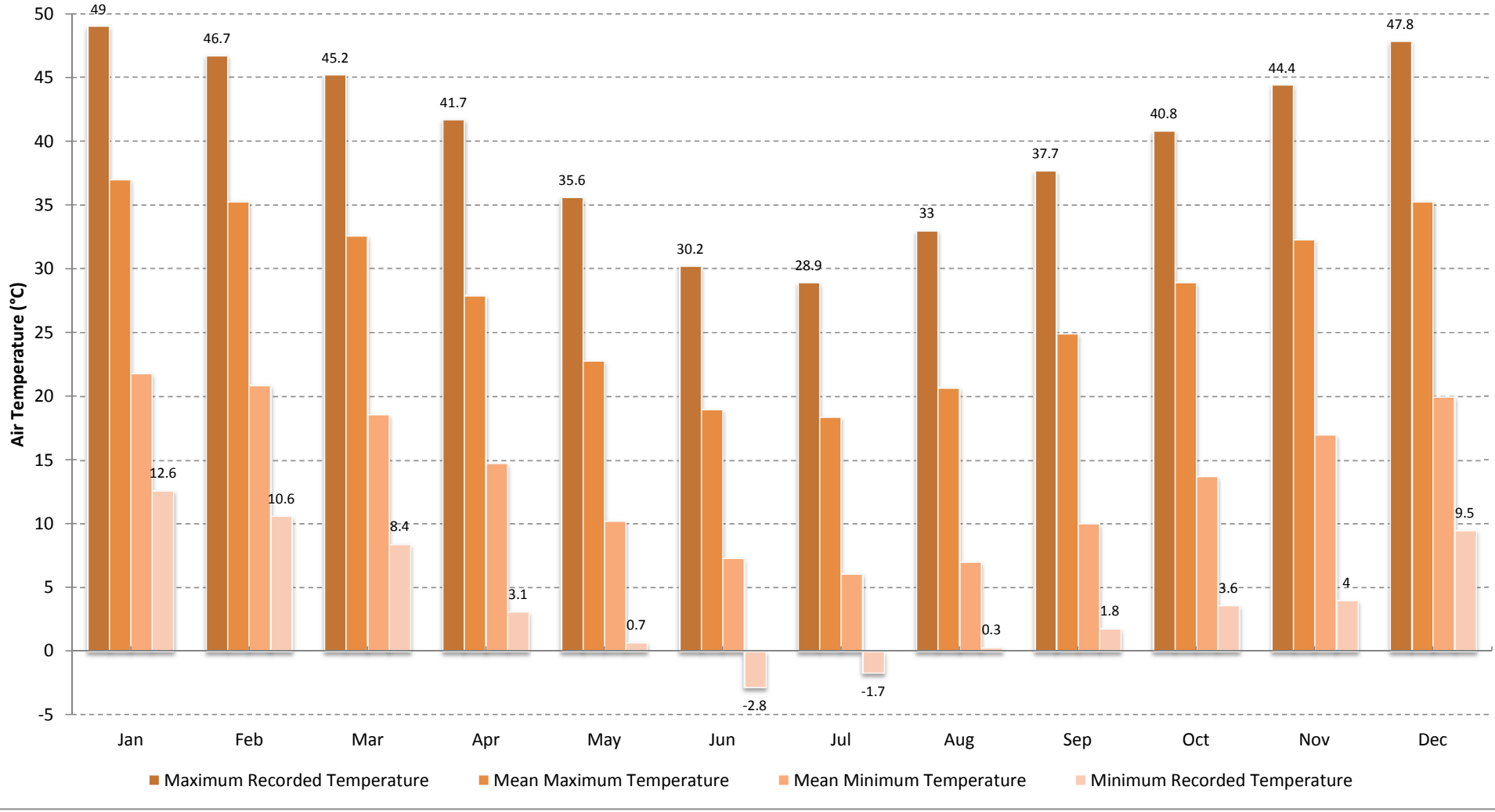
Station No.	Rainfall Station	Year	Month	Day	Precipitation to 9am (mm)	Rank
12093	Yundamindra	2011	2	17	126.0	1
12032	Glenorn	1975	2	22	109.2	2
12046	Leonora	2014	1	23	109.2	3
12046	Leonora	1995	2	27	105.9	4
12046	Leonora	1927	3	21	103.4	5
12093	Yundamindra	1955	1	1	101.6	6
12061	Minara	1955	1	1	100.6	7
12093	Yundamindra	1942	1	29	100.6	8
12046	Leonora	2006	1	10	98.2	9
12093	Yundamindra	1907	3	16	96.5	10
12093	Yundamindra	1960	1	31	96.3	11
12062	Nambi	2000	1	23	94.6	12
12032	Glenorn	1979	2	13	93.4	13
12062	Nambi	1923	4	9	93.2	14
12093	Yundamindra	1995	2	26	91.0	15
12061	Minara	1948	2	22	90.9	16
12032	Glenorn	1994	2	27	88.0	17
12032	Glenorn	1942	1	29	87.4	18
12061	Minara	1925	2	17	86.4	19
12061	Minara	1927	3	22	86.4	20
12093	Yundamindra	1975	2	22	86.0	21
12046	Leonora	1909	1	22	84.6	22
12093	Yundamindra	1995	2	28	84.0	23
12046	Leonora	1942	1	29	82.8	24
12046	Leonora	1939	1	14	82.6	25
12061	Minara	1907	3	16	82.6	26
12032	Glenorn	1995	2	27	79.8	27
12062	Nambi	1925	2	26	79.5	28
12061	Minara	1942	1	29	78.7	29
12093	Yundamindra	1997	1	10	78.6	30
12061	Minara	1995	2	1	76.4	31
12062	Nambi	1997	1	10	76.0	32
12093	Yundamindra	2007	1	4	76.0	33
12032	Glenorn	1974	3	2	75.6	34
12046	Leonora	1975	2	21	75.6	35
12046	Leonora	1975	2	22	75.6	36
12046	Leonora	2000	3	26	75.6	37
12032	Glenorn	1995	2	28	74.4	38
12032	Glenorn	1955	1	1	72.1	39
12062	Nambi	1987	1	22	70.6	40
12032	Glenorn	1942	12	22	68.6	41
12062	Nambi	2013	3	1	66.0	42
12061	Minara	1942	3	17	63.5	43
12062	Nambi	1987	1	20	63.0	44
12061	Minara	1919	12	10	62.2	45
12032	Glenorn	1952	1	23	62.0	46
12062	Nambi	1975	2	23	62.0	47
12062	Nambi	1927	3	22	61.0	48
12062	Nambi	2001	2	17	60.2	49
12061	Minara	1979	2	13	60.0	50

Top 50 Wettest Days at Local BoM Stations in Date Order

Station No.	Rainfall Station	Year	Month	Day	Precipitation to 9am (mm)
12093	Yundamindra	1907	3	16	96.5
12061	Minara	1907	3	16	82.6
12046	Leonora	1909	1	22	84.6
12061	Minara	1919	12	10	62.2
12062	Nambi	1923	4	9	93.2
12061	Minara	1925	2	17	86.4
12062	Nambi	1925	2	26	79.5
12046	Leonora	1927	3	21	103.4
12061	Minara	1927	3	22	86.4
12062	Nambi	1927	3	22	61.0
12046	Leonora	1939	1	14	82.6
12093	Yundamindra	1942	1	29	100.6
12032	Glenorn	1942	1	29	87.4
12046	Leonora	1942	1	29	82.8
12061	Minara	1942	1	29	78.7
12061	Minara	1942	3	17	63.5
12032	Glenorn	1942	12	22	68.6
12061	Minara	1948	2	22	90.9
12032	Glenorn	1952	1	23	62.0
12093	Yundamindra	1955	1	1	101.6
12061	Minara	1955	1	1	100.6
12032	Glenorn	1955	1	1	72.1
12093	Yundamindra	1960	1	31	96.3
12032	Glenorn	1974	3	2	75.6
12046	Leonora	1975	2	21	75.6
12032	Glenorn	1975	2	22	109.2
12093	Yundamindra	1975	2	22	86.0
12046	Leonora	1975	2	22	75.6
12062	Nambi	1975	2	23	62.0
12032	Glenorn	1979	2	13	93.4
12061	Minara	1979	2	13	60.0
12062	Nambi	1987	1	20	63.0
12062	Nambi	1987	1	22	70.6
12032	Glenorn	1994	2	27	88.0
12061	Minara	1995	2	1	76.4
12093	Yundamindra	1995	2	26	91.0
12046	Leonora	1995	2	27	105.9
12032	Glenorn	1995	2	27	79.8
12093	Yundamindra	1995	2	28	84.0
12032	Glenorn	1995	2	28	74.4
12093	Yundamindra	1997	1	10	78.6
12062	Nambi	1997	1	10	76.0
12062	Nambi	2000	1	23	94.6
12046	Leonora	2000	3	26	75.6
12062	Nambi	2001	2	17	60.2
12046	Leonora	2006	1	10	98.2
12093	Yundamindra	2007	1	4	76.0
12093	Yundamindra	2011	2	17	126.0
12062	Nambi	2013	3	1	66.0
12046	Leonora	2014	1	23	109.2


Mean Monthly Pan Evaporation at Regional Stations
& Apollo Hill Pilot Project Estimated
Pan Evaporation (mm)
450
425
400
375
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Kalgoorlie Airport
Yamarna
Apollo Hill Estimated

Leonora Maximum & Minimum Air Temperature (°C)
1900 to 2014



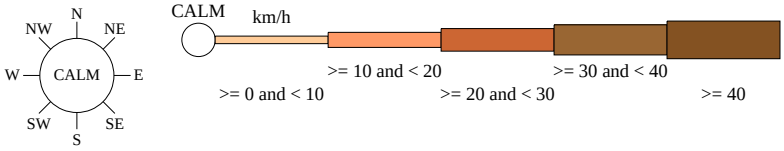
Rose of Wind direction versus Wind speed in km/h (01 Jan 1957 to 01 May 2014)

Custom times selected, refer to attached note for details

LEONORA

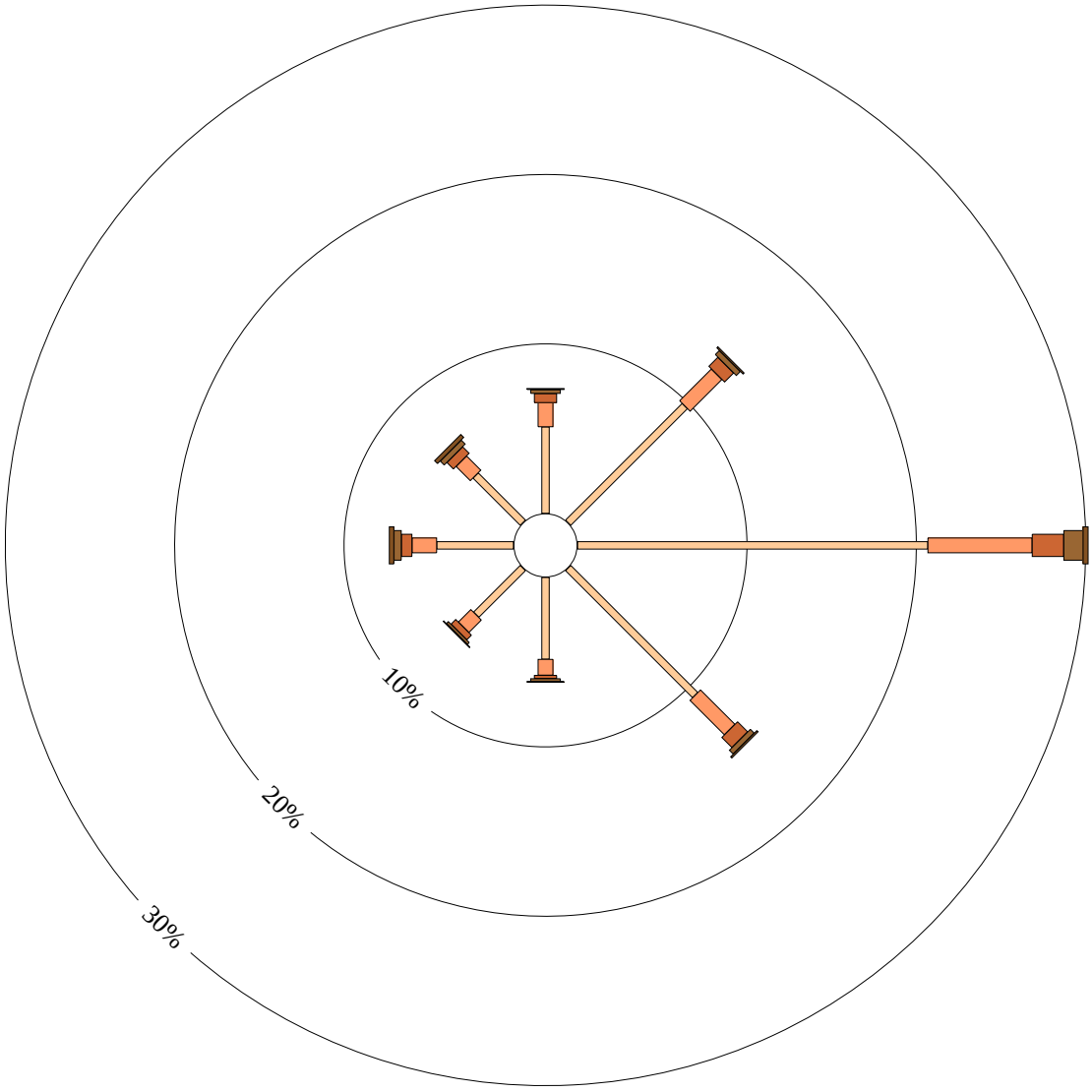
Site No: 012046 • Opened Jan 1898 • Still Open • Latitude: -28.8879° • Longitude: 121.3302° • Elevation 376m

An asterisk (*) indicates that calm is less than 0.5%.
Other important info about this analysis is available in the accompanying notes.



9 am
20770 Total Observations

Calm 9%



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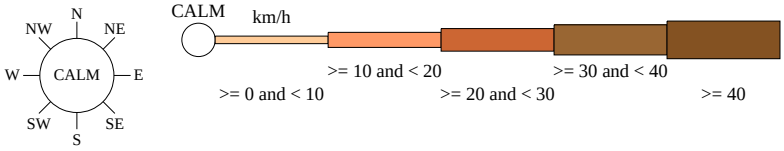
Rose of Wind direction versus Wind speed in km/h (01 Jan 1957 to 01 May 2014)

Custom times selected, refer to attached note for details

LEONORA

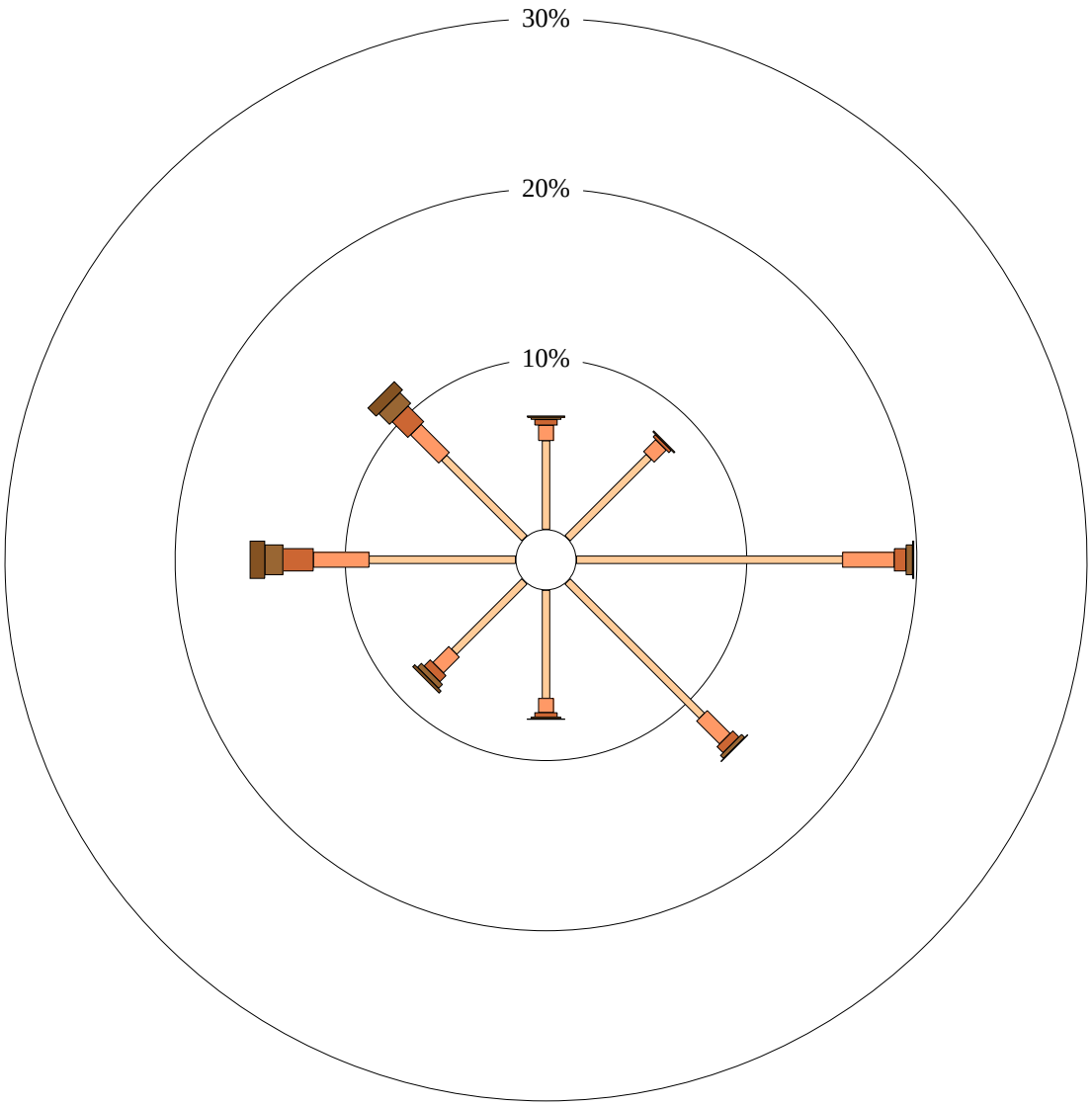
Site No: 012046 • Opened Jan 1898 • Still Open • Latitude: -28.8879° • Longitude: 121.3302° • Elevation 376m

An asterisk (*) indicates that calm is less than 0.5%.
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3 pm
20623 Total Observations

Calm 9%



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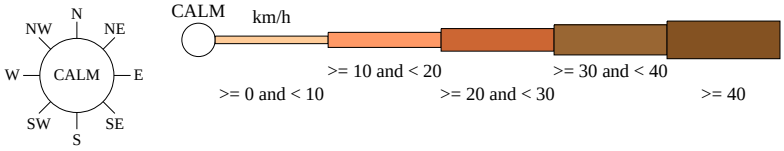
Rose of Wind direction versus Wind speed in km/h (22 Mar 1939 to 10 Aug 2022)

Custom times selected, refer to attached note for details

KALGOORLIE-BOULDER AIRPORT

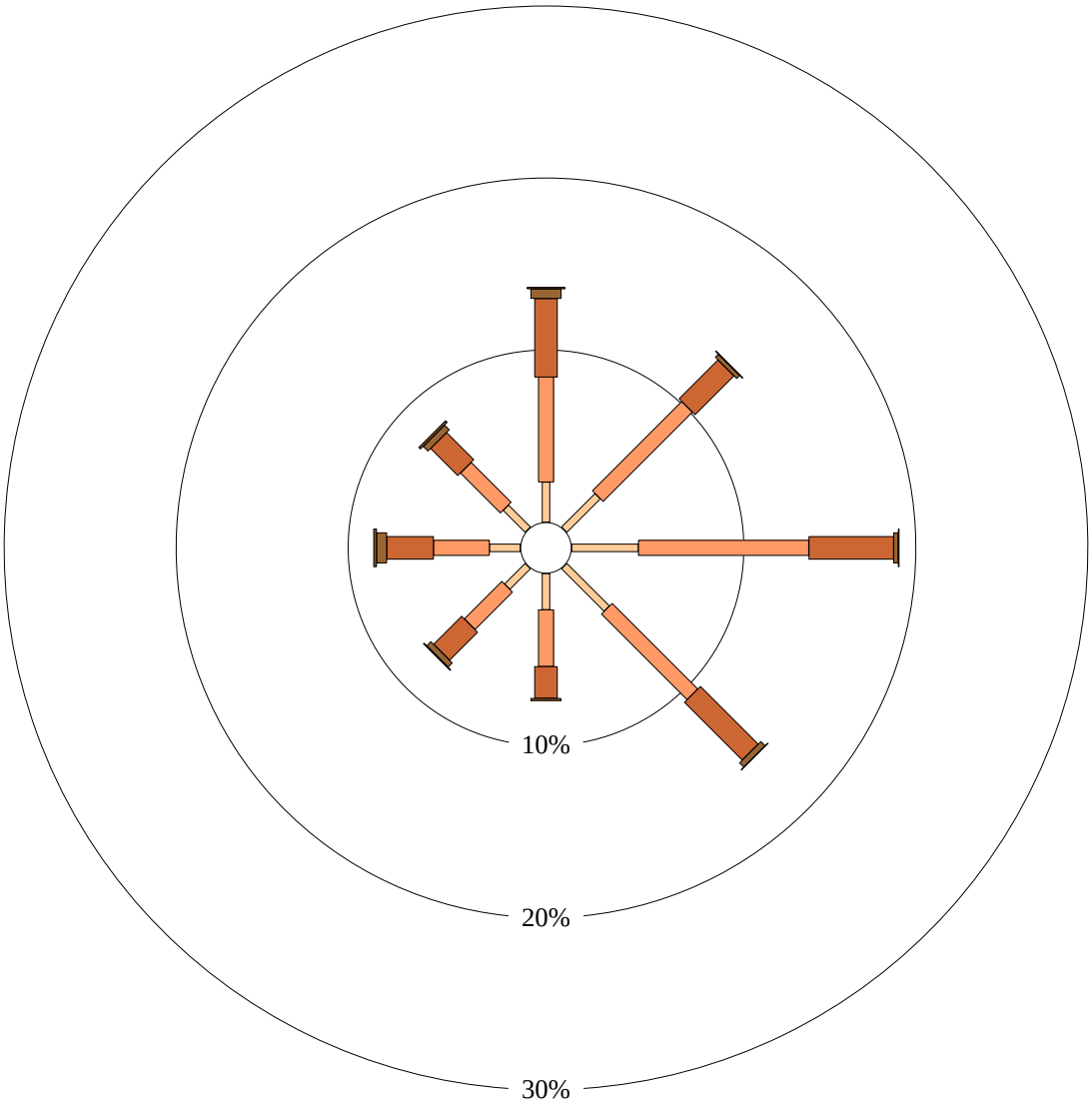
Site No: 012038 • Opened Feb 1939 • Still Open • Latitude: -30.7847° • Longitude: 121.4533° • Elevation 365.m

An asterisk (*) indicates that calm is less than 0.5%.
Other important info about this analysis is available in the accompanying notes.



9 am
30368 Total Observations

Calm 7%



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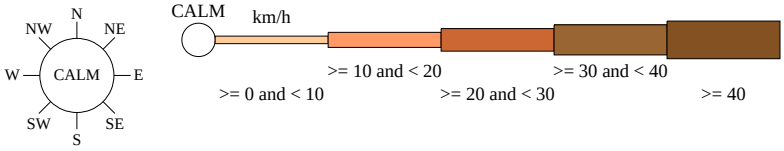
Rose of Wind direction versus Wind speed in km/h (22 Mar 1939 to 10 Aug 2022)

Custom times selected, refer to attached note for details

KALGOORLIE-BOULDER AIRPORT

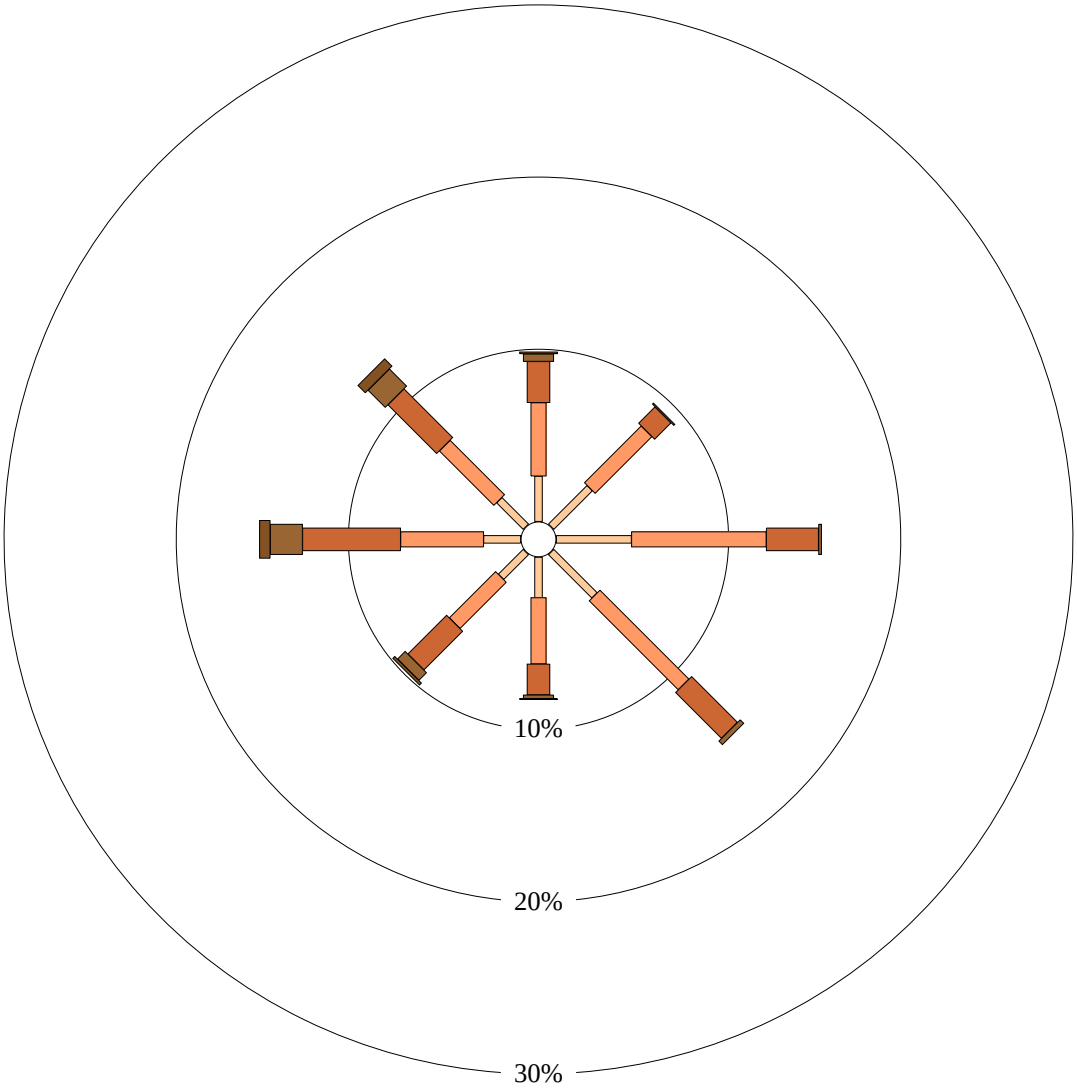
Site No: 012038 • Opened Feb 1939 • Still Open • Latitude: -30.7847° • Longitude: 121.4533° • Elevation 365.m

An asterisk (*) indicates that calm is less than 0.5%.
Other important info about this analysis is available in the accompanying notes.



3 pm
30310 Total Observations

Calm 5%



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Monthly Climate Statistics for 'LEONORA' [012046]

Created on [19 Jun 2024 15:05:49 UTC]

012046 LEONORA
Commenced: 1898
Last Record: 2020
Latitude: 28.89 Degrees South
Longitude: 121.33 Degrees East
Elevation: 376 m
State: WA

Statistic Element	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Number of Years	Start Year	End Year
Mean maximum temperature (Â°C) for years 1949 to 2014	37	35.3	32.6	27.9	22.8	19	18.4	20.7	24.9	28.9	32.3	35.3	27.9	64	1949	2014
Highest temperature (Â°C) for years 1957 to 2014	49	46.7	45.2	41.7	35.6	30.2	28.9	33	37.7	40.8	44.4	47.8	49	57	1957	2014
Date of Highest temperature Â°C for years 1957 to 2014	9-Jan-13	12-Feb-91	6-Mar-61	4-Apr-57	3-May-90	13-Jun-61	31-Jul-69	30-Aug-06	28-Sep-80	31-Oct-88	17-Nov-59	17-Dec-57	9-Jan-13	N/A	1957	2014
Lowest maximum temperature (Â°C) for years 1957 to 2014	18	18.3	16.2	14.4	12.2	9.8	10	9	11.7	11.2	14.5	17.5	9	57	1957	2014
Date of Lowest maximum temperature Â°C for years 1957 to 2014	30-Jan-06	1-Feb-68	19-Mar-84	24-Apr-66	10-May-97	20-Jun-68	11-Jul-11	12-Aug-86	5-Sep-64	13-Oct-78	14-Nov-08	4-Dec-88	12-Aug-86	N/A	1957	2014
Decile 1 maximum temperature (Â°C) for years 1957 to 2014	30.5	27.4	25.1	21.6	17.8	15	14.4	15.9	19	22.6	25.9	28.9		58	1957	2014
Decile 9 maximum temperature (Â°C) for years 1957 to 2014	43	41.7	39.1	34.1	28.8	23.3	23	26.3	30.9	35.8	38.7	41.1		58	1957	2014
Mean number of days >= 30 Â°C for years 1957 to 2014	28.2	23.3	20.3	10.8	1.9	0	0	0.5	4.4	13.6	19.8	26.4	149.2	57	1957	2014
Mean number of days >= 35 Â°C for years 1957 to 2014	20.9	15.5	10.4	2.1	0.1	0	0	0	0.3	4.5	9.4	17.1	80.3	57	1957	2014
Mean number of days >= 40 Â°C for years 1957 to 2014	9.9	5.6	2.2	0.1	0	0	0	0	0	0.2	1.9	5.2	25.1	57	1957	2014
Mean minimum temperature (Â°C) for years 1949 to 2014	21.8	20.9	18.6	14.8	10.2	7.3	6.1	7	10	13.7	17	20	14	64	1949	2014
Lowest temperature (Â°C) for years 1957 to 2014	12.6	10.6	8.4	3.1	0.7	-2.8	-1.7	0.3	1.8	3.6	4	9.5	-2.8	57	1957	2014
Date of Lowest temperature Â°C for years 1957 to 2014	20-Jan-76	28-Feb-94	24-Mar-01	26-Apr-60	17-May-62	23-Jun-81	12-Jul-69	20-Aug-68	12-Sep-04	8-Oct-92	7-Nov-97	2-Dec-73	23-Jun-81	N/A	1957	2014
Highest minimum temperature (Â°C) for years 1957 to 2014	33.5	32.2	30.6	25.9	21.7	19.8	17.3	24	24.9	27.8	27.2	30.4	33.5	57	1957	2014
Date of Highest minimum temperature Â°C for years 1957 to 2014	2-Jan-04	20-Feb-10	10-Mar-58	9-Apr-91	3-May-02	6-Jun-65	24-Jul-88	31-Aug-60	14-Sep-81	24-Oct-08	13-Nov-03	19-Dec-05	2-Jan-04	N/A	1957	2014
Decile 1 minimum temperature (Â°C) for years 1957 to 2014	17.4	16.3	14	10	5.6	3	2	2.9	5.6	9	12.7	15.4		58	1957	2014
Decile 9 minimum temperature (Â°C) for years 1957 to 2014	26.4	25.6	23.3	19.6	15.4	12.1	10.7	11.4	14.4	18.9	22.2	25		58	1957	2014
Mean number of days <= 2 Â°C for years 1957 to 2014	0	0	0	0	0.2	1.3	3.2	1.3	0.1	0	0	0	6.1	57	1957	2014
Mean number of days <= 0 Â°C for years 1957 to 2014	0	0	0	0	0	0.1	0.3	0	0	0	0	0	0.4	57	1957	2014
Mean daily ground minimum temperature Â°C for years null to null																
Lowest ground temperature Â°C for years null to null																
Date of Lowest ground temperature Â°C for years null to null														N/A		
Mean number of days ground min. temp. <= -1 Â°C for years null to null																
Mean rainfall (mm) for years 1898 to 2020	26.3	30.9	29	20.3	23.7	24.8	18.5	15.7	8.9	9.4	12.3	16.7	236.7	118	1898	2020
Highest rainfall (mm) for years 1898 to 2020	172	284.6	273.9	135.4	158.6	144	101.6	85.2	83.3	73	61.2	94	552.2	118	1898	2020
Date of Highest rainfall for years 1898 to 2020	2014	1995	1927	1918	1921	1955	1980	1958	1904	2011	1914	1988	1975	N/A	1898	2020
Lowest rainfall (mm) for years 1898 to 2020	0	0	0	0	0	0	0	0	0	0	0	0	57.8	118	1898	2020
Date of Lowest rainfall for years 1898 to 2020	2019	2019	2019	2020	2020	2019	2020	2018	2019	2019	2019	2018	1936	N/A	1898	2020
Decile 1 monthly rainfall (mm) for years 1898 to 2020	0	0	0	0	0	3.5	2.4	1	0	0	0	0	112.7	110	1898	2020
Decile 5 (median) monthly rainfall (mm) for years 1898 to 2020	11.4	13	11.2	13.2	17.8	19.9	15	11	5	3.7	7	10.4	221.1	110	1898	2020
Decile 9 monthly rainfall (mm) for years 1898 to 2020	82.2	81.2	68.3	51.8	53.8	52.8	35.6	37.5	24	30.2	31.1	39.5	380.6	110	1898	2020
Highest daily rainfall (mm) for years 1898 to 2020	109.2	105.9	103.4	54.6	56	39.9	70	37.3	32.6	34.4	44.4	51.8	109.2	112	1898	2020
Date of Highest daily rainfall for years 1898 to 2020	23-Jan-14	27-Feb-95	21-Mar-27	8-Apr-20	1-May-88	15-Jun-55	19-Jul-80	23-Aug-58	28-Sep-84	27-Oct-11	24-Nov-02	30-Dec-91	23-Jan-14	N/A	1898	2020
Mean number of days of rain for years 1898 to 2020	3.3	3.6	3.8	3.5	4.2	5.4	5.1	3.9	2.6	2.5	2.8	3.1	43.8	110	1898	2020
Mean number of days of rain >= 1 mm for years 1898 to 2020	2.3	2.4	2.6	2.5	2.9	3.5	3.2	2.5	1.5	1.5	1.8	2.2	28.9	112	1898	2020
Mean number of days of rain >= 10 mm for years 1898 to 2020	0.6	0.9	0.8	0.5	0.6	0.6	0.4	0.4	0.2	0.2	0.3	0.5	6	112	1898	2020
Mean number of days of rain >= 25 mm for years 1898 to 2020	0.2	0.3	0.3	0.1	0.1	0.1	0	0.1	0	0	0	0.1	1.3	112	1898	2020
Mean daily wind run (km) for years null to null																
Maximum wind gust speed (km/h) for years null to null																
Date of Maximum wind gust speed for years null to null														N/A		
Mean daily sunshine (hours) for years null to null																
Mean daily solar exposure (MJ/(m*m)) for years 1990 to 2017	27.8	24.5	21	16.8	13.4	11.4	12.6	16.1	20.7	24.7	27.4	28.7	20.4	28	1990	2017
Mean number of clear days for years 1957 to 2010	16.1	13.3	13.8	11.7	13.1	12.3	14.3	17.2	17.9	17.9	14.8	15.8	178.2	54	1957	2010
Mean number of cloudy days for years 1957 to 2010	6.2	7.4	7.5	8.9	9.1	9.7	7.7	5.8	4.7	4.7	5.9	5.4	83	54	1957	2010
Mean daily evaporation (mm) for years null to null																
Mean 9am temperature (Â°C) for years 1949 to 2010	27.7	26.2	24.1	20.4	15.5	11.8	10.9	13	17	20.9	24	26.5	19.8	61	1949	2010
Mean 9am wet bulb temperature (Â°C) for years 1949 to 2010	17.7	17.7	16.7	14.6	11.5	9.2	8.1	9.1	11.3	13.1	15.1	16.8	13.4	52	1949	2010
Mean 9am dew point temperature (Â°C) for years 1957 to 2010	9.5	11.2	10.6	9.3	7.1	6	4.6	4.3	4.9	5.1	6.7	8.2	7.3	45	1957	2010
Mean 9am relative humidity (%) for years 1949 to 2010	36	43	46	52	61	70	68	59	48	39	36	34	49	52	1949	2010
Mean 9am cloud cover (okas) for years 1949 to 2010	2.5	2.8	2.9	3.3	3.1	3.4	2.7	2.3	2.2	2.1	2.3	2.3	2.7	61	1949	2010
Mean 9am wind speed (km/h) for years 1957 to 2010	10.8	10.2	10.3	8.8	7.6	7.5	8.1	9.1	10.7	11.8	12.1	10.7	9.8	53	1957	2010
Mean 3pm temperature (Â°C) for years 1949 to 2010	35.8	34.2	31.8	26.9	21.8	18.2	17.6	19.7	23.9	27.8	31	34.1	26.9	61	1949	2010
Mean 3pm wet bulb temperature (Â°C) for years 1949 to 2010	20.2	20.3	19.1	16.9	14	12	11.2	11.9	13.8	15.4	17.2	19	15.9	52	1949	2010
Mean 3pm dew point temperature (Â°C) for years 1957 to 2010	7.8	9.8	9.2	8.1	6.1	5.1	3.5	2.9	2.8	2.7	4.2	5.9	5.7	45	1957	2010
Mean 3pm relative humidity (%) for years 1949 to 2010	21	27	28	34	39	45	43	36	28	22	21	20	30	52	1949	2010
Mean 3pm cloud cover (oktas) for years 1949 to 2010	3	3.2	3.1	3.7	3.6	3.7	3.3	2.7	2.1	2.4	3	2.9	3.1	61	1949	2010
Mean 3pm wind speed (km/h) for years 1957 to 2010	8.6	8.7	8.6	8.1	8.1	9.6	10.4	11.1	11.2	11.7	11.5	9.6	9.8	53	1957	2010

Monthly Climate Statistics for 'MENZIES' [012052]

Created on [19 Jun 2024 15:20:10 UTC]

012052 MENZIES
Commenced: 1896
Last Record: 2024
Latitude: 29.69 Degrees South
Longitude: 121.03 Degrees East
Elevation: 426 m
State: WA

Statistic Element	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Number of Years	Start Year	End Year
Mean maximum temperature (Â°C) for years 1898 to 1996	35.1	33.9	31.1	26.2	21.3	17.7	17	19	23.1	26.8	30.7	34	26.3	93	1898	1996
Highest temperature (Â°C) for years 1957 to 1996	46.2	45.6	45	39.4	33.9	28.3	28.3	31.1	36.4	40.8	42.9	45.2	46.2	37	1957	1996
Date of Highest temperature Â°C for years 1957 to 1996	13-Jan-91	25-Feb-70	10-Mar-73	14-Apr-81	2-May-72	13-Jun-61	31-Jul-69	31-Aug-62	28-Sep-80	25-Oct-83	23-Nov-82	11-Dec-70	13-Jan-91	N/A	1957	1996
Lowest maximum temperature (Â°C) for years 1957 to 1996	16.8	17.8	14.9	12.8	10.9	9.4	7.2	9.4	10.2	11.8	15.1	15	7.2	37	1957	1996
Date of Lowest maximum temperature Â°C for years 1957 to 1996	23-Jan-67	1-Feb-68	19-Mar-84	24-Apr-66	25-May-77	19-Jun-68	19-Jul-61	31-Aug-79	30-Sep-92	12-Oct-78	16-Nov-85	12-Dec-68	19-Jul-61	N/A	1957	1996
Decile 1 maximum temperature (Â°C) for years 1957 to 1996	30	27	24.4	20	16.8	14	13.6	14.9	17.8	20.6	24.4	28.1		37	1957	1996
Decile 9 maximum temperature (Â°C) for years 1957 to 1996	41.7	40.6	38.3	33.3	27.7	22.2	21.7	24.1	29.1	34.5	37.8	39.9		37	1957	1996
Mean number of days >= 30 Â°C for years 1957 to 1996	27.4	21.6	17.9	8.3	1.2	0	0	0.2	2.3	10	16.9	24.3	130.1	37	1957	1996
Mean number of days >= 35 Â°C for years 1957 to 1996	17.9	12.9	8.3	1.3	0	0	0	0	0.1	2.9	6.4	13.7	63.5	37	1957	1996
Mean number of days >= 40 Â°C for years 1957 to 1996	6.2	3.8	1.5	0	0	0	0	0	0	0.1	1.1	2.9	15.6	37	1957	1996
Mean minimum temperature (Â°C) for years 1897 to 1996	19.7	19.4	17.2	13.4	9.3	6.7	5.3	6.1	8.6	11.7	15.5	18.2	12.6	94	1897	1996
Lowest temperature (Â°C) for years 1957 to 1996	11.7	10	7.6	1.1	-1.4	-4.8	-4	-3	-0.6	0.6	3.4	6.8	-4.8	36	1957	1996
Date of Lowest temperature Â°C for years 1957 to 1996	15-Jan-67	15-Feb-63	22-Mar-82	26-Apr-60	23-May-75	22-Jun-81	31-Jul-75	25-Aug-95	7-Sep-60	15-Oct-68	20-Nov-92	25-Dec-74	22-Jun-81	N/A	1957	1996
Highest minimum temperature (Â°C) for years 1957 to 1996	31	28.9	30.3	24	20.2	18.9	14.5	17.9	23.3	25	27.2	29.4	31	36	1957	1996
Date of Highest minimum temperature Â°C for years 1957 to 1996	31-Jan-93	19-Feb-63	10-Mar-73	16-Apr-94	2-May-67	6-Jun-65	21-Jul-94	23-Aug-82	26-Sep-57	20-Oct-96	29-Nov-93	11-Dec-70	31-Jan-93	N/A	1957	1996
Decile 1 minimum temperature (Â°C) for years 1957 to 1996	15.6	15	13	8.9	5	2.5	1.2	1.7	4	7	11.1	13.9		37	1957	1996
Decile 9 minimum temperature (Â°C) for years 1957 to 1996	25	24.4	22	18.4	14.4	11.1	9.7	10.6	13	17.2	20.6	23.4		37	1957	1996
Mean number of days <= 2 Â°C for years 1957 to 1996	0	0	0	0.1	0.5	2	4.7	3.5	0.7	0.1	0	0	11.6	36	1957	1996
Mean number of days <= 0 Â°C for years 1957 to 1996	0	0	0	0	0.1	0.4	1.3	0.9	0.1	0	0	0	2.8	36	1957	1996
Mean daily ground minimum temperature Â°C for years null to null																
Lowest ground temperature Â°C for years null to null																
Date of Lowest ground temperature Â°C for years null to null														N/A		
Mean number of days ground min. temp. <= -1 Â°C for years null to null																
Mean rainfall (mm) for years 1896 to 2024	22.9	32	26.5	21.3	24.9	27.4	22.3	19.5	10.5	11.2	14.7	15.1	249	119	1896	2024
Highest rainfall (mm) for years 1896 to 2024	175.6	351	154.4	110.6	150.5	113.2	91.4	105.1	78.9	88.1	76.8	67	721.8	119	1896	2024
Date of Highest rainfall for years 1896 to 2024	1942	1995	1992	1995	1921	1986	1980	1992	1955	1975	2003	1987	1995	N/A	1896	2024
Lowest rainfall (mm) for years 1896 to 2024	0	0	0	0	0	0	0	0	0	0	0	0	75.9	119	1896	2024
Date of Lowest rainfall for years 1896 to 2024	2015	2022	2009	2007	2018	2013	2008	2006	2015	2007	1994	2022	1950	N/A	1896	2024
Decile 1 monthly rainfall (mm) for years 1896 to 2024	0	0	0	0	0.5	4.8	3.6	2.3	0.2	0	0.2	0	126	110	1896	2024
Decile 5 (median) monthly rainfall (mm) for years 1896 to 2024	8.6	10.2	15	11.4	18.6	21.1	18.4	14.8	6	5.6	9.8	8.7	240.2	110	1896	2024
Decile 9 monthly rainfall (mm) for years 1896 to 2024	63.4	79.1	68.4	59.5	61	60.5	42	42.5	21.7	22.7	36.5	43.1	386	110	1896	2024
Highest daily rainfall (mm) for years 1898 to 2024	108.7	168.4	83	70.4	52.3	47.2	35.9	36.6	50.8	43.9	60	54	168.4	110	1898	2024
Date of Highest daily rainfall for years 1898 to 2024	29-Jan-42	27-Feb-95	2-Mar-13	5-Apr-34	14-May-21	9-Jun-57	19-Jul-80	2-Aug-92	20-Sep-55	19-Oct-09	29-Nov-98	25-Dec-87	27-Feb-95	N/A	1898	2024
Mean number of days of rain for years 1896 to 2024	2.9	3.3	3.7	3.5	4.6	5.9	6	5	3.1	2.8	3.1	3.1	47	110	1896	2024
Mean number of days of rain >= 1 mm for years 1898 to 2024	2.1	2.4	2.8	2.5	3.2	3.9	3.9	3.4	2	1.8	2.2	2.1	32.3	110	1898	2024
Mean number of days of rain >= 10 mm for years 1898 to 2024	0.5	0.8	0.8	0.6	0.6	0.7	0.5	0.5	0.2	0.3	0.4	0.4	6.3	110	1898	2024
Mean number of days of rain >= 25 mm for years 1898 to 2024	0.2	0.3	0.2	0.1	0.1	0.1	0	0.1	0	0	0.1	0.1	1.3	110	1898	2024
Mean daily wind run (km) for years null to null																
Maximum wind gust speed (km/h) for years null to null																
Date of Maximum wind gust speed for years null to null														N/A		
Mean daily sunshine (hours) for years null to null																
Mean daily solar exposure (MJ/(m*m)) for years 1990 to 2017	27.8	24.4	21	16.4	12.8	10.9	12	15.6	20.1	24.4	27.3	28.7	20.1	28	1990	2017
Mean number of clear days for years 1957 to 1996	16	12.7	13.3	10.9	11.8	9.8	11.3	13.9	14.8	16.1	13.4	15.1	159.1	39	1957	1996
Mean number of cloudy days for years 1957 to 1996	5.4	7	7.1	8.6	9.4	10.7	9.3	7.6	5.3	5.5	5.7	5.2	86.8	39	1957	1996
Mean daily evaporation (mm) for years null to null																
Mean 9am temperature (Â°C) for years 1897 to 1996	26.2	25.1	22.9	19.2	14.9	11.7	10.7	12.4	16	19.3	22.9	25.4	18.9	98	1897	1996
Mean 9am wet bulb temperature (Â°C) for years 1897 to 1996	17.1	17.1	15.9	13.7	10.9	8.9	7.9	8.7	10.6	12.3	14.5	16.4	12.8	90	1897	1996
Mean 9am dew point temperature (Â°C) for years 1957 to 1996	9.2	10.8	9.8	8.7	6.7	5.9	4.8	4.4	4.5	4.7	6	8.1	7	31	1957	1996
Mean 9am relative humidity (%) for years 1938 to 1996	39	43	46	53	60	68	69	60	48	41	37	36	50	50	1938	1996
Mean 9am cloud cover (okas) for years 1897 to 1996	2	2.4	2.5	2.9	3	3.4	2.9	2.6	2.1	2.1	2.1	1.8	2.5	98	1897	1996
Mean 9am wind speed (km/h) for years 1957 to 1996	17.1	16.8	16.3	14.5	13.4	13	13.2	14.5	16.7	16.8	17	16.6	15.5	36	1957	1996
Mean 3pm temperature (Â°C) for years 1897 to 1996	33.9	32.8	30.1	25.4	20.4	16.9	16.3	18.2	22.3	25.8	29.6	32.7	25.4	98	1897	1996
Mean 3pm wet bulb temperature (Â°C) for years 1897 to 1996	19.5	19.5	18.3	16	13.2	11.2	10.5	11.1	12.9	14.5	16.5	18.4	15.1	90	1897	1996
Mean 3pm dew point temperature (Â°C) for years 1957 to 1996	7.1	9.3	8.2	7.1	5.5	5	4	2.9	2.3	2.4	3.2	5.5	5.2	31	1957	1996
Mean 3pm relative humidity (%) for years 1938 to 1996	23	26	27	34	40	46	45	37	28	24	21	20	31	50	1938	1996
Mean 3pm cloud cover (oktas) for years 1897 to 1996	2.4	2.8	2.8	3.2	3.3	3.7	3.3	3	2.1	2.3	2.6	2.4	2.8	97	1897	1996
Mean 3pm wind speed (km/h) for years 1957 to 1996	15.3	15.5	13.7	13.1	13.5	14.4	15.5	16	17	16.8	16.2	15	15.2	35	1957	1996

Monthly Climate Statistics for 'LAVERTON' [012045]

Created on [19 Jun 2024 15:04:00 UTC]

012045 LAVERTON
Commenced: 1899
Last Record: 2024
Latitude: 28.63 Degrees South
Longitude: 122.41 Degrees East
Elevation: 461 m
State: WA

Statistic Element	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Number of Years	Start Year	End Year
Mean maximum temperature (Â°C) for years 1900 to 1971	35.8	34.8	31.9	27.3	22.1	18.5	17.8	20	24.5	28	32.1	34.9	27.3	68	1900	1971
Highest temperature (Â°C) for years 1957 to 1971	46.1	45	42.8	40	33.3	30.2	28.4	31.4	35.6	40	43.3	44.4	46.1	12	1957	1971
Date of Highest temperature Â°C for years 1957 to 1971	14-Jan-57	17-Feb-71	1-Mar-65	4-Apr-57	13-May-57	13-Jun-61	31-Jul-69	31-Aug-62	28-Sep-61	28-Oct-65	28-Nov-62	17-Dec-57	14-Jan-57	N/A	1957	1971
Lowest maximum temperature (Â°C) for years 1957 to 1971	21.1	18.3	16.6	13.9	12.3	10.5	10	10.7	14.7	16.1	16.5	22.2	10	12	1957	1971
Date of Lowest maximum temperature Â°C for years 1957 to 1971	22-Jan-58	1-Feb-63	29-Mar-67	24-Apr-66	20-May-68	20-Jun-68	11-Jul-62	8-Aug-65	15-Sep-65	5-Oct-58	2-Nov-66	2-Dec-66	11-Jul-62	N/A	1957	1971
Decile 1 maximum temperature (Â°C) for years 1957 to 1971	29.7	27.7	25.2	21.2	17.2	14.5	13.9	15.5	18.3	21.7	26.1	27.8		13	1957	1971
Decile 9 maximum temperature (Â°C) for years 1957 to 1971	41.7	40.3	38.3	34.5	28.3	23.5	22	24.9	30	35	38.9	39.9		13	1957	1971
Mean number of days >= 30 Â°C for years 1957 to 1971	27.8	22.4	20.2	10.9	1.6	0.1	0	0.4	3.4	12.9	19.9	25.1	144.7	12	1957	1971
Mean number of days >= 35 Â°C for years 1957 to 1971	20	14	10	2.3	0	0	0	0	0.3	3.7	9.4	15.3	75	12	1957	1971
Mean number of days >= 40 Â°C for years 1957 to 1971	7.5	3.6	1.8	0.1	0	0	0	0	0	0.1	2.1	3.1	18.3	12	1957	1971
Mean minimum temperature (Â°C) for years 1900 to 1971	20.5	20	18	13.9	9.5	6.6	5.2	6.4	9.5	12.8	16.6	19.3	13.2	68	1900	1971
Lowest temperature (Â°C) for years 1957 to 1971	7.2	7.5	9.8	4	-0.4	-0.6	-2.4	-1.7	1.1	2.8	7.7	9.4	-2.4	12	1957	1971
Date of Lowest temperature Â°C for years 1957 to 1971	22-Jan-58	2-Feb-63	31-Mar-68	25-Apr-71	31-May-64	18-Jun-69	12-Jul-69	10-Aug-68	6-Sep-57	2-Oct-57	2-Nov-64	6-Dec-59	12-Jul-69	N/A	1957	1971
Highest minimum temperature (Â°C) for years 1957 to 1971	31.3	28.3	29.3	24.8	18.9	18.4	15.6	18.3	18.3	26.1	28.3	29.4	31.3	12	1957	1971
Date of Highest minimum temperature Â°C for years 1957 to 1971	26-Jan-65	23-Feb-68	8-Mar-61	7-Apr-69	18-May-69	6-Jun-65	15-Jul-64	29-Aug-65	23-Sep-61	30-Oct-65	30-Nov-57	26-Dec-61	26-Jan-65	N/A	1957	1971
Decile 1 minimum temperature (Â°C) for years 1957 to 1971	16.5	15	13.9	9.8	5	2.8	1.1	1.7	5	8.2	11.8	14		13	1957	1971
Decile 9 minimum temperature (Â°C) for years 1957 to 1971	25.7	24.9	22.6	19.4	15	11.7	10.6	10.6	13.8	18.9	22.3	23.9		13	1957	1971
Mean number of days <= 2 Â°C for years 1957 to 1971	0	0	0	0	0.6	1.5	5.4	3.7	0.2	0	0	0	11.4	12	1957	1971
Mean number of days <= 0 Â°C for years 1957 to 1971	0	0	0	0	0.2	0.2	1.6	0.8	0	0	0	0	2.8	12	1957	1971
Mean daily ground minimum temperature Â°C for years 1965 to 1969														2	1965	1969
Lowest ground temperature Â°C for years 1965 to 1969														2	1965	1969
Date of Lowest ground temperature Â°C for years 1965 to 1969														N/A	1965	1969
Mean number of days ground min. temp. <= -1 Â°C for years 1965 to 1969														2	1965	1969
Mean rainfall (mm) for years 1899 to 2024	26.9	31	30.6	21.6	22.2	22.8	16	13	8.8	9.7	15	18	235.4	119	1899	2024
Highest rainfall (mm) for years 1899 to 2024	179	233.6	181	204.5	123.8	126.2	66.1	84.8	67.3	67	152	134.6	525.6	119	1899	2024
Date of Highest rainfall for years 1899 to 2024	2000	1995	2000	1900	1921	1955	1963	1958	1904	2011	1914	1930	2000	N/A	1899	2024
Lowest rainfall (mm) for years 1899 to 2024	0	0	0	0	0	0	0	0	0	0	0	0	65.6	119	1899	2024
Date of Lowest rainfall for years 1899 to 2024	2019	2019	2008	2021	2019	2017	1982	2013	2020	2023	1991	1985	1928	N/A	1899	2024
Decile 1 monthly rainfall (mm) for years 1899 to 2024	0	0	0	0	0.8	3.1	1.5	0.8	0	0	0	0	120.6	113	1899	2024
Decile 5 (median) monthly rainfall (mm) for years 1899 to 2024	8.7	18.4	15.9	12.4	15	16.4	11.9	8.6	3.4	5.6	9	11.4	212	113	1899	2024
Decile 9 monthly rainfall (mm) for years 1899 to 2024	84.3	84.1	85	55.3	49	53.8	38.7	28.2	26.5	25.8	34.2	41.3	365.2	113	1899	2024
Highest daily rainfall (mm) for years 1899 to 2024	92.6	120.2	67.1	54	51.6	40.4	32.5	40.6	53.5	49	90.9	70.6	120.2	112	1899	2024
Date of Highest daily rainfall for years 1899 to 2024	24-Jan-00	17-Feb-11	21-Mar-29	4-Apr-74	24-May-11	11-Jun-55	26-Jul-71	21-Aug-19	5-Sep-77	13-Oct-40	11-Nov-14	30-Dec-30	17-Feb-11	N/A	1899	2024
Mean number of days of rain for years 1899 to 2024	3.3	3.6	3.9	3.5	4.3	4.8	4.4	3.3	1.9	2.2	2.9	3.2	41.3	113	1899	2024
Mean number of days of rain >= 1 mm for years 1899 to 2024	2.5	2.8	2.8	2.5	3	3.4	2.9	2.4	1.4	1.5	2.1	2.4	29.7	112	1899	2024
Mean number of days of rain >= 10 mm for years 1899 to 2024	0.6	0.8	0.9	0.5	0.5	0.5	0.3	0.3	0.2	0.2	0.4	0.4	5.6	112	1899	2024
Mean number of days of rain >= 25 mm for years 1899 to 2024	0.2	0.3	0.3	0.1	0.1	0.1	0	0	0	0	0.1	0.1	1.3	112	1899	2024
Mean daily wind run (km) for years null to null																
Maximum wind gust speed (km/h) for years null to null																
Date of Maximum wind gust speed for years null to null														N/A		
Mean daily sunshine (hours) for years null to null																
Mean daily solar exposure (MJ/(m*m)) for years 1990 to 2017	27.3	24.4	20.9	16.8	13.5	11.6	12.8	16.4	20.9	24.6	27.2	28.3	20.4	28	1990	2017
Mean number of clear days for years 1957 to 1969	17.2	15.3	18.2	13.5	15.2	13.3	16.6	18.7	19.3	18.8	16.2	17	199.3	12	1957	1969
Mean number of cloudy days for years 1957 to 1969	5.1	5.6	5.9	7.8	7.1	8.8	6.8	4.4	3.4	3.3	4.5	4.9	67.6	12	1957	1969
Mean daily evaporation (mm) for years null to null																
Mean 9am temperature (Â°C) for years 1900 to 1969	27.5	26.4	24.2	20.5	16.2	12.8	11.8	13.9	17.9	21.1	24.8	27	20.3	67	1900	1969
Mean 9am wet bulb temperature (Â°C) for years 1900 to 1969	17.8	17.6	16.6	14.3	11.6	9.5	8.4	9.4	11.3	13.4	15.5	17.2	13.5	66	1900	1969
Mean 9am dew point temperature (Â°C) for years 1957 to 1969	8.5	9.5	8.8	8	5.6	6.4	4.3	3.1	3.4	5.8	5.5	8	6.4	11	1957	1969
Mean 9am relative humidity (%) for years 1936 to 1969	34	39	43	48	57	65	63	53	42	37	34	33	46	31	1936	1969
Mean 9am cloud cover (okas) for years 1900 to 1969	2	2.2	2.4	2.7	2.7	3	2.5	2.1	1.5	1.7	1.9	1.9	2.2	60	1900	1969
Mean 9am wind speed (km/h) for years 1957 to 1969	13.1	12.3	12	10.9	9.8	9.5	9.4	11.2	12.4	11.7	13.1	12.6	11.5	12	1957	1969
Mean 3pm temperature (Â°C) for years 1900 to 1969	34.6	33.7	30.9	26.4	21.3	17.7	17.1	19.4	23.7	27.1	30.7	33.6	26.4	68	1900	1969
Mean 3pm wet bulb temperature (Â°C) for years 1900 to 1969	20.2	20	19	16.6	13.8	11.8	10.9	11.8	13.6	15.5	17.6	19.4	15.9	66	1900	1969
Mean 3pm dew point temperature (Â°C) for years 1957 to 1969	7.1	7.7	7.1	7.1	4.6	5.6	3.5	1.9	1.8	4.3	4	6.4	5.1	11	1957	1969
Mean 3pm relative humidity (%) for years 1936 to 1969	21	23	26	32	40	47	43	35	26	24	21	20	30	31	1936	1969
Mean 3pm cloud cover (oktas) for years 1900 to 1969	2.4	2.6	2.7	2.8	2.8	3	2.6	2.1	1.7	2	2.4	2.4	2.5	60	1900	1969
Mean 3pm wind speed (km/h) for years 1957 to 1969	10.6	10.1	9.6	9.9	8.8	11.3	10.4	12	11.9	10.9	12	10.5	10.7	11	1957	1969

Monthly Climate Statistics for 'LAVERTON AERO' [012305]

Created on [19 Jun 2024 15:04:04 UTC]

012305 LAVERTON AERO
Commenced: 1991
Last Record: 2024
Latitude: 28.61 Degrees South
Longitude: 122.42 Degrees East
Elevation: 464 m
State: WA

Statistic Element	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Number of Years	Start Year	End Year
Mean maximum temperature (Â°C) for years 1991 to 2024	35.7	34.2	30.8	27.1	22.3	18.6	18.7	21	24.9	28.9	31.4	34.1	27.3	32	1991	2024
Highest temperature (Â°C) for years 1991 to 2024	47.6	45.6	43.1	39.6	35.1	27.8	29.7	33.6	37.6	41.3	44.7	45.5	47.6	33	1991	2024
Date of Highest temperature Â°C for years 1991 to 2024	8-Jan-13	13-Feb-15	9-Mar-19	14-Apr-20	1-May-13	26-Jun-19	31-Jul-15	28-Aug-20	29-Sep-23	10-Oct-19	19-Nov-19	29-Dec-19	8-Jan-13	N/A	1991	2024
Lowest maximum temperature (Â°C) for years 1991 to 2024	15.4	16.8	15.9	16.1	11.6	10.5	9.5	10.5	11.3	12.9	14.7	16.4	9.5	33	1991	2024
Date of Lowest maximum temperature Â°C for years 1991 to 2024	1-Jan-06	1-Feb-18	11-Mar-07	29-Apr-00	10-May-97	5-Jun-01	27-Jul-98	22-Aug-16	2-Sep-10	1-Oct-92	14-Nov-08	13-Dec-01	27-Jul-98	N/A	1991	2024
Decile 1 maximum temperature (Â°C) for years 1991 to 2024	28.9	26.8	23.3	21.6	17.1	14.4	13.9	15.8	18.4	21.8	24.7	27.2		32	1991	2024
Decile 9 maximum temperature (Â°C) for years 1991 to 2024	42	41.4	37.6	33.1	27.5	22.9	23.3	26.9	31.4	36.2	37.8	40.4		32	1991	2024
Mean number of days >= 30 Â°C for years 1991 to 2024	25.7	21.3	17.1	7.5	0.6	0	0	0.8	5.2	12.6	17.3	23.8	131.9	33	1991	2024
Mean number of days >= 35 Â°C for years 1991 to 2024	17.4	13.1	7.7	1.2	0	0	0	0	0.4	4.3	7.8	13.8	65.7	33	1991	2024
Mean number of days >= 40 Â°C for years 1991 to 2024	6.5	4.5	0.7	0	0	0	0	0	0	0.2	1.1	3.8	16.8	33	1991	2024
Mean minimum temperature (Â°C) for years 1991 to 2024	21.6	20.9	18.5	15	10.4	6.9	5.9	7.5	10.8	14.5	17.2	19.9	14.1	32	1991	2024
Lowest temperature (Â°C) for years 1991 to 2024	12	12.3	8	4.3	0.3	-2	-3.3	-1.5	1.3	4.2	5.6	10.9	-3.3	33	1991	2024
Date of Lowest temperature Â°C for years 1991 to 2024	20-Jan-96	2-Feb-06	25-Mar-01	30-Apr-00	19-May-19	13-Jun-95	5-Jul-17	6-Aug-18	2-Sep-15	8-Oct-92	21-Nov-92	3-Dec-98	5-Jul-17	N/A	1991	2024
Highest minimum temperature (Â°C) for years 1991 to 2024	33.3	31.2	28.7	25.2	22.7	17.6	17.1	18.5	23.6	26.7	30.1	31.5	33.3	33	1991	2024
Date of Highest minimum temperature Â°C for years 1991 to 2024	11-Jan-24	16-Feb-10	1-Mar-22	4-Apr-22	3-May-02	18-Jun-22	26-Jul-13	27-Aug-23	30-Sep-08	24-Oct-08	19-Nov-19	7-Dec-19	11-Jan-24	N/A	1991	2024
Decile 1 minimum temperature (Â°C) for years 1991 to 2024	16.5	16.2	14	10.9	5.3	2.6	1.7	2.8	6	9.2	12.5	14.8		32	1991	2024
Decile 9 minimum temperature (Â°C) for years 1991 to 2024	26.9	26.1	23	19.6	15.6	12	10.8	12.3	15.5	19.7	22.4	25.2		32	1991	2024
Mean number of days <= 2 Â°C for years 1991 to 2024	0	0	0	0	0.3	2	3.8	1.7	0.1	0	0	0	7.9	33	1991	2024
Mean number of days <= 0 Â°C for years 1991 to 2024	0	0	0	0	0	0.3	1.1	0.3	0	0	0	0	1.7	33	1991	2024
Mean daily ground minimum temperature Â°C for years null to null																
Lowest ground temperature Â°C for years null to null																
Date of Lowest ground temperature Â°C for years null to null														N/A		
Mean number of days ground min. temp. <= -1 Â°C for years null to null																
Mean rainfall (mm) for years 1994 to 2024	47.2	50.6	40.8	18.8	13.4	14	14.5	9.9	7.4	13.1	19.5	26.1	275.8	30	1994	2024
Highest rainfall (mm) for years 1994 to 2024	177.2	232.8	180	50.2	72.2	47.7	52.6	32	53	50.6	77	75.4	522	30	1994	2024
Date of Highest rainfall for years 1994 to 2024	2017	2011	2000	2014	2001	1998	2004	1997	2010	2014	2008	2018	2011	N/A	1994	2024
Lowest rainfall (mm) for years 1994 to 2024	0.2	0	0	0	0	0	0.2	0	0	0	0	0.2	60.2	30	1994	2024
Date of Lowest rainfall for years 1994 to 2024	1996	2024	2008	2021	2019	2017	2017	2013	2020	2023	2019	1997	2019	N/A	1994	2024
Decile 1 monthly rainfall (mm) for years 1994 to 2024	1.9	0.2	3	1.3	0.2	1.6	0.6	0	0.4	0.2	3.3	2.7	127.8	30	1994	2024
Decile 5 (median) monthly rainfall (mm) for years 1994 to 2024	36.2	28.4	21.4	13.8	11	12.3	8.5	7.1	3.3	9.9	12.3	22.5	254.6	30	1994	2024
Decile 9 monthly rainfall (mm) for years 1994 to 2024	99.5	152.2	105.3	43.6	27.4	30.7	43.2	25.7	15.8	32.2	50	54.9	458.4	30	1994	2024
Highest daily rainfall (mm) for years 1994 to 2024	98.8	110.2	72.6	28.2	25	24	20.4	24	33	31	45.6	50	110.2	28	1994	2024
Date of Highest daily rainfall for years 1994 to 2024	17-Jan-17	17-Feb-11	10-Mar-24	9-Apr-04	2-May-01	26-Jun-03	9-Jul-10	5-Aug-97	1-Sep-10	20-Oct-14	23-Nov-08	19-Dec-94	17-Feb-11	N/A	1994	2024
Mean number of days of rain for years 1994 to 2024	5.5	5.4	5.6	4.7	3.8	4.5	4.8	3.6	2.6	3.3	4.3	4.5	52.6	30	1994	2024
Mean number of days of rain >= 1 mm for years 1994 to 2024	4.1	3.9	4.1	3	2.6	2.6	2.7	1.9	1.3	2.2	2.9	3	34.3	28	1994	2024
Mean number of days of rain >= 10 mm for years 1994 to 2024	1.3	1.5	1.1	0.6	0.3	0.4	0.4	0.2	0.2	0.4	0.5	0.9	7.8	28	1994	2024
Mean number of days of rain >= 25 mm for years 1994 to 2024	0.4	0.6	0.4	0	0	0	0	0	0	0.1	0.1	0.2	1.8	28	1994	2024
Mean daily wind run (km) for years 2003 to 2024	482	465	435	354	321	313	298	348	392	441	440	469	396	19	2003	2024
Maximum wind gust speed (km/h) for years 2003 to 2024	106	111	72	98	93	78	81	89	102	94	118	98	118	20	2003	2024
Date of Maximum wind gust speed for years 2003 to 2024	17-Jan-20	26-Feb-21	30-Mar-05	5-Apr-03	8-May-13	29-Jun-09	3-Jul-18	1-Aug-21	18-Sep-11	19-Oct-14	17-Nov-09	15-Dec-04	17-Nov-09	N/A	2003	2024
Mean daily sunshine (hours) for years null to null																
Mean daily solar exposure (MJ/(m*m)) for years 1990 to 2017	27.3	24.4	21	16.8	13.6	11.6	12.8	16.5	21	24.6	27.2	28.3	20.4	28	1990	2017
Mean number of clear days for years null to null																
Mean number of cloudy days for years null to null																
Mean daily evaporation (mm) for years null to null																
Mean 9am temperature (Â°C) for years 1991 to 2010	27	25.6	23.3	20.4	16.5	12.6	12.1	14.1	17.5	20.9	23.7	25.5	19.9	19	1991	2010
Mean 9am wet bulb temperature (Â°C) for years 1991 to 2010	17.3	17.5	16	14.6	11.6	9.1	8.5	9.1	11	12.5	14.9	15.9	13.2	16	1991	2010
Mean 9am dew point temperature (Â°C) for years 1991 to 2010	9.4	11.3	9.6	8.7	6.5	4.8	3.7	2.7	3.7	3.9	6.4	7.5	6.5	19	1991	2010
Mean 9am relative humidity (%) for years 1991 to 2010	38	47	48	51	55	62	60	50	43	37	37	36	47	19	1991	2010
Mean 9am cloud cover (okas) for years null to null																
Mean 9am wind speed (km/h) for years 1991 to 2010	23.5	23.8	23	20.5	19.7	18.2	17.2	20.3	22.1	23	22.5	22.6	21.4	19	1991	2010
Mean 3pm temperature (Â°C) for years 1991 to 2010	34.1	32.4	29.5	25.7	21.4	17.6	17.6	19.8	23.4	27	29.3	31.9	25.8	19	1991	2010
Mean 3pm wet bulb temperature (Â°C) for years 1991 to 2010	19.3	19.7	17.8	16	13.1	11	10.5	11.1	13.1	14.5	16.2	17.6	15	16	1991	2010
Mean 3pm dew point temperature (Â°C) for years 1991 to 2010	6.4	8.9	7.7	7.2	4.8	3.2	1.9	0.4	0.7	1	3.6	4.3	4.2	19	1991	2010
Mean 3pm relative humidity (%) for years 1991 to 2010	22	30	31	35	37	41	39	31	25	22	24	22	30	19	1991	2010
Mean 3pm cloud cover (oktas) for years null to null																
Mean 3pm wind speed (km/h) for years 1991 to 2010	19.2	19.6	18.3	16.7	16.3	17.9	17.9	19.5	21	20.8	20.6	20.5	19	19	1991	2010

Monthly Climate Statistics for 'LEINSTER AERO' [012314]
Created on [19 Jun 2024 15:05:31 UTC]

012314 LEINSTER AERO
Commenced: 1994
Last Record: 2024
Latitude: 27.84 Degrees South
Longitude: 120.70 Degrees East
Elevation: 497 m
State: WA

Statistic Element	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Number of Years	Start Year	End Year
Mean maximum temperature (Â°C) for years 1994 to 2024	37.3	35.6	32.1	28	23.2	19.3	19.1	21.8	25.8	29.9	32.8	35.8	28.4	29	1994	2024
Highest temperature (Â°C) for years 1994 to 2024	47.8	46.5	43.3	39.7	35.3	29.2	29.8	33.7	37.9	40.2	44.3	45.8	47.8	30	1994	2024
Date of Highest temperature Â°C for years 1994 to 2024	8-Jan-13	14-Feb-05	6-Mar-08	4-Apr-16	2-May-13	1-Jun-98	31-Jul-15	28-Aug-20	29-Sep-23	10-Oct-19	19-Nov-19	31-Dec-97	8-Jan-13	N/A	1994	2024
Lowest maximum temperature (Â°C) for years 1994 to 2024	15.9	19	16.6	16.1	11.7	10.9	9.7	12.8	11.6	14	19	18.2	9.7	30	1994	2024
Date of Lowest maximum temperature Â°C for years 1994 to 2024	30-Jan-18	1-Feb-18	30-Mar-06	8-Apr-95	10-May-97	8-Jun-96	11-Jul-11	5-Aug-18	2-Sep-10	5-Oct-17	10-Nov-21	18-Dec-10	11-Jul-11	N/A	1994	2024
Decile 1 maximum temperature (Â°C) for years 1994 to 2024	30.8	28.4	24.8	22.1	18.1	15.2	14.2	16.9	19.6	23.2	26.3	29.7		28	1994	2024
Decile 9 maximum temperature (Â°C) for years 1994 to 2024	42.9	42.1	38.3	34.1	28.3	23.6	23.6	27.8	31.8	36.2	38.7	41.3		28	1994	2024
Mean number of days >= 30 Â°C for years 1994 to 2024	27.7	23.1	19.8	9.3	1.1	0	0	1.2	6.4	15.4	20.5	26.7	151.2	30	1994	2024
Mean number of days >= 35 Â°C for years 1994 to 2024	22.4	15.6	9.5	1.8	0.1	0	0	0	0.6	5.1	10.5	18	83.6	30	1994	2024
Mean number of days >= 40 Â°C for years 1994 to 2024	10.3	5.9	1.1	0	0	0	0	0	0	0.1	1.5	5.1	24	30	1994	2024
Mean minimum temperature (Â°C) for years 1994 to 2024	23.3	22.2	19.3	15.4	10.4	7.2	6.2	7.8	10.9	14.9	18.3	21.4	14.8	29	1994	2024
Lowest temperature (Â°C) for years 1994 to 2024	12.5	13.5	8.7	5.3	1.4	-0.4	-1.6	-0.4	1.4	2.8	7.9	12.5	-1.6	30	1994	2024
Date of Lowest temperature Â°C for years 1994 to 2024	5-Jan-07	2-Feb-06	25-Mar-01	30-Apr-00	29-May-18	29-Jun-06	15-Jul-99	6-Aug-18	2-Sep-15	4-Oct-20	2-Nov-02	14-Dec-01	15-Jul-99	N/A	1994	2024
Highest minimum temperature (Â°C) for years 1994 to 2024	33.1	32.9	29.4	25.7	22.6	16.8	16.1	18.8	22	26.3	28.7	30.1	33.1	30	1994	2024
Date of Highest minimum temperature Â°C for years 1994 to 2024	2-Jan-04	14-Feb-05	3-Mar-98	27-Apr-05	2-May-05	23-Jun-19	17-Jul-20	26-Aug-23	12-Sep-23	24-Oct-08	17-Nov-19	7-Dec-19	2-Jan-04	N/A	1994	2024
Decile 1 minimum temperature (Â°C) for years 1994 to 2024	18.9	17.9	14.8	10.9	5.7	2.5	1.7	3	6	10	13.7	16.8		28	1994	2024
Decile 9 minimum temperature (Â°C) for years 1994 to 2024	27.7	26.9	23.8	19.8	15.6	12.3	11	13	15.5	20	23.1	25.8		28	1994	2024
Mean number of days <= 2 Â°C for years 1994 to 2024	0	0	0	0	0.1	1.7	3.6	1.5	0	0	0	0	6.9	30	1994	2024
Mean number of days <= 0 Â°C for years 1994 to 2024	0	0	0	0	0	0.2	0.6	0.1	0	0	0	0	0.9	30	1994	2024
Mean daily ground minimum temperature Â°C for years null to null																
Lowest ground temperature Â°C for years null to null																
Date of Lowest ground temperature Â°C for years null to null														N/A		
Mean number of days ground min. temp. <= -1 Â°C for years null to null																
Mean rainfall (mm) for years 1994 to 2024	39.4	39.9	35.8	23.9	14.1	13.5	15	8.5	4.1	11.3	16.2	22.4	245.9	29	1994	2024
Highest rainfall (mm) for years 1994 to 2024	133.4	128.4	193.8	74.2	94.8	64.4	72.8	45	26.8	69.4	77.2	125.8	439.4	29	1994	2024
Date of Highest rainfall for years 1994 to 2024	2000	2001	2017	1996	2005	1998	2004	1997	2010	2006	2008	1998	1997	N/A	1994	2024
Lowest rainfall (mm) for years 1994 to 2024	0	0	0	0.2	0	0	0	0	0	0	0	0.2	102.6	29	1994	2024
Date of Lowest rainfall for years 1994 to 2024	2015	2024	2008	2012	2018	2006	2023	2013	2020	2019	2020	2003	2020	N/A	1994	2024
Decile 1 monthly rainfall (mm) for years 1994 to 2024	0.7	0.4	3.1	2.7	0.1	1.4	0.2	0.2	0	0	0.2	1.8	143.9	29	1994	2024
Decile 5 (median) monthly rainfall (mm) for years 1994 to 2024	24.8	32.4	21.6	16.4	5	8.9	9.6	4.8	2	3	9.8	15	221.4	29	1994	2024
Decile 9 monthly rainfall (mm) for years 1994 to 2024	109.7	88.4	58.7	54.5	33.2	23.2	31.2	19.9	9.8	31.4	38	46.3	392.5	29	1994	2024
Highest daily rainfall (mm) for years 1994 to 2024	93.6	94	61	47	77.2	19	25	37	25.2	25.8	39.4	91	94	28	1994	2024
Date of Highest daily rainfall for years 1994 to 2024	26-Jan-24	23-Feb-01	11-Mar-00	12-Apr-96	6-May-05	11-Jun-96	14-Jul-98	5-Aug-97	1-Sep-10	26-Oct-06	17-Nov-08	7-Dec-98	23-Feb-01	N/A	1994	2024
Mean number of days of rain for years 1994 to 2024	5	5.6	5.8	4.6	4.1	4.6	4.5	3.5	2.1	2.8	4.2	4	50.8	29	1994	2024
Mean number of days of rain >= 1 mm for years 1994 to 2024	3.5	3.7	3.5	3.3	2	2.5	2.6	1.6	1	1.9	2.4	2.4	30.4	28	1994	2024
Mean number of days of rain >= 10 mm for years 1994 to 2024	1.2	1.4	0.9	0.6	0.4	0.4	0.3	0.1	0	0.4	0.4	0.6	6.7	28	1994	2024
Mean number of days of rain >= 25 mm for years 1994 to 2024	0.4	0.4	0.5	0.3	0	0	0	0	0	0	0.1	0.2	1.9	28	1994	2024
Mean daily wind run (km) for years 2003 to 2024	386	357	344	291	263	261	256	295	336	360	366	375	324	17	2003	2024
Maximum wind gust speed (km/h) for years 2003 to 2024	118	87	85	81	89	74	85	78	93	94	91	91	118	20	2003	2024
Date of Maximum wind gust speed for years 2003 to 2024	16-Jan-22	27-Feb-07	13-Mar-19	1-Apr-10	3-May-13	26-Jun-19	9-Jul-10	27-Aug-16	25-Sep-21	30-Oct-06	24-Nov-12	12-Dec-16	16-Jan-22	N/A	2003	2024
Mean daily sunshine (hours) for years null to null																
Mean daily solar exposure (MJ/(m*m)) for years 1990 to 2017	27.7	24.5	21.3	17.1	14	12	13.2	16.9	21.5	25.1	27.7	28.7	20.8	28	1990	2017
Mean number of clear days for years 2007 to 2010														3	2007	2010
Mean number of cloudy days for years 2007 to 2010														3	2007	2010
Mean daily evaporation (mm) for years null to null																
Mean 9am temperature (Â°C) for years 1994 to 2010	28.8	27.3	24.2	20.9	16.7	12.8	12	14.2	17.9	22.1	24.7	27.2	20.7	16	1994	2010
Mean 9am wet bulb temperature (Â°C) for years 1995 to 2010	17.8	18.1	16.3	14.9	11.7	9.4	8.6	9	11.2	12.8	15.2	16.6	13.5	13	1995	2010
Mean 9am dew point temperature (Â°C) for years 1995 to 2010	9	11.1	9.9	9.6	6.8	5.1	4.1	2.5	3.4	3.5	5.7	7.3	6.5	16	1995	2010
Mean 9am relative humidity (%) for years 1995 to 2010	34	42	45	52	55	62	62	49	41	33	34	32	45	16	1995	2010
Mean 9am cloud cover (okas) for years 2005 to 2010														3	2005	2010
Mean 9am wind speed (km/h) for years 1994 to 2010	21.4	21	20.6	17.7	17.4	16.3	16	18	19.8	20.8	20.8	20.6	19.2	16	1994	2010
Mean 3pm temperature (Â°C) for years 1994 to 2010	35.9	33.8	30.7	26.7	22.6	18.6	18	20.6	24.5	28.6	31.1	33.8	27.1	16	1994	2010
Mean 3pm wet bulb temperature (Â°C) for years 1995 to 2010	19.7	20.1	17.9	16.5	13.5	11.5	10.8	11.2	13.3	14.8	16.4	18	15.3	14	1995	2010
Mean 3pm dew point temperature (Â°C) for years 1995 to 2010	5.5	8.5	7.4	7.4	4.7	3.3	1.9	-0.5	-0.4	-0.3	1.8	3.5	3.6	16	1995	2010
Mean 3pm relative humidity (%) for years 1995 to 2010	20	27	28	34	34	40	38	28	22	18	19	18	27	16	1995	2010
Mean 3pm cloud cover (oktas) for years 2005 to 2010														4	2005	2010
Mean 3pm wind speed (km/h) for years 1994 to 2010	18	18.9	17.5	15.6	15.7	16.4	16.6	17.9	19.4	19.2	19.2	18.9	17.8	16	1994	2010

Monthly Climate Statistics for 'KALGOORLIE-BOULDER AIRPORT' [012038]

Created on [19 Jun 2024 14:53:33 UTC]

012038 KALGOORLIE-BOULDER AIRPORT
Commenced: 1939
Last Record: 2024
Latitude: 30.78 Degrees South
Longitude: 121.45 Degrees East
Elevation: 365 m
State: WA

Statistic Element	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Number of Years	Start Year	End Year
Mean maximum temperature (Â°C) for years 1939 to 2024	33.7	32.2	29.5	25.3	20.7	17.6	16.9	18.7	22.4	26	29.1	32.1	25.4	82	1939	2024
Highest temperature (Â°C) for years 1939 to 2024	46.5	46.5	44.5	40.1	33.4	27.6	28.7	32	37.9	40.9	44.7	45	46.5	83	1939	2024
Date of Highest temperature Â°C for years 1939 to 2024	22-Jan-90	21-Feb-24	10-Mar-73	11-Apr-19	2-May-02	15-Jun-47	30-Jul-01	26-Aug-23	29-Sep-23	16-Oct-95	17-Nov-19	31-Dec-72	21-Feb-24	N/A	1939	2024
Lowest maximum temperature (Â°C) for years 1939 to 2024	14.4	15	14.1	12.8	10.5	8.9	7.2	8.9	10.2	11.6	13.5	14.3	7.2	83	1939	2024
Date of Lowest maximum temperature Â°C for years 1939 to 2024	22-Jan-67	19-Feb-08	19-Mar-84	21-Apr-66	25-May-77	26-Jun-23	19-Jul-61	1-Aug-45	13-Sep-55	9-Oct-43	9-Nov-21	12-Dec-68	19-Jul-61	N/A	1939	2024
Decile 1 maximum temperature (Â°C) for years 1939 to 2024	27.2	25.3	22.8	19.6	16	13.8	13.1	14.3	16.9	19.6	22.7	25.8		81	1939	2024
Decile 9 maximum temperature (Â°C) for years 1939 to 2024	40.4	39.4	36.5	31.8	26	21.7	21	24	28.4	32.9	36	38.8		81	1939	2024
Mean number of days >= 30 Â°C for years 1939 to 2024	23.3	18.1	13.8	5.2	0.4	0	0	0.1	1.9	7.2	12.7	20.6	103.3	83	1939	2024
Mean number of days >= 35 Â°C for years 1939 to 2024	12.5	8.9	5	0.6	0	0	0	0	0.1	1.5	4.3	8.9	41.8	83	1939	2024
Mean number of days >= 40 Â°C for years 1939 to 2024	3.6	2.4	0.6	0	0	0	0	0	0	0	0.5	2	9.1	83	1939	2024
Mean minimum temperature (Â°C) for years 1939 to 2024	18.4	18	16.2	12.8	8.7	6.3	5.1	5.8	8.2	11.3	14.2	16.7	11.8	83	1939	2024
Lowest temperature (Â°C) for years 1939 to 2024	8.8	8.5	5.7	1.7	-1.8	-3	-3.4	-2.4	-0.6	-1	3.1	5.5	-3.4	83	1939	2024
Date of Lowest temperature Â°C for years 1939 to 2024	31-Jan-90	16-Feb-90	24-Mar-01	26-Apr-60	31-May-64	23-Jun-81	12-Jul-69	9-Aug-68	2-Sep-56	4-Oct-42	9-Nov-92	2-Dec-73	12-Jul-69	N/A	1939	2024
Highest minimum temperature (Â°C) for years 1939 to 2024	30.4	30.8	27.6	24.7	22.8	16.3	15.8	17.4	22.8	25.7	26.6	29.4	30.8	83	1939	2024
Date of Highest minimum temperature Â°C for years 1939 to 2024	24-Jan-94	24-Feb-91	6-Mar-90	1-Apr-89	3-May-47	5-Jun-57	30-Jul-16	28-Aug-50	12-Sep-23	28-Oct-09	27-Nov-17	7-Dec-19	24-Feb-91	N/A	1939	2024
Decile 1 minimum temperature (Â°C) for years 1939 to 2024	14.1	13.8	11.8	7.9	4	1.7	0.7	1.4	3.7	6.4	9.8	12.4		82	1939	2024
Decile 9 minimum temperature (Â°C) for years 1939 to 2024	23	22.6	20.4	17.2	13.5	10.8	9.4	10.4	12.6	15.8	18.9	21.7		82	1939	2024
Mean number of days <= 2 Â°C for years 1939 to 2024	0	0	0	0	0.7	3.6	6	4.4	0.8	0.1	0	0	15.6	83	1939	2024
Mean number of days <= 0 Â°C for years 1939 to 2024	0	0	0	0	0.1	0.6	1.7	0.9	0.1	0	0	0	3.4	83	1939	2024
Mean daily ground minimum temperature Â°C for years 1965 to 2009	16.9	16.8	14.5	11	6.8	3.9	2.8	3.1	5.7	9.1	12.7	15.4	9.9	44	1965	2009
Lowest ground temperature Â°C for years 1965 to 2016	7.7	4.6	2.3	-0.5	-3.7	-5.9	-8.3	-6.6	-4.9	-2.9	-0.9	2.8	-8.3	50	1965	2016
Date of Lowest ground temperature Â°C for years 1965 to 2016	31-Jan-90	23-Feb-67	26-Mar-72	30-Apr-00	28-May-72	19-Jun-66	13-Jul-69	7-Aug-66	4-Sep-70	2-Oct-66	1-Nov-68	2-Dec-73	13-Jul-69	N/A	1965	2016
Mean number of days ground min. temp. <= -1 Â°C for years 1965 to 2016	0	0	0	0	0.5	2.4	5.2	3.9	0.8	0.1	0	0	12.9	50	1965	2016
Mean rainfall (mm) for years 1939 to 2024	26.4	31.7	25.6	20.2	24.3	27	23.9	21.4	13.4	15.6	18.9	15.9	264.6	85	1939	2024
Highest rainfall (mm) for years 1939 to 2024	185.9	307.8	197	98.6	110.2	185.7	82.6	74	98.3	84.4	115.4	88.6	530.8	85	1939	2024
Date of Highest rainfall for years 1939 to 2024	1967	1948	1999	1961	1963	1968	1960	1992	1955	1982	1981	1988	1992	N/A	1939	2024
Lowest rainfall (mm) for years 1939 to 2024	0	0	0	0	0	1.4	0.6	1.6	0	0	0	0	108.7	85	1939	2024
Date of Lowest rainfall for years 1939 to 2024	1977	1998	2019	2001	1948	2008	1994	1989	2020	1979	1994	1964	1940	N/A	1939	2024
Decile 1 monthly rainfall (mm) for years 1939 to 2024	0.5	1.1	0.6	1.2	2.4	5.4	4.9	4.4	1	1	0.5	1.3	151.2	85	1939	2024
Decile 5 (median) monthly rainfall (mm) for years 1939 to 2024	10.8	14.6	10.6	12.8	18.4	18.8	20	16.2	10.4	10.2	15.4	11	245.4	85	1939	2024
Decile 9 monthly rainfall (mm) for years 1939 to 2024	76.1	80	73.8	54.2	46.8	53.9	48.8	42.9	29	33.4	40.4	39.7	388.9	85	1939	2024
Highest daily rainfall (mm) for years 1939 to 2024	154.4	177.8	70	49.8	45.2	57.2	28.6	49.6	44.2	45.6	77	50.6	177.8	85	1939	2024
Date of Highest daily rainfall for years 1939 to 2024	23-Jan-67	22-Feb-48	2-Mar-74	16-Apr-61	24-May-80	6-Jun-57	26-Jul-85	11-Aug-94	13-Sep-54	4-Oct-82	6-Nov-81	13-Dec-16	22-Feb-48	N/A	1939	2024
Mean number of days of rain for years 1939 to 2024	4	4.6	4.5	5.3	6.8	8.4	9	7.6	5.3	4.4	4.2	3.9	68	85	1939	2024
Mean number of days of rain >= 1 mm for years 1939 to 2024	2.5	3	2.7	3.3	3.8	4.7	4.7	4	2.8	2.7	2.7	2.4	39.3	85	1939	2024
Mean number of days of rain >= 10 mm for years 1939 to 2024	0.7	0.9	0.7	0.6	0.7	0.7	0.6	0.5	0.3	0.4	0.5	0.5	7.1	85	1939	2024
Mean number of days of rain >= 25 mm for years 1939 to 2024	0.2	0.3	0.3	0.1	0.1	0.1	0	0.1	0	0.1	0.1	0	1.4	85	1939	2024
Mean daily wind run (km) for years 1994 to 2024	430	405	361	297	265	273	285	300	346	378	401	419	347	27	1994	2024
Maximum wind gust speed (km/h) for years 1939 to 2024	141	118	118	104	122	102	97	108	109	117	139	122	141	82	1939	2024
Date of Maximum wind gust speed for years 1939 to 2024	14-Jan-94	16-Feb-70	28-Mar-71	24-Apr-73	5-May-75	4-Jun-74	30-Jul-48	12-Aug-64	13-Sep-65	3-Oct-50	7-Nov-79	10-Dec-46	14-Jan-94	N/A	1939	2024
Mean daily sunshine (hours) for years null to null																
Mean daily solar exposure (MJ/(m*m)) for years 1990 to 2017	27.6	24.1	20.4	15.9	12	10.3	11.2	14.7	19.1	23.8	26.6	28.5	19.5	28	1990	2017
Mean number of clear days for years 1939 to 2010	15.7	13.1	13.4	10.2	10.3	9.1	10.1	12.8	14.1	13.9	12.9	15.5	151.1	72	1939	2010
Mean number of cloudy days for years 1939 to 2010	5.6	6.3	6.9	9.2	10.2	10.4	9.7	7	6.2	5.9	6.5	5.3	89.2	72	1939	2010
Mean daily evaporation (mm) for years 1966 to 2016	12.5	10.8	8.6	5.8	3.6	2.6	2.8	3.8	5.8	8.4	10.3	12	7.2	50	1966	2016
Mean 9am temperature (Â°C) for years 1939 to 2010	23.8	22.8	21	17.9	13.9	11	9.9	11.6	14.8	17.9	20.6	22.7	17.3	72	1939	2010
Mean 9am wet bulb temperature (Â°C) for years 1939 to 2010	16.4	16.4	15.4	13.4	10.8	8.7	7.7	8.6	10.3	12	13.8	15.4	12.4	71	1939	2010
Mean 9am dew point temperature (Â°C) for years 1939 to 2010	10	11.2	10.4	9.2	7.4	6	4.9	4.6	4.9	5.5	6.9	8.6	7.5	65	1939	2010
Mean 9am relative humidity (%) for years 1939 to 2010	45	51	54	60	67	74	73	65	54	47	45	43	57	65	1939	2010
Mean 9am cloud cover (okas) for years 1939 to 2010	2.8	3.2	3.4	3.8	3.8	3.8	3.7	3.1	2.9	3	3.1	2.7	3.3	72	1939	2010
Mean 9am wind speed (km/h) for years 1939 to 2010	16.6	16.4	15.7	14.4	11.8	11.8	12.4	14.3	16.2	17.1	17.1	16.3	15	72	1939	2010
Mean 3pm temperature (Â°C) for years 1939 to 2010	32.3	30.9	28.6	24.3	19.9	16.8	16	17.8	21.3	24.7	27.8	30.7	24.3	72	1939	2010
Mean 3pm wet bulb temperature (Â°C) for years 1939 to 2010	18.8	18.9	17.8	15.6	13.1	11.2	10.4	10.9	12.5	14.1	15.9	17.7	14.7	71	1939	2010
Mean 3pm dew point temperature (Â°C) for years 1939 to 2010	7.2	9	8.4	7.5	6	4.9	3.5	2.4	2	2.3	3.8	5.8	5.2	65	1939	2010
Mean 3pm relative humidity (%) for years 1939 to 2010	24	30	32	38	44	48	46	39	31	27	25	24	34	65	1939	2010
Mean 3pm cloud cover (oktas) for years 1939 to 2010	2.8	3	3.1	3.8	4	4.3	4.1	3.5	3	3.1	3.3	2.8	3.4	72	1939	2010
Mean 3pm wind speed (km/h) for years 1939 to 2010	15.1	15.1	14.2	13.7	14.1	15.7	16.6	17.2	17.8	17.6	17.2	16	15.9	72	1939	2010

