REPORT

LAKE MACKAY POTASH PROJECT: DETAILED AND TARGETED VERTEBRATE FAUNA SURVEY AND CONSOLIDATION

PREPARED FOR **AGRIMIN LIMITED**

August 2021

Stantec

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Executive Summary

Background and Objective

Agrimin Ltd (Agrimin) are proposing to develop the Mackay Potash Project (the Project) into a Sulphate of Potash (SOP) fertiliser operation. The Project is located on and surrounding Lake Mackay, approximately 450 km south of Halls Creek, in the Shire of East Pilbara, Western Australia. Agrimin commissioned Stantec Australia Pty Ltd (Stantec) to undertake a two-phase detailed terrestrial vertebrate fauna survey (the Stantec Survey) and consolidate previous terrestrial fauna surveys conducted within the Study Area.

The Study Area is large, comprising a total of (443,985.37 ha), and a length of approximately 350 km from its northern to southern extents. The Study Area intersects two bioregions and encompasses two broad areas described as:

- **Lake and surrounds:** the Western Australian portion of Lake Mackay and its local surrounds, and totals 409,174 ha. This portion of the Study Area encompasses the following Development Envelops and surrounding for local context:
    - **On-LDE**: On Lake Development Envelope;
    - **Off-LDE**: Off Lake Development Envelope; and
    - **SIDE**: Southern Infrastructure Development Envelope.
- **Haul road corridor:** a linear corridor primarily for the proposed haul road that extends 350 km long and 1 km wide, and totals 33,927.86 ha. The corridor extends from the western margin of Lake Mackay to the Tanami Road (north of the township of Balgo). Subsequent to the completion of the baseline surveys, a 10 km section of the haul road corridor was realigned with a reduced corridor width to deviate around a population of Great Desert Skink. This portion of the Survey Area encompasses the NIDE (Northern Infrastructure Development Envelope).

The objective was to define the terrestrial fauna values of the Study Area, within a local and regional context, to inform environmental approvals for the Project. This objective was addressed by way of 17 terrestrial fauna surveys and an additional two GIS fauna desktop studies have been completed for the Project and consolidated within this technical report. The following surveys were completed by Stantec:

- **Preliminary Survey** of the Stantec Survey Area;
- **Consolidation Survey** which consolidated habitat mapping across the Study Area as a whole;
- **Detailed & Targeted surveys** (Phase 1 and Phase 2)(the Stantec Survey) of the Stantec Survey Area, which comprised a predominantly linear corridor of approximately 350 km long and 1 km wide totalling 34,622 ha;
- **Night Parrot Targeted Surveys**. Stage 1: August 2020; Stage 2: August – October 2020; Stage 3: October 2020; Stage 4: October – December 2020;
- **Night Parrot Habitat Mapping** Desktop Study of the entire Study Area October 2020;
- **Great Desert Skink Targeted Survey** of the Stantec Survey Area: October 2020.
- **Night Parrot Baseline Survey** around Lake Mackay: March – April 2021;
- **Waterbird Survey** at Lake Mackay following an inundation event: 30 March to 4 April 2021; and
- **Night Parrot Habitat Modelling** of extent of habitat in the regional surrounds.

Previous surveys in the Study Area that were consolidated into the overall dataset included:

- ecologia 2017 – Level 1 Fauna and Single-Phase Level 2 Flora Assessment: 6 to 13 September 2016
- 360 Environmental 2017 – Waterbird Survey at Lake Mackay: 10 to 19 May 2017
- 360 Environmental 2018 – Lake Mackay Sulphate of Potash Project: Single Phase Level 2 Fauna Survey at Lake Mackay: 10 to 19 May 2017

- Strategen 2018 – Lake Mackay sulphate of Potash Project Level 2 Vertebrate and Targeted Fauna Survey: 10 to 21 November 2017
- ecologia 2019 – Night Parrot Monitoring Lack Mackay: 21 April to 22 May 2018

Consolidated Survey Effort

Systematic survey effort undertaken within the Study Area encompassed; 30 systematic trapping sites totalling 11,735 trapping nights, 71 avifauna census hours, 24 systematic searching hours, 24 spotlighting hours, 358 motion-sensor camera nights and 54 bat echolocation recording nights. In addition, baseline targeted survey effort accounted for: 157 motion-sensor camera recording locations, 142 unique '2 ha plots' locations, 110 autonomous bird acoustic recording locations, 20 bat echolocation recording locations, and 153 habitat assessments. Subsequent to the baseline surveys, an additional 89 units were deployed (Stage 1-4) to better understand Night Parrot occurrence at two locations that coincide with the Study Area.

Fauna Habitats

The 12 broad fauna habitats were described and mapped in the Study Area and are considered typical of the Great Sandy Desert and Tanami bioregions. No TECs, PECs or GDVs were recorded in the Study Area. All habitats aside from drainage line were considered Significant as they potentially or were confirmed to support significant fauna. Of note are spinifex gravel plain, spinifex sandplain and claypans and claypan mosaic (and adjacent areas with old growth *Triodia*) are of particular significance as they were found to support the Bilby, Great Desert Skink and Night Parrot respectively, among other threatened and priority species. Furthermore the salt lake playa, associated islands and surrounding claypans and claypan mosaic and saline flats and depressions habitat would provide foraging and/or breeding habitat for various threatened and migratory avifauna when Lake Mackay is in flood. In general, based on available satellite imagery and hydrological modelling, the lake appears to inundate to a depth of approximately 2 m in the deepest portions on average once every 5 to 10 years. Primary habitats for the 25 significant species recorded or likely to occur within the Study Area is provided in **Table ES 1**.

Thirteen temporary water sources were noted largely from rocky habitats (rocky ridge and gorge, rocky drainage line and outcropping and stony rise) but also claypans and claypan mosaic habitat. One site 250 m downstream of the haul road corridor, was considered a permanent source.

Assemblages

A total of 245 terrestrial fauna species were recorded in the Study Area, representing 58% of the 421 species identified in the desktop assessment. Species recorded during the survey comprised the following; 23 native mammals, eight non-native mammals, 129 birds, 1 introduced bird, 80 reptiles, and four amphibians.

Eight non-native fauna species were recorded in the Study Area, including the European Cattle (*Bos taurus*), Camel (*Camelus dromedarius*), Feral Cat (*Felis catus*), Feral Dog (*Canis lupus*), Horse (*Equus caballus*), Rabbit (*Oryctolagus cuniculus*), House Mouse (*Mus musculus*) and Red Fox (*Vulpes vulpes*).

The fauna assemblages within the Study Area were sampled via systematic sampling methods. Species accumulation curved indicated that most (65-100%) of the fauna assemblages at each site were captured during the Stantec Survey. Additional species were also recorded from the Study Area via targeted and opportunistic surveys methods.

Significant Species

The desktop assessment identified 60 significant fauna species historically recorded from within the vicinity of the Study Area, comprising 24 mammals, 32 birds and four reptiles. Of these 21 were recorded and confirmed in the Study Area during the surveys, comprising four mammals, 14 birds and three reptiles. An additional five species were considered 'Likely 'to occur, and seven were considered 'Possible' to occur. Four significant species were recorded in especially high numbers or are of particular interest in the Study Area. These were the Night Parrot (En, Cr), Bilby (Vu, Vu), Great Desert Skink (Vu, Vu) and a range of waterbirds, including migratory shorebirds and threatened species recorded from the lake during inundation events.

Night Parrot foraging calls were recorded at two locations 25 km apart along the haul road corridor. The foraging calls were detected on acoustic units during long-term deployments after Phase 2 of the Stantec Survey, which occurred after rainfall. No calls were recorded at these same locations during the Phase 1 or during Phase 2 survey. Subsequent targeted surveys were undertaken at the two locations over four stages

of survey work to better understand how the species was utilising the drainage features both within and outside the Study Area. Analysis of the calls indicates that across the surveys, on average there were between two and five individuals in the north and between two and three individuals in the south. The records were associated with large, seasonally inundated broad drainage basins (associated with claypans and claypan mosaic habitat), which support seeding vegetation and old growth spinifex. Suitable habitat for roosting has been detected within the Study Area, in the form of old growth spinifex. These areas of old growth spinifex are visible on aerial imagery both within and outside the Study Area, particularly in association with the drainage basins containing claypans and claypan mosaic habitats. Based on fine scale mapping, it is estimated that a total of 11,522 ha of old growth spinifex occurs within the Study Area. In addition, regional modelling has subsequently identified 46,199 ha of habitat within 20 km of the Project which is potentially suitable for Night Parrots.

The Bilby was recorded at 130 locations (77 burrows) along the haul road corridor within the Study Area, predominantly in the following primary habitats: gravel spinifex plain (92 locations) and spinifex sandplain (33 locations). Three locations were identified with concentrated records of the Bilby, all occurring within the gravel spinifex plain habitat. The high numbers of records in this habitat is likely due to the increased occurrence of *Acacia hilliana* which supports root-dwelling larvae, a key Bilby food resource.

A population of Great Desert Skink was recorded approximately 22 km south of Yagga Yagga in spinifex sandplain habitat within the haul road corridor. The species lives communally in multi-generational family groups, with up to 10 individuals occupying a burrow system. Baseline and targeted surveys established that there are in excess of 74 burrows in the population (of which 64 were considered active). After the population was better defined through additional survey work, the proposed haul road was realigned so that all active burrows associated with the population were avoided with a buffer of at least 300 m.

Lake Mackay Inundation Events

The lake and associated wetlands are predominantly dry and subject to irregular and infrequent inundation. During major flood events, Lake Mackay supports a range of waterbird species including shorebirds, terns and ducks. The larger islands serve as waterbird breeding habitat while the lake playa and surrounding claypans/ saline depressions support foraging. Migratory and threatened bird species were recorded following large inundation events in 2001 and 2016 and during a smaller inundation event in 2021.

The waterbird survey during the 2001 flood event recorded 42,473 individuals from 27 species. These records included more than 1% of the estimated population for Banded Stilts, Black-winged Stilts and Red-necked Avocets. Additionally, 4,400 immature Banded Stilts were recorded which demonstrated a breeding event. The 2017 survey recorded a nationally significant count (3,273 individuals) of the Red-necked Stint (Mi, Mi). Note, both surveys occurred in sub optimal timing several months after the rainfall events, and as such are likely to underestimate waterbird abundance, diversity and breeding activity. The 2021 survey detected large congregations of waterbirds foraging on a localised area of the Lake Mackay playa, ranging from 9,301 to 35,038 individuals. These congregations included from 4.4% to 11.8% of the estimated population of Sharp-tailed Sandpipers.

Based on the analysis of available historical satellite imagery, Lake Mackay had 58 inundation events (over 20 % inundation) over the last 33 years of available imagery. Typically, the duration of these events lasted less than a month. Of the 58 events, 21 were equivalent or greater in duration to the event observed during the 2021 waterbird survey (24 days). However, only two were greater in duration than the event observed during the 2017 waterbird survey (more than 400 mm of rainfall; 89 days duration). These large inundation events (greater than 89 days) were 139 days in 2000 and the event observed during the 2001 waterbird survey estimated to be 398 days in duration. This event in 2000/2001 was the longest inundation event on available records and was nearly 30 times the average inundation duration. Lake levels were predicted to have reached approximately 4 m in the south-east of the lake, initially spilling into the surrounding riparian vegetation zone.

Inundation events in excess of 65 days duration meets the minimum time required for successful breeding of Banded Stilts. Based on the 33 years of available satellite imagery, six inundation events exceeded this minimum duration of inundation, with three of those events being marginal (estimates of 66, 69 and 72 days). However, the 2001 inundation event likely resulted in several reproductive events over the duration of the inundation. In summary, when inundated, Lake Mackay provides an important resource for foraging and breeding of waterbirds, however large inundation events are rare and infrequent with the majority lasting less than one month.

Fauna of other significance

In total, 39 vertebrate fauna specimens were vouchered and submitted to the WAM, 18 of which were genetically sequenced. In total, seven range extensions were recorded based on WAM morphological or genetic analysis or from field identifications, comprising the Broad-eyed Slider (*Lerista* aff. *robusta*) (P1), Spotted Ctenotus (*Ctenotus uber johnstonei*)(P4), Kimberley Lined Ctenotus (*Ctenotus rhabdotus*) and Ariadna's Ctenotus (*Ctenotus ariadnae*) (all confirmed by WA Museum), the Red-tailed Black Cockatoo (*Calyptorhynchus banksii macrorhynchus*) and Channel-billed Cuckoo (*Scythrops novaehollandiae*) (field records).

Specimens morphologically identified in the field as the Zigzag Velvet Gecko (*Amalosia rhombifer*?) and Sharp-browed Ctenotus (*Ctenotus superciliaris*) represent range extensions but are currently being verified by taxonomic experts.

Table ES 1: Significant fauna confirmed or likely to occur within the Study Area including number of locations where each species was recorded.

Scientific Name	Common Name	EPBC	BC Act	Primary habitat& number of locations recorded												Location of records	
				Salt lake playa	Lake margin	Claypans and claypan mosaic	Saline flats and depressions	Dune-field	Dune	Spinifex sandplain	Gravel spinifex plain	Rocky ridge and gorge	Outcropping and stony rise	Ridge slope	Drainage line	Haul road corridor	Lake and surrounds
Mammalia																	
Macrotis lagotis	Bilby	Vu	Vu			3		1	1	33	92					✓	-
Dasycercus blythi	Brush-tailed Mulgara	-	P4		1		1	2	1	19	1					✓	X
*Notoryctes caurinus / Notoryctes typhlops**	Northern / Southern Marsupial Mole	-	P4					3	6	1						✓	✓
Lagorchestes conspicillatus leichardti	Spectacled Hare-wallaby		P3													#	-
Aves																	
Pezoporus occidentalis	Night Parrot	En	Cr			1					1**					✓	-
Rostratula australis	Australian Painted Snipe	En	En				1									-	✓
Polytelis alexandrae	Princess Parrot	Vu	P4					1		1##						✓	-
Falco hypoleucos	Grey Falcon	-	Vu							1						✓	-
Amytornis striatus striatus	Striated Grasswren	-	P4						1	1	2					✓	✓
Apus pacificus	Fork-tailed Swift	Mi	IA	May use all habitats within the Study Area without being dependent on specific types.													✓
Charadrius veredus	Oriental Plover	Mi	IA							1						✓	-
*Plegadis falcinellus^*	Glossy Ibis	Mi	IA													-	✓
Calidris acuminata	Sharp-tailed Sandpiper	Mi	IA	5		1	5									✓	✓
Tringa stagnatilis	Marsh Sandpiper	Mi	IA				1									-	✓
*Sterna nilotica^*	Gull-billed Tern	Mi	IA	11	2		3									-	✓
Sterna leucopterus	White-winged Black Tern	Mi	IA	1													✓
Calidris ruficollis	Red-necked Stint	Mi	IA	4			1									-	✓
*Tringa nebularia^*	Common Greenshank	Mi	IA				1									-	✓
Actitis hypoleucos	Common Sandpiper	Mi	IA													-	#
Calidris melanotos	Pectoral Sandpiper	Mi	IA													-	#
Glareola maldivorum	Oriental Pratincole	Mi	IA													-	#
Tringa glareola	Wood Sandpiper	Mi	IA													-	#
Reptilia																	
Liopholis kintorei	Great Desert Skink	Vu	Vu							32^^						✓	
Lerista aff. *robusta*	Broad-eyed Slider	-	P1							1		1				✓	-
Ctenotus uber johnstonei	Spotted Ctenotus	-	P2								6		1	1		✓	-

Primary habitat for the species based on survey records and known ecology

* Both species have been recorded in the Study Area and have an overlapping range. As they cannot be differentiated based on tracks and signs and have the same conservation listing, they are discussed collectively.

** This record was in close proximity to claypan mosaic. The gravel spinifex plain is likely to have low potential to support foraging habitat from the spp when not in association with claypan and claypan mosaic.

^ Species recorded from Lake Mackay during waterbird survey in 2001. Location of records unavailable.

^^ denotes active burrows from within the Study Area. The population, which extends outside the Study Area exceeds a total of 64 active burrows.

 # denotes species considered likely to occur within the Study Area when the lake or claypans are inundated.

The species was flying over spinifex plain, with part of the flock landing to drink at a freshwater claypan. As such, spinifex plain is not considered primary habitat.

Agrimin Limited

Lake Mackay Potash Project: Detailed and Targeted Vertebrate Fauna Survey and Consolidation

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

APPENDIX

1. Introduction

1.1 Project Background

Agrimin Ltd (Agrimin) are proposing to develop the Mackay Potash Project (the Project) into a fertiliser operation. The Project is located on and surrounding Lake Mackay, approximately 450 km south of Halls Creek, in the Shire of East Pilbara, Western Australia (WA) (**Figure 1-1**). Stantec Australia Pty Ltd (Stantec) was commissioned by Agrimin to undertake a two-phase detailed and targeted terrestrial vertebrate fauna survey and consolidate previous terrestrial fauna surveys conducted within the Study Area.

The Study Area is large (443,985.37 ha), crosses two bioregions and encompasses the Project and its Development Envelopes (**Figure 1-2**). To better articulate the areas of previous survey, the locations of key findings and implications of the Project, the Study Area is described in this report in terms of two areas:

- **Lake and surrounds:** the Western Australian portion of Lake Mackay and its local surrounds, and totals 409,174 ha. This portion of the Study Area encompasses the following Development Envelops and surrounding for local context:
    - **On-LDE**: On Lake Development Envelope;
    - **Off-LDE**: Off Lake Development Envelope; and
    - **SIDE**: Southern Infrastructure Development Envelope.
- **Haul road corridor:** a linear corridor primarily for the proposed haul road that extends 350 km long and 1 km wide, and totals 33,927.86 ha. The corridor extends from the western margin of Lake Mackay to the Tanami Road (north of the township of Balgo). Subsequent to the completion of the baseline surveys, a 10 km section of the haul road corridor was realigned with a reduced corridor width to deviate around a population of Great Desert Skink. This deviation is hereon referred to as the GDS bypass. This portion of the Survey Area encompasses the **NIDE** (Northern Infrastructure Development Envelope).

Previous surveys for the Project have predominantly focused on the lake and surrounds and have been completed by ecologia (2017a), ecologia (2019), Strategen (2018a) and 360 Environmental (2017a, 2018) (**Appendix R**). This large body of work included level 1 and level 2 terrestrial fauna surveys, as well as targeted Night Parrot and waterbird surveys between 2016 and 2018. Subsequent to these surveys, Stantec was engaged to conduct surveys of the haul road (the Stantec Survey Area) as well as consolidate all previous work for the Project (**Figure 1-3**). This work is detailed within this report and includes:

- **Preliminary Survey** of the Stantec Survey Area;
- **Consolidation Survey** which consolidated habitat mapping across the Study Area as a whole;
- **Detailed & Targeted surveys** (Phase 1 and Phase 2)(the Stantec Survey) of the Stantec Survey Area;
- **Night Parrot Targeted Surveys**. Stage 1: August 2020; Stage 2: August – October 2020; Stage 3: October 2020; Stage 4: October – December 2020;
- **Night Parrot Habitat Mapping** Desktop Study of old growth spinifex within the entire Study Area October 2020;
- **Great Desert Skink Targeted Survey** the Stantec Survey Area: October 2020;
- **Night Parrot Baseline Survey** around Lake Mackay: March – April 2021;
- **Waterbird Survey** at Lake Mackay following a flooding event: 30 March to 4 April; and
- **Night Parrot Habitat Modelling** of extent in regional surrounds.

In addition, from 2001 to 2018, six surveys have been conducted in proximity to the Study Area, providing local and regional context (Cowan *et al.* 2015, Desert Support Services 2018, Duguid *et al.* 2005, Outback Ecology 2012a, Paltridge 2012, 2015) (**Figure 1-4**). The data and information from these surveys has been consolidated within this report.

1.2 Scope and Objectives

The objective was to define the terrestrial fauna values of the Study Area, within a local and regional context. The key findings will inform the approvals and environmental impact assessment (EIA) for the Environmental Protection Authority's (EPA) terrestrial fauna factor. This is in accordance with technical guidance and requirements for inclusion into the Project's Environmental Review Document (ERD).

The specific tasks undertaken to address the objective were to:

- complete a desktop review of the Study Area, including conducting database searches, a comprehensive literature review and a likelihood of occurrence assessment for significant fauna;
- conduct a two-phase detailed and targeted fauna survey to develop a list of vertebrate fauna species recorded in the Stantec Survey Area to:
    - assess the occurrence and likely distribution of fauna assemblages within the Stantec Survey Area;
    - ascertain the occurrence and distribution of significant fauna and relevant habitats; and
    - identify, describe, and map fauna habitats and their condition within the Stantec Survey Area.
- prepare a detailed and targeted terrestrial fauna survey report including consolidation of previous work completed, to provide local and regional context to inform environmental approvals.

The objectives and methods adopted for the Stantec Survey were aligned with the following relevant regulatory guidelines:

- Environmental Protection Authority (EPA), Environmental Factor Guideline – Terrestrial Fauna (EPA 2016a);
- EPA, Technical Guidance – Sampling Methods of Terrestrial Vertebrate Fauna (EPA 2016b);
- EPA, Technical Guidance – Terrestrial Fauna Surveys (EPA 2016c);
- Department of Biodiversity, Conservation and Attractions (DBCA), Interim Guideline for Preliminary Surveys of Night Parrot (*Pezoporus occidentalis*) in Western Australia (DPaW 2017b);
- Department of Parks and Wildlife (DPaW), The Conservation and Management of the Bilby (*Macrotis lagotis*) in the Pilbara (DPaW 2017a);
- Department of Biodiversity, Conservation and Attractions (DBCA), Guidelines for Surveys to Detect the Presence of Bilbies, and Assess the Importance of Habitat in Western Australia (DBCA 2017a);
- Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC), Survey Guidelines for Australia's Threatened Reptiles (DSEWPaC 2011b); and
- Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC), Survey Guidelines for Australia's Threatened Mammals (DSEWPaC 2011a).

Technical Guidance – Terrestrial Vertebrate Fauna Surveys for Environmental Impact (EPA 2020), was released in June 2020, after the completion of survey work for the Project. Broadly, the new guidance combines EPA (2016b) and (EPA 2016c), while outlining reporting requirements. This report has been aligned with the new guidance where appropriate.

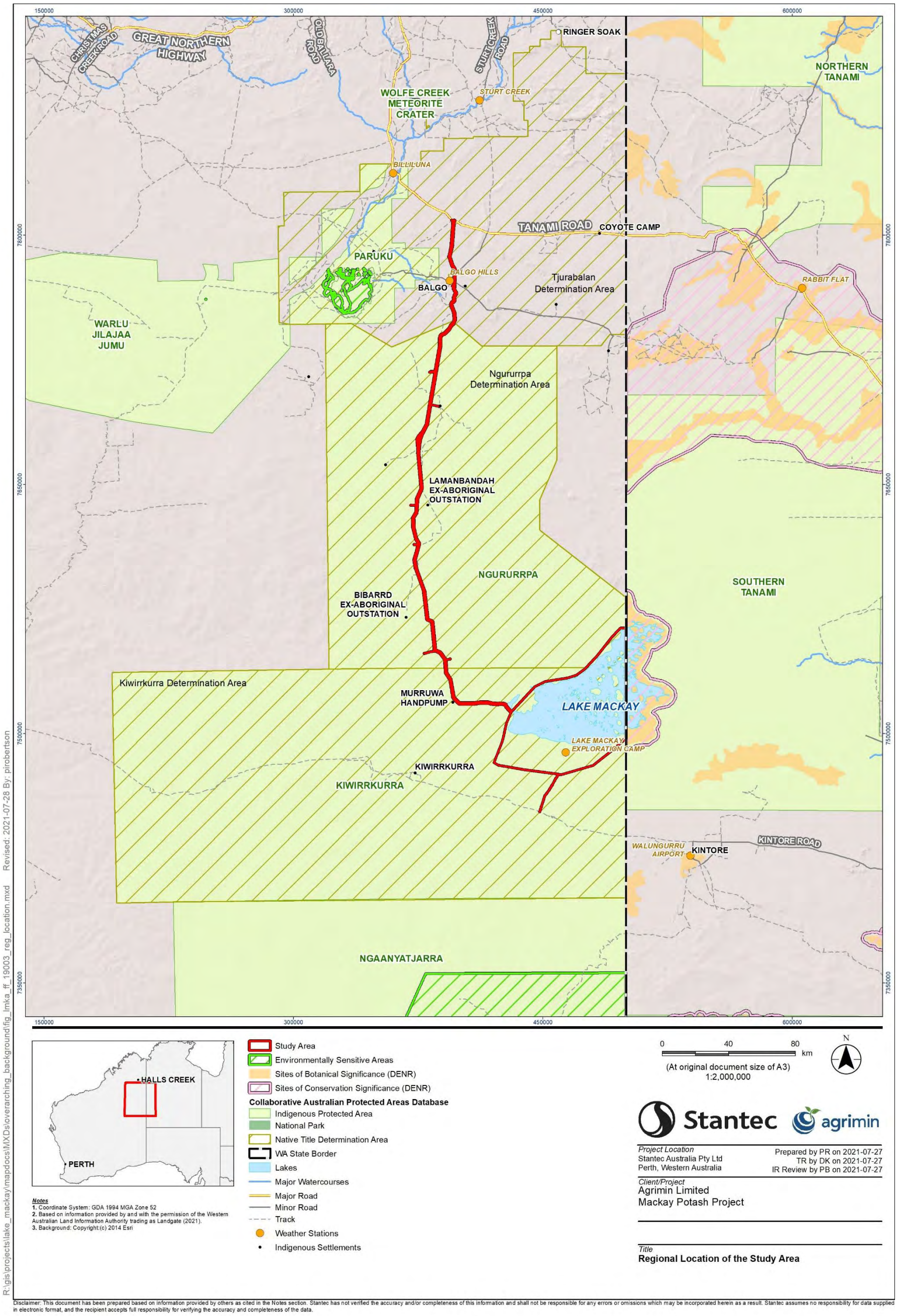

Figure 1-1: Regional location of the Study Area.

