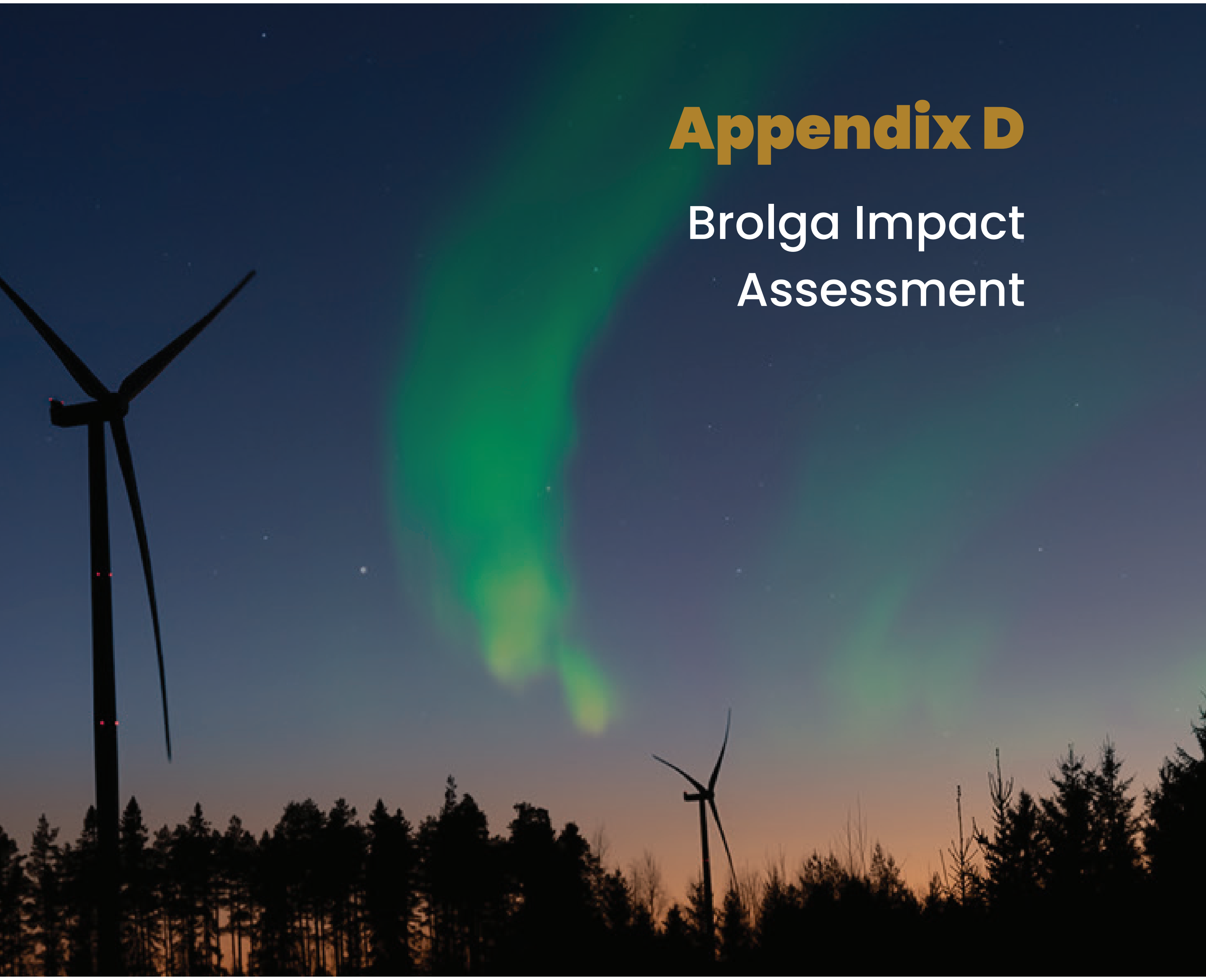
Appendix D

Brolga Impact Assessment



KENTBRUCK GREEN POWER HUB

Kentbruck Green Power Hub Environment Effects Statement Technical Report: Brolga impact assessment

Prepared for Neoen

21 August 2024

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1 Introduction

1.1 Project background

Biosis has been commissioned by Neoen to undertake flora and fauna assessments and impact assessment for the proposed Kentbruck Green Power Hub (KGPH; the Project), including a technical report for the Brolga using the *Interim guidelines for the assessment, avoidance, mitigation and offsetting of potential wind farm impacts on the Victorian Brolga population* (DSE 2012). This information will be used to:

- Inform ongoing design of the Project in a responsive manner to avoid and minimise impacts on Brolga.
- Permit a comprehensive assessment of any impacts that may be associated with a fully developed project design.
- Provide the Brolga technical report in response to the Environment Effects Statement (EES) Scoping Requirements for the Project.