Monthly Climate Statistics for 'YAMARNA' [012219]

Created on [19 Jun 2024 16:37:16 UTC]

012219 YAMARNA

Commenced: 1967

Last Record: 1998

Latitude: 28.17 Degrees South

Longitude: 123.66 Degrees East

Elevation: 442 m

State: WA

Statistic Element	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Number of Years	Start Year	End Year
Mean maximum temperature (Â°C) for years 1968 to 1997	35.9	34.2	32.4	27.8	22.4	19	18.6	20.8	24.7	28.9	32	34.6	27.6	26	1968	1997
Highest temperature (Â°C) for years 1968 to 1997	46.6	45.6	43	39.2	37.2	29	28.4	33	36.7	41	43.4	44.5	46.6	26	1968	1997
Date of Highest temperature Â°C for years 1968 to 1997	15-Jan-93	12-Feb-91	1-Mar-88	9-Apr-85	3-May-90	4-Jun-95	31-Jul-69	29-Aug-95	16-Sep-81	16-Oct-95	28-Nov-93	24-Dec-86	15-Jan-93	N/A	1968	1997
Lowest maximum temperature (Â°C) for years 1968 to 1997	18.8	15.4	17.6	15.5	11.1	11.3	10.8	10.4	11.4	11.9	13.9	18	10.4	26	1968	1997
Date of Lowest maximum temperature Â°C for years 1968 to 1997	16-Jan-78	3-Feb-80	19-Mar-84	13-Apr-87	20-May-68	20-Jun-68	26-Jul-74	7-Aug-90	30-Sep-92	13-Oct-78	3-Nov-75	12-Dec-75	7-Aug-90	N/A	1968	1997
Decile 1 maximum temperature (Â°C) for years 1968 to 1997	30	26.7	25.4	21.1	17.2	15.1	14.2	15.8	19	22	25.8	28		27	1968	1997
Decile 9 maximum temperature (Â°C) for years 1968 to 1997	42.2	41	38.5	34	28.4	23.1	23.2	26.7	31.4	35.9	38.3	40.5		27	1968	1997
Mean number of days >= 30 Â°C for years 1968 to 1997	25.8	21.1	20.6	10.6	1.5	0	0	0.2	4.7	12.6	19.2	24.4	140.7	26	1968	1997
Mean number of days >= 35 Â°C for years 1968 to 1997	17.3	13	10.2	1.7	0.1	0	0	0	0.2	4.1	8.2	15.8	70.6	26	1968	1997
Mean number of days >= 40 Â°C for years 1968 to 1997	7	4.3	1.5	0	0	0	0	0	0	0.3	1.4	4	18.5	26	1968	1997
Mean minimum temperature (Â°C) for years 1968 to 1997	20.6	19.8	18	13.7	9	5.7	4.2	5.9	9.2	12.8	16.2	19.1	12.9	26	1968	1997
Lowest temperature (Â°C) for years 1968 to 1997	10.5	11.7	9.5	0.9	-1.9	-4.3	-4.8	-4	-0.5	2.9	2	6.8	-4.8	27	1968	1997
Date of Lowest temperature Â°C for years 1968 to 1997	31-Jan-97	22-Feb-72	26-Mar-84	21-Apr-92	23-May-75	23-Jun-81	12-Jul-69	3-Aug-75	3-Sep-92	2-Oct-68	21-Nov-92	7-Dec-92	12-Jul-69	N/A	1968	1997
Highest minimum temperature (Â°C) for years 1968 to 1997	31	29.1	28	24.4	20.9	18.8	15.1	16.2	22.8	23.4	28.5	29.5	31	27	1968	1997
Date of Highest minimum temperature Â°C for years 1968 to 1997	9-Jan-80	1-Feb-79	8-Mar-90	8-Apr-69	4-May-90	2-Jun-88	30-Jul-96	18-Aug-75	15-Sep-81	31-Oct-88	28-Nov-79	9-Dec-77	9-Jan-80	N/A	1968	1997
Decile 1 minimum temperature (Â°C) for years 1968 to 1997	16	15.4	13.6	9	4.2	1.1	-0.2	1.4	4.6	8	11.6	14.2		27	1968	1997
Decile 9 minimum temperature (Â°C) for years 1968 to 1997	25.6	24.7	22.4	18	14.5	11	9.8	10.5	14	17.8	21.3	23.6		27	1968	1997
Mean number of days <= 2 Â°C for years 1968 to 1997	0	0	0	0	1	5	9.5	4.5	0.3	0	0	0	20.3	27	1968	1997
Mean number of days <= 0 Â°C for years 1968 to 1997	0	0	0	0	0.2	1.4	3.8	1.2	0.1	0	0	0	6.7	27	1968	1997
Mean daily ground minimum temperature Â°C for years 1968 to 1994	19.6	18.8	16.8	12.1	7.5	4.2	2.7	4.4	7.6	11.2	14.7	17.9	11.5	23	1968	1994
Lowest ground temperature Â°C for years 1968 to 1994	10.6	4.8	7.6	-1.6	-3.5	-5.7	-6.4	-5.3	-1.6	1	0.5	6.3	-6.4	23	1968	1994
Date of Lowest ground temperature Â°C for years 1968 to 1994	27-Jan-80	9-Feb-71	25-Mar-76	8-Apr-72	23-May-75	18-Jun-74	12-Jul-69	3-Aug-75	4-Sep-70	2-Oct-86	9-Nov-92	7-Dec-92	12-Jul-69	N/A	1968	1994
Mean number of days ground min. temp. <= -1 Â°C for years 1968 to 1994	0	0	0	0	0.6	2.2	4.9	1.7	0.1	0	0	0	9.5	23	1968	1994
Mean rainfall (mm) for years 1967 to 1998	19.6	35.2	19.5	22.8	24.6	20.9	16	14.8	10.1	11.6	13	19.8	229.7	29	1967	1998
Highest rainfall (mm) for years 1967 to 1998	134.6	299.6	104.2	139	60	71.9	64.8	47	63.2	56.6	38.6	75.2	576.8	29	1967	1998
Date of Highest rainfall for years 1967 to 1998	1973	1980	1992	1992	1988	1968	1974	1978	1979	1976	1975	1984	1992	N/A	1967	1998
Lowest rainfall (mm) for years 1967 to 1998	0	0	0	0	0	0	0	0	0	0	0	0	78.7	29	1967	1998
Date of Lowest rainfall for years 1967 to 1998	1972	1998	1978	1994	1994	1984	1992	1995	1989	1995	1990	1985	1977	N/A	1967	1998
Decile 1 monthly rainfall (mm) for years 1967 to 1998	0.2	0.2	0.8	0	0	1.7	0.1	0.2	0.2	0	2	1.3	121.1	29	1967	1998
Decile 5 (median) monthly rainfall (mm) for years 1967 to 1998	7.5	21.8	6.8	8.5	23.3	14.7	9.8	8.6	5.4	6.1	9.8	9.6	201.9	29	1967	1998
Decile 9 monthly rainfall (mm) for years 1967 to 1998	50.2	70.5	57.6	58.6	52.9	56.2	38.3	39.7	23	33.6	31.8	44.6	301.6	29	1967	1998
Highest daily rainfall (mm) for years 1967 to 1998	81.3	125.8	44.4	39.9	36.2	31.6	39.4	24.2	37.4	38.2	21.8	31.2	125.8	29	1967	1998
Date of Highest daily rainfall for years 1967 to 1998	26-Jan-73	4-Feb-80	20-Mar-92	17-Apr-70	3-May-88	14-Jun-91	28-Jul-74	1-Aug-78	21-Sep-79	1-Oct-92	30-Nov-89	28-Dec-82	4-Feb-80	N/A	1967	1998
Mean number of days of rain for years 1967 to 1998	3.1	3.7	3.9	4.4	4.4	4.9	4.7	3.7	3	2.8	3.5	4.8	46.9	29	1967	1998
Mean number of days of rain >= 1 mm for years 1967 to 1998	1.9	2.5	2.7	2.5	3.2	3.1	2.8	2.4	1.8	1.7	2.1	3	29.7	29	1967	1998
Mean number of days of rain >= 10 mm for years 1967 to 1998	0.4	0.9	0.6	0.7	0.8	0.6	0.3	0.3	0.2	0.3	0.3	0.5	5.9	29	1967	1998
Mean number of days of rain >= 25 mm for years 1967 to 1998	0.3	0.3	0.1	0.2	0.1	0.1	0.1	0	0	0.1	0	0.1	1.4	29	1967	1998
Mean daily wind run (km) for years null to null																
Maximum wind gust speed (km/h) for years null to null																
Date of Maximum wind gust speed for years null to null														N/A		
Mean daily sunshine (hours) for years null to null																
Mean daily solar exposure (MJ/(m*m)) for years 1990 to 2017	27.1	24.4	21	16.9	13.8	12	13.1	16.9	21.2	24.8	26.9	28	20.5	28	1990	2017
Mean number of clear days for years 1968 to 1997	13.9	12.3	13.1	11.6	12	12.9	15	16.8	17.2	15.8	13.1	13.4	167.1	27	1968	1997
Mean number of cloudy days for years 1968 to 1997	5	6.4	6.8	7.3	8.1	8.2	7.1	5.6	4.1	4.7	6.2	6.3	75.8	27	1968	1997
Mean daily evaporation (mm) for years 1968 to 1997	14	12.1	10.1	7.1	4.4	3.2	3.2	4.3	6.8	9.3	11.5	13.1	8.3	24	1968	1997
Mean 9am temperature (Â°C) for years 1968 to 1997	27.3	25.8	24.3	20.6	15.8	12.6	11.9	13.9	17.8	21.5	24.3	26.4	20.2	27	1968	1997
Mean 9am wet bulb temperature (Â°C) for years 1968 to 1997	17.1	17.4	16.2	14	11.3	9.2	8.2	9.2	11.1	13	14.8	16.5	13.2	24	1968	1997
Mean 9am dew point temperature (Â°C) for years 1968 to 1997	8.4	10.9	9.2	7.8	6.1	5	3.5	3.2	3.3	3.8	5.8	7.9	6.2	23	1968	1997
Mean 9am relative humidity (%) for years 1968 to 1997	35	46	43	48	56	63	60	52	42	36	35	35	46	23	1968	1997
Mean 9am cloud cover (okas) for years 1968 to 1997	2.8	3	3	3.3	3.5	3.4	2.8	2.5	2.2	2.3	2.7	2.7	2.8	27	1968	1997
Mean 9am wind speed (km/h) for years 1968 to 1997	16.2	16.2	13.9	12.5	10.5	8.8	9.8	12.4	14.2	15.5	15.5	14.9	13.4	26	1968	1997
Mean 3pm temperature (Â°C) for years 1968 to 1997	34.7	33.1	31.1	26.6	21.4	18.1	17.9	19.9	23.9	27.7	30.6	33.3	26.5	27	1968	1997
Mean 3pm wet bulb temperature (Â°C) for years 1968 to 1997	19.2	19.5	18.1	16	13.3	11.4	10.7	11.4	13.2	14.9	16.6	18.4	15.2	24	1968	1997
Mean 3pm dew point temperature (Â°C) for years 1968 to 1997	6	9.1	7.3	6.3	4.7	3.6	1.8	1.1	1	1.2	3.4	5.7	4.3	23	1968	1997
Mean 3pm relative humidity (%) for years 1968 to 1997	20	28	27	32	37	42	38	32	25	22	21	21	29	23	1968	1997
Mean 3pm cloud cover (oktas) for years 1968 to 1997	3.2	3.6	3.4	3.5	3.7	3.5	2.9	2.6	2.5	2.9	3.3	3.4	3.2	27	1968	1997
Mean 3pm wind speed (km/h) for years 1968 to 1997	13.2	12.8	11.8	10.4	10.2	10.2	12	12.8	13.4	14.4	13.6	13	12.3	25	1968	1997

Monthly Climate Statistics for 'YEELIRRIE' [012090]

Created on [19 Jun 2024 16:38:34 UTC]

012090 YEELIRRIE

Commenced: 1928

Last Record: 2017

Latitude: 27.28 Degrees South

Longitude: 120.09 Degrees East

Elevation: 487 m

State: WA

Statistic Element	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Number of Years	Start Year	End Year
Mean maximum temperature (Â°C) for years 1973 to 2017	37.9	36.1	33.2	28.9	23.5	19.6	19.4	21.8	25.8	30.2	33.1	36.3	28.8	42	1973	2017
Highest temperature (Â°C) for years 1973 to 2017	47.9	46	44	40.7	36.8	29.9	30.4	33.4	37.5	41.5	43.2	45.4	47.9	44	1973	2017
Date of Highest temperature Â°C for years 1973 to 2017	8-Jan-13	11-Feb-91	2-Mar-80	4-Apr-16	3-May-90	1-Jun-98	31-Jul-15	29-Aug-95	30-Sep-98	20-Oct-04	10-Nov-10	31-Dec-10	8-Jan-13	N/A	1973	2017
Lowest maximum temperature (Â°C) for years 1973 to 2017	18.4	20.6	17.1	16	12.8	11.6	9	9.2	13.2	11.1	15.2	20	9	44	1973	2017
Date of Lowest maximum temperature Â°C for years 1973 to 2017	31-Jan-06	16-Feb-01	8-Mar-82	23-Apr-83	11-May-79	24-Jun-93	13-Jul-04	30-Aug-77	30-Sep-09	13-Oct-78	3-Nov-75	17-Dec-10	13-Jul-04	N/A	1973	2017
Decile 1 maximum temperature (Â°C) for years 1973 to 2017	32.5	29.5	26.4	22.6	18.4	15.3	15	16.6	20	23.6	27	30.6		43	1973	2017
Decile 9 maximum temperature (Â°C) for years 1973 to 2017	42.8	41.9	39	34.5	29.1	24	24	27.5	31.9	36.4	39	41		43	1973	2017
Mean number of days >= 30 Â°C for years 1973 to 2017	28.7	24.5	22.7	12.7	1.8	0	0	0.7	6.2	15.8	21.9	27.4	162.4	44	1973	2017
Mean number of days >= 35 Â°C for years 1973 to 2017	23.3	17.5	12	1.9	0	0	0	0	0.4	5.7	10.8	19.7	91.3	44	1973	2017
Mean number of days >= 40 Â°C for years 1973 to 2017	11	6.2	1.9	0	0	0	0	0	0	0.1	1.8	5.8	26.8	44	1973	2017
Mean minimum temperature (Â°C) for years 1973 to 2017	22.2	21.3	18.3	14	8.2	4.7	3.6	4.7	7.9	12.7	16.4	20	12.8	42	1973	2017
Lowest temperature (Â°C) for years 1973 to 2017	12	10	6	3	-2.8	-5	-5.1	-4.8	-2.2	-0.4	1.9	7.6	-5.1	44	1973	2017
Date of Lowest temperature Â°C for years 1973 to 2017	8-Jan-89	17-Feb-90	29-Mar-07	30-Apr-99	27-May-77	23-Jun-81	27-Jul-00	2-Aug-93	5-Sep-99	7-Oct-94	2-Nov-99	1-Dec-87	27-Jul-00	N/A	1973	2017
Highest minimum temperature (Â°C) for years 1973 to 2017	31.6	31.4	28.8	24.3	20.5	16.4	15.7	17.9	21.4	26	27.9	29.6	31.6	44	1973	2017
Date of Highest minimum temperature Â°C for years 1973 to 2017	20-Jan-91	14-Feb-07	10-Mar-79	4-Apr-87	2-May-05	7-Jun-87	24-Jul-73	29-Aug-98	14-Sep-81	27-Oct-10	30-Nov-98	1-Dec-94	20-Jan-91	N/A	1973	2017
Decile 1 minimum temperature (Â°C) for years 1973 to 2017	17.8	16.7	13.2	9	2.5	-1	-2.1	-0.6	2.8	7	11.3	15		42	1973	2017
Decile 9 minimum temperature (Â°C) for years 1973 to 2017	26.6	25.6	23.2	18.6	14.3	11	10.2	10.4	13	18.1	21.4	24.6		42	1973	2017
Mean number of days <= 2 Â°C for years 1973 to 2017	0	0	0	0	2.2	9.1	12.5	8.4	1.9	0.1	0	0	34.2	44	1973	2017
Mean number of days <= 0 Â°C for years 1973 to 2017	0	0	0	0	0.5	4.7	7.3	4.3	0.6	0	0	0	17.4	44	1973	2017
Mean daily ground minimum temperature Â°C for years null to null																
Lowest ground temperature Â°C for years null to null																
Date of Lowest ground temperature Â°C for years null to null														N/A		
Mean number of days ground min. temp. <= -1 Â°C for years null to null																
Mean rainfall (mm) for years 1928 to 2017	30.2	31.2	34	24.1	24.7	22.6	17.2	12.3	4.7	9.4	10.4	19.9	240.2	90	1928	2017
Highest rainfall (mm) for years 1928 to 2017	159.9	166.2	155.1	211	89.4	146	101	80.3	39.2	90.4	63.6	102.4	506.8	90	1928	2017
Date of Highest rainfall for years 1928 to 2017	1955	2011	2017	1992	1982	1986	1974	1947	1984	2006	1975	1994	1975	N/A	1928	2017
Lowest rainfall (mm) for years 1928 to 2017	0	0	0	0	0	0	0	0	0	0	0	0	42.8	90	1928	2017
Date of Lowest rainfall for years 1928 to 2017	1998	2013	1989	1994	2017	1984	2017	2012	2015	2013	1997	2003	1950	N/A	1928	2017
Decile 1 monthly rainfall (mm) for years 1928 to 2017	0.7	0.3	0	0	0.5	1	1	0	0	0	0	0	121.8	90	1928	2017
Decile 5 (median) monthly rainfall (mm) for years 1928 to 2017	14.8	14.9	16.9	17.4	15	13.4	10.2	7.2	1.3	3.5	5.9	9.9	226.6	90	1928	2017
Decile 9 monthly rainfall (mm) for years 1928 to 2017	85.2	96	103.2	58.2	63.6	58.9	41.3	28.7	13.3	29.8	29	58.1	397	90	1928	2017
Highest daily rainfall (mm) for years 1928 to 2017	90.2	68.4	99.1	66.4	47	61.2	44	41.2	33.7	34.3	42	77	99.1	90	1928	2017
Date of Highest daily rainfall for years 1928 to 2017	23-Jan-52	2-Feb-85	30-Mar-31	16-Apr-92	1-May-30	13-Jun-89	19-Jul-80	30-Aug-77	1-Sep-10	25-Oct-06	15-Nov-17	19-Dec-94	30-Mar-31	N/A	1928	2017
Mean number of days of rain for years 1928 to 2017	4.1	4	4.2	3.9	4.1	5	4.4	3	1.6	2	2.5	3.1	41.9	90	1928	2017
Mean number of days of rain >= 1 mm for years 1928 to 2017	3.4	3.2	3.4	3.2	3	3.7	3.1	2.1	1.1	1.4	1.9	2.5	32	90	1928	2017
Mean number of days of rain >= 10 mm for years 1928 to 2017	0.9	0.8	0.9	0.7	0.8	0.6	0.5	0.3	0.1	0.3	0.2	0.6	6.7	90	1928	2017
Mean number of days of rain >= 25 mm for years 1928 to 2017	0.3	0.3	0.4	0.2	0.2	0.1	0	0	0	0.1	0.1	0.1	1.8	90	1928	2017
Mean daily wind run (km) for years null to null																
Maximum wind gust speed (km/h) for years null to null																
Date of Maximum wind gust speed for years null to null														N/A		
Mean daily sunshine (hours) for years null to null																
Mean daily solar exposure (MJ/(m*m)) for years 1990 to 2017	27.6	24.5	21.4	17.3	14.3	12.3	13.5	17.2	21.8	25.3	27.9	28.8	21	28	1990	2017
Mean number of clear days for years 1973 to 2010	15.2	11.2	13.7	11.1	14.1	13.3	16.1	17.7	18.8	18.2	15.9	15.4	180.7	37	1973	2010
Mean number of cloudy days for years 1973 to 2010	4.7	6.7	6.5	7.9	7.3	6.8	6.4	3.8	2.6	3	3.6	4.4	63.7	37	1973	2010
Mean daily evaporation (mm) for years 1982 to 1985														4	1982	1985
Mean 9am temperature (Â°C) for years 1973 to 2010	29.7	27.8	25.4	21.3	16.1	11.9	11.1	13.7	17.9	22.1	25.2	28.2	20.9	37	1973	2010
Mean 9am wet bulb temperature (Â°C) for years 1973 to 2010	18.8	18.6	17.2	15.2	11.8	9	8.2	9.4	11.4	13.4	15.4	17.5	13.8	34	1973	2010
Mean 9am dew point temperature (Â°C) for years 1973 to 2010	10.5	11.6	10.6	9.9	7.5	5.7	4.5	4.2	4.4	4.6	6.5	8.5	7.4	34	1973	2010
Mean 9am relative humidity (%) for years 1973 to 2010	34	42	43	52	59	68	66	56	44	36	33	32	47	34	1973	2010
Mean 9am cloud cover (okas) for years 1973 to 2010	2.2	3	2.7	3.3	3	3	2.7	2.2	1.7	1.9	2.1	2.1	2.5	37	1973	2010
Mean 9am wind speed (km/h) for years 1973 to 2010	13.2	12.4	11.7	9.8	8.1	6.9	7.4	10.3	12.8	14	13.8	12.7	11.1	36	1973	2010
Mean 3pm temperature (Â°C) for years 1973 to 2010	36.7	34.8	32.4	27.9	22.7	18.7	18.4	20.7	24.9	28.9	31.8	35	27.7	37	1973	2010
Mean 3pm wet bulb temperature (Â°C) for years 1973 to 2010	20.7	20.5	19.2	17.3	14.3	11.9	11.4	12.2	13.8	15.4	17.2	19.2	16.1	34	1973	2010
Mean 3pm dew point temperature (Â°C) for years 1973 to 2010	8.5	9.8	8.8	8.6	6	4.4	3.4	2.5	1.9	1.8	3.8	5.9	5.4	34	1973	2010
Mean 3pm relative humidity (%) for years 1973 to 2010	21	27	27	34	37	42	41	33	26	20	19	19	29	34	1973	2010
Mean 3pm cloud cover (oktas) for years 1973 to 2010	3.2	3.6	3.4	3.8	3.2	3.2	2.8	2.3	1.8	2.2	2.8	3.1	2.9	37	1973	2010
Mean 3pm wind speed (km/h) for years 1973 to 2010	10.7	11	10.1	8.9	9	9.3	10.6	12.5	13.8	14.3	13.2	11.4	11.2	35	1973	2010

APPENDIX B

RAINFALL INTENSITY FREQUENCY DURATION RELATIONSHIP FOR THE APOLLO HILL PILOT PROJECT

IFD Design Rainfall Depth (mm)

Issued: 03 June 2023

Rainfall depth for Durations, Exceedance per Year (EY), and Annual Exceedance Probabilities (AEP).
FAQ for New ARR probability terminology

Table | Chart

Unit: mm

	Annual Exceedance Probability (AEP)						
Duration	**63.2%**	**50%#**	**20%***	**10%**	**5%**	**2%**	**1%**
1 min	1.08	1.30	2.08	2.68	3.33	4.29	5.11
2 min	1.83	2.21	3.53	4.57	5.70	7.46	9.00
3 min	2.50	3.01	4.81	6.22	7.76	10.1	12.1
4 min	3.07	3.71	5.93	7.65	9.53	12.4	14.8
5 min	3.58	4.32	6.90	8.91	11.1	14.3	17.1
10 min	5.39	6.52	10.4	13.4	16.7	21.4	25.5
15 min	6.57	7.95	12.7	16.4	20.4	26.1	31.1
20 min	7.45	9.01	14.4	18.6	23.1	29.7	35.3
25 min	8.15	9.85	15.8	20.3	25.2	32.5	38.6
30 min	8.74	10.5	16.9	21.7	27.0	34.8	41.5
45 min	10.1	12.1	19.4	25.0	31.0	40.1	47.9
1 hour	11.1	13.3	21.2	27.3	34.0	44.0	52.7
1.5 hour	12.7	15.2	24.0	30.9	38.4	49.8	59.7
2 hour	13.9	16.6	26.2	33.7	41.8	54.2	64.9
3 hour	15.8	18.8	29.6	38.0	47.2	61.0	73.0
4.5 hour	18.0	21.5	33.6	43.0	53.3	68.8	82.2
6 hour	19.8	23.6	36.8	47.1	58.4	75.1	89.5
9 hour	22.6	26.9	42.0	53.7	66.6	85.4	102
12 hour	24.9	29.6	46.2	59.1	73.2	93.9	111
18 hour	28.2	33.6	52.6	67.5	83.9	108	128
24 hour	30.6	36.5	57.5	74.0	92.2	118	141
30 hour	32.4	38.8	61.3	79.2	98.9	127	152
36 hour	33.9	40.6	64.4	83.5	105	135	161
48 hour	36.0	43.2	69.1	90.0	113	147	177
72 hour	38.5	46.2	74.7	98.2	125	164	198
96 hour	39.8	47.8	77.7	103	131	173	211
120 hour	40.4	48.6	79.2	105	135	179	218
144 hour	40.8	49.1	79.9	106	136	181	221
168 hour	41.0	49.3	80.1	106	137	181	221

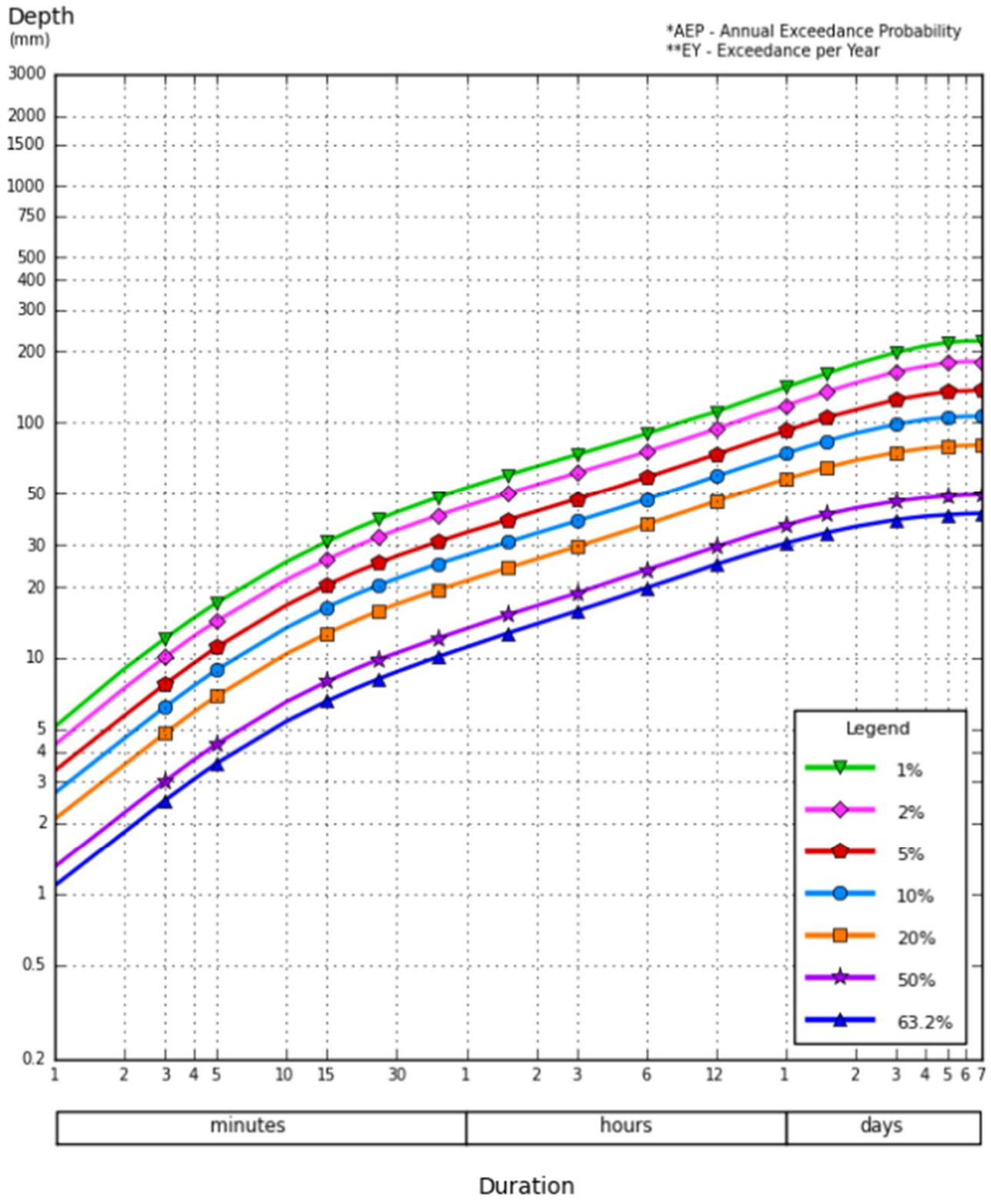
IFD Design Rainfall Depth (mm)

Issued: 03 June 2023

Rainfall depth for Durations, Exceedance per Year (EY), and Annual Exceedance Probabilities (AEP).
FAQ for New ARR probability terminology

Table | Chart

Unit: mm



CARRICK CONSULTING (WA) PTY LTD

APPENDIX A
POINT RAINFALL INTENSITY FREQUENCY DURATION CHART (FREQUENT/INFREQUENT EVENTS)

Date: June 24
Client: Saturn Metals Ltd.
Project: Apollo Hill Pilot Project
Document: J2209-R01
Ref: BoM Design Rainfall Data System (2016)

IFD Design Rainfall Intensity (mm/h)

Issued: 03 June 2023

Rainfall intensity for Durations, Exceedance per Year (EY), and Annual Exceedance Probabilities (AEP).
FAQ for New ARR probability terminology

Table | Chart

Unit: mm/h

	Annual Exceedance Probability (AEP)						
Duration	**63.2%**	**50%#**	**20%***	**10%**	**5%**	**2%**	**1%**
1 min	64.6	78.1	125	161	200	258	307
2 min	55.0	66.2	106	137	171	224	270
3 min	50.0	60.2	96.2	124	155	202	243
4 min	46.1	55.6	88.9	115	143	185	222
5 min	42.9	51.8	82.8	107	133	172	205
10 min	32.3	39.1	62.6	80.6	100	129	153
15 min	26.3	31.8	50.9	65.6	81.4	105	124
20 min	22.4	27.0	43.3	55.7	69.2	89.0	106
25 min	19.6	23.6	37.8	48.7	60.5	77.9	92.8
30 min	17.5	21.1	33.7	43.4	54.0	69.6	82.9
45 min	13.4	16.2	25.8	33.3	41.4	53.5	63.9
1 hour	11.1	13.3	21.2	27.3	34.0	44.0	52.7
1.5 hour	8.43	10.1	16.0	20.6	25.6	33.2	39.8
2 hour	6.93	8.29	13.1	16.8	20.9	27.1	32.5
3 hour	5.26	6.28	9.86	12.7	15.7	20.3	24.3
4.5 hour	4.01	4.77	7.46	9.56	11.9	15.3	18.3
6 hour	3.30	3.93	6.13	7.85	9.73	12.5	14.9
9 hour	2.52	2.99	4.67	5.97	7.40	9.49	11.3
12 hour	2.07	2.47	3.85	4.92	6.10	7.82	9.29
18 hour	1.57	1.87	2.92	3.75	4.66	5.97	7.09
24 hour	1.27	1.52	2.39	3.08	3.84	4.93	5.87
30 hour	1.08	1.29	2.04	2.64	3.30	4.25	5.06
36 hour	0.942	1.13	1.79	2.32	2.90	3.75	4.48
48 hour	0.751	0.900	1.44	1.88	2.36	3.07	3.68
72 hour	0.535	0.642	1.04	1.36	1.73	2.28	2.75
96 hour	0.414	0.498	0.809	1.07	1.37	1.81	2.20
120 hour	0.337	0.405	0.660	0.874	1.12	1.49	1.81
144 hour	0.283	0.341	0.555	0.735	0.946	1.26	1.53
168 hour	0.244	0.293	0.477	0.630	0.813	1.08	1.32

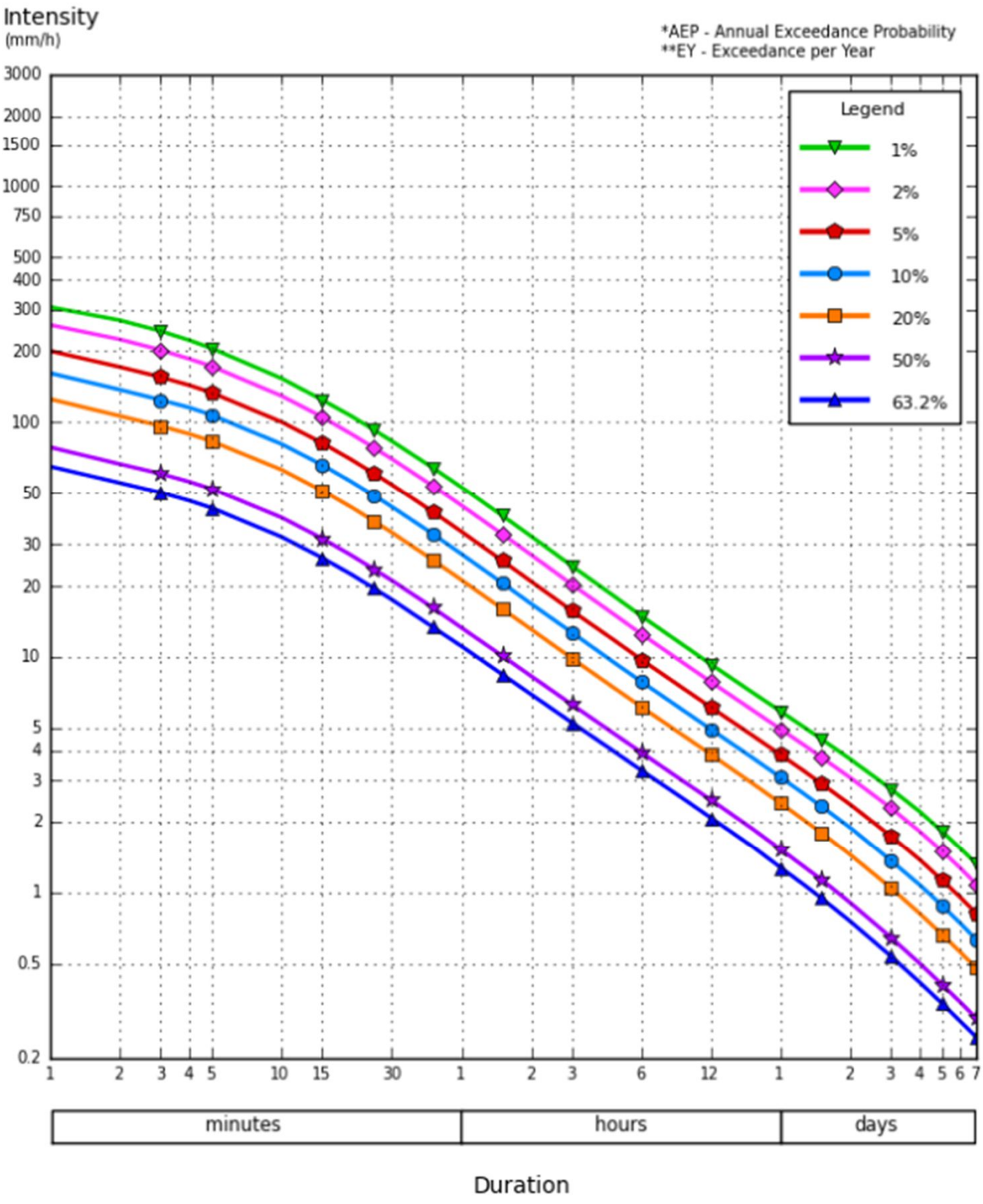
IFD Design Rainfall Intensity (mm/h)

Issued: 03 June 2023

Rainfall intensity for Durations, Exceedance per Year (EY), and Annual Exceedance Probabilities (AEP).
FAQ for New ARR probability terminology

Table | Chart

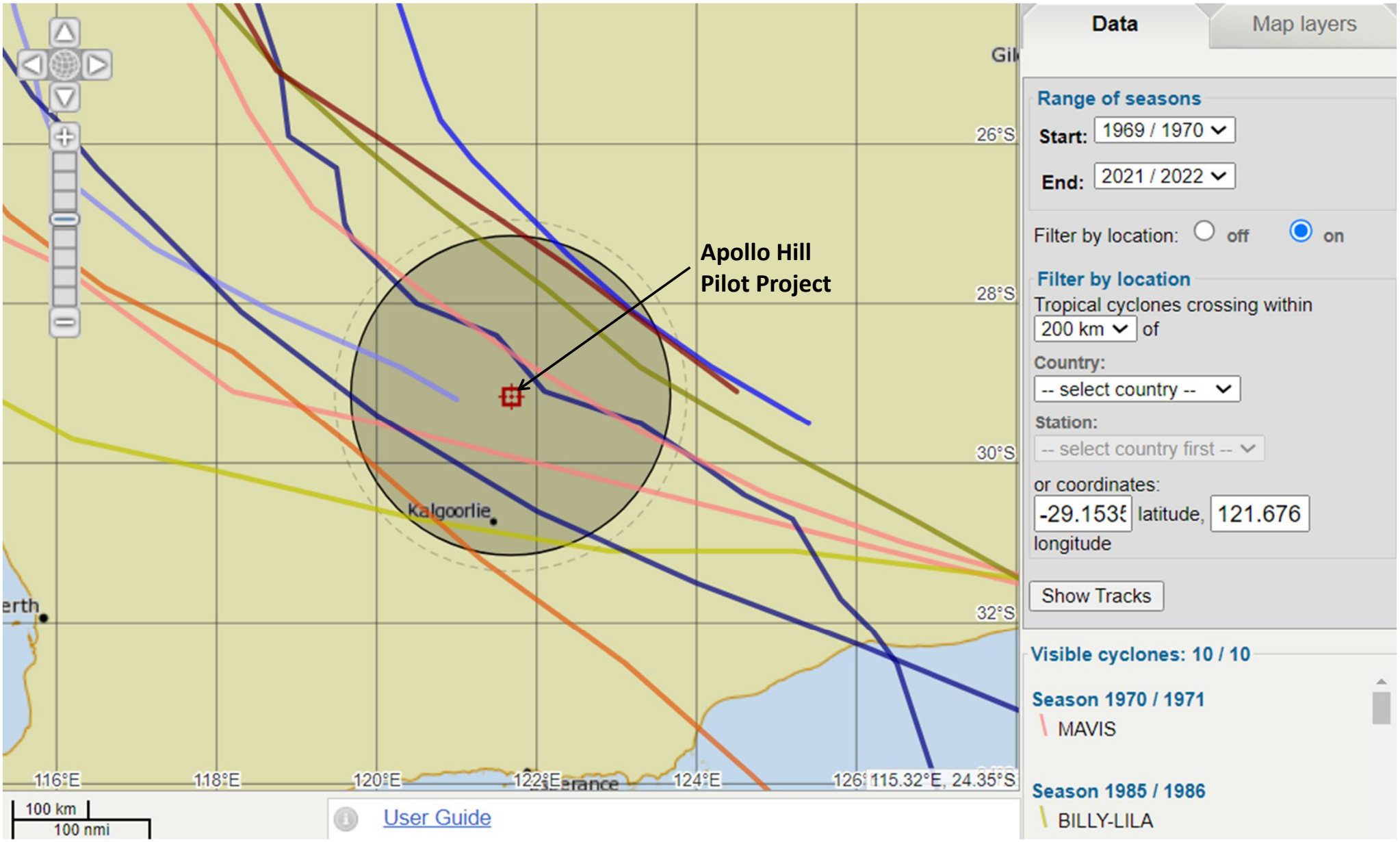
Unit: mm/h



CARRICK CONSULTING (WA) PTY LTD	**APPENDIX A** **POINT RAINFALL DEPTH FREQUENCY DURATION CHART (FREQUENT/INFREQUENT EVENTS)**	Date: June 24 Client: Saturn Metals Ltd. Project: Apollo Hill Pilot Project Document: J2209-R01 Ref: BoM Design Rainfall Data System (2016)

APPENDIX C

CYCLONE SWEPT PATH ANALYSIS



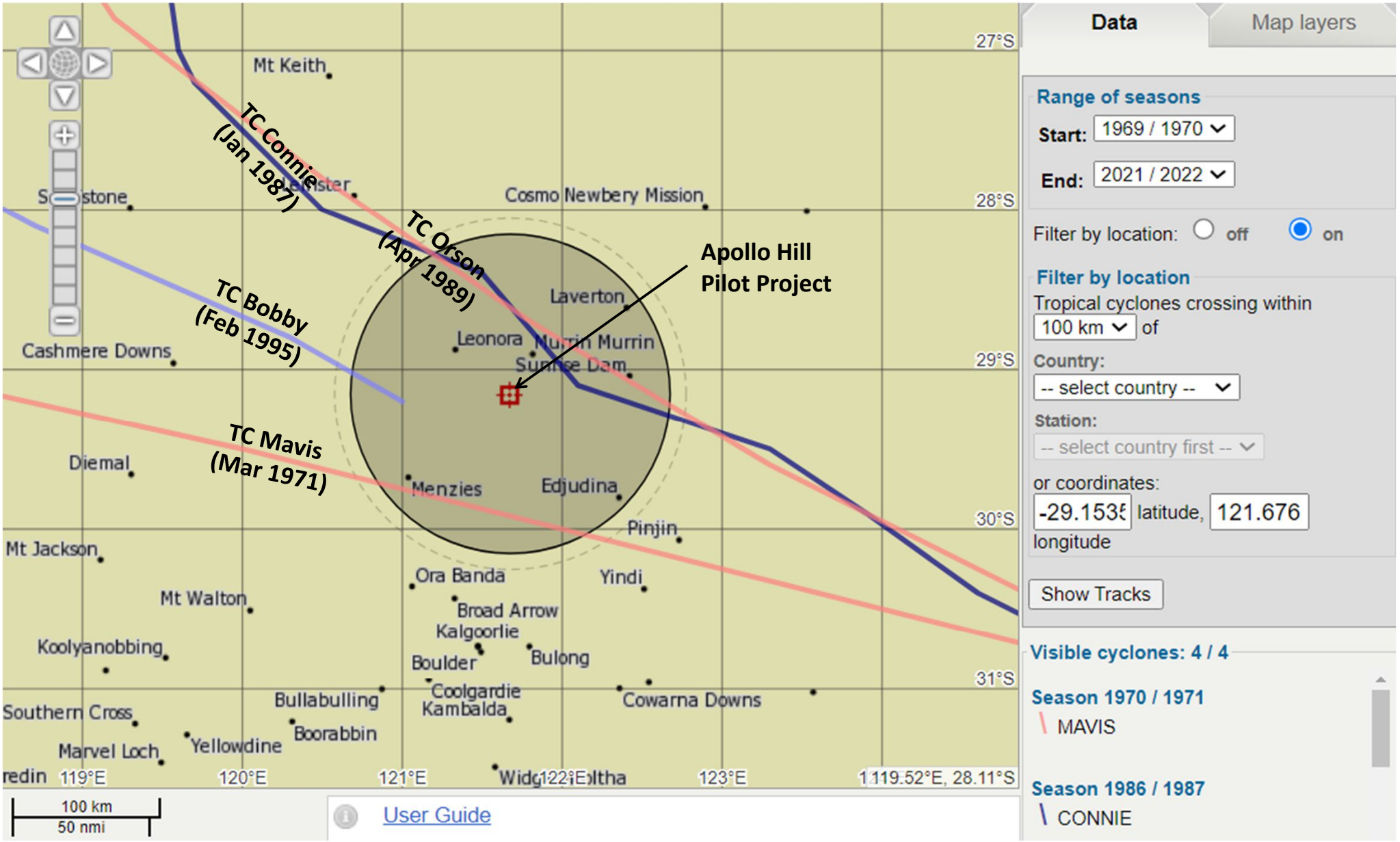
CARRICK CONSULTING (WA) PTY LTD

APPENDIX C
APOLLO HILL PILOT PROJECT
CYCLONE PATHS WITHIN 200 KM OF SITE

Date: June 24
Client: Saturn Metals Ltd
Project: Apollo Hill Pilot Project
Document: J2209-R01

Notes:
1. Figure not to scale.

Sources:
1. Cyclone paths from BoM data portal.



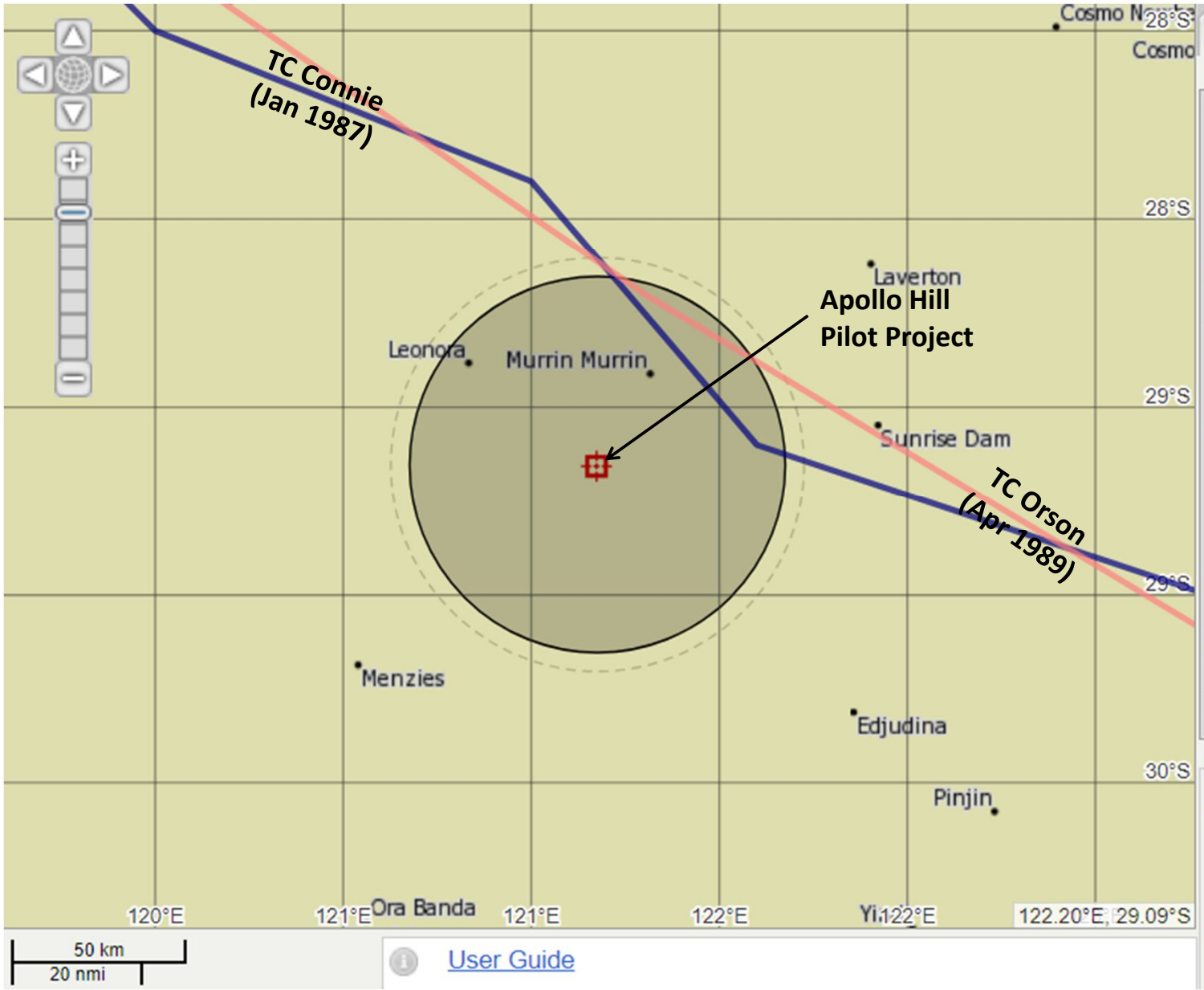
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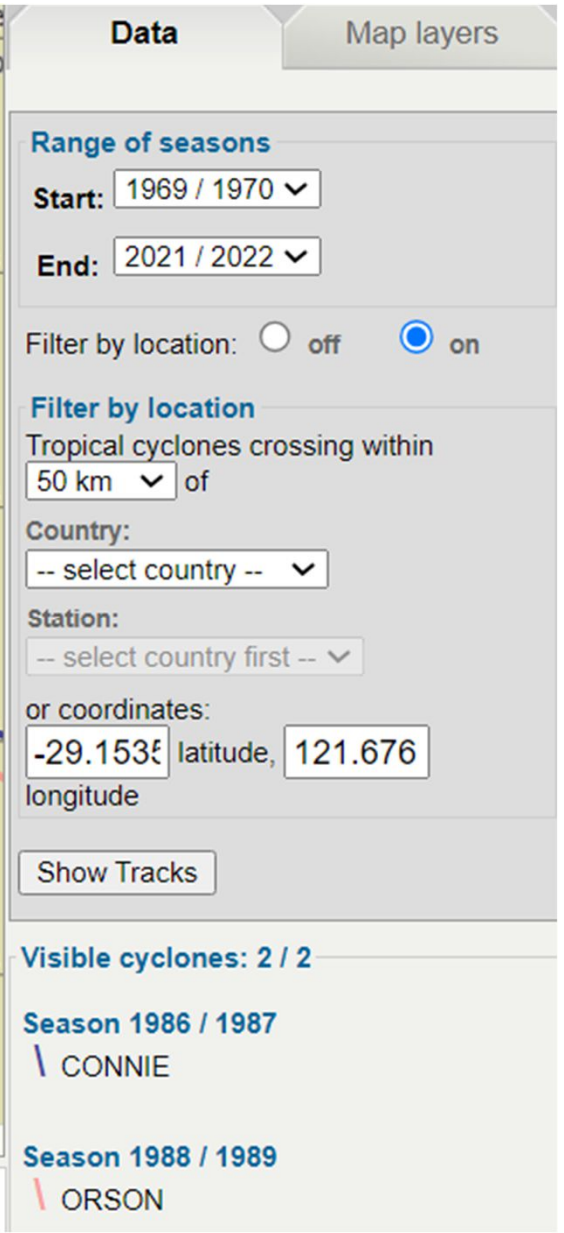
APPENDIX C
APOLLO HILL PILOT PROJECT
CYCLONE PATHS WITHIN 100 KM OF SITE

Date: June 24
Client: Saturn Metals Ltd
Project: Apollo Hill Pilot Project
Document: J2209-R01

Notes:
1. Figure not to scale.

Sources:
1. Cyclone paths from BoM data portal.





APPENDIX C
APOLLO HILL PILOT PROJECT
CYCLONE PATHS WITHIN 50 KM OF SITE

Date: June 24
Client: Saturn Metals Ltd
Project: Apollo Hill Pilot Project
Document: J2209-R01

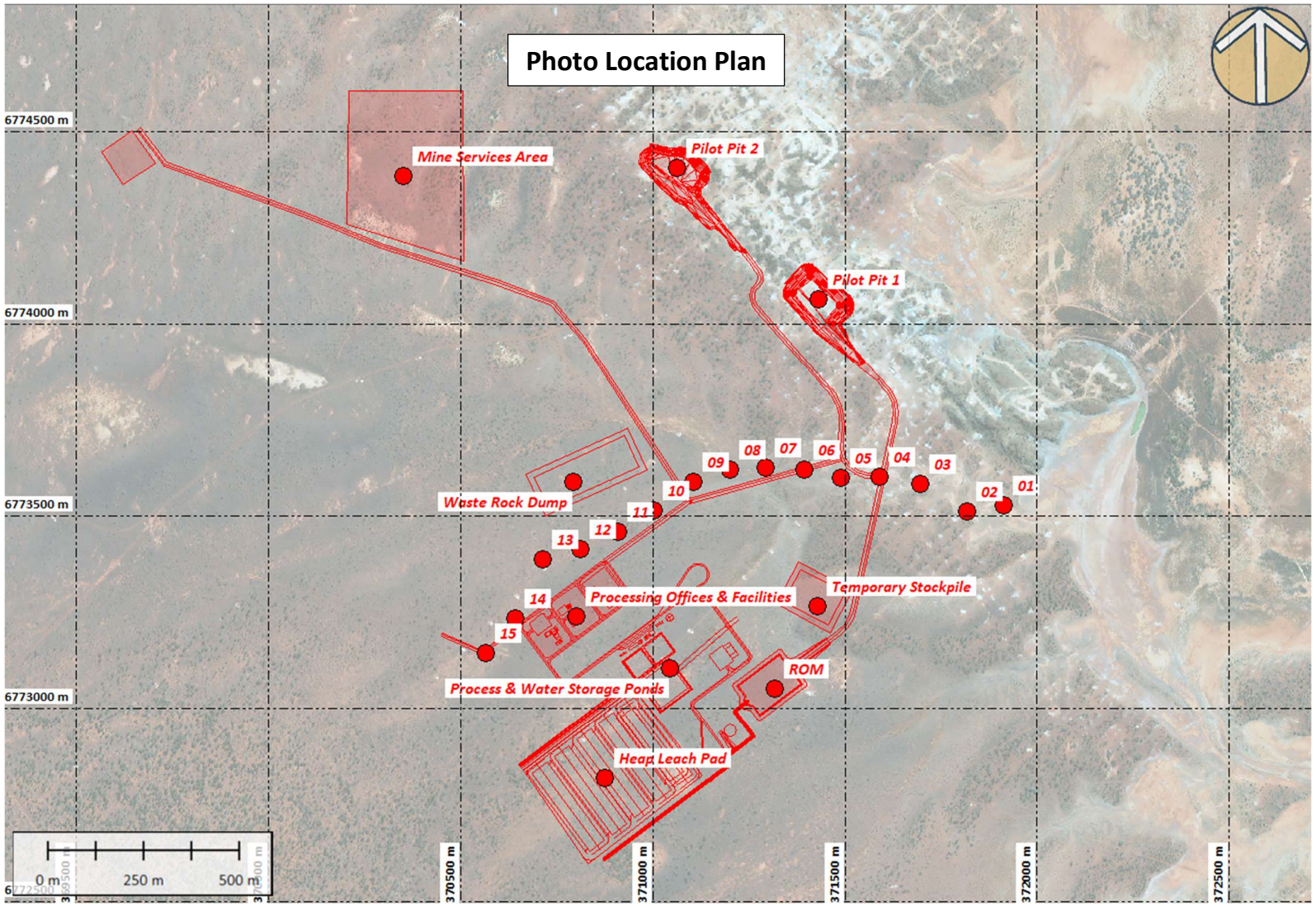
Notes:
1. Figure not to scale.

Sources:
1. Cyclone paths from BoM data portal.

APPENDIX D

SITE PHOTGRAPHS

(Photographs taken 25 June 2024)


Photo Location Plan
Mine Services Area
Pilot Pit 2
Pilot Pit 1
Waste Rock Dump
Processing Offices & Facilities
Temporary Stockpile
ROM
Process & Water Storage Ponds
Heap Leach Pad
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
6774500 m
6774000 m
6773500 m
6773000 m
370500 m
371000 m
371500 m
372000 m
372500 m
0 m
250 m
500 m



Central Drainage Location 1 - View North



Central Drainage Location 1 - View East



Central Drainage Location 1 - View South



Central Drainage Location 1 - View West



Central Drainage Location 2 - View North



Central Drainage Location 2 - View East



Central Drainage Location 2 - View South



Central Drainage Location 2 - View West



Central Drainage Location 3 - View North



Central Drainage Location 3 - View East



Central Drainage Location 3 - View South



Central Drainage Location 3 - View West



Central Drainage Location 4 - View North



Central Drainage Location 4 - View East



Central Drainage Location 4 - View South



Central Drainage Location 4 - View West



Central Drainage Location 5 - View North



Central Drainage Location 5 - View East



Central Drainage Location 5 - View South



Central Drainage Location 5 - View West



Central Drainage Location 6 - View North



Central Drainage Location 6 - View East



Central Drainage Location 6 - View South



Central Drainage Location 6 - View West



Central Drainage Location 7 - View North



Central Drainage Location 7 - View East



Central Drainage Location 7 - View South



Central Drainage Location 7 - View West



Central Drainage Location 8 - View North



Central Drainage Location 8 - View East



Central Drainage Location 8 - View South



Central Drainage Location 8 - View West



Central Drainage Location 9 - View North



Central Drainage Location 9 - View East



Central Drainage Location 9 - View South



Central Drainage Location 9 - View West



Central Drainage Location 10 - View North



Central Drainage Location 10 - View East



Central Drainage Location 10 - View South



Central Drainage Location 10 - View West



Central Drainage Location 11 - View North



Central Drainage Location 11 - View East



Central Drainage Location 11 - View South



Central Drainage Location 11 - View West



Central Drainage Location 12 - View North



Central Drainage Location 12 - View East



Central Drainage Location 12 - View South



Central Drainage Location 12 - View West



Central Drainage Location 13 - View North



Central Drainage Location 13 - View East



Central Drainage Location 13 - View South



Central Drainage Location 13 - View West



Central Drainage Location 14 - View North



Central Drainage Location 14 - View East



Central Drainage Location 14 - View South



Central Drainage Location 14 - View West



Central Drainage Location 15 - View North



Central Drainage Location 15 - View East



Central Drainage Location 15 - View South



Central Drainage Location 15 - View West



Heap Leach Pad Area - View North



Heap Leach Pad Area - View East



Heap Leach Pad Area - View South



Heap Leach Pad Area - View West



Mine Services Area - View North



Mine Services Area - View East



Mine Services Area - View South



Mine Services Area - View West



Pit 1 - View North



Pit 1 - View East



Pit 1 - View South



Pit 1 - View West



Pit 2 - View North



Pit 2 - View East



Pit 2 - View South



Pit 2 - View West



Process Pond Area - View North



Process Pond Area - View East



Process Pond Area - View South



Process Pond Area - View West



Processing Offices & Facilities - View North



Processing Offices & Facilities - View East



Processing Offices & Facilities - View South



Processing Offices & Facilities - View West



ROM Area - View North



ROM Area - View East



ROM Area - View South



ROM Area - View West



Temporary Stockpile Area - View North



Temporary Stockpile Area - View East



Temporary Stockpile Area - View South



Temporary Stockpile Area - View West



Waste Rock Dump Area - View North



Waste Rock Dump Area - View East



Waste Rock Dump Area - View South



Waste Rock Dump Area - View West

APPENDIX E

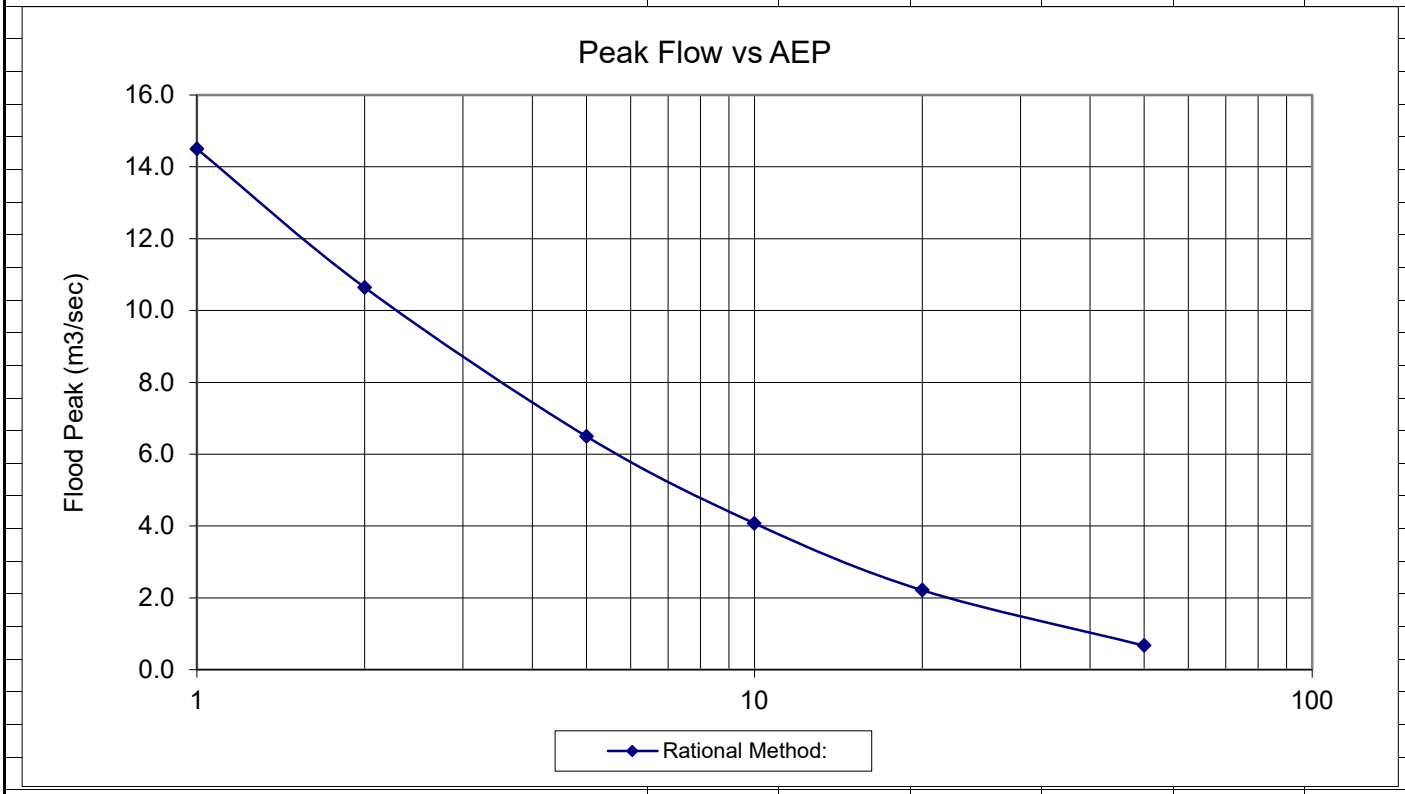
PEAK FLOW ESTIMATES &

HYDRAULIC DESIGN CALCULATIONS

Saturn Metals Ltd - Apollo Hill Pilot Project

Haul Road Crossing Sub-Catchment Peak Flow Estimate

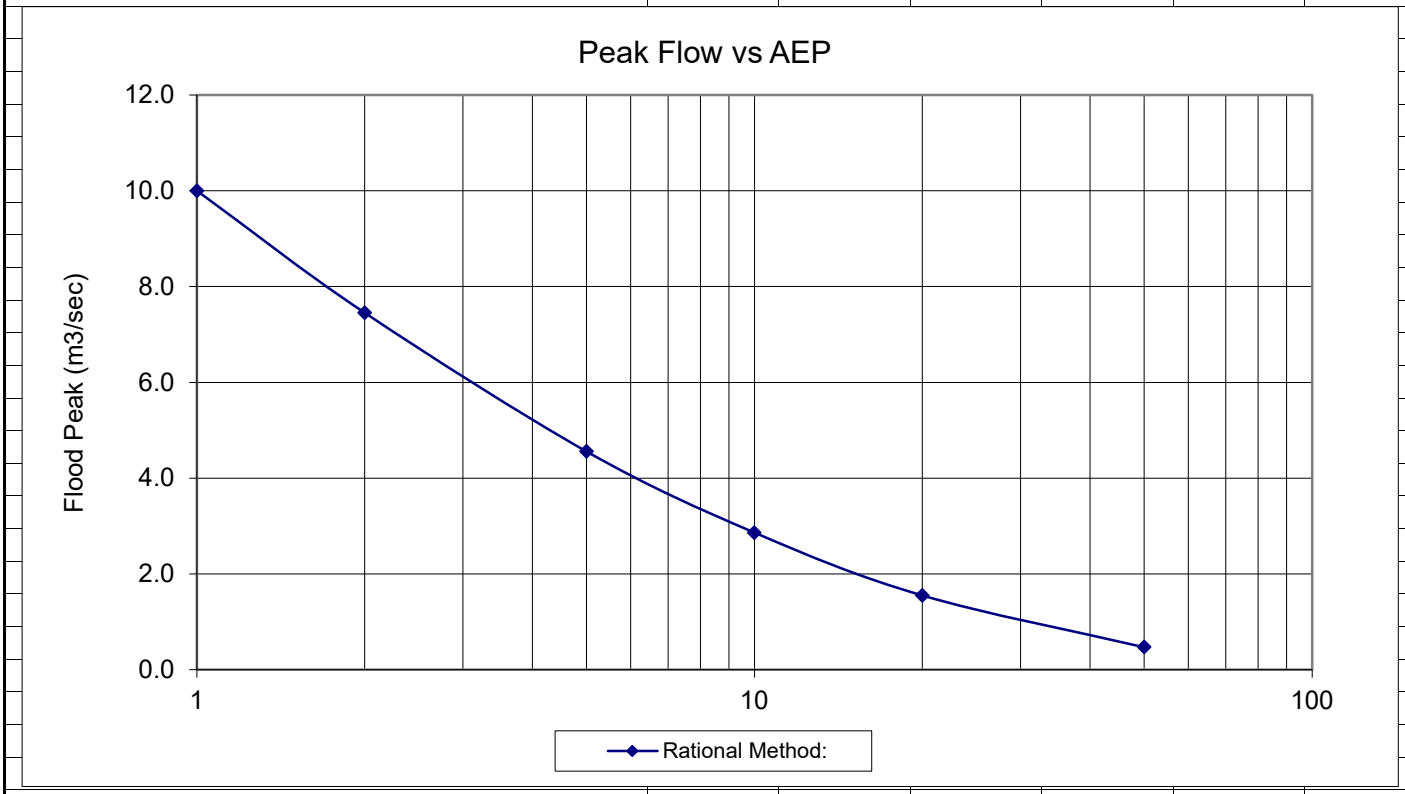
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Calc Date: 27 June 2024			Chk'd Date:			
Sub-Catchment Peak Flow Estimation						
(ref: AR&R 1987, Vol. 1, Book 4)						
Assume Wheatbelt Loamy soil catchments 75-100% cleared						
With Arid Interior Frequency Factors						
Catchment Characteristics:						
Catchment Area , A =	2.715	km2				
Mainstream Length, L =	3.290	km				
Equal Area Stream Slope, Se =	1.7	m/km				
Cleared Area as percentage of catchment, CL =	75-100	%				
Average Annual Rainfall, P =	239	mm				
Rational Method:	**50**	**20**	**10**	**5**	**2**	**1**
tc=0.76A^0.38=	1.11	hours =	67	mins		
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C10=3.46*10^-1L^-0.42=	0.210	-				
	50	**20**	**10**	**5**	**2**	**1**
Frequency Factor (C_Y/C_{10})	0.34	0.7	1	1.28	1.62	1.93
Flood Peak Qy=0.278C_{10}(Cy/C10)IA (m3/sec)	0.7	2.2	4.1	6.5	10.6	14.5



Saturn Metals Ltd - Apollo Hill Pilot Project

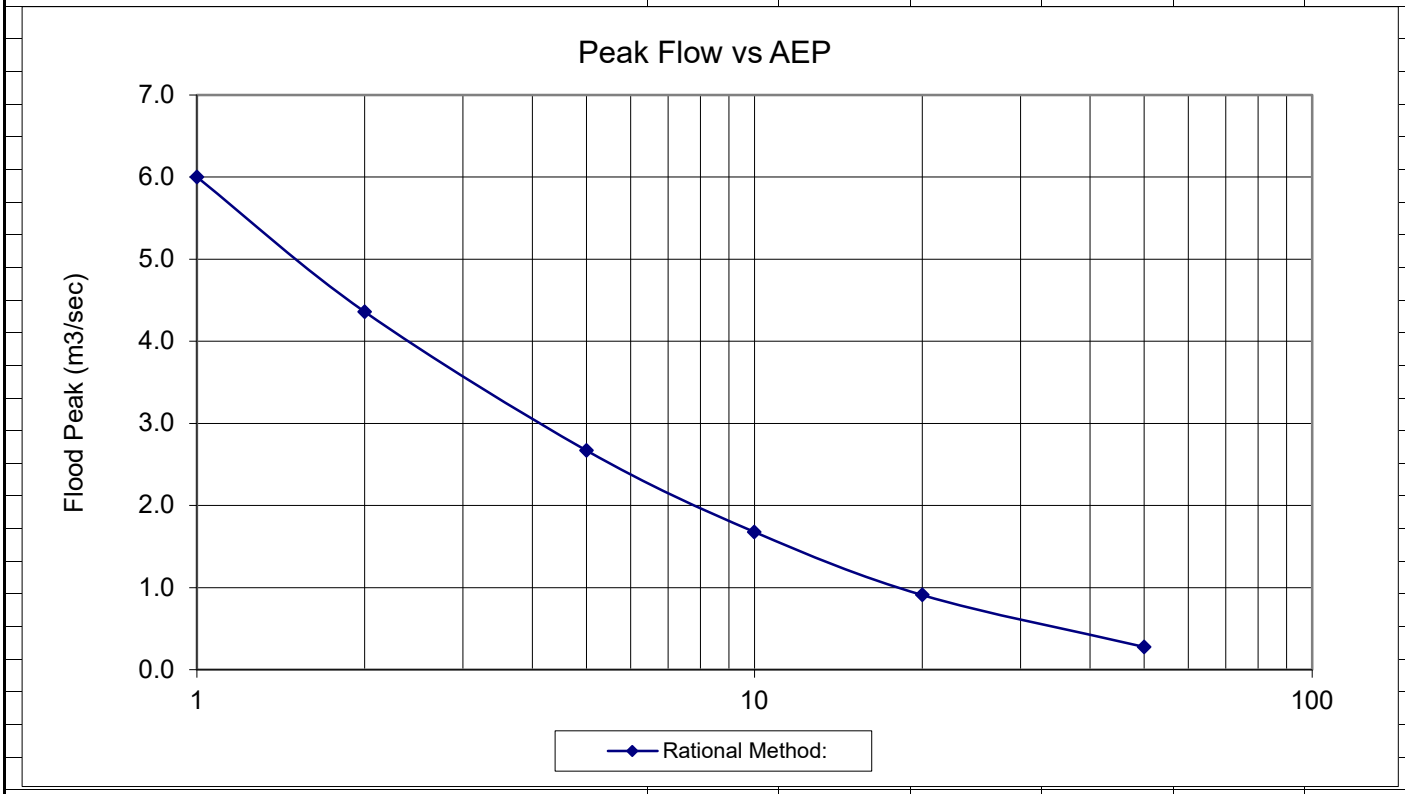
Processing Area Sub-Catchment Peak Flow Estimate

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Calc Date: 27 June 2024			Chk'd Date:			
Sub-Catchment Peak Flow Estimation						
(ref: AR&R 1987, Vol. 1, Book 4)						
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With Arid Interior Frequency Factors						
Catchment Characteristics:						
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Equal Area Stream Slope, Se =	1.5	m/km				
Cleared Area as percentage of catchment, CL =	75-100	%				
Average Annual Rainfall, P =	239	mm				
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C10=3.46*10^-1L^-0.42=	0.279	-				
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Frequency Factor (C_Y/C_{10})	0.34	0.7	1	1.28	1.62	1.93
Flood Peak Qy=0.278C_{10}(Cy/C10)IA (m3/sec)	0.5	1.6	2.9	4.6	7.5	10.0



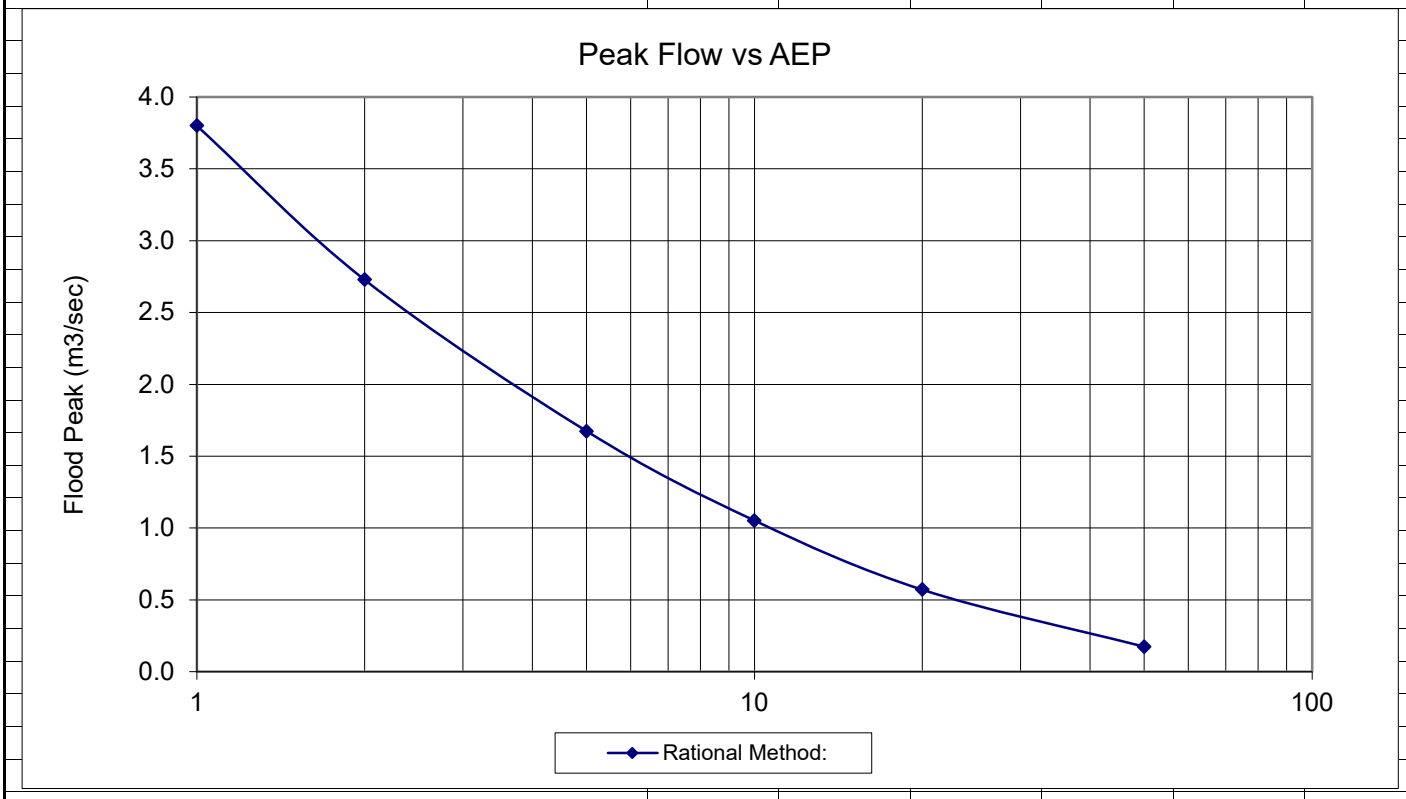
Saturn Metals Ltd - Apollo Hill Pilot Project
Mine Yard Sub-Catchment Peak Flow Estimate

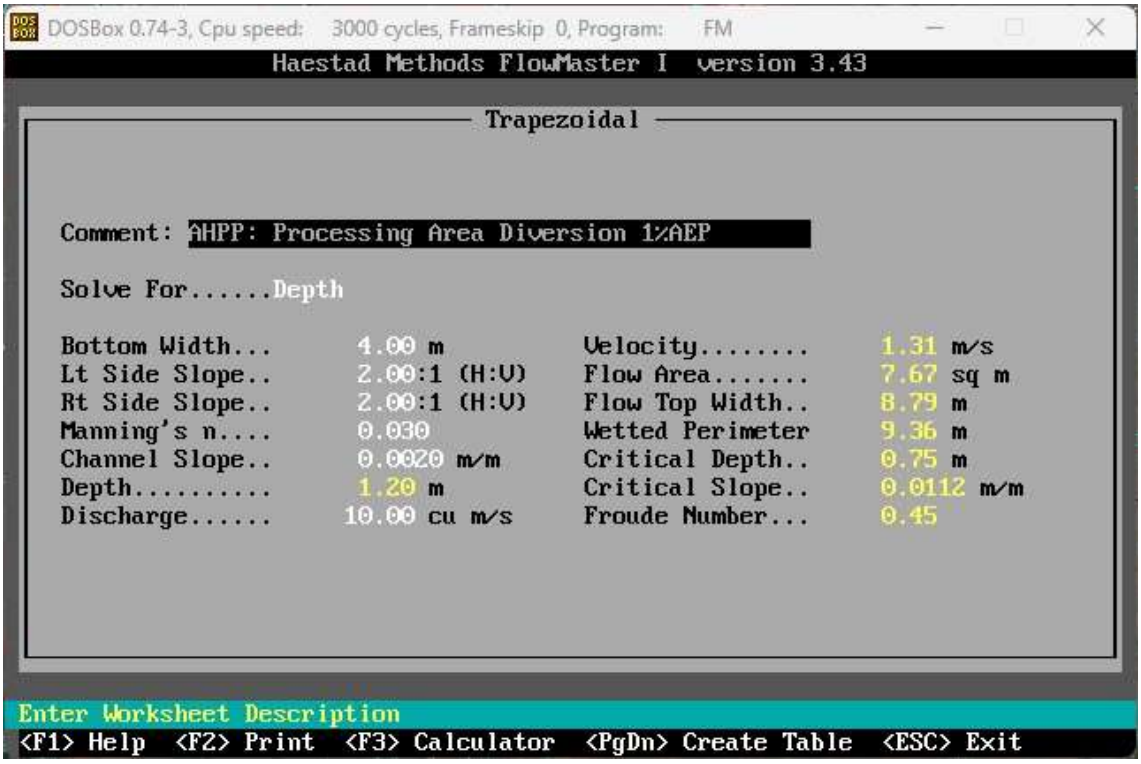
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Calc Date: 27 June 2024			Chk'd Date:			
Sub-Catchment Peak Flow Estimation						
(ref: AR&R 1987, Vol. 1, Book 4)						
Assume Wheatbelt Loamy soil catchments 75-100% cleared						
With Arid Interior Frequency Factors						
Catchment Characteristics:						
Catchment Area , A =	0.568	km2				
Mainstream Length, L =	1.735	km				
Equal Area Stream Slope, Se =	0.8	m/km				
Cleared Area as percentage of catchment, CL =	75-100	%				
Average Annual Rainfall, P =	239	mm				
Rational Method:	**50**	**20**	**10**	**5**	**2**	**1**
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Rainfall Intensity for Time of Concentration => $I_{tc,Y}$=	18.8	30.0	38.7	48.1	62.1	74.0
C10=3.46*10^-1L^-0.42=	0.275	-				
	50	**20**	**10**	**5**	**2**	**1**
Frequency Factor (C_Y/C_{10})	0.34	0.7	1	1.28	1.62	1.93
Flood Peak Qy=0.278C_{10}(Cy/C10)IA (m3/sec)	0.3	0.9	1.7	2.7	4.4	6.0

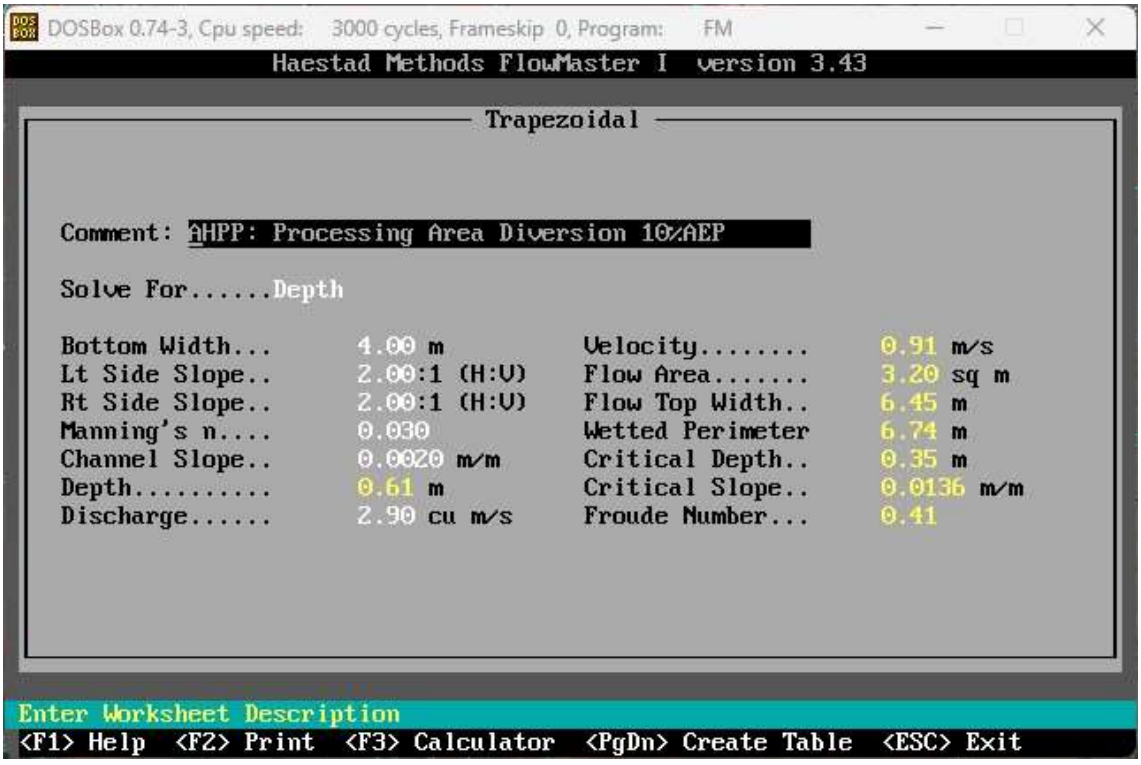


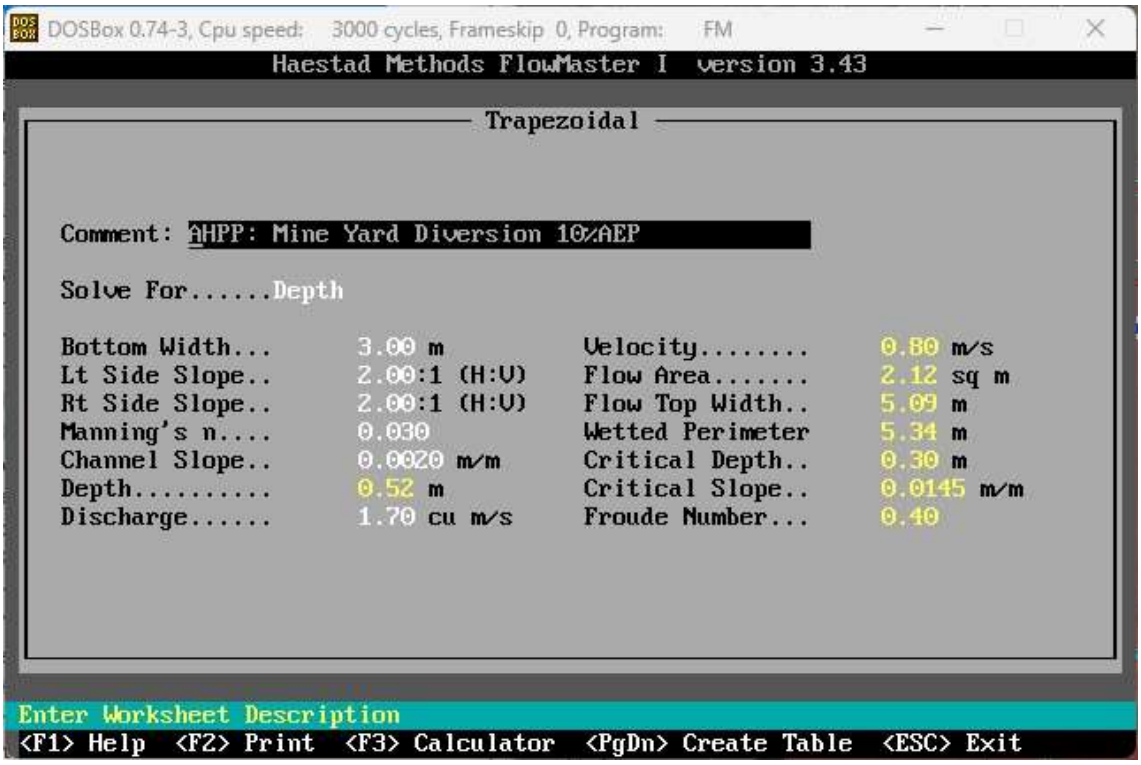
Saturn Metals Ltd - Apollo Hill Pilot Project
Magazine Sub-Catchment Peak Flow Estimate

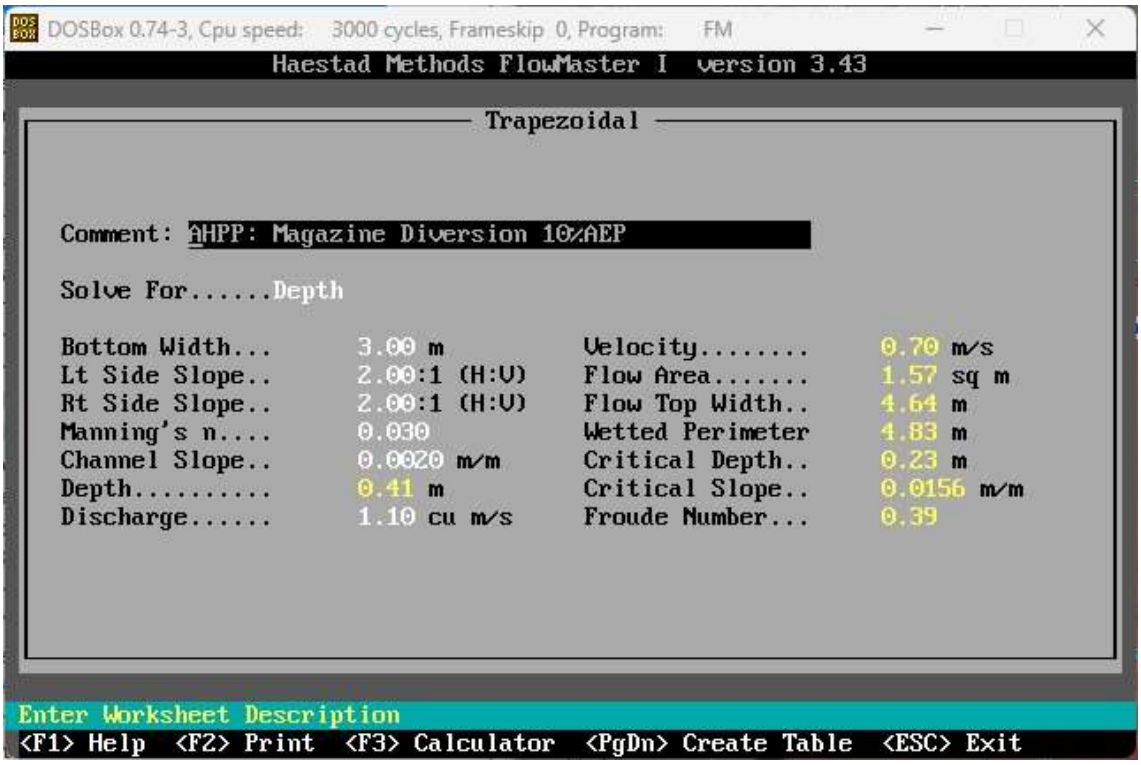
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With Arid Interior Frequency Factors						
Catchment Characteristics:						
Catchment Area , A =	0.246	km2				
Mainstream Length, L =	1.118	km				
Equal Area Stream Slope, Se =	1.0	m/km				
Cleared Area as percentage of catchment, CL =	75-100	%				
Average Annual Rainfall, P =	239	mm				
Rational Method:	**50**	**20**	**10**	**5**	**2**	**1**
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Rainfall Intensity for Time of Concentration => $I_{tc,Y}$=	22.6	36.2	46.6	57.9	74.6	88.8
C10=3.46*10^-1L^-0.42=	0.330	-				
	50	**20**	**10**	**5**	**2**	**1**
Frequency Factor (C_Y/C_{10})	0.34	0.7	1	1.28	1.62	1.93
Flood Peak Qy=0.278C_{10}(Cy/C10)IA (m3/sec)	0.2	0.6	1.1	1.7	2.7	3.8




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Haestad Methods FlowMaster I version 3.43
Trapezoidal
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Solve For.....Depth
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Lt Side Slope.. 2.00:1 (H:V)
Rt Side Slope.. 2.00:1 (H:V)
Manning's n.... 0.030
Channel Slope.. 0.0020 m/m
Depth..... 1.20 m
Discharge..... 10.00 cu m/s
Velocity..... 1.31 m/s
Flow Area..... 7.67 sq m
Flow Top Width.. 8.79 m
Wetted Perimeter 9.36 m
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Trapezoidal
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Lt Side Slope.. 2.00:1 (H:V)
Rt Side Slope.. 2.00:1 (H:V)
Manning's n.... 0.030
Channel Slope.. 0.0020 m/m
Depth..... 0.61 m
Discharge..... 2.90 cu m/s
Velocity..... 0.91 m/s
Flow Area..... 3.20 sq m
Flow Top Width.. 6.45 m
Wetted Perimeter 6.74 m
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Haestad Methods FlowMaster I version 3.43
Trapezoidal
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Bottom Width... 3.00 m
Lt Side Slope.. 2.00:1 (H:V)
Rt Side Slope.. 2.00:1 (H:V)
Manning's n.... 0.030
Channel Slope.. 0.0020 m/m
Depth..... 0.52 m
Discharge..... 1.70 cu m/s
Velocity..... 0.80 m/s
Flow Area..... 2.12 sq m
Flow Top Width.. 5.09 m
Wetted Perimeter 5.34 m
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Trapezoidal
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Rt Side Slope.. 2.00:1 (H:V)
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Discharge..... 1.10 cu m/s
Velocity..... 0.70 m/s
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APPENDIX B
Pentium Water (2023) Water Quality Results

PENTIUM WATER

APOLLO HILL PROJECT – PILOT PLANT AND BULK SAMPLE PIT DEVELOPMENT

Groundwater Studies

Saturn Metals

SATAPOL

15 March 2023



Document Status

Version	Purpose of document	Authored by	Reviewed by	Review Date
A	Draft for comment	EW	RS	28/02/2023
0	Revised	EW	NT	15/03/2023

Approval for Issue

Name	Signature	Date
Nathan Tetlaw		15/03/2023

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Version: 0

Date: 15 March 2023

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Executive Summary

Saturn Metals Limited (**Saturn**) are looking to develop the Pilot Plant and Bulk Sample Pit for their Apollo Hill Project (the **Project**) southeast of Leonora. To support their up-coming application for mining approval, Saturn engaged Pentium Water to undertake a hydrogeological assessment two pit options (The **Bulk Sample Pit** and The **Expansion Option**) at Apollo Hill.