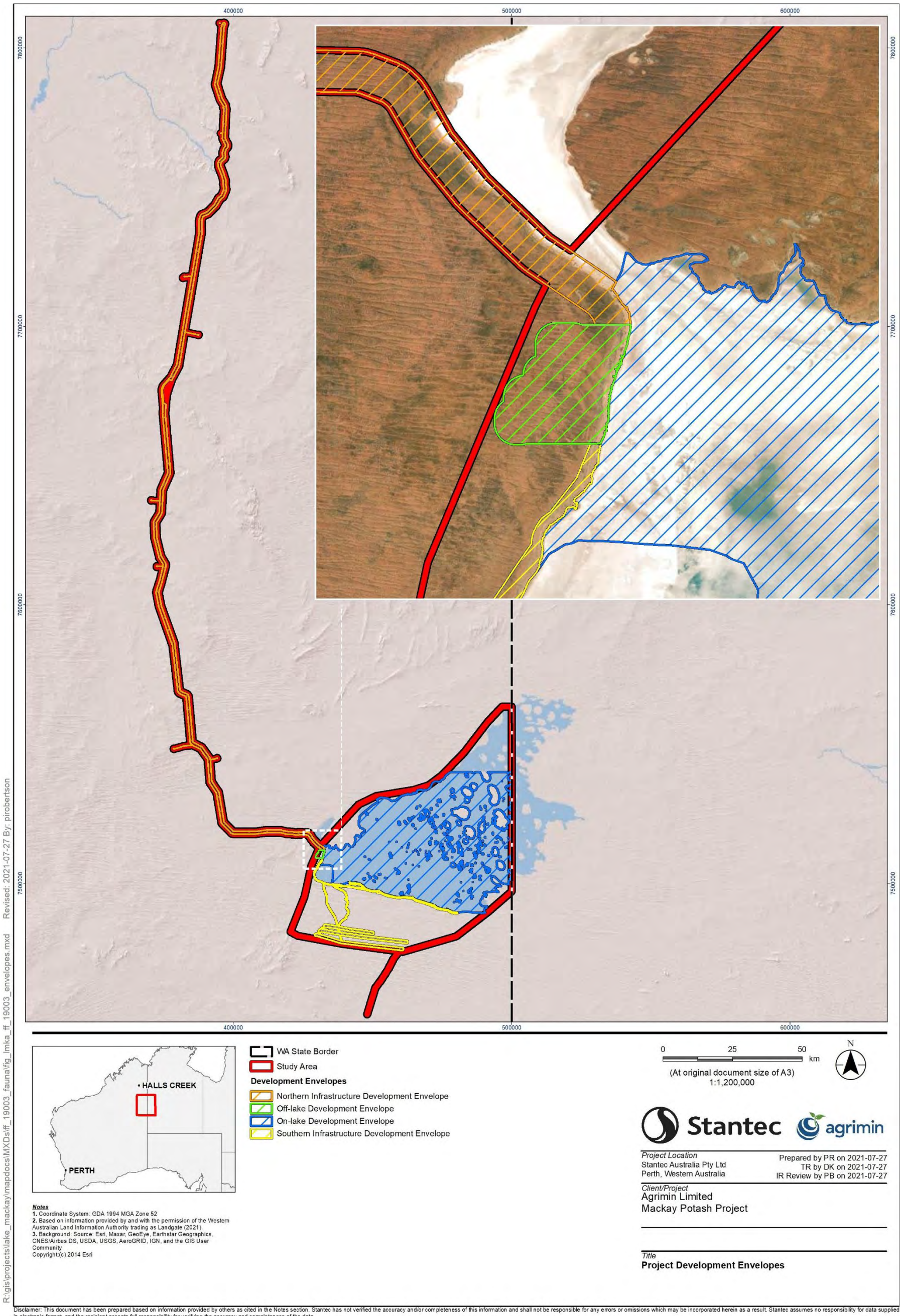

Figure 1-2: The Study Area and Development Envelopes for the Project.

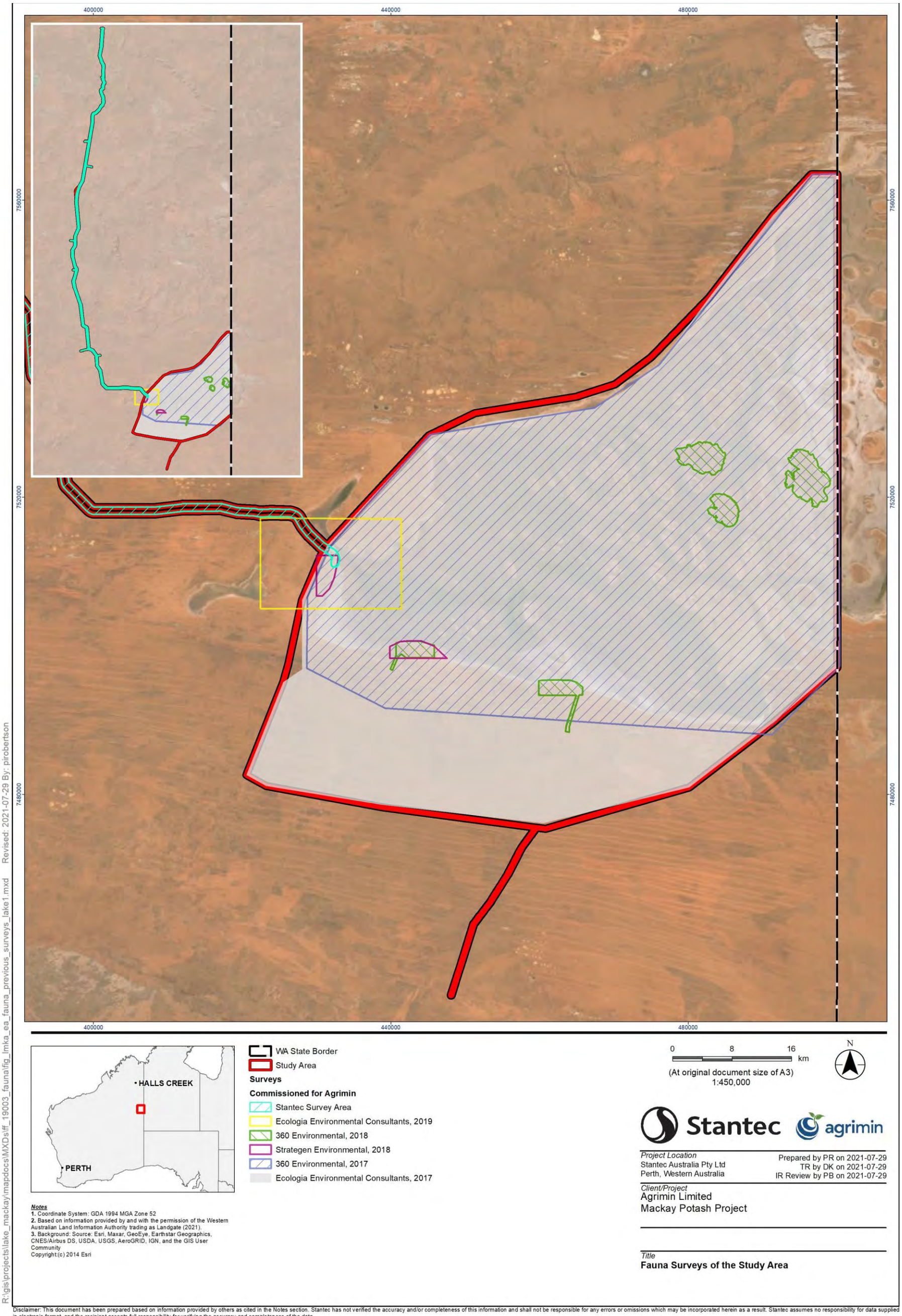

Figure 1-3: The Study Area for the Project and associated individual Survey Areas.

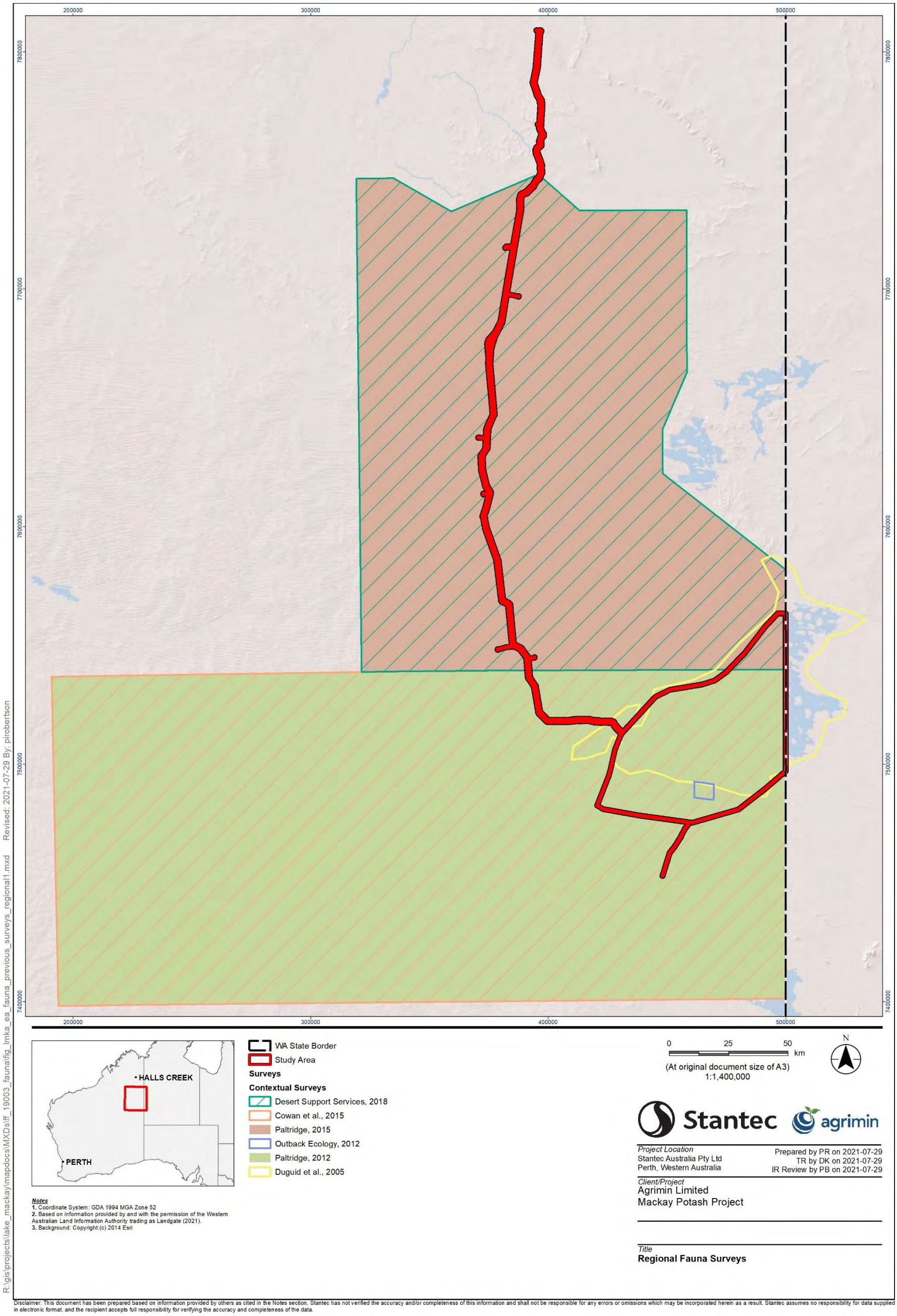

Figure 1-4: The Study Area for the Project and associated contextual Survey Areas.

2. Existing Environment

2.1 Biophysical Environment

2.1.1 Biogeographical Location

The Interim Biogeographic Regionalisation for Australia (IBRA) is a bioregional framework that divides Australia into 89 biogeographic regions and 419 subregions on the basis of climate, geology, landforms, vegetation and fauna (Thackway and Cresswell 1995). It was developed through collaboration between state and territory conservation agencies with coordination by the Commonwealth Department of the Environment, Water, Heritage and the Arts (now the Commonwealth Department of Agriculture, Water and the Environment; DoAWE).

The majority of the Study Area (435,743 ha, 98.1%) is located within the Mackay subregion (GSD2) of the Great Sandy Desert bioregion (**Figure 2-1**). The Great Sandy Desert is characterised by gently undulating plains dominated by longitudinal dunes of varying frequency, comprising tree-steppe degrading to shrub-steppe in the southeast and open hummock grasslands with scattered trees (*Owenia reticulata*, *Eucalyptus* spp.) and shrubs (*Acacia* spp. and *Grevillea* spp.) (Beard 1990). The Great Sandy Desert extends from the WA/NT border, west to within approximately 25 km of the coast, with the GSD2 subregion spanning to within 80 km of the coast. The GSD2 subregion comprises 18,636,695 ha within the Great Sandy Desert, encompassing palaeodrainage systems including chains of salt lakes, with samphire (*Tecticornia*) low shrublands, and areas of sand dune fields over sandstones (Kendrick 2001). The landscape includes laterised uplands that support *Acacia* shrublands over *Triodia pungens* hummock grass (Kendrick 2001).

The northern portion of the Study Area (8,242 ha, 1.9%) extends into the Tanami Desert 1 subregion (TAN1) of the Tanami Desert bioregion (**Figure 2-1**). Most of the bioregion occurs in the NT; approximately 10% occurs in WA. The Tanami Desert bioregion is characterised by gently undulating sandy plains with longitudinal dunes with shrub-steppe of *Triodia pungens*, and the occasional low rocky ranges and laterite-crusted uplands, comprising tree-steppe and plains of grass savanna (Beard 1990). The TAN1 subregion comprises 3,214,599 ha, encompassing sandplains that support *Hakea* spp., desert bloodwoods, *Acacia* spp. and *Grevillea* spp. over spinifex, with calcareous deposits from rivers and lakes throughout the landscape (Graham 2001). In the north of the subregion, the calcareous deposits support ribbon grass (*Chrysopogon* spp.) and Flinders grass (*Iseilema spp.*) and short-grasslands with river red gum (*Eucalyptus camaldulensis*) (Graham 2001). An estimated 25% of the entire Tanami Desert bioregion is used for grazing (DotE 2008, ILC 2013).

2.1.2 Land Systems

Land systems are defined as an area or group of areas throughout which there is a recurring pattern of topography, soils and vegetation (Tille 2006). An assessment of land systems provides an indication of the occurrence and distribution of vegetation within and surrounding the Study Area.

Land systems in the rangelands and arid interior of WA have been mapped by the Department of Primary Industries and Regional Development (formerly the Department of Agriculture and Food) and provide a comprehensive description of biophysical resources within the area (Tille 2006). The Study Area intersects 10 land systems; the most dominant being the SV12 land system (67% of the Study Area) (**Table 2-1**, **Figure 2-2**) The AB56 also comprises a sizeable proportion of the Study Area (approximately 24%). The remaining land systems account for less than 9% combined.

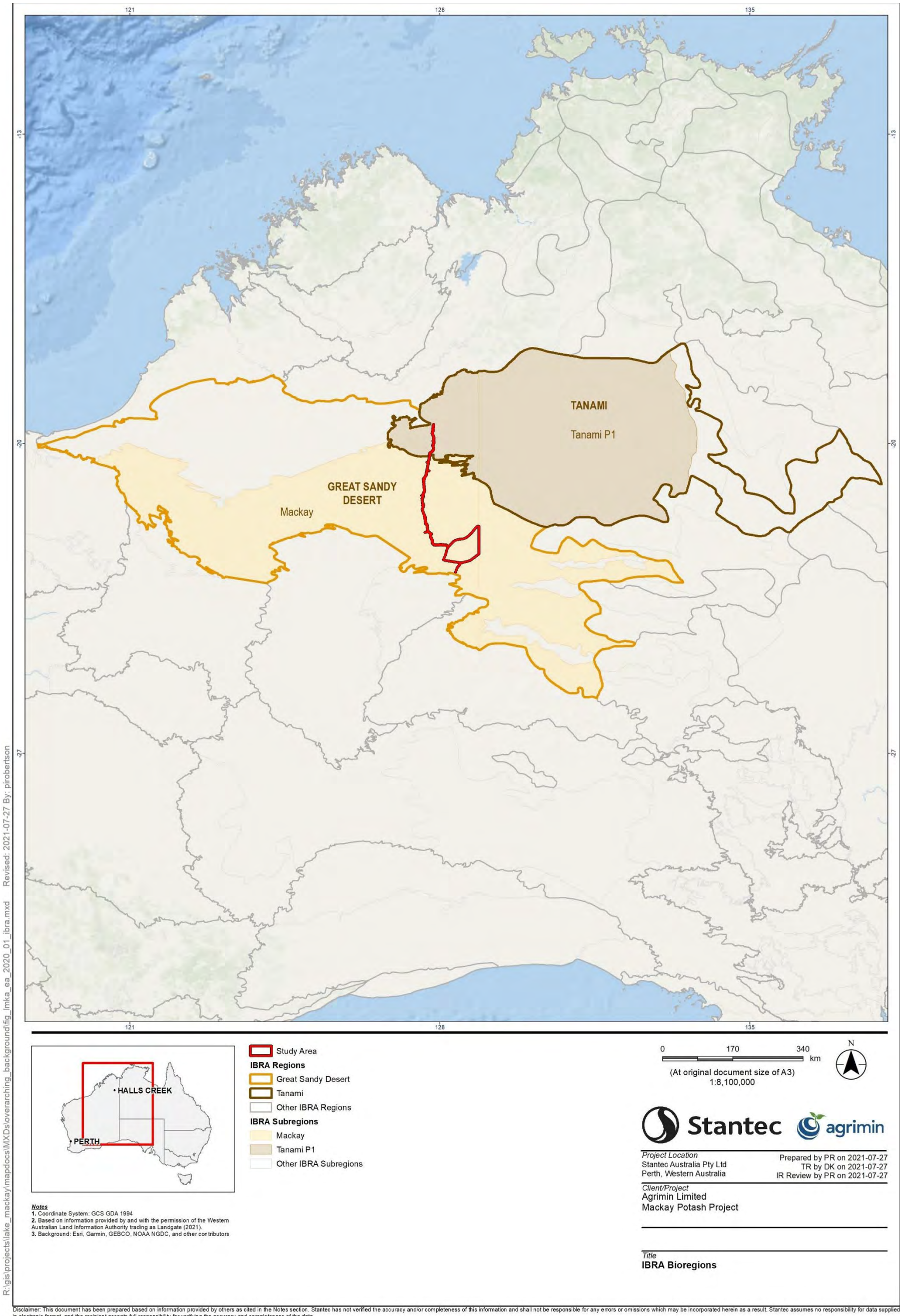

Figure 2-1: IBRA regions and subregions associated with the Study Area.

Table 2-1: Land systems and their extent within the Study Area.

Land system name	Description	Extent in the Great Sandy Desert Bioregion		Extent in the Tanami Bioregion		Extent within the Study Area	
		hectares	%	hectares	%	hectares	%
SV12	Plains studded with salt pans, seasonal lakes; calcrete (kunkar) platforms; and fringing dunes	657,968.15	1.67	9,580.42	0.04	297,874.25	67.09
AB56	Plains extensively covered with longitudinal dunes; some hilly residuals with rock outcrops	52,6049.52	1.33	<0.01	<0.01	108,410.65	24.42
My98	Low to steep hilly country with mesas and buttes sometimes capped with pisolitic ironstone and laterite on ferruginized and silicified sandstone and greywacke with extensive valley plains	650,914.22	1.65	49,455.46	0.19	10,613.42	2.39
AB39	Gently undulating plain dominated by longitudinal dunes of varying frequency; some exposures of ironstone gravels on low rises occur in the dune swales	1,632,688.97	4.13	0.00	<0.00	8,760.52	1.97
AB54	Gently undulating plains with linear dunes in some areas; there are also variable areas of calcrete (kunkar); pans, depressions, and lakes; and some isolated hilly residuals	721,033.01	1.83	84,427.54	0.32	6,273.56	1.41
AB53	Dune fields--gently undulating plains with linear dunes. There are areas of calcrete (kunkar) of variable extent, pans, lakes, depressions, and springs; and some isolated hilly residuals	2,219,844.28	5.62	36,671.42	0.14	5,133.49	1.16
AB29	Gently undulating plains	2,563.99	0.01	816,463.34	3.14	3,417.03	0.77
AB55	Broad, very gently undulating upland (tableland) elevated above adjacent dune fields; some low laterite-capped residuals showing exposures of sedimentary rocks; some dunes, some salt lakes and pans	546,493.22	1.38	0.00	0.00	2,311.21	0.52
Winnecke System	Low linear or rounded hills and associated valley floors and marginal sandplains, supporting soft spinifex hummock grasslands or sparse low snappy gum woodlands with spinifex.	734.05	0.00	24,779.19	0.10	661.19	0.15
BA5	Stony hills and ranges largely derived from sandstone and having flanking sand plains	219,952.26	0.56	283,003.11	1.09	150.40	0.03
unmapped	unmapped	n/a	n/a	n/a	n/a	379.65	0.09
Total		**39,486,135.50**	**18.18**	**25,997,277.47**	**5.02**	**443,985.37**	**100**

*A discrepancy in the location of the WA/NT border between the land systems mapping and the actual location of the border has resulted in a small area (379.7 ha, 0.09 %) being unmapped within the Study Area.

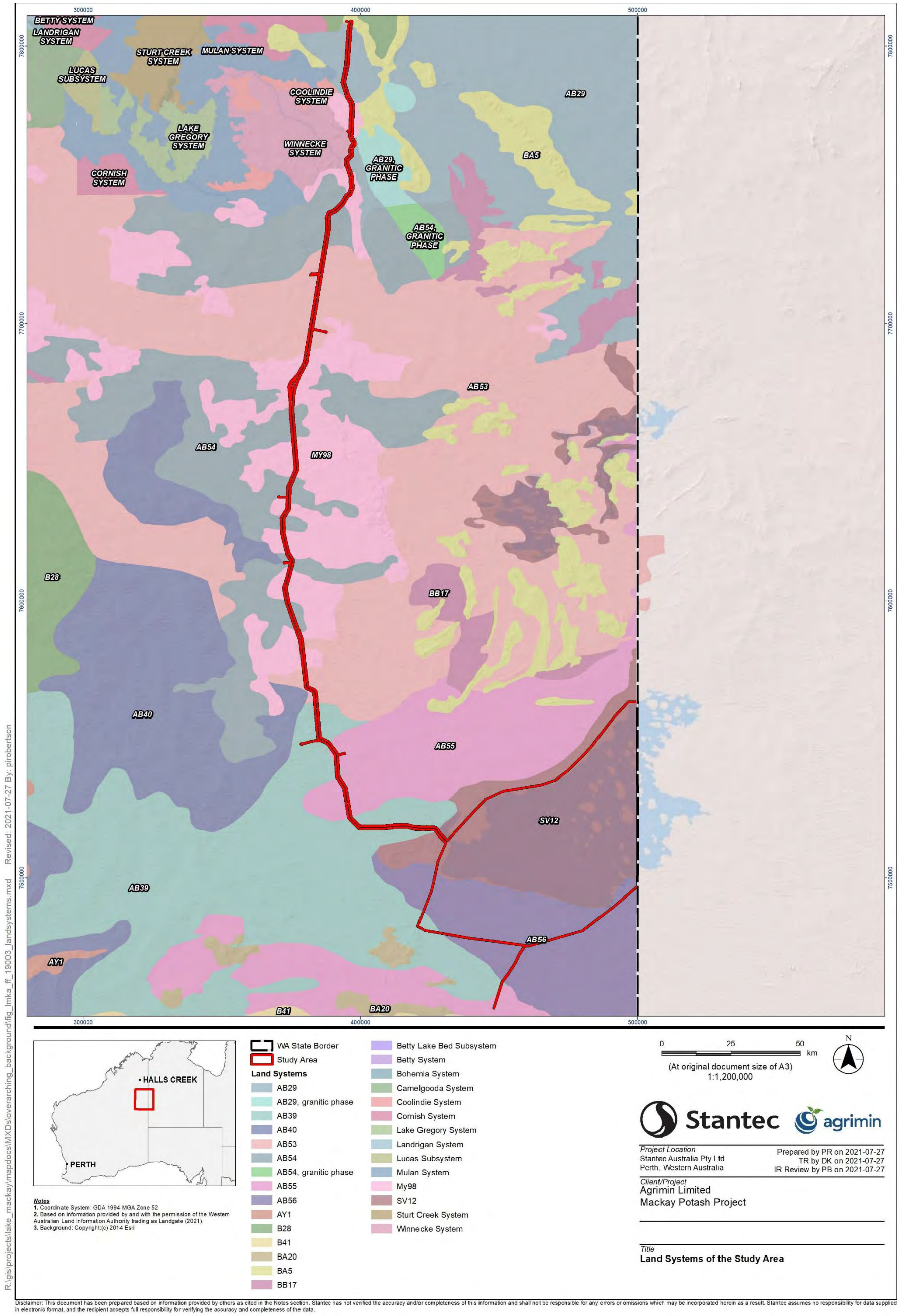

Figure 2-2: Land systems associated with the Study Area.

2.2 Physical Environment

2.2.1 Climate

The GSD2 and TAN1 have an arid tropical climate, with an average rainfall ranging between 200 mm and 300 mm (Beard 1990, Graham 2001, Kendrick 2001). The subregions are influenced by the monsoon, with the majority of rainfall received during the summer months, and often associated with tropical cyclones and low-pressure systems. However, there can be significant fluctuations in wet season rainfall from year to year, depending on the strength of the monsoonal system and cyclone activity (**Figure 2-3**,**Figure 2-4**). Temperatures are typically cool in the winter months and very hot during summer months (Graham 2001, Kendrick 2001).

Two BoM weather stations were used to provide long term climate information for the northern and southern portions of the Study Area. Balgo Hills (station No. 013007) is located approximately 3 km west of the northern portion of the Study Area (**Figure 1-1**) (BoM 2020a). Walungurru Airport (station No. 015664) is the nearest operating BoM weather station for the southern portion of the Study Area, located approximately 70 km to the south-east (**Figure 1-1**) (BoM 2020a).