The Project is located in south-west Victoria between Portland and Nelson in an area approximately 8,350 hectares. It comprises private land including farmland and the Green Triangle Forest Products (GTFP) pine plantation, and public land including road reserves and a proposed transmission line beneath an existing road through Cobboboonee National Park and Cobboboonee Forest Park.

The Project comprises a wind farm of approximately 600 MW capacity, consisting of up to 105 wind turbines and associated permanent and temporary infrastructure. The Project also includes a 275 kV transmission line, extending from the eastern boundary of the wind farm site to the Heywood Terminal Station.

Under the *Environment Effects Act 1978* (EE Act), the project requires an EES to be prepared to allow stakeholders to understand the likely environmental impacts of the project and how they are proposed to be managed. The Project is also a controlled action under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and is being assessed under the bilateral agreement between the State of Victoria and the Commonwealth. This report addresses matters of national and state environmental significance.

The biodiversity evaluation objective of the EES scoping requirements is "To avoid or minimise potential adverse effects on biodiversity values within the project site and its environs, including native vegetation, listed species and ecological communities other protected species and habitat for these species."

Biosis was commissioned to prepare this biodiversity technical report (existing conditions and impact assessment) to inform the EES process. This report on Brolga *Grus rubicunda,* forms one of three technical reports prepared as part of the EES process, which also includes reports on the biodiversity values (Biosis 2024a) and the Southern Bent-wing Bat *Miniopterus orianae bassanii* (Biosis 2024b).

This technical report presents the findings of existing conditions, investigations and impact assessments for the Brolga and forms part of the Environment Effects Statement. Some information on the project and the locality is repeated between these reports to provide the background and context for the Brolga assessment.

1.2 Description of the Project

The initial Project comprised of:

- A wind farm, consisting of up to 157 wind turbines and associated infrastructure.
- A battery storage, comprising a lithium-ion battery facility with up to 500-1,000MW hours of storage.
- A connection to the electricity grid via an overhead and/or underground transmission line connection.

The final Project as proposed would comprise:

- A wind farm of up to 600 MW, consisting of up to 105 wind turbines and associated permanent and temporary infrastructure.
- A new 275 kV transmission line, which would connect the Project to the existing AusNet electricity transmission network. The transmission line would extend from the eastern boundary of the wind farm site to the existing 275/500 kV Heywood Terminal Station. The transmission line would be up to 26.6 kilometres in length, and is proposed to be constructed as an underground facility, using trenching and directional drilling construction methods.
- A new 275 kV overhead transmission line along Portland–Nelson Road from the western collector substation to the eastern collector substation.

These project elements are located within close proximity of each other, as described in the following sections.

The Project is located about 330 kilometres west of Melbourne between Portland and Nelson, Victoria (Figure 1).

The Project Area encompasses a wind farm site of approximately 8,350 hectares of private and public land including some road reserves, and a transmission line connection to the electricity grid. Two transmission line options were investigated, detailed in Section 1.2.2. Option Two was removed as a viable option by Neoen in June 2021 and is therefore not considered during the impact assessment outlined in this report.

The Project Area is within the:

- Glenelg Plain, Bridgewater and Victorian Volcanic Plains Bioregions
- Glenelg River Basin
- Management area of the Glenelg Hopkins Catchment Management Authority (CMA)
- Glenelg Shire local government area.

1.2.1 Wind farm site

Portland–Nelson Road bisects the wind farm site in a generally east-west direction. The site is bound by plantation forestry to the north, highly modified grazing land to the east and west, Discovery Bay Coastal Park to the south, and the Lower Glenelg National Park and Cobboboonee National Park to the east and north-east (Figure 1).