Data on water levels and rock properties from exploration drilling at the site were used to establish baseline conditions and inform a hydrogeological conceptual model at the Project. Local groundwater quality is hypersaline (Total dissolved solids concentrations: 44,000 mg/L to 120,000 mg/L), with a depth to water of between 2 m and 16 m. The planned pits intersect both fresh and weathered mafic rocks, which represent low-yielding fractured rock aquifers typical of the goldfields.

An adapted Dupuit-Thiem equation was used to produce expected Pit dewatering rates and size of the drawdown cone for each of the options. It was found that the smaller Bulk Sample Pit may require a peak dewatering of about 2.9 L/s, while the larger Expansion Option pit may require up to 21.9 L/s.

The impact of drawdown from dewatering of both pit options was assessed against other groundwater users, GDEs and heritage areas. It was found that there was no impact to other groundwater users or identified GDEs. The Project lies within the Lake Raeside Heritage Area, but this heritage area is not likely associated with groundwater, and so unaffected by any drawdown.

The pit lake inflows for closure have also been modelled for both pits if mining were to cease. It was found that evaporation will exceed inflows in the Expansion Option, but that the Bulk Sample Pit would partially refill over time once pumping stops. However, Saturn plans to submit a revised MP-MCP application for a larger proposed pit in the future based on the economical outcomes of the initially proposed Pilot Plant and Bulk Sample Pit development. With the continued mining and dewatering at the Project following approval of this revised proposal, the development of this pit lake will not be realised.

1. Introduction

The Apollo Hill Project (the **Project**) is a gold project proposed by Saturn Metals Ltd (**Saturn**) in the goldfields region of Western Australia. The project is located approximately 50 km southeast of Leonora (Figure 1) and northeast of Kalgoorlie. The deposit is estimated at 76Mt ore and 1,469,000 oz gold.

Saturn intend to develop the Bulk Sample Pit (the **Pit**) to a final bench elevation of 330 m AHD (a depth of 30 m below current ground level), which will require dewatering to maintain a dry pit floor during operation. The Pit is in an Archean greenstone belt, to the west of the Raeside Paleodrainage. Two pit designs are discussed in this document, a smaller pit (the **Bulk Sample Pit**) and a larger pit (the **Expansion Option**).

Saturn has engaged Pentium Water to carry out groundwater studies to establish site hydrogeological conditions with consideration of required dewatering with the following key objectives:

- Develop a hydrogeological conceptual model of the pits.
- Estimate the likely groundwater inflows to the pits.
- Assess the potential impact, if any, of the dewatering.

These investigations will inform part of the Mining Approvals Documentation.

1.1. Project Development Plan

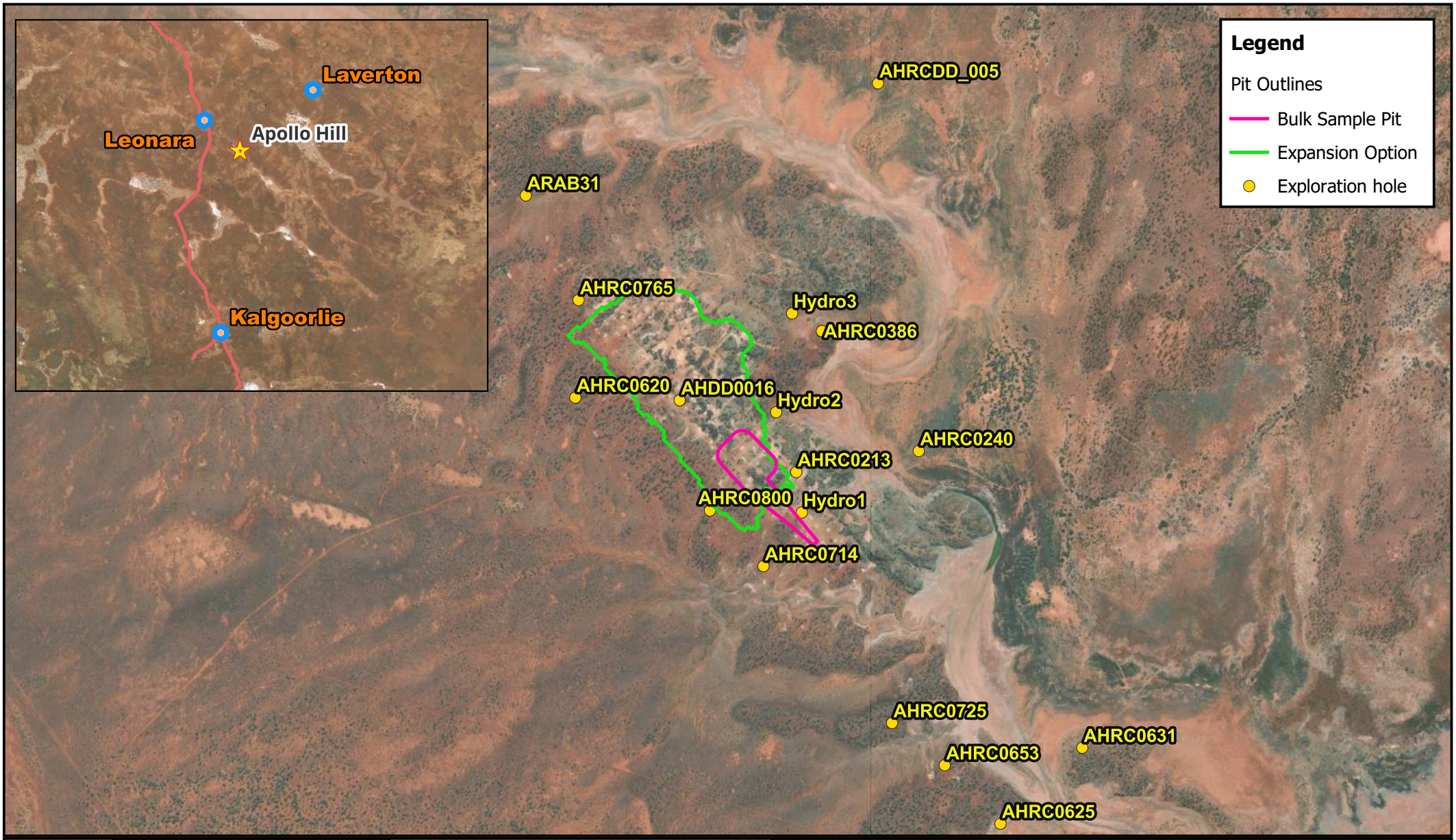
The general layout of the two pit options at the Apollo Hill Project is presented in Figure 1. The Apollo Hill project is located within M31/486 and M39/296 mining tenements completely owned by Saturn Metals Ltd.

1.1.1. Planned Pits

The dimensions of the planned Bulk Sample Pit and the larger Expansion Option are outlined below and in Figure 1.

Table 1: Planned pit extent details

	Bulk Sample Pit	Expansion Option
Starting ground elevation	357 – 363 mAHD	357 – 373 mAHD
Lowest Bench elevation	330 mAHD	330 mAHD
Depth below ground level	27 - 33 mbgl	27 – 43 mbgl
Maximum Area	2.16 Ha	28.3 Ha



PENTIUM WATER

Project code: SATAPOL
Date: 03/03/2023
Scale: 1:17500
Sources: data.gov.au, DWER, landgate

0 250 500 m

GDA2020 / MGA zone 51

Figure 1: Apollo Hill Locality Map

2. Project Setting

2.1. Climate

The climate in the Eastern Goldfields is semi-arid to arid and hot, dry summers and cool to mild winters. January is the hottest month with an average maximum temperature of 37°c and an average minimum of 22°c. July is the coolest month with an average maximum temperature of 18°c and an average minimum of 6°c.

The nearest Bureau of Meteorology (BoM) weather stations are Yerilla Station (40km north) and Kookynie Station (50 km to the southwest of the project). Both rainfall stations have data as far back as the early 1900s. The average annual rainfall is 239 mm at Kookynie station and 222 mm at Yerilla station.

Monthly average rainfall data from Yerilla and Kookynie stations, are presented in Table 2. The total average annual pan evaporation, based on at least 10 years of records from 1975 to 2005 (BoM, 2006) ranges between 2800 mm and 3200 mm measured by use of a Class A evaporation pan.

Table 2: Monthly Rainfall Averages (mm) from 1900–2018 (BoM)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Yerilla	22.4	28.3	27.9	18.8	22.1	22.8	18.7	16.7	8.8	10.9	13.8	15.8	227
Kookynie	24.5	26.3	33.3	19.7	24.3	23.4	19.1	16.7	9.5	11.1	15.1	16.5	239

2.2. Geology and Hydrogeology

2.2.1. Topography

Apollo Hill, in the middle of The Expansion Option, forms the highest point at 374 mAHD, while the lowest point locally is the surface water drainage channel within the wider Lake Raeside drainage system to the west of the pits at 348 mAHD.

2.2.2. Geology

The Project is situated within the Archean Wiluna-Norseman greenstone belt, in a mineralised structure that runs parallel to the district scale Keith-Kilkenny Fault system. The rock types includes a variably metamorphosed basalt unit which contains some dolerite textured zones and feldspar-hornblende or chlorite schist (Drummond and Wyche, 2023).

The weathering profile in the region is relatively shallow but where deeper weathering is noticed, it is related to structure-induced permeability. Both the proposed pit options are planned to be developed in an area mapped as outcropping metabasalt (Vanderhor, 1995).

Exploration drilling has indicated that the transition to fresh rock in within the Pit areas typically occurs between 320 mAHD and 364 mAHD i.e., between 10 mbgl and 30 mbgl.

2.2.3. Hydrogeology

The project area is underlain by variably fractured, weathered Archean bedrock, which is part of the Yilgarn Goldfields fractured rock groundwater province. The bedrock is locally covered by paleochannel deposits and alluvium (Johnson et al 1999).

2.2.3.1. Fractured Rock Aquifer

The Archean rocks found in the Project area do not have any intrinsic permeability and make exceptionally poor aquifers. However, secondary porosity contained in structural defects such as joints, faults, and shears; enhanced by weathering and the development of a saprolite profile does allow for water storage and transmission. This secondary porosity forms the fractured rock aquifer.

Figure 5 shows a typical saprolite weathering profile developed across the region (from Anand and Butt, 2010), and the more simplified hydrogeological grouping used in this report, which is described below.

The **Upper Saprolite** refers to the zone immediately beneath the ferruginous hard cap where the rock has undergone complete chemical decomposition into heavy textured clay minerals, which may display remnant rock textures. The upper saprolite is mostly unsaturated but can form a slow seepage zone where water is present.

The transition into **Lower Saprolite** (the zone of joint oxidation) is characterised by a change from heavy textured clay to soft, decomposed, friable rock 10–20m thick. The lower saprolite zone is typically the most reliable water zone.

The **Saprock** (the zone of broken fresh rock between the lower saprolite and the hard fresh rock) can also contain open water bearing defects, particularly within faults, shears and joints. These defects characteristically act as high permeability groundwater conduits but contain virtually no intrinsic groundwater storage.

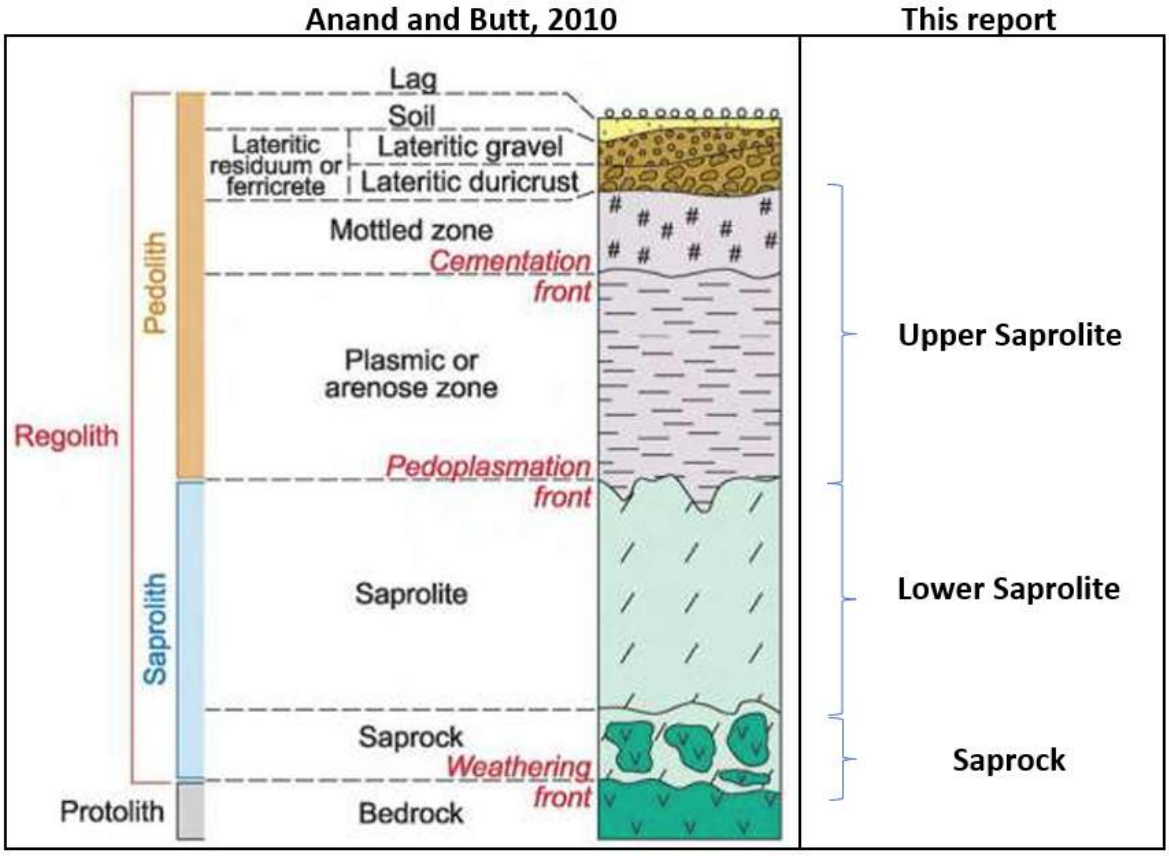


Figure 2: Project area geology profile from Anand and Butt, 2010.

The storativity and hydraulic conductivity of the fractured rock aquifer is related to the degree of weathering and fracturing of the rock. Greenstones, like those underlying this site, are generally more prospective for groundwater than granitoids. The weathered zone in greenstones is generally low yielding due to its clay content. However, the transitional zone can have moderate yields. Regional faults and shear zones can have high yields. The project sits on the western edge of the Keith Kilkenny Shear zone, which indicates there may be a high level of fracturing in the area.

Underlying the weathered and fractured aquifer, the fresh Archaean rocks in the area are essentially impermeable with limited aquifer storage characteristics.

2.2.3.2. Alluvium and Paleochannels

The site is near the Raeside Paleochannel, which is comprised of a multicoloured, plastic clay with minor sand and pisolite beds with an overall thickness of about 120 m. The paleochannel sand is highly permeable and contains large amounts of groundwater which is brackish in the tributaries and saline in the main drainages. The sand has limited groundwater storage with most of the water abstracted being the result of leakage from overlying sediments and surrounding fractured-rock aquifers (Johnson et al 1999).

While the location of the overlying modern drainage channel can be easily determined from satellite images, the exact position of the underlying paleochannel is likely further to the northeast of the Project based on the bedrock outcrops.

As the pits discussed in this document occur in outcrop and only reach a depth of 30 mbgl, there is unlikely to be any influence on the Raeside Paleochannel.

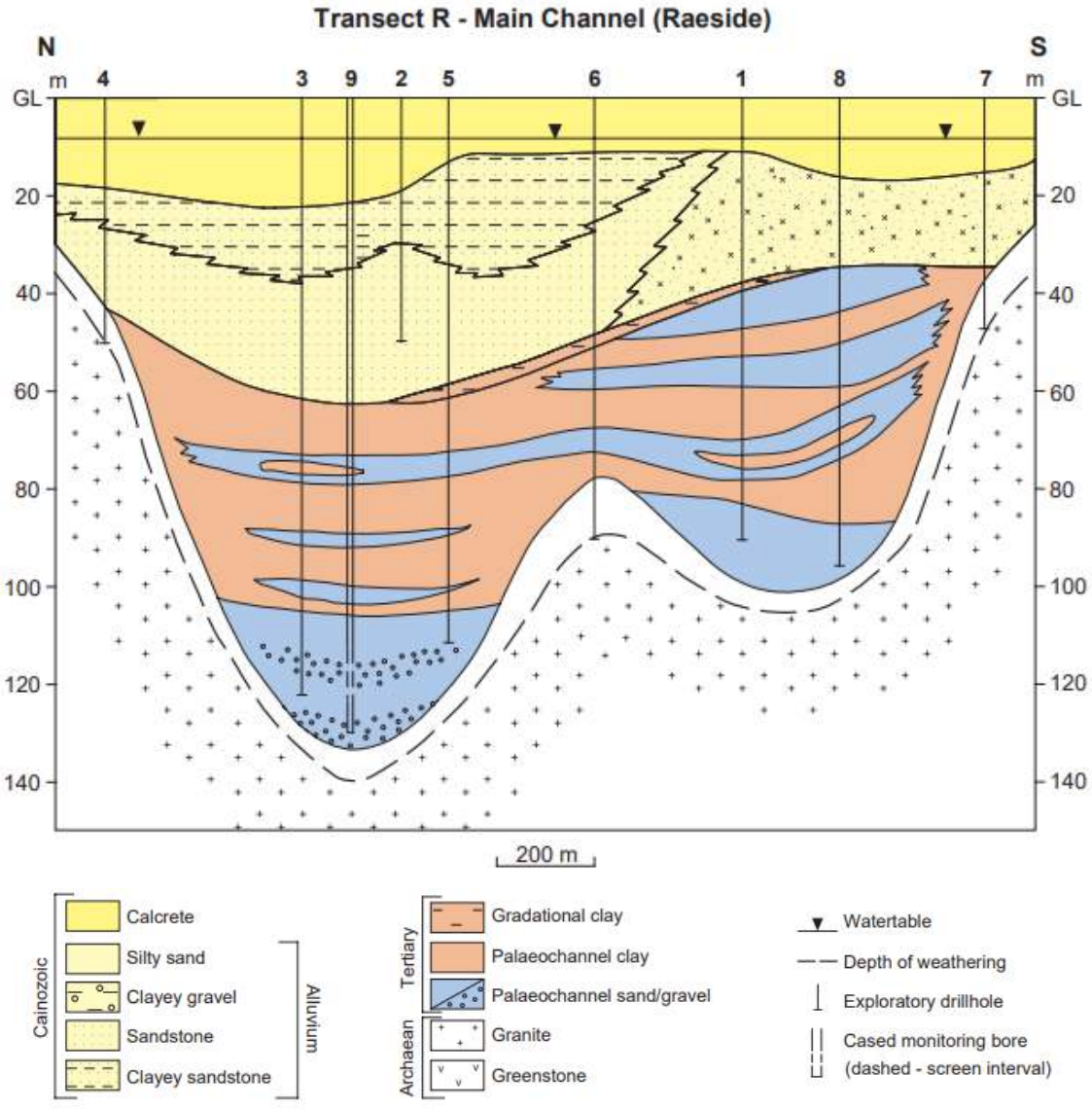


Figure 3: A hydrogeological cross section of the Raeside Channel from Johnson et al 1999.

2.3. Baseline Conditions

Saturn have retrofitted twenty-two exploration holes with PVC casing to create a wide array of new monitoring bores. All the monitoring bores were dipped and sampled during November 2022 (water samples analysed at a NATA accredited laboratory) and the resultant data were used to create detailed maps of baseline conditions on site.

2.3.1. Groundwater quality

Saturn has collected groundwater quality samples from the bores across the site. The data show that the Total Dissolved Solids (TDS) from these holes ranged from between 44,000 mg/L and 120,000 mg/L, indicating the groundwater is hypersaline in the area. Groundwater salinity contours based on these data are presented in Figure 4, showing salinity increasing towards and along drainage lines to the northeast.

Other than the high salinity, there are no analytes that appear elevated beyond the ranges experienced elsewhere in the Goldfields. The samples do have elevated total Aluminium and total Iron, which is likely due to the presence of clay minerals – samples were collected from recently cased holes that may have been turbid.

Refer to Attachment A for complete water quality data.

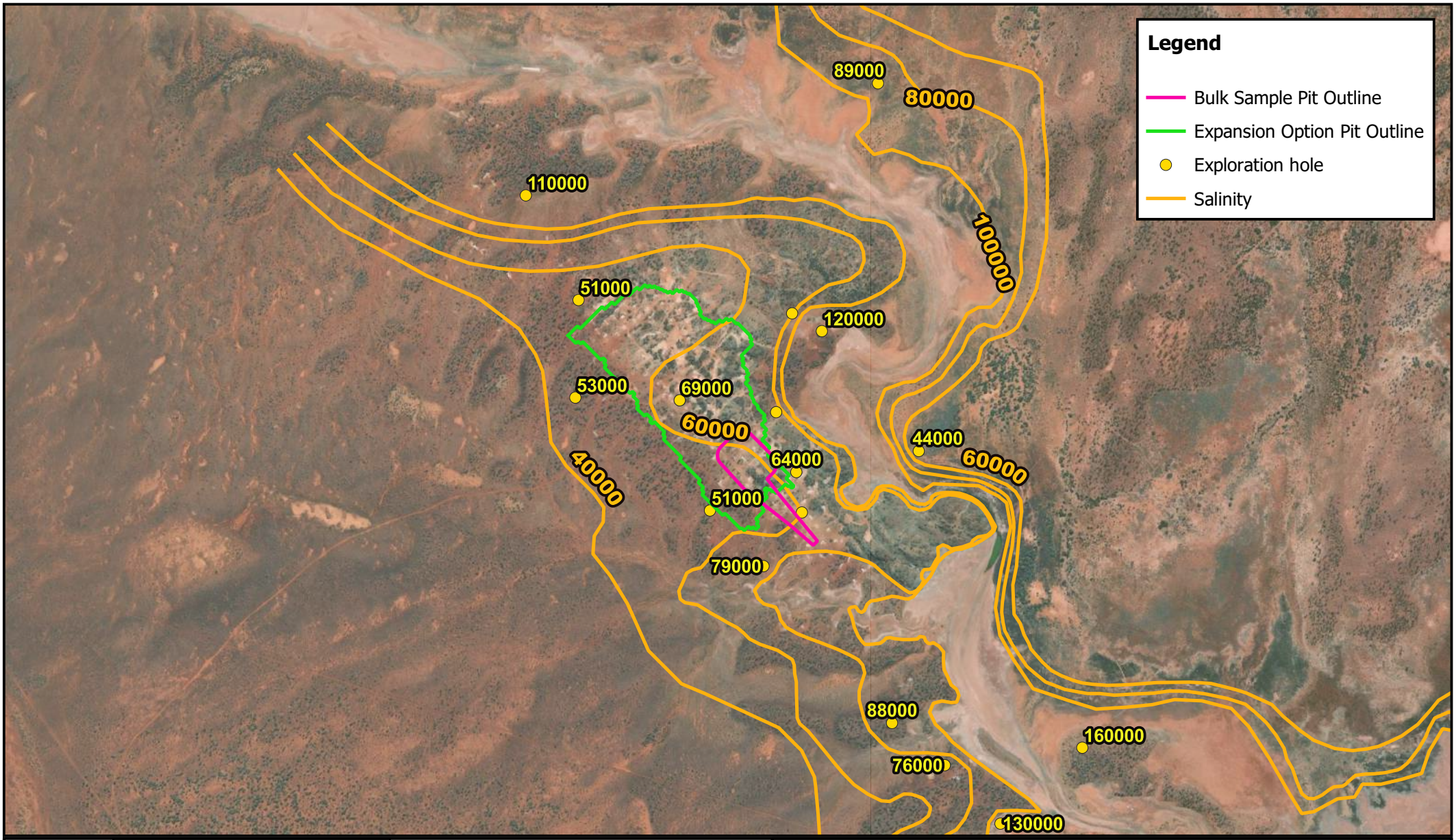
2.3.2. Groundwater Levels

The monitoring holes shown in Figure 5 have recent groundwater levels (November 2022) ranging from 1.24 mbgl to 16.36 mbgl, with the deeper levels generally seen in the higher relief areas.

The local water table ranges from 350 – 355 mAHD and is likely to have an eastern to south-eastern gradient with groundwater predominantly flowing into the drainage channel to the east of the project.

2.4. Other Groundwater Users

There are two other groundwater licences within 10 km of the project site (Figure 6). About 400 m to the northwest is a groundwater licence owned by GME Resources Ltd (167938) to extract 2 GL of groundwater from fractured rock (valid between 2019 and 2029). Another licence owned by Ulysses Mining Pty Ltd (173529) to extract 1.2 GL is present 4.5 km to the southeast.



PENTIUM WATER

Project code: SATAPOL
Date: 03/03/2023
Scale: 1:17500
Sources: data.gov.au, DWER, landgate

0 250 500 m

GDA2020 / MGA zone 51

Figure 4: Salinity Contour Map

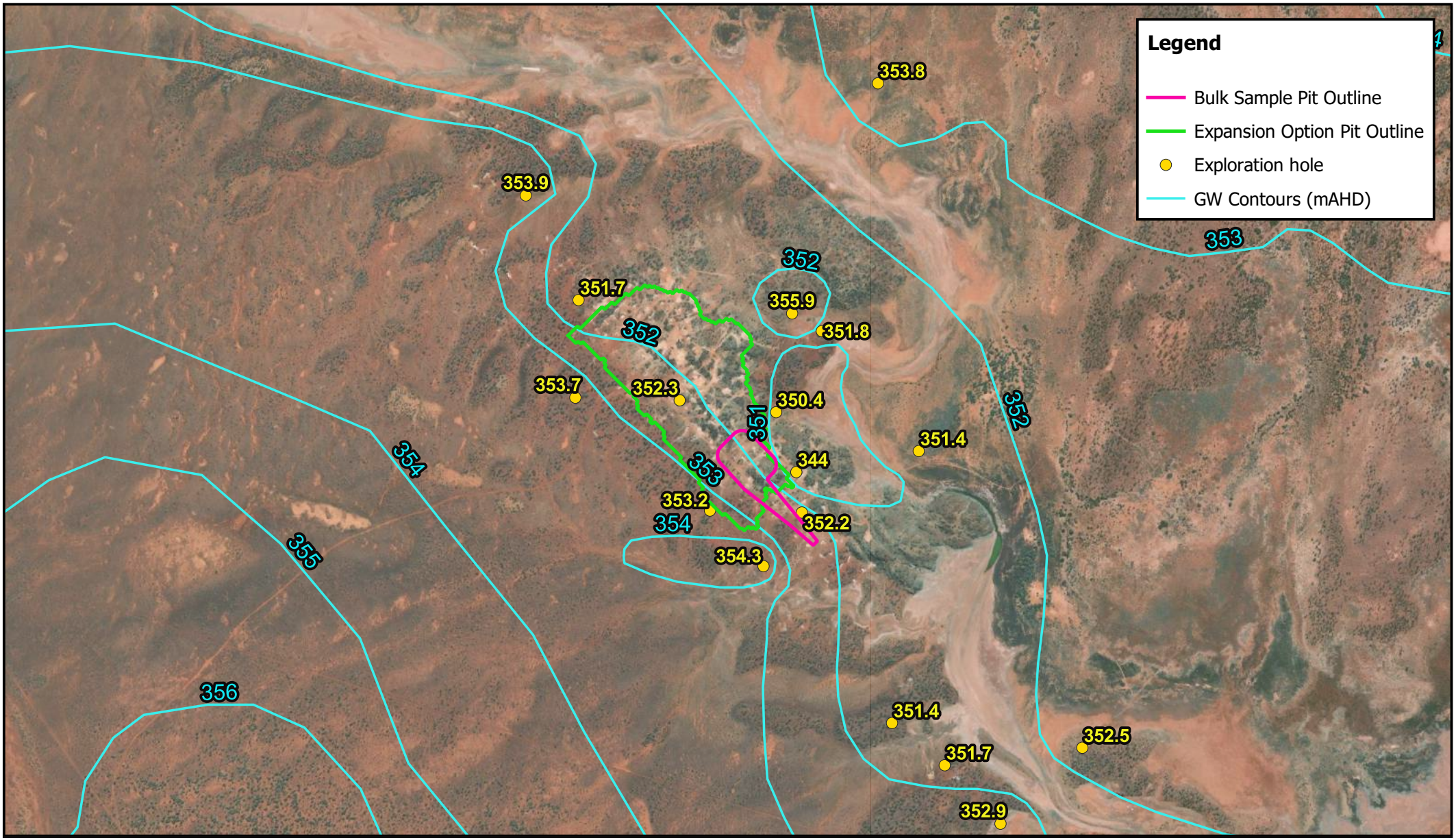
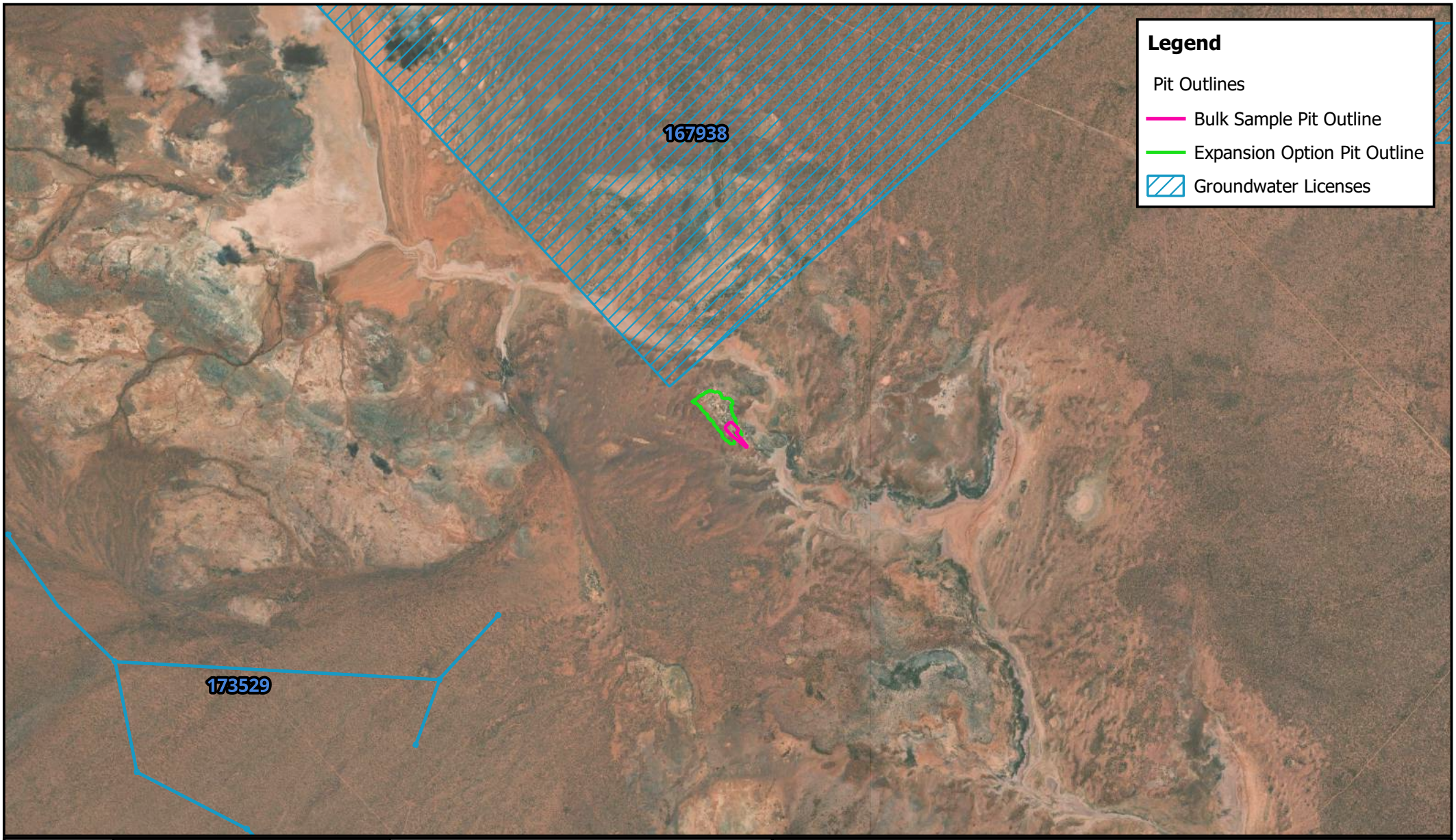


Figure 5: Groundwater Contour Map



PENTIUM WATER

Project code: SATAPOL
Date: 03/03/2023
Scale: 1:80000
Sources: data.gov.au, DWER, landgate

0 1 2 km

GDA2020 / MGA zone 51

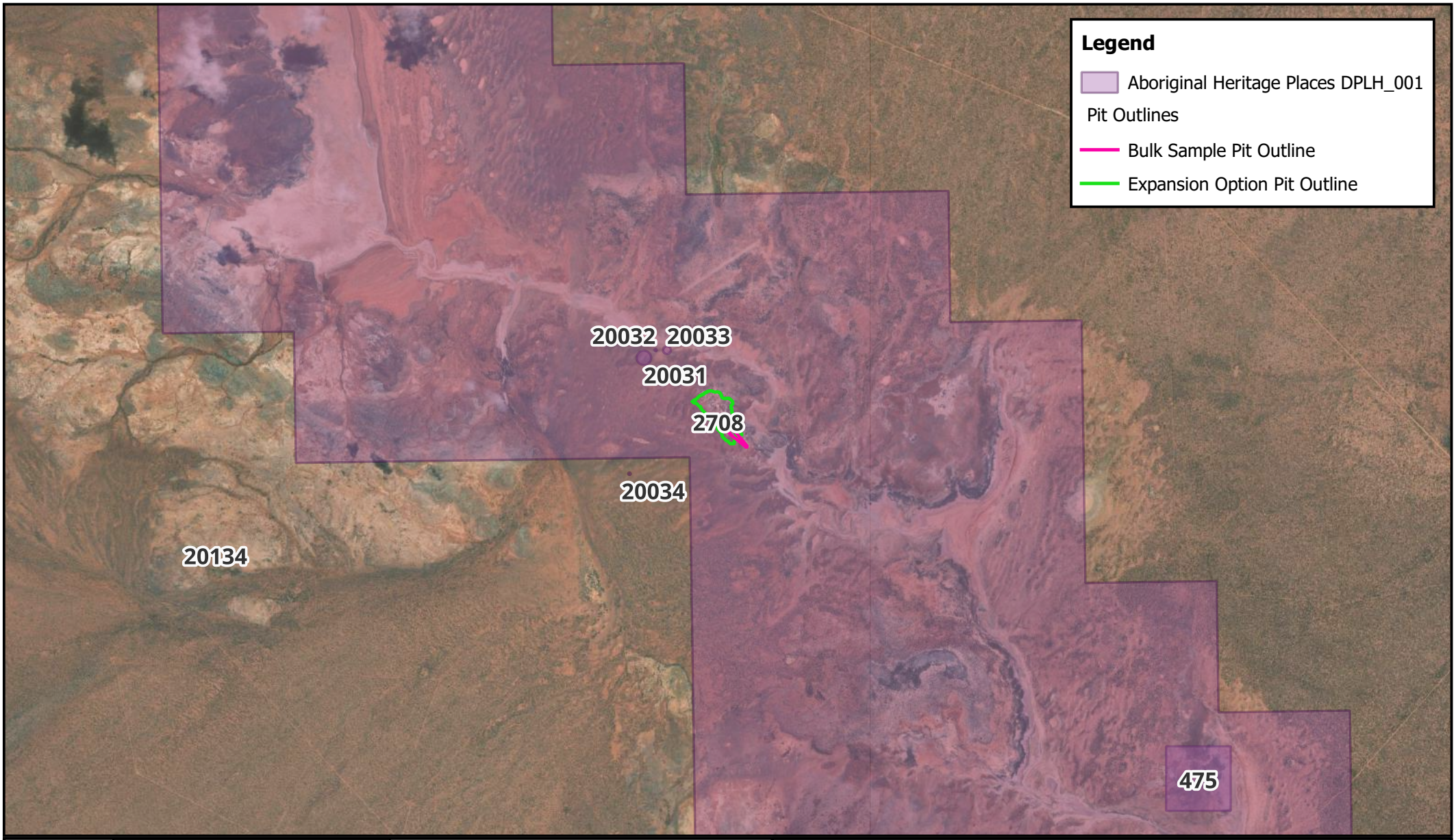
Figure 6: Surrounding Groundwater Licences

2.5. Heritage Sites

The Aboriginal heritage inquiry system from the Department of Planning, Lands and Heritage (DPLH) indicates that the entire Apollo hill project is within a registered mythological heritage site (place ID 2708, Lake Raeside). Other heritage sites shown in Figure 7 below (place IDs: 20031, 20032, 20033 and 20034) are within a 1 km radius from the pit perimeters. These sites are artifact/scatter sites.

2.6. Groundwater Dependent Ecosystems

The Groundwater Dependent Ecosystems Atlas (BoM) shows the closest registered aquatic GDEs are Lake Ballard and Lake Marmion, which are over 55 km to the south-west. There are no confirmed terrestrial GDEs in the area, however three potential terrestrial GDE areas have been identified within 10 km of the site (Figure 8).



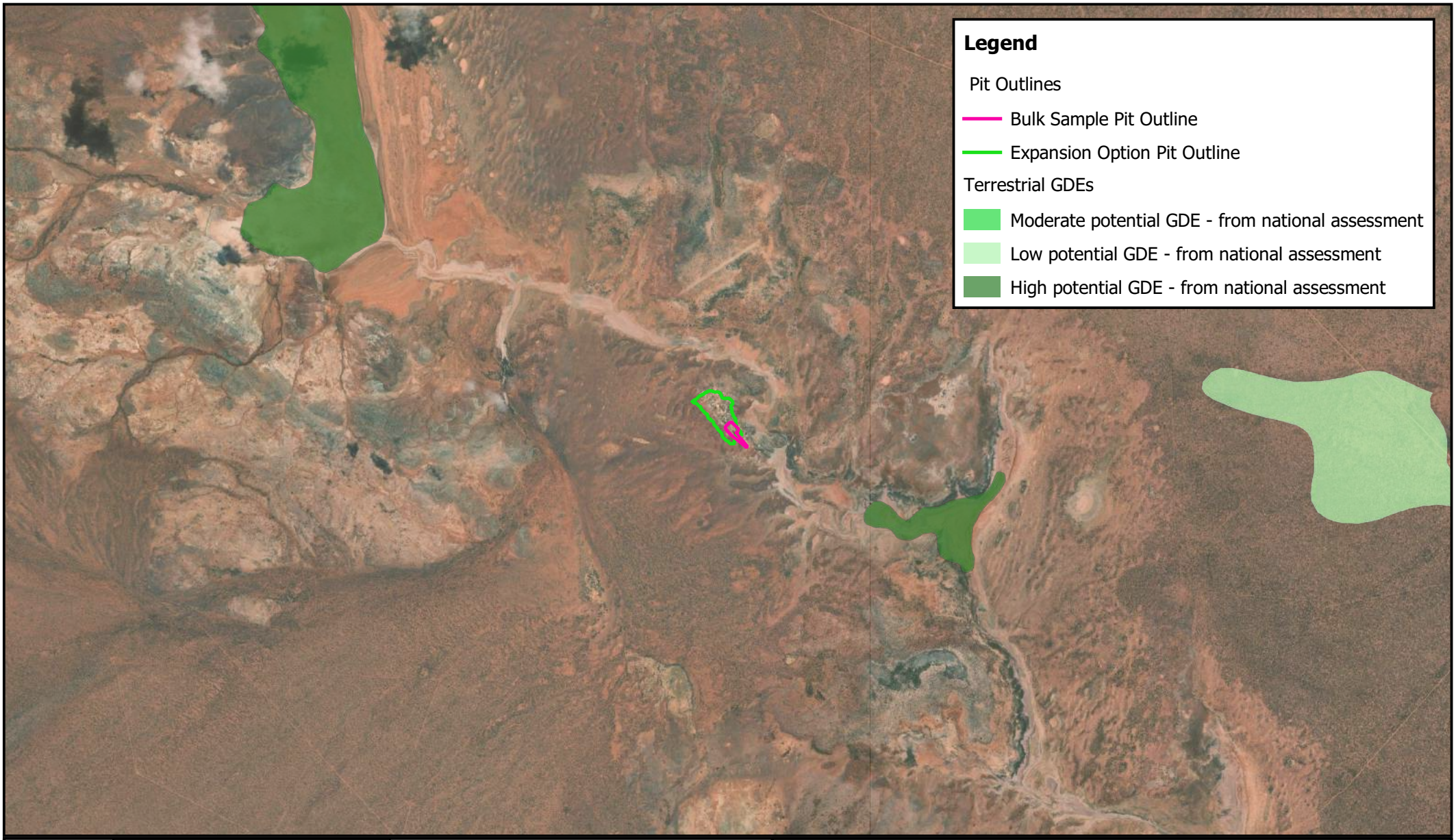
PENTIUM WATER

Project code: SATAPOL
Date: 03/03/2023
Scale: 1:80000
Sources: data.gov.au, DWER, landgate

0 1 2 km

GDA2020 / MGA zone 51

Figure 7: Aboriginal Heritage Areas



PENTIUM WATER

Project code: SATAPOL
Date: 03/03/2023
Scale: 1:80000
Sources: data.gov.au, DWER, landgate

0 1 2 km

GDA2020 / MGA zone 51

Figure 8: Groundwater Dependent Ecosystems

3. Dewatering Assessment

A high-level assessment of potential dewatering volumes and associated impacts was undertaken using an analytical model appropriate for this early stage of works. To maintain dry mining for the life of the Project, dewatering should exceed the potential pit inflows.

3.1. Hydrogeological Conceptual Model

The conceptual model is based on data from Saturn including pit outlines, water levels and geology data from the exploration drilling (cover, bottom of complete oxidation and top of fresh rock):

- The topography ranges between 357 mAHD and 363 mAHD in The Bulk Sample Pit and 357 mAHD and 373 mAHD in The Expansion Option.
- Pre-mining water level of 350 mAHD 352 mAHD (5 mbgl to 20 mbgl). A conservative 355 mAHD elevation has been used in the analytical model.
- The top of fresh rock ranges from 315 mAHD to 360 mAHD in the area. An elevation of 345 mAHD (15 mgl) has been used for the analytical model.

The fractured rock aquifer at Apollo Hill comprises slightly weathered basalt that extends to approximately 15 mbgl (345 mAHD), over weakly fractured fresh basalt that extends to the planned pit depth of 330 mAHD for both pits. A cross section of the conceptual model is shown in Figure 9. For simplicity, the upper weathered and partially weathered zones are combined into one layer “weathered basalt aquifer”, with the basement forming the second active layer in the analytical model.

No test pumping has been conducted on site, so hydraulic parameters (Table 3) have been estimated based on other studies in the goldfields (Johnson et al., 1999; GHD, 2019) and textbook values (Freeze and Cherry, 1979; Domenico and Schwartz, 1990). The hydraulic conductivity for the weathered layer is an expected average between the saprolite, which will have a low conductivity due to the abundance of clay, and the higher conductivity saprock.

Table 3: Aquifer properties for the conceptual model

Aquifer	Hydraulic conductivity (K) (m/d)	Aquifer thickness	Specific Yield
Weathered basalt	0.3	10 m	0.05
Fresh basalt	0.03	~50 m	0.01

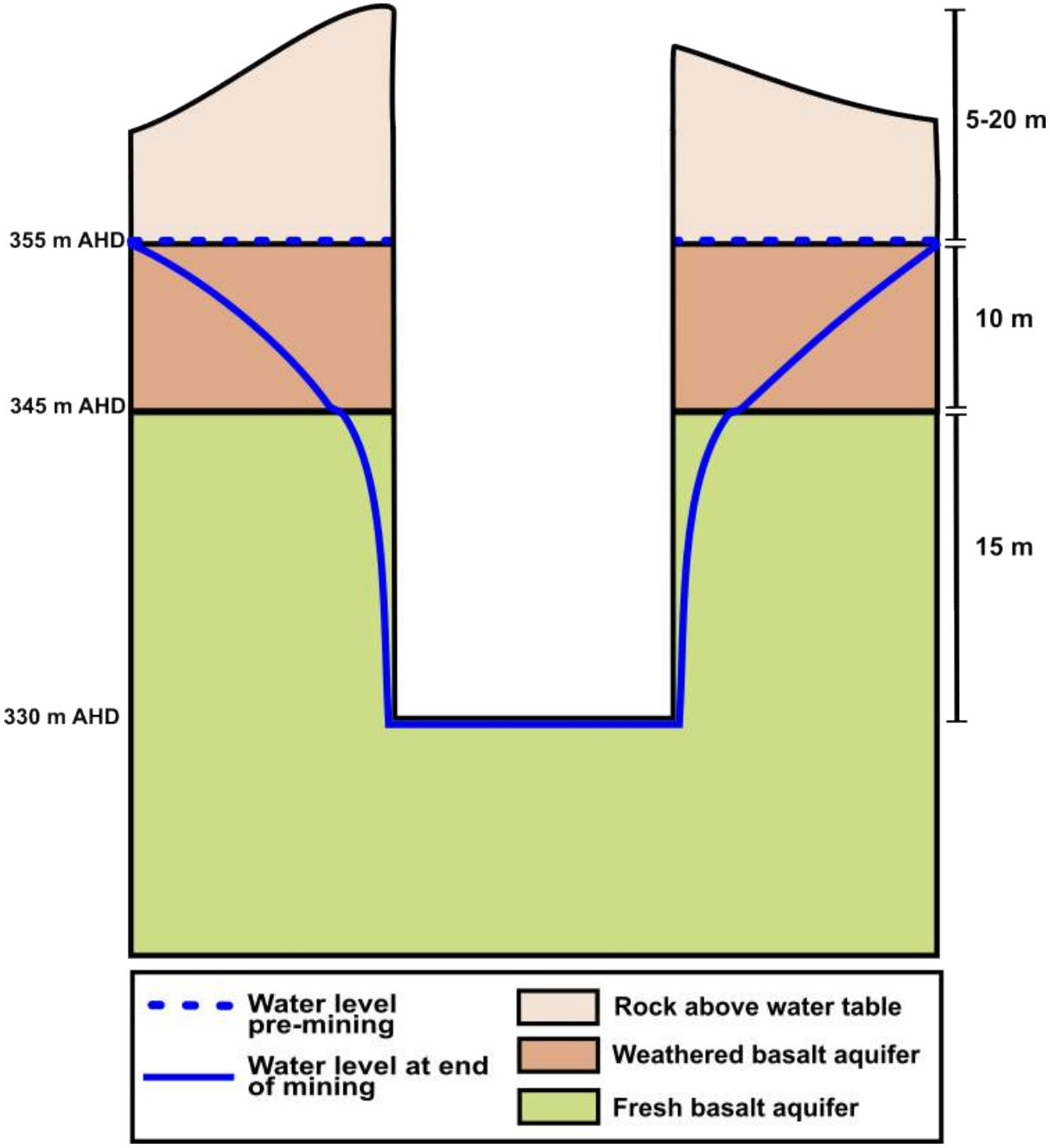


Figure 9: Conceptual cross section of the dewatering model.

3.2. Estimation of mine inflows

An analytical model using a Dupuit-Thiem equation for unconfined aquifer conditions (Fetter, 1988; see below) adjusted for narrow systems (Powers et al., 2007) was used to estimate inflows for a nominal 1-year Life of Mine (LoM). The model makes the simple assumption that mining will progress at an even rate, which mean the mine will be excavated for 180 days above the water table, 90 days in weathered rock and 90 days in fresh rock.

$$Q = \frac{\pi K(H^2 - h^2)}{ln(\frac{ro}{rs})} + 2(\frac{xK(H^2 - h^2)}{2L})$$

Q = Abstraction volume (m^3/day)
K = Hydraulic conductivity (m/day)
H = Aquifer thickness
h = Drawdown in well
ro = Radius of maximum extent of cone of drawdown = $\sqrt{\frac{2.25kHt}{Sy}} + 0.5x$
rs = Pit radius
x = Unit length of trench
L= Distance to source (estimated)
Sy = Specific yield
t = Time

The estimated volume of freely available stored water in the rock was also added to the total dewatering amount:

(*Sy x volume of rock removed*)

The modelled geometry of the pits has been estimated with straight sides as wide as the widest part of the Pit, which will overestimate the volume of rock removed and provide a conservative dewatering estimate.

	Bulk Sample Pit	Expansion Option
Area of Pit (m^2)	21,616	283,166
Depth of pit below water table (m)	25	25
Volume of rock removed below water table - estimate	540,400	7,079,150

As a sensitivity analysis, three scenarios were run with increasing hydraulic conductivity to gain an understanding of how the dewatering rate changes with increasing hydraulic conductivity:

- Base case conductivity
- Increased conductivity (double base case)
- Maximum conductivity (5 times base case)

The model inputs are summarised in Table 3 and the results are summarised in Table 4. The Base Case analytical model for The Bulk Sample Pit indicates that dewatering is anticipated to produce approximately 2.9 L/s (247 m^3/d), while the base case for The Expansion Option is expected to produce approximately 21.9 L/s (1830 m^3/d).

Table 4: Aquifer Properties for Dewatering Estimates –Bulk Sample Pit and Expansion Option

Scenarios	Hydraulic Conductivity (m/d)		Specific Yield	
	Weathered Rock	Fresh Rock	Weathered Rock	Fresh Rock
Base Case	0.3	0.03	0.05	0.01
Increased Conductivity	0.6	0.06	0.05	0.01
Maximum Conductivity	1.5	0.15	0.05	0.01

Table 5: Dewatering Estimate Results –Bulk Sample Pit and Expansion Option

Scenarios	The Bulk Sample Pit			The Expansion Option		
	LOM Dewatering Volume (ML)	Peak Dewatering Rate (ML/d)	Radius of Influence (m)	LOM Dewatering Volume (ML)	Peak Dewatering Rate (ML/d)	Radius of Influence (m)
Base Case	37	0.25	270	246	1.9	610
Increased Conductivity	51	0.32	340	270	2.0	690
Maximum Conductivity	89	0.48	490	362	2.5	840

3.2.1. Model Constraints

These estimates do not include any estimate of the impact of boundary effects or recharge from the Raeside Paleochannel or the surface water drainage line (and associated alluvial sediments) to the southeast. Based on the current understanding of the Pit options and the local geology it is considered very unlikely that either pit would have groundwater connection with the Raeside Paleochannel due to their position in outcrop and the shallow depth of the pits. It is likely that the hydraulic properties of the site are heterogeneous. For example, there may be greater hydraulic conductivity towards the drainage channel, but this has not been considered at this stage.

The model has also assumed constant excavation rates through a nominal six-months excavation below the water table.

3.3. Potential Impacts

3.3.1. The Bulk Sample Pit

The estimated radius of influence (maximum extent of drawdown) from the Dupuit-Thiem analytical model, gives a base-case value of 0.26 km, and the high hydraulic conductivity case gives a radius of 0.49 km (Figure 10). Beyond this distance dewatering has no effect on groundwater levels.

All identified potential GDE areas and groundwater users lie beyond this distance. The expected drawdown does not impact any other heritage areas other than the Lake Raeside heritage area, which occurs over the whole mining area.

3.3.2. The Expansion Option

The radius of influence for the Expansion Option is estimated to be 0.6 km, and the higher hydraulic conductivity (5 times base case) shows a radius of influence of 0.84 km (Figure 11).

All identified potential GDE areas lie beyond this distance. Both the high and low conductivity simulations indicate that the drawdown overlap with the edge of the tenure associated with GWL 167938, owned by GME resources (380 m to the northwest). Further investigation indicates that the closest well associated with this licence is over 6 km away from the drawdown area, and so will not be affected by drawdown at Apollo Hill. The expected drawdown does not impact any other heritage areas other than the Lake Raeside heritage area.



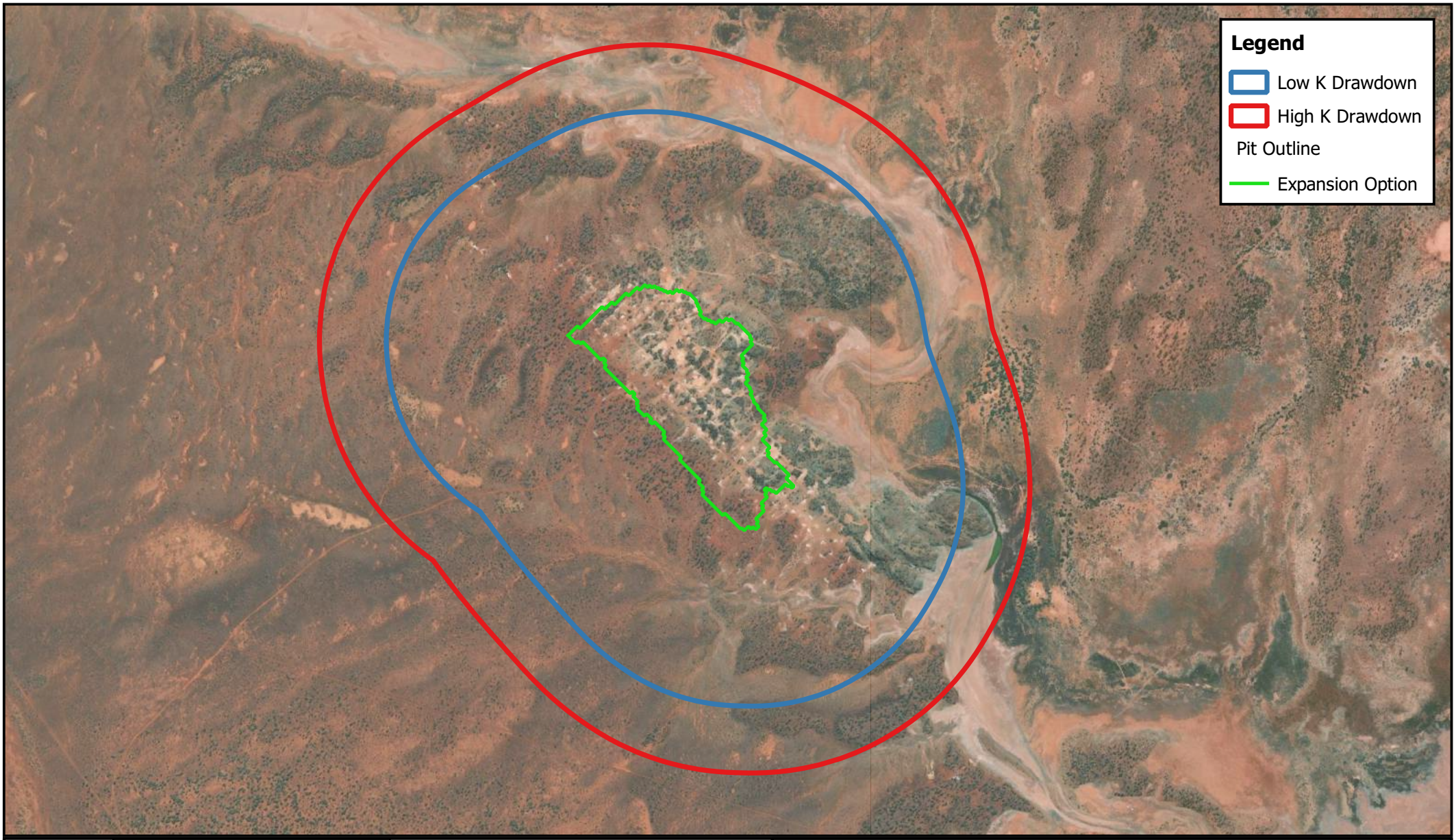
PENTIUM WATER

Project code: SATAPOL
Date: 03/03/2023
Scale: 1:17500
Sources: data.gov.au, DWER, landgate

0 250 500 m

GDA2020 / MGA zone 51

Figure 10: Bulk Sample Pit Expected Drawdown



PENTIUM WATER

Project code: SATAPOL
Date: 03/03/2023
Scale: 1:17500
Sources: data.gov.au, DWER, landgate

0 250 500 m

GDA2020 / MGA zone 51

Figure 11: Expansion Option Expected Drawdown

3.4. Pit Closure modelling

Following the end of mining, groundwater will flow back into the pit until it either returns to pre-mining levels or reaches equilibrium with evaporation. The recovery of groundwater of each pit option was modelled using the analytical methods of Marinelli and Niccoli (2000).

$$Q1 = W\pi(r_o^2 - r_p^2)$$

$$Q2 = 4r_p(\frac{K_{h2}}{m_2})(h_o - d)$$

$$m^2 = \sqrt{(\frac{K_{h2}}{K_{v2}})}$$

Where:

Q1 = volumetric flow rate from Zone 1
W = recharge flux. Estimated at 1% of rainfall.
rp = effective pit radius
ro = radius of influence
Q2 = volumetric flow rate from Zone 2
Kh2 = horizontal hydraulic conductivity
Kv2 = vertical hydraulic conductivity
m2 = anisotropy parameter (assumed to be 10 here)
h0 = pre-mining saturated thickness above base of Zone 1
d = depth of lake

To complete the water balance, evaporation and rainfall have been estimated for the pit lake areas from regional statistics. Average annual evaporation is estimated to be 2600 mm/year (BoM), while average rainfall is 217 mm/year. Rainfall for the calculation has been estimated for the rain captured within the pit areas. The evaporation rate was multiplied by a factor of 0.7 to estimate lake evaporation. The effect of salinity on evaporation was also considered, and given the salinity on site, a factor of 0.9 was also applied (Harbeck, 1955).

Final rate of inflow = Q1 + Q2 + rainfall – evaporation

The final inflow estimate was 49 m^3/day (0.57 L/s) for the Bulk Sample Pit, and -701 m^3/day (-8.1 L/s) for the Expansion Option. This indicates that the Expansion Option would not refill due to evaporation exceeding inflow, but the Bulk Sample Pit would partially refill over time (Table 6).

Table 6: Pit inflow equation values.

Properties	The Bulk Sample Pit	The Expansion Option
W	6.38E-06	6.38E-06
r_p	86	343
r_o	190	607
Q1 (M^3/day)	**0.54**	**4.68**
K_{h2}	0.054	0.054
r_p	86	343
r_o	190	607
m_2	3.2	3.2
h_0	25	25
d	0	0
Q2 (m^3/day)	**148.3**	**591**
Pit area (m^2)	21,616	283,166
Void volume below water table (m^3)	540,400	7,079,150
Evaporation (m^3/day)	111.93	1466
Rainfall/day (m^3)	12.85	168.35
Rate of inflow with evaporation and rainfall (m^3/day)	**49.84**	**-701.25**

This calculation shows that the evaporative outflow will exceed the expected groundwater inflow in the Expansion Option, making the pit a terminal groundwater sink.

The inflows exceed evaporation in the Bulk Sample Pit, showing it will likely refill over time once pumping ceases. The model further shows that as inflows decrease with lake depth increase, once the pit lake reaches 10 m depth, evaporation will exceed inflows and the pit will not continue filling. Evaporation will increase the salinity of the already hypersaline groundwater in the lake.

4. Conclusions

Groundwater assessments for two Pit options at Apollo hill have been developed. Both the Bulk Sample Pit and the Expansion Option pit would progress to a depth of 330 mAHD (30 mbgl to 40 mbgl), 20 m to 25 m of this excavation is expected to be below the water table, requiring dewatering to maintain dry mining over the life of the mine. Saturn have indicated that they will proceed, initially, with the Bulk Sample Pit as the preferred option.

Geology, groundwater quality and groundwater level data have been used to inform conceptual groundwater model for the pit options. An adapted Dupuit-Thiem equation was used for the model to calculate a first order approximation of the likely required dewatering. Peak groundwater flows associated with dewatering are anticipated to peak at approximately 3 L/s for the Bulk Sample Pit, and 22 L/s for the Expansion Option – noting the much greater extent of the latter. These results are constrained by the available data, for more accurate estimates, the models can be updated with site specific hydraulic conductivity and specific yield when available.

The Bulk Sample Pit is small and quite shallow, and it has been found that the drawdown will not impact other groundwater users or identified GDEs. The drawdown from the larger Expansion Option pit may overlap with tenure associated with another groundwater licence, but the drawdown will not affect any water bores.

Based on the modelling, at the end of mining the Bulk Sample Pit will develop a hypersaline pit lake about 10m deep. Local groundwater gradients towards the pit will remain after dewatering has ended, so groundwater flow will always be towards the pit, which will act as a groundwater sink. In contrast, the Expansion Option will remain as a dry pit on closure, as the evaporation exceeds groundwater inflows.

Saturn plans to continue further mining based on the economic outcomes of the Pilot Plant and Bulk Sample Pit development. A revised groundwater assessment will be developed during this stage that will support an expanded MP-MCP application. If the expansion is approved, mining and dewatering will continue and prevent the development of the pit lake in the Bulk Sample Pit. If the project is halted at the end of the Bulk Sample Pit Option, the pit will be backfilled to 2 m above the pre-mining water table to prevent the formation of the hypersaline pit lake.

Key findings for the selected Bulk Sample Pit Option are:

- Predicted dewatering rate of 3 L/s or 37 ML of water over the life of the Pit
- Expected drawdown will not impact other groundwater users or identified GDE areas.
- If closed, the Bulk Sample Pit will be backfilled to 2 m above the pre-mining water table.

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Attachment A

Envirolab Services (WA) Pty Ltd trading as MPL Laboratories
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Certificate of Analysis PDL0720

Client Details

Client	Saturn Metals Limited
Contact	David Smith
Address	9 Havelock Street, WEST PERTH, WA, 6005

Sample Details

Your Reference	Apollo Hill
Number of Samples	22 Water
Date Samples Received	12/12/2022
Date Samples Registered	12/12/2022

Analysis Details

Please refer to the following pages for results, methodology summary and quality control data.
Samples were analysed as received from the client. Results relate specifically to the samples as received.
Results are reported on a dry weight basis for solids and on an as received basis for other matrices.

Report Details

Date Results Requested by	19/12/2022
Date of Issue	22/12/2022

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Authorisation Details

Results Approved By	Heram Halim, Operations Manager Michael Mowle, Inorganics Supervisor Todd Lee, Group Operations Manager
Laboratory Manager	Michael Kubiak

Certificate of Analysis PDL0720

Samples in this Report

Envirolab ID	Sample ID	Depth	Matrix	Date Sampled	Date Received
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PDL0720-02	AHW0002	4.00	Water	11/12/2022	12/12/2022
PDL0720-03	AHW0003	2.38	Water	11/12/2022	12/12/2022
PDL0720-04	AHW0004	22.58	Water	11/12/2022	12/12/2022
PDL0720-05	AHW0005	10.40	Water	11/12/2022	12/12/2022
PDL0720-06	AHW0006	2.30	Water	11/12/2022	12/12/2022
PDL0720-07	AHW0007	2.83	Water	11/12/2022	12/12/2022
PDL0720-08	AHW0008	2.56	Water	11/12/2022	12/12/2022
PDL0720-09	AHW0009	1.42	Water	11/12/2022	12/12/2022
PDL0720-10	AHW0010	2.42	Water	11/12/2022	12/12/2022
PDL0720-11	AHW0011	2.20	Water	11/12/2022	12/12/2022
PDL0720-12	AHW0012	2.41	Water	11/12/2022	12/12/2022
PDL0720-13	AHW0013	1.96	Water	11/12/2022	12/12/2022
PDL0720-14	AHW0014	18.87	Water	11/12/2022	12/12/2022
PDL0720-15	AHW0015	4.86	Water	11/12/2022	12/12/2022
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PDL0720-20	AHW0020	2.26	Water	11/12/2022	12/12/2022
PDL0720-21	AHW0021	1.84	Water	11/12/2022	12/12/2022
PDL0720-22	AHW0022	2.09	Water	11/12/2022	12/12/2022

Acid Extractable Low Level Metals (Water)

Envirolab ID	Units	PQL	PDL0720-01	PDL0720-02	PDL0720-03	PDL0720-04	PDL0720-05
Your Reference			AHW0001	AHW0002	AHW0003	AHW0004	AHW0005
Date Sampled			11/12/2022	11/12/2022	11/12/2022	11/12/2022	11/12/2022
Depth			2.40	4.00	2.38	22.58	10.40
Silver	µg/L	1.0	<5.0 [4]	<10 [4]	<2.0 [4]	<10 [4]	<5.0 [4]
Aluminium	µg/L	10	300000	4400	9800	26000	45000
Arsenic	µg/L	1.0	33	<10 [4]	5.9	230	26
Boron	µg/L	20	14000	10000	6200	10000	5800
Barium	µg/L	1.0	600	88	200	100	150
Beryllium	µg/L	0.50	9.8	<5.0 [4]	<1.0 [4]	<5.0 [4]	<2.5 [4]
Cadmium	µg/L	0.10	1.4	2.7	<0.20 [4]	<1.0 [4]	<0.50 [4]
Cobalt	µg/L	1.0	190	28	8.3	160	140
Chromium	µg/L	1.0	1300	50	82	130	190
Copper	µg/L	1.0	340	16	16	290	120
Iron	µg/L	10	400000	14000	17000	81000	81000
Molybdenum	µg/L	1.0	14	33	7.7	<10 [4]	5.4
Nickel	µg/L	1.0	450	26	22	150	110
Lead	µg/L	1.0	120	<10 [4]	3.7	<10 [4]	<5.0 [4]
Selenium	µg/L	1.0	24	50	13	11	<5.0 [4]
Tin	µg/L	1.0	8.5	<10 [4]	<2.0 [4]	<10 [4]	<5.0 [4]
Zinc	µg/L	1.0	530	540	37	100	120

Envirolab ID	Units	PQL	PDL0720-06	PDL0720-07	PDL0720-08	PDL0720-09	PDL0720-10
Your Reference			AHW0006	AHW0007	AHW0008	AHW0009	AHW0010
Date Sampled			11/12/2022	11/12/2022	11/12/2022	11/12/2022	11/12/2022
Depth			2.30	2.83	2.56	1.42	2.42
Silver	µg/L	1.0	<5.0 [4]	<5.0 [4]	<10 [4]	<10 [4]	<2.0 [4]
Aluminium	µg/L	10	4400	13000	3000	5500	140000
Arsenic	µg/L	1.0	<5.0 [4]	9.8	<10 [4]	<10 [4]	17
Boron	µg/L	20	5400	14000	32000	11000	3300
Barium	µg/L	1.0	22	80	52	35	520
Beryllium	µg/L	0.50	<2.5 [4]	<2.5 [4]	<5.0 [4]	<5.0 [4]	3.8
Cadmium	µg/L	0.10	<0.50 [4]	0.55	<1.0 [4]	1.2	0.72
Cobalt	µg/L	1.0	5.0	14	<10 [4]	<10 [4]	78
Chromium	µg/L	1.0	47	150	60	97	460
Copper	µg/L	1.0	8.3	27	<10 [4]	12	100
Iron	µg/L	10	13000	37000	10000	13000	120000
Molybdenum	µg/L	1.0	<5.0 [4]	5.2	11	<10 [4]	4.0
Nickel	µg/L	1.0	14	34	22	24	180
Lead	µg/L	1.0	<5.0 [4]	6.9	<10 [4]	<10 [4]	38
Selenium	µg/L	1.0	21	26	89	37	8.5
Tin	µg/L	1.0	<5.0 [4]	<5.0 [4]	<10 [4]	<10 [4]	3.1
Zinc	µg/L	1.0	18	24	<10 [4]	42	210

Envirolab ID	Units	PQL	PDL0720-11	PDL0720-12	PDL0720-13	PDL0720-14	PDL0720-15
Your Reference			AHW0011	AHW0012	AHW0013	AHW0014	AHW0015
Date Sampled			11/12/2022	11/12/2022	11/12/2022	11/12/2022	11/12/2022
Depth			2.20	2.41	1.96	18.87	4.86
Silver	µg/L	1.0	<5.0 [4]	<1.0	<10 [4]	<5.0 [4]	<5.0 [4]
Aluminium	µg/L	10	20000	46000	9900	5800	31000
Arsenic	µg/L	1.0	16	15	<10 [4]	17	19

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Acid Extractable Low Level Metals (Water)

Envirolab ID	Units	PQL	PDL0720-11	PDL0720-12	PDL0720-13	PDL0720-14	PDL0720-15
Your Reference			AHW0011	AHW0012	AHW0013	AHW0014	AHW0015
Date Sampled			11/12/2022	11/12/2022	11/12/2022	11/12/2022	11/12/2022
Depth			2.20	2.41	1.96	18.87	4.86
Boron	µg/L	20	10000	2000	10000	4000	3200
Barium	µg/L	1.0	84	580	240	14	390
Beryllium	µg/L	0.50	<2.5 [4]	2.9	<5.0 [4]	<2.5 [4]	<2.5 [4]
Cadmium	µg/L	0.10	<0.50 [4]	0.72	1.7	<0.50 [4]	1.4
Cobalt	µg/L	1.0	34	120	24	62	57
Chromium	µg/L	1.0	100	310	110	49	140
Copper	µg/L	1.0	54	120	35	52	85
Iron	µg/L	10	50000	120000	31000	24000	78000
Molybdenum	µg/L	1.0	23	3.9	12	<5.0 [4]	6.6
Nickel	µg/L	1.0	54	140	53	74	110
Lead	µg/L	1.0	9.0	44	<10 [4]	<5.0 [4]	17
Selenium	µg/L	1.0	23	10	52	31	<5.0 [4]
Tin	µg/L	1.0	<5.0 [4]	5.2	<10 [4]	5.8	<5.0 [4]
Zinc	µg/L	1.0	80	150	210	76	280

Envirolab ID	Units	PQL	PDL0720-16	PDL0720-17	PDL0720-18	PDL0720-19	PDL0720-20
Your Reference			AHW0016	AHW0017	AHW0018	AHW0019	AHW0020
Date Sampled			11/12/2022	11/12/2022	11/12/2022	11/12/2022	11/12/2022
Depth			6.76	3.73	16.75	4.81	2.26
Silver	µg/L	1.0	<5.0 [4]	<10 [4]	300	<1.0 [4]	<10 [4]
Aluminium	µg/L	10	1700	1100	13000	47000	11000
Arsenic	µg/L	1.0	<5.0 [4]	<10 [4]	26	15	17
Boron	µg/L	20	2600	8400	3800	3100	5000
Barium	µg/L	1.0	45	38	250	310	58
Beryllium	µg/L	0.50	<2.5 [4]	<5.0 [4]	<2.5 [4]	1.3	<5.0 [4]
Cadmium	µg/L	0.10	0.55	<1.0 [4]	0.70	0.25	2.2
Cobalt	µg/L	1.0	<5.0 [4]	<10 [4]	80	49	21
Chromium	µg/L	1.0	34	80	110	290	190
Copper	µg/L	1.0	14	12	690	110	42
Iron	µg/L	10	6100	5100	68000	78000	39000
Molybdenum	µg/L	1.0	6.4	<10 [4]	190	2.8	<10 [4]
Nickel	µg/L	1.0	15	19	190	120	44
Lead	µg/L	1.0	<5.0 [4]	<10 [4]	13	24	<10 [4]
Selenium	µg/L	1.0	9.6	30	<5.0 [4]	9.0	22
Tin	µg/L	1.0	<5.0 [4]	<10 [4]	19	1.5	<10 [4]
Zinc	µg/L	1.0	29	76	4200	110	57

Envirolab ID	Units	PQL	PDL0720-21	PDL0720-22
Your Reference			AHW0021	AHW0022
Date Sampled			11/12/2022	11/12/2022
Depth			1.84	2.09
Silver	µg/L	1.0	<10 [4]	<5.0 [4]
Aluminium	µg/L	10	4300	2500
Arsenic	µg/L	1.0	<10 [4]	9.4
Boron	µg/L	20	9000	18000
Barium	µg/L	1.0	58	79
Beryllium	µg/L	0.50	<5.0 [4]	<2.5 [4]

Acid Extractable Low Level Metals (Water)

Envirolab ID	Units	PQL	PDL0720-21	PDL0720-22
Your Reference			AHW0021	AHW0022
Date Sampled			11/12/2022	11/12/2022
Depth			1.84	2.09
Cadmium	µg/L	0.10	1.0	<0.50 [4]
Cobalt	µg/L	1.0	16	6.0
Chromium	µg/L	1.0	63	40
Copper	µg/L	1.0	25	10
Iron	µg/L	10	16000	8000
Molybdenum	µg/L	1.0	<10 [4]	13
Nickel	µg/L	1.0	35	15
Lead	µg/L	1.0	<10 [4]	<5.0 [4]
Selenium	µg/L	1.0	19	9.6
Tin	µg/L	1.0	<10 [4]	<5.0 [4]
Zinc	µg/L	1.0	76	49

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Dissolved Metals (Water)

Envirolab ID	Units	PQL	PDL0720-01	PDL0720-02	PDL0720-03	PDL0720-04	PDL0720-05
Your Reference			AHW0001	AHW0002	AHW0003	AHW0004	AHW0005
Date Sampled			11/12/2022	11/12/2022	11/12/2022	11/12/2022	11/12/2022
Depth			2.40	4.00	2.38	22.58	10.40
Manganese	mg/L	0.010	0.62	3.5	0.013	1.5	14
Calcium	mg/L	0.50	220	800	130	580	350
Magnesium	mg/L	0.50	1200	5500	410	2800	1600
Potassium	mg/L	0.50	140	510	74	380	170
Sodium	mg/L	0.50	12000	47000	4600	31000	15000
Silica*	mg/L	0.20	52	22	81	11	24
Hardness as CaCO3	mg/L	3.0	5500	25000	2000	13000	7400

Envirolab ID	Units	PQL	PDL0720-06	PDL0720-07	PDL0720-08	PDL0720-09	PDL0720-10
Your Reference			AHW0006	AHW0007	AHW0008	AHW0009	AHW0010
Date Sampled			11/12/2022	11/12/2022	11/12/2022	11/12/2022	11/12/2022
Depth			2.30	2.83	2.56	1.42	2.42
Manganese	mg/L	0.010	<0.10	<0.10	<0.20	<0.20	0.059
Calcium	mg/L	0.50	420	440	550	560	240
Magnesium	mg/L	0.50	2400	2400	3100	4200	790
Potassium	mg/L	0.50	270	300	590	460	79
Sodium	mg/L	0.50	26000	24000	38000	41000	5900
Silica*	mg/L	0.20	19	21	17	21	54
Hardness as CaCO3	mg/L	3.0	11000	11000	14000	19000	3800

Envirolab ID	Units	PQL	PDL0720-11	PDL0720-12	PDL0720-13	PDL0720-14	PDL0720-15
Your Reference			AHW0011	AHW0012	AHW0013	AHW0014	AHW0015
Date Sampled			11/12/2022	11/12/2022	11/12/2022	11/12/2022	11/12/2022
Depth			2.20	2.41	1.96	18.87	4.86
Manganese	mg/L	0.010	<0.050	0.15	0.52	0.19	9.6
Calcium	mg/L	0.50	340	150	670	490	370
Magnesium	mg/L	0.50	1400	550	5600	2200	1400
Potassium	mg/L	0.50	180	57	590	230	180
Sodium	mg/L	0.50	14000	4300	52000	20000	15000
Silica*	mg/L	0.20	56	82	29	17	25
Hardness as CaCO3	mg/L	3.0	6700	2600	25000	10000	6700

Envirolab ID	Units	PQL	PDL0720-16	PDL0720-17	PDL0720-18	PDL0720-19	PDL0720-20
Your Reference			AHW0016	AHW0017	AHW0018	AHW0019	AHW0020
Date Sampled			11/12/2022	11/12/2022	11/12/2022	11/12/2022	11/12/2022
Depth			6.76	3.73	16.75	4.81	2.26
Manganese	mg/L	0.010	<0.10	<0.10	12	0.062	0.39
Calcium	mg/L	0.50	240	480	630	98	580
Magnesium	mg/L	0.50	1300	2800	1900	370	3700
Potassium	mg/L	0.50	160	280	220	52	300
Sodium	mg/L	0.50	15000	27000	22000	3800	37000
Silica*	mg/L	0.20	41	25	16	66	20
Hardness as CaCO3	mg/L	3.0	5900	13000	9400	1800	17000

Envirolab ID	Units	PQL	PDL0720-21	PDL0720-22
Your Reference			AHW0021	AHW0022
Date Sampled			11/12/2022	11/12/2022
Depth			1.84	2.09
Manganese	mg/L	0.010	<0.10	1.5

Dissolved Metals (Water)

Envirolab ID	Units	PQL	PDL0720-21	PDL0720-22
Your Reference			AHW0021	AHW0022
Date Sampled			11/12/2022	11/12/2022
Depth			1.84	2.09
Calcium	mg/L	0.50	610	570
Magnesium	mg/L	0.50	3800	2900
Potassium	mg/L	0.50	380	300
Sodium	mg/L	0.50	40000	27000
Silica*	mg/L	0.20	11	28
Hardness as CaCO3	mg/L	3.0	17000	13000

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Inorganics (Water)

Envirolab ID	Units	PQL	PDL0720-01	PDL0720-02	PDL0720-03	PDL0720-04	PDL0720-05
Your Reference			AHW0001	AHW0002	AHW0003	AHW0004	AHW0005
Date Sampled			11/12/2022	11/12/2022	11/12/2022	11/12/2022	11/12/2022
Depth			2.40	4.00	2.38	22.58	10.40
Anions as meq	meq/L	3.0	670	2800	260	1800	810
Cations as meq	meq/L	0.50	630	2600	240	1600	820
Total Anions	mg/L	100	25000	100000	9800	65000	30000
Total Cations	mg/L	10	14000	54000	5200	34000	17000
Ammonia as N	mg/L	0.0050	0.18	0.11	<0.0050	0.39	0.037
Chloride	mg/L	1.0	21000	87000	8000	56000	25000
Electrical Conductivity	µS/cm	2.0	54000	150000	23000	120000	67000
Fluoride	mg/L	0.10	0.19	<0.10	0.71	0.13	0.57
Nitrate as N	mg/L	0.0050	13	43	31	0.014	0.19
Total Nitrogen	mg/L	0.10	18	54	35	0.99	1.2
pH	pH units		7.5	7.3	7.7	7.0	7.6
Sulfate	mg/L	1.0	3800	17000	1400	8600	4700
Total Dissolved Solids	mg/L	5.0	40000	150000 [7]	14000	98000	51000
Nitrate as NO3 by calculation	mg/L	0.020	58	190	140	0.063	0.86
Ionic Balance	%		-3.8	-4.8	-4.8	-4.8	0.63
Carbonate Alkalinity as CaCO3	mg/L as CaCO3	5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Bicarbonate Alkalinity as CaCO3	mg/L as CaCO3	5.0	470	130	330	310	400
Hydroxide OH- as CaCO3	mg/L as CaCO3	5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Total Alkalinity as CaCO3	mg/L as CaCO3	5.0	470	130	330	310	400

Envirolab ID	Units	PQL	PDL0720-06	PDL0720-07	PDL0720-08	PDL0720-09	PDL0720-10
Your Reference			AHW0006	AHW0007	AHW0008	AHW0009	AHW0010
Date Sampled			11/12/2022	11/12/2022	11/12/2022	11/12/2022	11/12/2022
Depth			2.30	2.83	2.56	1.42	2.42
Anions as meq	meq/L	3.0	1500	1400	2100	2300	350
Cations as meq	meq/L	0.50	1400	1300	2000	2200	330
Total Anions	mg/L	100	53000	53000	76000	83000	13000
Total Cations	mg/L	10	29000	27000	42000	46000	7000
Ammonia as N	mg/L	0.0050	<0.050 [5]	<0.050 [5]	<0.050 [5]	<0.050 [5]	0.045
Chloride	mg/L	1.0	47000	45000	65000	71000	11000
Electrical Conductivity	µS/cm	2.0	98000	95000	130000	140000	31000
Fluoride	mg/L	0.10	0.23	0.30	0.20	0.15	0.33
Nitrate as N	mg/L	0.0050	5.1	30	28	18	23
Total Nitrogen	mg/L	0.10	6.1	33	30	19	27
pH	pH units		7.3	7.4	7.6	7.1	7.7
Sulfate	mg/L	1.0	6300	6900	11000	12000	1900
Total Dissolved Solids	mg/L	5.0	79000	76000	120000	130000	21000
Nitrate as NO3 by calculation	mg/L	0.020	23	130	120	80	100
Ionic Balance	%		-3.9	-5.1	-2.8	-2.3	-3.6
Carbonate Alkalinity as CaCO3	mg/L as CaCO3	5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Bicarbonate Alkalinity as CaCO3	mg/L as CaCO3	5.0	150	200	120	150	320
Hydroxide OH- as CaCO3	mg/L as CaCO3	5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Total Alkalinity as CaCO3	mg/L as CaCO3	5.0	150	200	120	150	320

Inorganics (Water)

Envirolab ID	Units	PQL	PDL0720-11	PDL0720-12	PDL0720-13	PDL0720-14	PDL0720-15
Your Reference			AHW0011	AHW0012	AHW0013	AHW0014	AHW0015
Date Sampled			11/12/2022	11/12/2022	11/12/2022	11/12/2022	11/12/2022
Depth			2.20	2.41	1.96	18.87	4.86
Anions as meq	meq/L	3.0	750	260	2900	1200	800
Cations as meq	meq/L	1.0	740	240	2800	1100	780
Total Anions	mg/L	100	28000	9800	110000	44000	30000
Total Cations	mg/L	20	16000	5100	59000	23000	17000
Ammonia as N	mg/L	0.0050	0.035	0.39	0.20	<0.050 [5]	2.2
Chloride	mg/L	1.0	23000	8300	90000	38000	25000
Electrical Conductivity	µS/cm	2.0	61000	23000	160000	83000	66000 [7]
Fluoride	mg/L	0.10	0.15	0.38	<0.10	0.32	0.18
Nitrate as N	mg/L	0.0050	6.8	19	23	12	0.30
Total Nitrogen	mg/L	0.10	8.0	22	26	13	5.4
pH	pH units		7.6	7.4	7.1	7.4	7.4
Sulfate	mg/L	1.0	4700	1200	17000	5700	3900
Total Dissolved Solids	mg/L	5.0	44000	16000	160000 [7]	64000	51000
Nitrate as NO3 by calculation	mg/L	0.020	30	86	100	54	1.3
Ionic Balance	%		-0.86	-5.0	-2.2	-5.4	-1.0
Carbonate Alkalinity as CaCO3	mg/L as CaCO3	5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Bicarbonate Alkalinity as CaCO3	mg/L as CaCO3	5.0	400	330	88	270	300
Hydroxide OH- as CaCO3	mg/L as CaCO3	5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Total Alkalinity as CaCO3	mg/L as CaCO3	5.0	400	330	88	270	300

Envirolab ID	Units	PQL	PDL0720-16	PDL0720-17	PDL0720-18	PDL0720-19	PDL0720-20
Your Reference			AHW0016	AHW0017	AHW0018	AHW0019	AHW0020
Date Sampled			11/12/2022	11/12/2022	11/12/2022	11/12/2022	11/12/2022
Depth			6.76	3.73	16.75	4.81	2.26
Anions as meq	meq/L	10	900	1500	1300	220	2100
Cations as meq	meq/L	1.0	760	1400	1100	200	2000
Total Anions	mg/L	400	33000	57000	48000	8400	79000
Total Cations	mg/L	20	16000	31000	24000	4400	42000
Ammonia as N	mg/L	0.0050	0.041	<0.050 [5]	2.6	0.17	0.18
Chloride	mg/L	1.0	29000	49000	42000	6900	67000
Electrical Conductivity	µS/cm	2.0	67000	100000	88000	20000	120000
Fluoride	mg/L	0.10	0.29	0.27	14	0.39	0.20
Nitrate as N	mg/L	0.0050	9.6	25	0.10	18	0.021
Total Nitrogen	mg/L	0.10	11	26	12	20	1.3
pH	pH units		7.4	7.7	7.2	7.8	7.3
Sulfate	mg/L	1.0	3900	7600	5400	1100	11000
Total Dissolved Solids	mg/L	5.0	53000	88000	69000	12000	110000 [7]
Nitrate as NO3 by calculation	mg/L	0.020	42	110	0.45	79	0.092
Ionic Balance	%		-8.8	-3.4	-7.0	-5.5	-4.0
Carbonate Alkalinity as CaCO3	mg/L as CaCO3	5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Bicarbonate Alkalinity as CaCO3	mg/L as CaCO3	5.0	200	170	230	390	110
Hydroxide OH- as CaCO3	mg/L as CaCO3	5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Total Alkalinity as CaCO3	mg/L as CaCO3	5.0	200	170	230	390	110

Inorganics (Water)

Envirolab ID	Units	PQL	PDL0720-21	PDL0720-22
Your Reference			AHW0021	AHW0022
Date Sampled			11/12/2022	11/12/2022
Depth			1.84	2.09
Anions as meq	meq/L	10	2200	1600
Cations as meq	meq/L	1.0	2100	1500
Total Anions	mg/L	400	81000	60000
Total Cations	mg/L	20	45000	31000
Ammonia as N	mg/L	0.0050	0.16	<0.050 [5]
Chloride	mg/L	1.0	68000	51000
Electrical Conductivity	µS/cm	2.0	130000	99000
Fluoride	mg/L	0.10	0.15	<0.10
Nitrate as N	mg/L	0.0050	0.51	<0.0050
Total Nitrogen	mg/L	0.10	1.1	1.2
pH	pH units		7.6	7.9
Sulfate	mg/L	1.0	13000	8900
Total Dissolved Solids	mg/L	5.0	120000 [1]	89000
Nitrate as NO3 by calculation	mg/L	0.020	2.3	<0.020
Ionic Balance	%		-2.6	-5.3
Carbonate Alkalinity as CaCO3	mg/L as CaCO3	5.0	<5.0	<5.0
Bicarbonate Alkalinity as CaCO3	mg/L as CaCO3	5.0	160	320
Hydroxide OH- as CaCO3	mg/L as CaCO3	5.0	<5.0	<5.0
Total Alkalinity as CaCO3	mg/L as CaCO3	5.0	160	320

Result Comments

Identifier	Description
[1]	Some EC to TDS ratios are outside normal expected values. Results were confirmed.
[4]	PQL(s) has/have been raised due to suppression of the internal standard, which required the sample(s) to be diluted. This is likely due to the high level of salts in the sample.
[5]	PQL(s) has/have been raised due to matrix interference.
[7]	EC to TDS ratio is outside a normal expected value due to sample being super-saline.