The long-term (1940-2016) mean annual rainfall recorded at Balgo Hills is 356.8 mm. Most rainfall occurs during the warmer months from December to March, with a collective average of 258.7 mm (**Figure 2-3**). Rainfall is typically in association with tropical cyclones and low-pressure systems; the highest monthly average rainfall is February with 84.2 mm. Minimal rainfall occurs during the cooler months. The three hottest months of the year occur between November and January, with maximum daily temperatures regularly exceeding 35º C (**Figure 2-3**). The coolest three months occur between June and August, with minimum temperatures regularly falling below 15º C.

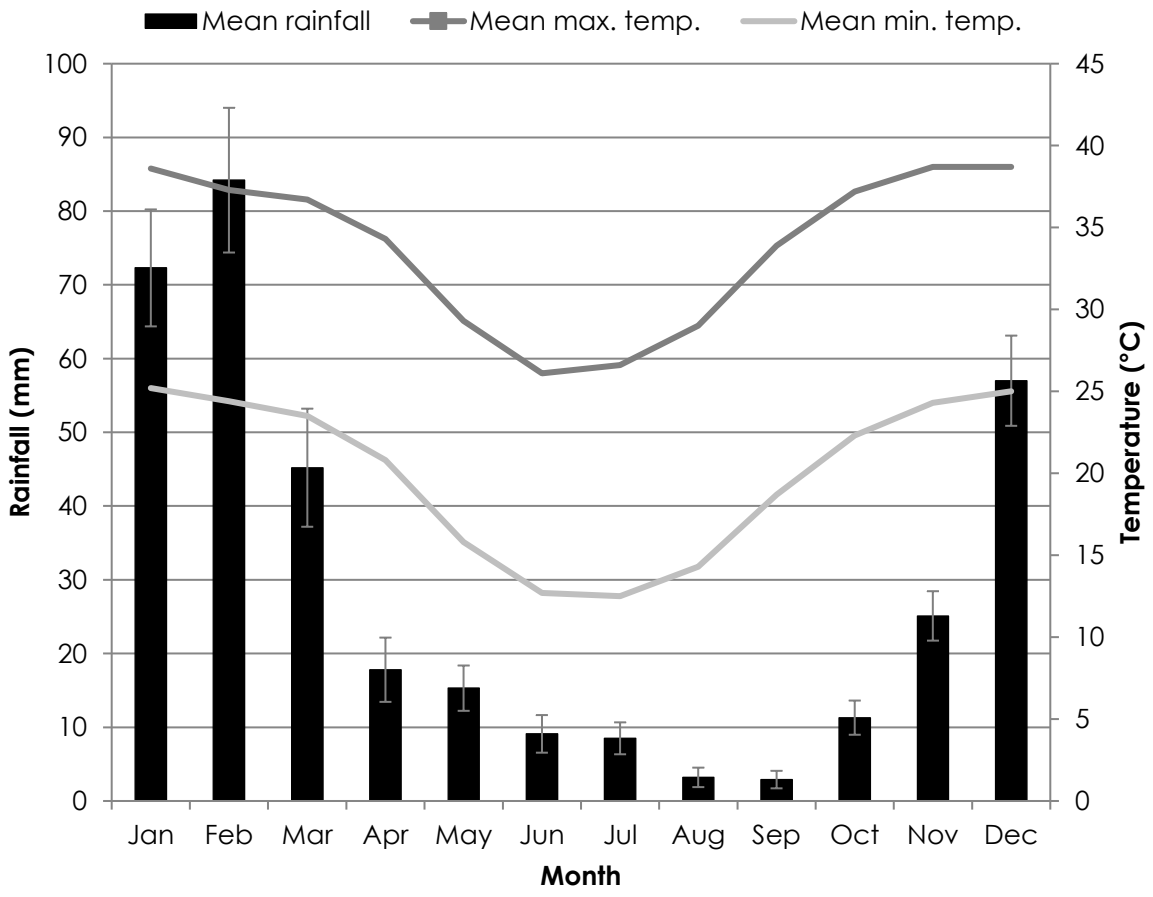

Figure 2-3: Long-term mean annual rainfall (1940-2016) and mean annual temperature (1950-2016) recorded at Balgo Hills weather station (No. 013007) (BoM 2020a).

The long-term (1998-2020) mean annual rainfall recorded at Walungurru Airport is 296.1 mm. Similar to the northern portion of the Study Area, most rainfall occurs during the warmer months of December to March, with a collective average of 176.6 mm (**Figure 2-4**). The highest monthly average rainfall is December with 59 mm, while minimal rainfall occurs during winter (**Figure 2-4**). The three hottest months occur between December and February, with daily maximum temperatures regularly exceeding 35° C. The coolest three months occur between July and August, with minimum temperatures regularly falling below 15° C (**Figure 2-4**)

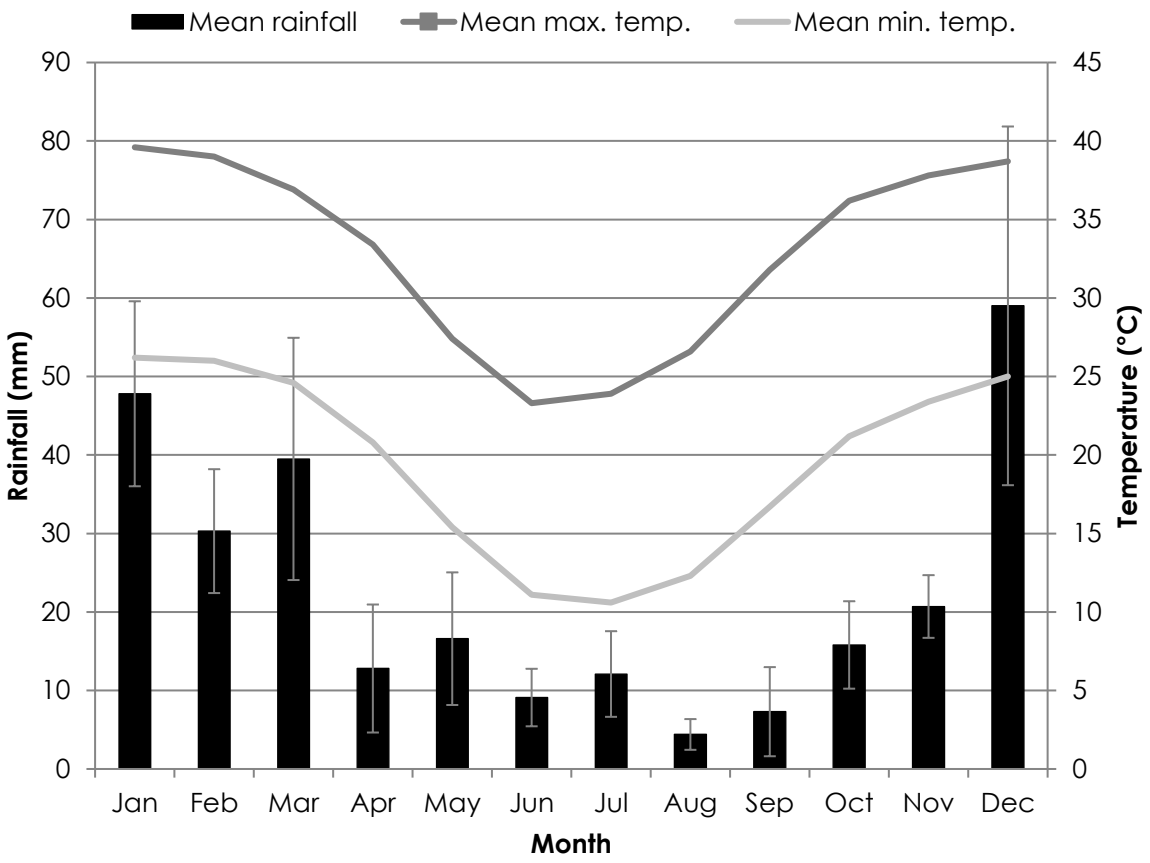

Figure 2-4: Long-term mean annual rainfall (1998-2020) and mean annual temperatures (2001-2020) recorded at Walungurru Airport weather station (No. 015664) (BoM 2020a).

2.2.2 Surface Geology and Soils

The GSD2 is an area of longitudinal sand dune fields, primarily running east to west, with swales opening into sandplains as well as isolated residual breakaway sandstone hills (Tille 2006). The red Quaternary sand dunes sit atop Jurassic and Cretaceous sandstones of the Canning and Armadeus Basins, with gently undulating laterised uplands and hills present (Kendrick 2001, Tille 2006). In addition to Lake Mackay, small claypans and depressions occur in the GSD2 (Tille 2006). The TAN1 consists of red Quaternary sandplains atop Permian and Proterozoic strata that can be exposed as hills and ranges (Graham 2001). Aspects of the TAN1 contain ironstone gravels and some breakaways that are capped by laterite duricrust (Tille 2006).

Nine geological units have been mapped within the Study Area (**Table 2-2**; **Figure 2-5**). The Cenozoic regolith 76542 unit is the most widespread of the geological units (approximately 83% of the Study Area) (**Table 2-2**). This unit broadly represents surficial or regolith units; poorly consolidated alluvial, colluvial, aeolian, lacustrine and ancient coastal deposits; and residual deposits. Surface geological mapping for the Study Area is provided in **Figure 2-5.**

The Study Area occurs within the Great Sandy Desert, Wiso Sandplain and Stansmore soil-landscape zones of WA (Tille 2006). The soils of these zones are described as red sandy earths with some deep red sands, salt lake soils, red loamy earths and calcareous loamy earth (Tille 2006).

Lake Mackay is a hypersaline lake occupying 54.84% of the Study Area (243,461.00 ha). Testing of materials collected from the playa showed that no soil samples were currently acid sulfate soils (ASS), and none that were potentially ASS.

The topography around Lake Mackay is mostly subdued; the lake itself and the immediate surrounding area is predominantly flat. However the lake is characterised by more than 270 islands, comprising highly variable area and elevations ranging from less than 1 ha to over 2,700 ha and from 1 m high to more than 13.5 m, respectively (Stantec 2020b).

Table 2-2: Geological units of the Study Area.

Geological code	Name	Geological description	Extent within Study Area	
			Hectares	%
Czu	Cenozoic regolith 76542	Surficial or regolith units; poorly consolidated alluvial, colluvial, aeolian, lacustrine and coastal deposits; residual deposits (eg, laterite).	367,386.08	82.75
Ps	Permian sedimentary rocks 76691	Predominantly sedimentary rocks; includes sedimentary rocks of low metamorphic grade and diapiric breccias	23,094.65	5.20
Ls	Paleoproterozoic sedimentary rocks 76605	Predominantly sedimentary rocks; includes sedimentary rocks of low metamorphic grade and diapiric breccias	16710.28	3.76
Ls	Paleoproterozoic sedimentary rocks 76610	Predominantly sedimentary rocks; includes sedimentary rocks of low metamorphic grade and diapiric breccias	14250.88	3.21
Ps	Permian sedimentary rocks 76693	Predominantly sedimentary rocks; includes sedimentary rocks of low metamorphic grade and diapiric breccias	10704.40	2.41
Ns	Neoproterozoic sedimentary rocks 76676	Predominantly sedimentary rocks; includes sedimentary rocks of low metamorphic grade and diapiric breccias	4917.63	1.11
Ly	Paleoproterozoic amphibolite-facies metamorphics 76621	Medium-grade metamorphic rocks, generally with amphibolite-facies assemblages; may have a greenschist overprint	4816.14	1.08
Os	Ordovician sedimentary rocks 76683	Predominantly sedimentary rocks; includes sedimentary rocks of low metamorphic grade and diapiric breccias	1433.81	0.32
Rs	Triassic sedimentary rocks 76703	Predominantly sedimentary rocks; includes sedimentary rocks of low metamorphic grade and diapiric breccias	669.49	0.15
unmapped	unmapped	n/a	2.01	0.0
Total			**443,985.37***	**100**

* A discrepancy in the geology mapping has resulted in a small area (2.01 ha) being unmapped within the Study Area.

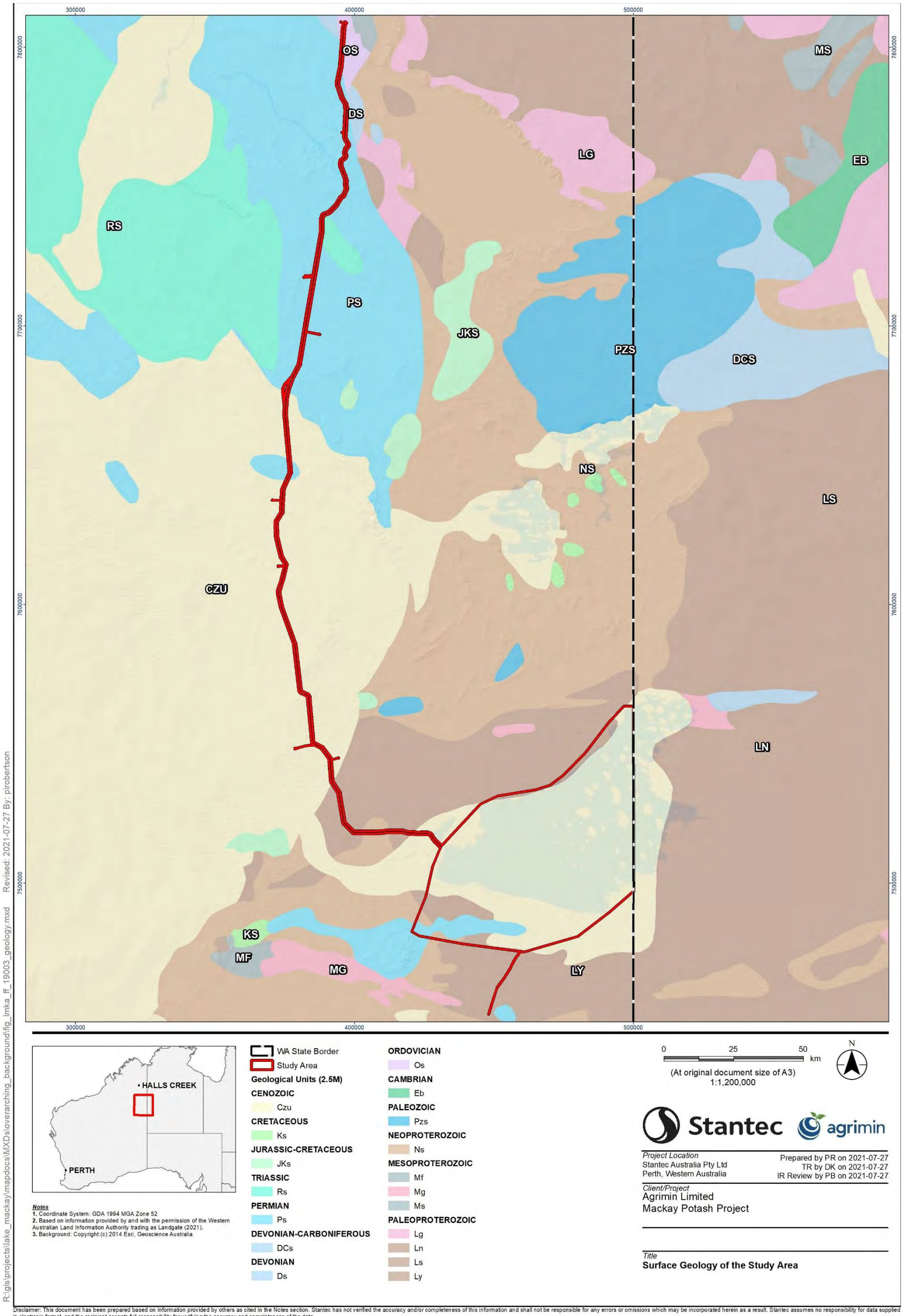

Figure 2-5: Surface geology of the Study Area

2.2.3 Surface Hydrology and Drainage

The Study Area traverses two drainage basins, the Victoria River-Wiso basin and the Sandy Desert basin (BoM 2012). There are no permanent rivers that cross the Study Area; surface water utilises paleaovalleys and palaeochannels to drain into nearby ephemeral lakes (BoM 2012). After heavy rainfall events, surface water in the northernmost portion of the Study Area drains to Lake Gregory (48 km west of the Study Area), and in the south, drains to Lake Mackay. The saline playa of Lake Mackay represents approximately 55% of the Study Area.

Lake Mackay is the largest lake in Western Australia and the fourth largest in Australia. This vast salt lake is usually devoid of surface water, but can retain surface water for many months following significant rain events (Duguid *et al.* 2005, Northern Territory Government 2009). Most recharge into Lake Mackay is from direct rainfall and surface runoff from the lake and its direct vicinity (Agrimin 2018).

In general, based on available satellite imagery and hydrological modelling, the lake appears to inundate to a depth of approximately 2 m in the deepest portions on average once every 5 to 10 years (Stantec 2020d). While the lake appears subject to a major flood under these conditions, the persistence of surface water is variable and dependent on preceding conditions. Typically, however, the lake may remain inundated for up several months.

2.2.3.1 Hydrogeology

Lake Mackay is an ephemerally flooded lacustrine environment, which hosts hypersaline groundwater (brine) within the lakebed sediments. Lake Mackay is further interpreted to be the endorheic or internally draining terminus of ground water discharge from within a larger catchment and palaeodrainage system (Woodgate et al. 2012). Potassium and other elements dissolved in the brine are derived from weathering of rocks within the catchment area.

The general lake recharge mechanisms are as follows.

- Direct infiltration to the sediments from the lake surface during seasonal rainfall events;
- Runoff from the surrounding catchment flowing into Lake Mackay causing inundation, predominantly in the east and south of the lake. Only likely with associated high rainfall events such as storms or cyclones; and
- Interflow – rainfall infiltrating into the upper soil profile of surrounding dune systems, flowing towards the lake and recharging lakebed sediments.

Groundwater discharge:

- Palaeovalleys interpreted to connect to Lake Mackay, bring water from the Northern Territory and discharge to the lakebed sediments at depth; and
- Upward hydraulic gradient from the deep palaeochannel sequence beneath the lakebed sediments.

2.2.4 Land Tenure and Use

The majority of land within the GSD2 is unallocated crown land, with areas of conservation, mining leases, and Aboriginal lands and reserves, and several small areas of urban development (DotE 2008, Kendrick 2001). Approximately 7% of the Great Sandy Desert bioregion is used for grazing (DotE 2008, Kendrick 2001). Within WA, TAN1 is dominated by unallocated crown land and crown reserves (Graham 2001).

The Study Area lies within three Native Title Determination Areas (**Figure 1-1**) proclaimed under the *Native Title Act 1993* (NT Act):

- Kiwirrkurra Determination Area (Determination Number: WCD2001/002);
- Ngururrpa Determination Area (Determination Number: WCD2007/004); and
- Tjurabalan Determination Area (Determination Number WCD2001/001).

2.2.5 Conservation Reserves and Environmentally Sensitive Areas

Conservation Reserves (including National Parks, Conservation Parks and Nature Reserves) are lands managed by DBCA for the preservation of wildlife and ecological values. National Parks often also

represent Environmentally Sensitive Areas (ESA). There are three Conservation Reserves within the Great Sandy Desert, none of which occur within the Study Area and no Conservation Reserves are listed within the Tanami bioregion.

Lake Gregory is listed as a nationally important wetland and represents the nearest ESA to the Study Area, located 48 km west of the northern end of the Study Area. The Wolfe Creek Meteorite Crater National Park (also an ESA) is the nearest conservation reserve, situated approximately 72 km north of the northern-most extent of the Study Area, and within the Ord Victoria Plain bioregion (**Figure 1-1**).

Within the NT, the Department of Environment and National Resources (DENR) (Northern Territory Government 2009, 2020) has listed the NT portion of Lake Mackay as a site of conservation significance (**Figure 1-1**). The NT DENR has listed the NT portion of the lake under the following criteria:

- International significance: Category - Wildlife aggregations (seabirds, waterbirds and shorebirds);
- National significance (possible international): Category – Wetlands; and
- Regional Significance:
    - Category: Threatened Species; and
    - Endemic Species (flora).

2.2.5.1 International significance

The NT portion of Lake Mackay is listed as being of international significance by the NT DENR due to its importance to seabirds, waterbirds and shorebirds that were recorded at Lake Mackay (including the WA portion of the lake) during an inundation event in 2001 (Duguid *et al.* 2005). The categories for this listing by the NT DENR include:

Seabirds: About 4600 White-winged and Whiskered Terns were recorded during an aerial survey of Lake Mackay in 2001.

Waterbirds: Total numbers of waterbirds: Significant numbers of birds use Lake Mackay opportunistically following inundation events. During a two hour aerial survey in September 2001, when the lake was inundated, 40 334 birds of at least 21 species were recorded. Counts of 4,653 Grey Teal and 8,460 unidentified ducks are reported from surveys in (Duguid *et al.* 2005). Breeding records: Islands and submerged aquatic plants such as *Ruppia tuberosa*, provide food and protected breeding sites for waterbirds during periods of inundation.

Shorebirds: Counts of individual species: Internationally significant counts (> 1% global population) of three shorebird species are reported from this site including: 12 000 Banded Stilts; 3262 Blackwinged Stilts; and 1295 Red-necked Avocets. Breeding records: The site is likely to be an occasional breeding location for the Banded Stilt. About 4400 juveniles were recorded during the aerial survey in 2001. The absence of large colonies of the Silver Gull at the site, which is a predator of Banded Stilt hatchings, enhances the significance of the site as a breeding area for this species. It is important to note that Lake Mackay is predominantly a dry playa and only floods infrequently and irregularly (**See Section 2.2.3**).

2.2.5.2 National significance (possible international)

Lake Mackay is not listed as a wetland of national significance under Directory of Important Wetlands in Australia (DIWA) or a wetland of international significance under Ramsar (DotEE 2020b). However, the lake was assessed by Duguid *et al.* (2005) as meeting some criteria of both levels of significance. Consequently, the lake has been raised as nationally significant and possibly internationally significant by the NT DENR. The details listed by the NT DENR include:

Ramsar criteria: Lake Mackay is not listed as a Ramsar site, however Duguid *et al.* (2005) assessed the lake against criteria for listing as a wetland of international importance under the Ramsar convention and concluded the Lake meets Criterion 1 and possibly Criteria 2, 4, 5 and 6.

DIWA criteria: Lake Mackay is not listed in the Directory of Important Wetlands in Australia (DIWA), however Duguid *et al.* (2005) assessed the lake against criteria for listing and concluded the Lake meets Criteria 1 and 4, and possibly Criterion 5.

Although Lake Mackay may meet some of these criteria during infrequent and irregular flood events, the majority of the time, over many years, the lake comprises a dry playa.

2.2.5.3 Regional Significance:

The NT portion of Lake Mackay is listed as being of regional significance by the NT DENR under two categories: threatened Species and endemic species (flora). One species of threatened fauna is recognised under the WA BC Act and under the EPBC Act: Bilby (*Macrotis lagotis*) (Vu/Vu).

2.2.6 Significant Wetlands

Lake Mackay is not listed as a declared Ramsar wetland and is not listed as a national important wetland (DotEE 2020b). However, the lake was assessed by Duguid *et al.* (2005) as meeting some criteria of both levels of significance (**Section 2.2.5.2**).

The closest Ramsar wetland is the Lake Argyle and Kununurra wetland site (approximately 350 km from the Study Area and 600 km from Lake Mackay) and the closest nationally important wetland is Lake Gregory (DotEE 2020b) (50 km west of the Study Area and 265 km from Lake Mackay). For regional context, a brief description of both of these important wetlands are provided below.

Lakes Argyle and Kununurra are large freshwater lakes that cover approximately 117,000 ha and were formed by the construction of dams on the Ord River for the supply of irrigation water to the Ord River Irrigation Area (Hale and Morgan 2010). The Lake Argyle and Kununurra wetland site meets five of the nine Ramsar criteria, briefly:

- Category 4: supports species at a critical stage in their life cycles
- Category 5: regularly supports 20,000 or more waterbirds
- Category 6: regularly supports one percent of the individuals in a population of one species or subspecies of waterbird
- Category 7: supports a significant proportion of indigenous fish
- Category 9: supports one percent of the individuals in a population of one species or subspecies of wetland dependent non-avian animal species ie the freshwater crocodile.

The Lake Gregory system is a nationally important wetland that is recognised as one of the best examples of a large brackish system, with inland (terminal) drainage lakes in Australia which has regular inflow and is near-permanent (DEC 2009). Lake Gregory comprises several interconnected waterbodies totalling 38,700 ha, fed primarily from the southeast Kimberley by Sturt Creek (DEC 2009) which originates 170 km north-east (DoAWE 2020). The lake is of particular importance for waterbirds of which 80 species have been recorded including 20 species under international treaties and 21 species that have been recorded breeding at the lake. Lake Gregory is also considered the most important inland wetland in Australia in terms of waterbird numbers (up to an estimated 650,000 recorded in 1988) (DEC 2009).

The Lake Gregory System is currently identified as a wetland of national importance under criteria 1, 2, 3, 4 and 6 of the Directory of Important Wetlands in Australia (DIWA) (DoAWE 2020):

1. It is a good example of a wetland type occurring within a biogeographic region in Australia.
2. It is a wetland that plays an important ecological or hydrological role in the natural functioning of a major wetland system/complex.
3. It is a wetland that is important as the habitat for animal taxa at a vulnerable stage in their life cycles, or provides a refuge when adverse conditions such as drought prevail.
4. The wetland supports 1% or more of the national populations of any native plant or animal taxa.
6. The wetland is of outstanding historical or cultural significance.

3. Desktop Assessment

3.1 Approach

A desktop assessment, comprising database searches and a literature review, was undertaken prior to the Stantec Survey to gather contextual information on the Study Area, and to inform the consolidation of previous survey findings. The purpose of the desktop assessment was to identify terrestrial fauna potentially occurring within and near the Study Area, particularly significant fauna.

Significant species and rankings were applied under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act), *Biodiversity Conservation Act 2016* (BC Act), and DBCA Priority list. These are defined in **Appendix A**.

3.2 Desktop Methods

3.2.1 Database Searches

Database searches were completed to generate a list of vertebrate fauna previously recorded within and near the Study Area. Five databases were searched using methods and buffers that were appropriate for the technical capabilities (maximum buffer, accuracy of data) of the database and the ecological features of the Study Area (**Table 3-1**). The results of a Northern Territory (NT) Fauna Atlas database search conducted by ecologia (2019) were also included due to the proximity of the Study Area to the NT border.