The proposed wind farm site is approximately 8,318 hectares in area and comprises 121 individual land parcels owned by 22 different landholders. The site is located primarily within an area that has been substantially modified and is used for commercial Radiata Pine softwood forestry production, with a small portion of land used for agricultural purposes (primarily grazing). The plantation area has an existing network of public and private roads.

At this stage, 4 MW to 8 MW wind turbines are proposed and will have the following features:

- Maximum hub height of 175 metres.
- Maximum rotor tip height of up to 270 metres.
- Maximum rotor diameter of 190 metres.
- Minimum lower blade sweep height of 60 metres.

1.2.2 Transmission line options

External powerline

This report includes assessment for the preferred Heywood (Option One) with an underground route. The Heywood option (underground) Portland option (overhead) assessment is discussed in Appendix 6 and Appendix 7. The Heywood option is a route with both underground and overhead lines is detailed below and shown in the report figures (e.g. Figure 1).

- Option One: underground route
  The Option One route extends between the eastern boundary of the proposed wind farm site and the existing Heywood Terminal Station located inside the western boundary of the Narrawong Flora Reserve / Mount Clay State Forest (on land owned by AusNet). This transmission line connection option is approximately 26.6 kilometres long. Within Cobboboonee National Park and Cobboboonee Forest Park, the transmission line would be located beneath Boiler Swamp Road (for a distance of approximately 17.6 kilometres) which bisects the Parks in an east to west direction. The underground section would be constructed within a 6.5 metre construction footprint, with cabling buried at a depth of approximately 1.25 metres beneath the existing road. Construction would be mostly via trenching, with horizontal directional drilling (HDD) used in several locations to avoid impacts on waterways, including the Surrey River. After exiting Cobboboonee Forest Park the underground line would continue for 1.2 kilometres through freehold agricultural land to the Surrey River. To the east of the Surrey River, the transmission line would continue underground, either trenched or directionally drilled to avoid native vegetation and road and rail crossings, for 7.8 kilometres until its connection point to the Heywood Terminal Station.

Onsite wind farm powerlines

The Project would involve the installation of up to 190 kilometres of underground powerlines (33 kV or 66 kV) connecting the wind turbines to the collector substations, and up to 27.8 kilometres of a high voltage powerline connecting the collector substations to the main substation. The high voltage powerline would likely be 275 kV (subject to detailed design), and would run overhead along Portland–Nelson Road from the western collector substation to the eastern collector substation. The powerline would then run adjacent to existing roads in the Green Triangle Forest Products (GTFP), pine plantation to the Portland-Nelson Road / Sandy Hill Road intersection. From there it would pass beneath Portland–Nelson Road then continue underground to the main substation through agricultural land.

1.2.3 Other project elements

The Project is proposed to include (but is not limited to):

- Internal site access tracks and upgrades to existing access points from the public road network.
- Hardstand areas at each turbine location, with a footprint of approximately 0.4 hectares.
- Three collector substations.

- Underground powerlines connecting the wind turbines to the collector substations.
- Overhead and underground electricity cabling (up to 275 kV) and a terminal station to provide connection to the 500 kV transmission line.
- Up to eight permanent meteorological monitoring masts (met masts).
- An operations and maintenance building.
- Temporary infrastructure including construction compounds, concrete batching plants, car parking, site buildings and amenities.
- A limestone quarry, to be located within the GTFP plantation on North Livingston Road. The quarry would require a Work Authority of approximately 18 ha, comprising approximately 9 ha of extraction area, 3.5 ha of overburden and product stockpiles and 1 ha of quarry office/parking infrastructure, with the remainder of the Work Authority being buffers. The quarry would be a traditional soft rock extraction operation and would not involve any drilling or blasting. The maximum depth of the extraction, including overburden, would be approximately 14 m.

1.2.4 Project alternatives and design evolution

The ecological database review and ecological survey program was initially designed to assess the Kentbruck Green Power Hub (KGPH) Project, as specified in the EES and EPBC referral documents. This included a Project Area with 157 turbines, two underground transmission line options (Boiler Swamp Road and Cut-out Dam Road), two overhead transmission line development envelopes and other project infrastructure. For the purpose of reference within these studies, this has been termed the "Original Layout".

During the course of the technical studies, the design of the KGPH has undergone several changes. These changes have been responses to the findings of technical studies undertaken including the ecological assessments, and have resulted in:

- Reductions to the Project area.
- Reduction in the number of proposed turbines.
- Revisions to the proposed locations of turbines (including siting turbines to avoid specific areas within the site).
- Revisions to the transmission line options.
- Undergrounding of the internal electricity network in the Gorae West area identified as breeding buffers or movement corridors for Brolga.