Method Summary

Method ID	Methodology Summary
Calc	Calculation
INORG-001	pH - Measured using pH meter and electrode based on APHA latest edition, Method 4500-H+. Please note that the results for water analyses are indicative only, as analysis can be completed outside of the APHA recommended holding times. Solids are reported from a 1:5 water extract unless otherwise specified. Alternatively, pH is determined in a 1:5 extract using 0.01M calcium chloride or a solid is extracted at a ratio of 1:2.5 (AS1289.4.3.1), pH is measured in the extract.
INORG-002	Conductivity and Salinity - measured using a conductivity cell at 25°C based on APHA latest edition Method 2510. Soil results reported from a 1:5 Soil:Water extract unless otherwise specified. Please note Resistivity is estimated by calculation and may not correlate with results otherwise obtained using the Resistivity current method (based on AS 1289.4.4.1), depending on the nature of the soil being analysed.
INORG-006	Alkalinity - determined titrimetrically based on APHA latest edition 2320-B. Solids reported from a 1:5 water extract unless otherwise specified. Total Carbon Dioxide - determined by calculation in accordance with APHA latest edition,4500-CO2 D.
INORG-018	Total Dissolved Solids - determined gravimetrically. The solids are dried at 180±10°C.
INORG-026	Fluoride determined by ion selective electrode (ISE) based on APHA latest edition, 4500-F-C. Solids are reported from a 1:5 water extract unless otherwise specified.
INORG-040	The concentrations of the major ions (mg/L) are converted to milliequivalents and summed. The ionic balance should be within +/- 15% i.e. total anions = total cations +/-15%.
INORG-055	Nitrate/Nitrite/NOx/TKN - determined colourimetrically. Waters samples are filtered on receipt prior to analysis. Soils/solids are analysed following a water extraction.
INORG-057	Ammonia - determined colourimetrically. Water samples are filtered on receipt prior to analysis. Soils and OHS media are analysed following a water extraction. Alternatively, Ammonia can be extracted from soil using 1M KCl.
INORG-081	Anions determined by Ion Chromatography. Waters samples are filtered on receipt prior to analysis. Solids are analysed from a water extract. Alternatively determined by colourimetry/turbidity using Discrete Analyser.
INORG-127	Total Nitrogen by high temperature catalytic combustion with chemiluminescence detection. Organic Carbon forms (inorganic, organic, total) determined using a TOC/NDIR analyser via combustion. Dissolved forms require filtering prior to determination.
METALS-020	Determination of various metals by ICP-OES.
METALS-022	Determination of various metals by ICP-MS.

Result Definitions

Identifier	Description
NR	Not reported
NEPM	National Environment Protection Measure
NS	Not specified
LCS	Laboratory Control Sample
RPD	Relative Percent Difference
>	Greater than
<	Less than
PQL	Practical Quantitation Limit
INS	Insufficient sample for this test
NA	Test not required
NT	Not tested
DOL	Samples rejected due to particulate overload (air filters only)
RFD	Samples rejected due to filter damage (air filters only)
RUD	Samples rejected due to uneven deposition (air filters only)
##	Indicates a laboratory acceptance criteria outlier, for further details, see Result Comments and/or QC Comments

Quality Control Definitions

Blank

This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, and is determined by processing solvents and reagents in exactly the same manner as for samples.

Surrogate Spike

Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

LCS (Laboratory Control Sample)

This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.

Matrix Spike

A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.

Duplicate

This is the complete duplicate analysis of a sample from the process batch. The sample selected should be one where the analyte concentration is easily measurable.

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria. Filters, swabs, wipes, tubes and badges will not have duplicate data as the whole sample is generally extracted during sample extraction. Spikes for Physical and Aggregate Tests are not applicable. For VOCs in water samples, three vials are required for duplicate or spike analysis.

General Acceptance Criteria (GAC) - Analyte specific criteria applies for some analytes and is reflected in QC recovery tables.

Duplicates: >10xPQL - RPD acceptance criteria will vary depending on the analytes and the analytical techniques but is typically in the range 20%-50% - see ELN-P05 QAQC tables for details (available on request); <10xPQL - RPD are higher as the results approach PQL and the estimated measurement uncertainty will statistically increase. Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals; 60-140% for organics (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was typically insufficient in order to satisfy laboratory QA/QC protocols.

Miscellaneous Information

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

Where sampling dates are not provided, Envirolab are not in a position to comment on the validity of the analysis where recommended technical holding times may have been breached. We have taken the sampling date as being the date received at the laboratory.

Two significant figures are reported for the majority of tests and with a high degree of confidence, for results <10*PQL, the second significant figure may be in doubt i.e. has a relatively high degree of uncertainty and is provided for information only.

Measurement Uncertainty estimates are available for most tests upon request.

Analysis of aqueous samples typically involves the extraction/digestion and/or analysis of the liquid phase only (i.e. NOT any settled sediment phase but inclusive of suspended particles if present), unless stipulated on the Envirolab COC or by correspondence. Notable exceptions include certain Physical Tests (pH/EC/BOD/COD/Apparent Colour etc.), Solids testing, Total Recoverable metals and PFAS where sediment/solids are included by default.

Urine Analysis - The BEI values listed are taken from the 2022 edition of *TLVs and BEIs Threshold Limits by ACGIH*.

Air volume measurements are not covered by Envirolab's NATA accreditation.

Data Quality Assessment Summary PDL0720

Client Details

Client	Saturn Metals Limited
Your Reference	Apollo Hill
Date Issued	22/12/2022

Recommended Holding Time Compliance

Recommended holding time exceedances exist - See detailed list below

Quality Control and QC Frequency

QC Type	Compliant	Details
Blank	Yes	No Outliers
LCS	Yes	No Outliers
Duplicates	No	Duplicate Outliers Exist - See detailed list below
Matrix Spike	No	Matrix Spike Outliers Exist - See detailed list below
Surrogates / Extracted Internal Standards	Yes	No Outliers
QC Frequency	Yes	No Outliers

Surrogates/Extracted Internal Standards, Duplicates and/or Matrix Spikes are not always relevant/applicable to certain analyses and matrices. Therefore, said QC measures are deemed compliant in these situations by default. See Laboratory Acceptance Criteria for more information

Data Quality Assessment Summary PDL0720

Recommended Holding Time Compliance

Analysis	Sample Number(s)	Date Sampled	Date Extracted	Date Analysed	Compliant
Total Metals (LL) | Water	1-10	11/12/2022	16/12/2022	16/12/2022	Yes
	11-22	11/12/2022	16/12/2022	21/12/2022	Yes
Dissolved Cations | Water	1-16, 19	11/12/2022	16/12/2022	19/12/2022	Yes
	17-18, 20-22	11/12/2022	16/12/2022	20/12/2022	Yes
Dissolved Metals | Water	1-16, 19	11/12/2022	16/12/2022	19/12/2022	Yes
	17-18, 20-22	11/12/2022	16/12/2022	20/12/2022	Yes
Alkalinity Suite | Water	1-22	11/12/2022	13/12/2022	13/12/2022	Yes
Chloride | Water	1, 3, 5, 10-12, 15	11/12/2022	13/12/2022	13/12/2022	Yes
	16, 19	11/12/2022	13/12/2022	14/12/2022	Yes
	2, 4, 6-9, 13-14, 17-18, 20-22	11/12/2022	13/12/2022	15/12/2022	Yes
EC | Water	1-22	11/12/2022	13/12/2022	13/12/2022	Yes
Fluoride | Water	1-22	11/12/2022	13/12/2022	13/12/2022	Yes
Ion Balance | Water	1-22	11/12/2022	14/12/2022	14/12/2022	Yes
Nitrogen - Ammonia | Water	1-2, 4-5, 10-13, 15-16, 18-21	11/12/2022	13/12/2022	14/12/2022	Yes
	3, 6-9, 14, 17, 22	11/12/2022	13/12/2022	15/12/2022	Yes
Nitrogen - Nitrate | Water	1-22	11/12/2022	13/12/2022	14/12/2022	Yes
Nitrogen - Total N | Water	1, 3-16	11/12/2022	14/12/2022	17/12/2022	No
	17-20	11/12/2022	14/12/2022	18/12/2022	No
	2	11/12/2022	14/12/2022	19/12/2022	No
	21-22	11/12/2022	15/12/2022	15/12/2022	No
pH | Water	1-22	11/12/2022	13/12/2022	13/12/2022	No
Sulfate | Water	1, 3, 5, 10-12, 15	11/12/2022	13/12/2022	13/12/2022	Yes
	16, 19	11/12/2022	13/12/2022	14/12/2022	Yes
	2, 4, 6-9, 13-14, 17-18, 20-22	11/12/2022	13/12/2022	15/12/2022	Yes
TDS | Water	1-10	11/12/2022	16/12/2022	16/12/2022	Yes
	11-22	11/12/2022	17/12/2022	17/12/2022	Yes

Data Quality Assessment Summary PDL0720

Outliers: Duplicates

METALS-022|Acid Extractable Low Level Metals (Water)| Batch BDL1775

Sample ID	Duplicate ID	Analyte	% Limits	RPD
BDL1775-DUP1#	DUP1	Copper	30.00	200[6]
BDL1775-DUP1#	DUP1	Zinc	30.00	126[6]

METALS-022|Acid Extractable Low Level Metals (Water)| Batch BDL1776

Sample ID	Duplicate ID	Analyte	% Limits	RPD
PDL0720-13	DUP1	Molybdenum	30.00	200[8]
PDL0720-17	DUP2	Aluminium	30.00	51.9[8]
PDL0720-17	DUP2	Zinc	30.00	74.5[8]

Outliers: Matrix Spike

INORG-055|Inorganics (Water)| Batch BDL1402

Sample ID	Analyte	% Limits	% Recovery
BDL1402-MS1#	Nitrate as N	70 - 130	##[3]

INORG-081|Inorganics (Water)| Batch BDL1336

Sample ID	Analyte	% Limits	% Recovery
PDL0720-02	Chloride	70 - 130	##[3]

METALS-020|Dissolved Metals (Water)| Batch BDL1788

Sample ID	Analyte	% Limits	% Recovery
BDL1788-MS1#	Silicon	70 - 130	##[2]
BDL1788-MS1#	Sodium	70 - 130	##[2]

METALS-020|Dissolved Metals (Water)| Batch BDL1789

Sample ID	Analyte	% Limits	% Recovery
PDL0720-18	Magnesium	70 - 130	##[2]
PDL0720-18	Sodium	70 - 130	##[2]

METALS-022|Acid Extractable Low Level Metals (Water)| Batch BDL1776

Sample ID	Analyte	% Limits	% Recovery
PDL0720-14	Aluminium	70 - 130	-156[2]
PDL0720-14	Boron	70 - 130	-777[2]
PDL0720-14	Iron	70 - 130	-2060[2]

Quality Control PDL0720

METALS-022|Acid Extractable Low Level Metals (Water) | Batch BDL1775

Analyte	Units	PQL	Blank	DUP1 BDL1775-DUP1# Samp | QC | RPD %	DUP2 PDL0720-03 Samp | QC | RPD %	LCS %	Spike % BDL1775-MS1#
Aluminium	µg/L	10	<10	<10 | <10 | [NA]	9800 | 9750 | 0.518	95.4	126
Arsenic	µg/L	1.0	<1.0	<1.0 | <1.0 | [NA]	5.88 | 5.58 | 5.24	97.1	117
Barium	µg/L	1.0	<1.0	<1.0 | <1.0 | [NA]	203 | 198 | 2.69	95.3	111
Beryllium	µg/L	0.50	<0.50	<0.50 | <0.50 | [NA]	<1.0 | <1.0 | [NA]	96.8	117
Boron	µg/L	20	<20	<20 | <20 | [NA]	6230 | 6350 | 2.01	105	106
Cadmium	µg/L	0.10	<0.10	<0.10 | <0.10 | [NA]	<0.20 | <0.20 | [NA]	98.1	115
Chromium	µg/L	1.0	<1.0	<1.0 | <1.0 | [NA]	82.2 | 81.5 | 0.855	100	118
Cobalt	µg/L	1.0	<1.0	<1.0 | <1.0 | [NA]	8.28 | 8.32 | 0.482	98.5	114
Copper	µg/L	1.0	<1.0	3.71 | <1.0 | 200 [6]	15.9 | 15.9 | 0.126	97.9	117
Iron	µg/L	10	<10	<10 | <10 | [NA]	17300 | 17800 | 3.01	103	124
Lead	µg/L	1.0	<1.0	<1.0 | <1.0 | [NA]	3.66 | 3.62 | 1.10	95.6	110
Molybdenum	µg/L	1.0	<1.0	<1.0 | <1.0 | [NA]	7.70 | 7.86 | 2.06	101	123
Nickel	µg/L	1.0	<1.0	<1.0 | <1.0 | [NA]	21.9 | 22.1 | 1.27	98.4	111
Selenium	µg/L	1.0	<1.0	<1.0 | <1.0 | [NA]	12.7 | 12.8 | 1.25	97.4	118
Silver	µg/L	1.0	<1.0	<1.0 | <1.0 | [NA]	<2.0 | <2.0 | [NA]	97.9	121
Tin	µg/L	1.0	<1.0	<1.0 | <1.0 | [NA]	<2.0 | <2.0 | [NA]	99.3	117
Zinc	µg/L	1.0	<1.0	10.2 | 2.34 | 126 [6]	37.3 | 33.8 | 9.78	98.1	117

The QC reported was not specifically part of this workorder but formed part of the QC process batch.

METALS-022|Acid Extractable Low Level Metals (Water) | Batch BDL1776

Analyte	Units	PQL	Blank	DUP1 PDL0720-13 Samp | QC | RPD %	DUP2 PDL0720-17 Samp | QC | RPD %	LCS %	Spike % PDL0720-14
Aluminium	µg/L	10	<10	9870 | 9890 | 0.174	1130 | 1920 | 51.9 [8]	105	-156[2]
Arsenic	µg/L	1.0	<1.0	<10 | <10 | [NA]	<10 | <10 | [NA]	107	108
Barium	µg/L	1.0	<1.0	245 | 262 | 6.86	38.5 | 49.0 | 24.0	104	106
Beryllium	µg/L	0.50	<0.50	<5.0 | <5.0 | [NA]	<5.0 | <5.0 | [NA]	99.8	99.2
Boron	µg/L	20	<20	10200 | 9680 | 5.10	8440 | 9290 | 9.51	114	-777[2]
Cadmium	µg/L	0.10	<0.10	1.70 | 1.80 | 5.71	<1.0 | <1.0 | [NA]	112	109
Chromium	µg/L	1.0	<1.0	111 | 110 | 0.181	80.3 | 83.9 | 4.38	110	112
Cobalt	µg/L	1.0	<1.0	23.6 | 24.1 | 2.10	<10 | <10 | [NA]	110	105
Copper	µg/L	1.0	<1.0	35.0 | 30.8 | 12.8	12.5 | 12.9 | 3.15	112	105
Iron	µg/L	10	<10	31000 | 30700 | 0.921	5070 | 6210 | 20.3	111	-2060[2]
Lead	µg/L	1.0	<1.0	<10 | <10 | [NA]	<10 | <10 | [NA]	103	97.9
Molybdenum	µg/L	1.0	<1.0	11.7 | <10 | 200 [8]	<10 | <10 | [NA]	108	127
Nickel	µg/L	1.0	<1.0	52.7 | 51.9 | 1.53	18.7 | 19.5 | 4.19	106	109
Selenium	µg/L	1.0	<1.0	51.5 | 40.2 | 24.6	30.0 | 31.7 | 5.51	107	84.7
Silver	µg/L	1.0	<1.0	<10 | <10 | [NA]	<10 | <10 | [NA]	119	92.0
Tin	µg/L	1.0	<1.0	<10 | <10 | [NA]	<10 | <10 | [NA]	112	102
Zinc	µg/L	1.0	<1.0	212 | 196 | 7.68	75.7 | 34.6 | 74.5 [8]	114	83.4

METALS-020|Dissolved Metals (Water) | Batch BDL1788

Analyte	Units	PQL	Blank	DUP1 BDL1788-DUP1# Samp | QC | RPD %	DUP2 PDL0720-07 Samp | QC | RPD %	LCS %	Spike % BDL1788-MS1#
Calcium	mg/L	0.50	<0.50	<0.50 | <0.50 | [NA]	444 | 453 | 1.92	95.4	97.5
Magnesium	mg/L	0.50	<0.50	<0.50 | <0.50 | [NA]	2370 | 2420 | 2.29	97.6	110
Manganese	mg/L	0.010	<0.010	<0.010 | <0.010 | [NA]	<0.10 | <0.10 | [NA]	99.0	105
Potassium	mg/L	0.50	<0.50	<0.50 | <0.50 | [NA]	296 | 297 | 0.351	99.7	102
Silicon	mg/L	0.1		<0.10 | <0.10 | [NA]	10.0 | 10.1 | 0.955	106	##[2]
Sodium	mg/L	0.50	<0.50	<0.50 | <0.50 | [NA]	24300 | 24900 | 2.11	97.4	##[2]
Hardness as CaCO3	mg/L	3.0	<3.0	<3.0 | <3.0 | [NA]	10900 | 11100 | 2.25	[NA]	[NA]
Silica	mg/L	0.10	<0.10	<0.10 | <0.10 | [NA]	21.4 | 21.6 | 0.955	[NA]	[NA]

The QC reported was not specifically part of this workorder but formed part of the QC process batch.

Quality Control PDL0720

METALS-020|Dissolved Metals (Water) | Batch BDL1789

Analyte	Units	PQL	Blank	DUP1 PDL0720-17 Samp | QC | RPD %	DUP2 BDL1789-DUP2# Samp | QC | RPD %	LCS %	Spike % PDL0720-18
Calcium	mg/L	0.50	<0.50	481 | 484 | 0.649	1.76 | 1.77 | 0.834	104	98.0
Magnesium	mg/L	0.50	<0.50	2760 | 2780 | 0.906	1.97 | 1.98 | 0.405	107	##[2]
Manganese	mg/L	0.010	<0.010	<0.10 | <0.10 | [NA]	<0.010 | <0.010 | [NA]	103	103
Potassium	mg/L	0.50	<0.50	282 | 279 | 0.938	3.15 | 3.06 | 3.07	109	90.6
Silicon	mg/L	0.1		11.8 | 11.8 | 0.289	0.546 | 0.550 | 0.577	114	117
Sodium	mg/L	0.50	<0.50	27300 | 27500 | 0.804	93.9 | 94.8 | 1.04	108	##[2]
Hardness as CaCO3	mg/L	3.0	<3.0	12600 | 12700 | 0.881	12.5 | 12.6 | 0.556	[NA]	[NA]
Silica	mg/L	0.20	<0.20	25.2 | 25.1 | 0.289	1.17 | 1.18 | 0.577	[NA]	[NA]

The QC reported was not specifically part of this workorder but formed part of the QC process batch.

INORG-026|Inorganics (Water) | Batch BDL1271

Analyte	Units	PQL	Blank	DUP1 BDL1271-DUP1# Samp | QC | RPD %	DUP2 PDL0720-07 Samp | QC | RPD %	LCS %	Spike % BDL1271-MS1#
Fluoride	mg/L	0.10	<0.10	1.87 | 1.84 | 1.62	0.295 | 0.295 | 0.00	103	102

The QC reported was not specifically part of this workorder but formed part of the QC process batch.

INORG-026|Inorganics (Water) | Batch BDL1272

Analyte	Units	PQL	Blank	DUP1 PDL0720-17 Samp | QC | RPD %	LCS %	Spike % PDL0720-19
Fluoride	mg/L	0.10	<0.10	0.267 | 0.266 | 0.375	99.6	90.4

INORG-002|Inorganics (Water) | Batch BDL1278

Analyte	Units	PQL	Blank	DUP1 BDL1278-DUP1# Samp | QC | RPD %	DUP2 PDL0720-10 Samp | QC | RPD %	LCS %
Electrical Conductivity	µS/cm	2.0	2.00	1160 | 1160 | 0.0946	30600 | 30600 | 0.0660	100
pH	pH units		5.5	7.2 | 7.2 | 0.00	7.7 | 7.8 | 0.258	102
Carbonate Alkalinity as CaCO3	mg/L as CaCO3	5.0	<5.0	<5.0 | <5.0 | [NA]	<5.0 | <5.0 | [NA]	[NA]
Bicarbonate Alkalinity as CaCO3	mg/L as CaCO3	5.0	<5.0	219 | 229 | 4.28	316 | 325 | 2.84	[NA]
Hydroxide OH- as CaCO3	mg/L as CaCO3	5.0	<5.0	<5.0 | <5.0 | [NA]	<5.0 | <5.0 | [NA]	[NA]
Total Alkalinity as CaCO3	mg/L as CaCO3	5.0	<5.0	219 | 229 | 4.28	316 | 325 | 2.84	102

The QC reported was not specifically part of this workorder but formed part of the QC process batch.

INORG-002|Inorganics (Water) | Batch BDL1279

Analyte	Units	PQL	Blank	DUP1 BDL1279-DUP1# Samp | QC | RPD %	DUP2 BDL1279-DUP2# Samp | QC | RPD %	LCS %
Electrical Conductivity	µS/cm	2.0	3.00	98.8 | 99.0 | 0.202	618 | 618 | 0.00	101
pH	pH units		5.4	7.2 | 7.3 | 1.10	5.4 | 5.4 | 0.369	101
Carbonate Alkalinity as CaCO3	mg/L as CaCO3	5.0	<5.0	<5.0 | <5.0 | [NA]	<5.0 | <5.0 | [NA]	[NA]
Bicarbonate Alkalinity as CaCO3	mg/L as CaCO3	5.0	<5.0	39.0 | 41.9 | 7.17	11.3 | 10.8 | 4.52	[NA]
Hydroxide OH- as CaCO3	mg/L as CaCO3	5.0	<5.0	<5.0 | <5.0 | [NA]	<5.0 | <5.0 | [NA]	[NA]
Total Alkalinity as CaCO3	mg/L as CaCO3	5.0	<5.0	39.0 | 41.9 | 7.17	11.3 | 10.8 | 4.52	101

The QC reported was not specifically part of this workorder but formed part of the QC process batch.

INORG-081|Inorganics (Water) | Batch BDL1336

Analyte	Units	PQL	Blank	DUP1 PDL0720-01 Samp | QC | RPD %	DUP2 PDL0720-11 Samp | QC | RPD %	LCS %	Spike % PDL0720-02
Chloride	mg/L	1.0	<1.0	20800 | 20800 | 0.0405	22900 | 22900 | 0.0947	106	##[3]
Sulfate	mg/L	1.0	<1.0	3770 | 3770 | 0.00278	4700 | 4720 | 0.318	102	105

Quality Control PDL0720

INORG-081 | Inorganics (Water) | Batch BDL1385

Analyte	Units	PQL	Blank	DUP1 PDL0720-21 Samp | QC | RPD %	DUP2 BDL1385-DUP2# Samp | QC | RPD %	LCS %	Spike % PDL0720-22
Chloride	mg/L	1.0	<1.0	68200 | 68200 | 0.00285	164 | 161 | 1.65	103	71.7
Sulfate	mg/L	1.0	<1.0	12900 | 12800 | 0.411	8.19 | 7.99 | 2.46	101	115

The QC reported was not specifically part of this workorder but formed part of the QC process batch.

INORG-057 | Inorganics (Water) | Batch BDL1402

Analyte	Units	PQL	Blank	DUP1 BDL1402-DUP1# Samp | QC | RPD %	DUP2 PDL0720-01 Samp | QC | RPD %	LCS %	Spike % BDL1402-MS1#
Ammonia as N	mg/L	0.0050	<0.0050	<0.0050 | <0.0050 | [NA]	0.182 | 0.184 | 0.846	117	104
Nitrate as N	mg/L	0.0050	<0.0050	17.2 | 17.2 | 0.0880	13.0 | 12.7 | 2.28	113	##[3]
Nitrate as NO3 by calculation	mg/L	0.020	<0.020			[NA]	[NA]

The QC reported was not specifically part of this workorder but formed part of the QC process batch.

INORG-057 | Inorganics (Water) | Batch BDL1403

Analyte	Units	PQL	Blank	DUP1 PDL0720-03 Samp | QC | RPD %	DUP2 PDL0720-13 Samp | QC | RPD %	LCS %	Spike % PDL0720-04
Ammonia as N	mg/L	0.0050	<0.0050	<0.0050 | <0.0050 | [NA]	0.204 | 0.199 | 2.33	111	121
Nitrate as N	mg/L	0.0050	<0.0050	30.8 | 31.2 | 1.17	23.4 | 23.9 | 2.36	111	102
Nitrate as NO3 by calculation	mg/L	0.020	<0.020			[NA]	[NA]

INORG-127 | Inorganics (Water) | Batch BDL1540

Analyte	Units	PQL	Blank	DUP1 PDL0720-01 Samp | QC | RPD %	DUP2 PDL0720-11 Samp | QC | RPD %	LCS %	Spike % PDL0720-02
Total Nitrogen	mg/L	0.10	<0.10	18.2 | 18.4 | 1.17	8.02 | 7.87 | 1.81	104	105

INORG-127 | Inorganics (Water) | Batch BDL1656

Analyte	Units	PQL	Blank	DUP1 BDL1656-DUP1# Samp | QC | RPD %	LCS %	Spike % BDL1656-MS1#
Total Nitrogen	mg/L	0.10	<0.10	34.3 | 34.3 | 0.00228	106	95.2

The QC reported was not specifically part of this workorder but formed part of the QC process batch.

INORG-018 | Inorganics (Water) | Batch BDL1837

Analyte	Units	PQL	Blank	DUP1 BDL1837-DUP1# Samp | QC | RPD %	DUP2 PDL0720-01 Samp | QC | RPD %	LCS %
Total Dissolved Solids	mg/L	5.0	5.00	1790 | 1800 | 0.279	39600 | 39300 | 0.570	104

The QC reported was not specifically part of this workorder but formed part of the QC process batch.

INORG-018 | Inorganics (Water) | Batch BDL1912

Analyte	Units	PQL	Blank	DUP1 PDL0720-11 Samp | QC | RPD %	DUP2 PDL0720-21 Samp | QC | RPD %	LCS %
Total Dissolved Solids	mg/L	5.0	<5.0	44400 | 44600 | 0.647	124000 | 122000 | 1.07	108

Quality Control PDL0720

QC Comments

Identifier	Description
[2]	Spike recovery is not applicable due to the relatively high analyte background in the sample (>3* spike level). However, the LCS recovery is within acceptance criteria.
[3]	Spike recovery is outside routine acceptance criteria (70-130%), this may be due to suspected non-homogeneity and/or matrix interference effects. However, an acceptable recovery was achieved for the LCS.
[6]	Duplicate %RPD may be flagged as an outlier to routine laboratory acceptance, however, where one or both results are <10*PQL, the RPD acceptance criteria increases exponentially.
[8]	These samples have been diluted for analysis - the raw results pass our normla QC acceptance criteria.

APPENDIX C
Flora and Fauna Assessments

APOLLO HILL GOLD PROJECT FLORA AND FAUNA ASSESSMENTS – PILOT PLANT AND BULK SAMPLE

Saturn Metals

ecoscape



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Revision	Author	QA Reviewer	Approved	Date
Draft Rev0	SK/RH/KP	LJA	LJA	30/8/2023
Draft Rev1	JT	SK	SK	29/2/2024
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EXECUTIVE SUMMARY

Saturn Metals proposes to commence initial pilot-scale mining activities at their Apollo Hill Gold Project, located approximately 50 km southeast of Leonora. To support environmental approvals documentation, Ecoscape was engaged by Saturn Metals to undertake a Detailed flora and vegetation survey and a Basic terrestrial vertebrate fauna survey. Targeted searches for conservation-listed flora, fauna and ecological communities were also undertaken. This report covers a biological assessment of an 822.50 ha area containing the proposed disturbance envelope for the Pilot Pit and Heap Leach Operation and access corridor.

The key findings of the desktop assessment were:

- three pre-European vegetation associations intersect the survey area, each with greater than 90% statewide extent remaining
- seven Priority Ecological Communities identified by the database search as having been recorded within 100 km; none of these have been recorded within the survey area
- 56 conservation-listed flora were identified as having been recorded within 100 km of the survey area by the database searches consisting of no Threatened Flora, 15 Priority 1, four Priority 2, 30 Priority 3 and six Priority 4
- three fauna species were assessed as being 'Likely to Occur' in the survey area, the Malleefowl (*Leipoa ocellata*) (VU EPBC status, VU BC status), Peregrine Falcon (*Falco peregrinus*) (OS BC status/DBCA status) and Southern Whiteface (*Aphelocephala leucopsis*) (VU EPBC status).

The flora and fauna field survey were conducted during March/April and September 2023. The key findings from the flora field survey and subsequent analysis were:

- 54 floristic quadrats established within the survey area
- 166 vascular flora recorded from the survey area including:
  - two Priority-listed flora; *Tecticornia globulifera* (P1) and *Hemigenia exilis* (P4)
  - one IUCN-listed species; *Santalum spicatum* (Sandalwood)
  - two introduced species; **Rumex vesicarius* (Ruby dock) and **Sonchus oleraceus* (Sowthistle)
  - one substantial range extension of *Tecticornia globulifera*
  - one potential new flora taxa; *Tecticornia* sp. nov. 2
- Twelve vegetation types were recorded from five landform types (drainage lines, dunes, flats/plains, rocky hills and wetlands). None of the vegetation types are representative of any currently described TEC or PEC. One vegetation type, **EcAbPd**, may be significant as Groundwater Dependent Vegetation.
- the vegetation condition ranged from Completely Degraded to Very Good with the majority in Very Good condition (84.91 %). The main factors affecting vegetation condition were clearing and grazing.

The fauna field survey identified:

- seven fauna habitats: Mulga Woodland (535.38 ha), Mixed Shrubland (96.17 ha), Chenopod Shrubland (116.91 ha), Rocky Escarpment (64.26 ha), Drainage Line (2.65 ha), Flood Plain (7.14 ha) and Cave/Mine Shaft (too small to be mapped). None are considered of local or regional significance.
- 35 vertebrate fauna species
- one species was conservation-listed (Black-eared Cuckoo *Chalcites osculans*, MA/MI EPBC status)
- the fauna habitat quality was reduced due to disturbance from roaming cattle across the entire survey area
- the Chenopod Shrubland and Flood Plain habitats are seasonally inundated, potentially providing resources for conservation-listed migratory wetland bird species.

ACRONYMS AND ABBREVIATIONS

Table 1: Acronyms and abbreviations

Acronyms	
BAM Act	Western Australian *Biosecurity and Agriculture Management Act 2007*
BC Act	Western Australian *Biodiversity Conservation Act 2016*
BoM	Bureau of Meteorology
C1, C2, C3	Declared Pest categories under the BAM Act
CD	Conservation Dependent (fauna; specially protected species under the Western Australian BC Act)
CR	Critically Endangered (listed under Commonwealth EPBC Act and/or Western Australian BC Act)
DAFWA	Department of Agriculture and Food, Western Australia (2006-2017, now DPIRD)
DAWE	Commonwealth Department of Agriculture, Water and Environment (2020-2022, now DCCEEW)
DBCA	Western Australian Department of Biodiversity, Conservation and Attractions
DCCEEW	Commonwealth Department of Climate Change, Energy, the Environment and Water
DEC	Western Australian Department of Environment and Conservation (2006-2013, now DBCA)
DEWHA	Commonwealth Department of the Environment, Water, Heritage and the Arts (2007-2010, now DCCEEW)
DMIRS	Western Australian Department of Mines, Industry Regulation and Safety
DPaW	Western Australian Department of Parks and Wildlife (2013-2017, now DBCA)
DoE	Commonwealth Department of the Environment (2013-2016, now DAWE)
DotEE	Commonwealth Department of the Environment and Energy (2016-2020)
DPIRD	Western Australian Department of Primary Industries and Regional Development
DSEWPaC	Commonwealth Department of Sustainability, Environment, Water, Population and Communities (2010-2013, now DCCEEW)
DWER	Western Australian Department of Water and Environmental Regulation
EN	Endangered (listed under Commonwealth EPBC Act and/or Western Australian BC Act)
EP Act	Western Australian *Environmental Protection Act 1986*
EPA	Western Australian Environmental Protection Authority
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
GDA 94	Geographic Datum of Australia 1994
GDE	Groundwater Dependent Ecosystem
IBRA	Interim Biogeographic Regionalisation for Australia
IUCN	International Union for Conservation of Nature
NVIS	National Vegetation Inventory System
MNES	Matters of National Environmental Significance
P; P1, P2, P3, P4	Priority Flora and Fauna species rankings (P1-P4) or Priority Ecological Communities (P1-P5)
PEC	Priority Ecological Community
PF	Priority Flora
PMST	Protected Matters Search Tool (hosted by DAWE, used to search for MNES)
sp.	Species (generally referring to an unidentified taxon or when a phrase name has been applied)
subsp.	Subspecies (infrataxon)
S1	Schedule 1 Fauna species listed under the BC Act
TEC	Threatened Ecological Community
TF	Threatened Flora (formerly termed Declared Rare Flora, DRF, in Western Australia)
var.	Variety (infrataxon)
VU	Vulnerable (listed under Commonwealth EPBC Act and/or Western Australian BC Act)
WAH	Western Australian Herbarium
WAM	Western Australian Museum
WONS	Weeds of National Significance
*****	Introduced flora species (i.e. weed)

1 INTRODUCTION

1.1 BACKGROUND

Saturn Metals is proposing to commence initial pilot-scale mining activities at their Apollo Hill Gold Project, located approximately 50 km southeast of Leonora. To support environmental approvals documentation, Ecoscape was engaged by Saturn Metals to undertake a Detailed flora and vegetation survey and a Basic terrestrial vertebrate fauna survey. Targeted searches for conservation-listed flora, fauna and ecological communities were also undertaken. The surveys focused on the disturbance envelope for the proposed Pilot Pit and Heap Leach Operation, with broader regional survey efforts also undertaken to provide baseline data for potential larger project development in the future.

This report specifically covers the proposed disturbance envelope for the Pilot Pit and Heap Leach Operation (the Project area).

1.2 SURVEY AREA

The proposed disturbance envelope for the Pilot Pit and Heap Leach Operation (the Project area), known as the 'survey area' in this report, is located within the Shire of Leonora (northern section) and the Shire of Menzies (southern section) in the Murchison bioregion, approximately 50 km southeast of Leonora and approximately 650 km east-northeast of Perth (**Figure 1**). The survey area encompasses the proposed disturbance footprints for the Project, including pilot-scale pit, heap leach facility and associated infrastructure, comprising a total area of 822.50 hectares (ha).

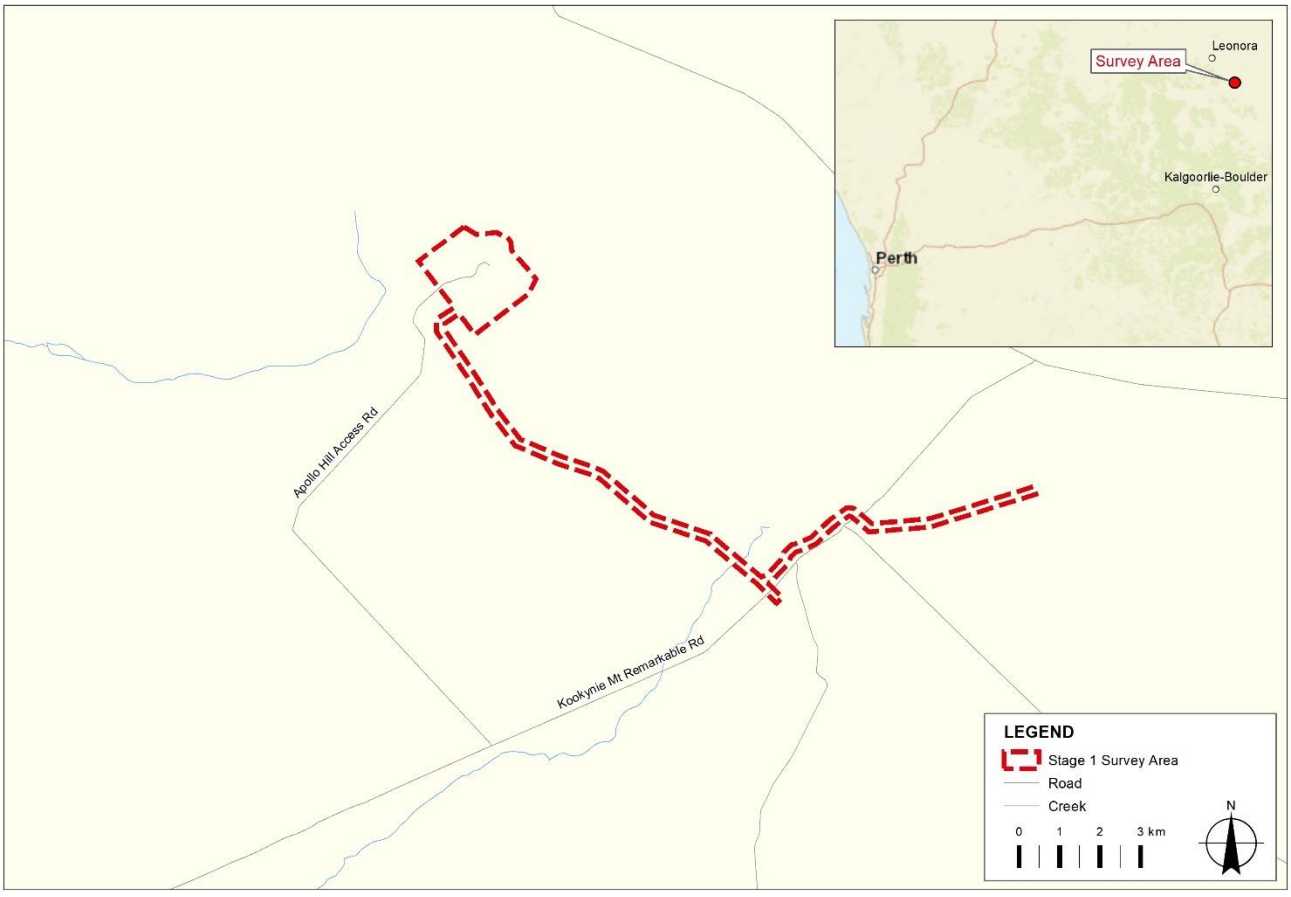


Figure 1: Survey area location

1.3 SURVEY REQUIREMENTS

The scope of works was to:

- conduct a Detailed flora and vegetation survey including targeted searches for significant flora and vegetation in accordance with Environmental Protection authority (EPA) guidelines
- conduct a Basic terrestrial vertebrate fauna survey including targeted searches for significant fauna in accordance with EPA guidelines
- prepare a comprehensive flora, vegetation and fauna assessment report
- preparation of spatial data.

1.4 COMPLIANCE

This environmental assessment was conducted in accordance with Commonwealth and State legislation and guidelines:

- Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)
- Western Australian *Environmental Protection Act 1986* (EP Act)
- Western Australian *Biodiversity Conservation Act 2016* (BC Act)
- Western Australian *Biodiversity Conservation Regulations 2018*
- Western Australian *Animal Welfare Act 2002*
- Department of Environment, Water, Heritage and the Arts (DEWHA 2009) *Matters of National Environmental Significance. Significant impact guidelines 1.1 - Environment Protection and Biodiversity Conservation Act 1999*
- Department of Sustainability Environment Water Population and Communities (DSEWPaC 2011a) *Survey guidelines for Australia's threatened mammals*
- DSEWPaC (2011b) *Survey guidelines for Australia's threatened reptiles*
- DEWHA (2010a) *Survey guidelines for Australia's threatened bats*
- DEWHA (2010b) *Survey guidelines for Australia's threatened birds*
- Department of Parks and Wildlife (DPaW 2017) *Interim Guideline for Preliminary Surveys of Night Parrot (Pezoporus occidentalis) in Western Australia*
- Threatened Species Scientific Committee (2016) *Conservation Advice Pezoporus occidentalis.*

Summaries of the main Acts under which this assessment was conducted, and related criteria and definitions, are available in **Appendix One**.

As well as those listed above, the assessment complied with EPA requirements for environmental survey and reporting in Western Australia, as outlined in:

- EPA (2020) *Technical Guidance – Terrestrial vertebrate fauna surveys for environmental impact assessment*, known herein as the Fauna Technical Guidance
- EPA (2016a) *Technical Guidance – Flora and Vegetation Surveys for Environmental Impact Assessment*, known herein as the Flora and Vegetation Technical Guidance
- EPA (2016b) *Environmental Factor Guideline – Flora and Vegetation*
- EPA (2016c) *Environmental Factor Guideline – Terrestrial Fauna*
- EPA (2021) *Statement of environmental principles, factors, objectives and aims of EIA*.

Additional details (definitions and criteria) relevant to these works are available in **Appendix One**.

2 DESKTOP ASSESSMENT

2.1 PHYSICAL ENVIRONMENT

2.1.1 CLIMATE

According to the Köppen-Geiger climate classification, the survey area has an arid-steppe climate with hot, dry summers (Class BSh) (Peel, Finlayson & McMahon 2007). This classification is considered to represent a dry arid and semiarid climate where the average temperature is above 18°C, summer maximum temperatures are hot or extremely hot and the coldest month maximum is above 0°C. Rainfall is less than the potential evapotranspiration.

The closest Bureau of Meteorology (BoM) station with long-term records for rainfall as well as temperature is Leonora (station number 12046, operating 1898-2024) (BoM 2023a), located approximately 48 km northwest of the survey area. The mean annual rainfall is 236.4 mm, with the highest from January to March. January is the hottest month, with a mean maximum temperature of 37°C and minimum of 21.8°C. July is the coldest month, with a mean maximum of 18.4°C and minimum of 6.1°C.

Figure 2 shows the average rainfall and temperatures of the survey area.

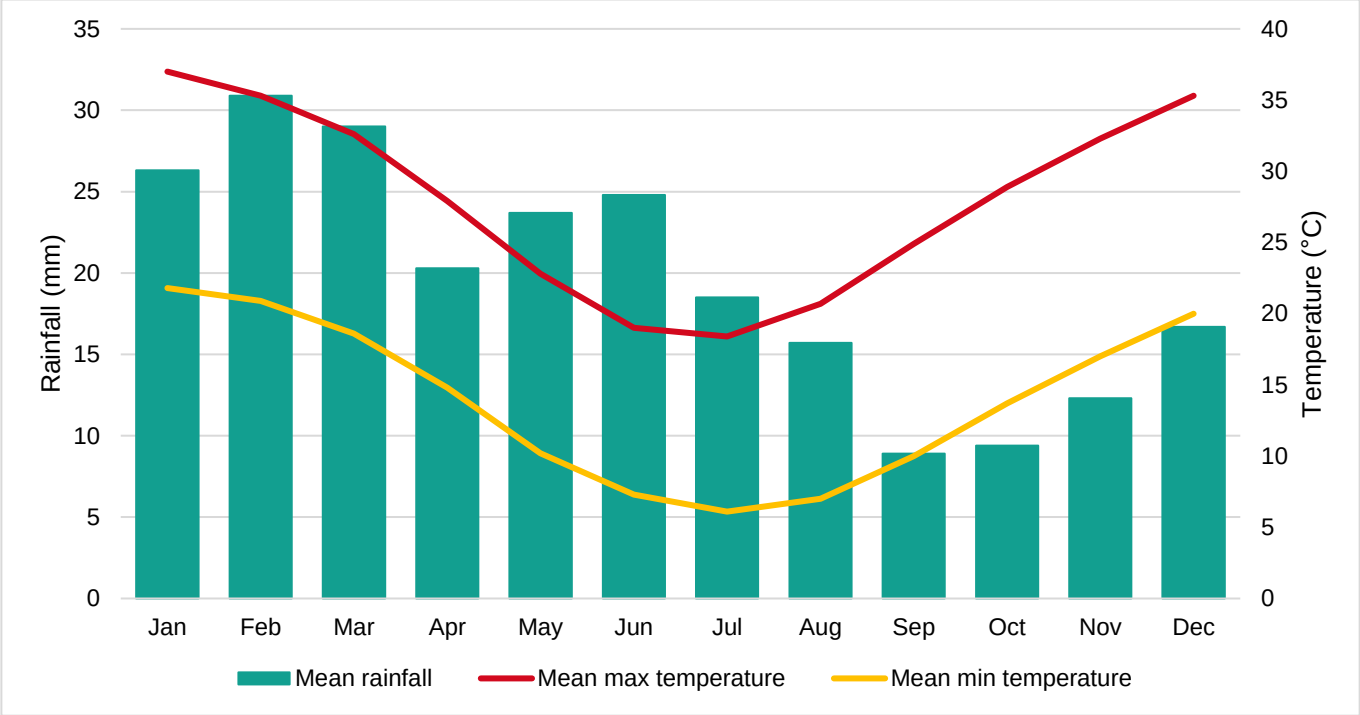


Figure 2: Long-term rainfall and temperature data for the study area using the Leonora weather station (BoM 2023a, station nr. 12046)

2.1.2 LAND SYSTEMS

According to the Department of Primary Industries and Regional Development (DPIRD 2020) soil landscape mapping, four land systems intersect the survey area (**Table 2** and **Map 1**). The Carnegie land system is the most widespread, occupying 66.96% of the survey area.

Table 2: Land systems (DPIRD 2020)

Mapping unit	Land system	Description	Extent (ha)	%
279Ca	Carnegie system	Salt lakes with fringing saline alluvial plains, kopi dunes and sandy banks, supporting halophytic shrublands and acacia tall shrublands	550.72	66.96
279Ju	Jundee system	Hardpan plains with variable gravelly mantles and minor sandy banks supporting weakly groved mulga shrublands	74.13	9.01
279Le	Leonora system	Low greenstone hills and stony plains supporting mixed chenopod shrublands	112.95	13.73
279Yo	Yowie system	Sandy plains supporting tall shrublands of mulga and bowgada with patchy wanderrie grasses	84.70	10.30

2.1.3 WETLANDS AND DRAINAGE

The survey area intersects the Lake Carey and Raeside-Ponton catchments (Landgate 2021). Thirteen non-perennial streams are identified within this area, with four classed as major and nine as minor. Among these creeks, only Bullock Hole Creek is specifically named. Additionally, small non-perennial lakes forming part of the upstream tributaries of Lake Raeside, located approximately 20 km south, are located within the survey area.

2.1.4 GROUNDWATER DEPENDENT ECOSYSTEMS

The Groundwater Dependent Ecosystems Atlas (BoM 2023b) indicates that the survey area does not intersect any mapped GDEs.

2.1.5 ENVIRONMENTALLY SENSITIVE AREAS

The survey area does not intersect or occur within proximity to any mapped Environmentally Sensitive Areas (ESAs) (DWER 2021). The nearest ESAs are:

- 42 km south, corresponding with Lake Marmion
- 47 km southwest, corresponding with Lake Ballard
- 67 km south, corresponding with Goongarrie National Park.

2.1.6 CONSERVATION LANDS

No National Parks, Nature Reserves or other conservation estate occur within proximity to the survey area. The nearest conservation estate is Goongarrie National Park, located approximately 67 km south of the survey area.

2.1.7 LAND USE HISTORY

The survey area is located within Glenorn station, and the current land use is predominantly cattle pastoralism. Other land uses within the subregion include mining (mostly gold and nickel) and conservation estates.

2.2 BIOLOGICAL ENVIRONMENT

2.2.1 BIOGEOGRAPHIC REGION

Biogeographic regions are delineated based on similar climate, geology, landforms, vegetation, and fauna and are defined in the Interim Biogeographical Regionalisation for Australia (IBRA) (Department of Agriculture Water and the Environment 2020).

The survey area is in the Murchison IBRA region in the Eastern Murchison subregion (MUR01), described as (Cowan 2001):

> *The northern parts of the 'Southern Cross' and 'Eastern Goldfields' Terrains of the Yilgarn Craton. Characterised by its internal drainage, and extensive areas of elevated red desert sandplains with minimal dune development. Salt lake systems associated with the occluded Paleodrainage system. Broad plains of red-brown soils and breakaway complexes as well as red sandplains. Vegetation is dominated by Mulga Woodlands often rich in ephemerals; hummock grasslands, saltbush shrublands and Halosarcia shrublands. Arid climate, with mainly winter rainfall (200 mm).*

2.2.2 PRE-EUROPEAN VEGETATION

During the 1970s, John Beard and associates conducted a systematic survey of native vegetation, describing the vegetation systems in Western Australia at a scale of 1:250,000 in the south-west and at a scale of 1:1,000,000 in less developed areas.

Beard's vegetation maps attempted to depict the native vegetation as it was presumed to be at the time of settlement and is known as the pre-European vegetation type and extent. Beard's vegetation maps have since been developed in digital form by Shepherd, Beeston & Hopkins (2002) and updated by DPIRD (2019). Extents are updated every two years by DBCA (2019). This mapping indicates that the survey area intersects three pre-European vegetation units:

- Association 18: Mulga *Acacia aneura* and associated species (174.23 ha, 21.18%)
- Association 125: salt lake (0.00008 ha, 0.000009 %)
- Association 389: Mulga, other wattle, *Casuarina, Atriplex* spp. *Maireana* spp. with *Acacia aneura*, *A. papyrocarpa, Allocasuarina cristata* (648.27 ha, 78.82%).

The pre-European vegetation associations identified from the survey area (DPIRD 2019) and their pre-European and current extents are listed in **Table 3** (DBCA 2019) and shown on **Map 2**.

Table 3: Pre-European vegetation association representation (DBCA 2019)

Region	Vegetation association	Original extent (ha)	Current extent (ha)	% remaining
Western Australia	18	19,892,306.46	19,843,148.07	99.75
	125	3,485,785.49	3,146,487.22	90.27
	389	642,356.85	640,468.79	99.71
IBRA biogeographic region (Murchison)	18	12,403,172.30	12,363,252.47	99.68
	125	711,483.67	710,255.44	99.83
	389	493,977.54	492,089.49	99.62
IBRA biogeographic sub-region (East Murchison)	18	10,269,896.44	10,234,838.22	99.66
	125	701,136.94	699,919.75	99.83
	389	493,977.54	492,089.49	99.62
LGA (Shire of Leonora)	18	2,010,057.25	2,002,508.00	99.62
	125	117,549.26	116,983.68	99.52
	389	21,519.33	21,403.33	99.46

2.2.3 THREATENED AND PRIORITY ECOLOGICAL COMMUNITIES

Threatened and Priority Ecological Communities (TECs and PECs) intersecting the survey area and nearby were identified by a *Protected Matters Search Tool* (PMST) search (Department of Climate Change Energy the Environment and Water 2023a [DCCEEW], using a 50 km buffer) and DBCA database search (search reference 45-1122EC using a 100 km buffer).

The PMST did not identify any occurrences of Commonwealth-listed TECs within the search area. The DBCA database search identified seven PECs within the search area (**Table 4**, **Map 3**); none occur within the survey area.

Table 4: TECs and PECs identified by PMST and DBCA database searches

Ecological Community	WA status
Emu Land System	Priority 3
Laverton Downs calcrete groundwater assemblage type on Carey palaeodrainage on Laverton Downs Station	Priority 1
Melita calcrete groundwater assemblage type on Raeside palaeodrainage on Melita (Sons of Gwalia) Station	Priority 1
Mount Jumbo Range vegetation complex (banded ironstone formation)	Priority 3
Mount Linden Range vegetation complex (banded ironstone formation)	Priority 3
Mount Morgan calcrete groundwater assemblage type on Carey palaeodrainage on Mt Weld Station	Priority 1
Sturt Meadows calcrete groundwater assemblage type on Raeside palaeodrainage on Sturt Meadows Station	Priority 1

2.2.4 THREATENED AND PRIORITY FLORA

The PMST search (as above) did not identify any EPBC-listed Threatened Flora (TF) within the 50 km search buffer area.

The DBCA database searches (reference 83-1122FL) were conducted using a 100 km buffer around the survey area. The results incorporate the TPFL List, taken from Threatened and Priority Flora Report Forms and DBCA surveys, and WA Herb, taken from vouchered specimens held in the Western Australian Herbarium. **Map 3** shows the locations of conservation-listed flora (TF and Priority Flora; PF) identified by the DBCA database search, with no records occurring within the survey area.

The combined database searches identified 56 conservation-listed flora taxa, listed in **Table 22** in **Appendix Three**, consisting of no TF, 15 Priority 1 (P1), four P2, 30 P3 and six P4.

2.2.4.1 Threatened and Priority Flora Likelihood Assessment

Ecoscape conducted a likelihood assessment to identify the TF and PF species that have potential to occur within the survey area. The likelihood of a species occurring was based on information available on *FloraBase* (WAH 1998–, WAH 2023), nearby surveys and other available literature for each species, such as taxonomic descriptions, assessed with respect to habitats and landforms likely to be present in the survey area.

The attributes taken into consideration were:

- broad soil type usually associated with the species
- broad landform usually associated with the species
- usual vegetation (characteristic species) with which the species is usually associated
- species having previously been recorded from within approximately 25 km of the survey area (considered as ‘nearby’) taking locational accuracy into consideration
- time since recorded (i.e. within the previous 25 years), taking into consideration land use changes since collection
- reliability of record: species identified by only a TPFL record, without an accompanying verified vouchered specimen, may have been incorrectly identified or been subject to taxonomic updates since the record was entered
- number of records for the species
- if the record is for a not naturally occurring population (planted).

The likelihood rating is assigned using the categories listed in **Table 5**.

Table 5: Categories for likelihood of occurrence of TF and PF

Likelihood Category	Criteria
Known to occur	Species previously recorded within the survey area.
Likely to occur	Suitable habitat is known to occur within the survey area and multiple records of the species exist within proximity*
May occur	Suitable habitat is expected to occur within the survey area and the species has previously been recorded within proximity**
Unlikely to occur	Suitable habitat is expected to occur within the survey area however previous records are limited and/or historic and/or not in proximity** OR Suitable habitat is not expected to occur within the survey area although previous records exist in proximity**
Very Unlikely to occur	Suitable habitat is not expected to occur in the survey area AND/OR previous records are limited and/or historic and/or not in proximity**

* close proximity = 25 km
** proximity = 50 km

The likelihood assessment is available in **Table 22** in **Appendix Three**. No TF or PF have been previously recorded from within the survey area. One P3 species (*Angianthus prostratus*) was assessed as 'likely to occur' with three species assessed as 'may occur' based on the information available during the desktop survey consisting of one P1 (*Ptilotus tetrandrus*), one P3 (*Triglochin protuberans*) and one P4 (*Hemigenia exilis*). These taxa were prioritised for survey.

The likelihood of occurrence was re-evaluated following the field survey when actual survey area characteristics (vegetation types, vegetation condition, visibility for individual species) were better understood, and the level of survey effort was considered. The post-survey likelihood is also incorporated into this table and discussed further in **Section 5.1.1.2**.

2.2.5 THREATENED AND PRIORITY FAUNA

Combined database search results are incorporated into **Table 23** in **Appendix Three**.

Species identified by these database searches that are excluded from the field survey and further assessments (including likelihood assessments) are listed in **Table 24** along with the reason for their exclusion (e.g. marine species whose habitat does not occur within the survey area, invertebrates are not within the scope of the survey). Such excluded species are not further referenced in this document.

2.2.5.1 EPBC-listed Threatened Fauna

The PMST (DCCEEW 2023a, using a 50 km buffer), identified the following as having been recorded or having potential to occur within the search area buffer:

- two mammals whose 'species or species habitat may occur within area',
- six birds whose 'species or species habitat known to occur within area', two 'species or species habitat likely to occur within area, and eight 'species or species habitat may occur within area'.

2.2.5.2 DBCA Database Search

A search of the DBCA databases was conducted (search reference: FAUNA#7456) using a 90 km buffer around the provided shapefiles of the survey area. Twenty-one conservation-listed fauna were identified as having previously been recorded from within the search area buffer, consisting of three mammals, 13 birds, one reptile and four invertebrates.

2.2.5.3 Threatened and Priority Fauna Likelihood Assessment

The likelihood of conservation-listed fauna species, as identified by the database and literature searches, occurring within the survey area was assessed using the following criteria:

- suitability of habitat types likely to be present within the survey area
- distance between previous record of conservation-listed species and the survey area
- frequency and number of records in the region
- date of record of conservation-listed species (recent or historical)
- the record is naturally occurring (not from a sanctuary or translocated population).

The following were also taken into consideration during the assessment:

- sufficiency of information
- behavioural and ecological characteristics such as cryptic behaviours, size, and mobility of species
- record certainty.

The categories of likelihood of occurrence, assessed using the above criteria, are shown in **Table 6**.

Table 6: Categories for likelihood of occurrence of conservation-listed fauna

Likelihood Category	Criteria
Known to occur	Species previously recorded within the survey area within 25 years.
Likely to occur	Suitable habitat is expected to occur within the survey area and records of the species within 25 years exist within close proximity*
May occur	Suitable habitat is expected to occur within the survey area and historic records of the species exist within close proximity* OR Suitable habitat is expected to occur within the survey area and recent (<25yrs) records exist within the database search buffer but not in close proximity*
Unlikely to occur	Suitable habitat is expected to occur within the survey area however previous records are limited and/or historic and/or not in proximity** OR Suitable habitat is not expected to occur within the survey area and recent (<25yrs) records do not occur in close proximity*
Very Unlikely to occur	Suitable habitat is not expected to occur in the survey area AND/OR previous records are limited and/or historic and/or not in proximity**

* close proximity = 22.5 km (¼ of the distance of the database search buffer)
** proximity = 45 km (½ of the distance of the database search buffer)

The likelihood of species occurring within the survey area are indicated in **Table 23** in **Appendix Three**. Three species were assessed as being Likely to occur within the survey area:

- *Leipoa ocellata* (Malleefowl) – VU EPBC status, VU BC status
- *Falco peregrinus* (Peregrine Falcon) – OS BC status, DBCA status.

Likelihood of occurrence does not consider factors such as the frequency that a species occurs (or may occur), the duration that such species occupies (or may occupy) the survey area, or dependence on habitat or resources within the survey area. Highly mobile species potentially only occur within (or for birds, overflying) the survey area for very brief periods and/or on very infrequent intervals. If a previous observation included in the database search records corresponds with this event it is listed as 'Recorded'; if such a transient visitation is possible in the future the likelihood of such species occurring is likely listed as 'Likely'.

Following the field survey, when actual survey area characteristics are better understood and the level of survey effort was considered, the likelihood of occurrence was re-evaluated. The post-survey likelihood is also incorporated into this table and discussed further in **Section 5.3.3.1**, including providing an indication of dependence of species on the habitat and resources available within the survey area.

2.2.6 FAUNA HABITAT

The literature review identified the following broad habitat types occur within the survey area or are known from nearby:

- Open Mulga woodland over scattered low shrubs and grasses (Terrestrial Ecosystems 2018, 2020a, 2020b)
- Open Chenopod shrubland over grasses (Terrestrial Ecosystems 2018)
- Chenopod and Mulga shrubland over scattered grasses (Terrestrial Ecosystems 2018)
- Banded ironstone rocky ridgeline with scattered Mulga and shrubs (Terrestrial Ecosystems 2018)
- Woodland of large Eucalypts over mixed shrubs and scattered grasses along an ephemeral creekline (Terrestrial Ecosystems 2020b)
- Acacia/Casuarina woodland on plains or slopes (BIOSTAT Pty Ltd 2020)
- *Eucalyptus*/Casuarina woodlands in valleys (BIOSTAT Pty Ltd 2020)
- *Eucalyptus* woodland (BIOSTAT Pty Ltd 2020)
- Drainage lines (BIOSTAT Pty Ltd 2020)
- Shrubland (BIOSTAT Pty Ltd 2020)
- *Eucalyptus*/Chenopod woodland (BIOSTAT Pty Ltd 2020)
- Casuarina woodland (BIOSTAT Pty Ltd 2020)
- Mallee woodland over shrubland (BIOSTAT Pty Ltd 2020).

2.3 RELEVANT LITERATURE

2.3.1 PREVIOUS SURVEYS

No previous field-based surveys have been identified as having been conducted in areas corresponding with the survey area. A desktop flora, vegetation and fauna assessment has previously been undertaken for part of the survey area (Botanica Consulting 2019).

2.3.2 IBSA DATA SEARCH

The Department of Water and Environmental Regulation's (DWER's) *Index of Biodiversity Surveys for Assessments (IBSA)* Portal (DWER 2023) was searched for recent environmental surveys in the vicinity of the survey area. The search, conducted on 20 December 2022, identified 18 surveys that have been undertaken within 100 km of the survey area:

- Alexander Holm & Associates (2021); *Vegetation Assessment within Expanded Porphyry Mine Clearing Envelope*. Unpublished report prepared for Northern Star Resources Ltd. This survey was largely a desktop assessment; a field assessment did not identify any conservation-listed flora or vegetation.
- EcoLogical Australia (2021); *Leonora Rail Track Flora, Vegetation and Fauna Survey* (Metadata only)
- Focused Vision Consulting (2021); *Northern Goldfields Interconnect (NGI) Pipeline Project, Supplementary Targeted Flora Surveys for Construction Avoidance*. Unpublished memorandum prepared for APA Northern Goldfields Interconnect Pty Ltd. This targeted survey identified one PF along a linear alignment.
- BIOSTAT Pty Ltd (2020); *Vegetation Clearing Fauna Assessment*. Unpublished report prepared for Ora Banda Mining over a 1,483 ha survey area, consisting of a fauna habitat assessment, listed 26 habitat descriptions of 9 broad habitat types.
- Botanica Consulting (2020); *Kookynie Project Reconnaissance Flora/ Vegetation and Basic Fauna Survey*. Unpublished report prepared for Genesis Minerals Ltd. (Metadata only)
- Mattiske Consulting (2020); *Assessment of Flora and Vegetation Values, St George, Great Western and Cables Mission Project Areas*. Unpublished report prepared for Red 5 Ltd. This survey identified eight vegetation types with 63 flora taxa, including no weeds or conservation-listed species. The vegetation condition was assessed as Completely Degraded to Very Good.
- Native Vegetation Solutions (2020); *Reconnaissance Flora and Vegetation Survey of Proposed TSF4, Granny Smith Mine*. Unpublished report prepared for Goldfields GSM Mining Company Pty Ltd. This

survey of a 331.62 ha area identified five vegetation types and 111 flora taxa, including one conservation-listed species and two weeds.

- Terrestrial Ecosystems (2020a); *Vertebrate Fauna Reconnaissance Survey for Great Western Project Area*, Unpublished report for Red 5 Ltd. The survey area was 225 ha; one habitat type was recorded, with no conservation-listed species recorded.
- Terrestrial Ecosystems (2020b); *Level 2 Vertebrate Fauna Assessment for the King of the Hills Project*. Unpublished report prepared for Red 5 Ltd. Survey area was 15,450 ha; two fauna habitats and 105 vertebrate species were recorded.
- Terrestrial Ecosystems (2020c); *Vertebrate Fauna Risk Assessment for the Granny Smith Tailing Storage Facility Expansion*. Unpublished report for Granny Smith Mining Company Pty Ltd. Survey area 332.1 ha; four broad habitat types found; no fauna species recorded.
- 360 Environmental (2019); *Wedge Survey Area Biological Assessment*. Unpublished report prepared for Focus Minerals (Laverton) Pty Ltd (Metadata only).
- Native Vegetation Solutions (2019); *Reconnaissance Flora and Vegetation Survey of Proposed GSM Solar Farm*. Unpublished report prepared for Goldfields GSM Mining Company Pty Ltd. This survey of a 150.05 ha area identified five vegetation types with 66 flora taxa, including one weed and no conservation-listed species. The vegetation condition was assessed as Good to Very Good.
- Terrestrial Ecosystems (2018); *Vertebrate Fauna Risk Assessment for the Granny Smith Solar Power Farm Project*. Unpublished report to Granny Smith Mining Company Pty Ltd. The survey area occupied 150 ha; four broad habitat types were found, and no fauna species were recorded.
- Goldfields Landcare Services (2016); *Flora and Vegetation Survey of the Menzies Project*. Unpublished report prepared for Australian Mineral Partners Pty Ltd. This survey of a 1,250 ha area identified four vegetation types with 114 flora taxa, including seven weeds and no conservation-listed species. The vegetation condition was assessed as Good.
- Greg Harewood (2016); *Fauna Assessment Ulysses Project (Mining Lease 40/166)*. Unpublished report prepared for Genesis Minerals Limited (Metadata only)
- Botanica Consulting (2016); *Level 1 Flora & Vegetation Survey Ulysses survey area*. Unpublished report prepared for Genesis Minerals Ltd (Metadata only).
- Western Botanical (2013); *Level 1 Flora and Vegetation Survey, Leonora Rail Yard Expansion Project*. Unpublished report prepared for Aurizon Holdings Ltd. This survey of a 7.66 ha area identified one vegetation association and 59 flora taxa, including seven weeds and no conservation-listed flora. Vegetation condition was assessed as Degraded to Good.

2.3.3 OTHER LITERATURE

A regional survey, *The Biological Survey of the Eastern Goldfields* (Biological Surveys Committee Western Australia 1984), was reviewed, though data and nomenclature were too dated to provide meaningful comparisons.

A survey undertaken by Ecoscape (2019) was located approximately 10 km from the survey area. This was undertaken as a reconnaissance flora and vegetation and basic terrestrial vertebrate fauna survey of a 6,797 ha area. The flora and vegetation survey identified 30 vegetation types and 155 vascular flora taxa, including three conservation-listed flora and seven weeds. The fauna survey identified four habitat types and 62 species, including one potentially conservation-listed.

3 METHODS

3.1 GUIDING PRINCIPLES

The flora and vegetation survey was conducted as a Detailed survey according to the Flora and Vegetation Technical Guidance (EPA 2016a). The EPA considers that a Detailed survey requires:

- a comprehensive survey design, including considering the survey timing that should be conducted during the primary season of survey for the bioregion and disturbance events and the potential requirement for supplementary surveys
- a minimum of three quadrats (in proportion to the extent of the vegetation unit), located throughout each preliminary vegetation type sampled throughout its geographic range, with additional quadrats and rescoring during supplementary surveys to clarify vegetation unit boundaries
- regional surveys if there is insufficient information available (identified during the desktop assessment) to provide local and regional context
- the survey may include several sampling techniques, including quadrats, relevés, transects and traverses, as well as opportunistic observations
- the flora inventory should be comprised of data collected from quadrats and relevés, supplemented by opportunistic observations, systematic surveys and targeted inspections of various habitat areas
- it may be appropriate to increase survey efforts in areas of unusual habitat
- sample sites should capture representative locations throughout the survey area considering landform, geology, elevation, slope, aspect, surface or groundwater expression, soil type, vegetation structure, composition, and condition.

Targeted searches were also conducted in areas of habitat suitable for TF and PF identified during the desktop assessment and previous surveys as having the potential to occur.

The fauna and fauna habitat survey was conducted as a Basic survey according to the Fauna Technical Guidance (EPA 2020). The EPA recommends a Basic survey should:

- be conducted as a low-intensity survey to gather broad fauna and habitat information
- verify the adequacy of the desktop assessment
- map, describe and photograph habitats
- record opportunistic fauna observations
- identify possible future survey site locations, access and logistics
- determine if a Detailed survey is required.

Targeted surveys were also conducted to gather information on significant fauna.

3.2 FLORA AND VEGETATION FIELD SURVEY

3.2.1 FIELD SURVEY METHODS

The methods utilised during the field survey followed those outlined in the Flora and Vegetation Technical Guidance (EPA 2016a), conducted as a single-phase Detailed survey.

Conservation criteria used in this assessment are outlined in **Table 16**, **Table 17** and **Table 18** in **Appendix One**.

Survey method details are outlined below.

3.2.1.1 Floristic Quadrats

Floristic quadrat ('quadrat') locations were selected using aerial photography, environmental values, and field observations to represent the vegetation values existing at the site. The unmarked quadrats were 20 m × 20 m in dimension, as required according to the Flora and Vegetation Technical Guidance (EPA 2016a). Where the vegetation consisted of a narrow linear corridor, quadrats were linear but of the same overall size, i.e. 400 m^2.

The following information was collected from within each quadrat:

- observer
- date
- quadrat/site number
- GPS location (GDA94) of the northwest corner
- digital photograph (spatially referenced with a reference number), taken from the northwest corner, looking diagonally across the quadrat
- broad soil type and colour
- topography
- list of flora species recorded with the average height and total cover within the quadrat for each species
- vegetation description (as per below)
- vegetation condition.

At least three quadrats per vegetation type were recorded for the Detailed survey where there was sufficient extent. Quadrat locations are displayed on the **Map 5** series.

3.2.1.2 Targeted Searches

Threatened and Priority Flora identified during the desktop analysis and previous surveys as known or having the potential to occur were targeted for searches in areas of potential habitat. Targeted searches were conducted in potentially suitable habitats of target species, with the remainder of the site opportunistically searched during site traverses. The central Pilot Plant and Bulk Sample area were extensively traversed at 200 m or less intervals whilst the entire length of the access corridor was also traversed.

The locations of all targeted taxa collected were recorded using a handheld GPS with the following data recorded:

- observer, date and time
- reproductive status and other features such as the health of plants, percentage flowering and fruiting
- local abundance/population size and/or population boundary, including outside the development envelopes where possible
- landform
- brief vegetation community description
- representative photos of each species and habitat
- collection of representative specimens.

3.2.1.3 Introduced Species

Introduced species (weeds) were recorded during the collection of the overall flora inventory.

3.2.1.4 Vegetation Description and Classification

Vegetation was described from each of the quadrats using the height and estimated cover of dominant and characteristic species of each stratum based on the National Vegetation Information System, recorded at Level V (NVIS Technical Working Group & DotEE 2017) (**Table 19** and **Table 20** in **Appendix Two**). Up to three species per stratum from each stratum (upper, mid, and ground) were used to formulate vegetation descriptions for each quadrat and each vegetation type.

Vegetation-type descriptions were created by combining quadrat descriptions and modifying, where necessary, based on the broader vegetation. Vegetation codes were formulated using the first letter of genus and species names of each stratum's dominant species, e.g., **AcEfPo** refers to ***A****cacia* ***c****aesaneura* low woodland over ***E****remophila* ***f****orrestii* subsp. *forrestii* mid sparse shrubland over ***P****tilotus* ***o****bovatus* low sparse shrubland.

3.2.1.5 Vegetation Condition Assessment

Vegetation condition was assessed broadly and continuously throughout the survey area and at each quadrat using the Vegetation Condition Scale for the Eremaean Botanical Province (EPA 2016a) (**Table 21** in **Appendix Two**). As quadrats are in the best condition parts of a vegetation type, the condition rating of the quadrat may not match that of the broader vegetation type due to the scale of mapping.

3.2.1.6 Field Survey Timing

The field survey was conducted during March/April, within the optimal period for a primary survey within the Eremaean Botanical Province, according to the Flora and Vegetation Technical Guidance (EPA 2016a). Supplementary surveys were conducted during August 2023. Specific survey timing and personnel involved are outlined in **Section 4.1.1**.

3.2.2 DATA MANAGEMENT AND ANALYSIS

3.2.2.1 Plant Identification

Any plants that could not be identified with certainty in the field, with the potential to be conservation-listed, introduced species, and having significance according to the Flora and Vegetation Technical Guidance (EPA 2016a) were collected during the field survey using WA Herbarium collecting protocols. Most plant collection identification was undertaken by Ecoscape taxonomists (primarily Stephen Kern) using relevant literature, taxonomic keys and reference specimens held at the WA Herbarium. All *Tecticornia* (samphire) collections were submitted to the WA Herbarium for formal identification by Dr Kelly Shepherd (WA Herbarium Senior Research Scientist and *Tecticornia* specialist).

3.2.2.2 Post-survey Likelihood Assessment

Following the field survey, a post-survey likelihood assessment was conducted to identify conservation-listed species that have the potential to occur on-site. This assessment was based on survey results and habitat identified within the survey area.

3.2.2.3 Floristic Analysis

PATN© software (Blatant Fabrications Pty Ltd 2013) was used to undertake statistical analysis to generate floristic groups using the data collected from the quadrats and relevés to define the local floristic units empirically. PATN analysis has been used for several local floristic analyses, including Gibson *et al.* (1994) for the Swan Coastal Plain.

PATN is a multivariate analysis tool that generates estimates of association (resemblance, affinity, distance) between sets of objects described by a suite of variables (attributes) and, classifies the objects into groups, condenses the information, and displays the patterns in the data graphically. It offers a choice of data transformations before multivariate analysis.

Floristic groups, identified using a dendrogram output of the analysis, inform vegetation-type groups at various hierarchical levels and spatial scales.

For this project, a variety of analyses were run. The most informative analysis used the Bray Curtis similarity coefficient for rows (species) and columns (sites) as this provides a reasonable estimation of association for ecological applications (Blatant Fabrications Pty Ltd 2013). We used a simple square root transformation of cover values for each species for this analysis.

Ensuring that these purely floristic groups translate into ecologically meaningful, recognisable, and mappable on-ground units is critical because it aids in understanding ecological patterns, biodiversity, habitat distribution, and land management strategies in the area. Generally, floristically related quadrats (i.e., have many species in common) are positioned close to each other on the dendrogram and form identifiable vegetation units. However, interpretation is frequently required for imperfect results. Vegetation types are therefore determined as a combination of floristic analysis and on-ground interpretation using dominant and characteristic species.

3.2.2.4 Adequacy of Sampling

To demonstrate sampling adequacy, a species accumulation curve was generated by the software Species Diversity and Richness IV (Pisces Conservation Ltd 2010) using five random selections of sample order, using quadrat data only.

3.3 FAUNA FIELD SURVEY

The methods used during the field survey followed those outlined in the Fauna Technical Guidance (EPA 2020), which was conducted as a 'Basic' survey.

Conservation criteria used in this assessment are included in **Table 16** and **Table 17** in **Appendix One**.

Survey method details are outlined below.

3.3.1 FAUNA SURVEY METHODS

The Basic fauna survey incorporated several survey techniques as per the Terrestrial Fauna Technical Guidance (EPA 2020), including habitat assessment, active searches (day and night-time), raking of spoil heaps and leaf litter, searches for secondary evidence such as scats and tracks, as well as opportunistic searches.

Terrestrial vertebrate fauna were the main targets of the field survey. Survey techniques included:

- opportunistic fauna observations while moving through the survey area
- bird surveys conducted during optimal periods of bird detectability (early morning) as per Birdlife Australia's standard methodology
- turning of surface debris (rocks, logs, vegetation spoil heaps) that reptiles and mammals may shelter beneath
- raking of litter beds to locate fossorial reptile species
- tree hollow inspection to detect arboreal fauna
- spotlight surveys to detect nocturnal species
- baited motion cameras (Reconyx HC500) to capture evidence of cryptic and nocturnal fauna species not easily observed directly
- Swift recorders fitted with ultrasonic microphones to sample for bats.

Fauna species were identified opportunistically based on sightings, calls, remains, diggings, and other signs. Potential habitats for conservation significant species were identified and evaluated (see **Section 3.3.1.1**), and their likelihood of occurrence was re-assessed.

3.3.1.1 Fauna Habitat Assessment

The fauna habitats present within the survey areas were identified and mapped. Fauna habitats were described as an area that is distinguishable from its surrounding area by its landform, vegetation, and fauna assemblage occupying the area. In addition, its likelihood of harbouring specialised fauna species not found in adjacent areas were considered.

The following information was used to identify and map all fauna habitats within the survey area:

- previous fauna habitat mapping
- land systems
- vegetation type and condition mapping
- aerial imagery
- landforms
- soil characteristic
- fauna assemblage information.

The composition and characteristics of each fauna habitat type were recorded, including noting suitability for various fauna suites or conservation-listed species. Habitat types were delineated in the field and digitised upon return from the field survey.

3.3.2 TARGETED SURVEY METHODS

Based on the desktop assessment, the following two conservation-listed vertebrate fauna species were identified as potentially occurring in the survey area, and they, and the habitat suitable to support them, were targeted during the field survey:

- *Leipoa ocellata* (Malleefowl) – VU EPBC status, VU BC status
- *Falco peregrinus* (Peregrine Falcon) – OS BC status/DBCA status.

3.3.2.1 Malleefowl Survey Methods

The *National Malleefowl Recovery Team Monitoring Manual* (NMRT 2019) guided Malleefowl survey methods. On-foot traverses with increased search effort in suitable habitats are deemed an appropriate survey method as nest mounds are readily identifiable, and Malleefowl have distinctive tracks, scats, and feathers. Malleefowl require dense vegetation, sandy soils, and high litter cover to build their mounds (Benshemesh 2007); therefore, this habitat type was targeted where present. The presence of nest mounds of any age and direct observations of Malleefowl or their scats and tracks were to be recorded if found.

3.3.2.2 Peregrine Falcon Survey Methods

The Peregrine Falcon is uncommon but wide-ranging throughout Australia; it is not restricted to any one habitat but prefers areas with rocky ledges, cliffs, watercourses, open woodland, or margins with cleared land. It nests on ledges, cliff faces, large tree hollows, electricity pylons and similar structures, or abandoned nests of other raptors (Debus 2012). The Peregrine Falcon is easily detected by sight by experienced zoologists. Bird survey points are the best detection technique, and their preferred habitat was targeted during the survey.

4 FIELD SURVEY RESULTS

4.1 FLORA AND VEGETATION SURVEY

4.1.1 SURVEY TIMING

The flora and vegetation survey was conducted during the following timeframes:

- 27 March to 7 April 2023 by Kyla Pannell (Botanist, Flora Collecting Permit FB62000261; Threatened Flora Collecting Permit TFL161-2122) and Sandra Ng (Graduate Ecologist, Flora Collecting Permit FB62000543)
- 3–10 April 2023 by Stephen Kern (Principal Botanist, Flora Collecting Permit FB62000001-2; Threatened Flora Collecting Permit TFL2223-0088) and Tracy de Vetter (Graduate Ecologist, Flora Collecting Permit FB62000546).
- 4–11 September 2023 by Stephen Kern, Emily Mayhew (Ecologist) and Sebastian Chadwick (Ecologist)
- 18–22 September 2023 by Kyla Pannell.

The rainfall during the six months before the April field survey (based on Leonora Aero, station number 12241, operating since 2007) was below average, with 42.86% of the long-term average. The August field survey followed six months of below-average rainfall (52.58%). However, there was above-average rainfall during August 2023 prior to the phase 2 field surveys.

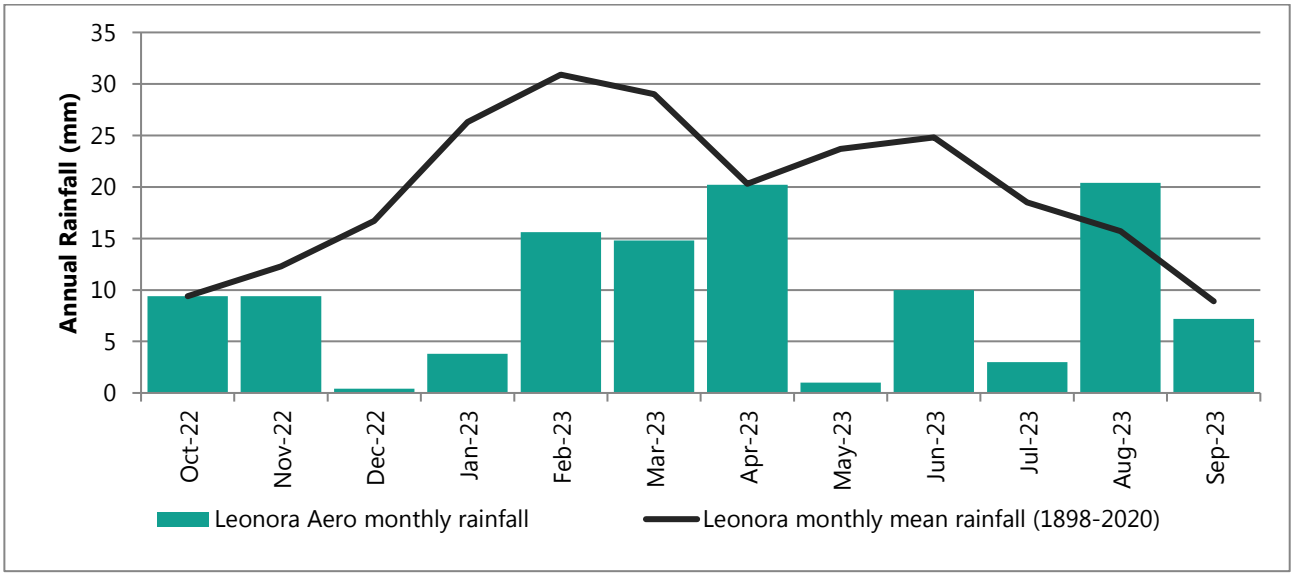


Figure 3: Rainfall and temperature data for Leonora (BoM 2023a)

4.1.2 FLORA

4.1.2.1 Flora Inventory

Fifty-four floristic quadrats were recorded from within the survey area. 166 vascular flora were recorded from 68 genera and 29 families from the quadrats, opportunistic observations, and searches for conservation-listed flora. Two of these were introduced (1.20 %), and 25 (8.43 %) could not be identified at the species level due to insufficient diagnostic reproductive material.

The most represented families were Chenopodiaceae (40 taxa), Fabaceae (26) and Scrophulariaceae (17). The most represented genera were *Eremophila* (17), *Acacia*, *Maireana* (14 each) and *Senna* (10).

The number of species per quadrat ranged from one (recorded from quadrat AH23027) to 28 (AH23125), with an average species diversity per quadrat of 13. The most commonly recorded species were *Scaevola spinescens* (from 32 quadrats), *Maireana triptera* (24) and *Ptilotus obovatus* (23).

The combined flora inventory is presented in **Table 25** and **Appendix Four**. Quadrat data is shown in **Appendix Five**.

4.1.2.2 Conservation-listed Flora

Threatened Flora

No Commonwealth EPBC Act or Western Australian BC Act-listed TF were recorded during the field survey. No taxa that were not identified with certainty resembled any currently described TF.

Priority Flora

Two PFs were recorded during the field survey:

- *Tecticornia globulifera* (P1)
- *Hemigenia exilis* (P4).

Locations of the PF are indicated in the **Map 5** series and described in more detail **Table 7**.

Table 7: PF recorded during the field survey

***Tecticornia globulifera* (P1)**	
Description: FloraBase (WAH 1998–) states that *Tecticornia globulifera* is a low compact samphire shrub to 0.5 m high. 	**Habitat:** recorded from a samphire dominated saltmarsh **Location:** near the eastern boundary of the survey area, close to proposed pits 1,2 and 3. **Survey results**: thirty-four plants in the survey area. **Populations:** one population. **Known records and distribution**: According to ALA (2023), there are 19 records of this species from the Pilbara, Gascoyne, and Great Sandy Desert bioregions, with an overall distribution of approximately 600 km (north-south) by 900 km (east-west). The record within the survey area represents a southern range extension, with the nearest known record occurring approximately 300 km north at Lake Carnegie.

***Hemigenia exilis* (P4)**	
Description: According to *FloraBase* (WAH 1998–), *Hemigenia exilis* [is an erect, multi-stemmed shrub to 2 m high with blue/purple/white flowers. 	**Habitat:** recorded from a sandy drainage line **Location:** along the southeastern corridor section of the survey area. **Survey results**: three plants in the survey area. **Populations:** one population. **Known records and distribution**: According to ALA (2023), there are 59 records of this species from the Murchison bioregion, with an overall distribution of approximately 350 km (north-south) by 400 km (east-west), all north of the survey area. Therefore, the record within the survey area is at the southern extent of the species' distribution.

4.1.2.3 Other Significant Flora

According to the criteria outlined in the Flora and Vegetation Technical Guidance (EPA 2016a), the following taxon may be significant:

- Sandalwood (*Santalum spicatum*), recorded from ten locations within the survey area. The International Union for the Conservation of Nature (IUCN) lists this species as vulnerable (IUCN 2022). However, it is not conservation-listed in Western Australia or protected under the EPBC Act.

4.1.2.4 Flora of Taxonomic Interest

The genus *Tecticornia* has a complex taxonomy and is the subject of ongoing research. All *Tecticornia* collections were submitted to the WA Herbarium for formal ID. Several collections of *Tecticornia* (samphires) either did not align with currently described species or could not be confirmed due to insufficient diagnostic material available. These were assigned unique names to distinguish them in the flora inventory (e.g. *Tecticornia* sp. 1) and a brief description is provided **Table 8**. Most of the unresolved taxa are known entities (based on existing WA Herbarium collections). However, one of these collections, *Tecticornia* sp. nov 2 (**Image 1**), did not match any other known collections and potentially represents a new species (K. Shepherd[1] pers. comm.). It was recorded near the eastern boundary of the survey area (**Map 5**).

Table 8: Summary of undescribed *Tecticornia* spp.

Name	Description
***Tecticornia* sp. 1**	Sterile, uncertain identification, though distinct
***Tecticornia* sp. 3**	Sterile, uncertain identification, though distinct
***Tecticornia* sp. 8**	Unusual, looks like *T.* aff Burnerbinmah/*T.* sp. Christmas Creek
***Tecticornia* sp. nov. 2**	Unusual, doesn't match known species

[1] Dr. Kelly Shepherd, WA Herbarium Senior Research Scientist and *Tecticornia* specialist



Image 1: *Tecticornia* sp. nov 2 shrub (A) and dried specimen with scale bar (B)

4.1.2.5 Introduced Flora

Two introduced flora species (weeds), **Rumex vesicarius* (Ruby dock) and **Sonchus oleraceus* (Sowthistle), were recorded during the field survey (**Image 2**), representing 0.95% of the overall flora inventory. **Sonchus oleraceus* was recorded from three localities within the survey area, where approximately 200 plants were observed. **Rumex vesicarius* was recorded from two localities within the survey area, where approximately 150 individuals were observed. **Sonchus oleraceus* and **Rumex vesicarius* do not have any specific significance, i.e. they are not Declared Pest plants or WoNS species.



Image 2: **Sonchus oleraceus* seedlings (A) and **Rumex vesicarius* (B)

4.1.3 VEGETATION

4.1.3.1 Vegetation Types

Twelve vegetation types were recorded from within the survey area (**Map 5 series)** based on a combination of structural vegetation types identified in the field and floristic analysis (see **Section 4.1.5**) and subsequent desktop review. The vegetation types within the survey area, grouped broadly based on landform types, were:

- drainage lines: **EcAbPd**
- dunes: **AaEmRd**
- flats/plains: **AcEfPo**, **AdMsMt**, **AkLs**, **AlAb**, **AmFs**, **CsLs**, **Mp**, **PaHpCs**
- rocky hills: **AaAePo**
- wetlands: **Tspp**.