Table 3-1: Database searches conducted for the desktop assessment.

Authority	Database Name	Search Method	Buffer (km)	Date of Receipt
Department of the Environment and Energy (now the Department of Agriculture Water and the Environment; DoAWE) (DotEE 2019a)	Protected matters Search Tool (PMST)	Northern and southern coordinates (52K) • 404735mE, 7801704mN • 390089mE, 7548559mN	100	02/04/2019
Department of Biodiversity Conservation and Attractions (DBCA 2019a)	Threatened and Priority Fauna	Shapefile	150	29/03/2019
Birdlife Australia (Birdlife Australia 2019)	Birdlife Bird Data	Shapefile	150	03/04/2019
DBCA (DBCA 2019b)	NatureMap^	Central coordinates (52K) • 440813mE, 7494352mN • 385669mE, 7548633mN • 372957mE, 7600798mN • 376333mE, 7649281mN • 376454mE, 7677516mN • 394680mE, 7745107mN • 396105mE, 7806063mN	40	05/04/2019
Atlas of Living Australia (ALA 2020)	Atlas of Living Australia (ALA)	Southern Buffer: Lat: -22.636011° Long: 128.998335° Northern Buffer Lat: -22.036763° Long: 128.998637°	100	21/07/2020
Northern Territory Department of Lands and Resources Management database	Northern Territory Fauna Database	Not specified; provided by ecologia (2017a)	Not specified	2016

^ The NatureMap database search was separated into seven smaller searches according to central coordinates with a 40 km buffer (limit) to cover the entirety of the Study Area.

3.2.2 Literature Review

A literature review can provide important information on species records and habitats that might be present and contributes to an overall understanding of an area and its regional context (EPA 2020). Prior to the survey work completed by Stantec and documented within this report, there have been five surveys undertaken within the Study Area for the Project (**Table 3-2**)**.** The respective survey areas are shown on **Figure 1-3**, and completed survey reports commissioned for the Project by Agrimin are provided in **Appendix R**. These include:

- ecologia (2019) Night Parrot Monitoring Lake Mackay;
- Strategen (2018a) Lake Mackay Sulphate of Potash Project Level 2 Vertebrate and Targeted Fauna Survey;
- 360 Environmental (2018) Lake Mackay Sulphate of Potash Project: Single Phase Level 2 Fauna Survey at Lake Mackay;
- 360 Environmental (2017a) Waterbird Survey at Lake Mackay by Senior Ornithologist Dr Colin Trainor; and
- ecologia (2017a) Level 1 Fauna and Single-Phase Level 2 Flora Assessment.

There were also seven regional surveys undertaken that intersect, occur within, or lie adjacent to the Study Area, providing important local and regional context (**Table 3-3**, **Figure 1-4**). Additionally, a full vertebrate fauna species list from the Australian Wildlife Conservancy's (AWC) Newhaven Wildlife Sanctuary was also included for regional Great Sandy Desert Bioregion context (**Table 3-3**). More broadly, there was limited regional survey information available. All of the records from previous surveys within the Study Area was consolidated into one dataset (**Section 4.2**) and incorporated into the field survey results of this report (**Section 5**). Detailed limitations and constraints of the surveys conducted in the Study Area are provided in **Section 5.**

Table 3-2: Summary of previous terrestrial fauna surveys conducted for the Project within the Study Area and appended to this report.

Reference	Study Details	Proximity to Study Area and Size	Survey Effort	Fauna Habitats	Fauna Assemblages Recorded	Species of Significance
ecologia (2019) (Appendix R.1)	Title: Night Parrot Monitoring Lake Mackay Location: Lake Mackay Study Type: Targeted automated acoustic surveys for Night Parrot Survey Date: 21 April and 22 May 2018	Within the Study Area. Survey Area not defined. Units deployed around the Western margin of Lake Mackay	• Seven acoustic recorder locations for a total of 91 recording sessions	• Long unburnt *Triodia*	N/A	None One call was detected that was similar pitch and length to some Night Parrot calls. However, based on the analysis of the call itself and the time it was detected, it was considered unlikely this call was a Night Parrot, however the possibility could not be ruled out.
Strategen (2018a) (Appendix R.2)	Title: Lake Mackay Sulphate of Potash Project Level 2 Vertebrate and Targeted Fauna Survey Location: Lake Mackay Study Type: Level 2 fauna and targeted fauna survey Survey Date: 10-21 November 2017	Within the Study Area Size = 2,419.5 ha	• Four trapping sites (7 nights) • 35 habitat assessments • 90-minute avifauna census at the four trapping sites • 240 minutes of spotlighting • Eight motion cameras (minimum of 5 nights) • 2 ha plots (quantity not stated) • 29 acoustic recorder locations (recording nights not stated) • Opportunistic records	• Dune/ swale • Claypan swale • Lake margin • Sandplain	117 taxa including: • 12 mammals (4 introduced) • 65 birds • 31 reptiles • 2 amphibians	N/A
360 Environmental (2018) (Appendix R.3)	Title: Lake Mackay Sulphate of Potash Project: Single Phase Level 2 Fauna Survey at Lake Mackay Location: Lake Mackay Study Type: Level 2 fauna survey Survey Date: 10 – 19 May 2017	Within the Study Area. Size = 5,547.3 ha	• Six trapping sites over seven nights (1059 trap nights) • Six SM2 Echolocation and acoustic recorder locations (minimum 6-night total) • 90-minute avifauna census (540 person minutes) • 120 minutes of spotlighting • Six motion camera locations (minimum of 6 nights total) • 22 habitat assessments • Opportunistic records	• Dune • Swale • Claypan swale • Lake margin	76 taxa including: • 11 mammals • 39 birds • 24 reptiles • 2 amphibians	• Fork-tailed Swift (IA, Mi)
360 Environmental (2017a) (Appendix R.4)	Title: Waterbird Survey at Lake Mackay Location: Lake Mackay Study Type: Level 2 fauna survey Survey Date: 14-17 April 2017 Senior Ornithologist: Dr Colin Trainor	Within the Study Area. Size = 256,000 ha	• 17 ground avifauna census sites, totaling 20 hrs and 47 minutes • 45 aerial avifauna census sites (hours not stated)	• Island • Claypan • Saline lake	52 taxa including: • 25 waterbirds • 27 land birds	• Australian Painted Snipe (EN, En) • Sharp-tailed Sandpiper (IA, Mi,) • Common Greenshank (IA, Mi) • Red-necked Stint (IA, Mi) • Gull-billed Tern (IA, Mi)
ecologia (2017a) (Appendix R.5)	Title: Level 1 Fauna and Single-Phase Level 2 Flora Assessment Location: Lake Mackay Study Type: Level 1 fauna and Level 2 flora Survey Date: 6-13 September 2016	Within the Study Area. Size = 400,138 ha	• Targeted searches (time spent not stated) • Habitat mapping • Nocturnal searches (time spent not stated) • 20 motion camera locations (for four nights each, totaling 80 nights) • 30-minute avifauna census (total not stated) • 3 echolocation recorders (seven nights)	• Sandplains • Saline flats • Dune-fields • Samphire • Mulga woodland • Stony rise	57 taxa including: • 11 mammals • 35 birds • 11 reptiles	• Northern Marsupial Mole (P4) • Rainbow Bee-eater (no longer listed)

Table 3-3: Summary of regional surveys that intersect, occur within or lie adjacent to the Study Area.

Reference	Study Details	Proximity to Study Area	Survey Effort	Fauna Habitats	Fauna Assemblages Recorded	Species of Significance
Desert Support Services (2018)	Title: Bilby Blitz Survey on the proposed Ngururrpa Indigenous Protected Area Location: Ngururrpa IPA Survey Type: Targeted Bilby survey Survey Date: 18-22 October 2018	Overlaps the Study Area. Predominantly the Stantec Survey Area.	• 27 2 ha plots • Opportunistic records	N/A	N/A	• Bilby (VU, Vu) • Great Desert Skink (VU, Vu)
Cowan *et al.* (2015) also presented in Butcher *et al.* (2015)	Title: Kiwirrkurra Indigenous Protected Area BushBlitz Survey Location: Area around Kiwirrkurra and Nyinmi (100 km west of Kiwirrkurra) and Lake Mackay Study Type: Bush Blitz Survey Date: 5-19 September 2015	Intersects the Study Area in the vicinity of Lake Mackay	• 14 trapping sites (4 within the Study Area) (333 trap nights) • 3 echolocation recorder locations for at least one night each • Active foraging (time not stated) • Targeted motion cameras (nights deployed not stated)	• Unburnt dune • Sandplains • Mulga woodland	71 vertebrate taxa including: • 23 mammals (5 introduced) • 48 reptiles • 1 amphibian	• Bilby (VU, Vu) • Evidence of Northern Marsupial Mole (P4) • Great Desert Skink (VU, Vu)
Paltridge (2015)	Title: Looking for animals on Ngururrpa Country Location: road between Yagga Yagga and Bibarrd Aboriginal Outstations Survey Type: Tracking Survey Survey Date: 28 July – 1 August 2015	Overlaps the Study Area. Predominantly the Stantec Survey Area	• 32 2 ha plots	• Sandplains • Dune-fields • Lateritic rises	• N/A	• Bilby (VU, Vu) • Brush-tailed Mulgara (P4) • Grey Falcon (VU, Vu)

Paltridge (2012)	Title: Kiwirrkura Threatened Species Survey 2012
	Location: Kiwirrkura, Nyinmi and Maruwa management zones (including western edge of Lake Mackay)
	Survey type: Tracking survey
	Survey date: 12-18 May 2012
		Maruwa management area encompasses the western edge of Lake Mackay and a southern portion of the Stantec Survey Area.	• 29 2 ha tracking plots	• Western edge of Lake Mackay
				  o Minor drainage depression
				  o Spinifex sandplain/dune fields
					• N/A	• Bilby (VU, Vu)
						• Brush-tailed Mulgara (P4)
						• Princess Parrot (Vu, P4)

Outback Ecology (2012a)	Title: Level 1 Terrestrial Fauna Assessment Location: Lake Mackay Survey Type: Level 1 fauna survey Survey Date: 7-14 June 2012	Within the Study Area	• 24 systematic searching sites, for 60 minutes each totalling 24 hours) • 12 hours of nocturnal searching • Two motion camera locations (total of six nights) • Opportunistic records • One echolocation recorder location (four recording nights) • Habitat assessments	• Spinifex sandplain • Sand dune • Saline flats and claypans • Mosaic of mulga woodland, saline flats and claypans	52 taxa including: • 15 mammals (5 introduced) • 14 reptiles • 23 birds	• Northern Marsupial Mole (P4) • Brush-tailed Mulgara (P4)
Duguid *et al.* (2005)	Title: Wetlands in the Arid Northern Territory Location: Northern Territory (including Lake Mackay) Survey type: Wetland survey (with shorebird/waterbird survey at Lake Mackay) Aerial Survey Date: 5-6 September 2001 Experienced Ornithologist: Ray Chatto Ground Survey: 3-10 October 2001 Zoologists: Peter Latz and Rachel Paltridge	Lake Mackay. Aerial survey of the perimeter of the Lake in the WA side and ground truthed sites on the Northern Territory side of the lake.	• Aerial avifauna census (time not stated)	• Lake Mackay and surrounds	• 20 bird species (42,473 individuals)	• Gull-billed Tern (Mi, IA) • Common Greenshank (Mi, IA) • Glossy Ibis (Mi, IA)

Reference	Study Details	Proximity to Study Area	Survey Effort	Fauna Habitats	Fauna Assemblages Recorded	Species of Significance
(Pedler *et al.* 2018)	Title: *Long-distance flights and high-risk breeding by nomadic waterbirds on desert salt lakes* Location: Lake Mackay Survey Date: 2014	Lake Mackay. Aerial survey of the lake.	• Once-off aerial Banded Stilt census (date not specified)	• Lake Mackay	• N/A	• 6,500 clutches of Banded Stilt eggs

Table 3-4: The fauna records from Newhaven are provided for regional context

Reference	Study Details	Proximity to Study Area	Survey Effort	Fauna Habitats	Fauna Assemblages Recorded	Species of Significance	Limitations identified in report
AWC (2019)	Newhaven Sanctuary Species List	Approximately 290 km E of the Study Area Great Sandy Desert Bioregion.	• N/A	• N/A	278 taxa including: • 24 mammals • 174 birds • 74 reptiles • 6 amphibians	• Letter-winged Kite (P4) • Curlew Sandpiper (VU; IA, Cr; Mi) • Grey Falcon (VU, Vu) • Striated Grasswren (P4) • Princess Parrot (P4, Vu) • Brush-tailed Mulgara (P4) • Black-footed Rock-wallaby (McDonnell Range) (VU, Vu) • Southern Marsupial Mole (Itjaritjari) (P4) • Great Desert Skink (VU, Vu)	• N/A

3.2.3 Likelihood of Occurrence of Significant Fauna

Prior to conducting the Stantec Survey, significant fauna identified from the desktop assessment were assessed for their likelihood of occurrence within the Study Area. This assessment was used to inform targeted survey methods employed during the Stantec Survey. The likelihood rankings for each species of significance was categorised according to the criteria presented in **Table 3-5**. Following the Stantec Survey, likelihoods for significant fauna were reassessed based on the habitats present and the findings of the targeted survey work (**Section 5.4**).

Table 3-5: Criteria for assessing the likelihood of occurrence of significant fauna in the Study Area.

Confirmed
The species has been recorded unambiguously during the last ten years (i.e. during recent surveys or from reliable records obtained via database searches) in the Study Area.
Likely
There is a medium to high likelihood that the species uses the Study Area as it occurs within the known species distribution, contains suitable habitat (either year round or intermittently, such as temporary water sources or features that are only relied upon during certain times of the year e.g. breeding caves) and the species has been recorded recently nearby.
Possible

There is a potential for the species to use the Study Area as;
• the species has not been recorded recently nearby however;
  o the species may not have been detected during previous surveys e.g. is rare, patchily distributed, highly mobile, or has an extensive foraging range; and
  o the species is known to be cryptic and may not have been detected despite extensive surveys.
• the species has been recorded recently nearby and species presence cannot be ruled out due to factors such as species ecology or distribution however;
  o doubt remains over taxonomic identification;
  o the majority of habitat does not appear suitable; and
  o coordinates are doubtful.

Unlikely
There is an outward potential for the species to use the Study Area as; • the Study Area lacks critical habitat, only supports marginally suitable habitat, or is severely degraded; and/or • there are few historic record/s and no other current records in the local area.
Not present
The species does not use the Study Area as; • the species is not known to occur within the IBRA bioregion based on current literature and distribution; • the Study Area lacks important habitat for a species that has highly selective habitat requirements; and • the species has been historically recorded within Study Area or locally; however, it is considered locally extinct due to significant habitat changes such as land clearing and/or introduced predators.

3.3 Desktop Results

3.3.1 Vertebrate Fauna

The desktop assessment (including database searches and the literature review) identified a total of 421 species of vertebrate fauna which have previously been recorded and/or have the potential to occur within the Study Area (**Table 3-6; Appendix B**). These comprised:

- 55 native mammals;
- 9 non-native mammals;
- 241 birds;
- 1 non-native bird;
- 106 reptiles; and
- 9 amphibians.

Eight of the mammalian species or subspecies are now considered to be extinct under the EPBC Act and/or BC Act.

Table 3-6: Summary of vertebrate fauna identified by the desktop assessment.

Faunal Group	Level 2 surveys			Level 1/targeted surveys						Database searches/ species lists						
	Strategen (2018a)	360 Environmental (2018)	Cowan *et al.* (2015)	360 Environmental (2017a)	ecologia (2017a)	Paltridge (2015)	Outback Ecology (2012a)	Desert Support Services (2018)	Duguid *et al.* (2005)	DBCA (2019a)	DotEE (2019a)	DBCA (2019b)	Birdlife Australia (2019)	AWC (2019)	ALA (2020)	Northern Territory Department of Environment and Natural Resources (2020)
Mammals	4	7	16	0	6	2	5	1	0	10	1	18	0	24	40	10
Mammals (non-native)	2	4	4	0	5	0	5	0	0	0	8	4	0	0	6	6
Birds	27	38	0	25	35	0	22	0	20	28	22	131	217	168	134	70
Reptiles	31	24	47	0	10	1	14	1	0	3	1	66	0	74	71	22
Amphibians	1	2	1	0	0	0	0	0	0	0	0	4	0	6	2	0
Total	65	75	68	25	56	3	46	2	20	41	32	223	217	272	253	108

3.3.2 Significant Vertebrate Fauna

Of the 421 species of vertebrate fauna identified as being previously recorded and/or having the potential to occur within the Study Area, 60 were classified as significant fauna, comprising 24 mammals, 32 birds and 4 reptile species (**Table 3-7**). Of these 60 significant fauna species, 12 species have previously been recorded from within the Study Area prior to the Stantec Survey.

Table 3-7: Significant vertebrate fauna species identified during the desktop assessment.

Scientific Name	Common Name	EPBC	BC Act
Mammalia			
Bettongia penicillata ogilbyi	Woylie	En	Cr
Myrmecobius fasciatus	Numbat	En	En
Petrogale lateralis lateralis	Black-footed Rock-wallaby	En	En
Perameles bougainville	Shark Bay Bandicoot	En	Vu
Dasyurus geoffroii	Chuditch	Vu	Vu
Isoodon auratus auratus	Golden Bandicoot	Vu	Vu
Petrogale lateralis 'MacDonnell Range form'	McDonnell Range Rock-wallaby	Vu	Vu
Macroderma gigas	Ghost Bat	Vu	Vu
*Macrotis lagotis**	Bilby	Vu	Vu
Phascogale calura	Red-tailed Phascogale	Vu	CD
Trichosurus vulpecula arnhemensis	Northern Brushtail Possum	-	Vu
Lagorchestes conspicillatus leichardti	Spectacled Hare-wallaby	-	P3
*Dasycercus blythi**	Brush-tailed Mulgara	-	P4
Leggadina lakedownensis	Short-tailed Mouse	-	P4
*Notoryctes caurinus**	Northern Marsupial Mole	-	P4
Notoryctes typhlops	Southern Marsupial Mole	-	P4
Bettongia anhydra	Desert Bettong	-	Ex
Macrotis leucura	Lesser Bilby	Ex	Ex
Bettongia lesueur graii	Burrowing Bettong	Ex	Ex
Chaeropus ecaudatus	Pig-footed Bandicoot	Ex	Ex
Perameles eremiana	Desert Bandicoot	Ex	Ex
Onychogalea lunata	Crescent Nailtail Wallaby	Ex	Ex
Lagorchestes hirsutus hirsutus	Rufous Hare-wallaby	Ex	Ex
Lagorchestes asomatus	Central Hare-wallaby	Ex	Ex
Aves			
Calidris ferruginea	Curlew Sandpiper	Cr; Mi	Vu; IA
Pezoporus occidentalis	Night Parrot	En	Cr
*Rostratula australis**	Australian Painted Snipe	En	En
Erythrura gouldiae	Gouldian Finch	En	P4
*Polytelis alexandrae**	Princess Parrot	Vu	P4
Falco hypoleucos	Grey Falcon	-	Vu
Falco peregrinus	Peregrine Falcon	-	S
*Apus pacificus**	Fork-tailed Swift	Mi	IA
*Charadrius veredus**	Oriental Plover	Mi	IA
Pluvialis fulva	Pacific Golden Plover	Mi	IA
Glareola maldivarum	Oriental Pratincole	Mi	IA
Hirundo rustica	Barn Swallow	Mi	IA
Sterna caspia	Caspian Tern	Mi	IA
Sterna leucoptera	White-winged Black Tern	Mi	IA
*Sterna nilotica**	Gull-billed Tern	Mi	IA
Motacilla cinerea	Grey Wagtail	Mi	IA
Motacilla flava	Yellow Wagtail	Mi	IA
Pandion haliaetus	Osprey	Mi	IA

Scientific Name	Common Name	EPBC	BC Act
*Calidris acuminata**	Sharp-tailed Sandpiper	Mi	IA
Calidris melanotos	Pectoral Sandpiper	Mi	IA
*Calidris ruficollis**	Red-necked Stint	Mi	IA
Calidris subminuta	Long-toed Stint	Mi	IA
Gallinago megala	Swinhoe's Snipe	Mi	IA
Limosa lapponica	Bar-tailed Godwit	Mi	IA
Numenius minutus	Little Curlew	Mi	IA
Tringa glareola	Wood Sandpiper	Mi	IA
Actitis hypoleucos	Common Sandpiper	Mi	IA
*Tringa nebularia**	Common Greenshank	Mi	IA
Tringa stagnatilis	Marsh Sandpiper	Mi	IA
*Plegadis falcinellus**	Glossy Ibis	Mi	IA
Amytornis striatus striatus	Striated Grasswren	-	P4
Elanus scriptus	Letter-winged Kite	-	P4
Reptilia			
*Liopholis kintorei**	Great Desert Skink	Vu	Vu
Pogona minor minima	Dwarf Bearded Dragon	-	Vu
Cryptagama aurita	Hidden Dragon	-	P1
Ctenotus uber johnstonei	Spotted Ctenotus	-	P2

*Shows species previously recorded within Study Area

4. Field Surveys

4.1 Overview of Methods

The survey effort for all 17 surveys within the Study Area has been consolidated and presented in **Section 4.2**. The approach and methods applied within the Stantec Survey Area during the Stantec Survey is detailed within **Section 4.3**. The approach and methods for previous surveys are detailed in the respective reports (**Appendix R.1-R.5**).

4.2 Study Area: Overview of Survey Effort

4.2.1 Approach

In total, 17 surveys have been completed within or overlapping the Study Area (including the Stantec Survey), summarised in the literature review (**Section 3**) and detailed for the Stantec Survey in **Section 4.3**. This includes 11 surveys undertaken for the Project and six regional surveys. This section summarises this survey effort across the entire Study Area (**Section 4.2.3**) and presents this effort over time and in relation to season and rainfall (**Section 4.2.2**). Detailed methods for previous surveys completed for the Project are provided in **Appendix R.1 - R.5**, or provided for the Stantec survey in **Section 4.3**.

This section also presents the approach and methods for consolidating the habitat mapping into a single spatial layer. Previous surveys within the Study Area described and delineated habitats at different scales and used different nomenclature, based on characteristics. The approach and methods for consolidating the habitat mapping across the Study Area into a single spatial layer is presented in **Section 4.2.4**.

4.2.2 Survey Season and Rainfall

Season and rainfall is an important consideration for fauna surveys (**Section 4.3.3**). The Study Area has been previously surveyed, in part on 12 occasions. This section provides an overview of these surveys in relation to season and rainfall to inform the adequacy of survey work completed within the Study Area as a whole (**Table 4-1**). Rainfall data has been sourced from Walungurru Airport (Kintore). Walungurru Airport is the closest weather station for the majority of surveys in proximity to Lake Mackay, with long-term data that extends across all surveys (**Figure 4-1**).

Table 4-1: Seasonal and rainfall preceding each survey conducted within, overlapping or adjacent to the Study Area (surveys completed for the Project are shaded grey).

Figure reference	Relevance		Survey	Survey dates	Conditions			Detectability of fauna: season/rainfall			
	Completed for the project	Proximity to Study Area (SA)			Season	Rainfall 12 mths	Rainfall 3 mths	Reptiles	Amphibians	Birds	Mammals
N/A	No	Overlaps portion of the SA (NT & WA portions of Lake Mackay)	Wetlands in the Arid Northern Territory (Duguid *et al.* 2005)	5–6 Sept 2001	Dry season	Well above average	Average*	N/A	N/A	High	N/A
A	No	Maruwa management area encompasses western edge of Lake Mackay and a southern portion of the Stantec Survey Area.	Kiwirrkura Threatened Species Survey 2012 (Paltridge 2012)	12-18 May 2012	Mid-year	Average	Below average	Low	Low	Moderate	Moderate
B	No	Within SA	Theseus Project: Level 1 Flora and Vegetation Assessment (Outback Ecology 2012a)	7-14 June 2012	Mid-year	Average	Below average	Low	Low	Moderate	Moderate
C	No	Overlaps the Study Area. Predominantly the Stantec Survey Area	Looking for animals on Ngururrpa Country (Paltridge 2015)	Aug 2015	Dry season	Average	Below average	Low	Low	Moderate	Moderate
D	No	Intersects the Study Area in the vicinity of Lake Mackay	Kiwirrkurra Indigenous Protected Area BushBlitz Survey (Cowan *et al.* 2015)	5-19 Sept 2015	Dry season	Average	Below average	High	Low	Moderate	Moderate
E	Yes	Within SA	Level 1 Fauna and Single-Phase Level 2 Flora Assessment (ecologia 2017a)	6-13 Sept 2016	Dry season	Average	Above average	High	Low	Moderate	Moderate
F	Yes	Within SA	Waterbird Survey at Lake Mackay (360 Environmental 2017a)	10-19 May 2017	Post-wet season survey	Well above average	Well above average	N/A	N/A	High	N/A
G	Yes	Within SA	Lake Mackay Sulphate of Potash Project: Single Phase Level 2 Fauna Survey at Lake Mackay (360 Environmental 2018)	10-19 May 2017	Post-wet season survey	Well above average	Well above average	Low	High	High	High
H	Yes	Within SA	Lake Mackay sulphate of Potash Project Level 2 Vertebrate and Targeted Fauna Survey (Strategen 2018a)	10-21 Nov 2017	Dry season survey	Average	Above average	High	Low	Moderate	Moderate
I	Yes	Within SA	Night Parrot Monitoring Lake Mackay (ecologia 2019)	21 April - 22 May 2018	Post-wet season	Below average	Below average	N/A	N/A	Moderate	N/A
J	No	Overlaps the Study Area. Predominantly the Stantec Survey Area.	Bilby Blitz Survey on proposed Ngururrpa Indigenous Protected Area (Desert Support Services 2018)	18-22 Oct 2018	Dry season	Below average	Average	N/A	N/A	N/A	Moderate
K	Yes	Stantec Survey Area	Lake Mackay Potash Project: Detailed and Targeted Terrestrial Fauna Survey (Phase 1)(this report)	5–20 Oct 2019 26 Oct - 10 Nov 2019	Dry season survey	Below average (See **Figure 4-8**)	Below average (See **Figure 4-8**)	High	North: Low South: Low	North: Moderate South: Moderate	North: Moderate South: Moderate
L	Yes	Stantec Survey Area	Lake Mackay Potash Project: Detailed and Targeted Terrestrial Fauna Survey (Phase 2) (this report)	7-22 March 2020	Post-wet season survey	Above average in northern half of the Stantec Survey Area, average in the southern half, below average in the vicinity of Lake Mackay (See **Figure 4-9**)	Above average in northern half of the Stantec Survey Area, average in the southern half, below average in the vicinity of Lake Mackay (See **Figure 4-9**)	High	North: High	North: High	North: High
M	Yes	Stantec Survey Area and surrounds	Night Parrot Targeted Surveys (**Appendix I**)	**Stage 1**: Aug 2020 **Stage 2**: Aug – Oct 2020 **Stage 3**: Oct 2020 **Stage 4**: Oct – Dec 2020	Dry season	Above average (rainfall not recorded at Walungurru)	Average	N/A	N/A	Moderate	N/A

Figure reference	Relevance		Survey	Survey dates	Conditions			Detectability of fauna: season/rainfall			
	Completed for the project	Proximity to Study Area (SA)			Season	Rainfall 12 mths	Rainfall 3 mths	Reptiles	Amphibians	Birds	Mammals
N	Yes	Stantec Survey Area and GDS Bypass	Great Desert Skink Targeted Survey (**Appendix K**)	19 Oct – 1 Nov 2020	Dry season	Above average (rainfall not recorded at Walungurru)	Average	High	N/A	N/A	N/A
O	Yes	Within SA	Night Parrot Baseline Survey around Lake Mackay (**Appendix L**)	March - April 2021	Post-wet season	Above average	Above average	N/A	N/A	High	N/A
P	Yes	Within SA	Waterbird Survey at Lake Mackay (**Appendix M**)	30 March - 4 April 2021	Post-wet season	Above average	Above average	N/A	N/A	High	N/A

*Data unavailable for Walungurru (closest station), Rabbit Flat used as replacement

In general, the Level 2/Detailed surveys within the Study Area have been undertaken at an appropriate time of year to detect faunal assemblages. In the vicinity of Lake Mackay, there have been two Level 2 surveys during opposing seasons; 360 Environmental (2018) post wet season; and Strategen (2018a) in spring. The post wet-season survey by 360 Environmental (2018) was at an optimal time post rainfall to detect amphibians, birds and mammals, however, temperatures may have been too cool for some reptiles. However, the dry season survey by Strategen (2018a) during warmer conditions in spring was optimal for reptiles.