The following design responses have been implemented to avoid and minimise potential impacts – the below lists all design responses inclusive of ones relevant for avoiding impacts on Brolgas:

- Reduction in the extent of the wind farm Project area. Several parcels of land that were shown in the Original Layout have been removed from the Project area and will not be used for project infrastructure, including parcels to the south of the GTFP Plantation near the Glenelg Estuary and Discovery Bay Ramsar site.
- Exclusion of turbines from within 300 metres of boundaries with surrounding conservation reserves and other public land supporting native vegetation.
- Exclusion of turbines from within 500 metres of wetlands within the Glenelg Estuary and Discovery Bay Ramsar site.

- Exclusion or relocation of turbines in areas where foundations may intersect groundwater near significant wetlands.
- Removal of the Cut-out Dam underground transmission line option.
- Exclusion of turbines from sections of farmland and blue gum plantation in the east of the Project area, in areas identified as breeding buffers or movement corridors for Brolga. Exclusion of turbines within 900 metres of the Long Swamp, Lake Mombeong and associated wetlands. Placing transmission line underground between Boiler Swamp Road and Heywood terminal. These turbine-free areas would also provide for movement between areas of potential habitat for other bird species that were observed in this area.
- Removal of the transmission line option involving vegetation removal along the boundary of Mount Clay State Forest.
- Undergrounding of the internal electricity network in the areas identified as breeding buffers or movement corridors for Brolga.
- Full undergrounding of the transmission line to the Heywood terminal station through areas with Brolga breeding habitat, to avoid potential collision impacts.

As a result of these changes, the current Project layout (June 2022) has been reduced to 105 turbines, with an overhead transmission line along Portland-Nelson Rd and an underground transmission line from Portland-Nelson Rd/Sandy Hill Rd (GFTP internal road) to the Heywood Terminal Station.

A range of ecological studies were undertaken near the existing AusNet easement adjacent to Mount Clay State Forest near the Heywood Terminal Station. Construction of this component of the transmission line would have resulted in extensive clearance of native vegetation and habitat. This section has now been removed from the project.

Due to these design modifications, some ecological field assessments were undertaken in areas which are no longer components of the project. Results from these studies are presented in full in the existing conditions sections of this report (Section 3.3 and Section 4.3), however the impact assessment focuses on the current Project layout.

An additional assessment on the southern transmission line route towards Portland has been added at the request of Neoen (in September 2022) (Appendix 6). Appendix 7 includes an impact assessment of the Portland option.

1.3 Terminology

The following terms are used throughout the report to define the geographic extents of the assessment (Figure 1a-c):

- **Wind farm** footprint– the area where wind farm infrastructure is planned, including turbines, hard stands, internal access roads, collector stations, reticulation and the terminal substation.
- **Transmission Line** – the transmission line corridor, extending from the terminal substation in the eastern end of the wind farm to the Heywood terminal station. This is now proposed to be entirely underground.
- **Project** – the Kentbruck Green Power Hub project, including the wind farm, transmission line and associated infrastructure.

- **Project Area** – includes title lots containing the wind farm and ancillary infrastructure, and the construction footprint of the transmission line. The Project Area covers an area of approximately 8,350 hectares.
- **Search Area** – the area used for collation of database records of flora and fauna, which includes the originally proposed Project Area plus a 10 kilometre buffer.
- **Investigation area** – the area in which field studies have been undertaken. This includes the Project Area plus areas surrounding the site where additional data collection was undertaken, including bird utilisation surveys, shorebird surveys, Brolga surveys and reference sites for threatened species. Where required, some field studies were undertaken more than 10 kilometres from the Project Area, for example checking reference sites for threatened flora species.
- **Plantation sub-area** – the Green Triangle Forest Products (GTFP) pine plantation, including the areas to the south and north of Portland–Nelson Road, and areas of blue gum plantation in the east of the Project Area.
- **North-eastern sub-area** – the portion of the Project Area to the north-east of Portland–Nelson Road, primarily on farmland and blue gum plantation.