Table 9: Vegetation types

Landform	Mapping unit	Vegetation type	Floristic quadrats	Representative photograph	Other characteristic species	Area (ha) and extent (%)
Rocky hills	**AaAePo**	*Acacia aneura* and *A. pteraneura* low open woodland over *A. effusifolia, A. tetragonophylla* and *A. ramulosa* var. *ramulosa* mid sparse shrubland over *Ptilotus obovatus* and *Sclerolaena obliquicuspis* low sparse shrubland/chenopod shrubland	AH23003 **AH23004** AH23005 AH23006 AH23007 AH23008 AH23015 AH23016		*Cheilanthes brownii, Enchylaena tomentosa, Enneapogon caerulescens, Eremophila forrestii* subsp. *forrestii, Hakea preissii, Maireana sedifolia, Maireana triptera, Salsola australis, Scaevola spinescens, Senna* sp. Meekatharra (E. Bailey 1-26), *Solanum lasiophyllum*	64.26 ha 7.81 %
Low dunes	**AaEmRd**	*Acacia aneura, A. incurvaneura* and *A. caesaneura* low woodland over *Eremophila miniata, Hakea preissii* and *Scaevola spinescens* mid sparse shrubland over *Rhagodia drummondii* and *Maireana pyramidata* low sparse chenopod shrubland.	AH23009 AH23010 **AH23011** AH23014 AH23030 AH23125 AH23158		*Aristida contorta, Calandrinia polyandra, Cratystylis subspinescens, Enchylaena tomentosa, Gunniopsis quadrifida, Leichhardtia australis, Maireana triptera, Ptilotus obovatus, Senna artemisioides* subsp. *filifolia*	120.04 ha 14.59 %

Landform	Mapping unit	Vegetation type	Floristic quadrats	Representative photograph	Other characteristic species	Area (ha) and extent (%)
Flat	**AcEfPo**	*Acacia caesaneura, A. incurvaneura* and *A. aneura* low woodland over *Eremophila forrestii* subsp. *forrestii* and *A. tetragonophylla* mid sparse shrubland over *Ptilotus obovatus, Teucrium teucriiflorum* and *Eragrostis eriopoda* low sparse shrubland/tussock grassland	AH23022 **AH23023** AH23024 AH23088 AH23129 AH23169 AH23170 AH23172		*Acacia ramulosa* var. *ramulosa, Leichhardtia australis, Monachather paradoxus, Rhagodia drummondii, Santalum lanceolatum, Scaevola spinescens, Senna glutinosa* subsp. *chatelainiana*	188.40 ha 22.91 %
Flat	**AdMsMt**	*Acacia duriuscula* low open woodland over *Maireana sedifolia, Senna artemisioides* subsp. *filifolia* and *Scaevola spinescens* mid sparse shrubland over *Maireana triptera, Ptilotus obovatus* and *Roepera ovata* low sparse chenopod shrubland/forbland	AH23159 AH23160 **AH23161**		*Acacia tetragonophylla, Acacia victoriae* subsp. *victoriae, Leichhardtia australis, Senna* sp. Meekatharra (E. Bailey 1-26)	29.82 ha 3.63 %

Landform	Mapping unit	Vegetation type	Floristic quadrats	Representative photograph	Other characteristic species	Area (ha) and extent (%)
Flat	**AkLs**	*Acacia kalgoorliensis* mid-sparse shrubland over *Lawrencia squamata*, *Scaevola spinescens* and *Maireana triptera* low sparse shrubland	AH23162 AH23163 **AH23164**		*Cratystylis subspinescens, Eremophila miniata, Eremophila oppositifolia* subsp. *angustifolia, Eremophila scoparia, Frankenia setosa, Gunniopsis quadrifida, Maireana carnosa, Maireana glomerifolia, Rhagodia drummondii, Sclerolaena eriacantha*	42.83 ha 5.21 %
Flat	**AlAb**	*Acacia ligulata* and *A. victoriae* subsp. *victoriae* tall open shrubland over *Atriplex bunburyana* and *Scaevola spinescens* low sparse chenopod shrubland/shrubland	**AH23165**		*Acacia burkittii, Acacia duriuscula, Acacia tetragonophylla, Austrostipa elegantissima, Leichhardtia australis, Maireana ?tomentosa, Maireana pentatropis, Pittosporum angustifolium, Rhagodia drummondii, Roepera ovata, Senna artemisioides* subsp. *filifolia, Senna flexuosa, Solanum lasiophyllum*	10.57 ha 1.28 %

Landform	Mapping unit	Vegetation type	Floristic quadrats	Representative photograph	Other characteristic species	Area (ha) and extent (%)
Flat	**AmFs**	*Acacia masliniana* and *Cratystylis subspinescens* mid-sparse shrubland over *Frankenia setosa* and *Lawrencia squamata* low sparse shrubland	AH23012 AH23018 **AH23021** AH23126		*Enchylaena tomentosa, Eremophila miniata, Hakea preissii, Maireana platycarpa, Maireana pyramidata, Maireana triptera, Scaevola spinescens, Senna* sp. Meekatharra (E. Bailey 1-26)	96.17 ha 11.69 %
Flat	**CsLs**	*Cratystylis subspinescens* and *Eremophila miniata* mid-sparse shrubland over *Lawrencia squamata* and *Frankenia setosa* low open shrubland	**AH23019** AH23020 AH23128 AH23171		*Hakea preissii, Maireana platycarpa, Scaevola spinescens, Sclerolaena cuneata, Senna* sp. Meekatharra (E. Bailey 1-26)	142.19 ha 17.29 %

Landform	Mapping unit	Vegetation type	Floristic quadrats	Representative photograph	Other characteristic species	Area (ha) and extent (%)
Drainage lines	**EcAbPd**	*Eucalyptus camaldulensis* subsp. *arida* mid woodland over *Acacia burkittii* tall sparse shrubland over *Pluchea dentex* low sparse forbland	**AH23157**		*Aristida contorta, Dodonaea rigida, Duperreya sericea, Grevillea extorris, Leichhardtia australis, Scaevola spinescens, Senna artemisioides* subsp. x *artemisioides*	2.65 ha 0.32 %
Flats	**Mp**	*Maireana pyramidata* and *Lawrencia squamata* low open chenopod shrubland/shrubland	**AH23166** AH23167 AH23168		*Atriplex bunburyana, Atriplex codonocarpa, Cratystylis subspinescens, Frankenia interioris, Frankenia laxiflora, Gunniopsis quadrifida, Maireana carnosa, Maireana tomentosa, Sclerolaena cuneata*	25.48 ha 3.10%

Landform	Mapping unit	Vegetation type	Floristic quadrats	Representative photograph	Other characteristic species	Area (ha) and extent (%)
Flats	**PaHpCs**	*Pittosporum angustifolium* low sparse woodland over *Hakea preissii* and *Acacia tetragonophylla* tall open shrubland over *Cratystylis subspinescens* low sparse shrubland.	**AH23076**		*Enchylaena tomentosa, Eremophila glabra* subsp. *glabra, Frankenia setosa, Ptilotus divaricatus, Scaevola spinescens, Sclerolaena cuneata, Sporobolus ramigerus*	1.52 ha 0.19%
Flat, saline drainage	**Tspp**	*Tecticornia* spp. low samphire shrubland	AH23001 AH23002 AH23013 AH23017 AH23025 **AH23026** AH23027 AH23028 AH23029 AH23031 AH23127		*Cratystylis subspinescens, Disphyma crassifolium, Frankenia cinerea, Frankenia laxiflora, Maireana amoena, Maireana pyramidata, Sclerolaena cuneata, Tecticornia indica* subsp. *bidens, Tecticornia* sp. 1, *Tecticornia* sp. 3, *Tecticornia* sp. 8, *Tecticornia* sp. Burnerbinmah (D. Edinger et al. 101), *Tecticornia* sp. Dennys Crossing (K.A. Shepherd & J. English KS 552)	91.43 ha 11.11 %
		Not native vegetation (bare ground or cleared)			7.14 ha	0.87 %
		TOTAL EXTENT			**822.51 ha**	**100 %**

4.1.4 VEGETATION SIGNIFICANCE

4.1.4.1 TECs and PECs

No vegetation recorded from the survey area was assessed as representative of any currently described TEC or PEC.

4.1.4.2 Other Significant Vegetation

According to the criteria outlined in the Flora and Vegetation Technical Guidance (EPA 2016a), the following vegetation types may be significant:

- **EcAbPd** as Groundwater Dependent Vegetation (GDV)
- **PaHpCs** and **EcAbPd** are vegetation types of restricted extent within the survey area.

Further detail on other significant vegetation types is provided in the following sections.

4.1.4.3 Groundwater Dependent Vegetation

Eucalyptus camaldulensis sens. lat. may be an obligate phreatophyte; therefore, vegetation with this species included is considered representative of GDV (Eamus et al. 2006a; Grierson 2010). *Eucalyptus camaldulensis* subsp. *arida* was the dominant species of one vegetation type (**EcAbPd**). The **EcAbPd** vegetation type corresponds with a single drainage line that intersects the corridor section and occupies 2.65 ha or 0.19 % of the survey area.

4.1.4.4 Sheet Flow Dependent Vegetation

An overview of Sheet Flow Dependent Vegetation (SFDV) is provided in **Appendix One**. There were numerous Mulga species recorded from the survey area, including *Acacia aneura, A. caesaneura, A. craspedocarpa, A. fuscaneura, A. incurvaneura* and *A pteraneura.* Within the survey area, these Mulga species formed the dominant vegetation stratum of three vegetation types (**AaAePo**, **AaEmRd** and **AcEfPo**). However, none of the vegetation types dominated by Mulga displayed the characteristic grove-intergrove formation considered to be representative of (SFDV). Therefore, SFDV is unlikely to occur within the survey area.

4.1.4.5 Vegetation Dominated by Conservation-listed Flora

There were no vegetation types with either dominant or characteristic flora that are conservation-listed.

4.1.4.6 Vegetation Types of Limited Spatial Extent

The following two vegetation types have extents of less than 1% of the survey area and are therefore restricted in extent within the survey area:

- **EcAbPd** (0.32%)
- **PaHpCs** (0.19%).

4.1.5 STATISTICAL ANALYSIS

4.1.5.1 Floristic Analysis

The floristic analysis dendrogram (**Figure 6** in **Appendix Six)** indicates that most vegetation types are well supported by floristic composition. However, several vegetation types are not clearly defined floristic units, partially explained by historical impacts to vegetation or quadrats that may be positioned within vegetation intergrades. Vegetation types with poor floristic groupings have also been retained if justified by the dominant structural composition. A summary of the floristic analysis per vegetation type is as follows:

- **AaAePo**: This is a poor floristic unit, however it corresponds with Apollo Hill and represents a good structural unit, occurring on a distinct landform. Impacts from extensive clearing have affected the floristic composition of quadrats. Potentially explaining the poor floristic grouping of quadrats.
- **AaEmRd**: represents a good floristic unit except for quadrats AH23125 and AH23158, retained within the vegetation type based on structural composition.
- **AcEfPo**: represents a poor floristic grouping with several clusters of quadrats located across a large section of the dendrogram. However, the vegetation type is retained based on the dominant structural composition.
- **AdMsMt**: represents a distinct floristic unit.
- **AkLs**: represents a good floristic unit except for quadrat AH23162.
- **AlAb**: is captured by one quadrat, maintained as distinct owing to the dominance of *Acacia victoriae*
- **AmFs**: floristically not distinct from **CsLs**, though retained based on distinct structural elements.
- **CsLs**: floristically not distinct from **AmFs**, though retained based on distinct structural elements.
- **EcAbPd**: characterises *Eucalyptus*-dominated drainage areas and is expressed by a small spatial extent within the survey area. Only one quadrat was established within this survey area.
- **Mp**: represents a distinct floristic unit.
- **PaHpCs**: occurs to a small spatial extent within the survey area and is described by one quadrat.
- **Tspp**: this vegetation type forms a heterogeneous cluster, with the exception of one outlier quadrat (AH23013) that occurs within an intergrade between vegetation types. However, the floristic analysis indicates that the **Tspp** vegetation type may warrant separation into as many as four separate vegetation types based on dominant species of *Tecticornia* taxa. Hence, **Tspp** should be considered to represent a mosaic of samphire dominated vegetation types.

4.1.5.2 Adequacy of Survey

The adequacy of the survey can be demonstrated using a species accumulation curve; if the curve has reached (or almost reached) an asymptote, it is considered that most species are likely to have been recorded from the survey area.

A species accumulation curve was generated using quadrat data (**Figure 4**). The analysis does not include opportunistic observations, which increase the number of species recorded. The species accumulation curve suggests the curve has not yet reached an asymptote. The Bootstrap estimate of species richness is 163.3. When considering opportunistic records, this figure is lower than the recorded number of flora taxa (166). This suggests that the survey effort was adequate.

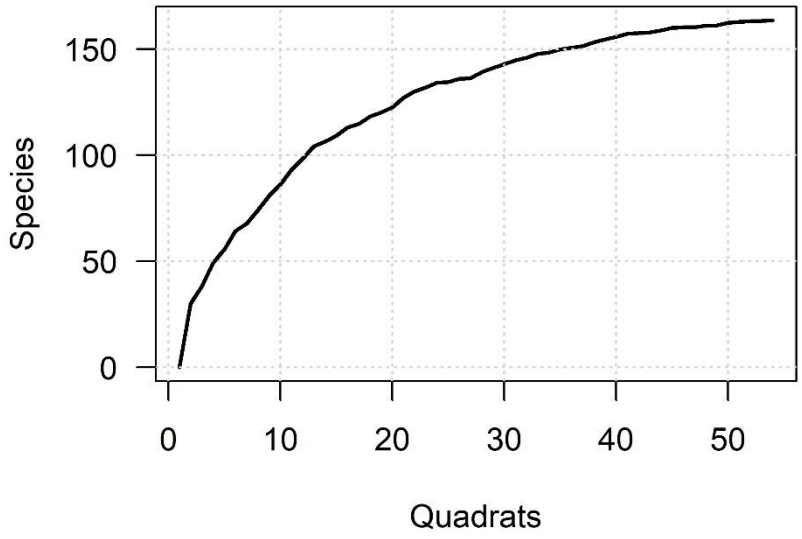


Figure 4: Species accumulation curve

4.1.6 VEGETATION CONDITION

The vegetation condition within the survey area ranged from Completely Degraded to Very Good condition, with the majority in Very Good condition (**Table 10**, **Map 6** series). The main factors affecting vegetation conditions were clearing and grazing. The vegetation of Apollo Hill was typically of lower condition rating than elsewhere within the survey area due to the impacts of historical clearing.

Table 10: Vegetation condition

Vegetation condition	Extent (ha)	Proportion (%)
Excellent	-	-
Very Good	698.41	84.91
Good	33.68	4.09
Poor	34.04	4.14
Degraded	46.50	5.65
Completely Degraded	2.75	0.33
Not vegetated or cleared	7.14	0.87

4.1.7 BOTANICAL LIMITATIONS

Survey design and type: two-phase, quadrat-based flora and vegetation survey with extensive traverses searching for conservation-listed flora.

Type of vegetation classification system: Vegetation was classified at NVIS Level V (NVIS Technical Working Group & DotEE 2017) using primarily structural vegetation types defined using dominant and characteristic species and vegetation structure as recorded during the field surveys. Floristic analysis was used to identify major floristic groups and outlier groups of floristic interest.

A complete summary of botanical limitations is presented in **Table 11**.

Table 11: Botanical limitations

Possible limitations	Constraints (yes/no): Significant, moderate or negligible	Comment
Availability of contextual information at a regional and local scale	No	There have been no previous surveys undertaken within the survey area or nearby that are publicly available. However, there is sufficient information available to provide contextual information.

Possible limitations	Constraints (yes/no): Significant, moderate or negligible	Comment
Competence/experience of the team conducting the survey, including experience in the bioregion surveyed	No	The lead botanist conducting the field survey has 17 years of experience undertaking flora and vegetation surveys in Western Australia, including extensive experience in the Murchison bioregion.
The proportion of the flora recorded and/or collected and any identification issues	No	166 vascular flora taxa were recorded during the field survey, of which 19 (11.45%) could not be identified with certainty to species level due to the lack of diagnostic reproductive material. None of the unidentified taxa are considered likely to represent any conservation-listed flora from the region. *Tecticornia* (samphires) have complex taxonomy with several taxa within the survey area that could not be completely resolved, with one of these potentially representing a new species.
Was the appropriate area fully surveyed (effort and extent)	No	There were 54 quadrats established within the survey area. All except three vegetation types were represented by at least three quadrats. The vegetation types represented by less than three quadrats were restricted in extent within the survey area and two were represented by additional quadrats within the broader stage 2 survey area.
Access restrictions within the survey area	No	The entire survey area was accessible via vehicle tracks and traverses on foot.
Survey timing, rainfall, season of survey	Timing: No Seasonal conditions: Yes, moderate	The phase 1 field survey was conducted during March-April 2023, which is within the optimal timing for a primary season survey in the Murchison bioregion. Supplementary surveys were undertaken during September 2023. Therefore, survey timing was not a limitation. The rainfall in the six months before the March-April and September field survey was below the mean for this timeframe (**Figure 2**), also indicated by the rainfall deciles (**Figure 5**, below). This represents a moderate constraint as annual and ephemeral species may not have been readily detectable/identifiable. One Priority-listed species considered likely to occur was an annual that may not have been present due to seasonal conditions, further representing the moderate constraint.
Disturbances that may have affected the results of the survey, e.g., fire, flood, clearing	No	No recent disturbances would have affected the survey results, and none of the survey areas had been recently burnt.

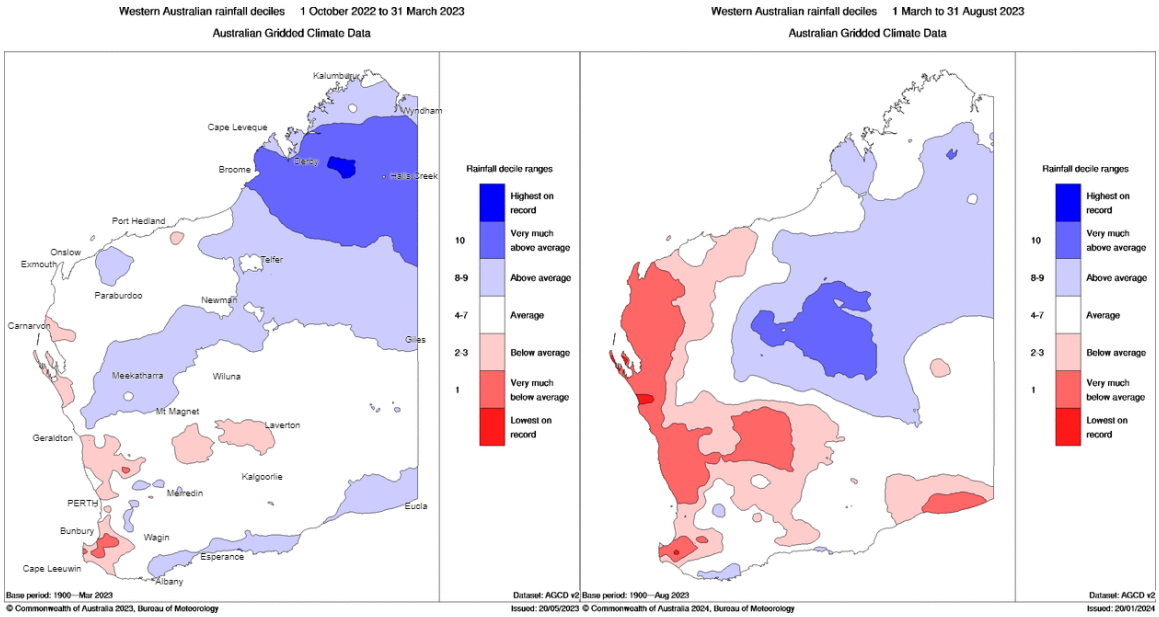


Figure 5: Rainfall deciles for the six months before the April field survey (left) and August field survey (right) (BoM 2023c).

4.2 VERTEBRATE FAUNA SURVEY

The fauna survey was conducted by Robert Hemsworth (Senior Zoologist) and Louisa Carlsson (Zoologist/Ecologist) from 27 March to 7 April 2023 and 18 to 22 September 2023.

The survey was conducted in accordance with the requirements for a Basic survey as outlined in the Fauna Technical Guidance (EPA 2020). The survey also complied with the conditions of *Fauna Taking (Biological Assessment) Licence* Number BA 08-005346-1.

The site was extensively traversed on foot, and all habitats were assessed for quality and capability of supporting both locally common and significant fauna species.

4.2.1 FAUNA HABITAT

Seven fauna habitat types were recorded within the survey area (**Table 12**):

- Mulga woodland (535.38 ha)
- Mixed shrubland (96.17 ha)
- Chenopod shrubland (116.91 ha)
- Rocky escarpment (64.26 ha)
- Flood plain (7.14 ha)
- Drainage line (2.65 ha)
- Mineshaft/cave (too small to be mapped).

The quality of each habitat type was based on the field surveyor's experience. It considered the level of disturbance to habitats from weeds, the amount of native vegetation, vegetation cover (density) and the context of the habitat with the surrounding landscape.

Table 12: Fauna habitat types

Habitat type	Description	Photograph
Mulga woodland	Open mulga woodland over mixed shrubs and bare ground. Soil variable, loam, sand, sandy-clay, clayey-sand. Litter cover 1–20 %. Disturbance low to high. **Extent**: 535.38 ha; 65.09 %	

Habitat type	Description	Photograph
Mixed shrubland	Open mixed shrublands dominated by *Acacia*, *Hakea* and *Melaleuca* species with smaller mixed shrubs. Soil sandy-clay to clayey-sand. Litter cover is low, 0–1 %. Disturbance is low to moderate. Fire age: >10 yrs. **Extent**: 96.17 ha; 11.69 %	
Chenopod shrubland	Low flat areas with low chenopod shrubs and occasional herbs. The soil was clay, sandy-clay, loamy-clay or loam. Litter cover is low, 0–1%. Disturbance variable. Fire age: >10 yrs. **Extent**: 116.91 ha; 14.21 %	
Rocky escarpment	Rocky escarpment that makes up Apollo Hill. Soils are rocky, vegetation is sparse, and litter cover is absent. Disturbance high. Fire age: >10 yrs. **Extent**: 64.26 ha; 7.81 %	

Habitat type	Description	Photograph
Flood plain	Low lying area of clay to clay-loam, vegetation absent or occasional scattered chenopod. Litter cover absent. Disturbance low. Fire age: >10 yrs. **Extent**: 7.14 ha; 0.87 %	
Drainage line	Shallow drainage lines, 5–20 m in width. Seasonally inundated. They were fringed with Eucalypt and Acacia species. The soil was sandy-clay. The litter cover was 5 %. Disturbance low. Fire age: >10 yrs. **Extent**: 2.65 ha; 0.32 %	
Cave/mine shaft	A mineshaft and several small caves were located on and around Apollo Hill. Disturbance high. Possible habitat for bat species. **Extent**: too small to be mapped.	

MULGA WOODLAND

Mulga woodland was found throughout the survey area and was comprised of *Acacia aneura, A. incurvaneura*, *A. caesaneura* and related species, with occasional scattered Eucalypts. These woodlands varied in density, from dense to sparse, with a variable understorey consisting of mixed shrubs and chenopods or were absent due to grazing cattle.

The Mulga woodland occurred on variable soils, sometimes in bands on slight sandy rises or on sandy-clay, clayey-sand or loam, sometimes with a gravel veneer. Litter cover was low (1–20%) and has remained unburnt

for over ten years. Overall disturbance was low to high, with evidence of cattle (*Bos taurus*) throughout much of the habitat and clearing for drill lines present.

These areas provide habitat for a suite of bird species, including Southern Whiteface (*Aphelocephala leucopsis,* VU EPBC status), Chestnut-rumped Thornbill (*Acanthiza uropygialis*), Grey Butcherbird (*Cracticus torquatus*), Hooded Robin (*Melanodryas cucullate*) and Crested Bellbird (*Oreoica gutturalis*). This habitat also supports reptile species such as the Gould's Monitor (*Varanus gouldii*) and mammals such as the Red Kangaroo (*Osphranter rufus*) and Spinifex Hopping Mouse (*Notomys alexis*).

MIXED SHRUBLAND

Various *Acacia*, *Hakea*, and *Melaleuca* species with an understorey of smaller mixed shrubs dominate these open mixed shrublands. The soils in this habitat are sandy-clay to clayey sand with low litter cover. The disturbance was low to moderate, depending on the presence of cattle.

These areas provide habitat to a similar faunal assemblage as the Mulga woodland habitat type, but when in flower, they will exhibit an increase in activity from bird species such as honeyeaters.

CHENOPOD SHRUBLAND

The Chenopod shrublands are low, flat areas associated with the floodplains and are seasonally inundated. The vegetation consisted of low Chenopod shrubs and herbs on clay, sandy-clay, loam to clayey loam soil, which is saline in some areas. The lack of larger trees or bushes means these areas have low litter cover and are unlikely to be affected by fire. The disturbance was variable, with evidence of cattle passing through and clearing for drill lines in some areas.

Chenopod plains have been reported as a foraging habitat for the Night Parrot (*P. occidentalis*) (Jackett et al. 2017; Murphy et al. 2017).

ROCKY ESCARPMENT

Within the survey area, Apollo Hill makes up this habitat type, consisting of large boulders and rocks with scattered Mulga, low shrubs, and grasses. The rocky escarpment habitat includes the specific cave/mine shaft habitat type (see below). Rocky escarpments are favoured by the Long-tailed Dunnart (*Sminthopsis longicaudata*) and for nesting raptors, such as the Peregrine Falcon (*Falco peregrinus*). However, Apollo Hill was found to be highly degraded due to mining exploration activity, and many fauna species are unlikely to occur in the area.

FLOOD PLAIN

The Flood plain habitat type consists of large low-lying areas that are seasonally inundated and fringed by the Chenopod shrubland habitat type. Beyond the Chenopod shrubland, these areas are devoid of vegetation and have no litter cover; therefore, they have limited habitat value except for migratory shorebirds such as the Common Sandpiper (*Actitis hypoleucos*) and Common Greenshank (*Tringa nebularia*) when inundated. Disturbance in these areas is low except where intersected by tracks.

DRAINAGE LINE

Minor ephemeral drainage lines intersect the survey area and feed into the Flood plain habitat type. These areas likely remain dry for much of the year, only flowing during heavy rainfall and summer cyclonic events. They are fringed by Eucalypts, Mulga, and mixed shrubs and intersect other habitats such as Mulga woodland and Chenopod shrubland.

The drainage lines were lined with small to medium river stones over coarse sand and silty loam, with the riverbanks predominantly of sandy clay. This habitat provides nesting and foraging opportunities for a variety of species, for example, Australian Ringnecks (*Barnardius zonarius*) and Galahs (*Eolophus roseicapilla*) that use tree hollows in the Eucalypts for nesting, and bat species such as Gould's Wattled Bat (*Chalinolobus gouldii*) that forage along drainage lines for insects.

MINESHAFT AND CAVES

This habitat type is associated with the rocky escarpment habitat type, with the caves formed by crevices between large boulders. The caves found were small and only extended into the rock for 3-4 m and are, therefore, unsuitable for many bat species. Several middens of old bones were found outside two cave entrances, but these are likely the remains of prey killed by cats or foxes.

A single historical mine shaft entrance occurs on the top of Apollo Hill, although its depth is unknown. This mine shaft may provide roosting habitat for local bat species, with all seven recorded bat species recorded at this location. However, it is not possible to determine if these species were recorded exiting and entering the mine shaft or whilst flying over the area.

4.2.2 FAUNA ASSEMBLAGE

Thirty-five vertebrate fauna species were recorded during the survey (**Table 13**), consisting of:

- 14 mammals (one introduced)
- 19 birds
- two reptiles.

One of the fauna species recorded was conservation-listed *Chalcites osculans* (Black-eared Cuckoo), MA/MI EPBC status.

Table 13: Recorded fauna species.

Species	Common name	EPBC Act status	Western Australian status
Mammals			
Austronomus australis	White-striped Free-tailed Bat		
*Bos primigenius taurus**	European Cattle		
Chalinolobus gouldii	Gould's Wattled Bat		
Notomys alexis	Spinifex Hopping mouse		
Nyctophilus geoffroyi	Lesser Long-eared Bat		
Osphranter robustus	Euro, Biggada		
Osphranter rufus	Red Kangaroo, Marlu		
Ozimops kitcheneri	Western Free-tailed Bat		
Ozimops petersi	Inland Free-tailed Bat		
Saccolaimus flaviventris	Yellow-bellied Sheath-tailed Bat		
Scotorepens balstoni	Inland Broad-nosed Bat		
Sminthopsis macroura	Stripe-faced Dunnart		
Tachyglossus aculeatus	Short-beaked Echidna		
Vespadelus finlaysoni	Finlayson's Cave Bat		
Birds			
Acanthiza apicalis	Inland Thornbill (Broad-tailed Thornbill)		
Acanthiza uropygialis	Chestnut-rumped Thornbill		
Aquila audax	Wedge-tailed Eagle		
Barnardius zonarius	Australian Ringneck		
Chalcites osculans	Black-eared Cuckoo	MA/MI	
Charadrius ruficapillus	Red-capped Plover		
Corvus bennetti	Little Crow		
Cracticus torquatus	Grey Butcherbird		
Cracticus nigrogularis	Pied Butcherbird		
Falco berigora	Brown Falcon		
Falco cenchroides	Australian Kestrel (Nankeen Kestrel)		
Gavicalis virescens	Singing Honeyeater		
Grallina cyanoleuca	Magpie-lark		
Gymnorhina tibicen	Australian Magpie		
Malurus assimilis rogersi	Lavender-flanked Fairywren		
Melanodryas cucullata	Hooded Robin		
Oreoica gutturalis	Crested Bellbird		
Rhipidura leucophrys	Willie Wagtail		
Tadorna tadornoides	Australian Shelduck		
Reptiles			
Strophurus strophurus	Western Spiny-tailed Gecko		
Varanus gouldii	Gould's Monitor		

*Introduced

Survey sites are listed in **Table 26** in **Appendix Four**. The Bat Call Analysis is included in **Appendix Eight**.

4.2.3 FAUNA SURVEY LIMITATIONS

Table 14: Fauna survey limitations

Possible limitations	Constraints (yes/no): Significant, moderate, or negligible	Comment
Availability of data and information	No	There was sufficient data from surveys conducted in the surrounding area to provide contextual information.
Competency/experience of the survey team, including bioregion experience	No	The zoologists are experienced with Basic and Targeted fauna survey methods used and with the identification of fauna and fauna habitat, including in the Murchison bioregion.
Scope of the survey, e.g., excluded fauna groups	No	Targeted species were adequately sampled, and no sampling methods were constrained due to external factors.
Timing, weather, season	Yes- moderate	The field survey was conducted in two phases in March/April and Sept 2023, with rainfall below the mean in the six months prior (Error! Reference source not found.). T his represents a moderate constraint as species that are reliant upon waterbodies e.g. migratory shorebirds are unlikely to be observed.
Disturbances that may have affected the results	No	No significant disturbances were observed that could negatively affect survey results.
Proportion of fauna identified, recorded, or collected	No	All recorded fauna species were able to be accurately identified.
Adequacy of survey intensity and proportion of survey achieved	No	All major fauna habitat types, including those favoured by conservation significant fauna, were investigated, and defined, with the survey area was extensively traversed on foot.
Access	No	No access issues were encountered; survey areas were adequately surveyed.
Data and analysis issues, including sampling biases	No	There were no sampling biases; no statistical analyses were required.

5 DISCUSSION

5.1 FLORA SIGNIFICANCE

A total of 166 vascular flora species were recorded from 54 floristic quadrats and opportunistic observations, including during searches for conservation-listed flora. While the survey was undertaken following a period of below-average rainfall, the flora diversity is considered low to moderate because of the conditions in the area rather than seasonal conditions. A small proportion of the total flora inventory (two species; 1.20%) were introduced, possibly reflecting a combination of dry seasonal conditions and generally low weed presence.

The species accumulation curve (**Figure 4**) and species richness estimate indicate that most species present during the survey were recorded. However, additional ephemeral species would be expected following periods of above-average rainfall.

5.1.1 FLORA SIGNIFICANCE

5.1.1.1 Conservation-listed Flora

Threatened Flora

No Threatened Flora species listed for protection under the Commonwealth EPBC Act or Western Australian BC Act were recorded. None of the unidentified taxa resembles any currently described TF. None were considered likely to occur, as none are known to occur within 100 km of the survey area.

Priority Flora

Two PF were recorded during the survey area, including:

- *Tecticornia globulifera* (P1); P1 flora taxa are considered poorly known species with records from few locations potentially at risk (DBCA 2020). The identification of this species represents a substantial southern range extension of approximately 300 km, with the nearest known record at Lake Carnegie (WAH 1998–). It was distributed within one established population of 34 plants located east of Pit 1. Potential habitat to support this species (salt lakes, saline drainage plains) is extensive outside the survey area. This species is not within the proposed disturbance footprint (**Map 8**); therefore, the potential impact is considered nil or negligible.
- *Hemigenia exilis* (P4); P4 flora taxa include rare species (which are not currently threatened but could become threatened if circumstances change), near threatened species or other species in need of monitoring (DBCA 2020). This species was recorded from one population within the survey area, where approximately 10 plants were observed. Three individuals intersect with the proposed pilot plant infrastructure (**Map 8**). *Hemigenia exilis* is known from 59 records within the Murchison bioregion, all to the north of the survey area. Considering the known distribution of the species and the low number of plants within the survey area, the potential impact is likely negligible.

None of the unidentified taxa resembles any currently described PF taxa.

5.1.1.2 Post-survey Likelihood Assessment

The likelihood of conservation-listed flora occurring in the survey area was revised following the field survey. This revised likelihood, which considers vegetation condition, grazing and other disturbances, actual habitat availability and search effort, is included in **Table 22** and **Appendix Three**.

The post-survey likelihood assessment identifies no additional flora taxa as Likely to occur, and one flora taxa May Occur (*Angianthus prostratus*). This species is known from saline depressions, potentially represented by **Tspp** within the survey area. However, below-average seasonal conditions may have made detecting this species unlikely during the March-April and September 2023 survey timeframes.

5.1.1.3 Other Significant Flora

Sandalwood (*Santalum spicatum*) is listed as vulnerable by the IUCN (2022). However, it has no Commonwealth or Western Australian conservation status. 'Taking' of Sandalwood requires a specific licence under the *Biodiversity Conservation Regulations 2018,* and it is understood that this species is being considered for conservation listing. It was recorded from five locations within the survey area, typically as single isolated plants.

One species (*Tecticornia globulifera*, described above in **Section 5.1.1.1**) represents a substantial range extension approximately 300 km from its nearest known location.

Several collections of samphire (*Tecticornia* spp.) were considered unresolved or uncertain entities, distinguished as '*Tecticornia* sp. 1' (etc) in the flora inventory. Whilst unresolved, most are previously known based on existing collections at the WA Herbarium. However, one of the collections, *Tecticornia* sp. nov 2, does not match any known collections and potentially represents a new species. It was recorded from a single location within the survey area that, based on the proposed development footprint (**Map 8**), is unlikely to be directly impacted.

5.1.1.4 Introduced Flora

Only two introduced flora species (**Rumex vesicarius*, Ruby dock and **Sonchus oleraceus*, Sowthistle) were recorded during the field survey from a single location each, indicating that weeds are only a minor component of the flora inventory. The recorded introduced flora species do not have any specific significance, i.e. they were not a Declared Pest plants or WoNS species. The low number of weeds may be partially a consequence of poor seasonal conditions during the survey period, and additional weeds may be present in more locations following periods of above-average rainfall.

5.2 VEGETATION SIGNIFICANCE

Twelve vegetation types were recorded from the survey area from a variety of landforms, including drainage lines, dunes, flats/plains, rocky hills and wetlands:

- **AaAePo**: *Acacia aneura, A. pteraneura* low open woodland over *A. effusifolia, A. tetragonophylla* and *A. ramulosa* var. *ramulosa* mid sparse shrubland over *Ptilotus obovatus* and *Sclerolaena obliquicuspis* low sparse shrubland/chenopod shrubland
- **AaEmRd**: *Acacia aneura, A. incurvaneura,* and *A. caesaneura* low woodland over *Eremophila miniata, Hakea preissii* and *Scaevola spinescens* mid sparse shrubland over *Rhagodia drummondii* and *Maireana pyramidata* low sparse chenopod shrubland
- **AcEfPo**: *Acacia caesaneura, A. incurvaneura* and *A. aneura* low woodland over *Eremophila forrestii* subsp. *forrestii* and *A. tetragonophylla* mid sparse shrubland over *Ptilotus obovatus, Teucrium teucriiflorum* and *Eragrostis eriopoda* low sparse shrubland/tussock grassland
- **AdMsMt**: *Acacia duriuscula* low open woodland over *Maireana sedifolia, Senna artemisioides* subsp. *filifolia* and *Scaevola spinescens* mid sparse shrubland over *Maireana triptera, Ptilotus obovatus* and *Roepera ovata* low sparse chenopod shrubland/forbland
- **AkLs**: *Acacia kalgoorliensis* mid sparse shrubland over *Lawrencia squamata*, *Scaevola spinescens* and *Maireana triptera* low sparse shrubland
- **AlAb**: *Acacia ligulata* and *A. victoriae* subsp. *victoriae* tall open shrubland over *Atriplex bunburyana* and *Scaevola spinescens* low sparse chenopod shrubland/shrubland
- **AmFs**: *Acacia masliniana* and *Cratystylis subspinescens* mid sparse shrubland over *Frankenia setosa* and *Lawrencia squamata* low sparse shrubland
- **CsLs**: *Cratystylis subspinescens* and *Eremophila miniata* mid sparse shrubland over *Lawrencia squamata* and *Frankenia setosa* low open shrubland
- **EcAbPd**: *Eucalyptus camaldulensis* subsp. *arida* mid woodland over *Acacia burkittii* tall sparse shrubland over *Pluchea dentex* low sparse forbland
- **Mp**: *Maireana pyramidata, Lawrencia squamata* low open chenopod shrubland/shrubland

- **PaHpCs**: *Pittosporum angustifolium* low sparse woodland over *Hakea preissii* and *Acacia tetragonophylla* tall open shrubland over *Cratystylis subspinescens* low sparse shrubland
- **Tspp**: *Tecticornia* spp. low samphire shrubland. Considered to represent a mosaic of up to four samphire dominated vegetation types.

The vegetation types are primarily supported by floristic analysis. However, floristic community types do not always correspond well with structural vegetation types that use dominant and characteristic species to define them. Several vegetation types were identified from the analysis as floristically similar (occurring within the same floristic group). However, these vegetation types are considered discrete based on distinct structural differences. Other factors identified as causing variation within the floristic groups include quadrat placement on vegetation intergrades and disturbance impacts across the survey area.

5.2.1 THREATENED AND PRIORITY ECOLOGICAL COMMUNITIES

According to the DBCA database search, the survey area does not correspond with any mapped TEC or PEC. Seven PECs were identified within a 100 km buffer of the survey area. None of the vegetation types are considered to represent these PECs or any others known from the Murchison bioregion.

5.2.2 OTHER SIGNIFICANT VEGETATION

Based on the criteria provided in the Flora and Vegetation Technical Guidance (EPA 2016a), several vegetation types may be considered significant. These are discussed below.

5.2.2.1 Groundwater Dependent Vegetation

GDV is characterised by phreatophytic species that require access to groundwater for at least part of their life cycle. Vegetation type **EcAbPd** occurred in a drainage line that intersected the corridor section of the survey area, characterised by *Eucalyptus camaldulensis* subsp. *arida*. This vegetation type is likely to intersect the proposed access road corridor, with minor direct impacts likely. Furthermore, any groundwater changes may potentially affect this vegetation type.

5.2.2.2 Sheet Flow Dependent Vegetation

An overview of Sheet Flow Dependent Vegetation (SFDV) is provided (**Appendix One**), with 'grove-intergrove' Mulga being Australia's most known form of SFDV. There were numerous Mulga species recorded from the survey area, including *Acacia aneura, A. caesaneura, A. craspedocarpa, A. fuscaneura, A. incurvaneura* and *A pteraneura.* Three vegetation types are dominated by one or more Mulga species in the upper stratum. However, none of the vegetation types dominated by Mulga displayed the characteristic grove-intergrove formation considered to be representative of (SFDV). Therefore, SFDV is considered unlikely to occur within the survey area.

5.2.2.3 Vegetation Dominated by Conservation-listed Flora

No vegetation types are either dominated or characterised by conservation-listed species.

5.2.2.4 Vegetation Types of Limited Spatial Extent

Two vegetation types were recorded from the survey area with restricted extents of less than 1%. Aside from their small extent, which is a function of the habitat within which they occur, they are not considered significant unless for reasons other than their size (see above).

5.2.3 LOCAL AND REGIONAL SIGNIFICANCE OF VEGETATION

There are minimal previous local or regional surveys available to provide local context. However, the vegetation of the survey area was observed to be typical of the surrounding area based on pre-European vegetation mapping and land system mapping. All pre-European vegetation associations in the survey area have greater than 90 % extent remaining at the statewide scale. None are representative of any described TEC or PEC, and none are characterised by any conservation-listed flora. Furthermore, none are historically threatened, have a specific role as a refuge or provide essential functions required to maintain the ecological

integrity of a significant ecosystem, with the potential exception of riparian (**EcAbPd**) or wetland vegetation (**Tspp**).

Therefore, the vegetation types recorded within the survey area are considered unlikely to have any specific local or regional significance.

5.2.4 VEGETATION CONDITION

The vegetation condition within the survey area ranged from Completely Degraded to Very Good condition, with the majority (84.91 %) in Very Good condition. The main factors affecting vegetation condition were clearing (particularly on Apollo Hill) and past and present grazing by livestock and goats.

5.3 FAUNA SIGNIFICANCE

5.3.1 FAUNA HABITAT TYPES

Seven fauna habitat types were recorded during the field survey (**Section 4.2.1**):

- Mulga woodland (535.38 ha)
- Mixed shrubland (96.17 ha)
- Chenopod shrubland (116.91 ha)
- Rocky escarpment (64.26 ha)
- Flood plain (7.14 ha)
- Drainage line (2.65 ha)
- Mineshaft/cave (too small to be mapped).

The fauna habitats recorded in the survey area are typical for the local area and represent the Eastern Murchison subregion; thus, they are not of local or regional significance. There were also signs of introduced species (cats, foxes, cattle) in all recorded habitats. The recorded habitats provide resources for the generalist fauna assemblage. However, high levels of degradation (grazing, trampling of vegetation and soil disturbance) from roaming cattle may have reduced the suitability of the survey area for ground-dwelling or fossorial species in some areas.

Some habitats (Flood Plain, Chenopod Shrubland and Drainage Lines) will likely experience seasonal variability in their fauna assemblage due to inundation, including waterbirds and amphibians during the wetter months.

The Rocky Escarpment habitat, associated with Apollo Hill, was highly degraded due to mining exploration activities, limiting its habitat value. Seven species of bat, none of them conservation-listed, were recorded at a historical mineshaft found on the upper slope of the hill. However, it is unknown if the shaft is a roost site or if the bats recorded were flying over the site.

5.3.2 FAUNA ASSEMBLAGE

Thirty-five vertebrate fauna species were recorded during the field survey, consisting of 14 mammals (one introduced), 19 birds, and two reptiles (**Section 4.2.2**), from active searches, habitat assessments, trail cameras and ultrasonic recording units. All species recorded were expected to occur and were considered typical for the region and the habitat surveyed.

5.3.3 RECORDED CONSERVATION-LISTED SPECIES

5.3.3.1 Black-eared Cuckoo (*Chalcites osculans*) – MA/MI EPBC status

The Black-eared Cuckoo is a cryptic, medium-sized species identified by its brown-grey underparts, pale rump, dark tail with white tip, dark eye stripe, and distinctive mournful descending whistle (Higgins 1999). This cuckoo is distributed across mainland Australia and occasionally in Papua New Guinea (Higgins 1999). The Black-eared Cuckoo travels large distances to find suitable densities of its host species, primarily the Redthroat *Pyrrholaemus brunneus* in W.A., to lay its egg in their nests (Higgins 1999). Both the cuckoo and its host are

threatened by impacts such as habitat damage caused by introduced herbivores, habitat fragmentation, and predation by introduced predators (Hope, Kerle & Doer 2020).

The Mulga Woodland and Mixed Shrubland habitat types are considered suitable habitat for this species. However, due to the high mobility of this species, it is unlikely that the Black-eared Cuckoo is dependent upon the survey area.

5.3.4 POST-SURVEY LIKELIHOOD ASSESSMENT

The post-survey likelihood assessment is incorporated into **Table 23** in **Appendix Three**.

Conservation-listed fauna species identified during the desktop assessment as having a High or Medium likelihood of occurring that were not recorded during the field survey are discussed below with respect to each species' habitat requirements, taking into consideration the findings of the field survey and survey effort.

High Likelihood Species

Malleefowl (*Leipoa ocellata*) – VU EPBC status, VU BC status

The Malleefowl belongs to the family Megapodiidae, or the mound builders, and uses external heat to incubate its eggs (Benshemesh 2007). This species inhabits the inland interior of Australia in dry scrub and low mallee woodlands habitat (Simpson & Day 2010b). A sandy substrate and abundant leaf litter are precise requirements for constructing the birds' incubator nests (Benshemesh 2007).

The DBCA database records show 40 records from within the 90 km survey area buffer, four of which are within 45 km of the survey area. No suitable Malleefowl habitat or evidence of Malleefowl or their mounds was found within the survey area. The habitat types within the survey area had only sparse leaf litter, making them unsuitable for Malleefowl to build mounds. High levels of disturbance due to pastoral grazing further reduce the likelihood that Malleefowl are present in the survey area.

The post-survey likelihood of occurrence of this species is 'Unlikely'.

Peregrine Falcon (*Falco peregrinus*) – OS BC status/DBCA status

This bird of prey saw massive declines in the 1960s and 1970s due to pesticide DDT. Although populations in Australia have recovered better than elsewhere in the world, the Peregrine Falcon remains a conservation-listed species. This species is not confined to a specific habitat, although it is usually seen perching on poles, fences, or dead trees in agricultural areas. It nests on cliffs, buildings, or the old stick nests of other species, e.g., Raven.

No Peregrine Falcons were recorded in the survey area. Nine recent (< 25 years) DBCA records indicate that this species occurs within the survey area search buffer, with four records from within 45 km of the survey area. Foraging habitat for this species occurs throughout the survey area. However, suitable breeding habitat is limited. Peregrine Falcon would likely only be transient and not dependent on any resources in the survey area.

The post-survey likelihood of the species occurring remains as 'Likely'.

Medium Likelihood Species

Long-tailed Dunnart (*Sminthopsis longicaudata*) – P4 DBCA status

The Long-tailed Dunnart (*Sminthopsis longicaudata*) is a small, nocturnal, insectivorous Dasyurid and can be distinguished from other *Sminthopsis* species by its tail being more than twice the length of the head and body (Van Dyck & Strahan 2008). Whilst generally rare (i.e. uncommon or sparsely distributed), it can become locally common when resources are abundant. It is found in rocky scree and plateau areas with little vegetation or spinifex hummock grassland, shrubs, and/or open woodland (Van Dyck & Strahan 2008; Gibson & McKenzie 2009). It is patchily distributed in central Western Australia (Pilbara, Murchinson, Northeastern Goldfields, Ashburton, and Gibson Desert regions) and a few sites in central southern Northern Territory (Van Dyck & Strahan 2008; Pavey 2002).

There appear to be no major threats to this species. However, in central Australia, this species is affected by the spread of exotic Buffel Grass (*Cenchrus* spp.), which increases the frequency and intensity of fires. This is also likely an issue in some areas of Western Australia (Pavey 2002). However, Buffel Grass was not recorded within this survey area.

There are seven DBCA records of this species from within the survey area buffer of 90 km. A suitable habitat exists within the survey area in the Rocky Escarpment habitat; however, it is highly disturbed, and it is unlikely that this species still resides in the area if it once did. The post-survey likelihood of occurrence of this species remains as 'May Occur'.

Southern Whiteface (*Aphelocephala leucopsis*) – VU EPBC status.

The Southern Whiteface is a small (10–11.5 cm) bird with a brown body, white belly, and distinctive white band with black edging across the forehead (Simpson & Day 2010b).

This species has recently been listed as Vulnerable (March 2023) due to a population decline of an estimated 30–50% every ten years since 1999. The likely cause of this decline is habitat loss and fragmentation, particularly where habitat has been completely removed for intensive agriculture. The Southern Whiteface is predominately sedentary, preferring open woodlands and shrublands, usually dominated by eucalypts or acacias, with an understorey of grasses and/or shrubs (Ehmke et al. 2021). The Southern Whiteface favours habitats with low tree density, and there is a herbaceous understorey with leaf litter, where they can forage for insects, spiders, and seeds. Trees with hollows and crevices are also essential for roosting and nesting, although they will also nest in low bushes (Ehmke et al. 2021). A large portion (535.38 ha, 65.09%) of the survey area constitutes a habitat for this species. However, this habitat is also characteristic of the local region, thus having no specific significance.

The post-survey likelihood of occurrence of this species remains as 'May Occur'.

Princess Parrot (*Polytelis alexandrae*) – VU EPBC status; P4 DBCA status

The Princess Parrot is restricted to arid regions of Western Australia, southern Northern Territory, and north-western South Australia, with all records being far inland except where the Great Sandy Desert reaches the coast south of Broome. It occurs only sparsely within its distribution, and sightings are rare except in the Great Sandy, Gibson, Tanami and Great Victoria Deserts and central ranges; the Great Sandy Desert is the 'core range'. Recorded habitats include sand dunes and flats with open savannah woodlands (scattered stands of *Eucalyptus gongylocarpa*, *E. chippendalei* and mallee species, *Casuarina* or *Allocasuarina*) over *Acacia*, *Eremophila*, *Grevillea*, *Hakea* and *Senna* shrublands, over *Triodia* hummock grassland (DCCEEW 2023).

The Princess Parrot feeds on seeds of grasses and shrubs, as well as some flowers, nectar, and leaves. They nest in hollows of Eucalypts close to watercourses or occasionally in *Allocasuarina* away from water. Their movements are poorly known but are described as nomadic, irruptive, or both. No threatening processes have been demonstrated for this species. Still, populations may have been impacted by changes in vegetation due to grazing, altered fire regimes, and competition from more water-dependent species following the provision of artificial water sources (DCCEEW 2023).

Suitable habitat exists within the survey area in the Mulga Woodland and Drainage Line habitat types. The PMST search found that the 'species or species habitat is known to occur within the area'; however, it was not recorded during the field survey, and there are no historical records of the Princess Parrot from within the 90 km survey area buffer. It is unlikely that this species is dependent upon the habitat within the survey area. Therefore, this species' likelihood has been re-evaluated and is considered 'Unlikely' to occur within the survey area.

Migratory Shorebirds – MI EPBC status; MI BC status

Many shorebird or wetland species are migratory, travelling thousands of kilometres to or from highly productive breeding grounds at different times of the year. The potentially occurring species within the survey area are listed below with their post-survey likelihood assessment rating:

- Common Sandpiper (*Actitis hypoleucos*) (May)
- Common Greenshank (*Tringa nebularia*) (May).

These two species are mainly found in coastal areas such as intertidal mudflats, estuaries, and inlets. However, they are also recorded inland, although less commonly, around ephemeral and permanent lakes, dams, and waterholes (Higgins & Davies 1996). The Common Sandpiper and Common Greenshank migrate to Australia in August and leave in March, coinciding with the survey's timing from late March to April and in September. Within the survey area, suitable habitat occurs in the Chenopod Shrubland habitat type when flooded, although these species do not prefer this habitat. However, the lack of any recent rainfall events before the survey meant that there was no habitat available for these species if they did occur. No migratory shorebird bird species were recorded during the survey. However, historical records for both species occur in the survey area buffer. Therefore, the post-likelihood assessment of these species is that they 'May' occur in the survey area.

6 DWER'S 10 CLEARING PRINCIPLES

The following table summarises the likely significant findings of the survey and how they will likely be assessed based on DWER's 10 clearing principles (Department of Environment Regulation 2014).

Table 15: Assessment against DWER's 10 clearing principles

Principle	Assessment	Outcome
Principle (a) Native vegetation should not be cleared if it comprises a high level of biological diversity.	There were 166 flora taxa recorded from the survey area. While the field survey was undertaken following periods of below-average rainfall, flora diversity is considered low to moderate.	Unlikely to be at variance
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.	Seven fauna habitats were recorded; none were of local significance. Thirty-one vertebrate fauna species were documented, one of which is conservation-listed (*Chalcites osculans*). This species depends on habitat types well represented in the surrounding landscape.	Not at variance
Principle (c) Native vegetation should not be cleared if it includes, or is necessary for the continued existence of, rare flora.	No Threatened Flora were recorded within the survey area, and none are considered likely to occur. Two Priority Flora (*Tecticornia globulifera* [P1] and *Hemigenia exilis* [P4]) were recorded, each from a single location. Based on the proposed disturbance footprints, there will be no direct impacts on *Tecticornia globulifera*. A small number of *Hemigenia exilis* plants (<10) may be impacted by the proposed access road, which is considered negligible to this species.	Unlikely to be at variance
Principle (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.	No TECs or PECs were recorded from the survey area.	Not at variance
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.	Pre-European vegetation association mapping indicates that all vegetation types have greater than 90% statewide distribution remaining.	Not at variance
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.	Vegetation type **EcAbPd** represents an ephemeral drainage line, whilst **Tspp** is a wetland vegetation type. The **EcAbPd** vegetation type will intersect with a proposed access road, representing a minor disturbance. The **Tspp**. vegetation type partially intersects proposed development footprints (**Map 8**). However, the impact is likely negligible, considering the vast areas of this vegetation outside the survey area.	May be at variance
Principle (g) Native vegetation should not be cleared if the clearing of the vegetation is likely to cause appreciable land degradation.	Clearing vegetation within the survey area is unlikely to cause appreciable land degradation in areas adjacent to the clearing. However, understanding of the potential for land degradation because of future works associated with proposed mining cannot be assessed from the results of this survey.	Unknown

Principle	Assessment	Outcome
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 National Parks, Nature Reserves or other conservation estates occur near the survey area. The nearest conservation estate is Goongarrie National Park, located approximately 67 km south of the survey area.	Not at variance
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.	The survey area intersects one drainage line along the corridor section, with deterioration in surface water quality unlikely. Impacts on groundwater are not part of this assessment. However, clearing vegetation within the survey area is considered unlikely to cause deterioration in groundwater quality.	Unlikely to be at variance
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 proposed clearing should be considered unlikely to exacerbate the incidence of flooding.	Unlikely to be at variance

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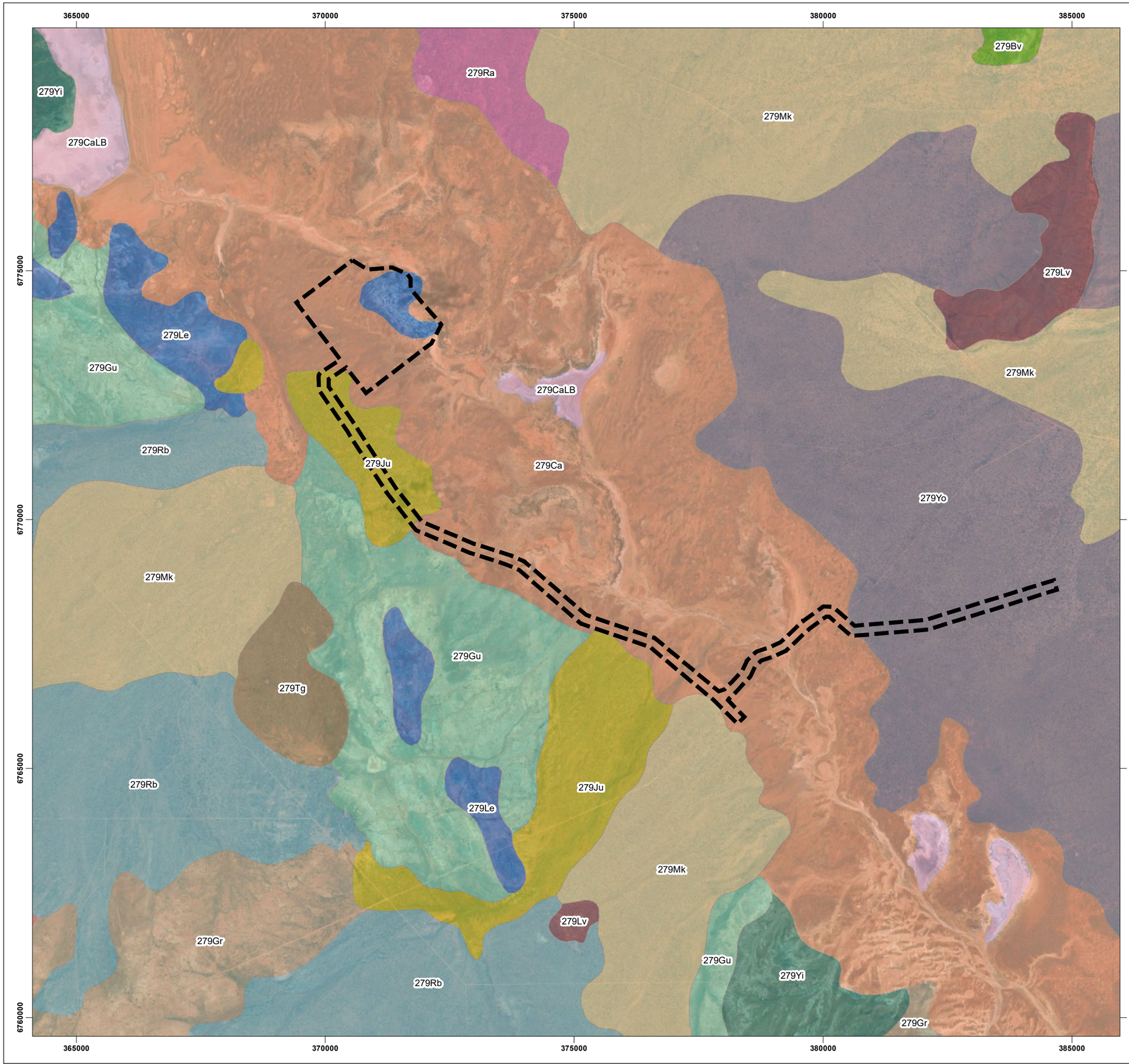
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MAPS



LEGEND

Survey Area

Soil Land Systems

- 279Bv: Irregular low ironstone hills with stony lower slopes supporting Mulga Shrublands
- 279Ca: Salt lakes with fringing saline alluvial plains, kopi dunes and sandy banks, supporting halophytic Shrublands and *Acacia* tall Shrublands
- 279CaLB: Bare lake beds inundated for short periods after rain
- 279Gr: Stony plains and low rises based on granite supporting mainly halophytic low Shrublands
- 279Gu: Extensive, gently undulating calcareous stony plains supporting bluebush Shrublands
- 279Ju: Hardpan plains with variable gravelly mantles and minor sandy banks supporting weakly groved Mulga Shrublands
- 279Le: Low greenstone hills and stony plains supporting mixed chenopod Shrublands
- 279Lv: Greenstone hills and ridges with *Acacia*
- 279Mk: Hardpan plains with occasional sandy banks supporting Mulga tall Shrublands and wanderrie grasses
- 279Ra: Hardpan plains and prominent broad drainage tracts supporting dense Mulga tall Shrublands
- 279Rb: Hardpan plains supporting Mulga tall Shrublands
- 279Tg: Gravelly hardpan plains and sandy banks with Mulga Shrublands and wanderrie grasses
- 279Wn: Gently undulating stony plains and low rises with quartz mantles on granite, supporting *Acacia-eremophila* Shrublands
- 279Yi: Low breakaways with saline gravelly lower plains supporting predominately halophytic low Shrublands
- 279Yo: Sandy plains supporting tall Shrublands of Mulga and bowgada with patchy wanderrie grasses

DATA SOURCES :
SOURCE DATA: SOIL-LANDSCAPE MAPPING WESTERN AUSTRALIA – BEST AVAILABLE SOILS (DPIRD-027) (DPIRD 2022)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER

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SOIL LANDSCAPES

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

N

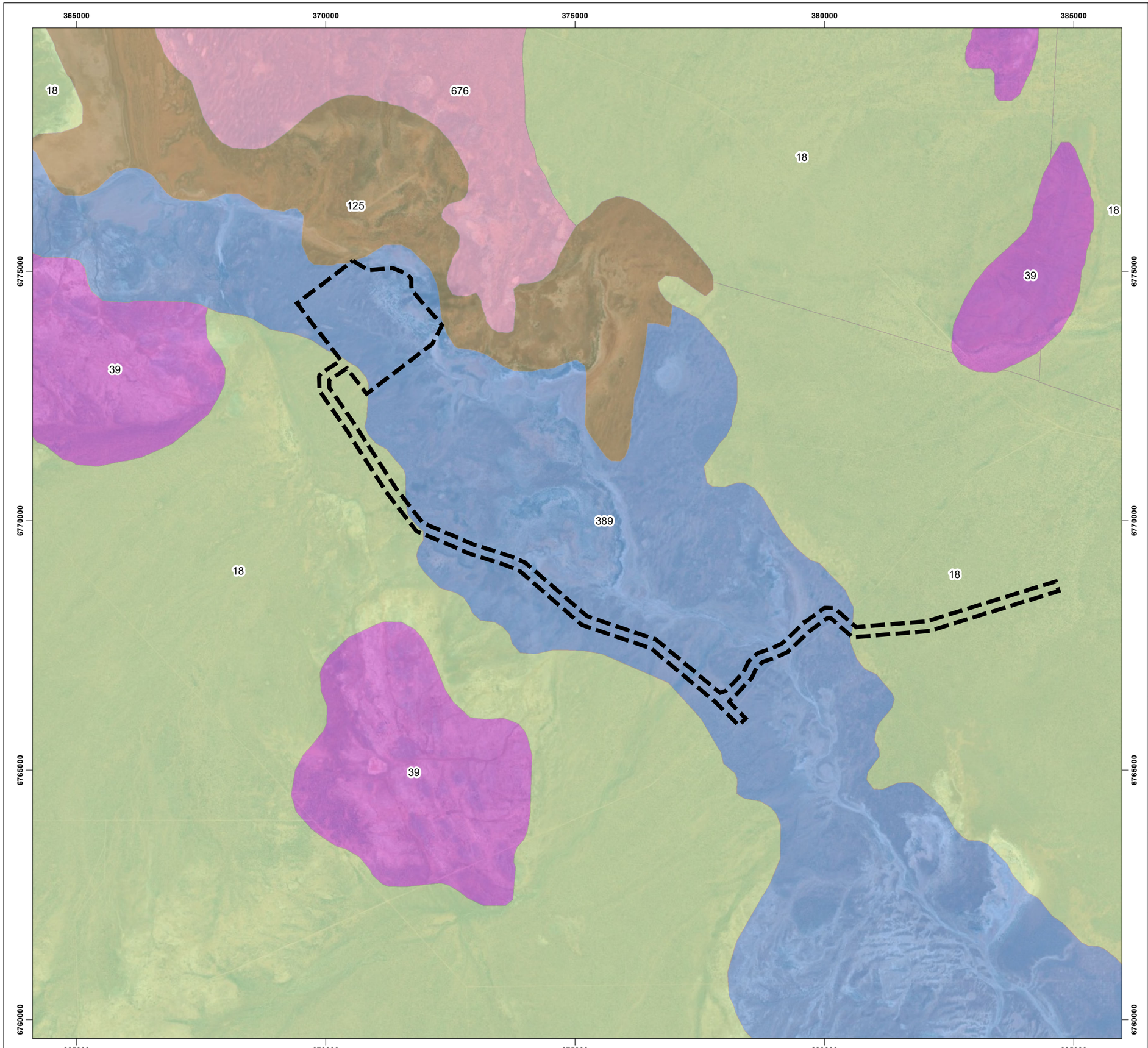
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PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	SK	07/06/2023

MAP 01



LEGEND

Survey Area

Pre-European Vegetation Unit

- 18: Low woodland, open low woodland or sparse woodland: Mulga *Acacia aneura* and associated species.
- 39: Scrub, open scrub or sparse scrub: Wattle, teatree and other species *Acacia* spp. *Melaleuca* spp.
- 125: Salt lake, lagoon, clay pan
- 389: Saltbush and/or bluebush with scattered low trees: Mulga, other wattle, *Casuarina atriplex* spp. *Maireana* spp. with *Acacia aneura, A. papyrocarpa, Allocasuarina cristata*
- 676: Samphire: *Tecticornia* spp. communities in saline

DATA SOURCES :
SOURCE DATA: PRE-EUROPEAN VEGETATION (DPIRD-006) (DPIRD 2019)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA

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PRE-EUROPEAN VEGETATION

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

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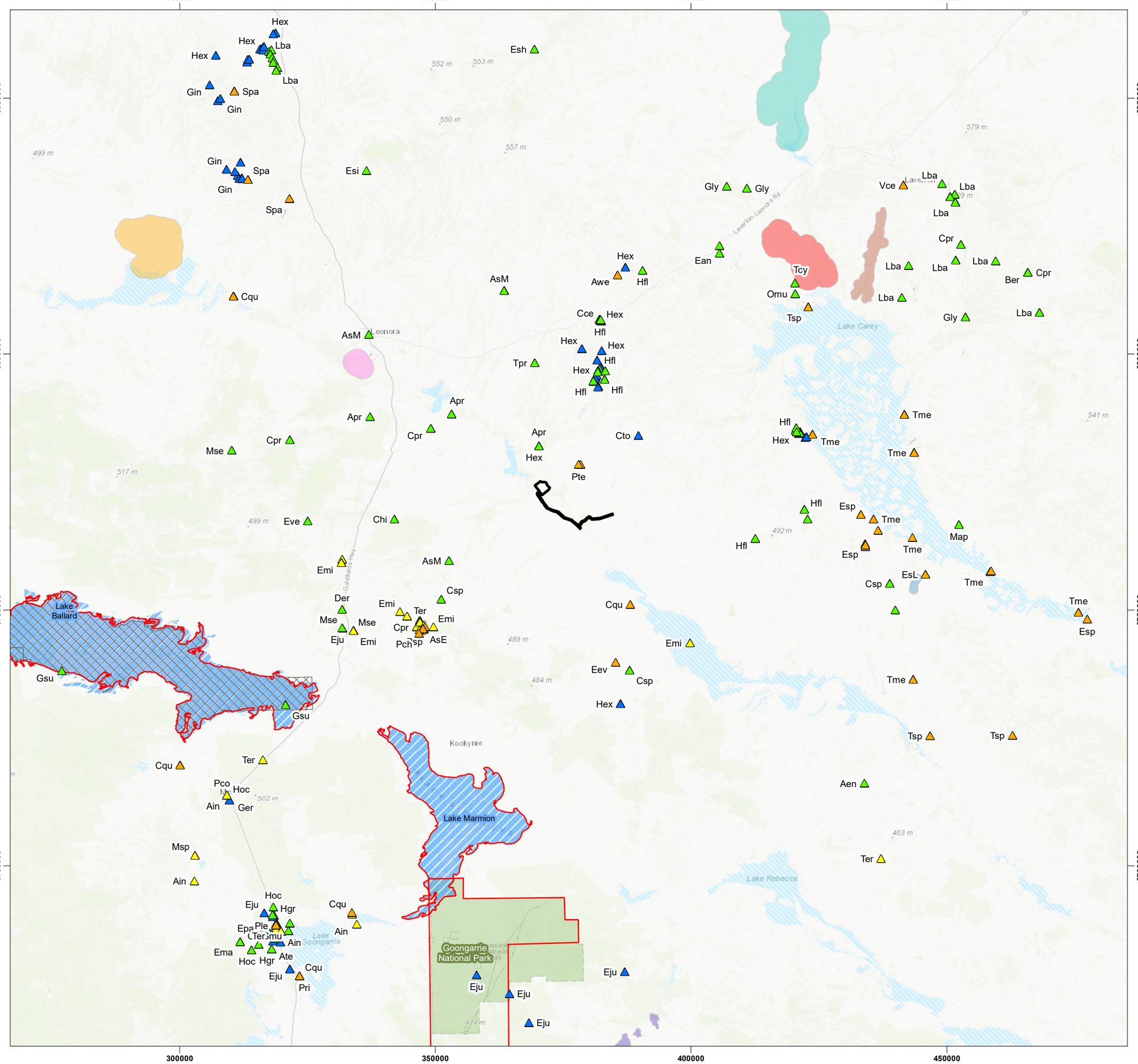
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PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	SK	07/06/2023

MAP
02



LEGEND

- Survey Area
- Environmentally Sensitive Area
- Ramsar Wetland
- DBCA Park and Reserve
- Directory of Important Wetland

Conservation-listed Flora

- Priority 1
- Priority 2
- Priority 3
- Priority 4

TEC/PECs

- Emu Land System
- Laverton Downs calcrete groundwater assemblage type on Carey palaeodrainage on Laverton Downs Station
- Melita calcrete groundwater assemblage type on Raeside palaeodrainage on Melita (Sons of Gwalia) Station
- Mount Jumbo Range vegetation complex (banded ironstone formation)
- Mount Linden Range vegetation complex (banded ironstone formation)
- Mount Morgan calcrete groundwater assemblage type on Carey palaeodrainage on Mt Weld Station
- Sturt Meadows calcrete groundwater assemblage type on Raeside palaeodrainage on Sturt Meadows Station

Code	Taxon	Status	Code	Taxon	Status
Aen	*Acacia eremophila* var. Numerous-nerved variant (A.S. George 11924)	3	Ger	*Grevillea erectiloba*	4
Aev	*Acacia eremophila* var. *variabilis*	3	Gin	*Grevillea inconspicua*	4
Ain	*Apatelantha insignis*	2	Gly	*Goodenia lyrata*	3
Apr	*Angianthus prostratus*	3	Gsu	*Grevillea subterlineata*	3
AsE	*Anacampseros* sp. *Eremaean* (F. Hort, J. Hort & J. Shanks 3248)	1	Hex	*Hemigenia exilis*	4
AsM	*Acacia* sp. Marshall Pool (G. Cockerton 3024)	3	Hfl	*Hybanthus floribundus subsp. chloroxanthus*	3
Ate	*Alyxia tetanifolia*	3	Hgr	*Homalocalyx grandiflorus*	3
Awe	*Acacia websteri*	1	Hoc	*Hysterobaeckea ochropetala* subsp. *cometes*	3
Ber	*Bossiaea eremaea*	3	Lba	*Lysiandra baeckeoides*	3
Cap	*Chrysocephalum apiculatum* subsp. *norsemanense*	3	Map	*Melaleuca apostiba*	3
Cce	*Cratystylis centralis*	3	Mse	*Micromyrtus serrulata*	3
Chi	*Calytrix hislopii*	3	Msp	*Malleostemon* sp. *Adelong* (G.J. Keighery 11825)	2
Cpr	*Calytrix praecipua*	3	Omu	*Olearia mucronata*	3
Cqu	*Calandrinia quartzitica*	1	Pch	*Ptilotus chortophytus*	1
Csp	*Calandrinia* sp. Menzies (F. Hort et al. FH 4100)	3	Pco	*Philotheca coateana*	3
Cto	*Conospermum toddii*	4	Ple	*Persoonia leucopogon*	1
Der	*Drosera eremaea*	3	Pri	*Ptilotus rigidus*	1
Ean	*Eremophila annosicaulis*	3	Psp	*Ptilotus* sp. *Kookynie* (J. Jackson & B. Moyle 261)	1
Eev	*Eremophila eversa*	1	Pte	*Ptilotus tetrandrus*	1
Eju	*Eucalyptus jutsonii* subsp. *jutsonii*	4	Smu	*Sowerbaea multicaulis*	4
Ema	*Elatine macrocalyx*	3	Spa	*Stenanthemum patens*	1
Emi	*Eremophila mirabilis*	2	Tcy	*Tecticornia cymbiformis*	3
Epa	*Eleocharis papillosa*	3	Ter	*Thryptomene eremaea*	2
Esh	*Eremophila shonae* subsp. *diffusa*	3	Tme	*Tecticornia mellarium*	1
Esi	*Eremophila simulans* subsp. *megacalyx*	3	Tpr	*Triglochin protuberans*	3
EsL	*Eragrostis* sp. Lake Carey (J. Paterson & J. Warden WB 40825)	1	Tsp	*Tecticornia* sp. Lake Way (P. Armstrong 05/961)	1
Esp	*Eremophila* sp. Lake Carey (E. Mattiske LM 197)	1	Vce	*Vittadinia cervicularis* var. *oldfieldii*	1
Eve	*Eremophila veronica*	3			

DATA SOURCES :
SOURCE DATA: FLORA AND TEC/PEC DATA (DBCA 2022); DBCA - LEGISLATED LANDS AND WATERS (DBCA-011) (DBCA 2021); CLEARING REGULATIONS - ENVIRONMENTALLY SENSITIVE AREAS (DWER-046) (DWER 2021); DIRECTORY OF IMPORTANT WETLANDS IN AUSTRALIA - WESTERN AUSTRALIA (DBCA-045) (DBCA 2018); RAMSAR SITES (DBCA-010) (DBCA 2017)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY

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DBCA DATABASE SEARCH RESULTS - FLORA

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

N

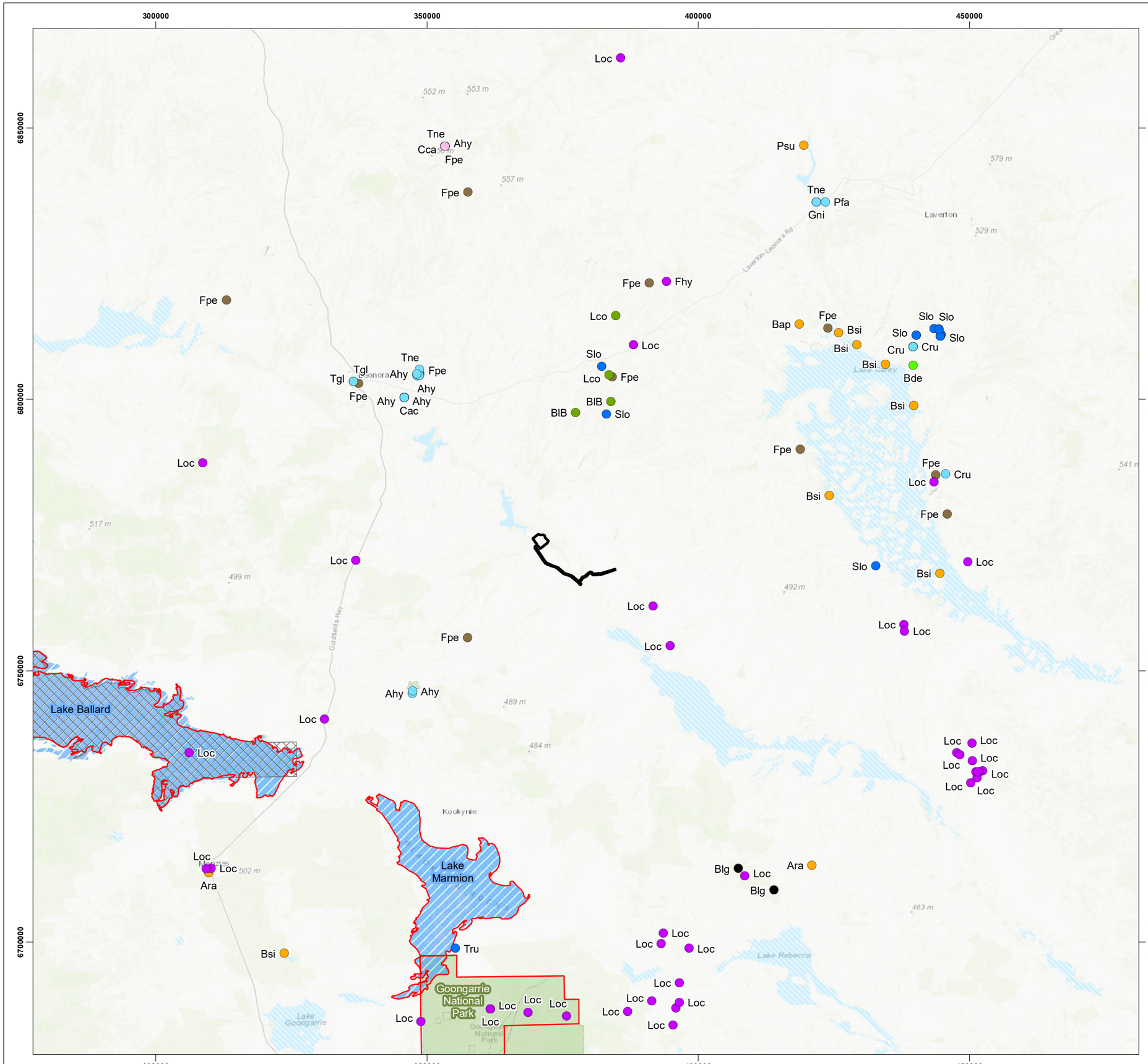
SCALE: 1:750,000 @ A3

0 10 20 30 km

PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	SK	07/06/2023

MAP 03


300000
350000
400000
450000
6850000
6800000
6750000
6700000
Loc
Tne
Cca
Ahy
Fpe
Psu
Tne
Pfa
Gni
Laverton
Laverton-Leonora Rd
Fpe
Fhy
Lco
Loc
Slo
Lco
Fpe
BIB
Slo
Bap
Fpe
Bsi
Slo
Slo
Slo
Bsi
Cru
Cru
Slo
Bsi
Bde
Bsi
Fpe
Fpe
Cru
Loc
Bsi
Fpe
Tne
Tgl
Leonora
Ahy
Fpe
Tgl
Fpe
Ahy
Ahy
Ahy
Cac
Loc
Slo
Loc
Bsi
Ara
Blg
Loc
Blg
Loc
Loc
Loc

370000
371000
372000
6776000
6775000
6774000

AH23030
AH23031
PaHpCs
AH23076
AH23018
AH23015
AH23016
AH23008
AaAePo
AH23009
AH23007
AH23029
AH23013
AaEmRd
AH23011
CsLs
AH23019
AH23027
AH23127
AH23020
AH23006
AH23128
AH23010
AH23002
AH23001
AH23021
AH23004
AH23003
AH23005
AmFs
X
AH23012
Tspp
AH23028

LEGEND

Survey Area

Significant Flora

Tecticornia globulifera (Priority 1)

Tecticornia sp. nov. 2 (Other)

Quadrat

Vegetation Types

AaAePo: *Acacia aneura* and *A. pteraneura* low open woodland

AaEmRd: *Acacia aneura*, *A. incurvaneura* and *A. caesaneura* low woodland

AmFs: *Acacia masliniana* and *Cratystylis subspinescens* mid sparse shrubland

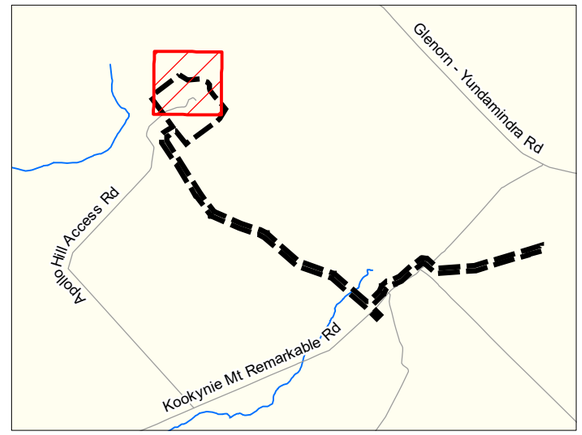
CsLs: *Cratystylis subspinescens* and *Eremophila miniata* mid sparse shrubland

PaHpCs: *Pittosporum angustifolium* low sparse woodland

Tspp: *Tecticornia* spp. low samphire

X: No vegetation/cleared

DATA SOURCES :
SOURCE DATA: SIGNIFICANT FLORA AND VEGETATION DATA (ECOSCAPE 2023), ROAD NETWORK (MRWA 2020) AND SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER



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VEGETATION TYPES

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

N

SCALE: 1:10,000 @ A3

0 100 200 300 400 m

PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	SK	28/06/2023

MAP 5-1

370000
371000
372000
6774000
6773000
6772000

AH23020
AH23128
AH23010
AH23006
AH23002
AH23001
AH23003
AH23004
AH23005
AH23021
AH23012
AH23028
AH23014
AH23126
AH23026
AH23025
AH23129
AH23022
AH23125
AH23024
AH23023
AH23172

CsLs
AaAePo
AmFs
Tspp
AaEmRd
X
AcEfPo

LEGEND

Survey Area

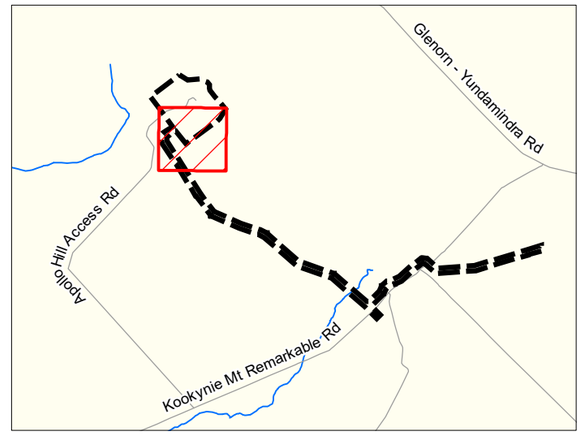
Significant Flora

- *Tecticornia globulifera* (Priority 1)
- *Santalum spicatum* (Other)
- Quadrat

Vegetation Types

- AaAePo: *Acacia aneura* and *A. pteraneura* low open woodland
- AaEmRd: *Acacia aneura*, *A. incurvaneura* and *A. caesaneura* low woodland
- AcEfPo: *Acacia caesaneura*, *A. incurvaneura* and *A. aneura* low woodland
- AmFs: *Acacia masliniana* and *Cratystylis subspinescens* mid sparse shrubland
- CsLs: *Cratystylis subspinescens* and *Eremophila miniata* mid sparse shrubland
- Tspp: *Tecticornia* spp. low samphire
- X: No vegetation/cleared

DATA SOURCES :
SOURCE DATA: SIGNIFICANT FLORA AND VEGETATION DATA (ECOSCAPE 2023), ROAD NETWORK (MRWA 2020) AND SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER



ecoscape

VEGETATION TYPES

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

N

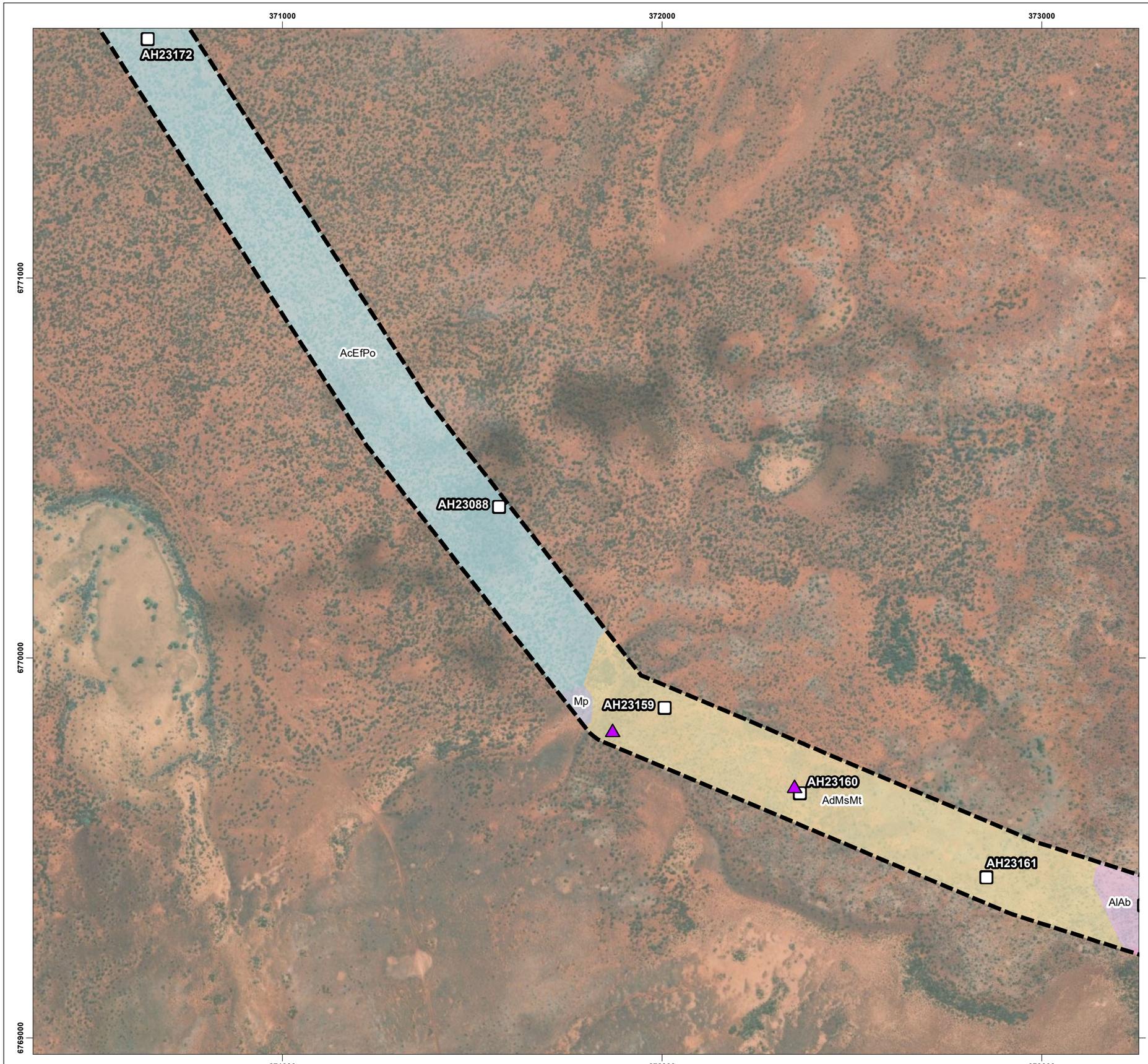
SCALE: 1:10,000 @ A3

0 100 200 300 400 m

MAP 5-2

PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	SK	28/06/2023



LEGEND

Survey Area

Significant Flora

Santalum spicatum (Other)

Quadrat

Vegetation Types

AcEfPo: *Acacia caesaneura*, *A. incurvaneura* and *A. aneura* low woodland

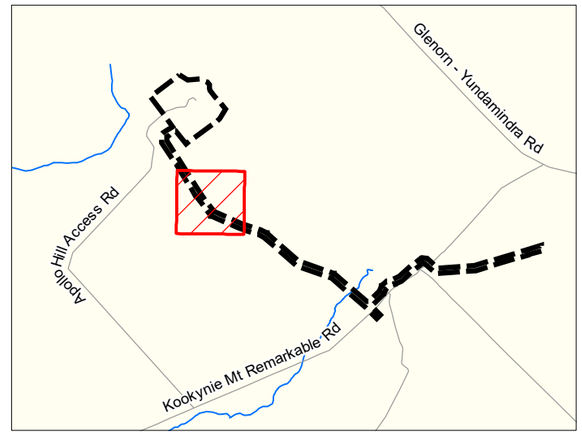
AdMsMt: *Acacia duriuscula* low open woodland over *Maireana sedifolia* mid sparse shrubland

AkLs: *Acacia kalgoorliensis* mid sparse shrubland

AlAb: *Acacia ligulata* and *A. victoriae* subsp. *victoriae* tall open shrubland

Mp: *Maireana pyramidata, Lawrencia squamata* low open chenopod shrubland/shrubland

DATA SOURCES :
SOURCE DATA: SIGNIFICANT FLORA AND VEGETATION DATA (ECOSCAPE 2023), ROAD NETWORK (MRWA 2020) AND SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER



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VEGETATION TYPES

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

N

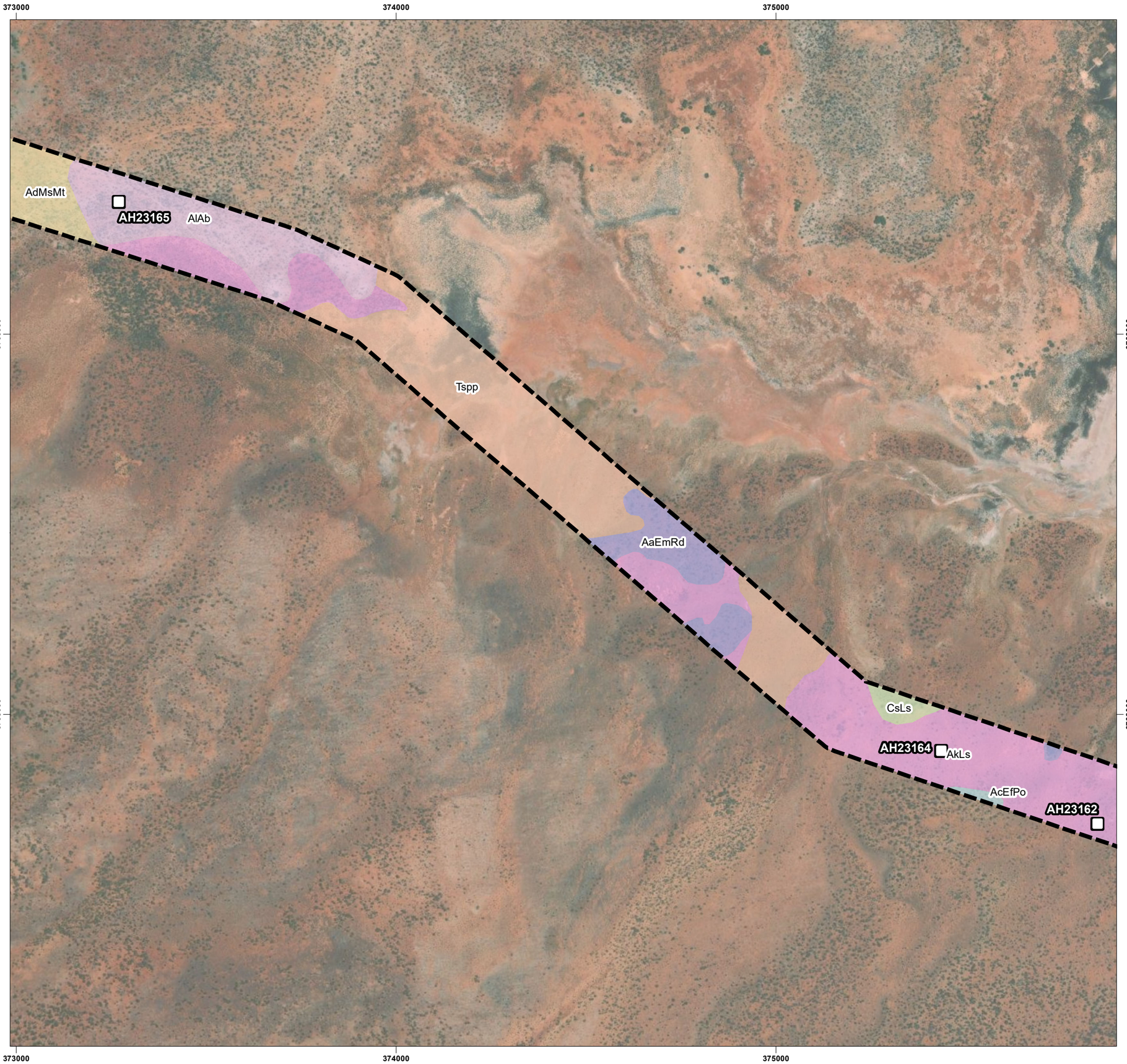
SCALE: 1:10,000 @ A3

0 100 200 300 400 m

MAP 5-3

PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	SK	28/06/2023



LEGEND

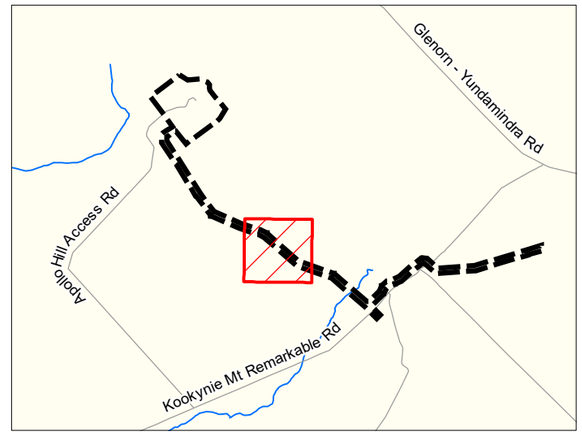
Survey Area

Quadrat

Vegetation Types

- AaEmRd: *Acacia aneura*, *A. incurvaneura* and *A. caesaneura* low woodland
- AcEfPo: *Acacia caesaneura*, *A. incurvaneura* and *A. aneura* low woodland
- AdMsMt: *Acacia duriuscula* low open woodland over *Maireana sedifolia* mid sparse shrubland
- AkLs: *Acacia kalgoorliensis* mid sparse shrubland
- AlAb: *Acacia ligulata* and *A. victoriae* subsp. *victoriae* tall open shrubland
- CsLs: *Cratystylis subspinescens* and *Eremophila miniata* mid sparse shrubland
- Tspp: *Tecticornia* spp. low samphire

DATA SOURCES :
SOURCE DATA: SIGNIFICANT FLORA AND VEGETATION DATA (ECOSCAPE 2023), ROAD NETWORK (MRWA 2020) AND SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER



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VEGETATION TYPES

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

N

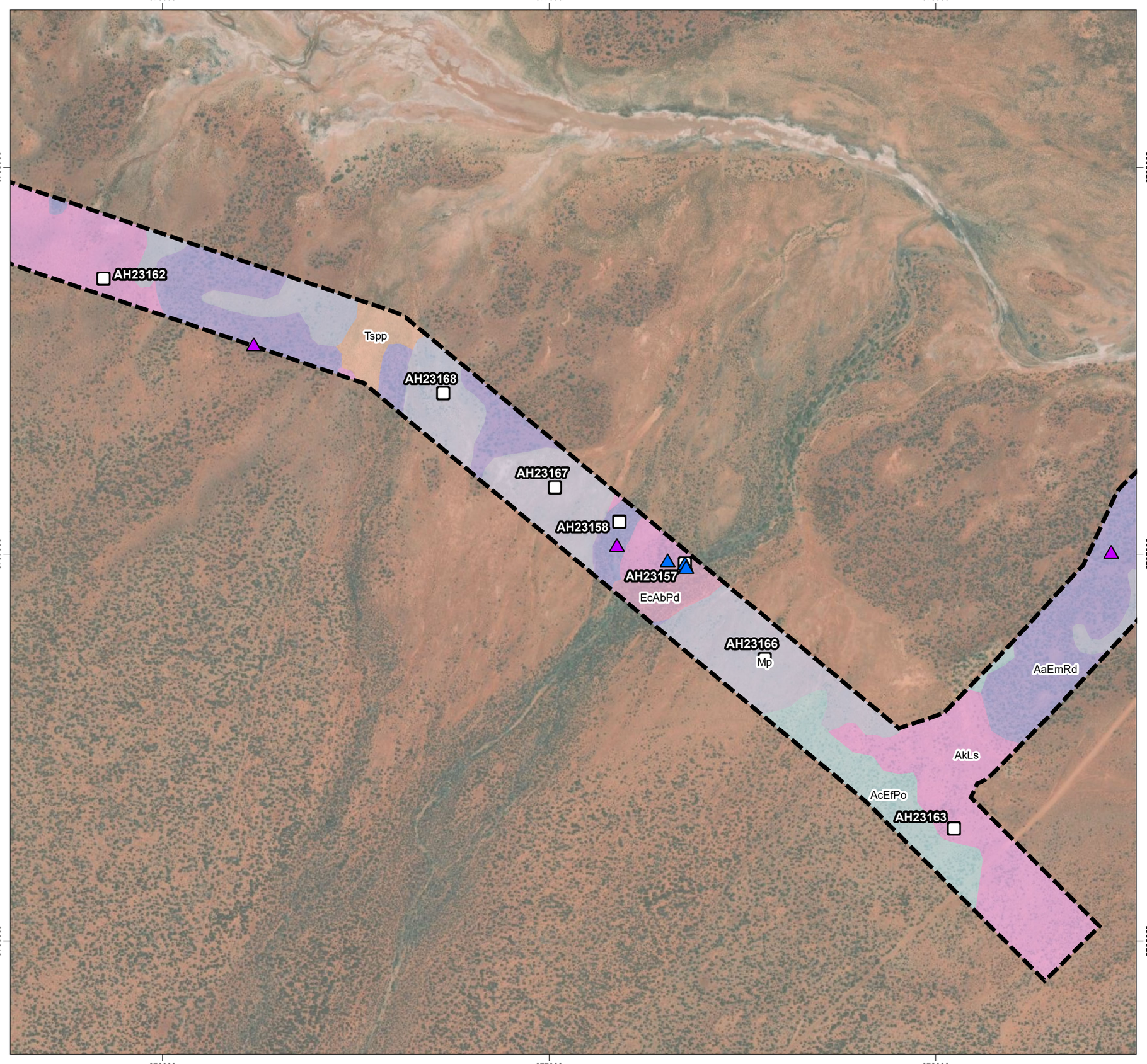
SCALE: 1:10,000 @ A3

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PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	SK	28/06/2023

MAP 5-4



LEGEND

Survey Area

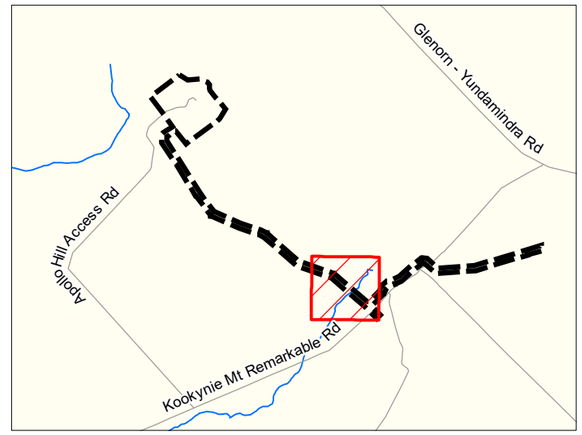
Significant Flora

- *Hemigenia exilis* (Priority 4)
- *Santalum spicatum* (Other)
- Quadrat

Vegetation Types

- AaEmRd: *Acacia aneura*, *A. incurvaneura* and *A. caesaneura* low woodland
- AcEfPo: *Acacia caesaneura*, *A. incurvaneura* and *A. aneura* low woodland
- AkLs: *Acacia kalgoorliensis* mid sparse shrubland
- EcAbPd: *Eucalyptus camaldulensis* subsp. *arida* mid woodland
- Mp: *Maireana pyramidata, Lawrencia squamata* low open chenopod shrubland/shrubland
- Tspp: *Tecticornia* spp. low samphire

DATA SOURCES :
SOURCE DATA: SIGNIFICANT FLORA AND VEGETATION DATA (ECOSCAPE 2023), ROAD NETWORK (MRWA 2020) AND SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER



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VEGETATION TYPES

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

N

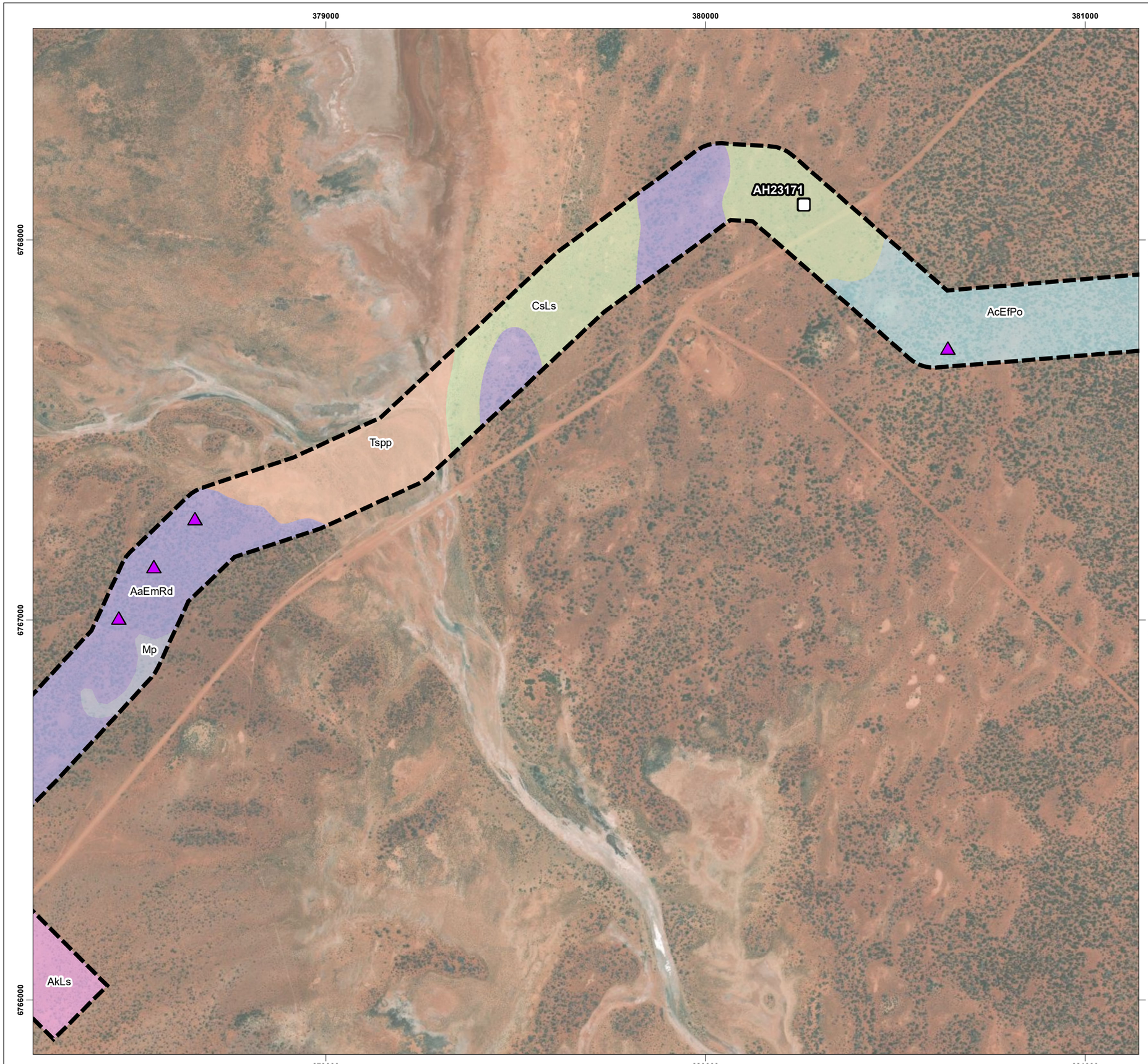
SCALE: 1:10,000 @ A3

0 100 200 300 400 m

PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	SK	28/06/2023

MAP 5-5



LEGEND

Survey Area

Significant Flora

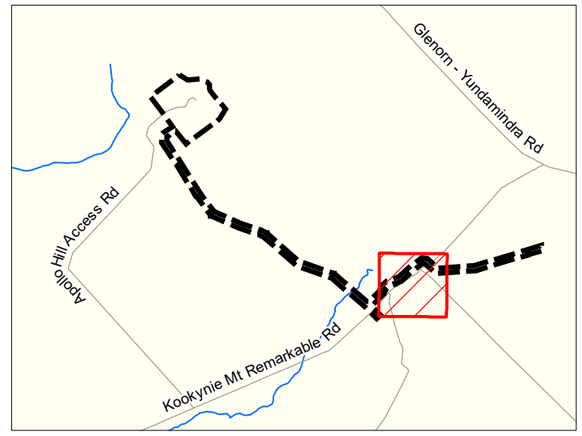
Santalum spicatum (Other)

Quadrat

Vegetation Types

- AaEmRd: *Acacia aneura*, *A. incurvaneura* and *A. caesaneura* low woodland
- AcEfPo: *Acacia caesaneura*, *A. incurvaneura* and *A. aneura* low woodland
- AkLs: *Acacia kalgoorliensis* mid sparse shrubland
- CsLs: *Cratystylis subspinescens* and *Eremophila miniata* mid sparse shrubland
- Mp: *Maireana pyramidata, Lawrencia squamata* low open chenopod shrubland/shrubland
- Tspp: *Tecticornia* spp. low samphire

DATA SOURCES :
SOURCE DATA: SIGNIFICANT FLORA AND VEGETATION DATA (ECOSCAPE 2023), ROAD NETWORK (MRWA 2020) AND SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER



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VEGETATION TYPES

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

N

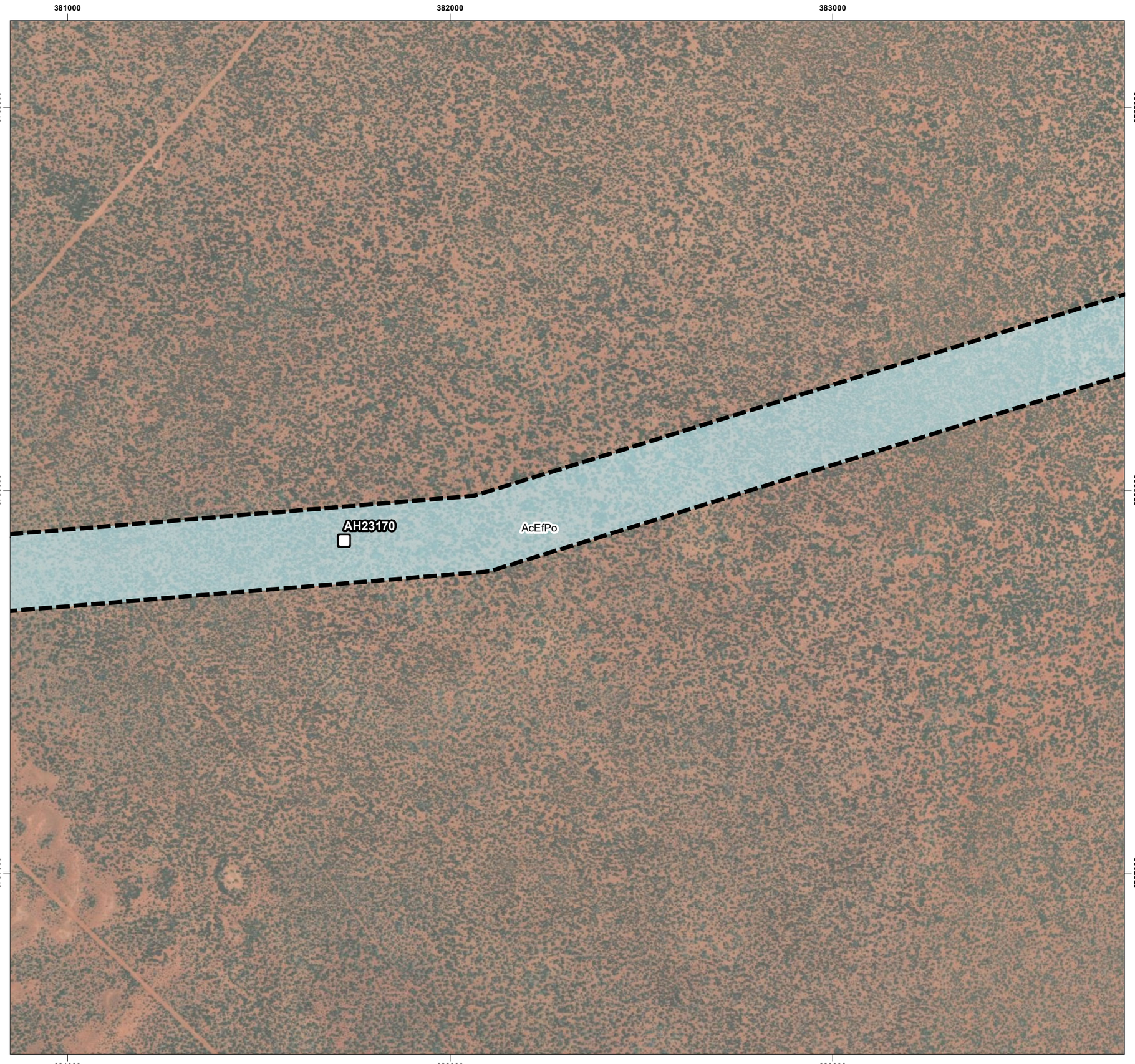
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PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	SK	28/06/2023

MAP 5-6



LEGEND

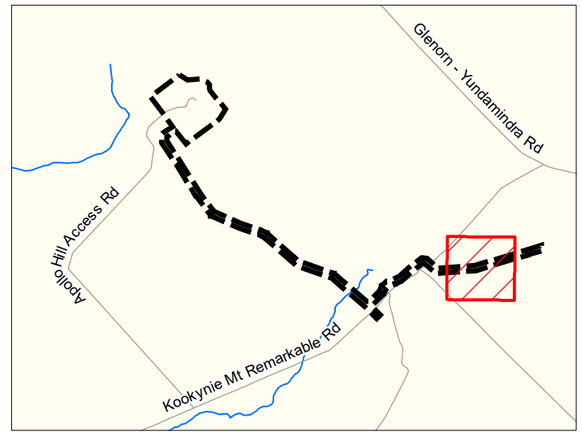
Survey Area

Quadrat

Vegetation Types

AcEfPo: *Acacia caesaneura*, *A. incurvaneura* and *A. aneura* low woodland

DATA SOURCES :
SOURCE DATA: SIGNIFICANT FLORA AND VEGETATION DATA (ECOSCAPE 2023), ROAD NETWORK (MRWA 2020) AND SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER



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VEGETATION TYPES

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

N

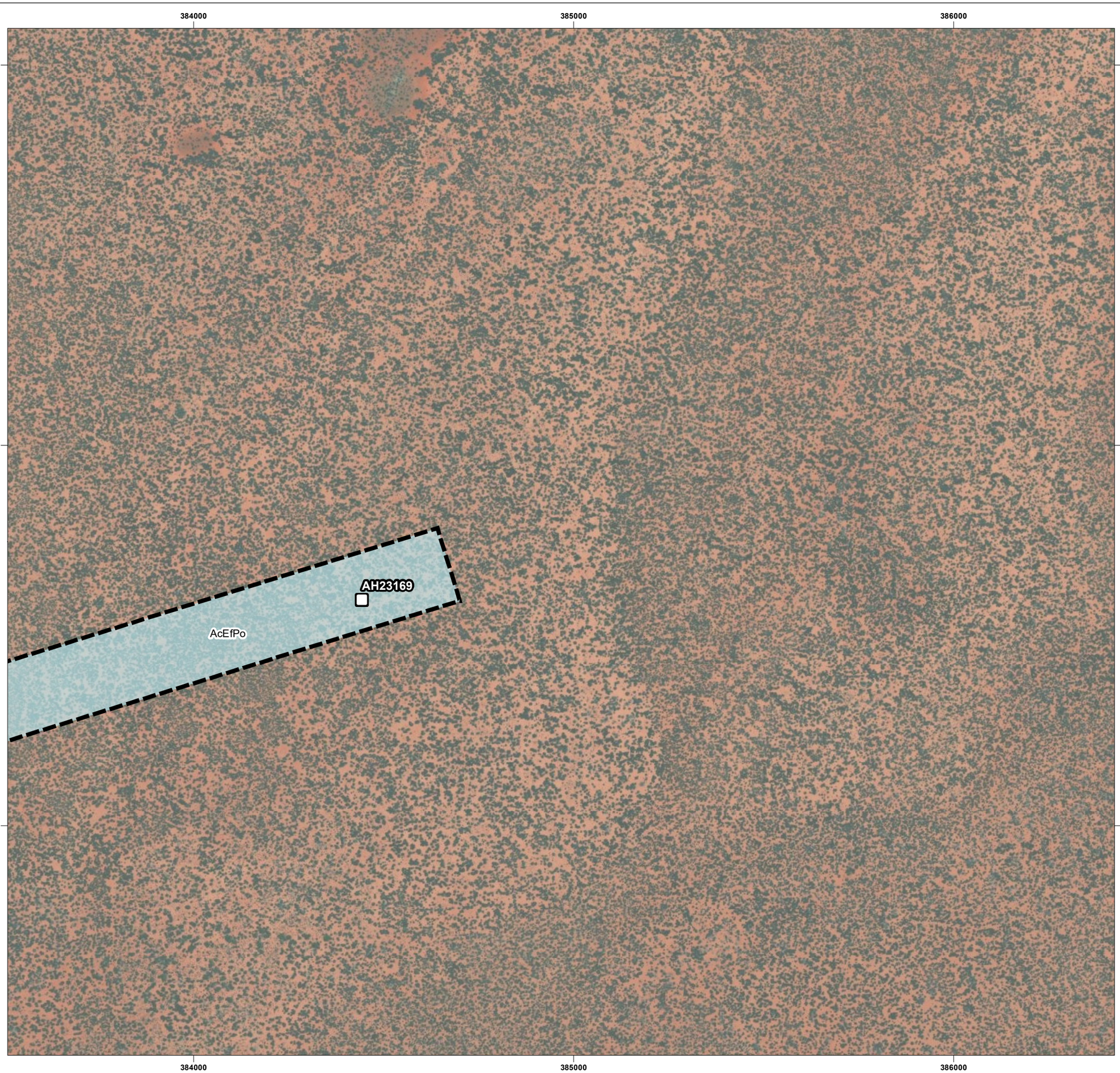
SCALE: 1:10,000 @ A3

0 100 200 300 400 m

PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	SK	28/06/2023

MAP 5-7



LEGEND

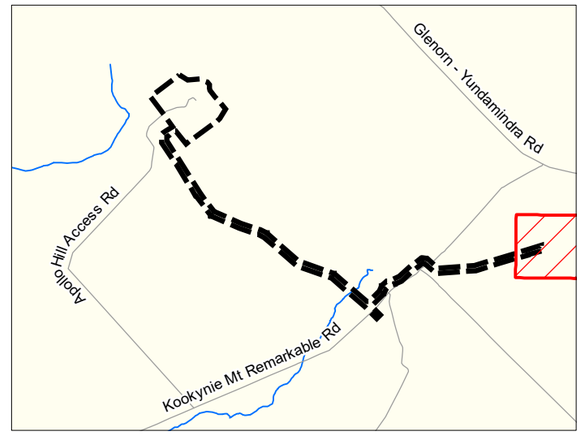
Survey Area

Quadrat

Vegetation Types

AcEfPo: *Acacia caesaneura*, *A. incurvaneura* and *A. aneura* low woodland

DATA SOURCES :
SOURCE DATA: SIGNIFICANT FLORA AND VEGETATION DATA (ECOSCAPE 2023), ROAD NETWORK (MRWA 2020) AND SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER



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VEGETATION TYPES

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

N

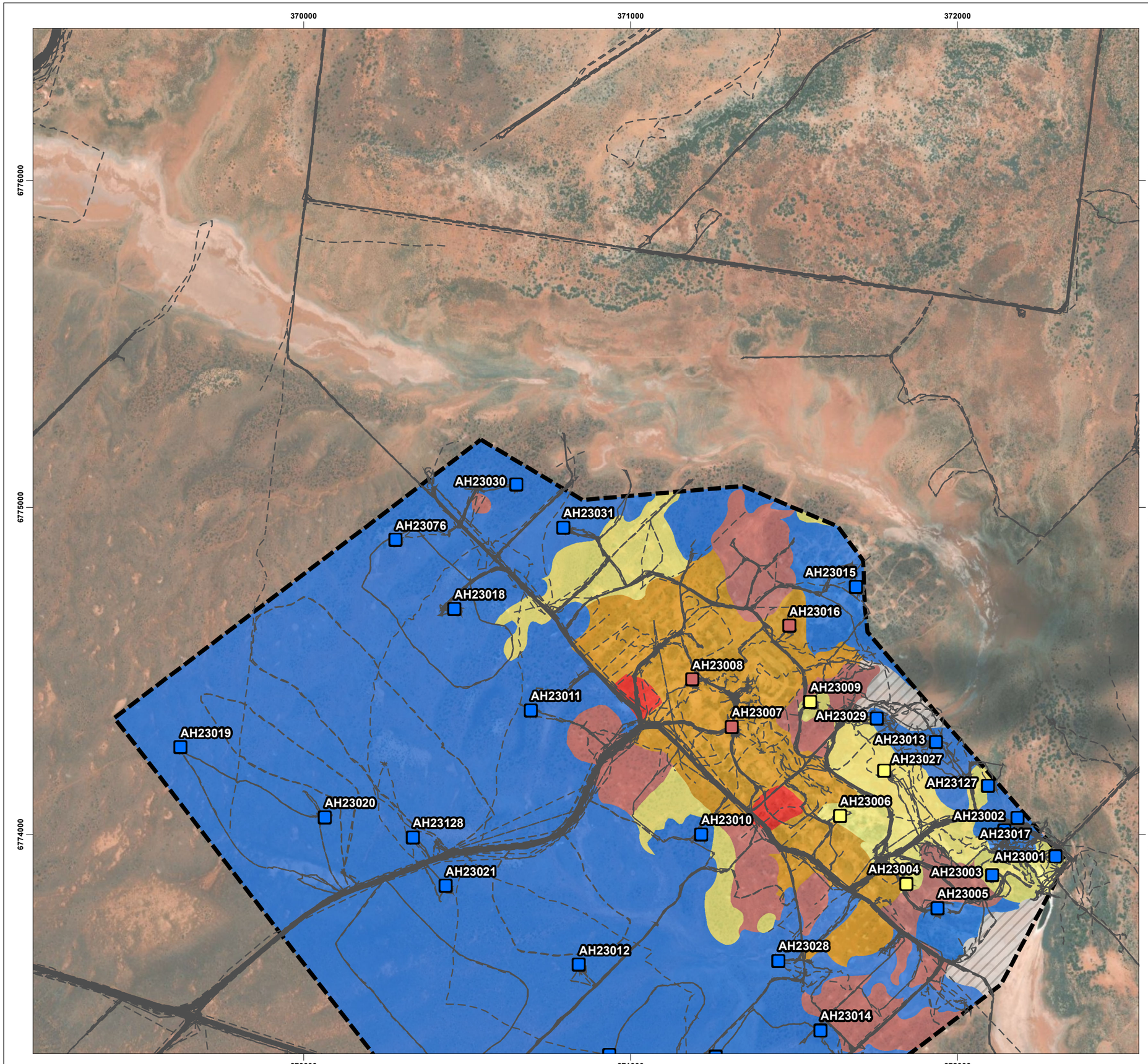
SCALE: 1:10,000 @ A3

0 100 200 300 400 m

MAP 5-8

PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	SK	28/06/2023



LEGEND

- Survey Area

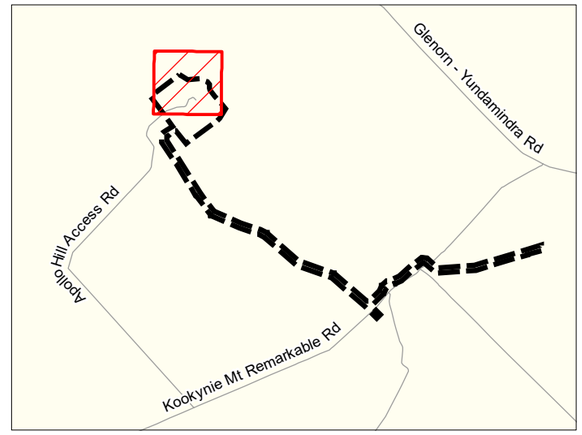
Quadrat Condition

- Very Good
- Good
- Poor

Vegetation Condition

- Very Good
- Good
- Poor
- Degraded
- Completely Degraded
- N/A: No vegetation / Cleared
- Survey Track

DATA SOURCES :
SOURCE DATA: VEGETATION DATA (ECOSCAPE 2023), ROAD NETWORK (MRWA 2020) AND SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER



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VEGETATION CONDITION

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

N

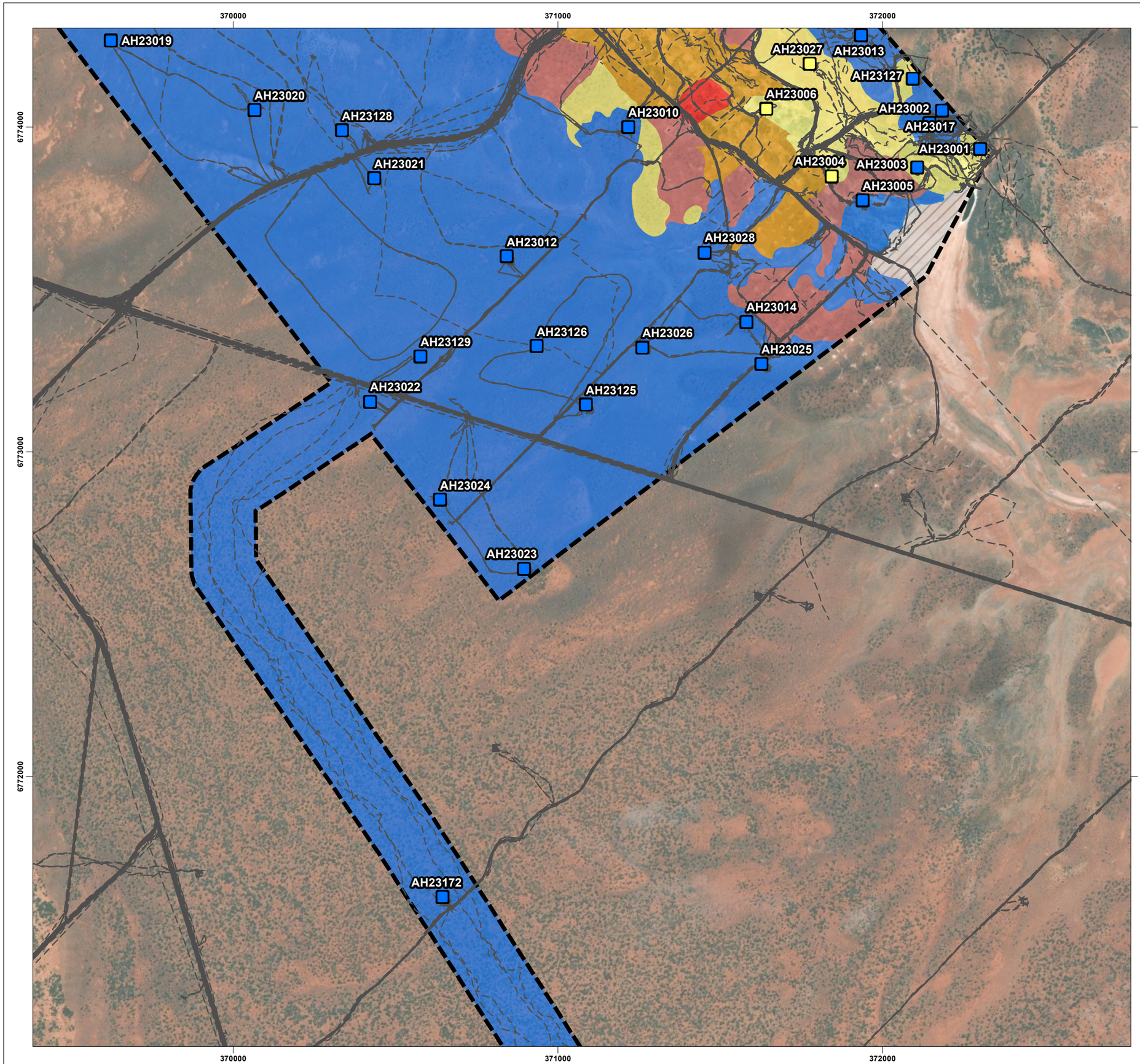
SCALE: 1:11,611 @ A3

0 100 200 300 400 m

MAP 6-1

PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	SK	27/06/2023



LEGEND

- Survey Area

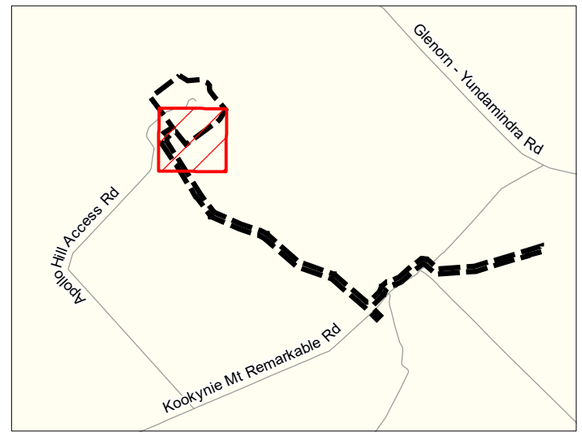
Quadrat Condition

- Very Good
- Good

Vegetation Condition

- Very Good
- Good
- Poor
- Degraded
- Completely Degraded
- N/A: No vegetation / Cleared
- Survey Track

DATA SOURCES :
SOURCE DATA: VEGETATION DATA (ECOSCAPE 2023), ROAD NETWORK (MRWA 2020) AND SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER



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VEGETATION CONDITION

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

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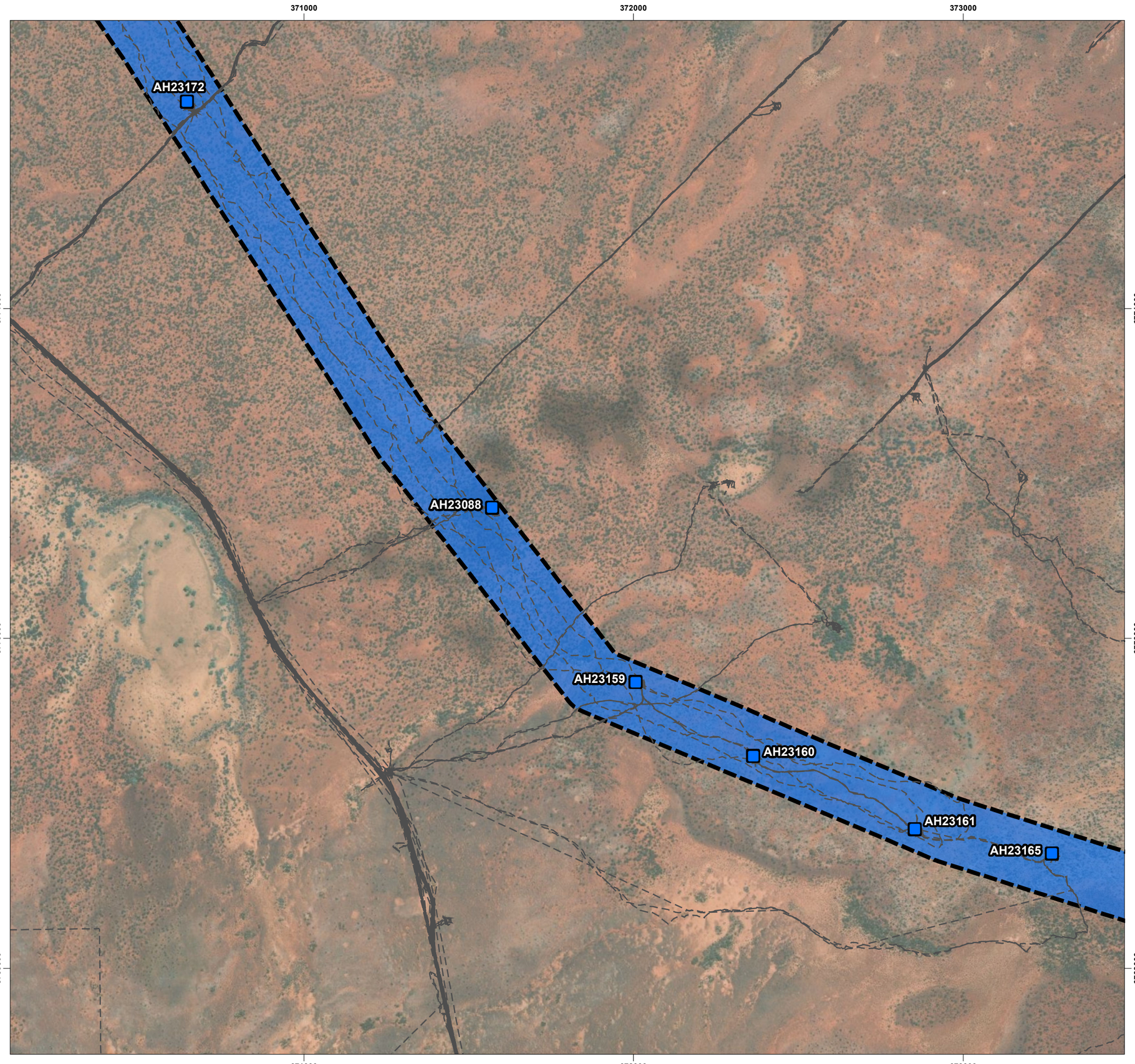
SCALE: 1:11,611 @ A3

0 100 200 300 400 m

MAP 6-2

PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	SK	27/06/2023



LEGEND

Survey Area

Quadrat Condition

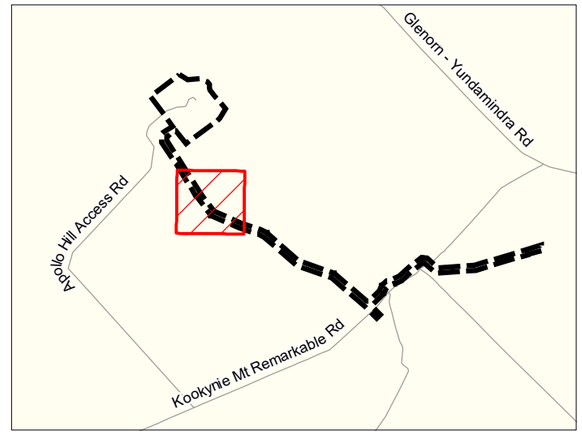
Very Good

Vegetation Condition

Very Good

Survey Track

DATA SOURCES :
SOURCE DATA: VEGETATION DATA (ECOSCAPE 2023), ROAD NETWORK (MRWA 2020) AND SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER



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VEGETATION CONDITION

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

N

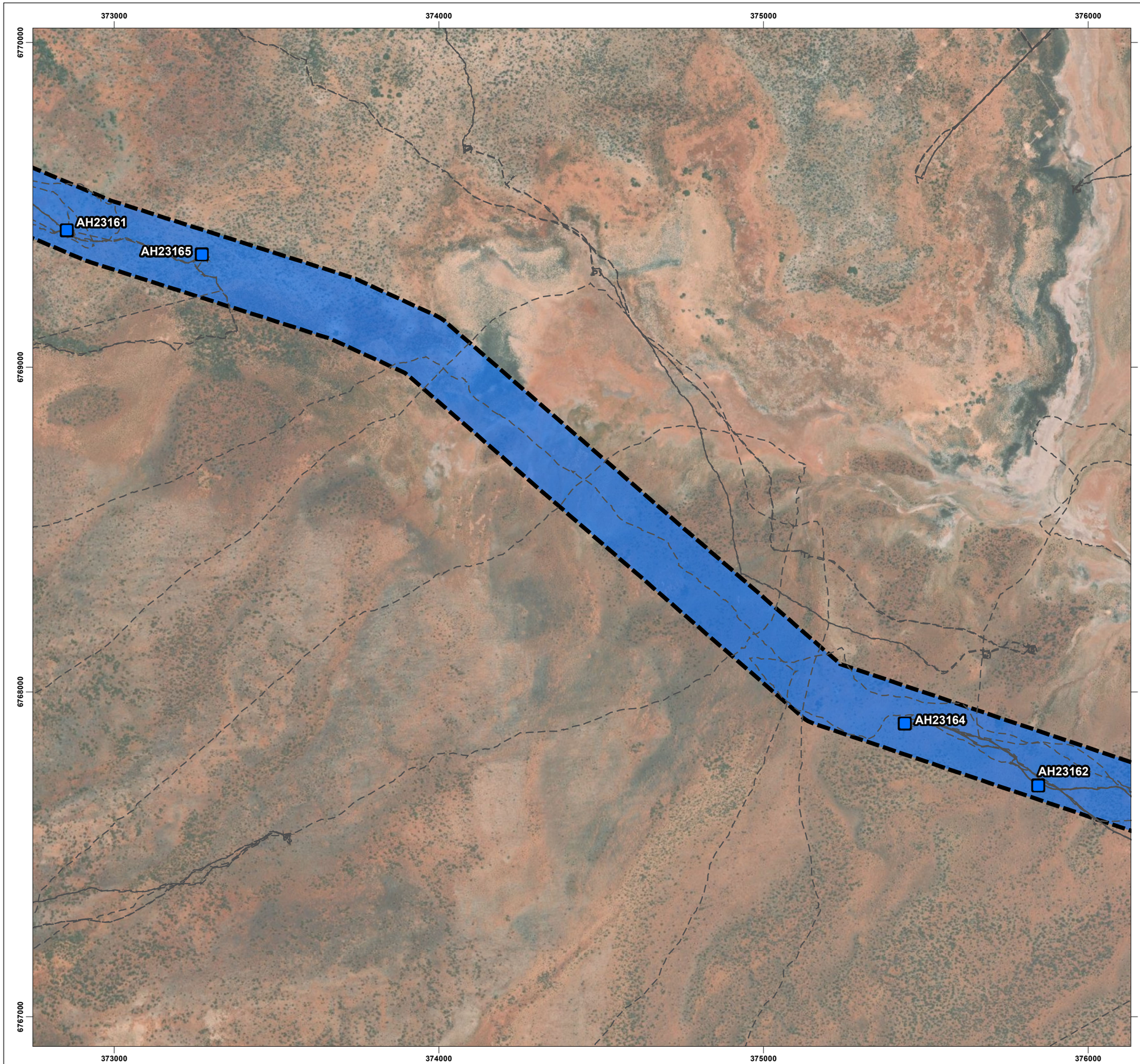
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MAP 6-3

PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	SK	27/06/2023



LEGEND

- Survey Area

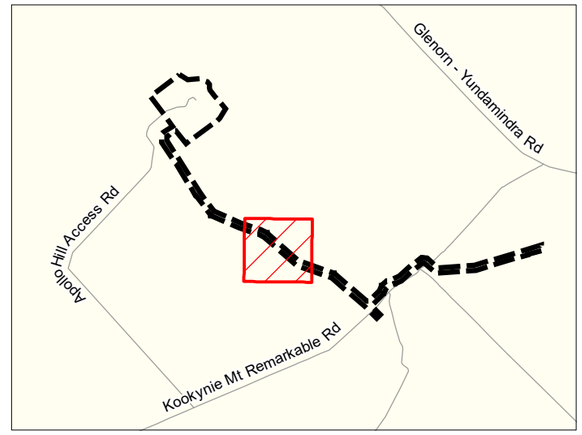
Quadrat Condition

- Very Good

Vegetation Condition

- Very Good
- Survey Track

DATA SOURCES :
SOURCE DATA: VEGETATION DATA (ECOSCAPE 2023), ROAD NETWORK (MRWA 2020) AND SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER



ecoscape

VEGETATION CONDITION

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

N

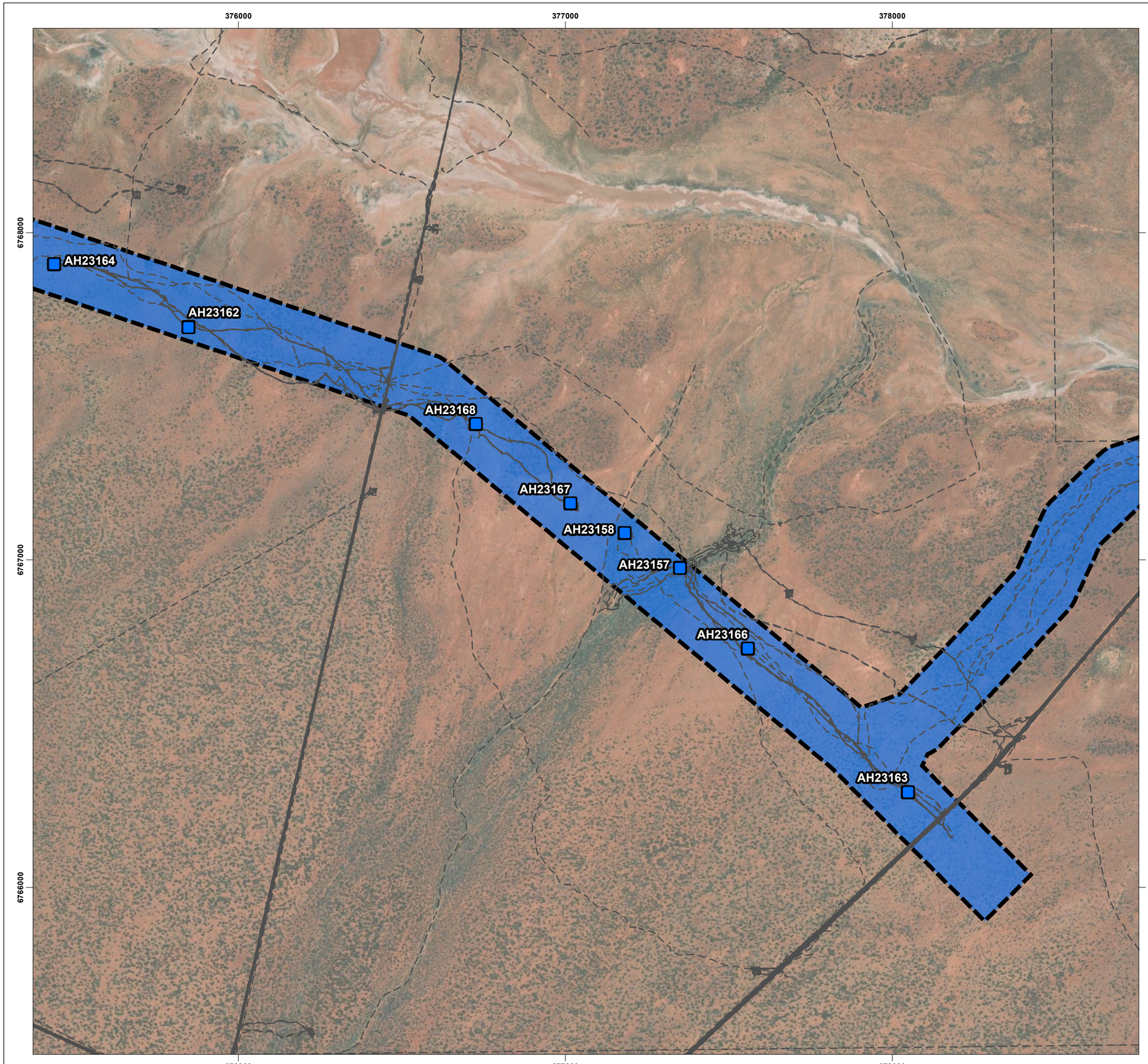
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0 100 200 300 400 m

MAP 6-4

PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	SK	27/06/2023



LEGEND

Survey Area

Quadrat Condition

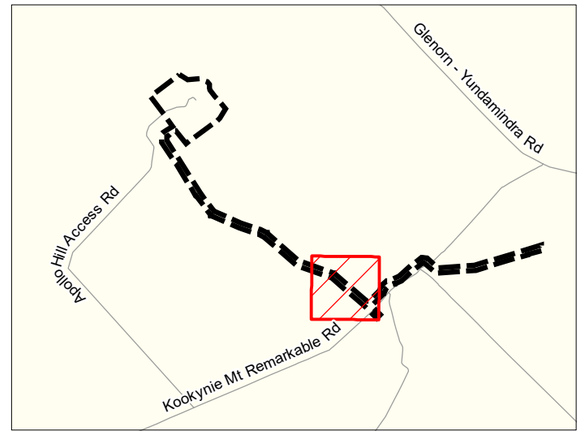
Very Good

Vegetation Condition

Very Good

Survey Track

DATA SOURCES :
SOURCE DATA: VEGETATION DATA (ECOSCAPE 2023), ROAD NETWORK (MRWA 2020) AND SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER



ecoscape

VEGETATION CONDITION

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

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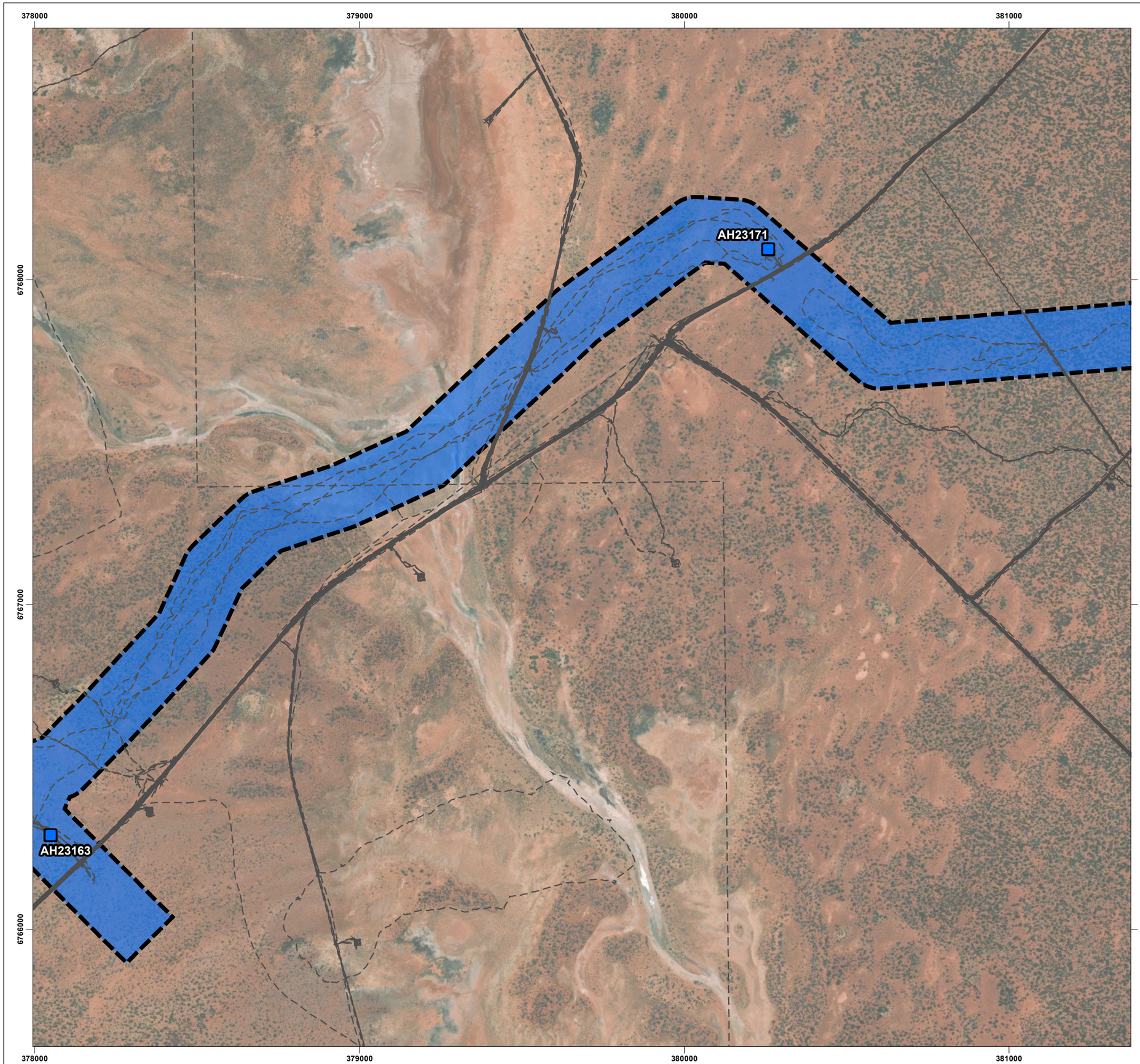
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MAP 6-5

PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	SK	27/06/2023



LEGEND

Survey Area

Quadrat Condition

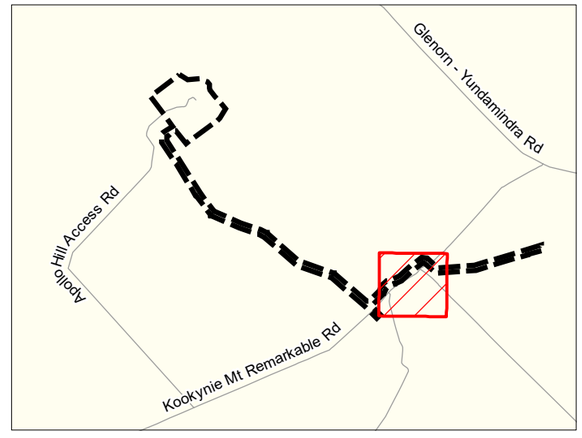
Very Good

Vegetation Condition

Very Good

Survey Track

DATA SOURCES :
SOURCE DATA: VEGETATION DATA (ECOSCAPE 2023), ROAD NETWORK (MRWA 2020) AND SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER



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VEGETATION CONDITION

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

N

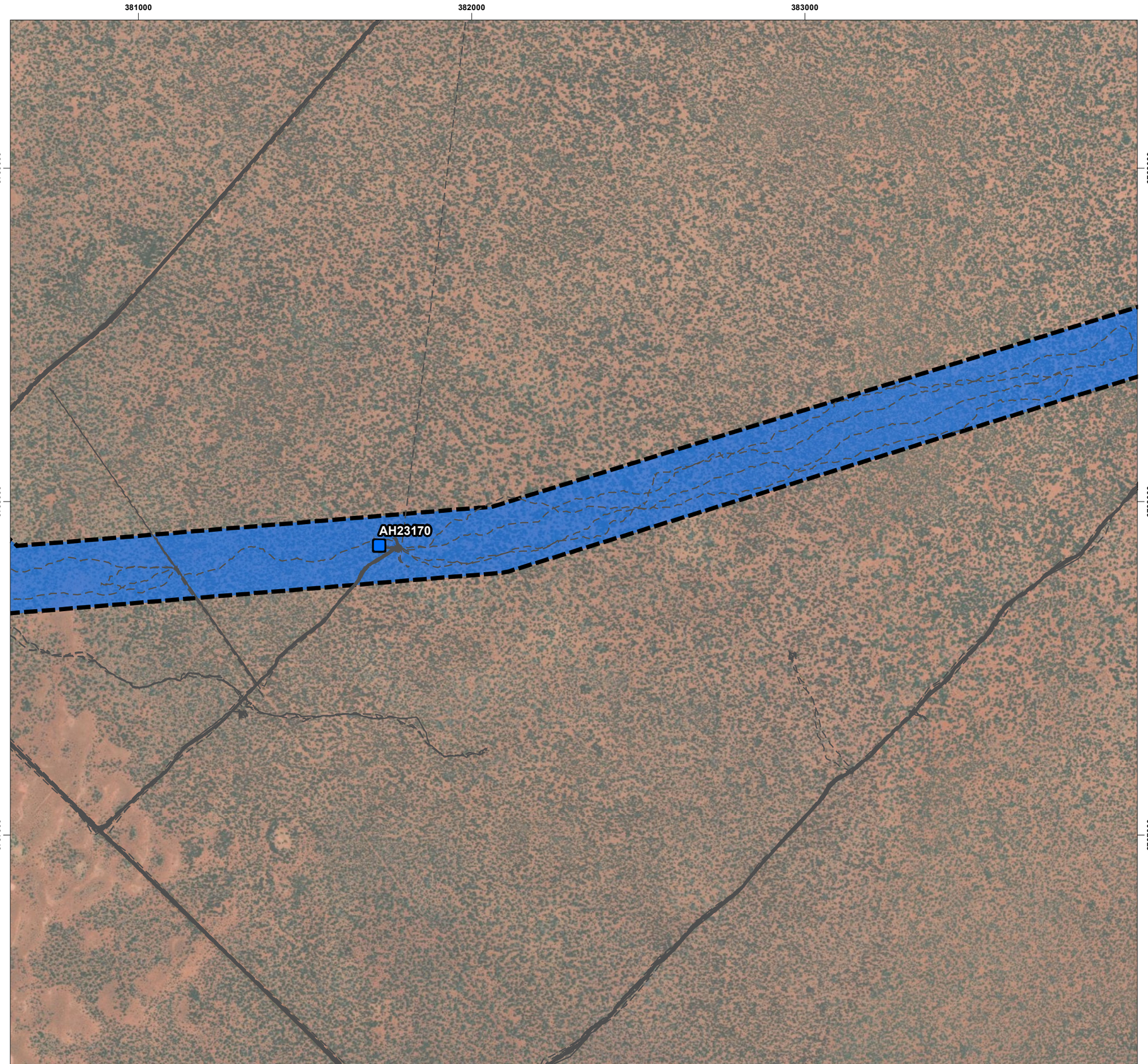
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0 100 200 300 400 m

MAP 6-6

PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	SK	27/06/2023



LEGEND

Survey Area

Quadrat Condition

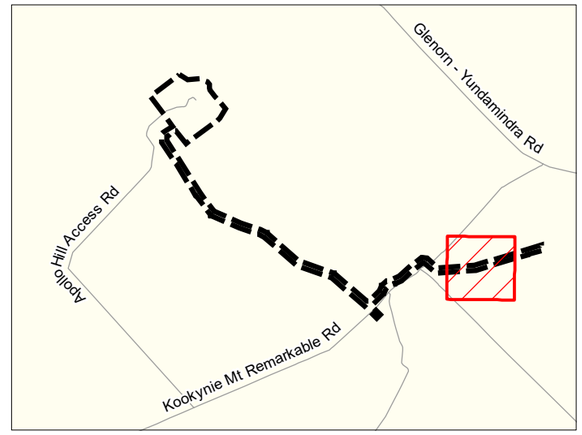
Very Good

Vegetation Condition

Very Good

Survey Track

DATA SOURCES :
SOURCE DATA: VEGETATION DATA (ECOSCAPE 2023), ROAD NETWORK (MRWA 2020) AND SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER



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VEGETATION CONDITION

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

N

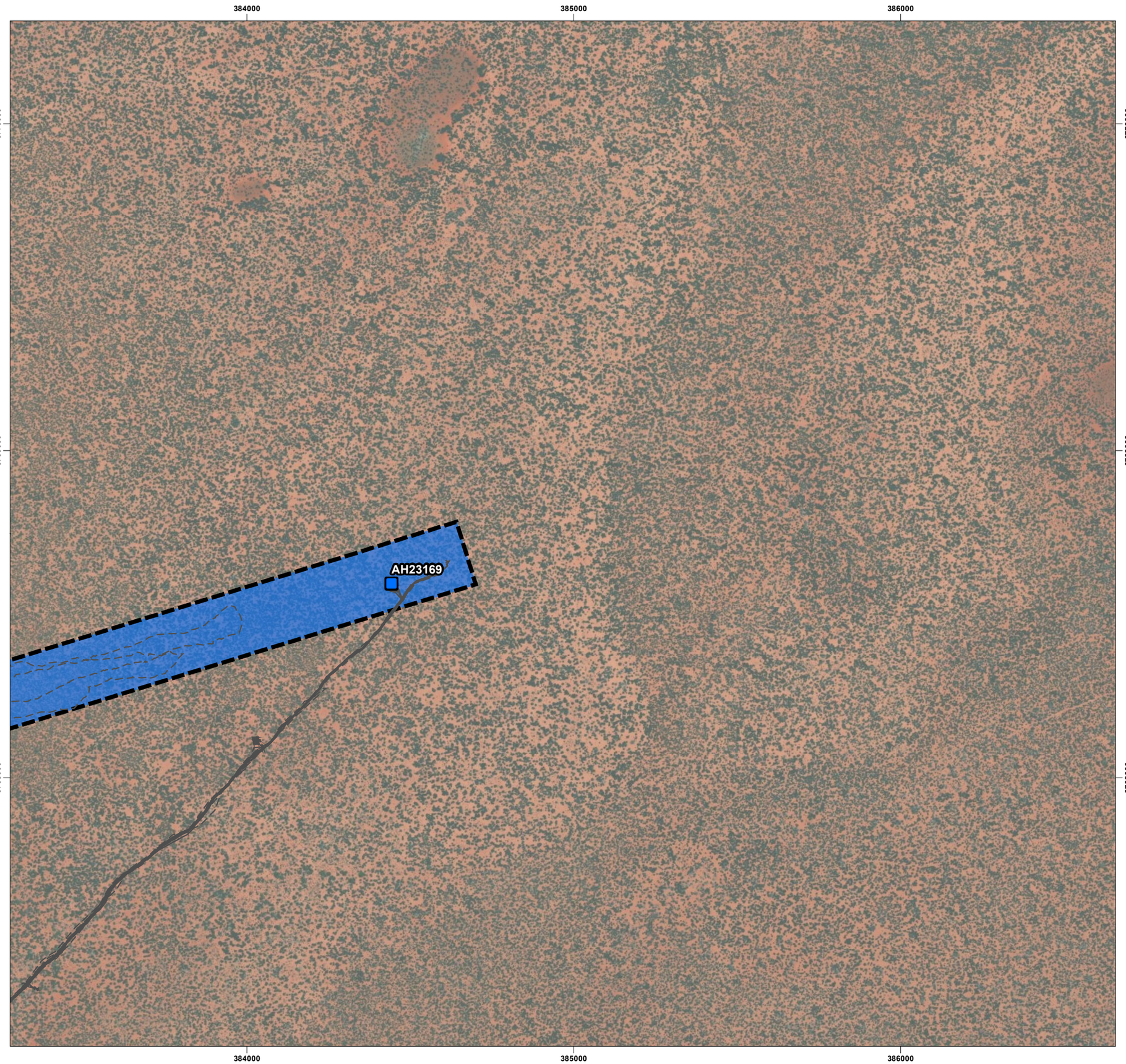
SCALE: 1:11,611 @ A3

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MAP 6-7

PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	SK	27/06/2023



LEGEND

Survey Area

Quadrat Condition

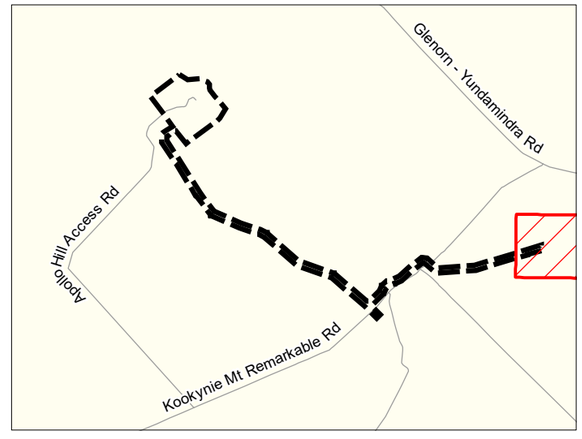
Very Good

Vegetation Condition

Very Good

Survey Track

DATA SOURCES :
SOURCE DATA: VEGETATION DATA (ECOSCAPE 2023), ROAD NETWORK (MRWA 2020) AND SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER



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VEGETATION CONDITION

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

N

SCALE: 1:11,611 @ A3

0 100 200 300 400 m

MAP 6-8

PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	SK	27/06/2023

370000
371000
372000
6776000
6775000
6774000

HAB64
HAB63
HAB3
FOB04
ABS03
HAB66
BS11
HAB4
MC019
FOB07
HAB110
FOB05
MC55
FOB33
FOB34
HAB48
HAB47
FOB59
HAB25
HAB2
MC084
BS12

LEGEND

Survey Area

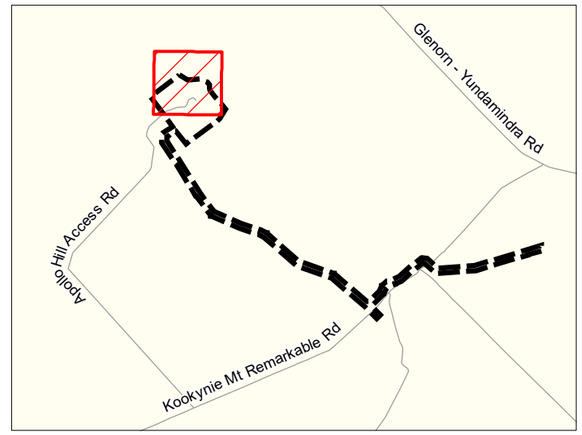
Fauna Survey Types

- Habitat Assessment Point
- Fauna observation point
- Audio Recording Device
- Bird Survey
- Camera

Fauna Habitat

- Chenopod shrubland
- Flood plain
- Mixed shrubland
- Mulga woodland
- Rocky escarpment
- Survey Track

DATASOURCES :
SOURCE DATA: FAUNA DATA (ECOSCAPE 2023), ROAD NETWORK (MRWA 2020) AND SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY



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FAUNA HABITAT

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

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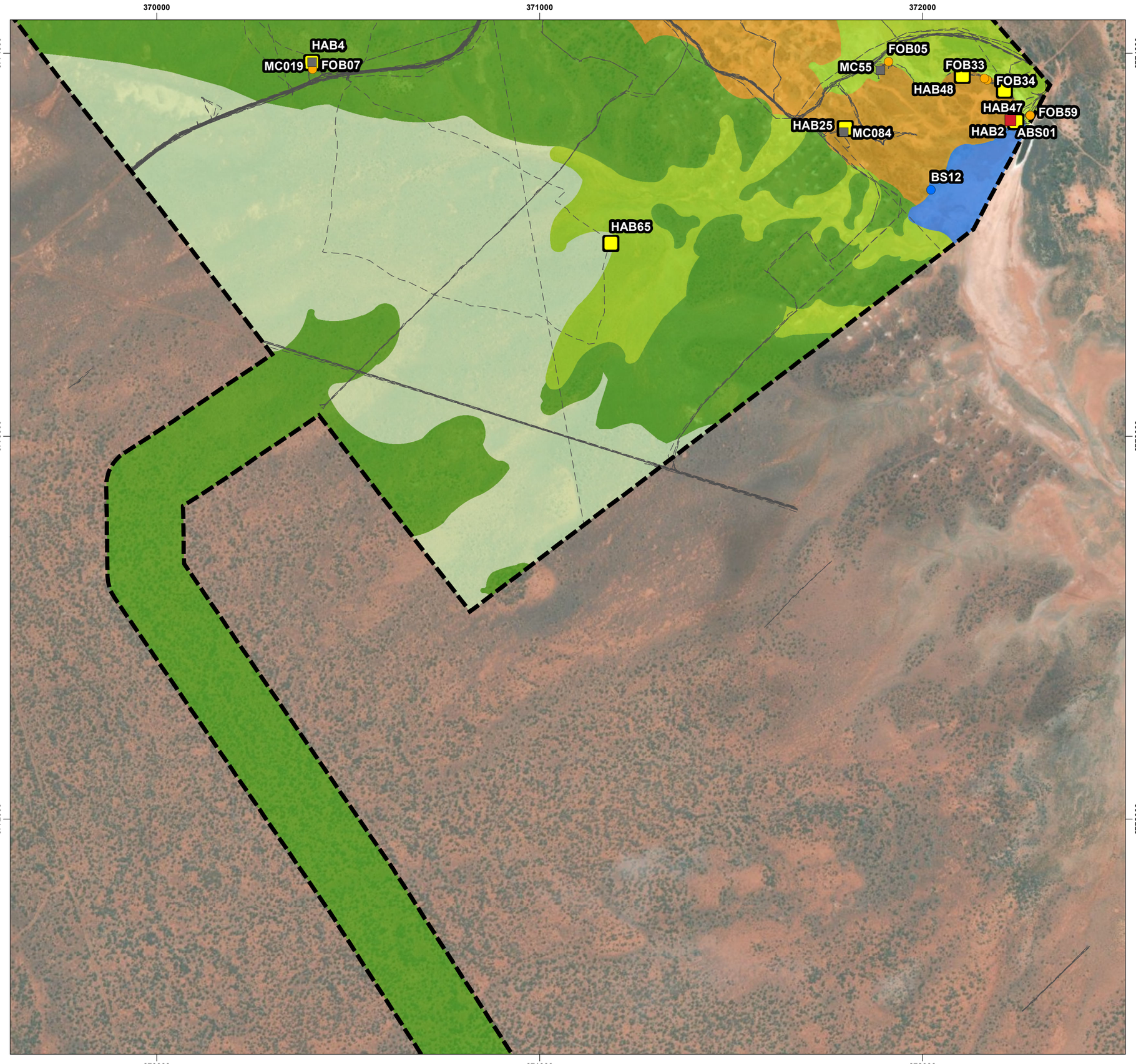
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0 100 200 300 400 m

PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	RH	29/06/2023
01	JT	SK	26/06/2024

MAP
7-1



LEGEND

- Survey Area

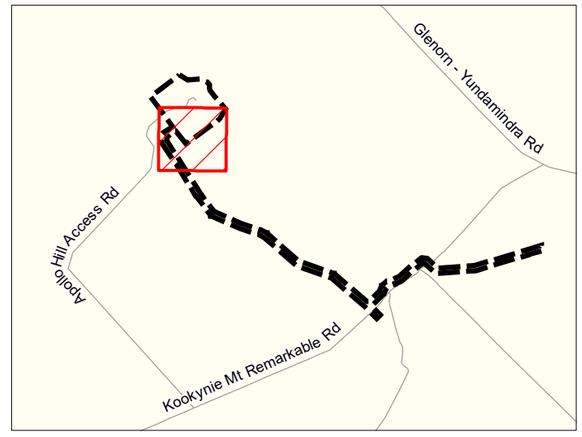
Fauna Survey Types

- Habitat Assessment Point
- Fauna observation point
- Audio Recording Device
- Bird Survey
- Camera

Fauna Habitat

- Chenopod shrubland
- Flood plain
- Mixed shrubland
- Mulga woodland
- Rocky escarpment
- Survey Track

DATASOURCES :
SOURCE DATA: FAUNA DATA (ECOSCAPE 2023), ROAD NETWORK (MRWA 2020) AND SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY



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FAUNA HABITAT

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

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SCALE: 1:10,000 @ A3

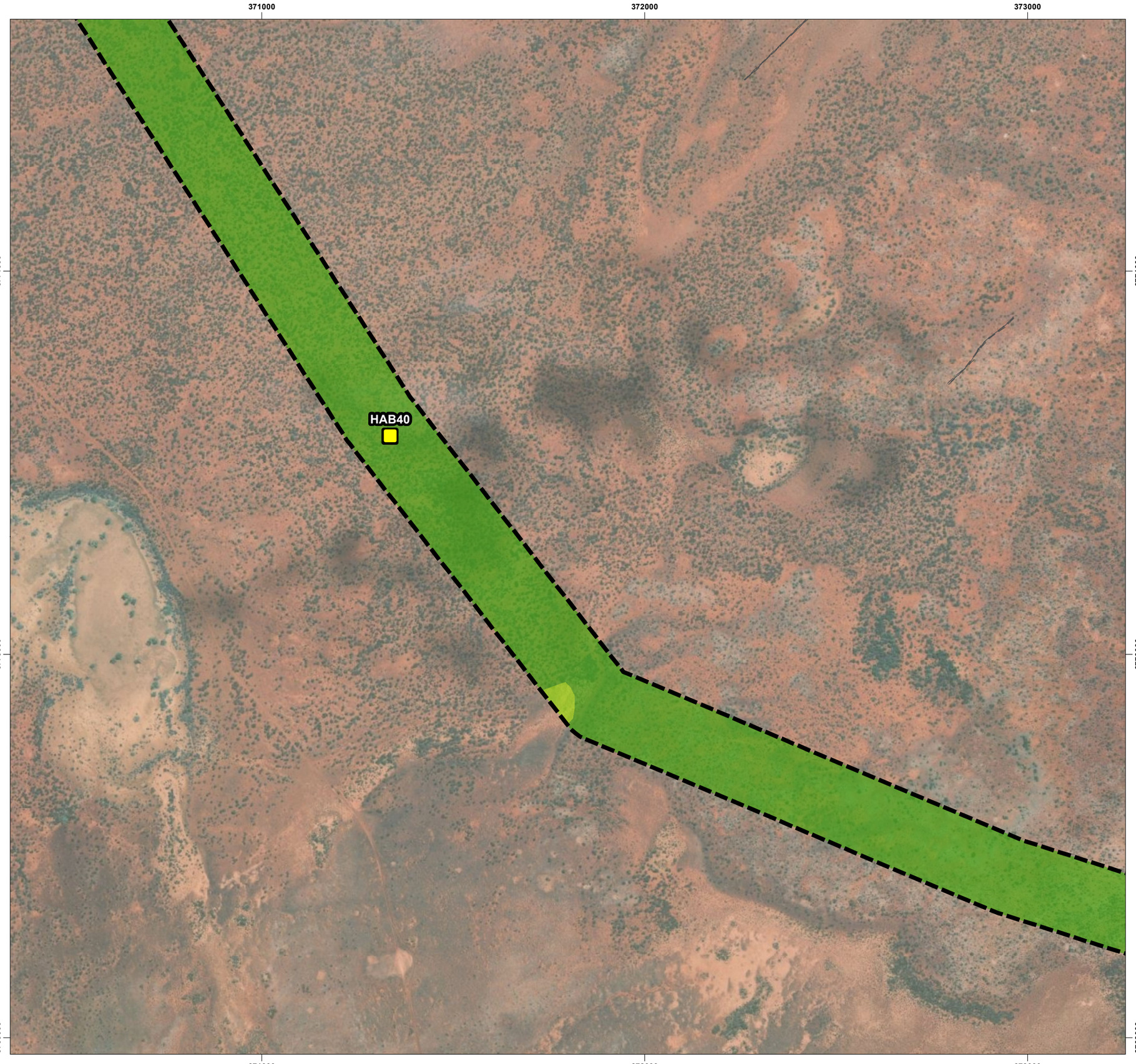
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PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	RH	29/06/2023
01	JT	SK	26/06/2024

MAP

7-2



LEGEND

Survey Area

Fauna Survey Types

Habitat Assessment Point

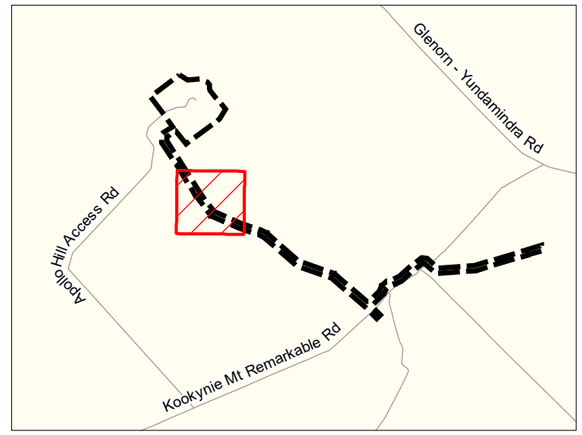
Fauna Habitat

Chenopod shrubland

Mulga woodland

Survey Track

DATASOURCES :
SOURCE DATA: FAUNA DATA (ECOSCAPE 2023), ROAD NETWORK (MRWA 2020) AND SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY



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FAUNA HABITAT

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

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SCALE: 1:10,000 @ A3

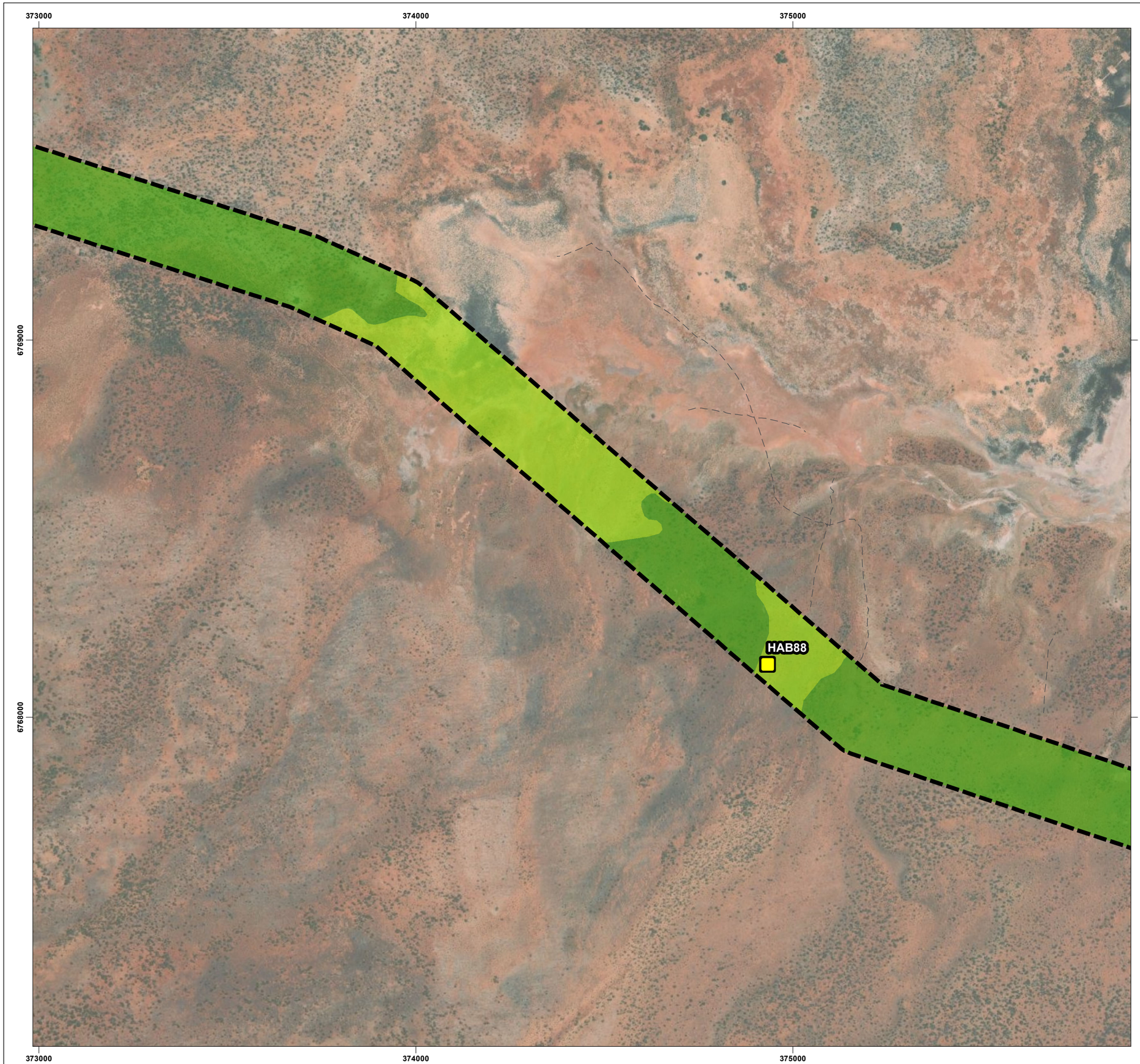
0 100 200 300 400 m

PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	RH	29/06/2023
01	JT	SK	26/06/2024

MAP

7-3



LEGEND

Survey Area

Fauna Survey Types

Habitat Assessment

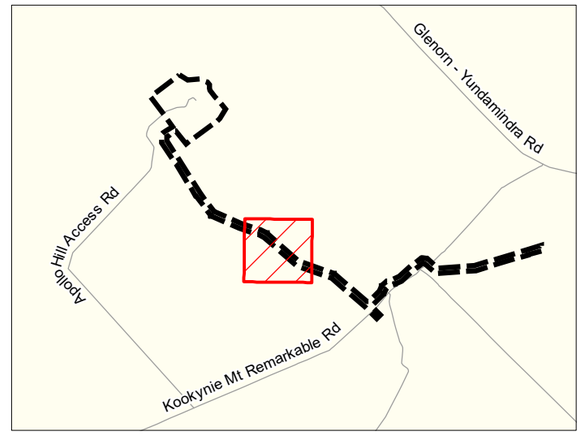
Fauna Habitat

Chenopod shrubland

Mulga woodland

Survey Track

DATASOURCES :
SOURCE DATA: FAUNA DATA (ECOSCAPE 2023), ROAD NETWORK (MRWA 2020) AND SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY



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FAUNA HABITAT

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

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SCALE: 1:10,000 @ A3

0 100 200 300 400 m

PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	RH	29/06/2023
01	JT	SK	26/06/2024

MAP

7-4



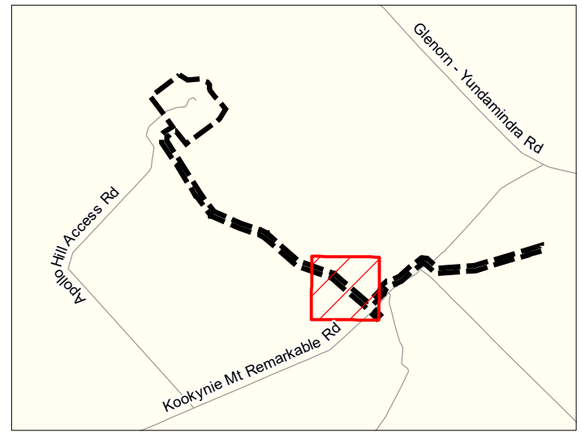
LEGEND

- Survey Area

Fauna Habitat

- Chenopod shrubland
- Drainage line
- Mulga woodland
- Survey Track

DATASOURCES :
SOURCE DATA: FAUNA DATA (ECOSCAPE 2023), ROAD NETWORK (MRWA 2020) AND SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY



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FAUNA HABITAT

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

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SCALE: 1:10,000 @ A3

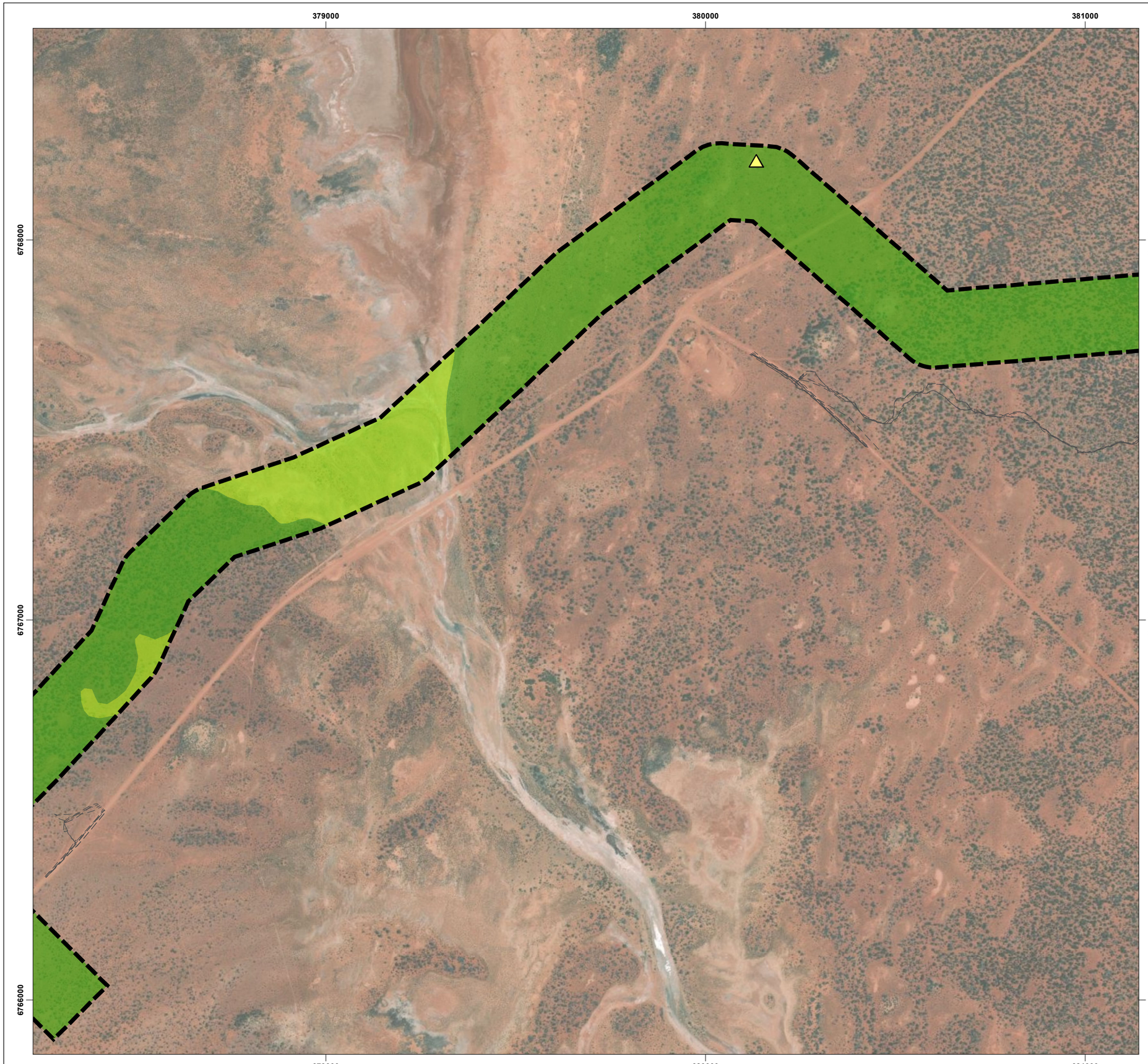
0 100 200 300 400 m

PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	RH	29/06/2023
01	JT	SK	26/06/2024

MAP

7-5



LEGEND

Survey Area

Significant Fauna

Chalcites osculans(MA/MI)

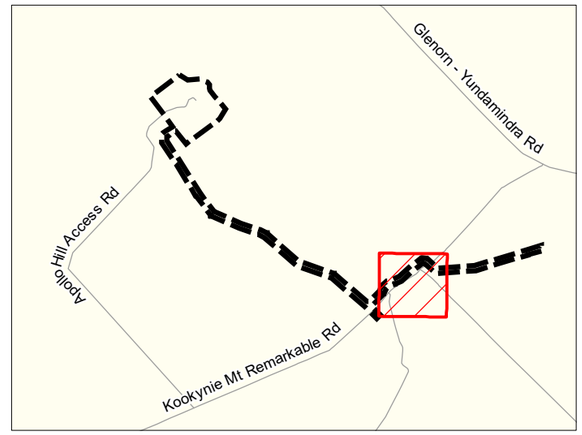
Fauna Habitat

Chenopod shrubland

Mulga woodland

Survey Track

DATASOURCES :
SOURCE DATA: FAUNA DATA (ECOSCAPE 2023), ROAD NETWORK (MRWA 2020) AND SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY



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FAUNA HABITAT

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

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SCALE: 1:10,000 @ A3

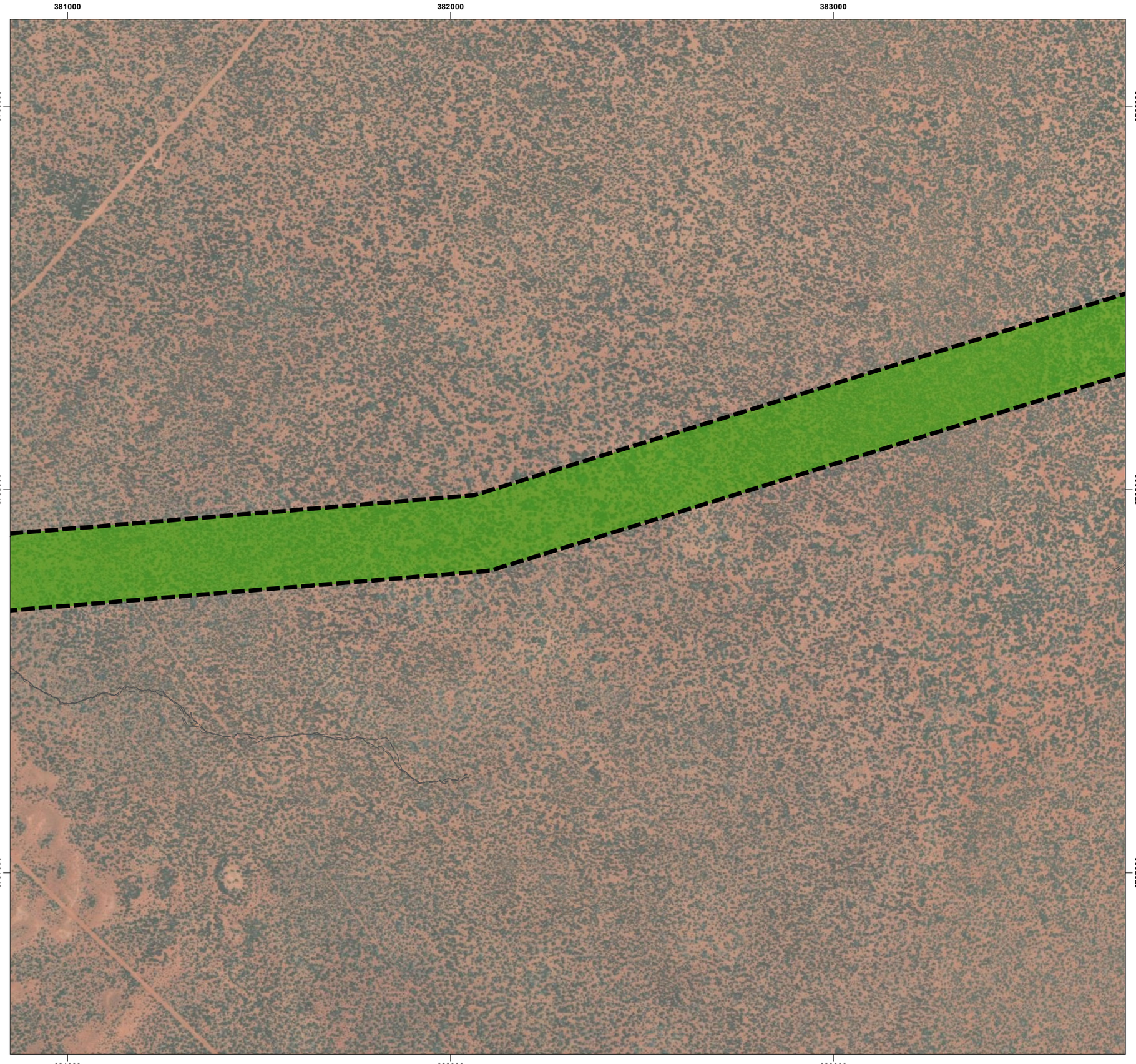
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PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	RH	29/06/2023
01	JT	SK	26/06/2024

MAP

7-6



LEGEND

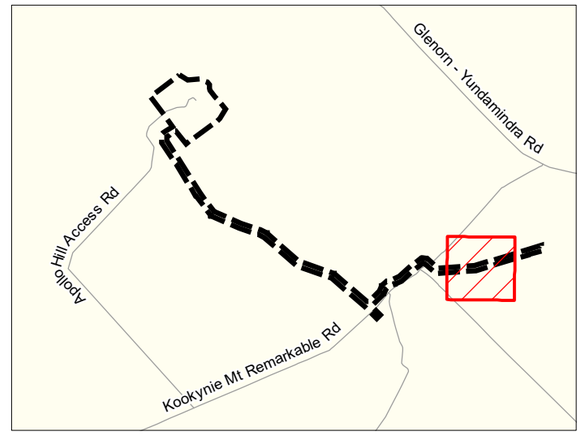
Survey Area

Fauna Habitat

Mulga woodland

Survey Track

DATASOURCES :
SOURCE DATA: FAUNA DATA (ECOSCAPE 2023), ROAD NETWORK (MRWA 2020) AND SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY



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FAUNA HABITAT

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

N

SCALE: 1:10,000 @ A3

0 100 200 300 400 m

PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	RH	29/06/2023
01	JT	SK	26/06/2024

MAP

7-7

384000 385000 386000

6770000 6769000 6768000

LEGEND

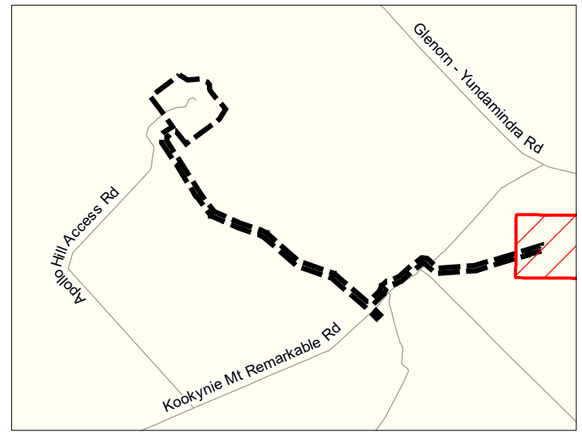
Survey Area

Fauna Habitat

Mulga woodland

Survey Track

DATASOURCES :
SOURCE DATA: FAUNA DATA (ECOSCAPE 2023), ROAD NETWORK (MRWA 2020) AND SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015)
BASEMAP: ESRI (VIVID 2019)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY



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FAUNA HABITAT

APOLLO HILL GOLD PROJECT
FLORA AND FAUNA ASSESSMENTS
PILOT PLANT AND BULK SAMPLE

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

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SCALE: 1:10,000 @ A3

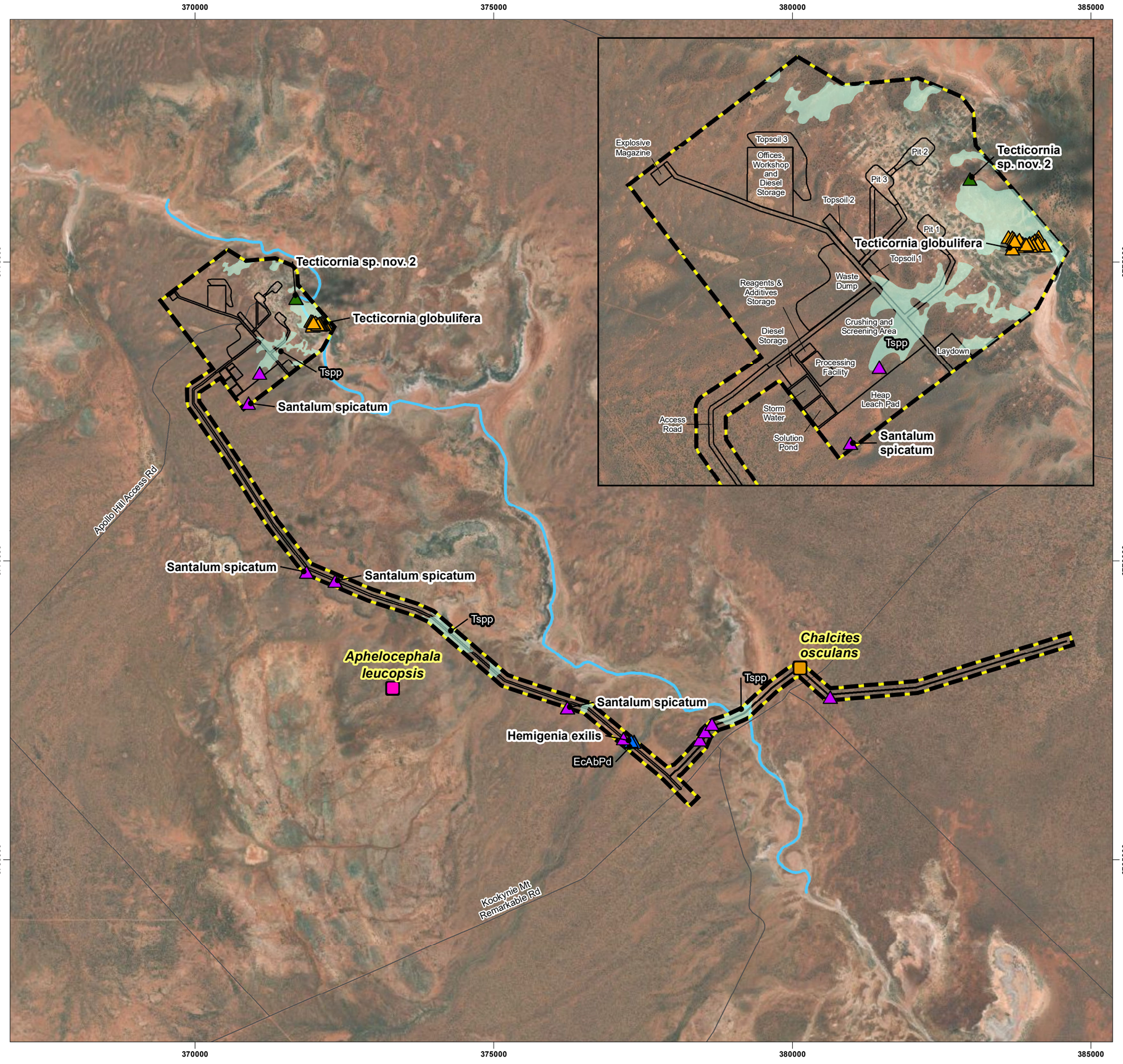
0 100 200 300 400 m

PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	RH	29/06/2023
01	JT	SK	26/06/2024

MAP

7-8



LEGEND

- Survey Area
- Pilot Plant Disturbance Footprint
- Proposed Pilot Plant Infrasructure

Significant Flora

- *Tecticornia* sp. nov. 2 (Other)
- *Santalum spicatum* (Other)
- *Tecticornia globulifera* (Priority 1)
- *Hemigenia exilis* (Priority 4)

Significant Fauna

- *Aphelocephala leucopsis* (VU)
- *Chalcites osculans* (MA/MI)
- Road
- Major creek

Vegetation Types

- EcAbPd: *Eucalyptus camaldulensis* subsp. *arida* mid woodland (GDV)
- Tspp: *Tecticornia* spp. low samphire shrubland (Wetland vegetation)

DATASOURCES :
SOURCE DATA: SIGNIFICANT FLORA AND VEGETATION (ECOSCAPE 2023), DEVELOPMENT ENVELOPES, PROPOSED PILOT PLANT INFRASTRUCTURE AND WATER BORE (SATURN METALS 2023), ROAD NETWORK (MRWA 2023) AND SURFACE HYDROLOGY LINES (NATIONAL) (GEOSCIENCE AUSTRALIA 2015)
BASEMAP: ESRI (MAXAR 2022)
SERVICE LAYERS: SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY

ecoscape

PILOT PLANT INFRASTRUCTURE

APOLLO HILL GOLD PROJECT FLORA AND FAUNA ASSESSMENTS

SATURN METALS

COORDINATE SYSTEM: GDA 1994 MGA ZONE 51
PROJECTION: TRANSVERSE MERCATOR
DATUM: GDA 1994
UNITS: METER

N

SCALE: 1:63,360 @ A3

0 1 2 3 km

PROJECT NO: 4782-22

REV	AUTHOR	APPROVED	DATE
00	NW	SK	31/08/2023

MAP 08

APPENDIX ONE LEGISLATIVE CONTEXT, DEFINITIONS AND CRITERIA

COMMONWEALTH ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION ACT 1999

The EPBC Act is a legal framework to protect and manage matters of national environmental significance (MNES) including important flora, fauna, ecological communities and heritage areas listed under the Act.