The regional Level 2 survey by Cowan *et al.* (2015) which overlaps the Study Area was also completed during suitable conditions for most fauna groups except amphibians. Survey timing for the Stantec Survey is detailed in **Section 4.3.3**. However in general, conditions were appropriate in Phase 1 (autumn) for most species (excluding amphibians) and optimal for all groups during Phase 2 (post wet season; northern portion only). **Section 6** summarises the limitations and constraints of seasonality for all surveys completed for the Project.

Targeted surveys for significant fauna should be undertaken at an appropriate time to detect the activity of the target species (EPA 2020). Significant fauna with potential to occur that were targeted during the surveys of the Study Area included the following groups:

- mammals (particularly the Bilby);
- reptiles (particularly the Great Desert Skink); and
- birds (particularly the Night Parrot and migratory waders).

Surveys targeting the Bilby are considered appropriate throughout the year, with surveys in the Study Area and regional surrounds appropriate for detecting the species (Cowan *et al.* 2015, Desert Support Services 2018, Paltridge 2012, 2015). Targeted surveys for the Great Desert Skink should be undertaken during the months when the species is active; September/October through to May/June. Of the surveys which targeted this species, most were at an appropriate time of year, with the exception of the 360 Environmental (2018) post wet season survey within the Study Area, and two of the regional surveys (Paltridge 2012) (Paltridge 2015).

Survey work for the Night Parrot is optimal in the months post rainfall (DPaW 2017b), as this is when the species forages more widely on available grain, however, roost sites may be detected throughout the year (ecologia 2019). Three surveys have been conducted in the vicinity of Lake Mackay (360 Environmental 2018, ecologia 2019, Strategen 2018a). Of these, the surveys by 360 Environmental (2018) and Strategen (2018a) were post wet season and following average or above rainfall resulting in optimal conditions for detecting the species. However the Night Parrot survey (ecologia 2019) was following below average rainfall and would be less likely to detect the species unless the recorders were deployed near roost locations. For the Stantec Survey, Phase 1 was following below average rainfall, which was sub-optimal for the detection of the species, while Phase 2 (northern portion only), was following above average rainfall in ideal conditions. Additional Night Parrot baseline work was undertaken around the lake post an above average wet season to address seasonal limitations of the previous work (**Appendix L**). Targeted work for the Night Parrot was undertaken over 4 stages during average seasonal conditions in locations where the species had been recorded during the Stantec baseline survey (**Appendix I**).

Surveys for migratory shorebirds should be undertaken during flooded lake conditions, and when the target species is likely to be in Australia. Migratory shorebirds journey south to Australia from northern countries along the East Asian – Australasian Flyway (DEWHA 2009). Generally, this occurs from August to November, with birds remaining in Australia from December to February, before migrating north again, from March to May (DEWHA 2009). While these timings are broad and vary for each species, it provides general periods of optimal surveying for species abundance and diversity.

Three waterbird surveys have been conducted at Lake Mackay following inundation events: 2001 (Duguid *et al.* 2005), 2017 (360 Environmental 2017a) and 2021 (**Appendix M**). The 2001 regional waterbird survey of Lake Mackay was conducted in September and October following two unusually wet seasons. Specifically an extreme rainfall event occurred in March 2001, which followed two high rainfall months (Duguid *et al.* 2005). Kintore received 494 mm of rain in February 2000 and 123 mm in February 2001 (above the annual average of 219 mm). In comparison, Rabbit Flat received 347 mm in March 2001, compared to the annual average of 440 mm (Kintore data unavailable) (Duguid *et al.* 2005).

The 2017 waterbird survey conducted for the Project (360 Environmental 2017a) was undertaken in April following an extremely high rainfall event in December. A total of (425.4mm of rain fell at Kintore in

December 2016, which was six times higher than the monthly average of 68.1 mm and was also above the long-term annual average of 306.1mm (360 Environmental 2017a).

This extreme rainfall would have promoted avifauna activity, however the surveys were conducted approximately four (360 Environmental 2017a) and six months (Duguid *et al.* 2005) following inundation and outside of optimal timing for the detection of migratory shorebirds. At the timing of these surveys, many migratory shorebirds would have started their migration from Australia to northern flyway countries (360 Environmental 2017a) or be on their migration to Australia (Duguid *et al.* 2005). Therefore, species abundance and diversity may have been underestimated and peak waterbird diversity and abundance may have occurred prior to surveying.

The 2021 waterbird survey was undertaken in March and April 2021 following a number of large rainfall events in January, February and March 2021. Large congregations of foraging waterbirds including migratory waterbirds and migratory shorebirds were recorded during the survey (**Appendix M**). The abundance of these waterbirds and the prevalence of aquatic invertebrates recorded during the aquatic survey indicates that conditions were appropriate for understanding the importance of the lake to these groups.

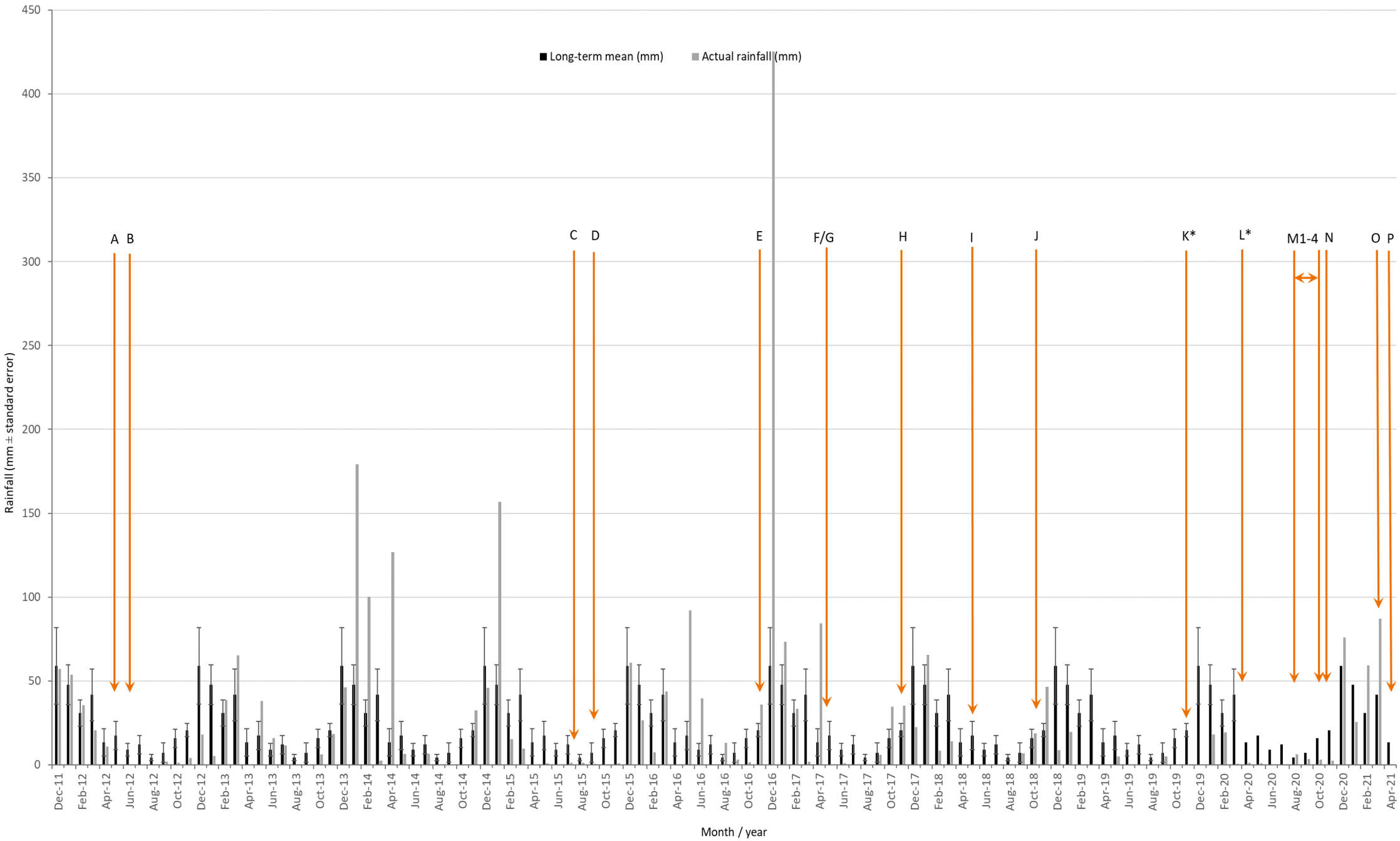

Figure 4-1: Long-term (1998-2020) mean monthly rainfall (mm) at Walungurru Airport weather station (No. 015664) (BoM 2020a). Arrows indicate survey timing (refer to Table 4-1). * indicates the Stantec 2020 Survey.

4.2.3 Survey Effort

Standardised systematic and targeted survey methods have been employed during the previous surveys of the Study Area. This has been undertaken to ensure that species assemblages and significant fauna with potential to occur could be adequately detected. Survey effort has been consolidated for the Study Area and detailed for systematic sites (**Table 4-2**) and targeted sites (**Table 4-3**), with locations of survey effort presented as an overview in **Figure 4-2 - Figure 4-5** with detailed figures provided in **Appendix D.** Subsequent to the baseline surveys, additional targeted search effort has been undertaken for the Night Parrot and Great Desert Skink. This survey effort is not captured under this section, but is detailed within the relevant memorandums (**Appendix I** and **Appendix K**).

In total, 11,735 trap-nights for vertebrate fauna were expended at systematic sites during surveys in the Study Area. This included 8,736 trap nights during the Stantec Survey (Phase 1: 5,824 trap nights and 2,912 trap nights), 1,669 trap nights during the 360 Environmental (2018) survey, 997 trap nights during the Strategen (2018a) survey and 333 trap nights during the Cowan *et al.* (2015) survey. Additionally, systematic sampling within the Study Area accounted for 71 avifauna census hours, 24 systematic searching hours, 24 spotlighting hours, 358 motion-sensor cameras sampling nights and 54 bat echolocation recording nights.

Targeted survey methods specific to each species of significance with potential to occur have been employed in suitable habitats, where encountered, across the Study Area. This targeted survey effort excludes systematic survey effort where the same methods were used at systematic sites.

Avifauna census sites were assessed in targeted waterbird assessments of Lake Mackay and peripheral wetlands in 2021 and 2017, detailed in **Appendix M** and **Appendix R.4**.

Motion cameras were deployed at 157 locations primarily to detect the presence/activity of the Bilby and the Great Desert Skink, but also the Marsupial Mole spp and the Brush-tailed Mulgara. Most of these deployments were within spinifex sandplain (42 locations), but also within dune-field (30 locations) and gravel spinifex plain (28 locations) habitats. Most of this effort was conducted during the Stantec Survey with 128 targeted deployments totalling 2,782 recording nights.

The '2 ha plot' survey method was also used primarily to detect the presence/activity of the Bilby and the Great Desert Skink, but also the Marsupial Mole spp and the Brush-tailed Mulgara. In total, 142 '2 ha plots' were conducted within the Study Area, with most undertaken in spinifex sandplain habitat (74 locations). All 142 '2 ha plots' in the Study Area were conducted during the Stantec Survey of the Stantec Survey Area. Note, previous surveys conducted targeted searches rather than '2 ha plot' searches with the exception of (Desert Support Services 2018), (Paltridge 2015), and (Paltridge 2012) (27, 32, and 29 '2 ha plots' respectively). These reports intersected the Study Area and spatial data of the '2 ha plots' was unavailable, however significant species recorded at these locations are included in the desktop analysis.

Survey effort for the Night Parrot was undertaken by deploying autonomous bird acoustic recorders and by conducting dusk census combined with call playback. In total, acoustic recorders have been deployed at 110 locations within the Study Area. Most of these deployments were within spinifex sandplain and dune-field habitats. Most of these deployments were undertaken by Stantec (68 locations) totalling 919 recording nights followed by the Strategen (2018a) survey (29 locations). Additionally, Night Parrot playback was undertaken during the Stantec Survey at a total of 16 locations within the Study Area. Subsequent to the baseline surveys, an additional 89 units (604 recording nights) were deployed (Stage 1-4) to better understand Night Parrot occurrence at two locations that coincide with the Study Area (**Appendix I**).

No significant bat species were anticipated to occur within the Study Area (the Ghost Bat was returned in database searches, however the Study Area is outside the species current range). However, targeted deployment of echolocation recorders was undertaken at habitats where bat species were more likely to be recorded (water sources and caves) to increase the knowledge of what bat species utilise the Study Area. In total, 20 bat echolocation recorders were deployed within the Study Area. The majority of these were deployed within rocky ridge and gorge habitat (six locations). Most of these deployments were undertaken during the Stantec Survey (18 locations) totalling 188 recording nights.

Habitat assessments have been undertaken throughout the Study Area during the previous surveys. Although not a targeted survey method, results are presented to provide an understanding of effort and spread across habitats within the Study Area, including at systematic sites. In total, 153 habitat assessments were conducted in the Study Area. Most were completed in spinifex sandplain habitat (52 locations), but also dune-field (28 locations) and gravel spinifex plain (24 locations) habitats. Most assessments (101 locations) were undertaken by Stantec within the Stantec Survey Area. Additionally, 21 microhabitat

assessments were undertaken during the Stantec Survey where microhabitats were encountered, such as caves or water sources that may be of importance to significant species or assemblages. Habitat descriptions of the playa were informed by assessments undertaken during the aquatic ecology surveys (Stantec 2020a).

Table 4-2: Consolidated systematic site survey effort within the Study Area.

Survey	Phase	Habitat	Site	Trap nights						Avifauna census (mins.)	Systematic searches (mins.)	Nocturnal searches (mins.)	Motion camera nights (locations)	Bat recording nights (locations)
				Buckets	Pipes	Funnels	Small Elliotts	Cages	Total					
Stantec (2020)	Phase 1	Lake Margin	A	35	35	140	140	14	364	140	60	60	14 (2)	2 (1)
		Dune	B	35	35	140	140	14	364	140	60	60	14 (2)	2 (1)
		Spinifex sandplain	C	35	35	140	140	14	364	140	60	60	14 (2)	2 (1)
		Claypans and claypan mosaic	D	35	35	140	140	14	364	140	60	60	14 (2)	2 (1)
		Spinifex sandplain	E	35	35	140	140	14	364	140	60	60	14 (2)	2 (1)
		Spinifex sandplain	F	35	35	140	140	14	364	140	60	60	14 (2)	2 (1)
		Gravel spinifex plain	G	35	35	140	140	14	364	140	60	60	14 (2)	2 (1)
		Dune	H	35	35	140	140	14	364	140	60	60	14 (2)	2 (1)
		Dune-field	I	35	35	140	140	14	364	140	60	60	14 (2)	2 (1)
		Gravel spinifex plain	J	35	35	140	140	14	364	140	60	60	14 (2)	2 (1)
		Rocky ridge and gorge	K	35	35	140	140	14	364	140	60	60	14 (2)	2 (1)
		Gravel spinifex plain	L	35	35	140	140	14	364	140	60	60	14 (2)	2 (1)
		Dune-field	M	35	35	140	140	14	364	140	60	60	14 (2)	2 (1)
		Spinifex sandplain	N	35	35	140	140	14	364	140	60	60	14 (2)	2 (1)
		Gravel spinifex plain	O	35	35	140	140	14	364	140	60	60	14 (2)	2 (1)
		Spinifex sandplain	P	35	35	140	140	14	364	140	60	60	14 (2)	2 (1)
			Total	560	560	2240	2240	224	5824	2240	960	960	224 (32)	32 (16)
	Phase 2	Dune-field	I	35	35	140	140	14	364	140	60	60	14 (2)	2 (1)
		Gravel spinifex plain	J	35	35	140	140	14	364	140	60	60	14 (2)	2 (1)
		Rocky ridge and gorge	K	35	35	140	140	14	364	140	60	60	14 (2)	2 (1)
		Gravel spinifex plain	L	35	35	140	140	14	364	140	60	60	14 (2)	2 (1)
		Dune-field	M	35	35	140	140	14	364	140	60	60	14 (2)	2 (1)
		Spinifex sandplain	N	35	35	140	140	14	364	140	60	60	14 (2)	2 (1)
		Gravel spinifex plain	O	35	35	140	140	14	364	140	60	60	14 (2)	2 (1)
		Spinifex sandplain	P	35	35	140	140	14	364	140	60	60	14 (2)	2 (1)
			Total	280	280	1120	1120	112	2912	1120	480	480	112 (16)	16 (8)
(360 Environmental 2018)	Phase 1	Dune-field	1	70	-	112	70	28	280	90	-	-	1 (1)	1 (1)
		Dune-field	2	70	-	112	70	28	280	90	-	-	1 (1)	1 (1)
		Claypans and claypan mosaic	3	67	-	112	70	28	277	90	-	-	1 (1)	1 (1)
		Claypans and claypan mosaic	4	70	-	112	70	28	280	90	-	-	1 (1)	1 (1)
		Dune-field	5	70	-	112	70	28	280	90	-	-	1 (1)	1 (1)
		Dune-field	6	62	-	112	70	28	272	90	-	-	1 (1)	1 (1)
			Total	409	-	672	420	168	1669	540	-	-	6 (6)	6 (6)
(Strategen 2018a)	Phase 2	Dune-field	SA1	67	-	112	40	28	247	90	-	-	2 (2)	-
		Dune-field	SA2	70	-	112	40	28	250	90	-	-	2 (2)	-
		Spinifex sandplain	WA1	70	-	112	40	28	250	90	-	-	2 (2)	-
		Spinifex sandplain	WA2	70	-	112	40	28	250	90	-	-	2 (2)	-
			Total	277	-	448	160	112	997	360	-	-	16 (8)	-
(Cowan *et al.* 2015)	Phase 1 (single phase)	Saline flats and depressions	V12	18	-	18	75	-	111	-	-	-	-	-
		Dune-field	V13	12	-	12	50	-	74	-	-	-	-	-
		Dune-field	V14	12	-	12	50	-	74	-	-	-	-	-
		Lake Margin	V15	12	-	12	50	-	74	-	-	-	-	-
			Total	54	-	54	225	-	333	-	-	-	-	-
Study Area Total				1,580	840	4,534	4,165	616	11,735	4,260	1,440	1,440	358	54

Table 4-3: Consolidated baseline targeted survey effort within the Study Area for each habitat (habitats in order of extent within the Study Area).

Habitat	Number of survey locations					
	Motion camera	2Ha Plots	Bird acoustic recorders	Night Parrot dusk census and call playback	Bat echolocation recorders	Habitat assessments
Salt lake playa			0		0	0
Spinifex sandplain	42	74	39	7	2	52
Dune-field	30	23	22	2	3	28
Claypans and claypan mosaic	14	9	8	1	0	14
Lake margin	1		13	1	1	12
Gravel spinifex plain	28	29	9	5	2	24
Saline flats and depressions	4		6		0	4
Dune	9	5	1		0	4
Outcropping and stony rise	4	2	0		1	5
Ridge slope	4		6		1	2
Drainage line	6		5		4	2
Rocky ridge and gorge	15		1		6	6
Cleared						
Total	157	142	110*	16	20	153

* excludes additional targeted Night Parrot surveys (Stage 1-4: 89 units)(**Appendix I**). These surveys were undertaken subsequent to the baseline surveys to better understand Night Parrot occurrence at two locations that coincide with the Study Area.

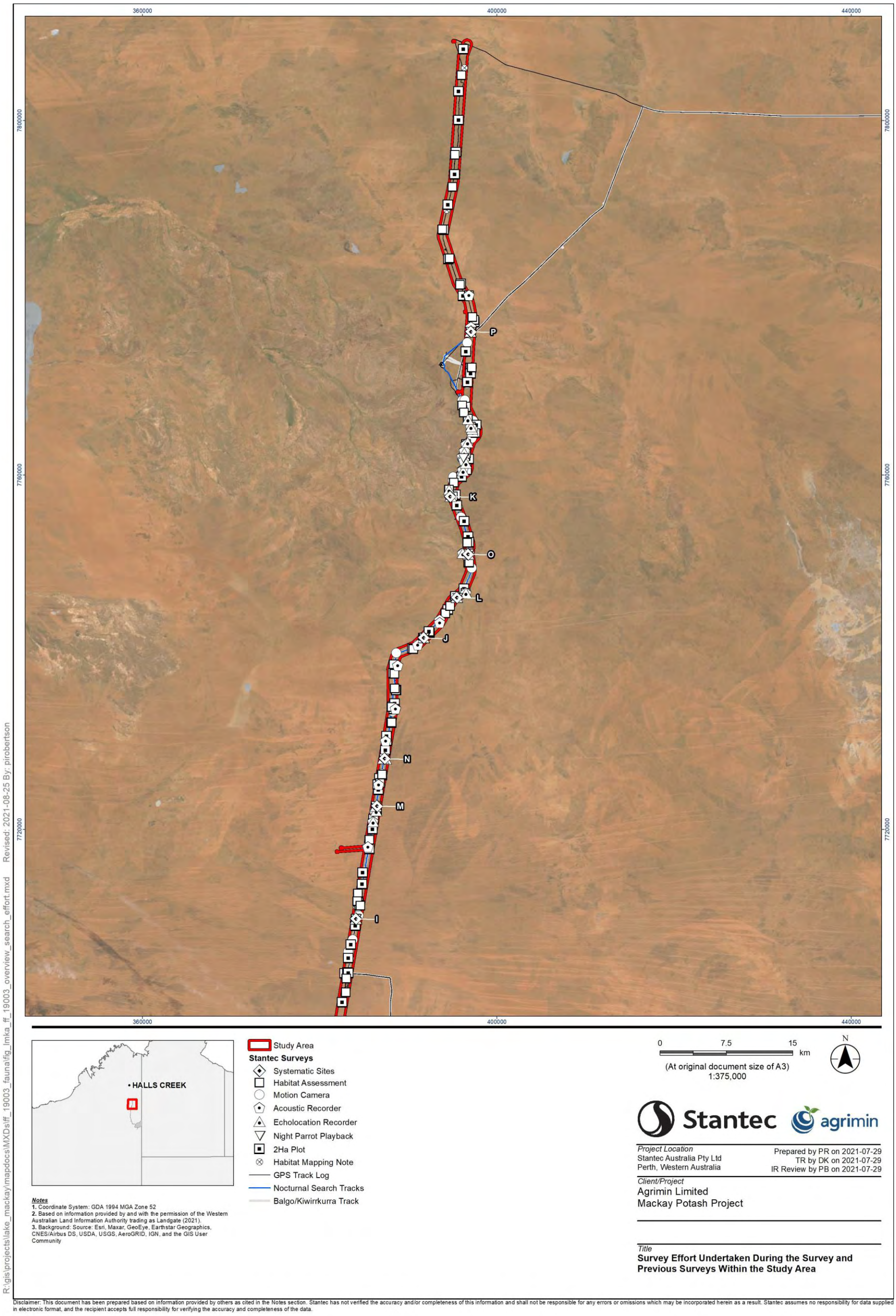

Figure 4-2: Overview: Consolidated survey effort undertaken within the Study Area (haul road - north).