1.3.1 Assessment scope and framework

The assessment was undertaken for the wind farm and Heywood transmission line option described in Section 1.2. An additional assessment for the Portland transmission line is included in Appendix 6 and Appendix 7.

The primary objective of studies and findings set out in this document are to address the scoping requirements for the Project EES, specific and relevant to the Brolga by:

- Providing an understanding of the existing conditions for the actual and potential occurrence, and habitat values within the project area and surrounding areas that might be affected by the project, specific to the FFG Act listed Brolga. This assessment also considers the potential use of the site and its environs for movement, breeding, flocking and foraging by the Brolga.

  This includes all components of the project, including the proposed locations of:

  - The wind farm infrastructure, including hardstands, roads, and permanent and temporary facilities.
  - Quarry.
  - Electrical substations and connections points.
  - Electricity powerlines along connection routes.
  - New roads and changed or upgraded roads and crossovers.
  - Area or values on- or off-site that may be directly or indirectly subject to effects such as dust, noise, artificial light and changes to surface and groundwater due to construction, operation or decommissioning of the project.
- Considering potential impacts of the project on the FFG Act listed Brolga, including direct and indirect impacts.
- Avoiding and mitigating impacts on FFG Act listed Brolga, in accordance to the assessment process set out in the *Interim guidelines for the assessment, avoidance, mitigation and offsetting of potential wind farm impacts on the Victorian Brolga population* (DSE 2012) (Section 1.1.2).

- Developing contingency measures to be implemented in the event of adverse residual effects (including ineffective mitigation) on flora and fauna values requiring further management.

1.3.2 Interim guidelines for wind energy facilities – Victorian Brolga population

The *Interim guidelines for the assessment, avoidance, mitigation and offsetting of potential wind farm impacts on the Victorian Brolga population* (DSE 2012) (Brolga guidelines herein) were used to assess potential impacts of the Project on the Victorian Brolga population, and to inform avoidance, mitigation and potential offsetting measures. This approach is consistent with the requirements set out in Clause 52.32 of the Glenelg Shire Planning Scheme for wind energy facilities.

The Brolga guidelines (DSE 2012) outline a staged three-level assessment methodology process for Brolga within the context of wind energy development:

1. To the extent that is practicable, design the wind farm including all infrastructure to avoid and mitigate potential effects consistent with the guidelines.
2. Estimate any remaining and unavoidable risk using tools such as collision risk modelling (CRM) and population viability analysis (PVA), to ascertain likely effects on the population.
3. Determine appropriate compensatory measures to, at a minimum, completely offset unavoidable effects.

The assessment framework objective is:

- to ensure the Project wind farm has, at a minimum, a zero net impact on the Victorian Brolga population (DSE 2012).

Breeding site and flock roost site definitions

For the purposes of assessing, avoiding and mitigating potential wind farm impacts on Brolgas, the breeding site, flock roost site and home range definitions in the Brolga guidelines (DSE 2012) are relevant.

A breeding site is defined as:

- The nest of a Brolga breeding pair and the perimeter of the surrounding wetland. Also includes wetlands with previous records of Brolga nests from any relevant information source. A wetland remains a breeding site providing it has not been permanently drained and/or planted with trees. Wetlands that have been ploughed can still be breeding sites provided the wetland retains some level of filling.

A flock roost site is defined as:

- A permanent or ephemeral wetland known to be utilised by a Brolga flock for nocturnal roosting. Specifically a flock roost site should meet the criteria listed in Table 1.

Table 1 Flock roost site criteria.

To meet the definition of a flock roost site, a wetland must meet all three criteria (DSE 2012; after Sheldon 2004)

Criteria	Justification
More than one year of recording	To ensure the selection of traditional and regularly used sites.
One or more records of counts equal to or greater than 10 birds	To include sites which have been used often or traditionally be flocking Brolgas. The assumption is made that if more than 10 birds are recorded on a wetland, flocking behaviour is likely.
Recorded in more than one month	To include sites where Brolgas flock for periods greater than one day or one week, i.e. to include sites used traditionally for the majority of the flocking or non-breeding season.