Threatened taxa (flora and fauna) are protected under the EPBC Act, which lists species and ecological communities that have been assessed as meeting the criteria to be listed as Critically Endangered, Endangered, Vulnerable, Conservation Dependant, Extinct, or Extinct in the Wild, as detailed in **Table 16**.

Threatened Ecological Communities protected under the EPBC Act are categorised as Critically Endangered, Endangered or Vulnerable, also detailed in this table.

Migratory species subject to international agreements are also protected under the EPBC Act. The definition of a migratory species under the Act follows that prescribed by the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention) (DCCEEW 2023c). The list of migratory species established under section 209 of the EPBC Act comprises:

- migratory species which are native to Australia and are included in the appendices to the Bonn Convention (Convention on the Conservation of Migratory Species of Wild Animals Appendices I and II);
- migratory species included in annexes established under the Japan-Australia Migratory Bird Agreement (JAMBA) and the China-Australia Migratory Bird Agreement (CAMBA); and
- native, migratory species identified in a list established under, or an instrument made under, an international agreement approved by the Minister, such as the Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA).

Table 16: EPBC Act categories for flora, fauna and ecological communities

Category	Threatened species	Threatened Ecological Communities
Extinct	A native species is eligible to be included in the extinct category at a particular time if, at that time, there is no reasonable doubt that the last member of the species has died.	n/a
Extinct in the wild	A native species is eligible to be included in the extinct in the wild category at a particular time if, at that time: (a) it is known only to survive in cultivation, in captivity or as a naturalised population well outside its past range; or (b) it has not been recorded in its known and/or expected habitat, at appropriate seasons, anywhere in its past range, despite exhaustive surveys over a time frame appropriate to its life cycle and form.	n/a
Critically Endangered (CR)	A native species is eligible to be included in the *critically endangered* category at a particular time if, at that time, it is facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with the prescribed criteria.	An ecological community is eligible to be included in the *critically endangered* category at a particular time if, at that time, it is facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with the prescribed criteria
Endangered (EN)	A native species is eligible to be included in the *endangered* category at a particular time if, at that time: (a) it is not critically endangered; and (b) it is facing a very high risk of extinction in the wild in the near future, as determined in accordance with the prescribed criteria.	An ecological community is eligible to be included in the *endangered* category at a particular time if, at that time: (a) it is not critically endangered; and (b) it is facing a very high risk of extinction in the wild in the near future, as determined in accordance with the prescribed criteria.

Category	Threatened species	Threatened Ecological Communities
Vulnerable (VU)	A native species is eligible to be included in the *vulnerable* category at a particular time if, at that time: (a) it is not critically endangered or endangered; and (b) it is facing a high risk of extinction in the wild in the medium term future, as determined in accordance with the prescribed criteria.	An ecological community is eligible to be included in the *vulnerable* category at a particular time if, at that time: (a) it is not critically endangered or endangered; and (b) it is facing a high risk of extinction in the wild in the medium term future, as determined in accordance with the prescribed criteria.
Conservation Dependent	A native species is eligible to be included in the conservation dependent category at a particular time if, at that time: (a) the species is the focus of a specific conservation program the cessation of which would result in the species becoming vulnerable, endangered or critically endangered; or (b) the following subparagraphs are satisfied: (i) the species is a species of fish; (ii) the species is the focus of a plan of management that provides for management actions necessary to stop the decline of, and support the recovery of, the species so that its chances of long-term survival in nature are maximised; (iii) the plan of management is in force under a law of the Commonwealth or of a State or Territory; (iv) cessation of the plan of management would adversely affect the conservation status of the species.	n/a

WESTERN AUSTRALIAN ENVIRONMENTAL PROTECTION ACT 1986

The Western Australian EP Act was created to provide for an Environmental Protection Authority (the EPA) that has the responsibility for:

- prevention, control and abatement of pollution and environmental harm
- conservation, preservation, protection, enhancement and management of the environment
- matters incidental to or connected with the above.

The EPA is responsible for providing the guidance and policy under which environmental assessments are conducted. It conducts environmental impact assessments (based on the information provided by the proponent), initiates measures to protect the environment and provides advice to the Minister responsible for environmental matters.

WESTERN AUSTRALIAN BIODIVERSITY CONSERVATION ACT 2016

The Western Australian BC Act provides for the conservation, protection and ecologically sustainable use of biodiversity and biodiversity components in Western Australia.

Threatened species (both flora and fauna) and ecological communities that meet the categories listed within the BC Act are protected under this legislation and require authorisation by the Minister to take or disturb. These are known as Threatened Flora, Threatened Fauna and Threatened Ecological Communities. The conservation categories of Critically Endangered, Endangered and Vulnerable are detailed in **Table 17**; these categories align with those of the EPBC Act. Some State-listed threatened species and ecological communities are provided with additional protection as they are also listed under the Commonwealth EPBC Act (see **Table 16** for conservation status category descriptions).

The most recent Western Australian flora and fauna listings were published in the Government Gazette on 30 September 2022 (Government of Western Australia 2022).

PRIORITY-LISTED FLORA AND FAUNA

Flora are listed as PF where populations are geographically restricted or threatened by local processes, or where there is insufficient information to formally assign them to TF categories. Whilst PF are not specifically listed in the BC Act, some may qualify as being of special conservation interest and thereby have a greater level of protection than unlisted species.

There are three categories covering Western Australian-listed TF and four categories covering PF species which are outlined in **Table 17**. PF for Western Australia are regularly reviewed by the DBCA whenever new information becomes available, with species status altered or removed from the list when data indicates that they no longer meet these requirements.

Conservation significant fauna species are listed by the DBCA as Priority Fauna where populations are geographically restricted or threatened by local processes, or where there is insufficient information to formally assign them to threatened fauna categories. Whilst Priority Fauna are not specifically listed in the BC Act, these have a greater level of significance than other native species. The categories covering Priority Fauna species are outlined in **Table 17**.

Flora and fauna species may be listed as being of special conservation interest if they have a naturally low population, have a restricted natural range, are subject to or recovering from a significant population decline or reduction of range or are of special interest, and the Minister considers that taking may result in depletion of the species. Migratory species and those subject to international agreement are also listed under the Act. These are known as 'specially protected species' in the BC Act.

Table 17: Conservation codes for Western Australian flora and fauna (DBCA 2020)

Conservation Codes for Western Australian Flora and Fauna	
Threatened, Extinct and Specially Protected fauna or flora[1] are species[2] which have been adequately searched for and are deemed to be, in the wild, threatened, extinct or in need of special protection, and have been gazetted as such. **The *Wildlife Conservation (Specially Protected Fauna) Notice 2018* and the *Wildlife Conservation (Rare Flora) Notice 2018* have been transitioned under regulations 170, 171 and 172 of the *Biodiversity Conservation Regulations 2018* to be the lists of Threatened, Extinct and Specially Protected species under Part 2 of the *Biodiversity Conservation Act 2016*.** **Categories of Threatened, Extinct and Specially Protected fauna and flora are:**	
T	**Threatened species** Listed by order of the Minister as Threatened in the category of critically endangered, endangered or vulnerable under section 19(1), or is a rediscovered species to be regarded as threatened species under section 26(2) of the *Biodiversity Conservation Act 2016* (BC Act). **Threatened fauna** is the species of fauna that are listed as critically endangered, endangered or vulnerable threatened species. **Threatened flora** is the species of flora that are listed as critically endangered, endangered or vulnerable threatened species. The assessment of the conservation status of threatened species is in accordance with the BC Act listing criteria and the requirements of Ministerial Guideline (Number 1) and Ministerial Guideline (Number 2) that adopts the use of the International Union for Conservation of Nature (IUCN) Red List of Threatened Species Categories and Criteria4, and is based on the national distribution of the species

Conservation Codes for Western Australian Flora and Fauna	
CR	**Critically endangered species** Threatened species considered to be "*facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with criteria set out in the ministerial guidelines*". Listed as critically endangered undersection 19(1)(a) of the BC Act in accordance with the criteria set out in section 20 and the ministerial guidelines.
EN	**Endangered species** Threatened species considered to be "*facing a very high risk of extinction in the wild in the near future, as determined in accordance with criteria set out in the ministerial guidelines*". Listed as endangered under section 19(1)(b) of the BC Act in accordance with the criteria set out in section 21 and the ministerial guidelines.
VU	**Vulnerable species** Threatened species considered to be "*facing a high risk of extinction in the wild in the medium-term future, as determined in accordance with criteria set out in the ministerial guidelines*". Listed as vulnerable undersection 19(1)(c) of the BC Act in accordance with the criteria set out in section 22 and the ministerial guidelines.
Extinct species **Listed by order of the Minister as extinct under section 23(1) of the BC Act as extinct or extinct in the wild.**	
EX	**Extinct species** Species where "*there is no reasonable doubt that the last member of the species has died*", and listing is otherwise in accordance with the ministerial guidelines (section 24 of the BC Act).
EW	**Extinct in the wild species** Species that "*is known only to survive in cultivation, in captivity or as a naturalised population well outside its past range; and it has not been recorded in its known habitat or expected habitat, at appropriate seasons, anywhere in its past range, despite surveys over a time frame appropriate to its life cycle and form*", and listing is otherwise in accordance with the ministerial guidelines (section 25of the BC Act).
Specially protected species Listed by order of the Minister as specially protected under section 13(1) of the BC Act. Meeting one or more of the following categories: species of special conservation interest; migratory species; cetaceans; species subject to international agreement; or species otherwise in need of special protection. Species that are listed as threatened species (critically endangered, endangered or vulnerable) or extinct species under the BC Act cannot also be listed as Specially Protected species.	
MI	**Migratory species** Fauna that periodically or occasionally visit Australia or an external Territory or the exclusive economic zone; or the species is subject of an international agreement that relates to the protection of migratory species and that binds the Commonwealth; and listing is otherwise in accordance with the ministerial guidelines (section 15of the BC Act). Includes birds that are subject to an agreement between the government of Australia and the governments of Japan (JAMBA), China (CAMBA) and The Republic of Korea (ROKAMBA), and fauna subject to the *Convention on the Conservation of Migratory Species of Wild Animals* (Bonn Convention), an environmental treaty under the United Nations Environment Program. Migratory species listed under the BC Act are a subset of the migratory animals that are known to visit Western Australia, protected under the international agreements or treaties, excluding species that are listed as Threatened species.
CD	**Species of special conservation interest (conservation dependent)** Species of special conservation need that are dependent on ongoing conservation intervention to prevent it becoming eligible for listing as threatened, and listing is otherwise in accordance with the ministerial guidelines (section 14 of the BC Act)
OS	**Other specially protected species** Fauna otherwise in need of special protection to ensure their conservation, and listing is otherwise in accordance with the ministerial guidelines (section 18of the BC Act).
P	**Priority species** Priority is not a listing category under the BC Act. All fauna and flora are protected in WA following the provisions in Part 10 of the BC Act. The protection applies even when a species is not listed as threatened or specially protected, and regardless of land tenure (State managed land (Crown land), private land, or Commonwealth land). Species that may possibly be threatened species that do not meet the criteria for listing under the BC Act because of insufficient survey or are otherwise data deficient, are added to the Priority Fauna or Priority Flora Lists under Priorities 1, 2 or 3. These three categories are ranked in order of prioritisation for survey and evaluation of conservation status so that consideration can be given to potential listing as threatened. Species that are adequately known, meet criteria for near threatened, or are rare but not threatened, or that have been recently removed from the threatened species list or conservation dependent or other specially protected fauna lists for other than taxonomic reasons, are placed in Priority 4. These species require regular monitoring. Assessment of priority status is based on the Western Australian distribution of the species, unless the distribution in WA is part of a contiguous population extending into adjacent States, as defined by the known spread of locations.

Conservation Codes for Western Australian Flora and Fauna	
1	**Priority 1: Poorly-known species – known from few locations, none on conservation lands** Species that are known from one or a few locations (generally five or less) which are potentially at risk. All occurrences are either: very small; or on lands not managed for conservation, for example, agricultural or pastoral lands, urban areas, road and rail reserves, gravel reserves and active mineral leases; or otherwise under threat of habitat destruction or degradation Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under immediate threat from known threatening processes. These species are in urgent need of further survey.
2	**Priority 2: Poorly-known species – known from few locations, some on conservation lands** Species that are known from one or a few locations (generally five or less), some of which are on lands managed primarily for nature conservation, for example, national parks, conservation parks, nature reserves and other lands with secure tenure being managed for conservation. Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements for threatened listing and appear to be under threat from known threatening processes. These species are in urgent need of further survey.
3	**Priority 3: Poorly-known species – known from several locations** Species that are known from several locations and the species does not appear to be under imminent threat or from few but widespread locations with either large population size or significant remaining areas of apparently suitable habitat, much of it not under imminent threat. Species may be included if they are comparatively well known from several locations but do not meet adequacy of survey requirements and known threatening processes exist that could affect them. These species need further survey.
4	**Priority 4: Rare, Near Threatened and other species in need of monitoring** (a) Rare. Species that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently threatened or in need of special protection but could be if present circumstances change. These species are usually represented on conservation lands. (b) Near Threatened. Species that are considered to have been adequately surveyed and that are close to qualifying for vulnerable but are not listed as Conservation Dependent. (c) Species that have been removed from the list of threatened species during the past five years for reasons other than taxonomy.
[1] The definition of flora includes algae, fungi and lichens. **[2] Species includes all taxa (plural of taxon - a classificatory group of any taxonomic rank, e.g. a family, genus, species or any infraspecific category i.e. subspecies or variety, or a distinct population).**	

THREATENED AND PRIORITY ECOLOGICAL COMMUNITIES

Western Australian TECs are protected under the BC Act and are categorised much like those of the EPBC Act. Western Australian definitions and criteria for TECs are shown in **Table 18**.

Currently described TECs are listed in the Government Gazette (Western Australian Government 2023).

DBCA also maintains a list of Priority Ecological Communities (PECs). PECs include potential TECs that do not meet survey criteria, or that are not adequately defined. They are not protected under legislation but are taken into consideration as part of the environmental approvals process.

Currently described PECs are listed on the DBCA website, with the most recent list dated 19 June 2023 (Species and Communities Program, DBCA 2023). Definitions and criteria for PECs are shown in **Table 18**.

Table 18: DBCA definitions and criteria for TECs and PECs (DEC 2013)

Criteria	Definition
Threatened Ecological Communities	
Presumed Totally Destroyed (PD)	An ecological community that has been adequately searched for but for which no representative occurrences have been located. The community has been found to be totally destroyed or so extensively modified throughout its range that no occurrence of it is likely to recover its species composition and/or structure in the foreseeable future. An ecological community will be listed as presumed totally destroyed if there are no recent records of the community being extant and either of the following applies (A or B): A. Records within the last 50 years have not been confirmed despite thorough searches of known or likely habitats or B. All occurrences recorded within the last 50 years have since been destroyed
Critically Endangered (CR)	An ecological community that has been adequately surveyed and found to have been subject to a major contraction in area and/or that was originally of limited distribution and is facing severe modification or destruction throughout its range in the immediate future, or is already severely degraded throughout its range but capable of being substantially restored or rehabilitated. An ecological community will be listed as Critically Endangered when it has been adequately surveyed and is found to be facing an extremely high risk of total destruction in the immediate future. This will be determined on the basis of the best available information, by it meeting any one or more of the following criteria (A, B or C): A. The estimated geographic range, and/or total area occupied, and/or number of discrete occurrences since European settlement have been reduced by at least 90% and either or both of the following apply (i or ii): i. geographic range, and/or total area occupied and/or number of discrete occurrences are continuing to decline such that total destruction of the community is imminent (within approximately 10 years); ii. modification throughout its range is continuing such that in the immediate future (within approximately 10 years) the community is unlikely to be capable of being substantially rehabilitated. B. Current distribution is limited, and one or more of the following apply (i, ii or iii): i. geographic range and/or number of discrete occurrences, and/or area occupied is highly restricted and the community is currently subject to known threatening processes which are likely to result in total destruction throughout its range in the immediate future (within approximately 10 years); ii. there are very few occurrences, each of which is small and/or isolated and extremely vulnerable to known threatening processes; iii. there may be many occurrences but total area is very small and each occurrence is small and/or isolated and extremely vulnerable to known threatening processes. C. The ecological community exists only as highly modified occurrences that may be capable of being rehabilitated if such work begins in the immediate future (within approximately 10 years).

Criteria	Definition
Endangered (EN)	An ecological community that has been adequately surveyed and found to have been subject to a major contraction in area and/or was originally of limited distribution and is in danger of significant modification throughout its range or severe modification or destruction over most of its range in the near future. An ecological community will be listed as Endangered when it has been adequately surveyed and is not Critically Endangered but is facing a very high risk of total destruction in the near future. This will be determined on the basis of the best available information by it meeting any one or more of the following criteria (A, B, or C): A. The geographic range, and/or total area occupied, and/or number of discrete occurrences have been reduced by at least 70% since European settlement and either or both of the following apply (i or ii): i. the estimated geographic range, and/or total area occupied and/or number of discrete occurrences are continuing to decline such that total destruction of the community is likely in the short term future (within approximately 20 years); ii. modification throughout its range is continuing such that in the short term future (within approximately 20 years) the community is unlikely to be capable of being substantially restored or rehabilitated. B. Current distribution is limited, and one or more of the following apply (i, ii or iii): i. geographic range and/or number of discrete occurrences, and/or area occupied is highly restricted and the community is currently subject to known threatening processes which are likely to result in total destruction throughout its range in the short term future (within approximately 20 years); ii. there are few occurrences, each of which is small and/or isolated and all or most occurrences are very vulnerable to known threatening processes; iii. there may be many occurrences but total area is small and all or most occurrences are small and/or isolated and very vulnerable to known threatening processes. The ecological community exists only as very modified occurrences that may be capable of being substantially restored or rehabilitated if such work begins in the short-term future (within approximately 20 years).
Vulnerable (VU)	An ecological community that has been adequately surveyed and is found to be declining and/or has declined in distribution and/or condition and whose ultimate security has not yet been assured and/or a community that is still widespread but is believed likely to move into a category of higher threat in the near future if threatening processes continue or begin operating throughout its range. An ecological community will be listed as Vulnerable when it has been adequately surveyed and is not Critically Endangered or Endangered but is facing a high risk of total destruction or significant modification in the medium to long-term future. This will be determined on the basis of the best available information by it meeting any one or more of the following criteria (A, B or C): A. The ecological community exists largely as modified occurrences that are likely to be capable of being substantially restored or rehabilitated. B. The ecological community may already be modified and would be vulnerable to threatening processes, is restricted in area and/or range and/or is only found at a few locations. C. The ecological community may be still widespread but is believed likely to move into a category of higher threat in the medium to long term future because of existing or impending threatening processes.
Priority ecological communities	
Priority One	*Poorly known ecological communities* Ecological communities with apparently few, small occurrences, all or most not actively managed for conservation (e.g. within agricultural or pastoral lands, urban areas, active mineral leases) and for which current threats exist. Communities may be included if they are comparatively well-known from one or more localities but do not meet adequacy of survey requirements, and/or are not well defined, and appear to be under immediate threat from known threatening processes across their range.
Priority Two	*Poorly known ecological communities* Communities that are known from few small occurrences, all or most of which are actively managed for conservation (e.g. within national parks, conservation parks, nature reserves, state forest, unallocated Crown land, water reserves, etc.) and not under imminent threat of destruction or degradation. Communities may be included if they are comparatively well known from one or more localities, but do not meet adequacy of survey requirements, and / or are not well defined, and appear to be under threat from known threatening processes.

Criteria	Definition
Priority Three	*Poorly known ecological communities* i. Communities that are known from several to many occurrences, a significant number or area of which are not under threat of habitat destruction or degradation or; ii. Communities known from a few widespread occurrences, which are either large or within significant remaining areas of habitat in which other occurrences may occur, much of it not under imminent threat, or; iii. Communities made up of large, and/or widespread occurrences, that may or may not be represented in the reserve system, but are under threat of modification across much of their range from processes such as grazing by domestic and/or feral stock, and inappropriate fire regimes. Communities may be included if they are comparatively well known from several localities, but do not meet adequacy of survey requirements and / or are not well defined, and known threatening processes exist that could affect them.
Priority Four	Ecological communities that are adequately known, rare but not threatened or meet criteria for Near Threatened, or that have been recently removed from the threatened list. These communities require regular monitoring. i. Rare. Ecological communities known from few occurrences that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently threatened or in need of special protection, but could be if present circumstances change These communities are usually represented on conservation lands. ii. Near Threatened. Ecological communities that are considered to have been adequately surveyed and that do not qualify for Conservation Dependent, but that are close to qualifying for Vulnerable. iii. Ecological communities that have been removed from the list of threatened communities during the past five years.
Priority Five	*Conservation Dependent Ecological Communities* Ecological Communities that are not threatened but are subject to a specific conservation program, the cessation of which would result in the community becoming threatened within five years.

FLORA CRITERIA

OTHER SIGNIFICANT FLORA

According to the Flora and Vegetation Technical Guidance (EPA 2016a) other than being listed as Threatened or Priority Flora, a species can be considered as significant if it is considered to be:

- locally endemic or association with a restricted habitat type (e.g. Groundwater Dependent Ecosystems, Sheet Flow Dependent Vegetation)
- a new species or has anomalous features that indicate a potential new species
- at the extremes of range, recently discovered range extensions (generally considered greater than 100 km or in a different bioregion), or isolated outliers of the main range)
- unusual species, including restricted subspecies, varieties or naturally occurring hybrids
- relictual status, being representative of taxonomic groups that no longer occur widely in the broader landscape.

INTRODUCED FLORA

Introduced plant species, known as weeds, are plants that are not indigenous to an area and have been introduced either directly or indirectly (unintentionally) through human activity. Species are regarded as introduced if they are listed as 'alien' on *FloraBase* (WAH 1998–) and are designated with an asterisk (*) in this document.

Weeds of National Significance

At a national level there are 32 weed species listed as Weeds of National Significance (WoNS) (Weeds Australia & Centre for Invasive Species Solutions 2021). The Commonwealth *Australian Weeds Strategy 2017-2027* (Invasive Plants and Animals Committee 2016) describes broad goals and objectives to manage these species.

Declared Pest Plants

The Western Australian Organism List (WAOL) details organisms listed as Declared Pests under the *Biosecurity and Agriculture Management Act 2007* (BAM Act). Under the BAM Act, Declared Pests are listed as one of the three categories, or exempt:

- C1 (exclusion), that applies to pests not established in Western Australia; control measures are to be taken to prevent their entry and establishment
- C2 (eradication), that applies to pests that are present in Western Australia but in low numbers or in limited areas where eradication is still a possibility
- C3 (management), that applies to established pests where it is not feasible or desirable to manage them in order to limit their damage
- exempt (no category).

VEGETATION CRITERIA

OTHER SIGNIFICANT VEGETATION

According to the Flora and Vegetation Technical Guidance (EPA 2016a) other than being listed as a TEC or PEC, vegetation can be considered as significant if it is considered to have:

- restricted distribution
- a degree of historical impact from threatening processes
- a role as a refuge
- provides an important function required to maintain ecological integrity of a significant ecosystem.

Groundwater Dependent and Sheet Flow Dependent Mulga vegetation may be considered as significant and are described below.

Groundwater Dependent Vegetation

Groundwater Definition

Groundwater is water that is found in the saturated zone of the soil, where all soil pores are filled with water. The water table is the upper surface of the saturated zone in an unconfined aquifer. Groundwater may also occur as a perched aquifer located above unsaturated rock formations as a result of a discontinuous permeable layer or held under pressure in a confined aquifer (Goulburn-Murray Water 2010).

Groundwater Dependent Ecosystems Definition

Groundwater Dependent Ecosystems (GDEs) have been defined as ecosystems that are dependent on groundwater for their survival at some stage or stages of their lifecycle, however groundwater use cannot be equated with groundwater dependence (Eamus 2009). In some contexts (including that of a flora and vegetation assessment), GDEs are also known as Groundwater Dependent Vegetation (GDV).

Hatton and Evans (1998) identified four types of GDEs based on their geographic setting: terrestrial vegetation (vegetation communities and dependent fauna that have seasonal or episodic dependence on groundwater), river base flow systems (aquatic and riparian ecosystems that exist in or adjacent to streams that are fed by groundwater base flow), aquifer and cave ecosystems, and wetlands.

Eamus *et al.* (2006b) identified three primary classes based on type of groundwater reliance:

1. Aquifer and cave ecosystems.
2. All ecosystems dependent on the surface expression of groundwater:
    a) river base flows
    b) wetlands, swamplands
    c) seagrass beds in estuaries
    d) floodplains
    e) mound springs
    f) riparian vegetation
    g) saline discharge to lakes
    h) low lying forests.
3. All ecosystems dependent on the subsurface presence of groundwater, often accessed via the capillary fringe (non-saturated zone above the water table) when roots penetrate this zone:
    a) River Red Gum (*Eucalyptus camaldulensis*) forests
    b) Banksia woodlands
    c) Riparian vegetation in the wet/dry tropics.

Atlas of Groundwater Dependent Ecosystems

The Groundwater Dependent Ecosystems Atlas (BoM 2023b) indicates the presence of known GDEs and Inflow Dependent Ecosystems (IDEs) in Australia.

An Inflow Dependent Ecosystem is one in which the vegetation within the landscape is likely to be accessing water in addition to rainfall, from soil or surface water or groundwater, assessed using remotely sensed data. The likelihood of a landscape using additional water is rated from one to 10 (low to high), with a rating above six indicating that a landscape is likely to be inflow dependent (BoM 2023b).

Sheet Flow Dependent Mulga

Sheet Flow Dependent Vegetation (SFDV) occurs through much of the arid and semi-arid zones of the world and is characterised by a mosaic of low cover or bare areas with low water infiltration rates (run-off areas) and high biomass cover with high infiltration rates (run-on areas) (Saco, Willgoose & Hancock 2007). The high biomass component in Australia is generally characterised by Mulga (a suite of related Acacia species; Maslin & Reid 2012), although other vegetation is also considered as SFDV (Ecologia Environment 2010).

These mosaics form over time due to a positive feedback wherein the increases in soil moisture in vegetated patches reinforces the pattern. They are considered to have an important role in stabilising the ecosystem

and assist ecosystem recovery from disturbance. World-wide, these mosaics occur frequently in the form of irregular clusters of vegetation surrounded by bare soil, but also form bands, stripes or arcs with banded vegetation usually forming along contour lines and intercepting surface water flow. They occur most frequently on gentle slopes but also occur on relatively steep slopes. Interruptions to the banding pattern result in the formation of erosion gullies and rills that concentrate water flow, with the landscape no longer displaying sheet flow and disrupting the formation of banded vegetation (Saco, Willgoose & Hancock 2007).

The most commonly known form of SFDV in Australia is 'grove-intergrove' Mulga wherein the 'grove' of Mulga trees and shrubs form the high-infiltration, high-biomass component and the 'intergrove' represents the low-infiltration, low-biomass component of the system. These form on relatively flat (very gently sloping) landscapes (Muller 2005; The University of Western Australia, Grierson & Page 2012). Grove-intergrove Mulga formations are known to occur over much of Australia including in Queensland, Western Australia, New South Wales and South Australia, and all occur on gently sloping alluvial-colluvial plains (Dunkerley 2002). The relatively soil high nutrient status (due to interception and retention of organic material), moisture (including soil moisture), shelter and diversity of structure within the Mulga groves are significant as habitat for both flora and fauna species (Freudenberger & Hiernaux 2001; Page 2013; Woinarski, Burbidge & Harrison 2014), including fossorial fauna species that, through their burrows and nests, aerate the soil and increase rainwater infiltration (Tongway 1994), in an otherwise depauperate environment.

Linear infrastructure, including roads and railways, are known to alter surface water hydrology, thereby placing SFDV at risk of degradation (Astron Environmental Services 2010).

ENVIRONMENTALLY SENSITIVE AREAS

There are a number of areas within Western Australia identified as being of environmental significance within which the exemptions to the Native Vegetation Clearing Regulations do not apply. These are referred to as Environmentally Sensitive Areas (ESAs), and are declared under section 51B of the EP Act and described in the *Environmental Protection (Environmentally Sensitive Areas) Notice*.

CONSERVATION ESTATE

The National Reserve System is a network of protected areas managed for conservation under international guidelines. The objective of placing areas of bushland into the Conservation Estate is to achieve and maintain a comprehensive, adequate and representative reserve system for Western Australia. The Conservation and Parks Commission is the vesting body for conservation lands, forest and marine reserves that are managed by DBCA (Government of Western Australia 2018).

APPENDIX TWO FIELD SURVEY CRITERIA

Table 19: NVIS structural formation terminology, terrestrial vegetation (NVIS Technical Working Group & DotEE 2017)

	Cover characteristics							
	Foliage cover *	70-100	30-70	10-30	<10	» 0 (scattered)	0-5 (clumped)	unknown
	Cover code	d	c	i	r	bi	bc	unknown
Growth Form	**Height Ranges (m)**	**Structural Formation Classes**						
tree, palm	<10,10-30, >30	closed forest	open forest	woodland	open woodland	isolated trees	isolated clumps of trees	tree, palm
tree mallee	<3, <10, 10-30	closed mallee forest	open mallee forest	mallee woodland	open mallee woodland	isolated mallee trees	isolated clumps of mallee trees	tree mallee
shrub, cycad, grass-tree, tree-fern	<1,1-2,>2	closed shrubland	shrubland	open shrubland	sparse shrubland	isolated shrubs	isolated clumps of shrubs	shrub, cycad, grass-tree, tree-fern
mallee shrub	<3, <10, 10-30	closed mallee shrubland	mallee shrubland	open mallee shrubland	sparse mallee shrubland	isolated mallee shrubs	isolated clumps of mallee shrubs	mallee shrub
heath shrub	<1,1-2,>2	closed heathland	heathland	open heathland	sparse heathland	isolated heath shrubs	isolated clumps of heath shrubs	heath shrub
chenopod shrub	<1,1-2,>2	closed chenopod shrubland	chenopod shrubland	open chenopod shrubland	sparse chenopod shrubland	isolated chenopod shrubs	isolated clumps of chenopod shrubs	chenopod shrub
samphire shrub	<0.5,>0.5	closed samphire shrubland	samphire shrubland	open samphire shrubland	sparse samphire shrubland	isolated samphire shrubs	isolated clumps of samphire shrubs	samphire shrub
hummock grass	<2,>2	closed hummock grassland	hummock grassland	open hummock grassland	sparse hummock grassland	isolated hummock grasses	isolated clumps of hummock grasses	hummock grass
tussock grass	<0.5,>0.5	closed tussock grassland	tussock grassland	open tussock grassland	sparse tussock grassland	isolated tussock grasses	isolated clumps of tussock grasses	tussock grass
other grass	<0.5,>0.5	closed grassland	grassland	open grassland	sparse grassland	isolated grasses	isolated clumps of grasses	other grass
sedge	<0.5,>0.5	closed sedgeland	sedgeland	open sedgeland	sparse sedgeland	isolated sedges	isolated clumps of sedges	sedge
rush	<0.5,>0.5	closed rushland	rushland	open rushland	sparse rushland	isolated rushes	isolated clumps of rushes	rush
forb	<0.5,>0.5	closed forbland	forbland	open forbland	sparse forbland	isolated forbs	isolated clumps of forbs	forb
fern	<1,1-2,>2	closed fernland	fernland	open fernland	sparse fernland	isolated ferns	isolated clumps of ferns	fern
bryophyte	<0.5	closed bryophyte-land	bryophyte-land	open bryophyteland	sparse bryophyteland	isolated bryophytes	isolated clumps of bryophytes	bryophyte
lichen	<0.5	closed lichenland	lichenland	open lichenland	sparse lichenland	isolated lichens	isolated clumps of lichens	lichen
vine	<10,10-30, >30	closed vineland	vineland	open vineland	sparse vineland	isolated vines	isolated clumps of vines	vine

Table 20: NVIS height classes (NVIS Technical Working Group & DotEE 2017)

Height		Growth form				
Height Class	**Height Range (m)**	**Tree, vine (M & U), palm (single-stemmed)**	**Shrub, heath shrub, chenopod shrub, ferns, samphire shrub, cycad, tree-fern, grass-tree, palm (multi-stemmed)**	**Tree mallee, mallee shrub**	**Tussock grass, hummock grass, other grass, sedge, rush, forbs, vine (G)**	**Bryophyte, lichen, seagrass, aquatic**
8	>30	tall	NA	NA	NA	NA
7	10-30	mid	NA	tall	NA	NA
6	<10	low	NA	mid	NA	NA
5	<3	NA	NA	low	NA	NA
4	>2	NA	tall	NA	tall	NA
3	1-2	NA	mid	NA	tall	NA
2	0.5-1	NA	low	NA	mid	tall
1	<0.5	NA	low	NA	low	low
Source: (based on Walker & Hopkins 1990)						

Table 21: Vegetation condition scale for the Eremaean and Northern Botanical Provinces (EPA 2016a)

Condition rating	Description
Excellent	Pristine or nearly so, no obvious signs of disturbance or damage caused by human activities since European settlement.
Very Good	Some relatively slight signs of damage caused by human activities since European settlement. For example, some signs of damage to tree trunks caused by repeated fire, the presence of some relatively non-aggressive weeds, or occasional vehicle tracks.
Good	More obvious signs of damage caused by human activity since European settlement, including some obvious impact on the vegetation structure such as that caused by low levels of grazing or slightly aggressive weeds.
Poor	Still retains basic vegetation structure or ability to regenerate it after very obvious impacts of human activities since European settlement, such as grazing, partial clearing, frequent fires or aggressive weeds.
Degraded	Severely impacted by grazing, very frequent fires, clearing or a combination of these activities. Scope for some regeneration but not to a state approaching good condition without intensive management. Usually with a number of weed species present including very aggressive species.
Completely Degraded	Areas that are completely or almost completely without native species in the structure of their vegetation; i.e. areas that are cleared or 'parkland cleared' with their flora comprising weed or crop species with isolated native trees or shrubs.

APPENDIX THREE DESKTOP ASSESSMENT RESULTS AND LIKELIHOOD ASSESSMENTS

Table 22: Flora database search results, habitat and likelihood assessment

Blue shading indicates high likelihood; dark blue indicates species is known (recorded) from the survey area

Species name	Habitat	Flowering	Likelihood of occurrence	
			Desktop	Post-survey
DBCA Priority 1				
Acacia websteri	Red sand, clay or loam. Low lying areas, flats.		Very unlikely	Very unlikely
Anacampseros sp. Eremaean (F. Hort, J. Hort & J. Shanks 3248)	Sand patches inside rocks, brown sandy clay, granite.	Sep	Very unlikely	Very unlikely
Calandrinia quartzitica	Low erect scrambling herb.		Unlikely	Unlikely
Eragrostis sp. Lake Carey (J. Paterson & J. Warden WB 40825)	Floodplain, edges of lakes, low slopes. Red-brown silty loam with quartz/red-brown clayey sand.		Unlikely	Unlikely
Eremophila eversa			Unlikely	Unlikely
Eremophila sp. Lake Carey (E. Mattiske LM 197)	Rocky red soil. Slopes and plains.		Very unlikely	Very unlikely
Persoonia leucopogon	Yellow sand or sandy clay.	Oct-Dec	Very unlikely	Very unlikely
Ptilotus chortophytus	Rocky yellow-brown loam, on breakaways. Hillsides.	Nov	Unlikely	Unlikely
Ptilotus rigidus	Rocky outcrops, hill slopes. Orange-red soil.	Nov	Very unlikely	Very unlikely
Ptilotus sp. Kookynie (J. Jackson & B. Moyle 261)	Rocky hills with quartz.		Unlikely	Unlikely
Ptilotus tetrandrus	Loamy sand.	Oct	May	Unlikely
Stenanthemum patens	Rocky hillsides. Sandy loam soils.		Very unlikely	Very unlikely
Tecticornia mellarium	On fringes of salt lakes. Brown sandy clay soils.		Unlikely	Unlikely
Tecticornia sp. Lake Way (P. Armstrong 05/961)	Seasonally inundated lake beds or lake edges. Grey loamy clay sand.		Very unlikely	Very unlikely
Vittadinia cervicularis var. *oldfieldii*	Red alluvial soil.	Aug-Sep	Very unlikely	Very unlikely
DBCA Priority 2				
Apatelantha insignis	Yellow/red sand plains or dunes.		Very unlikely	Very unlikely
Eremophila mirabilis	Clay sand, stony clay loam soils. Granite geology.	Jul-Sep	Unlikely	Very unlikely
Malleostemon sp. Adelong (G.J. Keighery 11825)	Red sand.	Oct	Very unlikely	Very unlikely
Thryptomene eremaea	Red or yellow sand. Sandplains.	Jul-Sep	Unlikely	Very unlikely
DBCA Priority 3				
Acacia eremophila var. Numerous-nerved variant (A.S. George 11924)	Sandy soils. Flats.	Sep	Very unlikely	Very unlikely
Acacia eremophila var. *variabilis*	Sand or sandy loam.	Sep	Very unlikely	Very unlikely

Species name	Habitat	Flowering	Likelihood of occurrence	
			Desktop	Post-survey
Acacia sp. Marshall Pool (G. Cockerton 3024)	Brown clayey sand. Rocky hills, slopes. Creek lines.	May	Unlikely	Unlikely
Alyxia tetanifolia	Sandy clay loam and gravel. Drainage lines and near lakes.	May-Nov	Very unlikely	Very unlikely
Angianthus prostratus	Saline depressions. Red clay or loamy soils.	Jul-Sep	Likely	May
Bossiaea eremaea	Deep red sand,	Jul-Sep	Very unlikely	Very unlikely
Calandrinia sp. Menzies (F. Hort et al. FH 4100)	Flats. Orange-red-brown soil.		Unlikely	Unlikely
Calytrix hislopii	Laterite ridge, breakaways. Red/brown soil.		Unlikely	Very unlikely
Calytrix praecipua	Skeletal sandy soils over granite or laterite. Breakaways and outcrops.	Jun-Nov	Unlikely	Very unlikely
Chrysocephalum apiculatum subsp. *norsemanense*	Sandplains.		Very unlikely	Very unlikely
Cratystylis centralis	Red sandy loam with ironstone gravel. Flats, breakaways.		Unlikely	Very unlikely
Drosera eremaea	Granite outcrops, hills.		Very unlikely	Very unlikely
Elatine macrocalyx	Shallow sands over clay. Margins of playa lakes and clay pans.	May-Oct	Very unlikely	Very unlikely
Eleocharis papillosa	Claypans, open clay flats. Red/brown clay soil.	Nov	Very unlikely	Very unlikely
Eremophila annosicaulis	Plains and small hills. Rocky soil.	Jul	Very unlikely	Very unlikely
Eremophila shonae subsp. *diffusa*	Stony yellow or red sandy soils.	Aug-Oct	Very unlikely	Very unlikely
Eremophila simulans subsp. *megacalyx*	Plains, ironstone outcrops. Loamy or sandy soils.	Aug-Sep	Very unlikely	Very unlikely
Eremophila veronica	Stony clay, clay loam. Lateritic breakaways.	Apr-May	Very unlikely	Very unlikely
Goodenia lyrata	Edge of wetlands, on plains and claypans. Orange-red sand or clay loam soil.	May-Oct	Unlikely	Unlikely
Grevillea subterlineata	Flats, drainage lines. Sandy or clay loam soil.	Aug	Very unlikely	Very unlikely
Homalocalyx grandiflorus	Yellow sand, sandplains.	Oct-Dec	Very unlikely	Very unlikely
Hybanthus floribundus subsp. *chloroxanthus*	Dark red-brown soil, laterite. Rocky areas, creek banks, along drainage lines.	Aug-Oct	Unlikely	Unlikely
Hysterobaeckea ochropetala subsp. *cometes*	Flat to slightly undulating sand plains. Red soil.		Very unlikely	Very unlikely
Lysiandra baeckeoides	Red-orange sandy loam. Low hills and breakaways.		Very unlikely	Very unlikely
Melaleuca apostiba	Seasonally inundated salt flats, edges of wetlands. Red clayey sand.	Jun	Unlikely	Unlikely
Micromyrtus serrulata	Brown sandy and clayey soils over granite.	Jun-Nov	Unlikely	Unlikely
Olearia mucronata	Schistose hills, along drainage channels, bases of ironstone cliffs, hill crests and slopes. Red-brown silty clay soils.	Aug - Jan	Very unlikely	Very unlikely
Philotheca coateana	Red sand.	Aug-Sep	Very unlikely	Very unlikely
Tecticornia cymbiformis	Saline soils. Along the edges of creeklines.		Unlikely	Unlikely
Triglochin protuberans	Red loam, grey mud over clay. Winter-wet sites, claypans, near salt lakes, margins of pools.	Oct	May	Unlikely
DBCA Priority 4				

Species name	Habitat	Flowering	Likelihood of occurrence	
			Desktop	Post-survey
Conospermum toddii	Yellow sand. Sand dunes.	Jul-Oct	Unlikely	Very unlikely
Eucalyptus jutsonii subsp. *jutsonii*	Red to pale orange deep sands. Undulating areas and sand dunes.		Very unlikely	Very unlikely
Grevillea erectiloba	Gravelly loam. Lateritic ridges.	Sep-Oct	Very unlikely	Very unlikely
Grevillea inconspicua	Loamy soils, gravel. Along drainage lines on rocky outcrops.	Jun-Aug	Very unlikely	Very unlikely
Hemigenia exilis	Laterite. Breakaways, slopes.	Apr-Nov	May	Known
Sowerbaea multicaulis	Yellow-brown sand.	Oct-Jan	Very unlikely	Very unlikely

Habitat references:

- *FloraBase* (WAH 1998–)
- (for *Acacia* species) *World Wide Wattle* (WAH et al. 2020)

Table 23: Fauna database results and likelihood assessments

Blue shading indicates high likelihood; darker blue indicates species is known (recorded) from the survey area. Species identified by database searches but not included in this assessment are listed in **Table 24**, along with the reason for their exclusion.

Species	Common name	Conservation status		Database		Likelihood of occurrence	
		EPBC Act	WA	PMST**	DBCA	Desktop	Post-survey
Mammals							
Dasyurus geoffroii	Chuditch, Western Quoll	VU	VU	May	-	Very Unlikely	Very Unlikely
Leporillus conditor	Greater Stick-nest Rat, Wopilkara	VU	CD	-	X	Very Unlikely	Very Unlikely
Sminthopsis longicaudata	Long-tailed Dunnart	-	P4	-	X	May	May
Sminthopsis psammophila	Sandhill Dunnart	EN	EN	May	-	Very Unlikely	Very Unlikely
Birds							
Actitis hypoleucos	Common Sandpiper	MI	MI	Known	X	May	May
Aphelocephala leucopsis	Southern Whiteface	VU		Known	-	May	May
Apus pacificus	Fork-tailed Swift	MI	MI	Likely	-	Unlikely	Unlikely
Calidris acuminata	Sharp-tailed Sandpiper	MI	MI	May	X	Very Unlikely	Very Unlikely
Calidris canutus	Red Knot	EN & MI	EN	-	X	Very Unlikely	Very Unlikely
Calidris melanotos	Pectoral Sandpiper	MI	MI	May	-	Very Unlikely	Very Unlikely
Calidris ruficollis	Red-necked Stint	MI	MI	-	X	Very Unlikely	Very Unlikely
Charadrius veredus	Oriental Plover	MI	MI	May	-	Very Unlikely	Very Unlikely
Chrysococcyx osculans	Black-eared Cuckoo	MA/MI		Known		May	Recorded
Falco hypoleucos	Grey Falcon	-	VU	May	X	Very Unlikely	Very Unlikely

Species	Common name	Conservation status		Database		Likelihood of occurrence	
		EPBC Act	WA	PMST**	DBCA	Desktop	Post-survey
Falco peregrinus	Peregrine Falcon	-	OS	-	X	Likely	Likely
Gelochelidon nilotica	Gull-billed Tern	MI	MI	-	X	Very Unlikely	Very Unlikely
Leipoa ocellata	Malleefowl	VU	VU	Known	X	Likely	Unlikely
Merops ornatus	Rainbow Bee-eater	MA/MI		May		Unlikely	Unlikely
Motacilla cinerea	Grey Wagtail	MI	MI	May	-	Very Unlikely	Very Unlikely
Motacilla flava	Yellow Wagtail	MI	MI	May	-	Very Unlikely	Very Unlikely
Pezoporus occidentalis	Night Parrot	EN	CR	May	-	Very Unlikely	Very Unlikely
Plegadis falcinellus	Glossy Ibis	MI	MI	-	X	Very Unlikely	Very Unlikely
Pluvialis fulva	Pacific Golden Plover	MI	MI	-	X	Unlikely	Unlikely
Polytelis alexandrae	Princess Parrot	VU	P4	Known	-	May	Unlikely
Thinornis rubricollis	Hooded Plover, Hooded Dotterel	-	P4	Known	X	Unlikely	Unlikely
Tringa glareola	Wood Sandpiper	MI	MI	-	X	Unlikely	Unlikely
Tringa nebularia	Common Greenshank	MI	MI	Likely	X	May	May
Reptiles							
Aspidites ramsayi	Woma (southwest subpopulation)	-	P1	-	X	Very Unlikely	Very Unlikely

Table 24: Excluded species and reason for exclusion

Species	Common name	Conservation status		Reason excluded from assessment
		EPBC Act	WA	
Bettongia lesueur graii	Burrowing bettong (inland), boodie (inland)	EX	EX	Presumed extinct
Bettongia lesueur subsp. (Barrow and Boodie Islands)	Barrow Island burrowing bettong, boodie (Barrow and Boodie Islands)	VU	CD	Not on mainland
Branchinella apophysata	A fairy shrimp (Laverton)	-	P1	Invertebrate; not within the scope of the project
Branchinella denticulata	a fairy shrimp (Carnarvon to Kalgoorlie)	-	P3	Invertebrate; not within the scope of the project
Branchinella simplex	a fairy shrimp (inland WA)	-	P1	Invertebrate; not within the scope of the project
Paraplatyarthrus subterraneus	Poseidon slater	-	P1	Invertebrate; not within the scope of the project

APPENDIX FOUR FIELD SURVEY RESULTS

Table 25: Flora inventory (site ×species matrix)

Family	Species	AH23001	AH23002	AH23003	AH23004	AH23005	AH23006	AH23007	AH23008	AH23009	AH23010	AH23011	AH23012	AH23013	AH23014	AH23015	AH23016	AH23017	AH23018	AH23019	AH23020	AH23021	AH23022	AH23023	AH23024	AH23025	AH23026	AH23027	AH23028	AH23029	AH23030	AH23031	AH23076	AH23088	AH23125	AH23126	AH23127	AH23128	AH23129	AH23157	AH23158	AH23159	AH23160	AH23161	AH23162	AH23163	AH23164	AH23165	AH23166	AH23167	AH23168	AH23169	AH23170	AH23171	AH23172	Opp
Aizoaceae	*Disphyma crassifolium*																																																×						
	Gunniopsis propinqua																												×																												×
	Gunniopsis quadrifida										×			×					×																×															×						
	Tetragonia eremaea																																																								×
Amaranthaceae	*Ptilotus divaricatus*												×						×					×									×																								
	Ptilotus exaltatus																																		×									×		×				×		×				
	Ptilotus helipteroides			×			×		×	×						×																																							×
	Ptilotus obovatus			×	×	×	×	×	×		×	×	×				×							×	×									×	×				×	×	×	×		×	×						×					
Apocynaceae	*Leichhardtia australis*								×		×		×	×										×		×									×	×	×		×	×											×				
Asteraceae	*Angianthus tomentosus*																																			×																				
	Brachyscome ciliaris																																																								×
	Calotis multicaulis																																																								×
	Cratystylis subspinescens										×		×	×					×	×	×	×							×				×		×	×		×											×		×			×	
	Pluchea dentex																																								×																
	Rhodanthe charsleyae																																																							×
	Rhodanthe chlorocephala subsp. *splendida*																																																							×
	Sonchus oleraceus																																																							×
	Streptoglossa liatroides																																																							×
	Vittadinia sp.					×		×																																			×								×		×	×			
Boraginaceae	*Heliotropium curassavicum*																																																						×
Brassicaceae	*Lepidium muelleri-ferdinandi*													×																																										
	Lepidium sp.																																																							
Chenopodiaceae	*Atriplex bunburyana*																																																					
	Atriplex codonocarpa							×						×			×		×	×		×																																	
	Atriplex semilunaris																																																						×
	Atriplex sp.	×															×																			×																		
	Chenopodiaceae sp.																																								×														
	Chenopodium curvispicatum							×						×																																								
	Einadia nutans subsp. *eremaea*																																		×																			
	Enchylaena tomentosa					×		×		×	×	×	×			×	×		×		×	×		×							×		×		×			×														
	Maireana ?tomentosa				×			×																																															
	Maireana amoena													×																×																										
	Maireana carnosa																			×																																				
	Maireana georgei															×				×		×	×						×																										
	Maireana glomerifolia												×							×																																				
	Maireana pentatropis					×																																																		
	Maireana platycarpa																				×																																			
	Maireana pyramidata									×				×					×			×													×																				
	Maireana sedifolia				×	×		×									×																																						
	Maireana sp.																			×				×																																
	Maireana suaedifolia																																																						
	Maireana thesioides												×																								×																		
	Maireana tomentosa																		×			×																															×	×				×	

Family	Species	AH23001	AH23002	AH23003	AH23004	AH23005	AH23006	AH23007	AH23008	AH23009	AH23010	AH23011	AH23012	AH23013	AH23014	AH23015	AH23016	AH23017	AH23018	AH23019	AH23020	AH23021	AH23022	AH23023	AH23024	AH23025	AH23026	AH23027	AH23028	AH23029	AH23030	AH23031	AH23076	AH23088	AH23125	AH23126	AH23127	AH23128	AH23129	AH23157	AH23158	AH23159	AH23160	AH23161	AH23162	AH23163	AH23164	AH23165	AH23166	AH23167	AH23168	AH23169	AH23170	AH23171	AH23172	Opp
	Maireana triptera			×	×	×	×	×	×		×				×		×		×			×	×	×	×													×	×		×	×	×			×		×			×		
	Rhagodia drummondii			×		×				×	×	×		×				×						×						×										×												×	
	Rhagodia eremaea														×																																							
	Salsola australis				×	×		×	×								×																								×													×
	Sclerolaena cuneata													×				×		×		×								×		×							×	×								×				
	Sclerolaena densiflora																																						×				×										
	Sclerolaena deserticola			×						×																					×																					
	Sclerolaena diacantha																																										×	×							×		
	Sclerolaena eriacantha																×	×																																				
	Sclerolaena obliquicuspis				×	×	×	×	×									×																	×							×	×						×	×		×
	Tecticornia globulifera		×																																																	
	Tecticornia indica subsp. leiostachya													×				×																																				
	Tecticornia sp. 1																									×		×		×		×																						
	Tecticornia sp. 3		×															×								×	×		×	×		×							×													
	Tecticornia sp. 8																												×																								
	Tecticornia sp. Burnerbinmah (D. Edinger et al. 101)	×	×																																																		
	Tecticornia sp. Dennys Crossing (K.A. Shepherd & J. English KS 552)																									×	×		×	×		×																					
	Tecticornia sp. nov. 2																																																				×
	Tecticornia tenuis																	×																																				×
Euphorbiaceae	*Euphorbia drummondii*								×																																											
	Euphorbia tannensis subsp. *eremophila*				×				×																																											×
Fabaceae	*Acacia aneura*			×		×	×	×	×	×	×	×			×									×	×							×				×															
	Acacia burkittii																																								×	×										
	Acacia caesaneura																																	×																×	×		×	
	Acacia craspedocarpa																							×	×												×															
	Acacia duriuscula																																				×							×	×	×			×			×	
	Acacia effusifolia			×	×		×		×																																											
	Acacia fuscaneura																																				×															
	Acacia incurvaneura																							×	×	×																											×	
	Acacia kalgoorliensis																																																			
	Acacia masliniana												×						×			×																×														
	Acacia pteraneura			×	×										×																																						
	Acacia ramulosa var. *ramulosa*						×	×	×																																											
	Acacia tetragonophylla			×	×		×	×	×		×						×						×	×	×							×		×																
	Acacia victoriae subsp. *victoriae*				×	×					×							×																																		
	Glycine canescens				×		×																																														×
	Senna artemisioides subsp. *filifolia*								×					×				×			×																																
	Senna artemisioides subsp. *helmsii*						×	×																																												
	Senna artemisioides subsp. x *artemisioides*				×																																														
	Senna cardiosperma								×																																											
	Senna charlesiana														×									×													×			×	×						×		×		×		
	Senna flexuosa																																				×		×													
	Senna glaucifolia															×																																					
	Senna glutinosa subsp. *chatelainiana*											×												×																													

Family	Species	AH23001	AH23002	AH23003	AH23004	AH23005	AH23006	AH23007	AH23008	AH23009	AH23010	AH23011	AH23012	AH23013	AH23014	AH23015	AH23016	AH23017	AH23018	AH23019	AH23020	AH23021	AH23022	AH23023	AH23024	AH23025	AH23026	AH23027	AH23028	AH23029	AH23030	AH23031	AH23076	AH23088	AH23125	AH23126	AH23127	AH23128	AH23129	AH23157	AH23158	AH23159	AH23160	AH23161	AH23162	AH23163	AH23164	AH23165	AH23166	AH23167	AH23168	AH23169	AH23170	AH23171	AH23172	Opp
	Senna sp. Austin (A. Strid 20210)																			×	×														×	×																			
	Senna sp. Meekatharra (E. Bailey 1-26)				×	×		×	×								×			×	×	×	×												×		×																	
	Templetonia incrassata																																																									×
Frankeniaceae	*Frankenia cinerea*																	×																			×																			
	Frankenia fecunda																																																									×
	Frankenia interioris																																																									
	Frankenia laxiflora													×										×			×		×	×		×																							×
	Frankenia punctata																																																									×
	Frankenia setosa									×			×				×		×	×	×	×											×		×	×		×	×																
	Frankenia sp.																																														×	×				×	×				
Goodeniaceae	*Goodenia havilandii*																																																						×			×
	Goodenia sp.																																																									×
	Scaevola spinescens			×	×	×		×			×	×	×		×		×		×	×	×	×		×	×	×					×		×		×	×		×	×	×	×	×	×	×			×					×	
Haloragaceae	*Haloragis odontocarpa*																																																						×			
Hemerocallidaceae	*Dianella revoluta*			×																																																					
Lamiaceae	*Hemigenia exilis*																																																									
	Teucrium teucriiflorum																							×	×																															
Loranthaceae	*Amyema fitzgeraldii*																																																									×
Malvaceae	*Abutilon cryptopetalum*						×																																																			
	Abutilon otocarpum																																																									×
	Abutilon oxycarpum subsp. Prostrate (A.A. Mitchell PRP 1266)																																																									×
	Brachychiton gregorii																																																									×
	Hibiscus sp. Gardneri (A.L. Payne PRP 1435)															×																																									
	Lawrencia densiflora																																																									×
	Lawrencia squamata										×		×						×	×	×	×														×	×		×						×			×	×	×			×		
	Sida calyxhymenia																																																									×
	Sida ectogama																							×																																	×	
	Sida sp. dark green fruits (S. van Leeuwen 2260)								×																×																																
Montiaceae	*Calandrinia polyandra*									×	×				×																																											
	Calandrinia sp.																																																									×
Myrtaceae	*Eucalyptus camaldulensis* subsp. *arida*																																																									
	Melaleuca xerophila													×				×																																						
Pittosporaceae	*Pittosporum angustifolium*				×							×							×														×		×																			×
Poaceae	*Aristida contorta*									×						×										×																														
	Austrostipa ?scabra							×	×																																																	×
	Austrostipa elegantissima																																																								
	Austrostipa sp.																																																								×
	Cymbopogon ambiguus				×	×																																																			
	Enneapogon caerulescens				×	×	×		×																																																
	Enneapogon cylindricus																																																								
	Enteropogon ramosus																																																							
	Eragrostis dielsii													×																																											
	Eragrostis eriopoda																																		×																					
	Monachather paradoxus																																																							

Family	Species	AH23001	AH23002	AH23003	AH23004	AH23005	AH23006	AH23007	AH23008	AH23009	AH23010	AH23011	AH23012	AH23013	AH23014	AH23015	AH23016	AH23017	AH23018	AH23019	AH23020	AH23021	AH23022	AH23023	AH23024	AH23025	AH23026	AH23027	AH23028	AH23029	AH23030	AH23031	AH23076	AH23088	AH23125	AH23126	AH23127	AH23128	AH23129	AH23157	AH23158	AH23159	AH23160	AH23161	AH23162	AH23163	AH23164	AH23165	AH23166	AH23167	AH23168	AH23169	AH23170	AH23171	AH23172	Opp
	Poaceae sp.								×	×						×																																								
	Sporobolus ramigerus																																×																							
Polygonaceae	*Rumex vesicarius*																																																							
Proteaceae	*Grevillea extorris*										×																														×				×											×
	Hakea preissii				×	×		×			×				×		×		×	×	×	×										×		×				×				×	×										
Pteridaceae	*Cheilanthes brownii*			×		×			×							×																																							
	Cheilanthes sieberi subsp. *sieberi*																							×																																
Rubiaceae	*Psydrax rigidula*			×																				×																																
Santalaceae	*Exocarpos aphyllus*																																								×																
	Santalum lanceolatum																																																								
	Santalum spicatum																							×												×																				
Sapindaceae	*Dodonaea lobulata*								×								×																																							
	Dodonaea rigida			×																																																						
Scrophulariaceae	*Eremophila alternifolia*																																								×																
	Eremophila falcata																																													×		×								
	Eremophila forrestii subsp. *forrestii*				×											×							×	×											×												×	×		×						
	Eremophila glabra																																								×								×								
	Eremophila glabra subsp. *glabra*																			×				×									×		×																				
	Eremophila latrobei			×																																									×											
	Eremophila longifolia						×																	×																											×						
	Eremophila maculata subsp. brevifolia																							×																																
	Eremophila metallicorum																							×																								×								
	Eremophila miniata				×					×	×	×	×		×					×	×	×	×								×					×													×		×				
	Eremophila oldfieldii subsp. *angustifolia*					×		×									×																																							
	Eremophila oppositifolia subsp. *angustifolia*																																																							
	Eremophila platycalyx subsp. Leonora (J. Morrisey 252)															×																																									
	Eremophila scoparia																×																																							×		×
	Eremophila serrulata																																																								×
	Eremophila sp.																																																								
	Eremophila youngii subsp. *youngii*																																																							×
Solanaceae	*Solanum cleistogamum*																																																							×
	Solanum lasiophyllum				×	×	×		×																																×				×	×		×				×	×			×
	Solanum nummularium								×																																												×				×
Zygophyllaceae	*Roepera ovata*																																																						×
	Roepera sp.								×																																															

Table 26: Fauna sites (GDA94, Zone 51)

Site Name	Site Type	Easting	Northing
HAB2	Habitat Assessment	372244.15	6773822.06
HAB3	Habitat Assessment	371072.44	6774569.97
HAB4	Habitat Assessment	370404.32	6773976.44
HAB25	Habitat Assessment	371798.57	6773804.28
HAB40	Habitat Assessment	371334.68	6770569.34
HAB47	Habitat Assessment	372214.53	6773904.53
HAB48	Habitat Assessment	372104.52	6773942.70
HAB63	Habitat Assessment	370655.92	6774658.76
HAB64	Habitat Assessment	370592.18	6774897.24
HAB65	Habitat Assessment	371186.26	6773503.64
HAB66	Habitat Assessment	370210.59	6774463.46
HAB88	Habitat Assessment	374933.12	6768140.04
HAB110	Habitat Assessment	371852.94	6774187.75
HAB121	Habitat Assessment	370388.18	6772145.58
HAB122	Habitat Assessment	370388.19	6772145.59
HAB123	Habitat Assessment	371126.08	6771014.42
HAB124	Habitat Assessment	371996.77	6769899.94
HAB125	Habitat Assessment	378826.64	6767304.89
HAB126	Habitat Assessment	378633.58	6767287.71
HAB127	Habitat Assessment	378044.87	6766409.50
HAB129	Habitat Assessment	381083.02	6767844.57
HAB130	Habitat Assessment	383197.91	6768152.92
HAB131	Habitat Assessment	379877.43	6768008.80
HAB132	Habitat Assessment	380886.83	6767754.12
HAB133	Habitat Assessment	376260.23	6767649.87
HAB134	Habitat Assessment	375324.56	6767853.58

APPENDIX FIVE FLORISTIC QUADRAT DATA

AH23001

Staff KCP **Date** 28/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 372301 **mE** 6773933 **mN** **Lat.** -29.1568 **Long.** 121.6870

Habitat Saline drainage

Aspect N/A **Slope** N/A

Soil Type Red brown clay

Rock Type Nil

Loose Rock 0 % cover **Litter** <1 % cover ; 1 cm in depth

Bare ground 10 % cover **Weeds** 0 % cover

Vegetation G+ ^*Tecticornia* sp. Burnerbinmah (D. Edinger et al. 101)\^samphire shrub\1\d

Veg. Condition Very Good

Disturbance Adjacent drilling

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Atriplex sp.		.45	<1	
Tecticornia sp. Burnerbinmah (D. Edinger et al. 101)		.35	90	

AH23002

Staff KCP **Date** 28/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 372144 **mE** 6774012 **mN** **Lat.** -29.1560 **Long.** 121.6854

Habitat Saline drainage

Aspect N/A **Slope** N/A

Soil Type Red brown clay

Rock Type Nil

Loose Rock 0 % cover **Litter** 1 % cover ; 1 cm in depth

Bare ground 20 % cover **Weeds** 0 % cover

Vegetation G+ ^*Tecticornia* sp. Burnerbinmah (D. Edinger et al. 101)\^samphire shrub\1\d

Veg. Condition Very Good

Disturbance Cattle tracks

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Tecticornia globulifera	P 1	.35	<1	1
Tecticornia sp. 3		.36	<1	
Tecticornia sp. Burnerbinmah (D. Edinger et al. 101)		.35	80	

AH23003

Staff KCP **Date** 28/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 372107 **mE** 6773876 **mN** **Lat.** -29.1573 **Long.** 121.6850

Habitat Crest

Aspect S **Slope** Moderate

Soil Type Red brown clay

Rock Type Mixed

Loose Rock 20-50 % cover; 6-20 mm in size **Litter** <1 % cover ; 1 cm in depth

Bare ground 60 % cover **Weeds** 0 % cover

Vegetation U+ ^*Acacia pteraneura*\^tree\6\i;M ^*Acacia effusifolia*,^*Acacia tetragonophylla*\^shrub\3\i;G ^*Sclerolaena deserticola*\^shrub\1\bi

Veg. Condition Very Good

Disturbance Drilling tracks

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia aneura		1	<1	
Acacia effusifolia		1.5	8	
Acacia pteraneura		4	10	
Acacia tetragonophylla		1.5	2	
Cheilanthes brownii		.1	<1	

Dianella revoluta	.6	<1
Dodonaea rigida	1.4	<1
Eremophila latrobei	.8	<1
Maireana triptera	.3	<1
Psydrax rigidula	.7	<1
Ptilotus helipteroides	.3	<1
Ptilotus obovatus	.3	<1
Rhagodia drummondii	.8	<1
Scaevola spinescens	1	<1
Sclerolaena deserticola	.2	<1

AH23004

Staff KCP **Date** 29/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 371843 **mE** 6773849 **mN** **Lat.** -29.1575 **Long.** 121.6823

Habitat Mid-Slope

Aspect NW **Slope** Moderate

Soil Type Red brown loam

Rock Type Mixed

Loose Rock 20-50 % cover; 6-20 mm in size **Litter** <1 % cover ; 1 cm in depth

Bare ground 80 % cover **Weeds** 0 % cover

Vegetation M+ ^^*Hakea preissii*,*Eremophila miniata*,*Acacia effusifolia*\^shrub\3\r;G ^,^*Sclerolaena obliquicuspis*,*Ptilotus obovatus*\^,chenopod shrub,shrub\1\r

Veg. Condition Good

Disturbance Drilling adjacent, tracks through site

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia effusifolia		1	3	
Acacia pteraneura		1.8	<1	
Acacia tetragonophylla		.6	<1	
Acacia victoriae subsp. *victoriae*		1	<1	
Cymbopogon ambiguus		.15	<1	

Enneapogon caerulescens	.1	<1
Eremophila forrestii subsp. *forrestii*	.5	<1
Eremophila miniata	2	3
Euphorbia tannensis subsp. *eremophila*	.35	<1
Glycine canescens	.4	<1
Hakea preissii	2	4
Maireana ?tomentosa	1	<1
Maireana sedifolia	1	<1
Maireana triptera	.5	<1
Pittosporum angustifolium	2	<1
Ptilotus obovatus	.3	2
Salsola australis	.35	<1
Scaevola spinescens	1	<1
Sclerolaena obliquicuspis	.3	3
Senna artemisioides subsp. *x artemisioides*	.5	<1
Senna sp. Meekatharra (E. Bailey 1-26)	1	<1
Solanum lasiophyllum	.1	<1

AH23005

Staff KCP **Date** 29/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 371939 **mE** 6773775 **mN** **Lat.** -29.1582 **Long.** 121.6833

Habitat Mid-Slope

Aspect S **Slope** Moderate

Soil Type Orange brown loam

Rock Type Mixed

Loose Rock 50-90 % cover; 20-60 mm in size **Litter** <1 % cover ; 1 cm in depth

Bare ground 65 % cover **Weeds** 0 % cover

Vegetation U+ ^*Acacia aneura*\^tree\6\r;M ^*Hakea preissii*\^shrub\4\r;G ^^*Maireana sedifolia*,*Ptilotus obovatus*,*Enchylaena tomentosa*\^shrub,chenopod shrub\2\i

Veg. Condition Very Good

Disturbance Clearing nearby

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia aneura		9	3	
Acacia victoriae subsp. *victoriae*		1	<1	
Cheilanthes brownii		.1	<1	
Cymbopogon ambiguus		.2	<1	
Enchylaena tomentosa		.4	<1	

Enchylaena tomentosa	.5	2
Enneapogon caerulescens	.1	<1
Eremophila oldfieldii subsp. *angustifolia*	1	<1
Hakea preissii	5	4
Maireana pentatropis	.2	<1
Maireana sedifolia	1	5
Maireana triptera	.4	<1
Ptilotus obovatus	.5	3
Rhagodia drummondii	1	<1
Salsola australis	.3	<1
Scaevola spinescens	.4	<1
Sclerolaena obliquicuspis	.3	2
Senna sp. Meekatharra (E. Bailey 1-26)	1	<1
Solanum lasiophyllum	.2	<1
Vittadinia sp.	.1	<1

AH23006

Staff KCP **Date** 29/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 371642 **mE** 6774056 **mN** **Lat.** -29.1556 **Long.** 121.6802

Habitat Mid-Slope

Aspect N **Slope** Moderate

Soil Type Red brown loam

Rock Type Mixed

Loose Rock 50-90 % cover; 6-20 mm in size **Litter** 2 % cover ; 5 cm in depth

Bare ground 75 % cover **Weeds** 0 % cover

Vegetation U+ ^*Acacia aneura*\^tree\6\r;M ^*Acacia effusifolia*,^*Acacia ramulosa* var. *ramulosa*\^shrub\3\i;G ^*Ptilotus obovatus*\^shrub\1\bi

Veg. Condition Good

Disturbance Drilling

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Abutilon cryptopetalum		.3	<1	
Acacia aneura		6	2	
Acacia effusifolia		1.5	10	
Acacia ramulosa var. *ramulosa*		2	1.5	
Acacia tetragonophylla		.5	<1	

Enneapogon caerulescens	.15	<1
Enneapogon caerulescens	.1	<1
Eremophila longifolia	1.7	<1
Glycine canescens	.5	<1
Maireana triptera	.4	<1
Ptilotus helipteroides	.15	<1
Ptilotus obovatus	.35	1
Sclerolaena obliquicuspis	.2	<1
Senna artemisioides subsp. *helmsii*	.3	<1
Solanum lasiophyllum	.07	<1

AH23007

Staff KCP **Date** 29/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 371310 **mE** 6774329 **mN** **Lat.** -29.1531 **Long.** 121.6769

Habitat Crest

Aspect E **Slope** Moderate

Soil Type Red brown loam

Rock Type Mixed

Loose Rock 50-90 % cover; 20-60 mm in size **Litter** 1 % cover ; 1 cm in depth

Bare ground 65 % cover **Weeds** 0 % cover

Vegetation U+ ^*Acacia aneura*\^tree\6\r;M ^*Senna* sp. Meekatharra (E. Bailey 1-26)\^shrub\3\r;G ^^*Maireana triptera*,*Ptilotus obovatus*,*Sclerolaena obliquicuspis*\^chenopod shrub,shrub\1\r

Veg. Condition Poor

Disturbance Drilling

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia aneura		7	4	
Acacia ramulosa var. *ramulosa*		.6	<1	
Acacia tetragonophylla		1.5	<1	
Atriplex codonocarpa		.2	<1	
Austrostipa ?scabra		.15	<1	

Chenopodium curvispicatum	.5	<1
Enchylaena tomentosa	.3	<1
Eremophila oldfieldii subsp. *angustifolia*	1	<1
Hakea preissii	1	<1
Maireana ?tomentosa	.35	<1
Maireana sedifolia	.8	<1
Maireana triptera	.4	3
Ptilotus obovatus	.3	2
Salsola australis	.3	<1
Scaevola spinescens	.4	<1
Sclerolaena obliquicuspis	.2	1
Senna artemisioides subsp. *helmsii*	.5	<1
Senna sp. Meekatharra (E. Bailey 1-26)	1	8
Vittadinia sp.	.1	<1

AH23008

Staff KCP **Date** 29/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 371188 **mE** 6774474 **mN** **Lat.** -29.1518 **Long.** 121.6756

Habitat Crest

Aspect S **Slope** N/A

Soil Type Red brown loam

Rock Type Mixed

Loose Rock 50-90 % cover; 6-20 mm in size **Litter** <1 % cover ; 1 cm in depth

Bare ground 70 % cover **Weeds** 0 % cover

Vegetation U+ ^*Acacia aneura*\^tree\6\r;M ^*Acacia ramulosa* var. *ramulosa*,^*Acacia effusifolia*\^shrub\3\r;G ^*Dodonaea lobulata*,^*Ptilotus obovatus*\^shrub\2\r

Veg. Condition Poor

Disturbance Drilling and clearing

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia aneura		5	5	
Acacia effusifolia		1.8	1	
Acacia ramulosa var. *ramulosa*		1.4	1	
Acacia tetragonophylla		.5	<1	
Austrostipa ?scabra		.15	<1	

Cheilanthes brownii	.1	<1
Dodonaea lobulata	1	2
Enneapogon caerulescens	.1	<1
Euphorbia drummondii	.1	<1
Euphorbia tannensis subsp. *eremophila*	.3	<1
Leichardtia australis	1	<1
Maireana triptera	.35	<1
Poaceae sp.	.15	<1
Ptilotus helipteroides	.3	2
Ptilotus obovatus	.35	1
Roepera sp.	.15	<1
Salsola australis	.3	<1
Sclerolaena obliquicuspis	.1	<1
Senna artemisioides subsp. *filifolia*	1	<1
Senna cardiosperma	.4	<1
Senna sp. Meekatharra (E. Bailey 1-26)	.5	<1
Sida sp. dark green fruits (S. van Leeuwen 2260)	.15	<1
Solanum lasiophyllum	.2	<1
Solanum nummularium	.4	<1

AH23009

Staff KCP **Date** 28/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 371550 **mE** 6774405 **mN** **Lat.** -29.1524 **Long.** 121.6793

Habitat Dunes

Aspect S **Slope** Very Gentle

Soil Type Red brown sand

Rock Type Nil

Loose Rock 0 % cover **Litter** 2 % cover ; 1 cm in depth

Bare ground 75 % cover **Weeds** 0 % cover

Vegetation U+ ^*Acacia aneura*\^tree\6\i;M ^*Eremophila miniata*\^shrub\3\bi;G ^*Rhagodia drummondii*\^shrub\2\bi

Veg. Condition Good

Disturbance Drilling, cattle, track

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia aneura		4	27	
Aristida contorta		.08	<1	
Calandrinia polyandra		.05	<1	
Enchylaena tomentosa		.35	<1	
Eremophila miniata		1.8	1	

Frankenia setosa	.35	<1
Maireana pyramidata	.4	<1
Poaceae sp.	.1	<1
Ptilotus helipteroides	.1	<1
Rhagodia drummondii	.6	<1
Sclerolaena deserticola	.4	<1

AH23010

Staff KCP **Date** 29/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 371217 **mE** 6774000 **mN** **Lat.** -29.1561 **Long.** 121.6759

Habitat Dunes

Aspect W **Slope** Very Gentle

Soil Type Red brown sandy clay

Rock Type Nil

Loose Rock 0 % cover **Litter** 2 % cover ; 1 cm in depth

Bare ground 80 % cover **Weeds** 0 % cover

Vegetation U+ ^*Acacia aneura*\^tree\6\r;M ^*Eremophila miniata*,^*Grevillea extorris*,*Hakea preissii*\^shrub\4\r;G ^^*Rhagodia drummondii*,*Lawrencia squamata*,*Enchylaena tomentosa*\^chenopod shrub,shrub\2\r

Veg. Condition Very Good

Disturbance Cattle, clearing nearby

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia aneura		6	8	
Acacia tetragonophylla		1	<1	
Acacia victoriae subsp. *victoriae*		1.6	<1	
Calandrinia polyandra		.15	<1	
Cratystylis subspinescens		1	<1	

Enchylaena tomentosa	.36	<1
Enchylaena tomentosa	.4	0.5
Eremophila miniata	4	6
Grevillea extorris	2	2
Gunniopsis quadrifida	.3	<1
Hakea preissii	2.3	1
Lawrencia squamata	1	1
Leichardtia australis	1	<1
Maireana triptera	.5	<1
Ptilotus obovatus	.35	<1
Rhagodia drummondii	.5	3
Rhagodia drummondii	1	<1
Scaevola spinescens	1.2	<1

AH23011

Staff KCP **Date** 29/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 370695 **mE** 6774379 **mN** **Lat.** -29.1526 **Long.** 121.6705

Habitat Dunes

Aspect E **Slope** Gentle

Soil Type Red brown sand

Rock Type Nil

Loose Rock 0 % cover **Litter** 2 % cover ; 1 cm in depth

Bare ground 70 % cover **Weeds** 0 % cover

Vegetation U+ ^*Acacia aneura*\^tree\6\r;M ^*Eremophila miniata*\^shrub\4\r;G ^*Rhagodia drummondii*\^chenopod shrub\2\r

Veg. Condition Very Good

Disturbance Cattle

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia aneura		6.5	5	
Enchylaena tomentosa		.3	<1	
Eremophila miniata		3.5	3	
Pittosporum angustifolium		.4	<1	
Ptilotus obovatus		.1	<1	

Rhagodia drummondii	.5	1
Scaevola spinescens	1	<1
Senna glutinosa subsp. *chatelainiana*	1.6	<1

AH23012

Staff KCP **Date** 31/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 370842 **mE** 6773601 **mN** **Lat.** -29.1596 **Long.** 121.6720

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Red brown clay loam

Rock Type Mixed

Loose Rock >90 % cover; 2-6 mm in size **Litter** 2 % cover ; <1 cm in depth

Bare ground 80 % cover **Weeds** 0 % cover

Vegetation M+ ^*Acacia masliniana*,^*Eremophila miniata*\^shrub\4\i;G ^^*Cratystylis subspinescens*,*Frankenia setosa*,*Scaevola spinescens*\^shrub\2\r

Veg. Condition Very Good

Disturbance Cattle

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia masliniana		3	10	
Cratystylis subspinescens		1	2	
Enchylaena tomentosa		0.3	<1	
Eremophila miniata		2.5	2	
Frankenia setosa		0.5	1.5	

Lawrencia squamata	0.35	<1
Leichardtia australis	1	<1
Maireana glomerifolia	0.4	<1
Maireana thesioides	0.4	<1
Ptilotus divaricatus	0.35	<1
Ptilotus obovatus	0.35	<1
Scaevola spinescens	0.6	1.5

AH23013

Staff KCP **Date** 28/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 371934 **mE** 6774282 **mN** **Lat.** -29.1536 **Long.** 121.6833

Habitat Fringe of drainage

Aspect N/A **Slope** Very Gentle

Soil Type Orange brown sandy clay

Rock Type Nil

Loose Rock 0 % cover **Litter** <1 % cover ; 1 cm in depth

Bare ground 65 % cover **Weeds** 0 % cover

Vegetation M+ ^*Melaleuca xerophila*\^shrub\4\r;G ^^*Tecticornia indica* subsp. *leiostachya*,*Rhagodia drummondii*,*Cratystylis subspinescens*\^samphire shrub,chenopod shrub,shrub\2\i

Veg. Condition Very Good

Disturbance Minimal

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Atriplex codonocarpa		.1	<1	
Chenopodium curvispicatum		.35	<1	
Cratystylis subspinescens		.6	6	
Eragrostis dielsii		.07	<1	
Frankenia laxiflora		.2	<1	

Gunniopsis quadrifida	.3	<1
Leichardtia australis	.5	<1
Lepidium muelleri-ferdinandi	.1	<1
Maireana amoena	.3	<1
Maireana pyramidata	.4	<1
Melaleuca xerophila	2.3	10
Rhagodia drummondii	.8	5
Sclerolaena cuneata	.3	1
Senna artemisioides subsp. *filifolia*	1	<1
Tecticornia indica subsp. *leiostachya*	.35	20

AH23014

Staff KCP **Date** 30/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 371581 **mE** 6773400 **mN** **Lat.** -29.1615 **Long.** 121.6795

Habitat Dunes

Aspect S **Slope** Gentle

Soil Type Red brown sand

Rock Type Nil

Loose Rock 0 % cover **Litter** 3 % cover ; 2 cm in depth

Bare ground 55 % cover **Weeds** 0 % cover

Vegetation U+ ^*Acacia aneura*,^*Acacia aneura*\^tree\6\i;M ^^*Hakea preissii*,*Eremophila miniata*,*Scaevola spinescens*\^shrub\3\r;

Veg. Condition Very Good

Disturbance Cattle

Fire Age >5 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia aneura		3	15	
Acacia aneura		8	8	
Calandrinia polyandra		.1	<1	
Eremophila miniata		1.6	1.5	
Hakea preissii		1.3	4	

Maireana triptera	.3	<1
Rhagodia eremaea	.5	<1
Scaevola spinescens	1	2.5
Senna charlesiana	.5	<1

AH23015

Staff KCP **Date** 28/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 371690 **mE** 6774757 **mN** **Lat.** -29.1493 **Long.** 121.6808

Habitat Crest

Aspect SW **Slope** Gentle

Soil Type Red brown clay loam

Rock Type Mixed

Loose Rock 20-50 % cover **Litter** 1 % cover ; 5 cm in depth

Bare ground 75 % cover **Weeds** 0 % cover

Vegetation U+ ^*Acacia pteraneura*\^tree\6\r;M ^^*Senna glaucifolia*,*Eremophila platycalyx* subsp. Leonora (J. Morrisey 252),*Eremophila forrestii* subsp. *forrestii*\^shrub\3\i;

Veg. Condition Very Good

Disturbance Drilling in adjacent areas

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia pteraneura		4	10	
Aristida contorta		.15	<1	
Cheilanthes brownii		.08	<1	
Enchylaena tomentosa		.3	<1	
Eremophila forrestii subsp. *forrestii*		.5	<1	

Eremophila forrestii subsp. *forrestii*	.4	1
Eremophila platycalyx subsp. Leonora (J. Morrisey 252)	1.3	2
Hibiscus sp. Gardneri (A.L. Payne PRP 1435)	.2	<1
Maireana georgei	.2	<1
Poaceae sp.	.13	<1
Ptilotus helipteroides	.2	
Senna glaucifolia	1.3	10

AH23016

Staff KCP **Date** 29/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 371486 **mE** 6774638 **mN** **Lat.** -29.1503 **Long.** 121.6787

Habitat Mid-Slope

Aspect S **Slope** Moderate

Soil Type Red brown loam

Rock Type Mixed

Loose Rock 20-50 % cover; 6-20 mm in size **Litter** 1 % cover ; 5 cm in depth

Bare ground 6 % cover **Weeds** 0 % cover

Vegetation M+ ^^*Acacia tetragonophylla*,*Eremophila oldfieldii* subsp. *angustifolia*,*Dodonaea lobulata*\^shrub\3\r;G ^*Maireana sedifolia*,^*Ptilotus obovatus*\^shrub\1\r

Veg. Condition Poor

Disturbance Clearing and drilling

Fire Age >10 years

Notes Impacts from drilling



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia tetragonophylla		1.7	3	
Atriplex codonocarpa		.3	<1	
Atriplex sp.		.2	<1	
Dodonaea lobulata		1.2	1.5	
Enchylaena tomentosa		.2	<1	

Eremophila oldfieldii subsp. *angustifolia*	1.2	2.5
Eremophila scoparia	1	<1
Frankenia setosa	.2	<1
Hakea preissii	.2	<1
Maireana sedifolia	.5	5
Maireana triptera	.2	<1
Ptilotus obovatus	.3	1
Salsola australis	.2	<1
Scaevola spinescens	1	1
Sclerolaena eriacantha	.2	<1
Senna artemisioides subsp. *filifolia*	.4	<1
Senna sp. Meekatharra (E. Bailey 1-26)	1	<1

AH23017

Staff KCP **Date** 31/03/2023 **Season** P

Revisit

Type Q 40 m x 10 m

Location

MGA Zone 51 372184 **mE** 6774050 **mN** **Lat.** -29.1557 **Long.** 121.6858

Habitat Edge of saline drainage

Aspect N/A **Slope** N/A

Soil Type Red brown clay

Rock Type Nil

Loose Rock 0 % cover **Litter** 5 % cover ; 1 cm in depth

Bare ground 55 % cover **Weeds** 0 % cover

Vegetation M+ ^*Melaleuca xerophila*\^shrub\4\r;G ^*Rhagodia drummondii*,^*Tecticornia* sp. 3\^chenopod shrub,samphire shrub\1\c

Veg. Condition Very Good

Disturbance Cattle

Fire Age >10 years

Notes Oriented parallel to track, close to survey boundary.