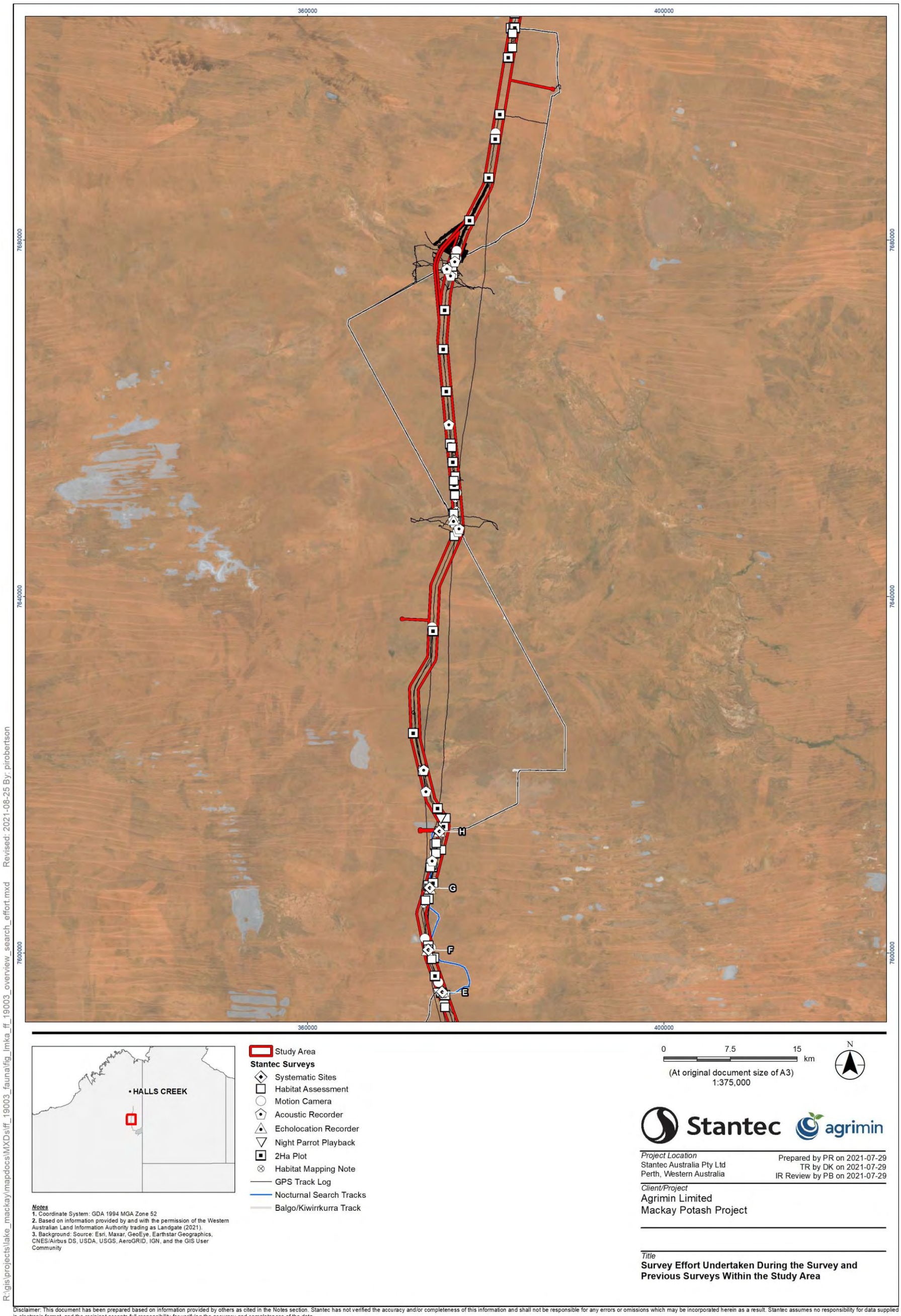

Figure 4-3: Overview: Consolidated survey effort undertaken within the Study Area (haul road - central).

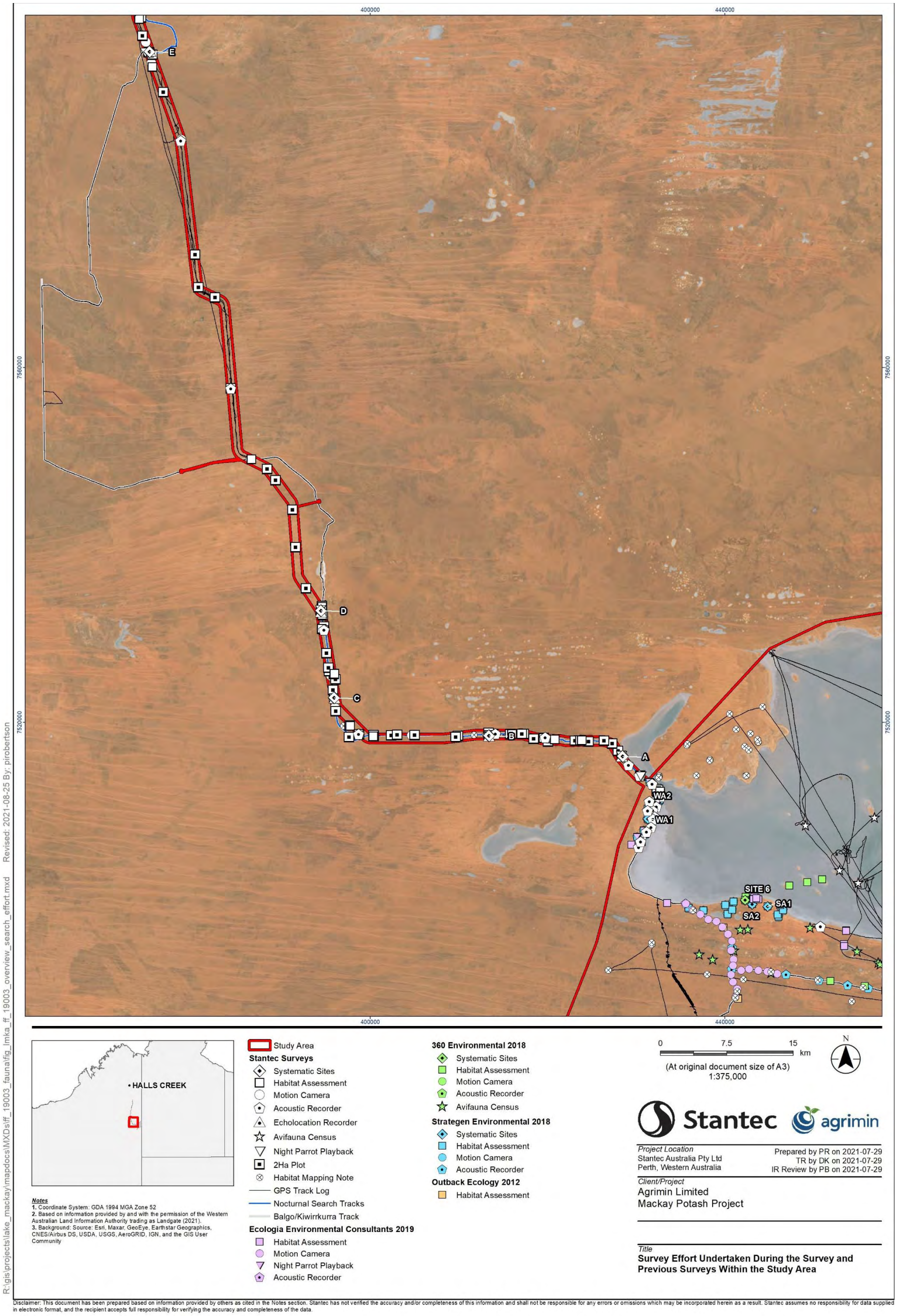

Figure 4-4: Overview: Consolidated survey effort undertaken within the Study Area (haul road – south).

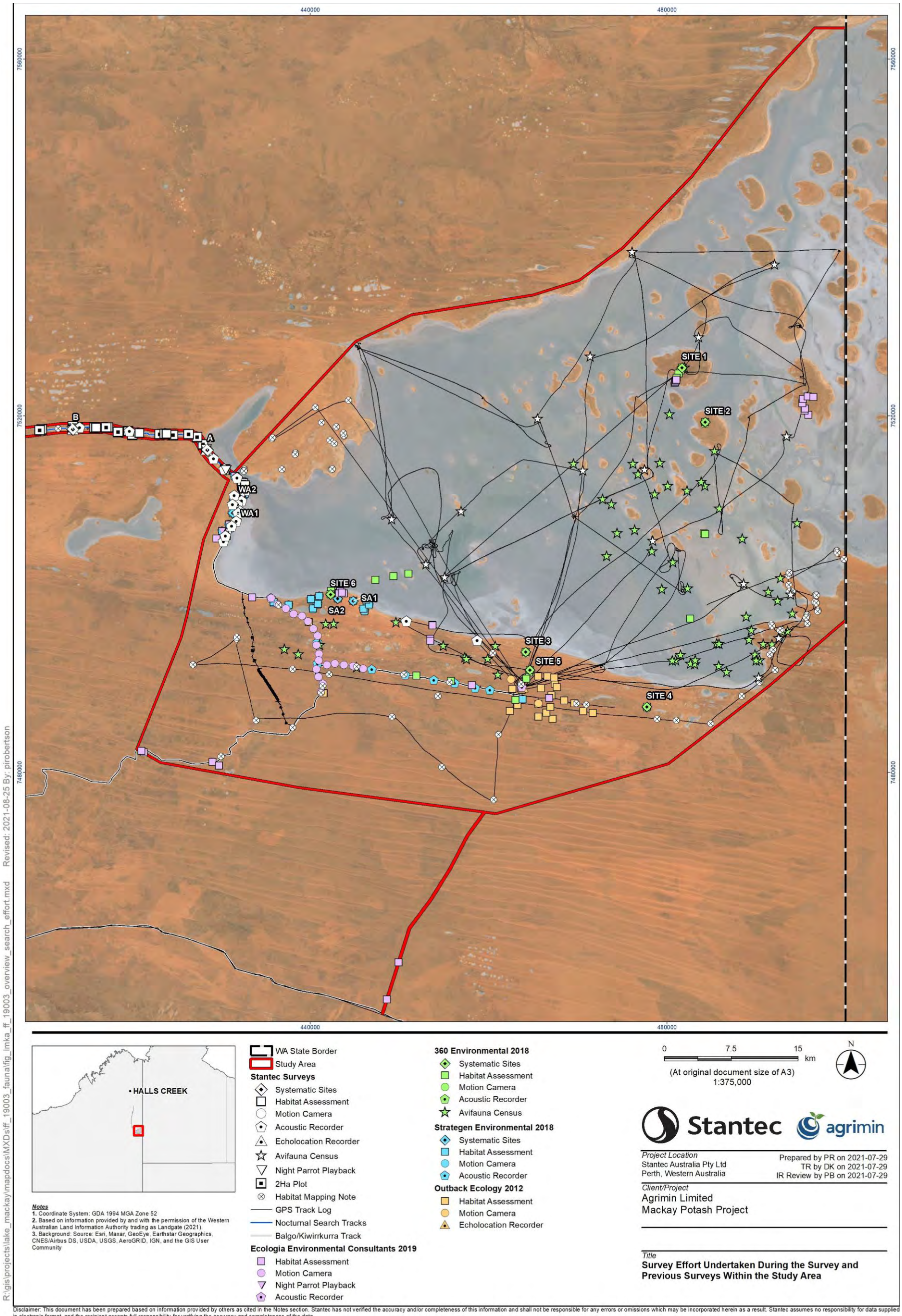

Figure 4-5: Overview: Consolidated survey effort undertaken within the Study Area (Lake Mackay).

4.2.4 Consolidation of Mapping

Habitat types described and mapped for the four previous surveys (360 Environmental 2018, ecologia 2017a, Outback Ecology 2012b, Strategen 2018a) was combined with mapping from the Stantec Surveys to create one consolidated mapping dataset. This was achieved by initially categorising the described habitats, adopting consistent nomenclature, remapping these habitats to a consistent scale and delineating each of these habitats based on set characteristics. The characteristics used to delineate each habitat was based on location, landform, substrate, vegetation type and their importance to different faunal groups, particularly importance to fauna of significance.

Where possible, ground-truthing of the previous mapping was conducted in the field by Stantec zoologist, Samantha Lostrom. Broad boundaries were delineated initially by inspection from the helicopter and were subsequently refined through a number of on-ground assessments and aerial imagery interpretation. Photographs of the described habitats from each survey were assessed to confirm grouping of comparable habitat descriptions. Given the size and remoteness of the Study Area, it was necessary to extrapolate the habitat mapping in a number of areas. Extrapolation was required where there was an absence of sample site data, or on-ground coverage did not occur. For example, a lack of access to all but three of the (approximately 240) islands of Lake Mackay necessitated the interpretation of aerial imagery and analysis of sample site data from equivalent habitats to define and delineate habitat types. The mapping consolidation process also involved:

- reviewing mapping notes that were recorded during the Stantec surveys to verify and define habitat descriptions and delineate habitat boundaries;
- desktop interpretation of aerial imagery to assist in interpreting landforms and habitat patterns in order to modify polygon boundaries defined in previous reports;
- aligning the scale of all previous and current mapping;
- reviewing vegetation descriptions, quadrats and relevés where previous fauna survey effort was unavailable, or where mapping at a finer scale was required;
- where habitat type mapping was extrapolated, the following were used to confirm and delineate polygons:
  - previous report text, figures and photographs, where available;
  - land system data, which informed substrate and geology;
  - aerial imagery, which informed features including, outcropping and stony rises, breakaways and gorges, sand dunes, depressions or claypans and lake margins.
- major linear dunes were mapped in a semi-automated workflow, with a digital elevation model and GIS used to calculate the geomorphic characteristics of each pixel and group them into unique features, from which the dunes were extracted before being cleaned manually.

4.3 Stantec Surveys

4.3.1 Survey Timing and Logistics

Vertebrate fauna surveys completed by Stantec within the Study Area are summarised as follows:

- Preliminary Survey of the Stantec Survey Area: 25 February to 4 March 2019;
- Consolidation Survey of habitat mapping across the Study Area: 2 October to 6 October 2019;
- Detailed & Targeted surveys of the Stantec Survey Area (the Stantec Survey);
  - Phase 1: Southern portion: 7 to 20 October 2019;
  - Phase 1: Northern portion: 26 October to 10 November 2019;
  - Phase 2: Northern portion: 7 to 22 of March 2020;
- Night Parrot Targeted Surveys: deployments within the Stantec Survey Area (first deployments on 22 August 2020);

- Night Parrot Habitat Mapping Desktop Study. Habitat mapping of old growth spinifex across the entire Study Area to determine the occurrence of potential roost habitat; and
- Great Desert Skink Targeted Survey: in the Stantec Survey Area: 19 October to 1 November 2020.
- Night Parrot Baseline Survey of Lake Mackay (**Appendix L**)
- Waterbird Survey of Lake Mackay (**Appendix M**)
- Night Parrot Habitat: Regional Modelling (**Appendix N**)

The broad tasks of each survey were as follows:

- **Preliminary Survey:** Given the detailed survey was anticipated to be logistically complex as well as covering a broad range of habitats across two bioregions, a Preliminary Survey was undertaken for planning and reconnaissance purposes. This involved a self-supported survey of the Stantec Survey Area, travelling the proposed alignment from south to north over a period of five days (where 4WD access permitted). The key objective was to plan remote camps, logistics, supply options, align broad habitat mapping and select indicative survey sites for the subsequent detailed and targeted fauna surveys. The rationale behind the selection of survey sites is discussed in **Section 4.3.4.2**. SRE wet pitfall traps were deployed along the proposed Stantec Survey Area; all vertebrate fauna by-catch was included in this report.
- **Consolidation Survey:** This survey was based at the Lake Mackay camp, and covered parts of the Study Area that were surveyed by other consultants (360 Environmental 2018, ecologia 2017a, Outback Ecology 2012b, Strategen 2018a). Broadly, these previous surveys encompassed Lake Mackay and the immediate surrounds. The Consolidation Survey focused on amalgamating previous habitat type mapping by aligning scale, descriptions and defining characteristics. It also involved ground-truthing key areas of interest around the lake via 4WD vehicle and helicopter. The approach and methods are detailed in **Section 4.2 and the** consolidated survey effort within the Study Area is provided in **Section 4.2.3.** Logistical constraints shortened the survey, however all the main areas of interest were visited (**Section 6**).
- **Detailed and targeted Surveys:** These surveys extended across the entire length of the Stantec Survey Area. Given the size and logistical constraints involved, the survey was split into two halves. They were completed as separate surveys involving four zoologists and two field surveys per phase. It should be noted however that the phase 2 survey effort could not be conducted in the southern portion of the Stantec Survey Area due to COVID-19 restrictions (**Section 4.2.2** and **Section 6**).
    - The southern half of the Stantec Survey Area was surveyed by establishing two remote camps. This was required given the distances and relatively slow vehicle speeds (~40 km/h) along the Balgo Track. The south camp was established at the Murruwa handpump (52 K 396811mE, 7519376mN). The north camp was established at "Camp B" a large claypan (52 K 372685mE, 7601155mN) roughly equidistant between the decommissioned aboriginal outposts of Bibarrd and Lamanbandah. Both camps were intermittently supplied over the duration of the survey.
    - The northern half of the Stantec Survey Area was surveyed from a single base camp established at "Balgo Rise" (52 K 396359mE 7760354mN) located approximately 12 km south of the town of Balgo. Access was good in the northern half of the Stantec Survey Area which permitted each survey team to travel north or south to check trapping sites within acceptable time frames after sunrise. The single camp was used during both Phase 1 and Phase 2 surveys of the northern half of the Stantec Survey Area. The camp was supplied and supported for the duration of the survey.
- **Night Parrot Targeted Survey (Appendix I):** These surveys were informed by Night Parrot call results detected during the detailed and targeted Stantec Survey. The survey comprised acoustic units deployed in grids within optimal habitat surrounding known call locations to locate potential nearby roosts. Units were deployed inside and immediately adjacent to the Study Area and were collected and redeployed in stages according to methods specified in **Section 4.3.4.4.3** as follows:
    - Stage 1: 24 units deployed 22 August 2020, collected 30 and 31 August 2020. All calls analysed by Nigel Jackett and incorporated into report.
    - Stage 2: 24 units deployed 30 and 31 August 2020, collected on the 20 October 2020. All calls analysed by Nigel Jackett and incorporated into report.

- Stage 3: 17 units: deployed 21 October 2020, collected 27 October 2020. All calls analysed by Nigel Jackett and incorporated into report.
- Stage 4: 24 units: deployed 27 and 28 October, collected in December 2020. All calls analysed by Nigel Jackett and incorporated into report.

- **Night Parrot Habitat Mapping Desktop Study** (**Appendix J**): Habitat mapping of old growth spinifex across the entire Study Area to determine the occurrence of potential roost habitat.
- **Great Desert Skink Targeted Survey (Appendix K):** The targeted survey was informed by the detection of active burrows at one broad location assessed in the Stantec Survey, and was conducted from 19 October, 2020 to the 1 November, 2020. Survey effort focused on quantifying the occurrence of the population in suitable habitat within and surrounding the Study Area to identify a route that potentially avoided or minimised impacts to the species while furthering understanding of the population.
- **Night Parrot Baseline Survey** around Lake Mackay (**Appendix L**)
- **Waterbird Survey** at Lake Mackay following a flooding event (**Appendix M**)
- **Night Parrot Habitat Modelling** of extent in regional surrounds (**Appendix N**)

4.3.2 Survey Team and Licencing

All surveys were led by Stantec staff (botanists and zoologists) who have extensive experience in survey planning, logistics, significant species and survey methods in the arid zone (**Table 4-4**). The Preliminary Survey and the Consolidation Survey were conducted by Alice Bott (Senior Botanist) and Samantha Lostrom (Zoologist). Alice and Samantha worked closely during the Preliminary Survey to plan remote camps, logistics and supply options, align broad mapping and select indicative survey sites for the subsequent detailed and targeted Surveys of the Stantec Survey Area.

The Stantec Survey (Phase 1) was conducted by experienced zoologists Samantha Lostrom (Stantec), Jeff Turpin, Ray Lloyd and Steph Williams (Stantec)(**Table 4-4**). Phase 2 was conducted by Samantha Lostrom (Stantec), Jeff Turpin, Ray Lloyd and Melissa Jensen (Stantec). All team leads had extensive experience conducting fauna surveys in the arid zone, including the identification of significant fauna and the deployment of survey equipment. In particular, Jeff and Ray are arid zone specialists who were engaged due to the likely occurrence of significant fauna and range extensions, particularly herpetofauna.

Survey effort and local fauna knowledge during Phase 1 of the Stantec Survey was substantially increased by the participation and contribution of traditional owners. These included the Kiwirrkurra, Ngururrpa and Paruku Indigenous rangers and representatives from Tjurabalan within each of their respective native title determinations. In particular, the survey work completed by Kiwirrkurra and Ngururrpa rangers within their determinations added considerable knowledge on the occurrence of significant fauna within the Stantec Survey Area. Survey work by these groups was coordinated by experienced remote survey coordinators Kate Crossing, Rachael Paltridge and Steve Eldridge of Desert Support Services (DSS). These surveys were conducted as independent targeted surveys for significant fauna in the Stantec Survey Area.

The targeted survey methods carried out by the Kiwirrkurra and Ngururrpa rangers and DSS comprised 2 ha plots and the deployment of motion cameras, bird acoustic recorders, and bat echolocation recorders in suitable habitat for the detection of significant fauna (**Section 4.3.4.4**). The logistics and supplies for these surveys were completed concurrently with the Stantec Detailed Flora and Vegetation Survey (Stantec 2020c), which traversed the Stantec Survey Area over 12 days (excluding four days mobilisation and demobilisation).

This approach allowed increased survey coverage by each group by having a moving camp. This approach also permitted access to the helicopter for targeted survey work and infill areas that were not accessible by 4WD. Additionally, the Paruku rangers and Tjurabalan representatives shared the locations of caves, permanent water and other important sites within and surrounding the Stantec Survey Area, which would also have significance for fauna.

Analysis of bat echolocation recordings were analysed by Robert Bullen of BatCall WA. Analysis of acoustic recordings were completed by specialist Night Parrot ornithologist Nigel Jackett using a Western Australian Night Parrot call library. All components of the field survey were conducted under DBCA Regulation 27 licence BA27000146 issued on the 01/10/2019, and a Section 40 Authorisation to Take or Disturb Threatened Species TFA 20119-0067 issued on the 27/09/2019.

Table 4-4: Survey teams undertaking field surveys of the Stantec Survey Area.

Personnel	Qualifications	Role	Years' Experience
Preliminary Survey			
Alice Bott	BSc (Environmental Biology) BSocSc (Geography)	Senior Botanist	11
Samantha Lostrom	First Class Honours (Zoology) BSc (Marine Biology and Zoology)	Zoologist	6
Consolidation survey			
Alice Bott	BSc (Environmental Biology) BSocSc (Geography)	Senior Botanist	11
Samantha Lostrom	First Class Honours (Zoology) BSc (Marine Biology and Zoology)	Zoologist	6
Stantec 2020 Survey: Phase 1			
Jeff Turpin	BSc (Zoology)	Senior Zoologist (arid zone specialist) and team lead	15
Samantha Lostrom	First Class Honours (Zoology) BSc (Marine Biology and Zoology)	Zoologist and survey lead	6
Ray Lloyd	First Class Honours (Zoology) BSc (Zoology)	Senior Zoologist (arid zone specialist) and team lead	15
Steph Williams	BSc (Conservation Biology and Zoology), BSc (Biomedical Science)	Zoologist	2
Nolia Yukultji Ward	Kiwirrkurra Senior Ranger	Rangers provided integral local knowledge of the area, conducted independent Targeted Surveys for significant fauna (including vital coverage of areas with limited access).	
Jodie Ward	Kiwirrkurra Rangers		
Loretta Gibson			
Conway Gibson			
Kathryn Njamme	Ngururrpa Senior Rangers		
Gary Njamme			
Antoinette Milner	Ngururrpa Rangers		
Nathan Sunfly			
Georgina Sunfly			
Keith Njamme			
Melissa Sunfly			
Clare Galova			
-	Tjurabalan Elder	Provided integral local knowledge of the area	
Nathaniel Stretch	Tjurabalan Chairman	Provided integral local knowledge of the area, co-ordinated Tjurabalan involvement and facilitated Stantec field work	
Jamie Brown	Paruku Rangers and representatives	Rangers provided integral local knowledge of the area and facilitated Stantec field work	
Lachlan Brown			
Courtney Yoomarie			
Kiefer Johns			
Kate Crossing	BSc (hons), Masters (Community Development)	Desert Support Services Ngururrpa and Kiwirrkurra ranger coordinators and survey leads	20
Rachel Paltridge	BSc (hons) PhD (Zoology)		30
Steve Eldridge	BSc (hons)		30
Stantec 2020 Survey: Phase 2			

Personnel	Qualifications	Role	Years' Experience
Jeff Turpin	Bachelor of Science (Zoology)	Senior Zoologist and team lead	15
Samantha Lostrom	First Class Honours (Zoology) BSc (Marine Biology and Zoology)	Zoologist and survey lead	6
Ray Lloyd	First Class Honours (Zoology) BSc (Zoology)	Senior Zoologist and team lead	15
Melissa Jensen	First Class Honours (Ecology) BAppSc (Wildlife Science)	Senior Zoologist	11
Nathaniel Stretch	Tjurabalan Chairman	Provided integral local knowledge of the area, co-ordinated Tjurabalan involvement and facilitated Stantec field work	
Eric Moora	Ngururrpa representative	Provided integral local knowledge of the area and facilitated Stantec field work	

4.3.3 Season, Weather and Rainfall

Fauna activity is closely linked to season, weather conditions and rainfall in the months prior to surveying (EPA 2020). The EPA (2020) acknowledge that it can be difficult to plan and implement surveys around key triggers for vertebrate fauna activity, such as rain-bearing depressions. In addition, temporal differences in activity patterns of fauna means that repeat surveys are often required to yield a more comprehensive species inventory (EPA 2020).

The Stantec Survey Area occurs within the northern Eremean botanical province, which is typically represented by warmer temperatures and summer influenced rainfall events. Within this region, the EPA (EPA 2020) recommends different survey timing for different faunal groups as follows:

- reptiles – most active in warmer months (September to April);
- amphibians – immediately after significant rain events (summer and autumn), when they break aestivation to breed;
- birds – immediately after rain events (summer and autumn), particularly for granivores which feed on prolific seed available post rain; and
- mammals – no preferred time, however population cycles often relate to rainfall and for efficiency, it is considered appropriate to survey mammals concurrently with reptiles.