A home range is defined as:

- The area that a Brolga occupies while undertaking daily activities including breeding, flocking, feeding, and roosting. An individual Brolga will utilise different and generally distinct home range areas in the breeding and non-breeding seasons. Based on current understanding, non-breeding season home ranges appear to be contained within a 5 kilometre radius of the flock roost site. Breeding season home ranges can include areas up to 3.2 kilometres from breeding sites. Current research is focussed on better understanding Brolga home ranges.[1]

Ultimately, the aim of the Brolga guidelines (DSE 2012) assessment is to:

- Locate and identify all potential breeding and flocking wetlands that Brolgas have used, or may use, within the wind farm's assumed impact zone:
  - 3.2 kilometres for breeding sites.
  - 5 kilometres for flock roost sites.
- Avoid and mitigate wind farm-related impacts through applying turbine-free buffers, as a general recommendation:
  - Use generic guideline of 3.2 kilometre radius around a breeding site,
  - Use generic guideline of 5 kilometre radius around a flock roost site.

Proponent can propose alternative buffer areas as stated in the Brolga guidelines:

[1] It should be noted that since the Brolga guidelines (DSE 2012) were released, a substantial amount of new information exists on movements and home ranges of Brolgas (Veltheim 2018, Veltheim et al. 2019, Veltheim et al. 2022). This information has been drawn upon in the current assessment.

> *"Recognising that the spatial requirements of Brolgas are not well understood, a proponent may propose reduced buffer areas providing that they can be shown to meet the objectives set for breeding and non-breeding habitats. Proposed buffer distances should meet with the satisfaction of the DSE."*

For each breeding site and flock roost site, this involves determining the size and shape as identified in Level Two Assessment and/or data from site specific investigations as per the following statement.

The turbine-free buffer zone in the Brolga guidelines is defined as:

> *"Turbine-free buffer zones are recommended to remove potential impacts of wind farm developments on breeding and non-breeding Brolga habitats. Within these areas new powerlines should generally be excluded or placed underground. Other infrastructure which might impact on Brolgas such as new roads should be placed to avoid disturbance."*

In accordance with the definitions of breeding sites provided in the Brolga guidelines (DSE 2012), turbine and powerline exclusion buffers are measured from the perimeter of the relevant wetland. Roosting sites are defined as permanent or ephemeral freshwater or saline wetlands (including dams, swamps etc) at which Brolgas have been observed to roost (nocturnally or diurnally), however, the guidelines do not describe the point location of buffering for flock roost sites, or mention using the perimeter as they do for the breeding sites.

The Brolga guidelines (DSE 2012) do not specify whether the turbine-free buffer extends to the blade-tip of a turbine, or the turbine base. The intention of the buffers is to exclude turbines altogether and no part of turbine infrastructure should extend into the buffers. Turbine-free buffers developed as part of the current assessment should be treated and interpreted as such.

This report details the methodology Biosis used to address the above aims of the Brolga guidelines (DSE 2012). Summary of the assessment methodology is outlined in Table 2, and details are provided in the following sections. This report outlines methods and results of the assessment and incorporates:

- Level One Assessment
- Level Two Assessment
- Level Three Assessment: Step One, Step Two and Step Three

Step Four – Identifying appropriate compensation strategies is a Brolga guidelines requirement, to achieve net zero impact is excluded as it requires further work and consultation with DEECA. A brief treatment of this requirement is included in Section 6 and included in Table 2. A Brolga Compensation Plan will be prepared as part of post-approval consent.

A section is also provided (Section 6.5) with general discussion on impact mitigation beyond the Brolga guidelines (DSE 2012) requirements and on adaptive management. This section includes cross-references to mitigation measures and the draft bird and bat adaptive management plan (BBAMP).

Table 2 Assessment requirements to avoid, mitigate and offset potential wind farm impacts on the Victorian Brolga population, including triggers for Brolga guidelines Level One, Two and Three assessments and the Biosis methodology used to address assessment objectives