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia victoriae subsp. *victoriae*		1.4	<1	
Frankenia cinerea		.1	0.5	
Melaleuca xerophila			10	
Rhagodia drummondii		.5	20	
Sclerolaena cuneata		.2	<1	

Sclerolaena eriacantha	.2	<1
Sclerolaena obliquicuspis	.2	<1
Tecticornia indica subsp. *leiostachya*	.3	<1
Tecticornia sp. 3	.5	18
Tecticornia tenuis	.4	<1

AH23018

Staff KCP **Date** 29/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 370461 **mE** 6774689 **mN** **Lat.** -29.1498 **Long.** 121.6682

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Red brown sandy loam

Rock Type Mixed

Loose Rock 50-90 % cover; 6-20 mm in size **Litter** <1 % cover ; 1 cm in depth

Bare ground 65 % cover **Weeds** 0 % cover

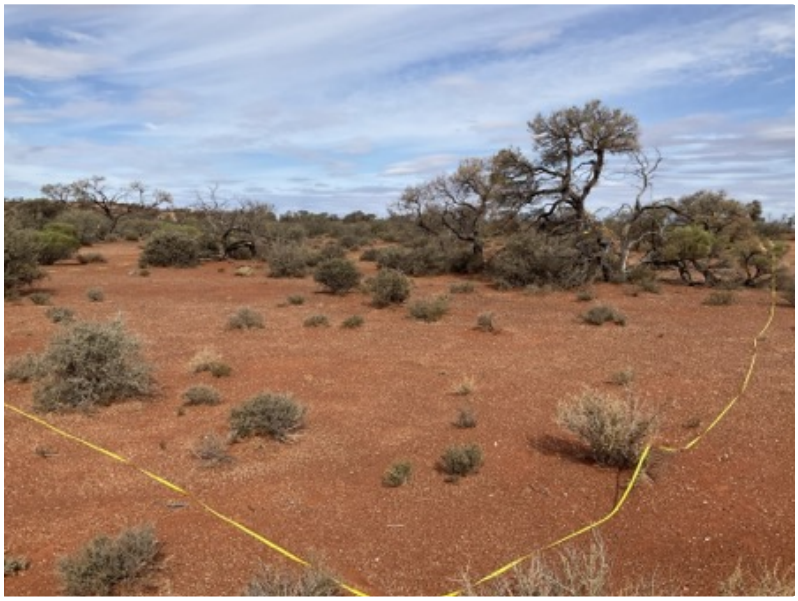
Vegetation M+ ^*Acacia masliniana*\^shrub\4\r;G ^*Cratystylis subspinescens*,*Frankenia setosa*\^shrub\2\i

Veg. Condition Very Good

Disturbance Cattle tracks

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia masliniana		3.5	5	
Atriplex codonocarpa		.2	<1	
Cratystylis subspinescens		1	9	
Enchylaena tomentosa		.36	<1	
Frankenia setosa		.45	5	
Gunniopsis quadrifida		.3	<1	

Hakea preissii	1.8	<1
Lawrencia squamata	1	<1
Maireana pyramidata	.3	<1
Maireana tomentosa	.2	<1
Maireana triptera	.3	<1
Pittosporum angustifolium	.5	<1
Ptilotus divaricatus	.35	<1
Scaevola spinescens	1	<1

AH23019

Staff KCP **Date** 30/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 369623 **mE** 6774266 **mN** **Lat.** -29.1535 **Long.** 121.6595

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Red brown sandy clay

Rock Type Mixed

Loose Rock 50-90 % cover; 2-6 mm in size **Litter** <1 % cover ; <1 cm in depth

Bare ground 85 % cover **Weeds** 0 % cover

Vegetation M+ ^^*Senna* sp. Meekatharra (E. Bailey 1-26),*Eremophila miniata*,*Cratystylis subspinescens*\^shrub\3\r;G ^^*Frankenia setosa*,*Lawrencia squamata*,*Frankenia setosa*\^shrub\1\r

Veg. Condition Very Good

Disturbance Cattle

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Atriplex codonocarpa		.1	<1	
Cratystylis subspinescens		1	2	
Eremophila glabra subsp. *glabra*		.6	<1	
Eremophila miniata		1.8	2.5	

Frankenia setosa	.3	6
Frankenia setosa	.2	2
Hakea preissii	2	1
Lawrencia squamata	.35	2
Maireana carnosa	.1	<1
Maireana georgei	.1	<1
Maireana glomerifolia	.2	<1
Maireana sp.	.15	<1
Scaevola spinescens	.2	1
Sclerolaena cuneata	.2	<1
Senna artemisioides subsp. *filifolia*	.7	<1
Senna sp. Austin (A. Strid 20210)	.4	<1
Senna sp. Meekatharra (E. Bailey 1-26)	1	3

AH23020

Staff KCP **Date** 30/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 370065 **mE** 6774052 **mN** **Lat.** -29.1555 **Long.** 121.6640

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Red brown sandy clay

Rock Type Mixed

Loose Rock 50-90 % cover; 2-6 mm in size **Litter** <1 % cover ; <1 cm in depth

Bare ground 80 % cover **Weeds** 0 % cover

Vegetation M+ ^^*Eremophila miniata*,*Cratystylis subspinescens*,*Senna* sp. Meekatharra (E. Bailey 1-26) \^shrub\3\r;G ^*Frankenia setosa*,^*Lawrencia squamata*\^shrub\1\r

Veg. Condition Very Good

Disturbance Cattle

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Cratystylis subspinescens		1	3	
Enchylaena tomentosa		.3	<1	
Eremophila miniata		1.3	3.5	
Frankenia setosa		.2	0.5	
Frankenia setosa		.3	4	

Hakea preissii	1.2	0.5
Lawrencia squamata	.3	3
Maireana platycarpa	.2	<1
Scaevola spinescens	1	<1
Senna sp. Austin (A. Strid 20210)	.2	<1
Senna sp. Meekatharra (E. Bailey 1-26)	1	2

AH23021

Staff KCP **Date** 30/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 370435 **mE** 6773843 **mN** **Lat.** -29.1574 **Long.** 121.6678

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Red brown sandy clay

Rock Type Mixed

Loose Rock 50-90 % cover; 2-6 mm in size **Litter** <1 % cover ; 1 cm in depth

Bare ground 80 % cover **Weeds** 0 % cover

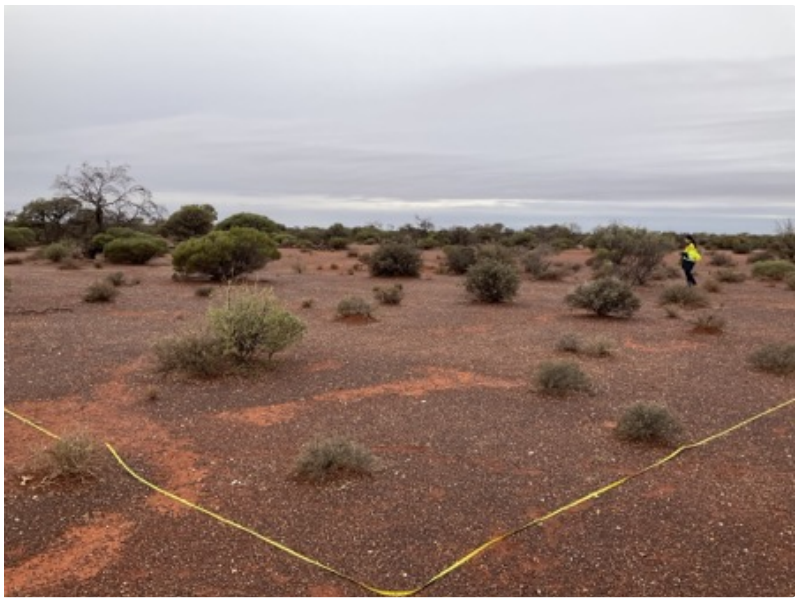
Vegetation M+ ^^*Cratystylis subspinescens*,*Hakea preissii*,*Acacia masliniana*\^shrub\3\r;G ^*Lawrencia squamata*,^\^shrub\1\r

Veg. Condition Very Good

Disturbance Cattle

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia masliniana		1.6	1	
Atriplex codonocarpa		.15	<1	
Cratystylis subspinescens		1.2	4	
Enchylaena tomentosa		.3	<1	
Eremophila miniata		1	1	

Frankenia setosa	.3	4
Frankenia setosa	.2	<1
Hakea preissii	1.7	2
Lawrencia squamata	.45	5
Maireana georgei	.3	<1
Maireana pyramidata	.35	<1
Maireana tomentosa	.3	<1
Maireana triptera	.2	<1
Sclerolaena cuneata	.2	<1
Senna sp. Meekatharra (E. Bailey 1-26)	1	<1

AH23022

Staff KCP **Date** 30/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 370421 **mE** 6773154 **mN** **Lat.** -29.1636 **Long.** 121.6676

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Red brown clay loam

Rock Type Mixed

Loose Rock 50-90 % cover; 2-6 mm in size **Litter** 1 % cover ; 2 cm in depth

Bare ground 75 % cover **Weeds** 0 % cover

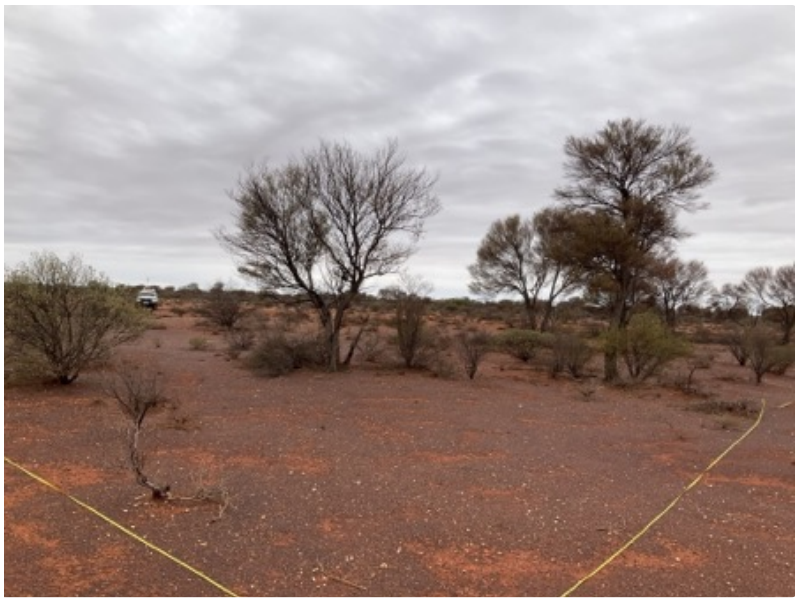
Vegetation U+ ^*Acacia incurvaneura*,^*Acacia aneura*\^tree\6\r;M ^^*Senna charlesiana*,*Senna* sp. Meekatharra (E. Bailey 1-26),*Eremophila miniata*\^shrub\3\r;G ^*Ptilotus obovatus*\^shrub\1\bi

Veg. Condition Very Good

Disturbance Cattle

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia aneura		5	3	
Acacia craspedocarpa		.4	<1	
Acacia incurvaneura		6	3.5	
Acacia tetragonophylla		1.8	<1	
Eremophila forrestii subsp. *forrestii*		.5	<1	

Eremophila miniata	2	1
Leichardtia australis	.2	<1
Maireana georgei	.06	<1
Maireana triptera	.08	<1
Ptilotus obovatus	.3	<1
Scaevola spinescens	1.2	<1
Senna charlesiana	1.2	1.5
Senna glutinosa subsp. *chatelainiana*	1.8	<1
Senna sp. Meekatharra (E. Bailey 1-26)	.6	1.5

AH23023

Staff KCP **Date** 30/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 370895 **mE** 6772640 **mN** **Lat.** -29.1683 **Long.** 121.6724

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Red brown clay

Rock Type Mixed

Loose Rock <2 % cover; 6-20 mm in size **Litter** 5 % cover ; 2 cm in depth

Bare ground 35 % cover **Weeds** 0 % cover

Vegetation U+ ^^*Acacia incurvaneura*,*Acacia aneura*,*Santalum spicatum*\^tree\6\i;M ^*Acacia tetragonophylla*, ^*Scaevola spinescens*\^shrub\4\i;G ^^*Teucrium teucriiflorum*,*Eremophila metallicorum*,*Eremophila forrestii* subsp. *forrestii*\^shrub\1\r

Veg. Condition Very Good

Disturbance Cattle

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia aneura		3	3	
Acacia craspedocarpa		2	0.5	
Acacia incurvaneura		7	7	
Acacia tetragonophylla		2.3	9	

Cheilanthes sieberi subsp. *sieberi*	.15	<1
Enchylaena tomentosa	.1	<1
Eremophila forrestii subsp. *forrestii*	1	1.5
Eremophila glabra subsp. *glabra*	1.8	<1
Eremophila longifolia	1	<1
Eremophila maculata subsp. *brevifolia*	.3	<1
Eremophila metallicorum	.5	2
Frankenia laxiflora	.4	<1
Maireana sp.	.3	<1
Maireana triptera	.2	1
Psydrax rigidula	1	<1
Ptilotus divaricatus	.45	<1
Ptilotus obovatus	.3	<1
Ptilotus obovatus	.35	<1
Rhagodia drummondii	.7	2
Santalum spicatum	4	2
Scaevola spinescens	2.2	5
Sida ectogama	.5	<1
Teucrium teucriiflorum	.5	2.5

AH23024

Staff KCP **Date** 30/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 370637 **mE** 6772852 **mN** **Lat.** -29.1664 **Long.** 121.6698

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Red brown sandy clay

Rock Type Mixed

Loose Rock 50-90 % cover; 2-6 mm in size **Litter** 5 % cover ; 1 cm in depth

Bare ground 60 % cover **Weeds** 0 % cover

Vegetation U+ ^*Acacia incurvaneura*\^tree\6\i;M ^*Acacia tetragonophylla*\^shrub\3\r;

Veg. Condition Very Good

Disturbance Cattle

Fire Age >5 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia incurvaneura		5	20	
Acacia tetragonophylla		2	3	
Aristida contorta		.1	<1	
Leichardtia australis		1	<1	
Maireana triptera		.1	<1	
Scaevola spinescens		1	0.5	

Sida sp. dark green fruits (S. van Leeuwen 2260)	.3	<1
Teucrium teucriiflorum	.4	<1

AH23025

Staff KCP **Date** 30/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 371627 **mE** 6773270 **mN** **Lat.** -29.1627 **Long.** 121.6800

Habitat Saline drainage

Aspect N/A **Slope** N/A

Soil Type Red brown clay loam

Rock Type Mixed

Loose Rock 20-50 % cover; 2-6 mm in size **Litter** <1 % cover ; 1 cm in depth

Bare ground 70 % cover **Weeds** 0 % cover

Vegetation G+ ^^*Tecticornia* sp. Dennys Crossing (K.A. Shepherd & J. English KS 552),*Tecticornia* sp. 3, *Tecticornia* sp. 1\^samphire shrub\1\c

Veg. Condition Very Good

Disturbance Clearing nearby, cattle

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Tecticornia sp. 1		.3	<1	
Tecticornia sp. 3		.35	<1	
Tecticornia sp. Dennys Crossing (K.A. Shepherd & J. English KS 552)		.4	30	

AH23026

Staff KCP **Date** 30/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 371260 **mE** 6773321 **mN** **Lat.** -29.1622 **Long.** 121.6762

Habitat Saline drainage

Aspect N/A **Slope** N/A

Soil Type Red brown clay loam

Rock Type Mixed

Loose Rock 20-50 % cover; 2-6 mm in size **Litter** <1 % cover ; 1 cm in depth

Bare ground 68 % cover **Weeds** 0 % cover

Vegetation G+ ^,^*Tecticornia* sp. 3\^,samphire shrub\1\i

Veg. Condition Very Good

Disturbance Cattle, drilling nearby

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Frankenia laxiflora		. 2	<1	
Tecticornia sp. 3		.4	30	
Tecticornia sp. Dennys Crossing (K.A. Shepherd & J. English KS 552)		.4	0.5	

AH23027

Staff KCP **Date** 28/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 371776 **mE** 6774195 **mN** **Lat.** -29.1543 **Long.** 121.6816

Habitat Drainage

Aspect N/A **Slope** N/A

Soil Type Red brown clay

Rock Type Nil

Loose Rock 0 % cover **Litter** <1 % cover ; <1 cm in depth

Bare ground 85 % cover **Weeds** 0 % cover

Vegetation G+ ^*Tecticornia* sp. 1\^samphire shrub\1\i

Veg. Condition Good

Disturbance Drlling, tracks

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Tecticornia sp. 1		.4	15	

AH23028

Staff KCP **Date** 30/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 371452 **mE** 6773614 **mN** **Lat.** -29.1596 **Long.** 121.6782

Habitat Saline drainage

Aspect N/A **Slope** N/A

Soil Type Red brown sandy clay

Rock Type Mixed

Loose Rock 50-90 % cover; 2-6 mm in size **Litter** <1 % cover ; 3 cm in depth

Bare ground 80 % cover **Weeds** 0 % cover

Vegetation G+ ^*Tecticornia* sp. 3,^*Tecticornia* sp. Dennys Crossing (K.A. Shepherd & J. English KS 552) \^samphire shrub\1\i

Veg. Condition Very Good

Disturbance Drilling nearby, cattle

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Cratystylis subspinescens		.6	<1	
Frankenia laxiflora		.3	<1	
Gunniopsis propinqua		.05	<1	
Maireana georgei		.1	<1	
Tecticornia sp. 3		.4	18	

Tecticornia sp. 8	0.3	2	10
Tecticornia sp. Dennys Crossing (K.A. Shepherd & J. English KS 552)	.4	1	

AH23029

Staff KCP **Date** 28/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 371754 **mE** 6774354 **mN** **Lat.** -29.1529 **Long.** 121.6814

Habitat Fringe of drainage

Aspect N/A **Slope** N/A

Soil Type Orange brown sandy clay

Rock Type Nil

Loose Rock 0 % cover **Litter** <1 % cover ; 1 cm in depth

Bare ground 60 % cover **Weeds** 0 % cover

Vegetation G+ ^^*Tecticornia* sp. 3,*Tecticornia* sp. Dennys Crossing (K.A. Shepherd & J. English KS 552), *Frankenia laxiflora*\^samphire shrub,shrub\1\c

Veg. Condition Very Good

Disturbance Tracks, drilling nearby

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Frankenia laxiflora		.3	1.5	
Maireana amoena		.3	<1	
Sclerolaena cuneata		.25	<1	
Tecticornia sp. 1		.3	<1	
Tecticornia sp. 3		.3	35	

Tecticornia sp. Dennys Crossing (K.A. Shepherd & J. English KS 552)	.35	2

AH23030

Staff KCP **Date** 28/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 370651 **mE** 6775070 **mN** **Lat.** -29.1463 **Long.** 121.6702

Habitat Dunes

Aspect S **Slope** Gentle

Soil Type Red brown sand

Rock Type Nil

Loose Rock 0 % cover **Litter** 5 % cover ; 10 cm in depth

Bare ground 75 % cover **Weeds** 0 % cover

Vegetation U+ ^*Acacia aneura*,^*Acacia aneura*\^tree\6\i;M ^*Eremophila miniata*\^shrub\3\r;G ^*Maireana pyramidata*\^chenopod shrub\2\r

Veg. Condition Very Good

Disturbance Cattle, drilling nearby

Fire Age >5 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia aneura		6	6	
Acacia aneura		6	7	
Enchylaena tomentosa		.35	<1	
Eremophila miniata		1.8	2	
Maireana pyramidata		.4	4	

Rhagodia drummondii	.4	<1
Scaevola spinescens	1.3	<1
Sclerolaena deserticola	.2	<1

AH23031

Staff KCP **Date** 28/03/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 370794 **mE** 6774938 **mN** **Lat.** -29.1475 **Long.** 121.6716

Habitat Depression

Aspect N/A **Slope** N/A

Soil Type Orange brown sandy clay

Rock Type Nil

Loose Rock 0 % cover **Litter** <1 % cover ; 1 cm in depth

Bare ground 55 % cover **Weeds** 0 % cover

Vegetation G+ ^^*Tecticornia* sp. 1,*Tecticornia* sp. Dennys Crossing (K.A. Shepherd & J. English KS 552), *Tecticornia* sp. 3\^samphire shrub\1\c

Veg. Condition Very Good

Disturbance Cattle tracks

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Frankenia laxiflora		.3	<1	
Tecticornia sp. 1		.3	30	
Tecticornia sp. 3		.3	2	
Tecticornia sp. Dennys Crossing (K.A. Shepherd & J. English KS 552)		.3	22	

AH23076

Staff KCP **Date** 6/04/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 370281 **mE** 6774901 **mN** **Lat.** -29.1478 **Long.** 121.6663

Habitat Open Depression

Aspect N/A **Slope** N/A

Soil Type Light brown clay

Rock Type Nil

Loose Rock 0 % cover **Litter** 5 % cover ; <1 cm in depth

Bare ground 85 % cover **Weeds** 0 % cover

Vegetation U ^*Pittosporum angustifolium*\^tree\6\r;M+ ^*Hakea preissii*,^*Acacia tetragonophylla*\^shrub\4\i;G ^*Cratystylis subspinescens*\^shrub\2\r

Veg. Condition Very Good

Disturbance Cattle

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia tetragonophylla		2.5	4	
Cratystylis subspinescens		1	4	
Enchylaena tomentosa		.2	<1	
Enchylaena tomentosa		.1	<1	
Eremophila glabra subsp. *glabra*		1.5	1	

Frankenia setosa	.3	0.5
Hakea preissii	3	6
Pittosporum angustifolium	6	7
Ptilotus divaricatus	.5	<1
Scaevola spinescens	.2	<1
Sclerolaena cuneata	.15	<1
Sporobolus ramigerus	.5	<1

AH23088

Staff SOK **Date** 8/04/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 371571 **mE** 6770397 **mN** **Lat.** -29.1886 **Long.** 121.6791

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Red brown clay loam

Rock Type Nil

Loose Rock 0 % cover **Litter** 10 % cover ; 0-1 cm in depth

Bare ground 90 % cover **Weeds** 0 % cover

Vegetation U+ ^*Acacia caesaneura*\^tree\6\i;M ^*Eremophila forrestii* subsp. *forrestii*\^shrub\3\r;G ^*Eragrostis eriopoda*\^tussock grass\1\bi

Veg. Condition Very Good

Disturbance Grazing

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia caesaneura		5	12	
Eragrostis eriopoda		0.3	<1	
Eremophila forrestii subsp. *forrestii*		1.2	2	
Ptilotus obovatus		0.4	<1	

AH23125

Staff KCP **Date** 5/04/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 371086 **mE** 6773145 **mN** **Lat.** -29.1638 **Long.** 121.6744

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Red brown sandy loam

Rock Type Mixed

Loose Rock 20-50 % cover; 6-20 mm in size **Litter** 40 % cover ; 1 cm in depth

Bare ground 25 % cover **Weeds** 0 % cover

Vegetation U+ ^*Acacia fuscaneura*,^*Acacia aneura*\^tree\6\i;M ^^*Scaevola spinescens*,*Cratystylis subspinescens*,*Acacia tetragonophylla*\^shrub\3\i;

Veg. Condition Very Good

Disturbance Cattle

Fire Age >5 years

Notes Lots of dead shrubs



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia aneura		7	5	
Acacia craspedocarpa		.4	<1	
Acacia duriuscula		5	<1	
Acacia fuscaneura		5	17	
Acacia tetragonophylla		1.2	5	

Acacia victoriae subsp. *victoriae*	1	<1
Atriplex sp.	.5	<1
Cratystylis subspinescens	1.5	6
Einadia nutans subsp. *eremaea*	.5	<1
Enchylaena tomentosa	.35	<1
Eremophila glabra subsp. *glabra*	1.4	<1
Frankenia setosa	.35	<1
Gunniopsis quadrifida	.1	<1
Hakea preissii	1.5	4
Lawrencia squamata	.4	<1
Leichardtia australis	1	<1
Leichardtia australis	.5	<1
Maireana pyramidata	1	<1
Maireana triptera	.2	<1
Pittosporum angustifolium	4	1
Ptilotus exaltatus	.02	<1
Ptilotus obovatus	.3	<1
Rhagodia drummondii	.5	<1
Santalum spicatum	5	2
Scaevola spinescens	1.8	6
Sclerolaena obliquicuspis	.1	<1
Senna artemisioides subsp. *filifolia*	1	<1
Senna charlesiana	1.3	<1
Senna sp. Austin (A. Strid 20210)	1	<1

AH23126

Staff KCP **Date** 5/04/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 370935 **mE** 6773325 **mN** **Lat.** -29.1621 **Long.** 121.6729

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Clay loam

Rock Type Mixed

Loose Rock 50-90 % cover; 20-60 mm in size **Litter** 2 % cover ; <1 cm in depth

Bare ground 85 % cover **Weeds** 0 % cover

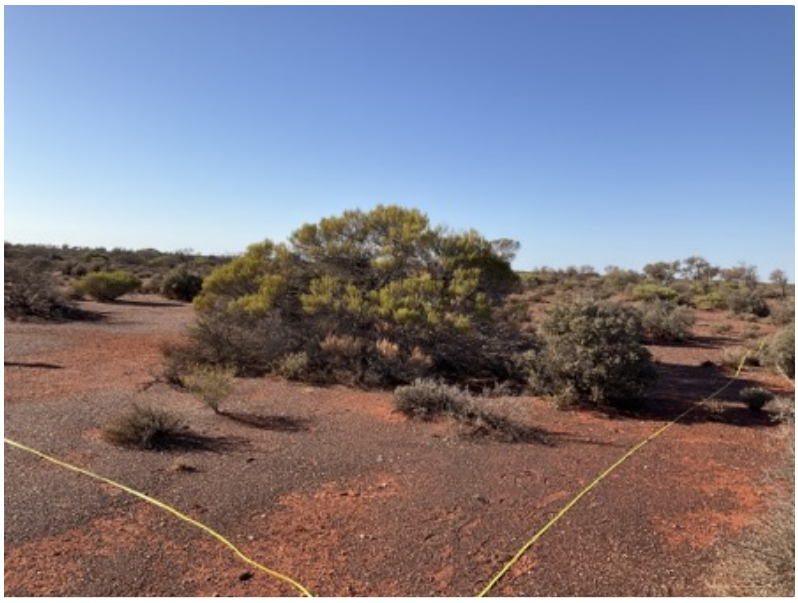
Vegetation M+ ^^*Acacia masliniana*,*Cratystylis subspinescens*,*Scaevola spinescens*\^shrub\3\i;G ^*Lawrencia squamata*,^*Frankenia setosa*\^shrub\1\r

Veg. Condition Very Good

Disturbance Cattle

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia masliniana		2.5	5	
Cratystylis subspinescens		1.3	4	
Eremophila miniata		0.7	<1	
Frankenia setosa		0.35	2.5	
Lawrencia squamata		0.4	4	

Leichardtia australis	0.8	<1
Maireana georgei	0.2	<1
Maireana glomerifolia	0.35	<1
Maireana pyramidata	0.2	<1
Maireana thesioides	0.5	<1
Maireana triptera	0.2	<1
Scaevola spinescens	1	2
Senna flexuosa	0.3	<1
Senna sp. Austin (A. Strid 20210)	0.5	<1
Senna sp. Meekatharra (E. Bailey 1-26)	1	0.5

AH23127

Staff KCP **Date** 5/04/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 372093 **mE** 6774149 **mN** **Lat.** -29.1548 **Long.** 121.6849

Habitat Edge of drainage

Aspect N/A **Slope** N/A

Soil Type Red brown clay

Rock Type Nil

Loose Rock 0 % cover **Litter** 10 % cover ; 1 cm in depth

Bare ground 30 % cover **Weeds** 0 % cover

Vegetation M+ ^*Melaleuca xerophila*,^*Rhagodia drummondii*\^shrub,chenopod shrub\3\c;G ^*Tecticornia* sp. 3\^samphire shrub\1\i

Veg. Condition Very Good

Disturbance Clearing nearby, cattle

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Angianthus tomentosus		.15	<1	
Frankenia cinerea		.02	<1	
Maireana georgei		.2	<1	
Melaleuca xerophila		2	35	
Rhagodia drummondii		1	3	

Sclerolaena cuneata	.3	<1
Tecticornia sp. 3	.4	25

AH23128

Staff KCP **Date** 5/04/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 370335 **mE** 6773990 **mN** **Lat.** -29.1561 **Long.** 121.6668

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Red brown sandy clay loam

Rock Type Mixed

Loose Rock 50-90 % cover; 2-6 mm in size **Litter** <1 % cover ; <1 cm in depth

Bare ground 90 % cover **Weeds** 0 % cover

Vegetation M+ ^^*Eremophila miniata*,*Cratystylis subspinescens*,*Hakea preissii*\^shrub\3\r;G ^*Frankenia setosa*\^shrub\1\bi

Veg. Condition Very Good

Disturbance Cattle

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia tetragonophylla		1.5	<1	
Aristida contorta		.05	<1	
Cratystylis subspinescens		1.5	3	
Eremophila miniata		1.7	4	
Frankenia setosa		0.35	1	

Hakea preissii	1.8	2
Lawrencia squamata	0.35	<1
Maireana platycarpa	0.15	<1
Pittosporum angustifolium	3.5	<1
Pittosporum angustifolium	2	<1
Scaevola spinescens	1	0.5
Sclerolaena densiflora	0.1	<1
Senna charlesiana	0.5	<1
Senna flexuosa	1.5	<1
Senna sp. Meekatharra (E. Bailey 1-26)	0.7	0.5

AH23129

Staff KCP **Date** 5/04/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 370577 **mE** 6773294 **mN** **Lat.** -29.1624 **Long.** 121.6692

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Red brown clay loam

Rock Type Mixed

Loose Rock 50-90 % cover; 6-20 mm in size **Litter** 1 % cover ; <1 cm in depth

Bare ground 85 % cover **Weeds** 0 % cover

Vegetation U+ ^,*Acacia aneura*\^,tree\6\r;M ^*Scaevola spinescens*\^shrub\3\r;

Veg. Condition Very Good

Disturbance Cattle

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia aneura		6	3	
Acacia aneura		.5	1	
Acacia incurvaneura		1.3	2	
Aristida contorta		.1	<1	
Chenopodiaceae sp.		.1	<1	
Frankenia setosa		.3	<1	

Maireana georgei	.1	<1
Maireana pyramidata	.7	<1
Ptilotus obovatus	.3	<1
Rhagodia drummondii	.6	<1
Scaevola spinescens	1.5	6
Senna charlesiana	1.5	<1
Solanum lasiophyllum	.2	<1

AH23157

Staff SOK **Date** 5/09/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 377351 **mE** 6766976 **mN** **Lat.** -29.2200 **Long.** 121.7381

Habitat Creek

Aspect N/A **Slope** N/A

Soil Type Red brown sandy loam

Rock Type Ironstone, quartz

Loose Rock 50-90 % cover; 6-20 mm in size **Litter** 20 % cover ; 0-4 cm in depth

Bare ground 95 % cover **Weeds** 0 % cover

Vegetation U+ ^*Eucalyptus camaldulensis* subsp. *arida*\^tree\7\r;M ^*Acacia burkittii*\^shrub\3\r;G ^*Pluchea dentex*\^forb\1\r

Veg. Condition Very Good

Disturbance Grazing

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia burkittii		2	4	
Enchylaena tomentosa		0.7	<1	
Eucalyptus camaldulensis subsp. *arida*		11	8	
Exocarpos aphyllus		1	<1	
Grevillea extorris		1	<1	

Hemigenia exilis	P 4	0.8	<1	1
Leichardtia australis		0.4	<1	
Pluchea dentex		0.3	1	
Ptilotus obovatus		0.3	<1	
Scaevola spinescens		0.5	<1	
Senna artemisioides subsp. *x artemisioides*		1	<1	

AH23158

Staff SOK **Date** 5/09/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 377182 **mE** 6767084 **mN** **Lat.** -29.2191 **Long.** 121.7364

Habitat Creek

Aspect N/A **Slope** N/A

Soil Type Red brown sandy loam

Rock Type Ironstone, quartz

Loose Rock 20-50 % cover; 6-20 mm in size **Litter** 2 % cover ; 0-1 cm in depth

Bare ground 85 % cover **Weeds** 0 % cover

Vegetation M+ ^*Acacia burkittii*,^*Hakea preissii*\^shrub\4\i;G ^,^*Scaevola spinescens*\^,shrub\2\r

Veg. Condition Very Good

Disturbance Grazing

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia burkittii		3	8	
Eremophila alternifolia		2	<1	
Eremophila glabra		0.6	<1	
Eremophila miniata		2	<1	
Hakea preissii		4	4	
Leichardtia australis		0.3	<1	

Maireana pyramidata	0.6	<1
Maireana suaedifolia	1	<1
Rhagodia drummondii	1	<1
Scaevola spinescens	1	<1
Senna artemisioides subsp. *filifolia*	1	<1
Senna artemisioides subsp. *x artemisioides*	1.5	<1

AH23159

Staff SOK **Date** 7/09/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 372007 **mE** 6769868 **mN** **Lat.** -29.1934 **Long.** 121.6835

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Red brown clay loam

Rock Type Calcrete

Loose Rock 2-10 % cover; 20-60 mm in size **Litter** 2 % cover ; 0-2 cm in depth

Bare ground 90 % cover **Weeds** 0 % cover

Vegetation U+ ^*Acacia duriuscula*\^tree\6\r;M ^*Eremophila platycalyx* subsp. Leonora (J. Morrisey 252), ^*Acacia tetragonophylla*\^shrub\3\r;G ^*Maireana triptera*,^*Maireana carnosa*\^chenopod shrub\1\r

Veg. Condition Very Good

Disturbance Grazing

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia duriuscula		6	3	
Acacia tetragonophylla		1.5	1	
Aristida contorta		0.1	<1	
Enchylaena tomentosa		0.4	<1	
Eremophila platycalyx subsp. Leonora (J. Morrisey 252)		2	3	

Leichardtia australis	0.2	<1
Maireana carnosa	0.1	<1
Maireana georgei	0.3	<1
Maireana sedifolia	1	<1
Maireana triptera	0.3	<1
Ptilotus obovatus	0.3	<1
Roepera ovata	0.1	<1
Scaevola spinescens	0.6	<1
Sclerolaena cuneata	0.2	<1
Sclerolaena densiflora	0.2	<1
Senna cardiosperma	0.5	<1

AH23160

Staff SOK **Date** 7/09/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 372363 **mE** 6769644 **mN** **Lat.** -29.1955 **Long.** 121.6871

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Red brown clay loam

Rock Type Calcrete

Loose Rock 10-20 % cover; 20-60 mm in size **Litter** 2 % cover ; 0-1 cm in depth

Bare ground 90 % cover **Weeds** 0 % cover

Vegetation U+ ^*Acacia duriuscula*\^tree\6\r;M ^^*Maireana sedifolia*,*Eremophila platycalyx* subsp. Leonora (J. Morrisey 252),*Scaevola spinescens*\^chenopod shrub,shrub,tree\3\r;G ^*Maireana triptera*\^chenopod shrub\1\r

Veg. Condition Very Good

Disturbance Grazing

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia aneura		0.5	<1	
Acacia duriuscula		5	3	
Aristida contorta		0.1	<1	
Eremophila oldfieldii subsp. *angustifolia*		1.5	<1	

Eremophila platycalyx subsp. Leonora (J. Morrisey 252)	1.5	2
Maireana carnosa	0.1	<1
Maireana georgei	0.3	<1
Maireana sedifolia	1	2
Maireana triptera	0.3	<1
Ptilotus obovatus	0.3	<1
Roepera ovata	0.2	<1
Scaevola spinescens	1	1
Sclerolaena cuneata	0.2	<1
Sclerolaena diacantha	0.3	<1
Sclerolaena obliquicuspis	0.2	<1
Senna artemisioides subsp. *filifolia*	1	<1
Vittadinia sp.	0.1	<1

AH23161

Staff SOK **Date** 7/09/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 372854 **mE** 6769422 **mN** **Lat.** -29.1975 **Long.** 121.6922

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Red brown clay loam

Rock Type Calcrete

Loose Rock 10-20 % cover; 20-60 mm in size **Litter** 3 % cover ; 0-1 cm in depth

Bare ground 90 % cover **Weeds** 0 % cover

Vegetation U+ ^*Acacia duriuscula*\^tree\6\r;M ^*Maireana sedifolia*,^*Scaevola spinescens*\^chenopod shrub, shrub\3\r;G ^*Roepera ovata*\^forb\1\r

Veg. Condition Very Good

Disturbance Grazing

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia duriuscula		5	6	
Acacia tetragonophylla		0.8	<1	
Aristida contorta		0.1	<1	
Atriplex bunburyana		0.4	<1	
Enneapogon caerulescens		0.2	<1	

Eremophila latrobei	0.5	<1
Eremophila platycalyx subsp. Leonora (J. Morrisey 252)	0.4	<1
Leichardtia australis	0.2	<1
Lepidium sp.	0.1	<1
Maireana sedifolia	1	3
Ptilotus exaltatus	0.3	<1
Ptilotus obovatus	0.3	<1
Roepera ovata	0.2	<1
Salsola australis	0.2	<1
Scaevola spinescens	1	<1
Sclerolaena diacantha	0.2	<1
Sclerolaena obliquicuspis	0.2	<1
Senna artemisioides subsp. *filifolia*	0.1	<1
Solanum lasiophyllum	0.3	<1

AH23162

Staff SOK **Date** 6/09/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 375847 **mE** 6767712 **mN** **Lat.** -29.2133 **Long.** 121.7228

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Red brown sandy loam

Rock Type Ironstone, quartz

Loose Rock 50-90 % cover; 6-20 mm in size **Litter** 3 % cover ; 0-1 cm in depth

Bare ground 90 % cover **Weeds** 0 % cover

Vegetation M+ ^*Acacia kalgoorliensis*\^shrub\4\r;G ^*Maireana georgei*,^*Scaevola spinescens*\^chenopod shrub,shrub\2\r

Veg. Condition Very Good

Disturbance Grazing

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia kalgoorliensis		2.5	<1	
Atriplex bunburyana		0.4	<1	
Enchylaena tomentosa		0.3	<1	
Eremophila falcata		1.6	<1	
Eremophila forrestii subsp. *forrestii*		0.3	<1	

Eremophila metallicorum	0.3	<1
Eremophila oppositifolia subsp. *angustifolia*	1.8	<1
Frankenia sp.	0.2	<1
Grevillea extorris	1.6	<1
Hakea preissii	0,5	<1
Leichardtia australis	0.3	<1
Maireana georgei		<1
Maireana triptera	0.3	<1
Ptilotus obovatus	0.2	<1
Rhagodia drummondii	0.5	<1
Scaevola spinescens	0.6	<1
Senna artemisioides subsp. *x artemisioides*	1	<1
Senna charlesiana	0.6	<1
Senna sp. Austin (A. Strid 20210)	0.5	<1
Solanum lasiophyllum	0.3	<1

AH23163

Staff SOK **Date** 5/09/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 378048 **mE** 6766291 **mN** **Lat.** -29.2263 **Long.** 121.7452

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Red brown sandy loam

Rock Type Quartz

Loose Rock 2-10 % cover; 6-20 mm in size **Litter** 5 % cover ; 0-1 cm in depth

Bare ground 95 % cover **Weeds** 0 % cover

Vegetation M+ ^*Acacia kalgoorliensis*\^shrub\3\r;G ^^*Maireana triptera*,*Lawrencia squamata*,*Frankenia* sp. \^chenopod shrub,shrub\1\r

Veg. Condition Very Good

Disturbance Grazing

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia kalgoorliensis		1.8	3	
Eremophila sp.		0.3	<1	
Frankenia sp.		0.3	<1	
Hakea preissii		0.5	<1	
Lawrencia squamata		0.3	<1	

Maireana georgei	0.3	<1
Maireana tomentosa	0.3	<1
Maireana triptera	0.3	1
Ptilotus exaltatus	0.3	<1
Scaevola spinescens	0.5	<1

AH23164

Staff SOK **Date** 6/09/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 375436 **mE** 6767904 **mN** **Lat.** -29.2115 **Long.** 121.7185

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Red brown sandy loam

Rock Type Ironstone, quartz

Loose Rock 20-50 % cover; 6-20 mm in size **Litter** 5 % cover ; 0-2 cm in depth

Bare ground 9 % cover **Weeds** 0 % cover

Vegetation M+ ^*Acacia kalgoorliensis*\^shrub\4\r;G ^\^\2\r

Veg. Condition Very Good

Disturbance Grazing

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia kalgoorliensis		2.5	7	
Eremophila falcata		0.7	<1	
Maireana georgei		0.3	<1	
Maireana triptera		0.2	<1	
Ptilotus obovatus		0.3	<1	
Scaevola spinescens		0.5	<1	

Senna charlesiana	1	<1
Senna sp. Austin (A. Strid 20210)	0.7	<1
Sida ectogama	0.6	<1
Solanum lasiophyllum	0.2	<1

AH23165

Staff SOK **Date** 7/09/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 373270 **mE** 6769348 **mN** **Lat.** -29.1982 **Long.** 121.6964

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Brown clay loam

Rock Type Calcrete

Loose Rock 2-10 % cover; 20-60 mm in size **Litter** 2 % cover ; 0-1 cm in depth

Bare ground 90 % cover **Weeds** 0 % cover

Vegetation M+ ^*Acacia victoriae* subsp. *victoriae*\^shrub\4\i;G ^*Senna artemisioides* subsp. *filifolia*\^shrub\2\r

Veg. Condition Very Good

Disturbance Grazing

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia duriuscula		2	<1	
Acacia tetragonophylla		2	<1	
Acacia victoriae subsp. *victoriae*		3	10	
Austrostipa elegantissima		0.8	<1	
Austrostipa sp.		0.4	<1	
Enneapogon caerulescens		0.2	<1	

Eremophila glabra	0.4	<1
Eremophila longifolia	1	<1
Leichardtia australis	0.6	<1
Maireana pentatropis	0.1	<1
Ptilotus obovatus	0.4	<1
Roepera ovata	0.1	<1
Salsola australis	0.2	<1
Santalum lanceolatum	1.6	<1
Scaevola spinescens	1	<1
Senna artemisioides subsp. *filifolia*	1	6
Solanum nummularium	0.4	<1
Vittadinia sp.	0.1	<1

AH23166

Staff SOK **Date** 5/09/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 377558 **mE** 6766729 **mN** **Lat.** -29.2223 **Long.** 121.7402

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Red brown sandy loam

Rock Type Quartz, ironstone

Loose Rock 20-50 % cover; 6-20 mm in size **Litter** 1 % cover ; 0-1 cm in depth

Bare ground 95 % cover **Weeds** 0 % cover

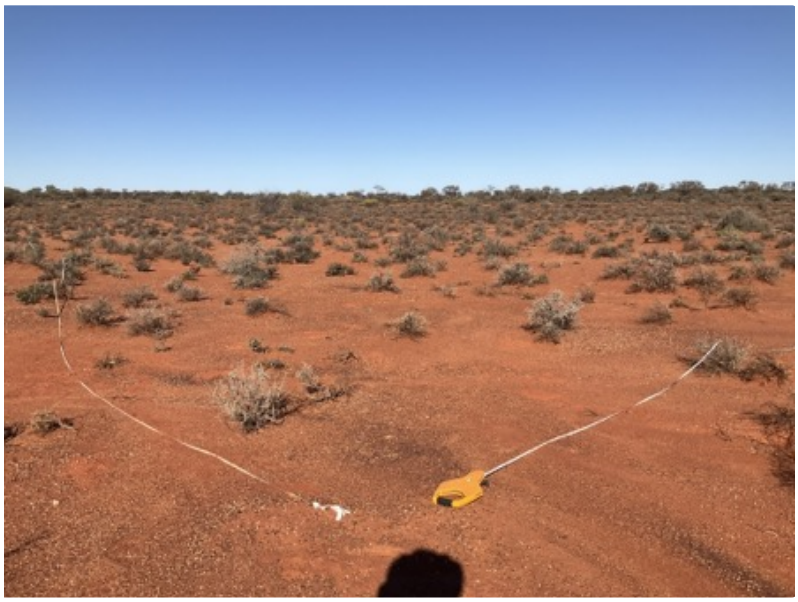
Vegetation G+ ^*Lawrencia squamata*,^*Maireana glomerifolia*\^shrub,chenopod shrub\1\r

Veg. Condition Very Good

Disturbance Grazing

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Cratystylis subspinescens		0.5	<1	
Eremophila miniata		0.5	<1	
Frankenia interioris		0.2	<1	
Frankenia setosa		0.3	<1	
Lawrencia squamata		0.4	4	
Maireana carnosa		0.2	<1	

Maireana georgei	0.3	<1
Maireana glomerifolia	0.3	2
Maireana tomentosa	0.2	<1
Maireana triptera	0.3	<1
Ptilotus exaltatus	0.3	<1
Senna charlesiana	0.5	<1

AH23167

Staff SOK **Date** 6/09/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 377015 **mE** 6767172 **mN** **Lat.** -29.2182 **Long.** 121.7347

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Red brown sandy

Rock Type Quartz

Loose Rock <2 % cover; 6-20 mm in size **Litter** 2 % cover ; 0-1 cm in depth

Bare ground 85 % cover **Weeds** 0 % cover

Vegetation G+ ^*Maireana pyramidata*,^*Lawrencia squamata*\^chenopod shrub,shrub\1\r

Veg. Condition Very Good

Disturbance Grazing

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Aristida contorta		0.2	<1	
Atriplex bunburyana		0.4	<1	
Atriplex codonocarpa		0.2	<1	
Calandrinia sp.		0.1	<1	
Disphyma crassifolium		0.1	<1	
Eragrostis dielsii		0.1	<1	

Frankenia interioris	0.2	<1
Frankenia sp.	0.2	<1
Gunniopsis quadrifida	0.3	<1
Lawrencia squamata	0.4	2
Maireana georgei	0.2	<1
Maireana pyramidata	0.5	3
Maireana tomentosa	0.2	<1
Sclerolaena cuneata	0.3	<1
Sclerolaena obliquicuspis	0.2	<1
Vittadinia sp.	0.2	<1

AH23168

Staff SOK **Date** 6/09/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 376726 **mE** 6767415 **mN** **Lat.** -29.2160 **Long.** 121.7318

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Red brown sandy loam

Rock Type Calcrete, ironstone

Loose Rock 20-50 % cover; 6-20 mm in size **Litter** 2 % cover ; 0-1 cm in depth

Bare ground 85 % cover **Weeds** 0 % cover

Vegetation G+ ^*Maireana pyramidata*,^*Lawrencia squamata*\^chenopod shrub,shrub\1\i

Veg. Condition Very Good

Disturbance Grazing

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Aristida contorta		0.1	<1	
Atriplex bunburyana		0.5	<1	
Cratystylis subspinescens		1	<1	
Enneapogon caerulescens		0.2	<1	
Enneapogon cylindricus		0.1	<1	
Enteropogon ramosus		0.3	<1	

Eremophila miniata	0.3	<1
Frankenia sp.	0.4	<1
Lawrencia squamata	0.4	2
Leichardtia australis	0.4	<1
Maireana carnosa	0.1	<1
Maireana georgei	0.3	<1
Maireana glomerifolia	0.3	<1
Maireana pyramidata	0.5	4
Maireana triptera	0.2	<1
Ptilotus exaltatus	0.2	<1
Ptilotus obovatus	0.3	<1
**Rumex vesicarius*	0.3	<1
Scaevola spinescens	0.6	<1
Sclerolaena obliquicuspis	0.2	<1
Solanum lasiophyllum	0.3	<1
Solanum nummularium	0.4	<1
**Sonchus oleraceus*	0.3	<1
Vittadinia sp.	0.2	<1

AH23169

Staff SOK **Date** 6/09/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 384443 **mE** 6768594 **mN** **Lat.** -29.2061 **Long.** 121.8113

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Red brown sandy loam

Rock Type Nil

Loose Rock 0 % cover **Litter** 20 % cover ; 0-2 cm in depth

Bare ground 95 % cover **Weeds** 0 % cover

Vegetation U+ ^*Acacia caesaneura*,^*Acacia aneura*\^tree\6\i;M ^*Acacia ramulosa* var. *ramulosa*\^shrub\3\bi;G ^*Eragrostis eriopoda*,^*Eremophila forrestii* subsp. *forrestii*\^tussock grass,shrub\1\r

Veg. Condition Very Good

Disturbance Grazing

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia aneura		5	10	
Acacia caesaneura		6	10	
Acacia ramulosa var. *ramulosa*		2	1	
Eragrostis eriopoda		0.1	2	
Eremophila forrestii subsp. *forrestii*		0.5	<1	

Eremophila sp.	0.2	<1
Monachather paradoxus	0.	<1
Solanum lasiophyllum	0.1	<1

AH23170

Staff SOK **Date** 6/09/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 381723 **mE** 6767869 **mN** **Lat.** -29.2124 **Long.** 121.7832

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Red brown sandy loam

Rock Type Nil

Loose Rock 0 % cover **Litter** 10 % cover ; 0-2 cm in depth

Bare ground 90 % cover **Weeds** 0 % cover

Vegetation U+ ^*Acacia caesaneura*\^tree\6\r;M ^*Acacia ramulosa* var. *ramulosa*\^shrub\3\r;G ^*Eragrostis eriopoda*,^*Monachather paradoxus*\^tussock grass\1\r

Veg. Condition Very Good

Disturbance Grazing

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia caesaneura		6	8	
Acacia ramulosa var. *ramulosa*		2	8	
Eragrostis eriopoda		0.3	2	
Eremophila forrestii subsp. *forrestii*		0.4	<1	
Goodenia havilandii		0.1	<1	

Goodeniaceae sp.	0.1	<1
Haloragis odontocarpa	0.4	<1
Monachather paradoxus	0.2	<1

AH23171

Staff SOK **Date** 5/09/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 380259 **mE** 6768094 **mN** **Lat.** -29.2102 **Long.** 121.7682

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Red brown sandy loam

Rock Type Nil

Loose Rock 0 % cover **Litter** 1 % cover ; 0-1 cm in depth

Bare ground 85 % cover **Weeds** 0 % cover

Vegetation G+ ^^*Cratystylis subspinescens*,*Lawrencia squamata*,*Maireana georgei*\^shrub,chenopod shrub\2\r

Veg. Condition Very Good

Disturbance Grazing

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia duriuscula		2	<1	
Aristida contorta		0.1	<1	
Calandrinia sp.			<1	
Cratystylis subspinescens		1	2	
Enneapogon caerulescens		0.2	<1	

Eragrostis dielsii	0.1	<1
Eremophila miniata	0.5	<1
Eremophila scoparia	0.5	<1
Frankenia interioris	0.3	<1
Hakea preissii	0.5	<1
Lawrencia squamata	0.5	2
Maireana georgei	0.3	<1
Maireana glomerifolia	0.3	<1
Maireana pyramidata	0.4	<1
Maireana sedifolia	0.5	<1
Maireana tomentosa	0.2	<1
Maireana triptera	0.3	<1
Sclerolaena diacantha	0.3	<1
Senna artemisioides subsp. *filifolia*	1	<1

AH23172

Staff SOK **Date** 5/09/2023 **Season** P

Revisit

Type Q 20 m x 20 m

Location

MGA Zone 51 370645 **mE** 6771629 **mN** **Lat.** -29.1774 **Long.** 121.6697

Habitat Flat

Aspect N/A **Slope** N/A

Soil Type Red brown clay

Rock Type Quartz, ironstone

Loose Rock <2 % cover; 6-20 mm in size **Litter** 4 % cover ; 0-2 cm in depth

Bare ground 85 % cover **Weeds** 0 % cover

Vegetation U+ ^*Acacia caesaneura*,^*Acacia incurvaneura*\^tree\6\r;M ^*Scaevola spinescens*,^*Acacia tetragonophylla*\^shrub\3\r;G ^*Eragrostis eriopoda*\^tussock grass\1\bi

Veg. Condition Very Good

Disturbance Grazing

Fire Age >10 years

Notes



Species	WA Cons.	Height (m)	Cover (%)	Count
Acacia caesaneura		7	3	
Acacia incurvaneura		7	2	
Acacia ramulosa var. *ramulosa*		1.5	1	
Acacia tetragonophylla		1.5	1	
Eragrostis eriopoda		0.1	<1	

Eremophila forrestii subsp. *forrestii*	0.5	1
Leichardtia australis	0.5	<1
Rhagodia drummondii	0,7	<1
Scaevola spinescens	1	2
Sida ectogama	1	<1

APPENDIX SIX DBCA REPORT FORMS

Department of **Biodiversity, Conservation and Attractions**

GOVERNMENT OF WESTERN AUSTRALIA

Threatened and Priority Flora Report Form

Version 1.4 March 2021

Please complete as much of the form as possible, with emphasis on those sections bordered in black. For information on how to complete the form please refer to the Threatened & Priority Flora Report Form (TPRF) manual on the DBCA website at www.dpaw.wa.gov.au/plants-and-animals/threatened-species-and-communities/threatened-plants

TAXON: Hemigenia exilis **TPFL Pop. No:**

OBSERVATION DATE: 4/4/2023 **CONSERVATION STATUS:** P4 **New population** ☒

OBSERVER/S: S. Kern **PHONE** 08 9430 8955

ROLE: Botanist **ORGANISATION:** Ecoscape

EMAIL: stephenk@ecoscape.com.au

DESCRIPTION OF LOCATION (Provide at least nearest town/named locality, and the distance and direction to that place)**:**

Approximately 50 km southeast of Leonora

Reserve No:

DBCA DISTRICT: Goldfields **LGA:** Shire of Leonora Land manager present: ☐

DATUM:

GDA94 / MGA94 ☒
AGD84 / AMG84 ☐
WGS84 ☐
Unknown ☐

COORDINATES: (If UTM coords provided, **Zone** is also required)

DecDegrees ☐ DegMinSec ☐ UTMs ☒

Lat / Northing: 6767049

Long / Easting: 377502

ZONE: 51

METHOD USED:

GPS ☒ Differential GPS ☐ Map ☐

No. satellites: ____ Map used: _____

Boundary polygon captured: ☐ Map scale: _____

LAND TENURE:

Nature reserve ☐	Timber reserve ☐	Private property ☐	Rail reserve ☐	Shire road reserve ☐
National park ☐	State forest ☐	Pastoral lease ☒	MRWA road reserve ☐	Other Crown reserve ☐
Conservation park ☐	Water reserve ☐	UCL ☐	SLK/Pole _____ to _____	Specify other: _____

AREA ASSESSMENT: Edge survey ☐ Partial survey ☒ Full survey ☐ Area observed (m²): _____

EFFORT: Time spent surveying (minutes): _____ No. of minutes spent / 100 m²: _____

POP'N COUNT ACCURACY: Actual ☐ Extrapolation ☐ Estimate ☒ Count method: _____ (Refer to field manual for list)

WHAT COUNTED: Plants ☒ Clumps ☐ Clonal stems ☐

TOTAL POP'N STRUCTURE:

	Mature:	Juveniles:	Seedlings:	Totals:
Alive	10			
Dead				

Area of pop (m²): _____

Note: Pls record count as numbers (not percentages) for database.

QUADRATS PRESENT: No. ___ Size _____ Data attached ☐ Total area of quadrats (m²): _____

Summary Quad. Totals: Alive				

REPRODUCTIVE STATE: Clonal ☐ Vegetative ☐ Flowerbud ☐ Flower ☐ Immature fruit ☐ Fruit ☒ Dehisced fruit ☐ Percentage in flower: 100%

CONDITION OF PLANTS: Healthy ☒ Moderate ☐ Poor ☐ Senescent ☐

COMMENT:

THREATS - type, agent and supporting information: Eg clearing, too frequent fire, weed, disease. Refer to field manual for list of threats & agents. **Specify agent** where relevant. Rate current and potential threat impact: N=Nil, L=Low, M=Medium, H=High, E=Extreme Estimate time to potential impact: S=Short (<12mths), M=Medium (<5yrs), L=Long (5yrs+)	**Current impact (N-E)**	**Potential Impact (L-E)**	**Potential Threat Onset (S-L)**
• Mining Grazing	N	L	M
•			
•			

Please return completed form to **Species And Communities Program** DBCA,
Locked Bag 104, BENTLEY DELIVERY CENTRE WA 6983 **OR** email to: flora.data@dbca.wa.gov.au

RECORDS: Please forward to **Flora Administrative Officer,** Species and Communities Program.

Record entered by:_____ **Sheet No.:**_____ **Record Entered in Database** ❑

Department of **Biodiversity, Conservation and Attractions**

GOVERNMENT OF WESTERN AUSTRALIA

Threatened and Priority Flora Report Form

Version 1.4 March 2021

HABITAT INFORMATION:

LANDFORM:
- Crest ☐
- Hill ☐
- Ridge ☐
- Outcrop ☐
- Slope ☐
- Flat ☐
- Open depression ☐
- Drainage line ☒
- Closed depression ☐
- Wetland ☐

ROCK TYPE:
- Granite ☐
- Dolerite ☐
- Laterite ☐
- Ironstone ☒
- Limestone ☐
- Quartz ☐

Specify other: _____

LOOSE ROCK: (on soil surface; eg gravel, quartz fields)
- 0-10% ☐
- 10-30% ☐
- 30-50% ☒
- 50-100% ☐

SOIL TYPE:
- Sand ☐
- Sandy loam ☒
- Loam ☐
- Clay loam ☐
- Light clay ☐
- Peat ☐

Specify other: _____

SOIL COLOUR:
- Red ☒
- Brown ☒
- Yellow ☐
- White ☐
- Grey ☐
- Black ☐

Specify other: _____

DRAINAGE:
- Well drained ☒
- Seasonally inundated ☐
- Permanently inundated ☐
- Tidal ☐

Specific **Landform** Element: _____
(Refer to field manual for additional values)

CONDITION OF SOIL: Dry ☒ Moist ☐ Waterlogged ☐ Inundated ☐

VEGETATION CLASSIFICATION*:

Eg: **1**. Banksia woodland (B. attenuata, B. ilicifolia); **2**. Open shrubland (Hibbertia sp., Acacia spp.) ; **3**. Isolated clumps of sedges (M.tetragona)

1. _____
2. _____
3. _____
4. _____

ASSOCIATED SPECIES: _____

Other (non-dominant) spp _____

* Please record up to four of the most representative vegetation layers (with up to three dominant species in each layer). Structural Formations should follow 2009 *Australian Soil and Land Survey Field Handbook* guidelines – refer to field manual for further information and structural formation table.

CONDITION OF HABITAT: Pristine ☐ Excellent ☐ Very good ☐ Good ☒ Degraded ☐ Completely degraded ☐

COMMENT: _____

FIRE HISTORY: **Last Fire:** Season/Month: _____ Year: _____ **Fire Intensity:** High ☐ Medium ☐ Low ☐ No signs of fire ☒

FENCING: Not required ☒ Present ☐ Replace / repair ☐ Required ☐ Length req'd: _____

ROADSIDE MARKERS: Not required ☒ Present ☐ Replace / reposition ☐ Required ☐ Quantity req'd: _____

OTHER COMMENTS: (Please include recommended management actions and/or implemented actions - include date. Also include details of additional data available, and how to locate it.) _____

FLORA AUTHORISATION / LICENCE No: FB62000001-2 Note if only observing plants (i.e. no specimens or plant matieral is taken) then no authorisation/licence is required. For further information on authorisation and licening requirements see the Threatened Flora and Wildlife Licensing pages on DBCA's website. Any actions carried out under authorisations/licences should be recorded above in the OTHER COMMENTS section.

SPECIMEN: Collectors No: WA Herb. ☐ Regional Herb. ☐ District Herb. ☐ Other: _____

LODGEMENT: WA Herb Lodgement No: _____

ATTACHED: Map ☐ Mudmap ☐ Photo ☐ GIS data ☐ Field notes ☐ Other: _____

COPY SENT TO: Regional Office ☐ District Office ☐ Other: _____

Submitter of Record: S. Kern Role: Botanist Signed: Stephen Kern Date: 25/08/2023

Please return completed form to **Species And Communities Program** DBCA,
Locked Bag 104, BENTLEY DELIVERY CENTRE WA 6983 **OR** email to: flora.data@dbca.wa.gov.au

RECORDS: Please forward to **Flora Administrative Officer,** Species and Communities Program.

Record entered by:_____ **Sheet No.:**_____ **Record Entered in Database** ❑

Department of **Biodiversity, Conservation and Attractions**

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Version 1.4 March 2021

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TAXON: Tecticornia globulifera **TPFL Pop. No:**

OBSERVATION DATE: 28/3/2023 **CONSERVATION STATUS:** P1 **New population** ☒

OBSERVER/S: K. Pannell **PHONE** 08 9430 8955

ROLE: Botanist **ORGANISATION:** Ecoscape

EMAIL: kylap@ecoscape.com.au

DESCRIPTION OF LOCATION (Provide at least nearest town/named locality, and the distance and direction to that place)**:**

Approximately 43 km southeast of Leonora

Reserve No:

DBCA DISTRICT: Goldfields **LGA:** Shire of Leonora Land manager present: ☐

DATUM:

GDA94 / MGA94 ☒
AGD84 / AMG84 ☐
WGS84 ☐
Unknown ☐

COORDINATES: (If UTM coords provided, **Zone** is also required)

DecDegrees ☐ DegMinSec ☐ UTMs ☒

Lat / Northing: 6774012

Long / Easting: 372144

ZONE: 51

METHOD USED:

GPS ☒ Differential GPS ☐ Map ☐

No. satellites: ____ Map used: _____

Boundary polygon captured: ☐ Map scale: _____

LAND TENURE:

Nature reserve ☐	Timber reserve ☐	Private property ☐	Rail reserve ☐	Shire road reserve ☐
National park ☐	State forest ☐	Pastoral lease ☒	MRWA road reserve ☐	Other Crown reserve ☐
Conservation park ☐	Water reserve ☐	UCL ☐	SLK/Pole _____ to _____	Specify other: _____

AREA ASSESSMENT: Edge survey ☐ Partial survey ☒ Full survey ☐ Area observed (m²): _____

EFFORT: Time spent surveying (minutes): _____ No. of minutes spent / 100 m²: _____

POP'N COUNT ACCURACY: Actual ☐ Extrapolation ☐ Estimate ☒ Count method: _____ (Refer to field manual for list)

WHAT COUNTED: Plants ☒ Clumps ☐ Clonal stems ☐

TOTAL POP'N STRUCTURE:

	Mature:	Juveniles:	Seedlings:	Totals:
Alive	1			
Dead				

Area of pop (m²): _____

Note: Pls record count as numbers (not percentages) for database.

QUADRATS PRESENT: No. ___ Size _____ Data attached ☐ Total area of quadrats (m²): _____

Summary Quad. Totals: Alive				

REPRODUCTIVE STATE: Clonal ☐ Vegetative ☐ Flowerbud ☐ Flower ☐ Immature fruit ☐ Fruit ☒ Dehisced fruit ☐ Percentage in flower: 100%

CONDITION OF PLANTS: Healthy ☒ Moderate ☐ Poor ☐ Senescent ☐

COMMENT:

THREATS - type, agent and supporting information: Eg clearing, too frequent fire, weed, disease. Refer to field manual for list of threats & agents. **Specify agent** where relevant. Rate current and potential threat impact: N=Nil, L=Low, M=Medium, H=High, E=Extreme Estimate time to potential impact: S=Short (<12mths), M=Medium (<5yrs), L=Long (5yrs+)	**Current impact (N-E)**	**Potential Impact (L-E)**	**Potential Threat Onset (S-L)**
• Mining Grazing	N	L	M
•			
•			

Please return completed form to **Species And Communities Program** DBCA,
Locked Bag 104, BENTLEY DELIVERY CENTRE WA 6983 **OR** email to: flora.data@dbca.wa.gov.au

RECORDS: Please forward to **Flora Administrative Officer,** Species and Communities Program.

Record entered by:_____ **Sheet No.:**_____ **Record Entered in Database** ❑

Department of **Biodiversity, Conservation and Attractions**

GOVERNMENT OF WESTERN AUSTRALIA

Threatened and Priority Flora Report Form

Version 1.4 March 2021

HABITAT INFORMATION:

LANDFORM:
Crest ☐
Hill ☐
Ridge ☐
Outcrop ☐
Slope ☐
Flat ☐
Open depression ☐
Drainage line ☐
Closed depression ☐
Wetland ☒

ROCK TYPE:
Granite ☐
Dolerite ☐
Laterite ☐
Ironstone ☐
Limestone ☐
Quartz ☐
Specify other: _____

LOOSE ROCK:
(on soil surface; eg gravel, quartz fields)
0-10% ☒
10-30% ☐
30-50% ☐
50-100% ☐

SOIL TYPE:
Sand ☐
Sandy loam ☐
Loam ☐
Clay loam ☒
Light clay ☐
Peat ☐
Specify other: _____

SOIL COLOUR:
Red ☒
Brown ☒
Yellow ☐
White ☐
Grey ☐
Black ☐
Specify other: _____

DRAINAGE:
Well drained ☐
Seasonally inundated ☒
Permanently inundated ☐
Tidal ☐

Specific **Landform** Element: _____
(Refer to field manual for additional values)

CONDITION OF SOIL: Dry ☒ Moist ☐ Waterlogged ☐ Inundated ☐

VEGETATION CLASSIFICATION*:
Eg: **1**. Banksia woodland (B. attenuata, B. ilicifolia); **2**. Open shrubland (Hibbertia sp., Acacia spp.) ; **3**. Isolated clumps of sedges (M.tetragona)

1. Tecticornia sp. Burnerbinmah (D. Edinger et al. 101) low samphire shrubland
2.
3.
4.

ASSOCIATED SPECIES:

Other (non-dominant) spp

* Please record up to four of the most representative vegetation layers (with up to three dominant species in each layer). Structural Formations should follow 2009 *Australian Soil and Land Survey Field Handbook* guidelines – refer to field manual for further information and structural formation table.

CONDITION OF HABITAT: Pristine ☐ Excellent ☐ Very good ☒ Good ☐ Degraded ☐ Completely degraded ☐

COMMENT:

FIRE HISTORY: **Last Fire:** Season/Month: _____ Year: _____ **Fire Intensity:** High ☐ Medium ☐ Low ☐ No signs of fire ☒

FENCING: Not required ☒ Present ☐ Replace / repair ☐ Required ☐ Length req'd: _____

ROADSIDE MARKERS: Not required ☒ Present ☐ Replace / reposition ☐ Required ☐ Quantity req'd: _____

OTHER COMMENTS: (Please include recommended management actions and/or implemented actions - include date. Also include details of additional data available, and how to locate it.)

FLORA AUTHORISATION / LICENCE No: FB62000261-2 Note if only observing plants (i.e. no specimens or plant matieral is taken) then no authorisation/licence is required. For further information on authorisation and licening requirements see the Threatened Flora and Wildlife Licensing pages on DBCA's website. Any actions carried out under authorisations/licences should be recorded above in the OTHER COMMENTS section.

SPECIMEN: Collectors No:AH23002-2 WA Herb. ☒ Regional Herb. ☐ District Herb. ☐ Other: _____

LODGEMENT: WA Herb Lodgement No: _____

ATTACHED: Map ☐ Mudmap ☐ Photo ☐ GIS data ☐ Field notes ☐ Other: _____

COPY SENT TO: Regional Office ☐ District Office ☐ Other: _____

Submitter of Record: S. Kern Role: Botanist Signed: Stephen Kern Date: 25/08/2023

Please return completed form to **Species And Communities Program** DBCA,
Locked Bag 104, BENTLEY DELIVERY CENTRE WA 6983 **OR** email to: flora.data@dbca.wa.gov.au

RECORDS: Please forward to **Flora Administrative Officer,** Species and Communities Program.

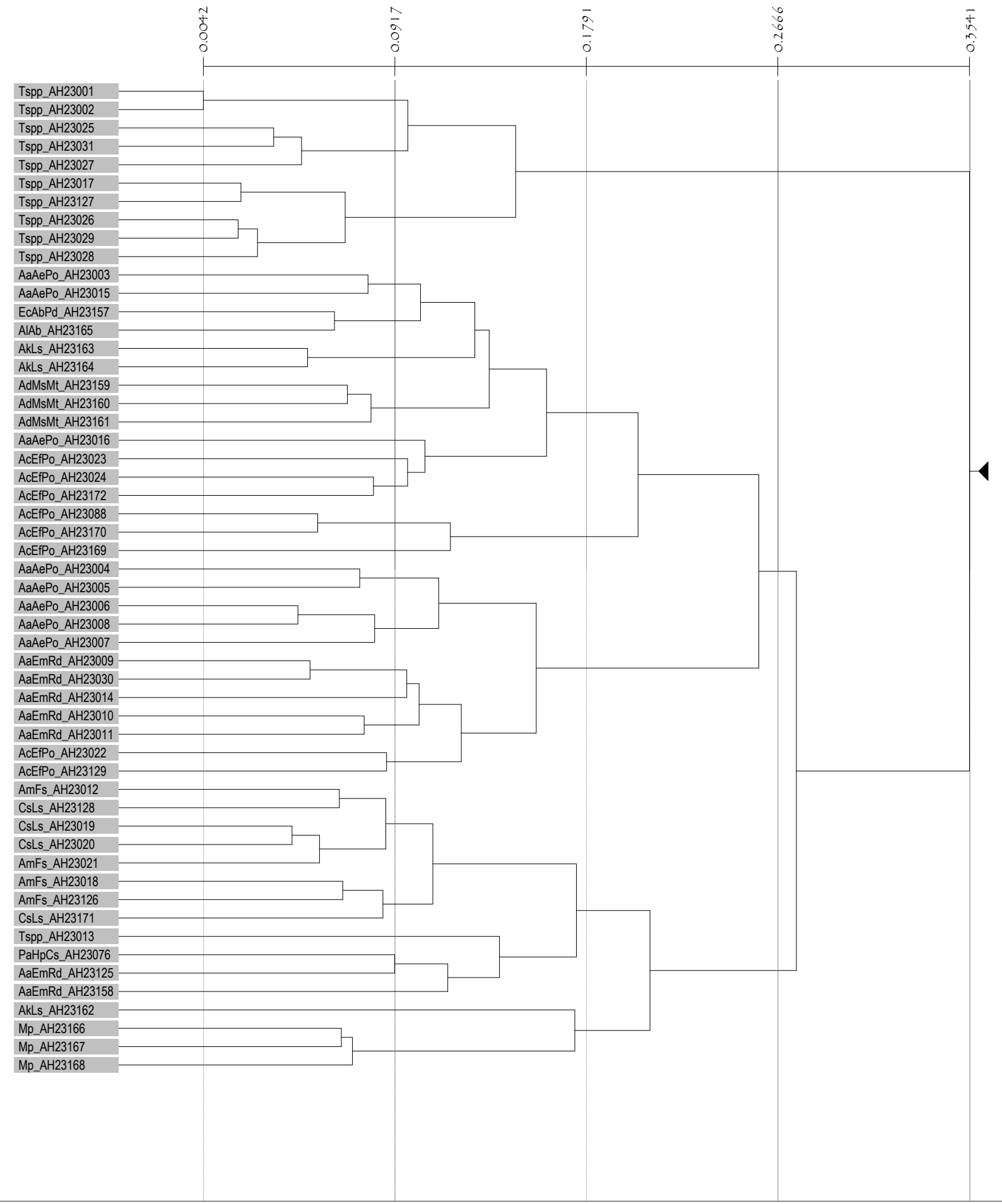
Record entered by:_____ **Sheet No.:**_____ **Record Entered in Database** ❑

APPENDIX SEVEN FLORISTIC ANALYSIS DENDROGRAM

Figure 6: Floristic analysis dendrogram

Fusion Type: Flexible UPGMA Beta = -0.10
On Association: Two-Step (Columns) Created on: 16:47:09, February 08, 2024

Column Fusion Dendrogram



APPENDIX EIGHT BAT CALL ANALYSIS

Acoustic analysis and bat call identification from Apollo Hill, Western Australia

Prepared for **Ecoscape Australia Pty Ltd**

Version **23 June 2023**

SZ project reference **SZ675**



Prepared by **Dr Kyle Armstrong and Yuki Konishi**

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Specialised Zoological (2023). Acoustic analysis and bat call identification from Apollo Hill, Western Australia. Unpublished report by Specialised Zoological for Ecoscape Australia Pty Ltd, 23 June 2023, project reference SZ675.

Summary

Bat identifications from acoustic recordings are provided from the Apollo Hill project area, near Leonora in the Goldfields region of Western Australia. Eight species of bat were identified as being present (**Tables 1** and **2**). None are listed as Threatened species. Representative echolocation calls for each identification are illustrated (**Figure 1**), as recommended by the Australasian Bat Society (ABS 2006). Further details are available should verification be required.

Methods

The data provided were recorded in Zero Crossings format with Titley Scientific Anabat Swift bat detectors (set to turn on automatically at sunset and off at sunrise). All Zero Crossings sound files were inspected in Titley Scientific Anabat Insight software version 2.0.7. The identification of bat species from Zero Crossings-format recordings of their echolocation calls was based on measurements of characteristic frequency and observation of pulse shape in sequences. Species attributions were made based on information in the author's own unpublished material, as well as Churchill (2008). Nomenclature follows Jackson and Groves (2015). Distribution information for all bat species considered here was checked against the BatMap resource hosted by the Australasian Bat Society, Inc (https://www.ausbats.org.au/batmap.html).

Comments on identifications

Most species were identified unambiguously. Some call types of Gould's Wattled Bat *Chalinolobus gouldii* appear similar to those of two candidate species of free-tailed bat *Ozimops* sp., and all attributions to *C*. *gouldii* were made based on examples that showed repeated alternation of high and low characteristic frequency in successive pulses.

The identifications of the free-tailed bat species *Ozimops* spp. contains a degree of uncertainty because calls with pulse shape and characteristic frequencies consistent with those of the Western Free-tailed Bat *O. kitcheneri* were present even though the accepted distribution of this species does not extend northwards to the study area. In addition, the variation in call characteristics associated with *C. gouldii* made it difficult to distinguish calls of the Inland Free-tailed Bat *Ozimops petersi*; and this latter species was expected rather than *O. kitcheneri*. A few examples were observed that were clearly consistent with *O. petersi*.

The most likely candidate for calls attributable to a species of long-eared bat *Nyctophilus* sp. given the survey location is the Lesser Long-eared Bat *Nyctophilus geoffroyii*.

The lack of calls clearly attributable to the Inland Forest Bat *Vespadelus baverstocki* is a conspicuous absence.

There was a single example sequence that was consistent with the calls of the Yellow-bellied Sheath-tailed Bat *Saccolaimus flaviventris*, but the study area is much further south than the accepted southern distribution limit for this species. Zero Crossings representations of the White-striped Free-tailed Bat *Austronomus australis* can sometimes resemble calls of *S.*

flaviventris. However, the example in this dataset appeared to be a high-quality example of *S. flaviventris*. Harmonic information that would have resolved the ambiguity (Armstrong et al. 2021) is not usually present in Zero Crossings sound files.

Limitations

The identifications presented in this report have been made within the following context:

1. The identifications made herein were based on the ultrasonic acoustic data recorded and provided by a 'third party' (the client named on the front of this report).
2. The scope of this report extended to providing information on the identification of bat species in bulk ultrasonic recordings. Further comment on these species and the possible impacts of a planned project on bat species were not part of the scope.
3. In the case of the present report, the recording equipment was not set up or supplied by Specialised Zoological. The equipment was operated by the third party during the survey.
4. Other than the general location of the study area, Specialised Zoological has not been provided with detailed information of the survey area, has not made a visit to observe the habitats available for bats, nor have we visited the specific project areas on a previous occasion.
5. Specialised Zoological has had no input into the overall design and timing of this bat survey, recording site placement, nor the degree of recording site replication.
6. While Specialised Zoological has made identifications to the best of our ability given the available materials, and reserves the right to re-examine the data and revise any identification following a query, it is the client's and / or proponent's responsibility to provide supporting evidence for any identification, which might require follow-up trapping effort or non-invasive methods such as video recordings. Specialised Zoological bears no liability for any follow-up work that may be required to support an identification based initially on the analysis of acoustic recordings undertaken and reported on here.
7. There are a variety of factors that affect the 'detectability' of each bat species, given the frequency, power and shape characteristics of their calls. Further information on the analysis and the various factors that can impinge on the reliability of identifications can be provided upon request.
8. The analysis of ultrasonic recordings is one of several methods that can be used to survey for bats, and comprehensive surveys typically employ more than one method. If an identification in the present report is ambiguous or in question, a trapping programme would help to resolve the presence of the possibilities in the project area.
9. This version of the document supersedes any previous version. Previous drafts are not authorised by us for submission to the regulator or the public domain.

References

ABS (2006). Recommendations of the Australasian Bat Society Inc for reporting standards for insectivorous bat surveys using bat detectors. *The Australasian Bat Society Newsletter* 27: 6–9. [ISSN 1448-5877]

Armstrong K.N., Broken-Brow J., Hoye G., Ford G., Thomas M. and Corben C. (2021). Effective detection and identification of sheath-tailed bats of Australian forests and woodlands. *Australian Journal of Zoology* 68:346–363. https://doi.org/10.1071/ZO20044

Churchill, S.K. (2008). *Australian bats.* 2nd ed. Allen and Unwin, Crows Nest, NSW.

Jackson, S.M. and Groves, C.P. (2015). *Taxonomy of Australian mammals*. CSIRO Publishing, Victoria.

Table 1. Species identified in the present survey from all sites combined.

EMBALLONURIDAE	
Yellow-bellied Sheath-tailed Bat	*Saccolaimus flaviventris*
VESPERTILIONIDAE	
Gould's Wattled Bat	*Chalinolobus gouldii*
Lesser Long-eared Bat	*Nyctophilus geoffroyi*
Inland Broad-nosed Bat	*Scotorepens balstoni*
Finlayson's Cave Bat	*Vespadelus finlaysoni*
MOLOSSIDAE	
White-striped Free-tailed Bat	*Austronomus australis*
Western Free-tailed Bat	*Ozimops kitcheneri*
Inland Free-tailed Bat	*Ozimops petersi*

Table 2. Species identifications, with the degree of confidence indicated by a code. Date and recording unit number correlates with site; see *Table 1* for full species names.

		A. australis	*C. gouldii*	*N. geoffroyi*	*O. kitcheneri*	*O. petersi*	*S. balstoni*	*S. flaviventris*	*V. finlaysoni*
Swift 622828	**Site ABS01**								
28/03/2023	-29.144467, 121.628708	.	X	NC	X	NC	X	.	X
29/03/2023	-29.144575, 121.628822	X	X	NC	X	NC	X	.	X
30/03/2023	-29.144627, 121.628968	.	X	NC	.	NC	.	.	X
31/03/2023	-29.144537, 121.628793	X	X	NC	X	NC	.	.	.
1/04/2023	-29.144555, 121.628810	X	X	NC	X	NC	X	.	.
2/04/2023	-29.145023, 121.627873	X	X	NC	X	NC	X	.	X
3/04/2023	-29.144587, 121.628808	X	X	NC	X	X	X	.	.
Swift 622905	**Site ABS02**								
28/03/2023	-29.180958, 121.716807	X	X	NC	.	NC	.	.	X
29/03/2023	-29.180863, 121.716815	X	X	.	.	NC	.	.	.
30/03/2023	-29.180850, 121.716700	.	.	.	X	.	.	.	.
31/03/2023	-29.180925, 121.716807	X	X	NC	.	.	.	.	X
1/04/2023	-29.180915, 121.716897	X	X	NC	.	NC	.	.	X
2/04/2023	-29.181058, 121.716908	X	X	NC	.	NC	X	.	X
3/04/2023	-29.180943, 121.716815	X	X	NC	X	NC	X	.	X
Swift 622742	**Site ABS03**								
28/03/2023	-29.150942, 121.674450	X	X	NC	X	.	X	.	X
29/03/2023	-29.150948, 121.674430	X	X	NC	.	.	.	.	X
30/03/2023	-29.150925, 121.674423	X	X	NC	.	.	.	.	X
31/03/2023	-29.150933, 121.674460	X	.	NC	.	.	.	.	X
1/04/2023	-29.150898, 121.674510	X	X	NC	.	.	.	.	X
2/04/2023	-29.150953, 121.674408	X	X	NC	X	NC	X	.	X
3/04/2023	-29.150927, 121.674437	X	X	NC	X	.	X	.	X
Swift 622898	**Site ABS04**								
28/03/2023	-29.157785, 121.686327	X	X	.	X	.	.	.	X
29/03/2023	-29.157593, 121.685377	X	X	.	X	.	.	.	X
30/03/2023	-29.157775, 121.686395	X	X	.	.	.	.	.	X
31/03/2023	-29.157767, 121.686300	X	X	.	X	NC	X	.	X
1/04/2023	-29.157778, 121.686385	X	X	.	NC	.	X	NC	X
2/04/2023	-29.157863, 121.686390	X	X	NC	X	NC	X	.	X
3/04/2023	-29.157850, 121.686495	X	X	NC	X	NC	X	.	X

Definition of confidence level codes

. Not detected.

X Unambiguous identification of the species at the site based on measured call characteristics and comparison with available reference material. Greater confidence in this ID would come only after capture and supported by morphological measurements or a DNA sequence.

NC Needs Confirmation. Either call quality was poor, or the species cannot be distinguished reliably from another that makes similar calls. Alternative identifications are indicated in the *Comments on identifications* section of this report. If this is a species of conservation significance, further survey work might be required to confirm the record.

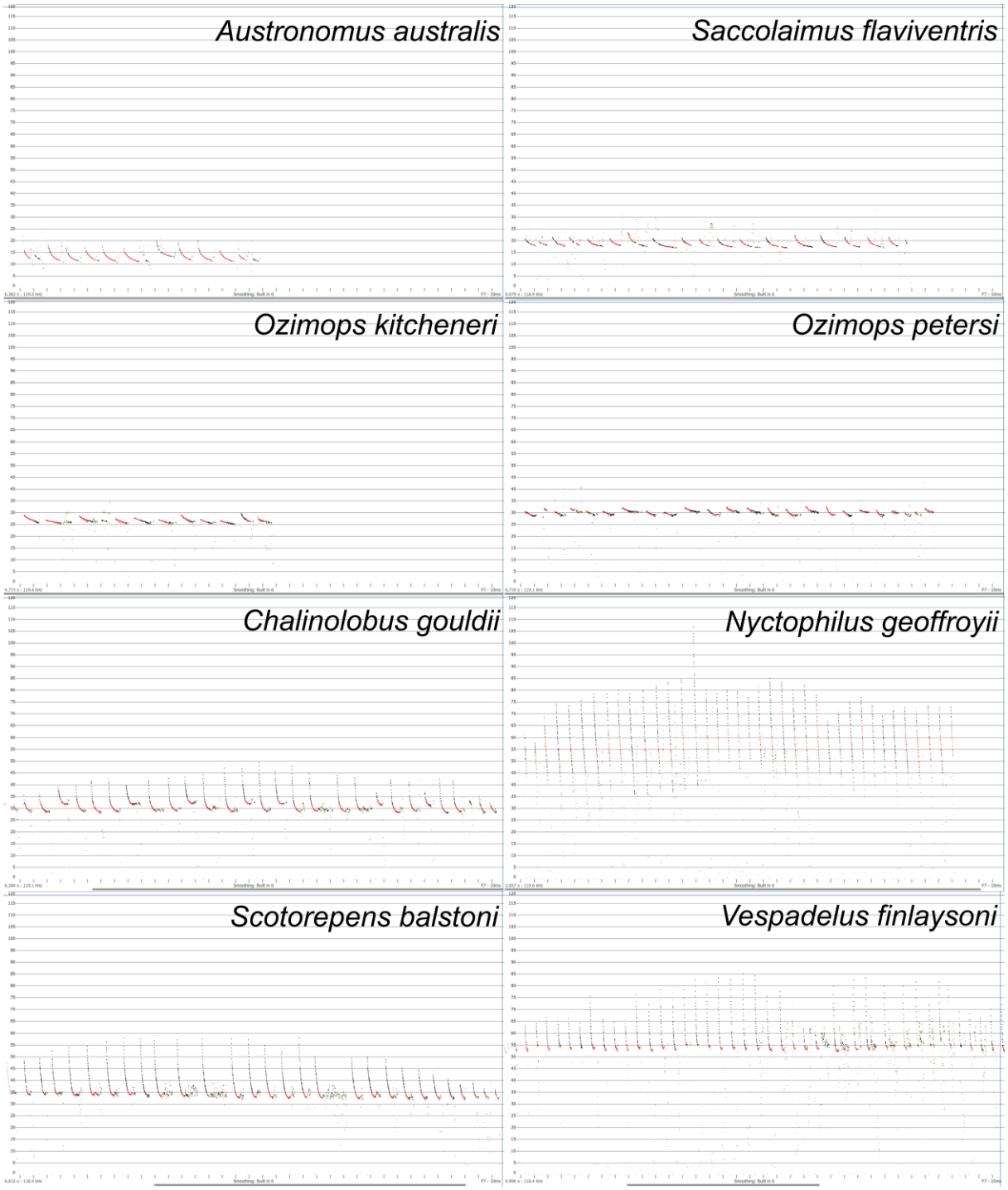


Figure 1. Representative echolocation call sequence portions of the species identified (time between pulses has been compressed).

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