The Phase 1 survey was conducted in spring between October and November and was therefore within the optimal timing for reptiles and was also appropriate for mammals. The Phase 2 was conducted post 'wet season' in March and was therefore during optimal for all vertebrate fauna groups.

To understand the influence of weather conditions and rainfall leading up to the surveys, weather data was considered and collated from active weather stations in the vicinity of the Stantec Survey Area (**Table 4-5**, **Figure 1-2**). Based on the availability of data and proximity to the Stantec Survey Area, rainfall data was collated from Billiluna in the north and the Lake Mackay Exploration Camp in the south. Temperature data was collated from Rabbit Flat in the north and the Lake Mackay Exploration Camp in the south.

Table 4-5: Active weather stations in proximity to the Stantec Survey Area.

Weather Station	Station number	Operation	Temperature	Rainfall	Proximity to the Stantec Survey Area
Sturt Creek	002029	1899-Current	×	✓	75 km north
Billiluna	002051	1970-Current	×	✓	45 km north-west
Rabbit Flat	015666	1996-Current	✓	✓	210 km east
Lake Mackay Exploration Camp	N/A	2017-Current	✓	✓	35 km south-east
Walungurru Airport (Kintore)	015664	1998-Current	✓	✓	135 km south-east

Rainfall in the 12 months preceding the Phase 1 survey in October 2019 was well below the long-term average for the region, primarily due to a very dry wet season. In the north, Billiluna received 162.3 mm in the 12 months prior to the survey compared to an annual average of 473.2 mm (**Figure 4-6**). In the six months prior to the survey, Billiluna recorded 9.2 mm compared to an average of 62.9 mm. In the south (limited long-term data), the Lake Mackay Exploration camp received 147.7 mm in the 12 months prior to the survey, compared to an average of 148.2 mm (**Figure 4-7**). Although the 12-month data is similar to the average, it is likely an artifact of having limited long-term data, given that the annual average at Walungurru airport (Kintore) is 296.1 mm. Similarly, the Lake Mackay Exploration Camp recorded a low rainfall of 6.9m m in the six months prior to the survey (short term average of 7.5 mm). According to the BoM rainfall percentage maps for the three months preceding Phase 1 of the Stantec Survey, rainfall in the region was well-below average (less than 60% of the mean rainfall) (**Figure 4-8**).

Tropical Cyclone (TC) Esther formed on 24 February 2020 over the Gulf of Carpentaria, which became an intense and wide ranging tropical low, delivering significant rainfall to the NT and northern WA. Record breaking one-day rainfall totals occurred at five locations in WA, with the tropical low travelling through regions including Kununurra, Derby, Halls Creek, then to Tennant Creek in late February and early March (BoM 2020b). Rainfall preceding Phase 2 of the Stantec Survey was positively influenced by this large rain bearing tropical low, which resulted in substantial rainfall, particularly across the northern half of the Study Area in the two weeks prior to Phase 2 of the Stantec Survey. Over 125% of the mean rainfall was recorded for parts of the northern GSD2 and the TAN1 subregions between 1 January and 31 March 2020 (**Figure 4-9**).

Ex-TC Esther crossed the northern half of the Stantec Survey Area near Balgo on 2 and 3 March. At Billiluna, 294.8 mm of rainfall was received in the three months prior to the Phase 2 survey (including rainfall in early March), similar to an average of 296.3 mm for the comparable period of December to February (**Figure 4-6**). Over half of that rainfall occurred in early March, just prior to Phase 2. However, the influence of ex-TC Esther did not extend the whole length of the Stantec Survey Area. In the south, the Lake Mackay Exploration Camp received 93.5 mm in the three months (including rainfall in early March), prior to the survey compared to the short-term average of 89.1 mm for the same period (**Figure 4-7**). However, the mean rainfall at the Lake Mackay Exploration Camp was likely to be underestimated. At Walungurru airport (Kintore) only 38.2 mm of rainfall was received in the three months prior to the survey, less than a third of the long-term average of 137.7 mm for the same period. According to the BoM rainfall percentage maps for the three months preceding Phase 2, rainfall in the region was well above average for the northern portion of the Survey Area, average for the majority of the Study Area and just below average in the southern portion of the Study Area, in the vicinity of the Lake Mackay Exploration Camp(**Figure 4-9**).

The low rainfall during the wet season and in the months preceding Phase 1 of the Stantec Survey may have impacted the availability of faunal resources, therefore reducing the abundance and capture rate of some fauna groups. Particularly, birds and small mammals may have less prevalence as populations are cyclical in response to, and/or abundance is locally influenced by, food resources such as grain. The high rainfall prior to Phase 2 of the Stantec Survey (northern portion only) would have increased resource availability and therefore increased the local abundance and activity of all fauna groups. Specifically, the presence of water would have increased amphibian activity and local birds for species that are attracted to water sources (including water birds) and granivorous species attracted by the prevalence of seeding grasses.

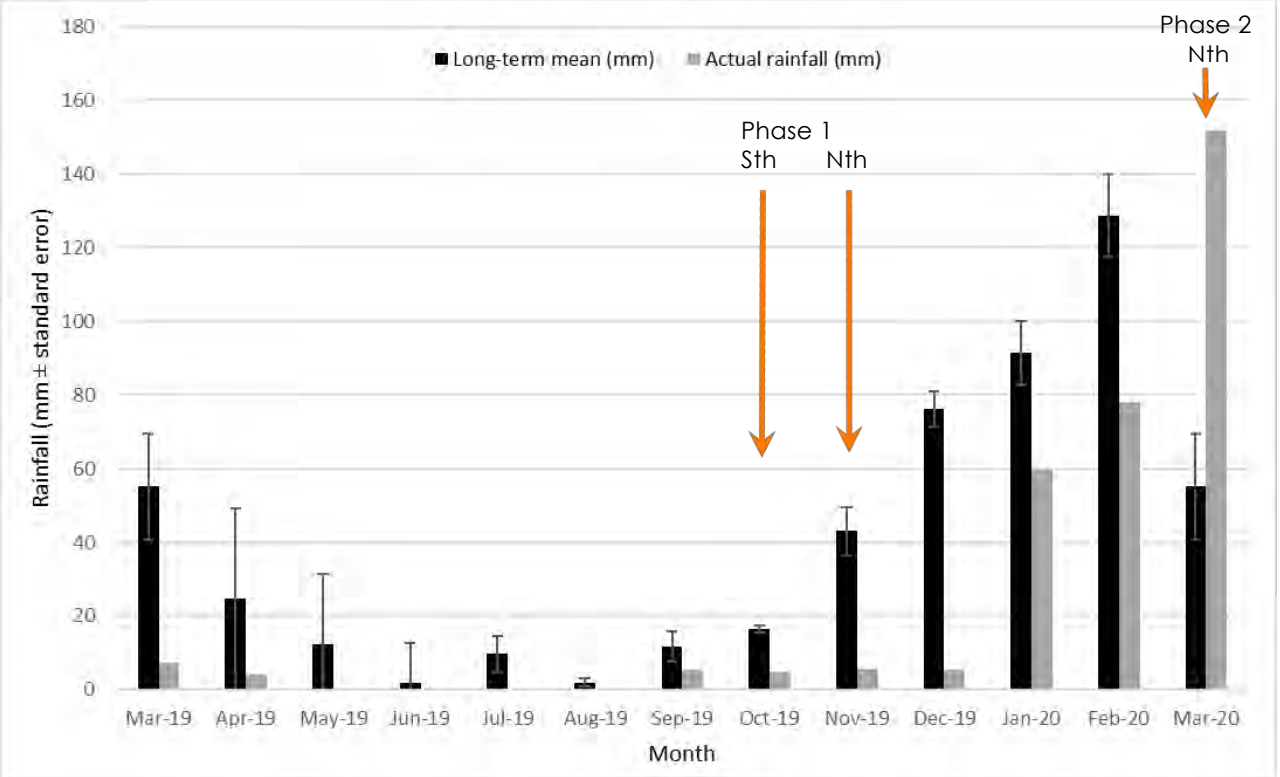

Figure 4-6: Long-term mean monthly rainfall (1971 to 2020) and actual rainfall in the 12 months preceding the Stantec Survey at Billiluna weather station (002051) (BoM 2020b). Arrows indicate Phase 1 and Phase 2 survey timing.

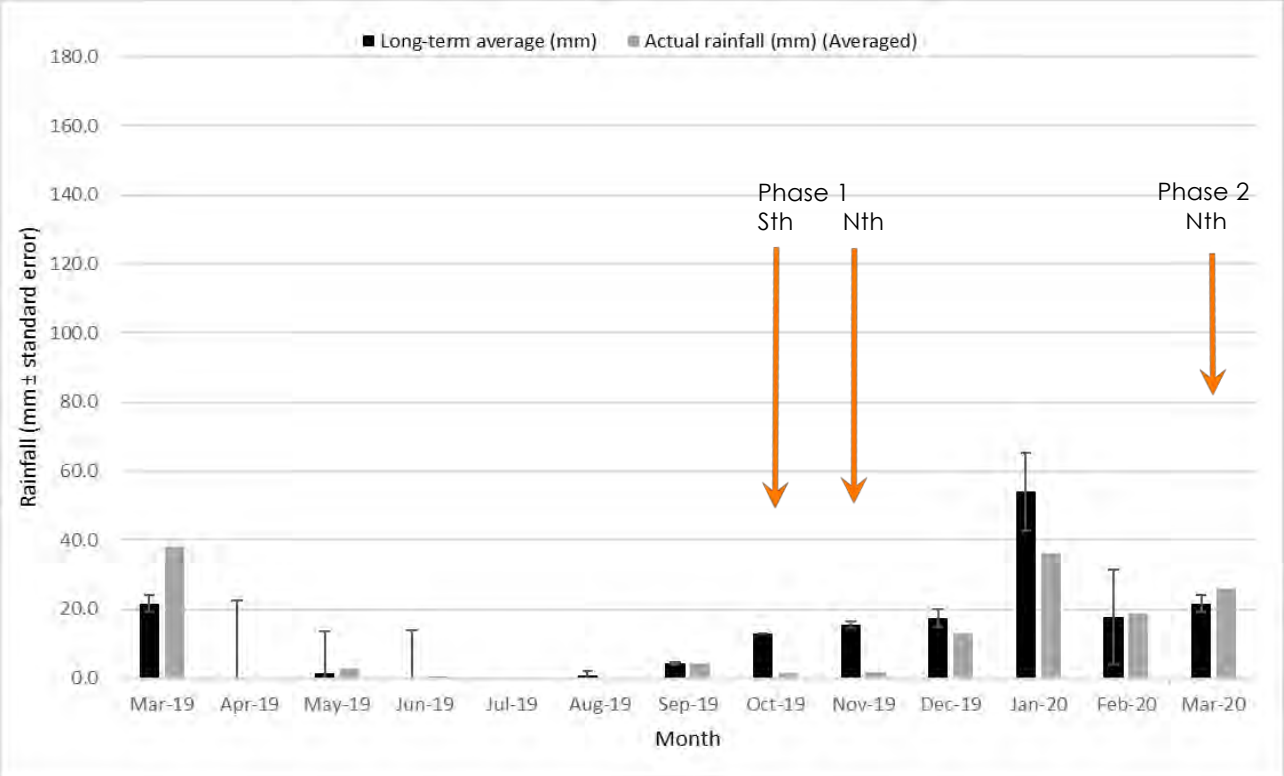

Figure 4-7: Mean monthly rainfall (2017 to 2020) and actual rainfall in the 12 months preceding Phase 1 and Phase 2 of the Stantec Survey at the Lake Mackay Exploration Camp weather station. Arrows indicate Phase 1 and Phase 2 survey timing.

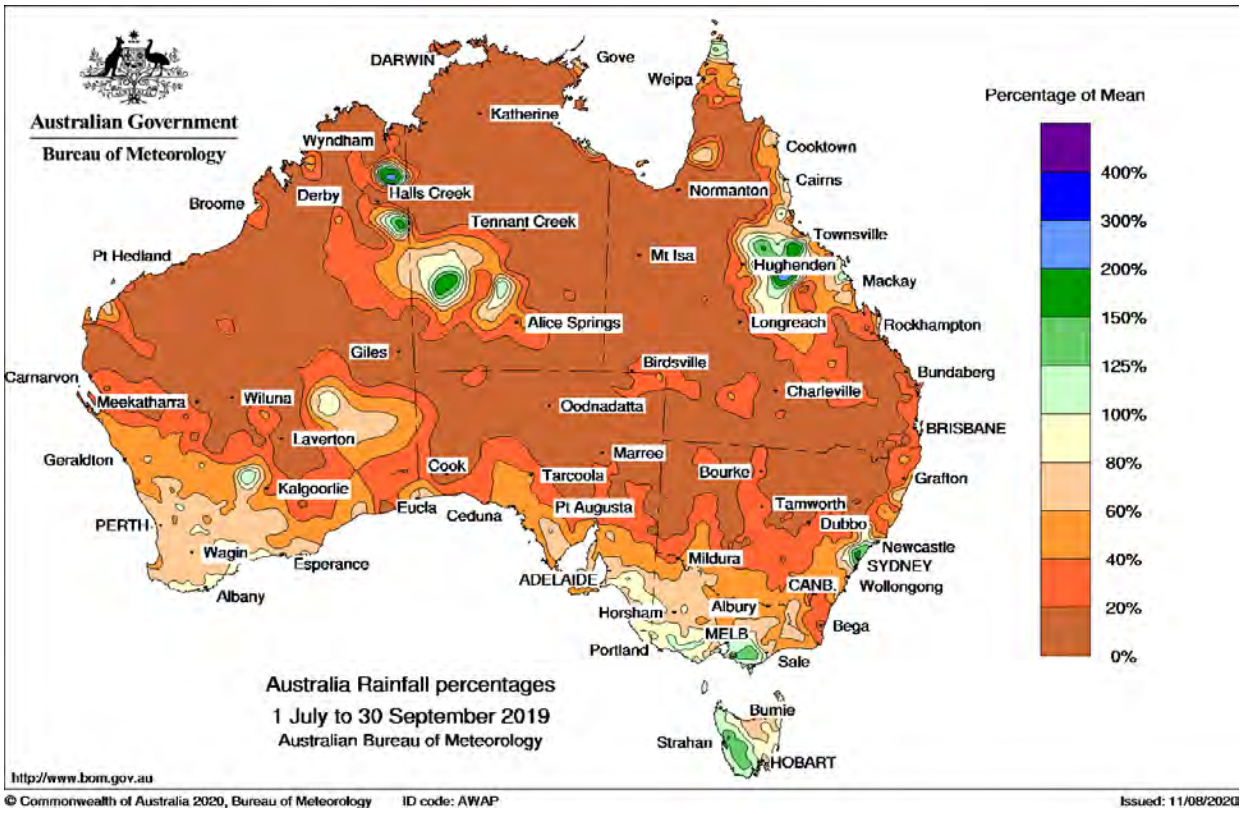

Figure 4-8: Australian rainfall presented as a percentage of the mean for the three months preceding Phase 1 of the Stantec Survey (BoM 2020b).

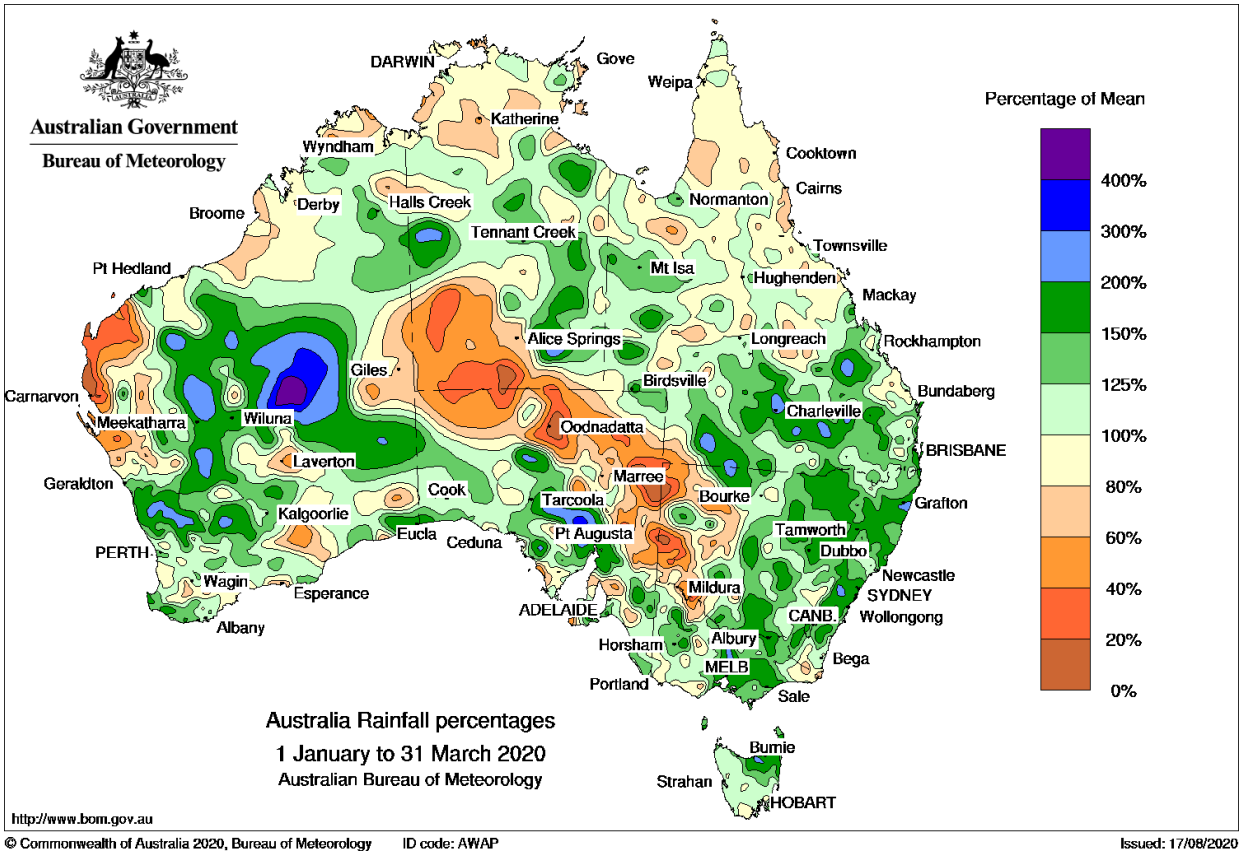

Figure 4-9: Australian rainfall presented as a percentage of the mean for the three months preceding Phase 2 of the Stantec Survey (BoM 2020b).

Weather conditions during Phase 1 of the Stantec Survey were hot and dry (**Table 4-6**), which is typical for the time of year. During the Phase 1 survey of the southern portion, maximum daily temperatures ranged from 37.7°C to 41.6°C, while minimum daily temperatures ranged from 20.0°C to 25.4°C. During the Phase 1 survey of the northern portion, maximum daily temperatures ranged from 35.1°C to 40.9°C, while minimum daily temperatures ranged from 11.9°C to 24.6°C.

Weather conditions during Phase 2 of the Stantec Survey, northern portion only, were very similar to Phase 1, with the exception of having a higher minimum temperature. Maximum daily temperatures ranged from 35.9°C to 41°C, while minimum daily temperatures ranged from 18.0°C to 25°C. No rain was recorded during the Phase 1 or Phase 2 of the Stantec Survey at either of the weather stations. Weather conditions during the surveys would have been appropriate to record most fauna groups, particularly reptiles, but may have been less conducive to bird and amphibian activity, particularly during Phase 1 of the Stantec Survey.

Table 4-6: Temperatures and rainfall recorded during the Stantec Survey. Phase 1-Trip 1 data from onsite Lake Mackay Exploration Camp weather station, Phase 1-Trip 2 and Phase 2-Trip 1 data from Rabbit Flats weather station (No. 015666) (BoM 2020a).

Trip	Date*	Temperature (ºC)		Rainfall (mm)	Relative Humidity (%)	
		Min	Max		Min	Max
Phase 1						
Southern portion	07-10-19	21.3	39.7	0.0	6.7	24.2
	08-10-19	22.8	39.6	0.0	6.8	30.5
	09-10-19	22.5	38.5	0.0	7.8	28.7
	10-10-19	21.0	38.0	0.0	8	17.7
	11-10-19	22.1	37.7	0.0	5.8	18.7
	12-10-19	25.4	38.4	0.0	3.9	15.0
	13-10-19	24.0	41.6	0.0	5.5	15.8
	14-10-19	20.0	41.6	0.0	5.9	24.8
	15-10-19	21.2	40.8	0.0	8.2	23.5
	16-10-19	22.8	41.1	0.0	8.3	23.5
	17-10-19	22.3	38.7	0.0	9.8	32.3
	18-10-19	24.2	39.4	0.0	10.2	22.5
					0900^	1500^
Northern portion	28-10-19	18.5	35.1	0.0	31	9
	29-10-19	17.6	35.7	0.0	31	11
	30-10-19	13.8	38.2	0.0	10	3
	31-10-19	15.9	40.0	0.0	7	3
	01-11-19	17.0	41.9	0.0	9	6
	02-11-19	24.6	41.6	0.0	13	8
	03-11-19	21.2	39.6	0.0	7	6
	04-11-19	24.2	38.6	0.0	20	12
	05-11-19	23.6	36.9	0.0	9	5
	06-11-19	13.0	38.0	0.0	7	2
	07-11-19	11.9	39.6	0.0	3	1
	08-11-19	13.4	40.9	0.0	3	1
Phase 2						
Northern portion	09-03-20	18.0	35.9	0.0	36	15
	10-03-20	21.1	36.8	0.0	30	14

Trip	Date*	Temperature (°C)		Rainfall (mm)	Relative Humidity (%)	
		Min	Max		Min	Max
	11-03-20	19.3	37.5	0.0	28	16
	12-03-20	22.4	39.7	0.0	40	15
	13-03-20	25.1	41.0	0.0	28	11
	14-03-20	20.4	38.2	0.0	32	14
	15-03-20	20.4	36.9	0.0	31	20
	16-03-20	22.3	36.6	0.0	27	14
	17-03-20	18.0	36.6	0.0	26	13
	18-03-20	18.5	37.4	0.0	39	20
	19-03-20	21.7	38.1	0.0	43	20

* Does not include mobilisation dates.
^ Note: Different method of recording relative humidity between station at Lake Mackay and BOM station at Rabbit Flats.

4.3.4 Detailed and Targeted Sampling Techniques

The following sampling techniques are specific to the detailed and targeted Stantec Survey. The subsequent targeted surveys for the Night Parrot and Great Desert Skink are provided within **Appendix J** and **Appendix K** respectively. Sampling techniques used by previous surveys of the Study Area are detailed in the respective reports (**Appendix R.1 - R.5**). However, the survey effort from all fauna surveys is summarised in **Section 4.2.3.**

4.3.4.1 Habitat Assessment and Mapping

Prior to the Stantec Survey, the habitat types within the Stantec Survey Area were identified and broadly delineated during the Preliminary Survey. This was conducted in conjunction with the inspection of aerial photography, satellite imagery and topographical maps, and previous survey results. The extent of the habitat types was ground-truthed and representative areas were selected for detailed habitat assessment.

Ground-truthing was undertaken by vehicle, where access permitted. In areas of the Stantec Survey Area away from the Balgo track, ground-truthing was informed by mapping notes and quadrats completed by Stantec botanists, aided by the use of the helicopter during Phase 1 of the Stantec Survey (Stantec 2020c). The consolidation of habitat types, description and mapping is discussed in **Section 4.2.4**. Habitat type mapping of the GDS bypass was conducted with consideration of the findings from Stantec botanists traversing this portion of the Study Area, and the subsequent vegetation type mapping.

Habitat assessments were undertaken to characterise the quality and complexity of habitat provided for fauna focusing on significant fauna. A total of 101 fauna habitat assessments were undertaken during the Stantec Survey (**Appendix C**). **Table 4-7** presents the key parameters that were recorded from each habitat assessment.

Table 4-7: Key parameters recorded during habitat assessments.

Parameter	Description
Unique field ID	The unique name that was assigned to the site that was assessed
Recorder and date	The recorder(s) involved
Coordinates	Measured using built-in GPS on mobile device, and via handheld GPS device (in GDA94 format)
Site photograph	At least one representative photograph of the site
Landform	A description of the landform, aspect and slope
Soil type and colour	A description of the soil type and colour
Woody debris and tree hollows	A description of the presence of shelter at the site
Condition	A list of any disturbances in the habitat, if present. An estimation of the time since the vegetation was last burnt and overall condition of the site

Parameter	Description
Ground cover	A description of the rock, soil and leaf litter cover at the site
Vegetation description	A description of the vegetation, in reference to upper, middle and lower stratum, of the site

Any significant microhabitat features, such as caves or water sources, were also recorded and where applicable sampled via opportunistic or targeted survey methods. The effort expended during the Stantec Survey was dictated by access. Therefore, significant microhabitat features may exist in areas that were inaccessible at the time of the survey. However, efforts were made to ground-truth areas that had potential for microhabitat features based on the analysis of aerial imagery.

4.3.4.2 Site Selection

Following the habitat assessments, sites for systematic sampling (**Section 4.3.4.3**) and targeted survey effort (**Section 4.3.4.4**) were identified. The indicative location of sampling sites captured the main broad habitat types in the Stantec Survey Area, while also:

- maximising coverage and diversity of habitats/landforms; and
- considering accessibility and the likelihood of habitats supporting significant fauna.

4.3.4.3 Systematic Sampling

Sixteen sites were established within the Stantec Survey Area, eight to the south and eight to the north. These sites represented the broad habitats present within the Stantec Survey Area: lake margin, dune, spinifex sandplain, claypan and claypan mosaic, gravel spinifex plain, dune-field, and rocky ridge and gorge habitat types (**Table 4-8**). Systematic sites were established to gain an understanding of the main fauna assemblages present, or within habitats likely to be important to significant or unique fauna or assemblages. The sampling program implemented at each of these sites comprised standardised trapping, fixed-time avifauna census, systematic searching, nocturnal spotlighting/head torching, motion-sensor camera deployments, and bat echolocation recordings. A detailed breakdown of survey effort expended at each site is detailed in **Section 4.3.4**.

Table 4-8: Systematic trapping sites sampled during the Stantec Survey.

			
Site: A	Habitat: lake margin	Site: B	Habitat: dune
			
Site: C	Habitat: spinifex sandplain	Site: D	Habitat: claypans and claypan mosaic
			
Site: E	Habitat: spinifex sandplain	Site: F	Habitat: spinifex sandplain

Site: G	Habitat: gravel spinifex plain

Site: H	Habitat: dune

Site: I	Habitat: dune-field

Site: J	Habitat: gravel spinifex plain

Site: K	Habitat: rocky ridge and gorge

Site: L	Habitat: gravel spinifex plain

			
Site: M	Habitat: dune-field	Site: N	Habitat: spinifex sandplain
			
Site: O	Habitat: gravel spinifex plain	Site: P	Habitat: spinifex sandplain

4.3.4.3.1 Trapping

A standardised trapping grid was established at each systematic site to capture terrestrial mammals, reptiles and amphibians (**Figure 4-10**). Each trapping grid comprised two drift fences; 40 cm high and 50 m long, set into the substrate. The following was installed along the drift fences within each standard trapping grid:

- two types of pitfall traps: five standard 20 L PVC buckets and five PVC pipe traps (15 cm in diameter and 50 cm deep). Pitfall traps were set flush with the surface of the ground, with the drift fence running through the centre;
- twenty funnel traps measuring 75 cm x 18 cm x 18 cm were placed with one side pressed firmly against the fence in pairs; and
- twenty small Elliott box traps (9 cm x 10 cm x 33 cm) and two Sheffield cage traps (31 cm x 31 cm x 70 cm) were positioned in the trap line surrounds. To protect animals from heat stress, Elliott and Sheffield traps were placed in shaded locations and covered with vegetation and/or custom shade covers. Elliott and Sheffield traps were baited with universal bait (a mixture of oats, peanut butter and sardines).

Traps were left open overnight and checked early the following morning for seven nights, equating to a total trapping effort of 364 nights per site, totalling 5,824 trapping nights for phase 1 and 2,912 trapping nights for phase 2 of the Stantec Survey (**Section 4.2.3**).

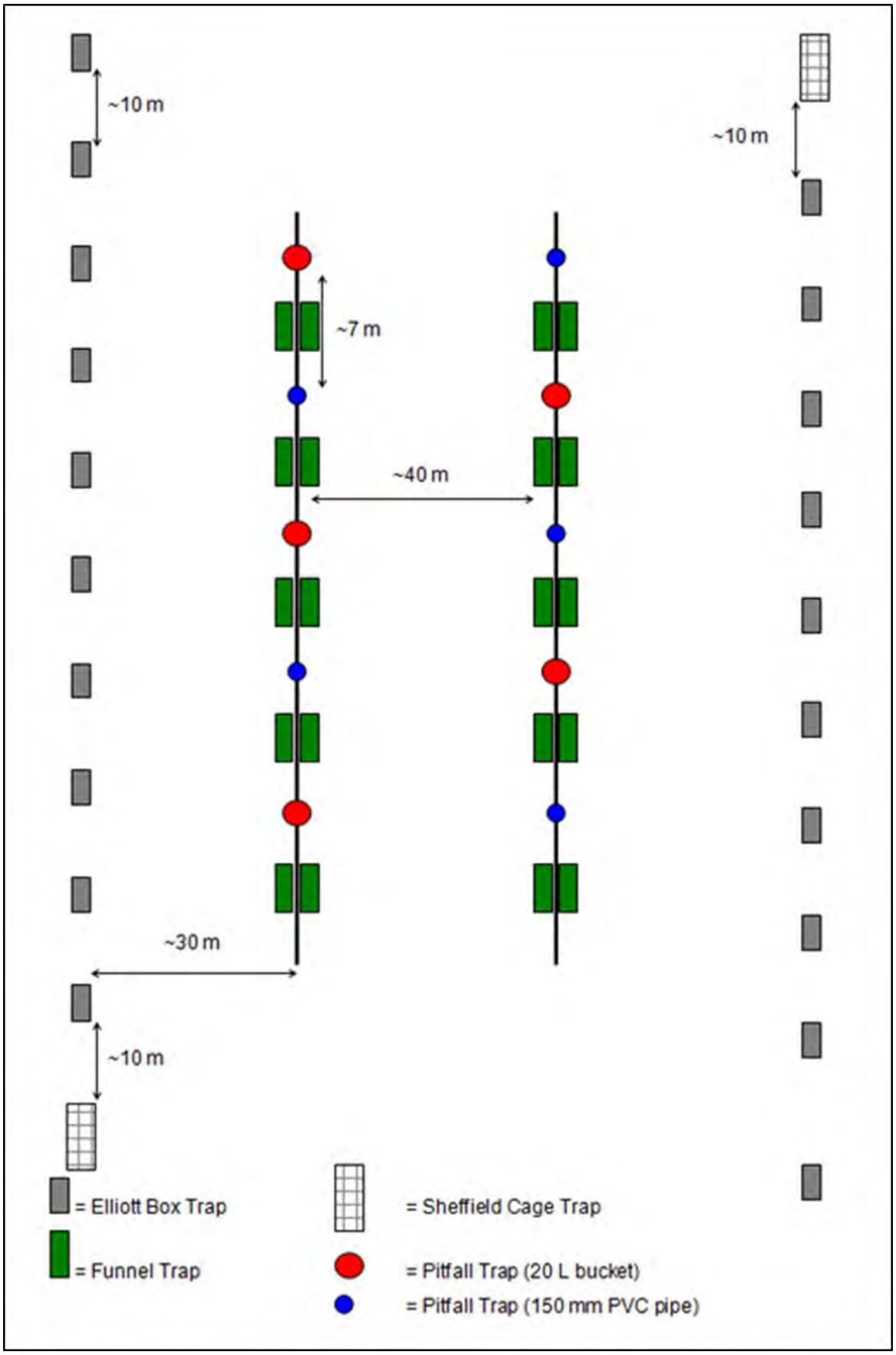

Figure 4-10: Layout of standardised trapping grid deployed at each systematic trapping site.

4.3.4.3.2 Avifauna Census

A 20-minute avifauna census was conducted at each systematic site each morning during each phase of the Stantec Survey. Each avifauna census was conducted between 5:30 am and 11:00 am while undertaking trap clearing activities. During each census sightings, calls or other indirect signs of presence i.e. feathers, scats, nests were recorded. A total of 140 minutes of avifauna census was conducted at each site, totalling 2,240 minutes for phase 1 and 1,120 minutes during the phase 2 trapping period (**Section 4.2.2**).

4.3.4.3.3 Systematic Searches

Systematic diurnal searching for vertebrate fauna was conducted at each site. This technique allows for the observation of species that are unlikely to be trapped because of their biology or behaviour. For example, large individuals or diurnal species that are inactive when traps are open at night and/or species that do not forage far from specific habitat features. The specific methods employed included identification of active animals, investigating caves, crevices, overturning logs and stones, searching beneath the bark of dead trees, investigating burrows and recording tracks, diggings, scats and any other indirect signs. Systematic searching was performed for a total of one-person hour at each systematic site during Phase 1 of the Stantec Survey (**Section 4.2.2**). Systematic searches were performed at sites I – P for a total of one-person hour during Phase 2 of the Stantec Survey (**Section 4.2.3**).

4.3.4.3.4 Head torching and Spotlighting

Spotlighting was conducted on foot (using head torches) and opportunistically by vehicle (using headlights) while travelling between sites to identify nocturnal species that were unlikely to be trapped, such as nocturnal birds, frogs and some reptiles. Head torching was conducted for a total of one-person hour at each systematic site during Phase 1, and at sites I – P during Phase 2 of the Stantec Survey (**Section 4.2.3**).

4.3.4.3.5 Motion-sensor Cameras

Motion-sensor cameras were used to document the presence of vertebrate fauna that are rarely captured via other trapping methods, or systematic searches due to factors including size or general behaviour, such as macropods and large carnivores. Each motion camera was baited with universal bait. Two motion-sensor cameras (Reconyx HF2X) were deployed at each systematic site for seven consecutive nights during Phase 1 and at sites I – P during Phase 2 of the Stantec Survey (**Section 4.2.3**).

4.3.4.3.6 Bat Echolocation Recorders

Bat recordings were captured using SM4 (Wildlife Acoustic Inc.) ultrasonic bat recorders fitted with an external omnidirectional SMM-U1 ultrasonic microphone. The location of the unit was selected to provide an unobstructed line of sight between the microphone and a likely bat flyway. Each unit was preconfigured to activate at astronomical sunset daily and deactivate at astronomical sunrise the following morning, capturing peak bat activity. Echolocation recordings were analysed by BatCall WA to develop a species inventory per systematic site. One unit was deployed at each systematic sampling site for two nights during Phase 1 and at sites I and M during Phase 2 of the Stantec Survey, however units did not record at sites N and J (**Section 4.2.3**).

4.3.4.4 Targeted Methods

Targeted survey methods were used to sample parts of the Stantec Survey Area and unique fauna habitat/features not covered by systematic sampling. Targeted survey efforts also focussed on identifying cryptic species and/or significant fauna identified as having the potential to occur in the Stantec Survey Area in the desktop assessment, such as the Bilby, Night Parrot, Great Desert Skink, Brush-tailed Mulgara, Spotted Ctenotus, Marsupial Mole and Princess Parrot. Various targeted survey methods were employed during the Stantec Survey, including motion-sensor camera deployments, bat echolocation recorder deployments, acoustic recorder deployments for the Night Parrot, 2 ha plots and targeted searches for significant microhabitats, scat, tracks, burrows and signs of significant fauna. Survey effort during the Stantec Survey is consolidated and summarised with all other fauna surveys under **Section 4.2.3.**

4.3.4.4.1 Motion-sensor Cameras

Motion-sensor cameras were established throughout the Stantec Survey to;

- increase the survey effort in areas and habitats that were not readily accessible; and

- target significant species such as, the Bilby, Great Desert Skink, Night Parrot, Marsupial Mole and Brush-tailed Mulgara, during the Stantec Survey.

In addition to cameras deployed at systematic sites, motion-sensor cameras were deployed at 94 locations during Phase 1 and at 35 locations during Phase 2 of the Stantec Survey. Each camera was baited with universal bait (a mixture of oats, peanut butter and sardines), with the exception of cameras deployed at Bilby, Great Desert Skink and Brush-tailed Mulgara burrows, where no bait was used to reduce the risk of attracting predators.

Motion-sensor cameras were deployed for a period of between one and 24 nights between the 10 October and 17 November 2019 during Phase 1 and for between three and eight nights between the 12 - 20 March 2020 during Phase 2 of the Stantec Survey. Twelve cameras were also deployed long-term, either between the two phases or after Phase 2 for between 80 - 238 days. Motion cameras were deployed throughout the Stantec Survey Area for a total of 2,783 camera trap nights across 129 locations. The Kiwirrkurra and Ngururrpa rangers and DSS were integral to the identification of Bilby and Great Desert Skink burrows and deployment of motion cameras, particularly in areas with poor accessibility a substantial distance from the Balgo track, which were surveyed by these groups via helicopter and vehicle.

4.3.4.4.2 Bat Echolocation Recorders

In addition to the SM4 ultrasonic units deployed at systematic sampling sites, units were deployed opportunistically throughout the Stantec Survey Area. The purpose of these deployments was to:

- increase the survey effort in areas and habitats that were not readily accessible; and
- target species not recorded at systematic sites.

Deployments focussed on habitat features known to be important microhabitats, such as caves, rocky gorges, alcoves and water sources. A total of 18 locations were sampled over 188 recording nights, which mainly comprised alcoves and water sources.

4.3.4.4.3 Bird Acoustic Recorders

Bird acoustic recording units, or autonomous recording units (ARUs) were deployed in suitable Night Parrot nesting, roosting and foraging habitat in accordance with the 2017 interim guidelines (DPaW 2017b). Fifty acoustic SM4 recording units were deployed during Phase 1 and Phase 2 of the Stantec Survey. Each unit was positioned in suitable Night Parrot habitat and deployed for a minimum of six nights in line with the interim guidelines (range 6-10 days; plus one unit deployed for 4 days to target the Princess Parrot) (DPaW 2017b). Of these, 16 acoustic SM4 recording units during the Stantec Survey were deployed long-term between Phase 1 and 2, or following Phase 2, for between 14 and 156 nights.

Potential habitat within the Stantec Survey Area comprised large long-unburnt spinifex (*Triodia*), particularly dense clump-forming rings (DPaW 2017b, Jackett *et al.* 2017, Pyke and Ehrlich 2014), and ephemeral habitats including seasonally inundated plains and depressions associated with floodplains and/or gilgais on stony plains (Murphy *et al.* 2017). The Kiwirrkurra and Ngururrpa rangers and DSS were integral to the deployment of ARUs and identification of potential habitat, particularly in areas with poor accessibility a substantial distance from the Balgo track, which were surveyed by these groups via helicopter and vehicle.

Units were set to begin recording one hour prior to sunset and to finish one-hour post sunrise. This targeted peak calling times for non-breeding individuals, which tend to call within two hours after sunset and within two hours of sunrise. This also allowed for the capture of potential calls associated with breeding and foraging birds, which may occur throughout the night and closer to sunset and sunrise (DPaW 2017b). Methods to analyse calls are discussed in **Section 4.3.6.2**.

4.3.4.4.4 Night Parrot Playback

Targeted Night Parrot call broadcasts (playbacks) were undertaken in suitable nesting and roosting habitat within the Stantec Survey Area. The playbacks were conducted at dusk, and in accordance with the DPaW (2017b) interim guidelines. At each playback location, team members listened for 30 minutes for spontaneous calls. When no calls were heard WA specific Night Parrot calls were broadcast, followed by a five-minute listening period, this was then repeated for up to 20 minutes.

4.3.4.4.5 Two Hectare Plots

Targeted 2 ha plot searches conducted for 20 minutes each were undertaken across the Stantec Survey Area to detect significant species and important microhabitats for significant fauna. Specifically, 2 ha plots

were conducted to survey for bilbies in alignment with the guidelines (DBCA 2017a, DPaW 2017a), but were also used to target the followings species;

- Great Desert Skink: Spinifex sandplains for evidence such as tracks, burrows, and latrines;
- Night Parrot: Long-unburnt spinifex in spinifex sandplains for evidence such as nests, roosting tunnels, and feathers;
- Brush-tailed Mulgara: Spinifex sandplains and dune-fields for evidence such as tracks, scat and burrows;
- Princess Parrot: Patches of desert oak for evidence such as feathers, or direct calls and/or observations; and
- Greater Bilby: Spinifex sandplains and gravel spinifex plains for evidence such as tracks, scats, diggings and burrows. Where numerous signs of Bilby were identified in an area, it was unfeasible to spatially record all tracks and signs. All burrows and scats were recorded, however, tracks and diggings were only recorded when they occurred in relative isolation.

The Kiwirrkurra and Ngururrpa rangers and DSS were integral to the identification of potential habitat and significant fauna tracks and signs via 2 ha plot searches, particularly in areas with poor accessibility a substantial distance from the Balgo track. These areas were surveyed by these groups via helicopter and vehicle.

4.3.4.4.6 Targeted Searches

Targeted searches with extended time frames (2–3 hours) were conducted at two locations where evidence of the Great Desert Skink and Bilby were recorded. This was to deduce the extent to which the habitat was utilised by the species and potentially important microhabitats. Specifically, targeted searches included searches on foot to locate the extent of burrows, tracks, scats and diggings throughout the area. However, due to time restraints and the scale of activity throughout the landscape, these searches were not always exhaustive or could not determine the full extent to which the species used that habitat/area.

4.3.4.5 Opportunistic Records

Vertebrate fauna observed during the Stantec Survey outside of the systematic and targeted sampling were documented and the resulting records were classified as opportunistic. Opportunistic records can be direct, such as from visual or aural observations, or indirect, from locating bones, carcasses, tracks, scats, burrows or structures. Opportunistic records were generated from observations made as follows;

- before or after the fixed-time systematic searches or bird censuses;
- during trap line establishment;
- while travelling to and from survey sites; and
- at any time while working in or travelling within the Stantec Survey Area.

4.3.5 Specimen Identification and Nomenclature

Fauna taxonomy is dynamic due to the ongoing description and revision of new species, and the increased understanding of the relationships of taxa through genetic and morphological studies. The nomenclature and taxonomy of all vertebrate fauna in this report follows the Checklist of the Vertebrates of Western Australia (WAM 2020), unless a species resides outside of WA, or a species name has been updated following recent taxonomic work (conducted since the last checklist update).

Vertebrate fauna species were identified in the field, as required, using standard field guides or scientific publications for:

- Mammals (Menkhorst and Knight 2011, van Dyck et al. 2013, van Dyck and Strahan 2008);
- Birds (Menkhorst et al. 2017, 2019, Pizzey and Knight 2012);
- Reptiles (Wilson and Swan 2013, 2017); and
- Amphibians (Cogger 2014, Tyler and Doughty 2009)

Specimens that did not key out well to known species were vouchered as per Western Australian Museum (WAM) guidelines. Given the remoteness and under surveyed nature of the Study Area, Stantec contacted the WAM prior to conducting field work to identify specimens of particular interest to the WAM collection.

4.3.6 Data Management and Analysis

4.3.6.1 Echolocation Data Treatment

Bat echolocation recordings from the Stantec Survey were analysed by BatCall WA to identify species diversity, using COOL EDIT 2000 (now available as AUDITION from Adobe Systems Inc.). Once identified, calls were compared to a database of reference calls.

4.3.6.2 Acoustic Data Treatment

Bird acoustic recording recordings from the Stantec Survey were analysed by Nigel Jackett, a WA Night Parrot specialist. Calls were compared to a library of WA Night Parrot calls, which appear to be subtly different to those of the eastern states. Additionally, Night Parrot calls can sometimes sound very similar to those of other bird species (e.g. Pallid Cuckoo). The Horsfield's Bush Lark has also been identified as another species that may produce similar calls in the Great Sandy Desert bioregion and is discussed in **Section 5.4.4**.

Analysis methods have been summarised below and are presented in full in the analysis report (**Appendix H**). Analysis was undertaken using the software Kaleidoscope Pro v5.1.8, targeting the frequency range of 1000 Hz – 4000 Hz, for which all known calls of the Night Parrot are distributed within (Jackett *et al.* 2017, Leseberg *et al.* 2019, Murphy *et al.* 2017). Searching for calls over a large frequency range such as this is likely to produce a high number of false-positive results due to many other bird species calling at similar frequencies. However, this is necessary to capture the potential repertoire of the Night Parrot.

Potential Night Parrot calls detected during the analysis were compared to a reference library comprising 897 known Night Parrot calls from Western Australia. This library consists of calls recorded at sites where Night Parrots have been confirmed using visual means and is therefore considered highly reliable for comparison. The library also comprises multiple examples of all known Night Parrot call types from Western Australia (Leseberg *et al.* 2019).

For the Stantec Survey, Kaleidoscope Pro search parameters were optimised using a random selection of 250 Night Parrot call examples manually detected from Great Sandy Desert and East Murchison datasets, of which 205 (82.0%) were automatically detected. The probability of non-detection of a single true-positive call was 18.0%; two true-positive calls was 3.2%; three true-positive calls was 0.6%; subsequently decreasing with increasing positive call numbers. Of the data tested, the median number of consecutive calls (spaced at <5 minutes apart) in a sequence when Night Parrots were recorded was five (1–34, n=29). The probability of at least one call being detected within a sequence of median length was >99.9%.

4.3.6.3 Species Accumulation Curves

Species accumulation curves can be used to estimate the sampling adequacy of systematic observation techniques for a survey (EPA 2016b, EPA and DEC 2010). When a curve approaches an asymptote, it suggests that sampling effort has been sufficient to adequately collect the majority of species comprising the faunal assemblage at the locations sampled (Thompson and Withers 2003). The value at which the curve asymptotes can also be used as an approximate measure of the total size of the species complement at that location (Thompson and Withers 2003).

Species accumulation curves for the Stantec Survey were calculated using avifauna census data for birds, and systematic trapping data for mammals and herpetofauna (reptiles and amphibians combined). Species accumulation curves included Sobs (Mao Tao), to reflect the number of species observed (based on a given total of species recorded), and richness estimators (Chao 1, Chao 2, Jackknife 1 and Bootstrap), to predict the total number of species that could potentially be recorded using these techniques.

While species accumulation curves were created using only systematic trapping and avifauna census data, many species were also detected via alternate sampling techniques. In addition, many species may not have been detected at the time of survey for various reason such as;

- weather patterns – species such as burrowing frogs may occur within the Study Area year-round but are not detected in the absence of specific climatic events that trigger emergence;

- variation in detectability – some species are readily trapped, seen and/or heard, but other species are more cryptic and require concerted, highly targeted surveys for detection; and
- species rarity – species with restricted distributions or population sizes may not be detected without major, resource-intensive targeted surveys.

Species diversity measures are biased when sample sizes are small, with unobserved species being under-sampled resulting in the relative abundance of observed species being overestimated (Gotelli and Chao 2013). As biotic diversity is often high and biodiversity sampling is usually labour intensive, these biases can be substantial (Gotelli and Chao 2013), therefore bias-corrected formulas are used for Chao 1 and Chao 2 indicators.

4.3.6.4 Multi-Dimensional Scaling (nMDS) analysis

An analysis was undertaken of systematic fauna data for all surveys completed for the Project within the Study Area using PRIMER v7. This was to allow a comparison of terrestrial fauna assemblage results across a temporal and spatial scale. The site by species matrix was combined for each survey, with separate datasets established for avifauna, mammals and reptiles. Consistent with previous work, the following records were excluded from the contextual analysis due to their potential to cause bias:

- opportunistic records;
- frog species (amphibians), as the recording of these species is associated with unique weather conditions rather than survey effort or habitat;
- bat species, as these records are determined by echolocation recordings, which cannot be used to calculate abundance; and
- sites considered outliers, which were removed from the datasets to allow for meaningful interpretation.

Each dataset was imported into PRIMER v7 and pre-treatment was applied in the form of a square-root transformation. This reduced skewness, considered the influence of highly abundant species. A resemblance matrix was generated for each dataset using the Bray-Curtis index to calculate coefficient similarities between sites, suitable for biological data.

A non-metric Multi-Dimensional Scaling (nMDS) plot was generated, indicating the similarity between sites based on fauna composition. A 20% similarity level was used to inform assemblage groupings for the nMDS. Hierarchical was also performed on each faunal dataset from the resemblance matrix (based on the group-average linking algorithm). The results have been presented in the form of a dendrogram (link-tree).

4.4 Assessment against Matters of National Environmental Significance

For the purposes of this report, matters of national environmental significance (MNES) are defined as fauna that are listed under the EPBC Act and that have been confirmed to occur within the Study Area or are considered likely to occur. The criteria for assessment is based on the MNES Significant Impact Guidelines (DotE 2013b)

4.4.1 Threatened species

Significant impact criteria for threatened species requires an assessment of whether the records represent an 'important population' of a species and whether the habitat in the Study Area represents 'critical habitat to the survival of a species'.

An important population is defined by DotE (2013a) as a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:

- key source populations either for breeding or dispersal;
- populations that are necessary for maintaining genetic diversity; and/or
- populations that are near the limit of the species range.

For the species listed above, habitat critical to the survival of a species or ecological community is defined by DotE (2013a) as areas that are necessary:

- for activities such as foraging, breeding, roosting, or dispersal;
- for the long-term maintenance of the species or ecological community (including the maintenance of species essential to the survival of the species or ecological community, such as pollinators);
- to maintain genetic diversity and long-term evolutionary development; and/or
- for the reintroduction of populations or recovery of the species or ecological community.

4.4.2 Migratory species

Significant impact criteria for migratory bird species, requires an assessment of whether the Study Area represents 'important habitat' for a migratory species and whether the records represent 'an ecologically significant proportion' of the 'population of a migratory species'.

As defined by DotE (2013a) an ecologically significant proportion of the population of migratory species varies with each species. When assessing an ecologically significant proportion the following factors should be considered;

- populations status,
- genetic distinctiveness and
- species-specific behavioural patterns.

'Population', in relation to migratory species, means the entire population or any geographically separate part of the population of any species or lower taxon of wild animals, a significant proportion of whose members cyclically and predictably cross one or more national jurisdictional boundaries including Australia.

An 'important habitat' for the migratory species is defined by DotE (2013a) as:

- habitat utilised by a migratory species occasionally or periodically within a region that supports an ecologically significant proportion of the population of the species; and/or
- habitat that is of critical importance to the species at particular life-cycle stages; and/or
- habitat utilised by a migratory species which is at the limit of the species range; and/or
- habitat within an area where the species is declining.

4.4.3 Migratory Shorebirds

Significant impact criteria for migratory shorebirds, requires an assessment of whether the area includes important habitat for migratory shorebirds (excluding Latham's snipe). For migratory shorebirds, the DotEE (2017) defines internationally important and nationally important habitat using a similar approach to the international criteria under the Ramsar Convention on Wetlands. Under these criteria, the DotEE (2017) considers wetland habitat to be considered internationally important if it regularly supports:

- 1% of the individuals in a population of one species or subspecies of waterbird (Ramsar criteria 6); or
- a total abundance of at least 20,000 waterbirds (Ramsar criteria 5).

The DotEE (2017) defines 'important' habitat for migratory shorebirds if it meets the following criteria:

- Is the shorebird area already identified as internationally important i.e. identified as an internationally important wetland (RAMSAR); and/or
- Does the shorebird area support (defined differently depending on permanent or ephemeral habitat):
    - at least 0.1 % of the flyway population of the species, as defined by Hansen et al. (2016); or
    - at least 2,000 migratory shorebirds; or
    - at least 15 shorebird species.

For ephemeral wetlands such as Lake Mackay, 'support' is defined as: habitat that migratory shorebirds have ever been recorded in, and where that habitat has not been lost permanently due to previous actions. Due to Australia's highly variable climate and rainfall, these ephemeral wetlands may not be used for many years between major flood events. However, when these areas receive substantial rain that leads to flooding and the persistence of surface water, they can provide productive and important food sources for migratory shorebirds (DotEE 2017).