Triggers	KGPH meets criteria	Assessment objectives	DSE 2012 Methodology	Summary of Biosis methodology *With reference to relevant report section*
Level One Assessment – Initial Risk Assessment				
The proposed wind farm site is situated within the Victorian range of the Brolga.	✓	• Identify all known and potential Brolga habitats within the radius of investigation (10 km). • Develop a comprehensive understanding of all Brolga sightings within the radius of investigation. • Estimate the likelihood and extent of Brolga use of radius of investigation, including past use.	**Step One** • Desktop studies to identify known and potential breeding and flocking sites within the radius of investigation (10 km).	**Step One** Desktop studies involving 10 km searches of relevant databases. *Section 3.1.1*
The presence of Brolgas within the radius of investigation (i.e. within 10 km of the proposed wind farm boundary).	✓			
The presence of potential Brolga habitat within the radius of investigation.	✓		**Step Two** • Field inspection. • Local community consultation.	**Step Two** • Field inspection within 10 km 9–11 October 2018. • Consultation with DEECA (previously DELWP) locally and with local naturalists in late 2018 (as per Section 3.1.3). • Community consultation in Portland, Mt Richmond and Nelson December 2019. • Discussions with local community members in 2020/2021.
The location of the proposed development is within an area that may be used by Brolgas during seasonal movements between breeding and flocking habitats.	✓			

Triggers	KGPH meets criteria	Assessment objectives	DSE 2012 Methodology	Summary of Biosis methodology *With reference to relevant report section*
				Section 3.3.2 and Section 3.3.3 (Section 4.1.5)
Level Two Assessment				
Records of breeding or flocking habitats within the radius of investigation.	✓	• Obtain detailed information on the occurrence of Brolgas within the radius of investigation. • Obtain data on Brolga flight behaviour suitable for CRM should a Level Three Assessment be required. • Assess the magnitude, extent and likelihood of potential direct and indirect impacts	Range of methods can be used. Field investigations should include one or more of the methods below: • Roaming surveys • Aerial surveys • Flight behaviour studies – for use to inform buffer location & design and for CRM inputs • Gradient studies • Time-activity budgets	**Roaming surveys** • Breeding season survey 3-4 days in July, September and November 2020. • Additional breeding season surveys at locations where brolgas were found in 2020. • Within 5 km of wind farm boundary and transmission line. • Overhead transmission route from Cobboboonee NP to Heywood substation in October 2021. *Section 4.1.1* **Aerial surveys** • Aerial survey on 30 November and 4 December 2020. • Within 4 km of wind farm and powerline boundary. *Section 4.1.2* **Flight behaviour studies** • Bird utilisation survey (BUS) in 2020/2021.
The proposed development is located in an area which may be used by Brolgas moving seasonally between breeding and foraging sites, and may potentially create a barrier effect reducing movements between these habitats.	✓			
The proposed development is located in an area which may be used by Brolgas for diurnal movements between foraging and roosting sites.	✓			
The proposed location of new powerlines associated with the development may create new collision risks for Brolgas.	✓			

Triggers	KGPH meets criteria	Assessment objectives	DSE 2012 Methodology	Summary of Biosis methodology *With reference to relevant report section*
				Section 4.1.3 **Targeted flocking season survey** • Monthly flocking season survey December 2020 to June 2021 at dusk/midday/dawn located at a DEECA-mapped wetland with frequent Brolga activity. • Recording flight behaviour. *Section 4.1.6* **Remote nest camera** • Remote nest camera deployment at a suspected Brolga nest site July-August 2021. *Section 4.1.7* **Wetland habitat assessment** • Field assessment and mapping of suitable breeding wetland habitat in October 2021, within private property Mt Kincaid Rd, Gorae West. *Section 4.1.8* **Follow up breeding pair survey**

Triggers	KGPH meets criteria	Assessment objectives	DSE 2012 Methodology	Summary of Biosis methodology *With reference to relevant report section*
				• Re-visit to Mt Kincaid Rd, Gorae West during breeding season to record status and progress of nests. *Section 4.1.9*
Level Three Assessment				
Qualitative risk assessment (AusWea 2005) of project following site design is greater than "low"	✓	Identify suitable mitigation measures for the proposed development to produce a zero net impact on the Victorian Brolga population.	**Step One: Avoid or mitigate all potential impact to Brolga breeding and flocking home ranges within the radius of investigation with turbine-free buffer areas** *Objective: remove any significant impact on Brolgas within their breeding and non-breeding home ranges.* • Avoid the Brolga breeding home range (identified in the Level Two Assessment or use the generic guideline of 3.2 km). • Avoid the Brolga non-breeding home range (identified in the Level Two Assessment or use the generic guideline of 5 km). • Avoid an additional 300 m radius around each home range to avoid disturbance effects.	**Step One** • Breeding sites were identified in the Level Two assessment. Site-specific buffers were applied using field data from Biosis surveys and knowledge and principles of breeding home ranges and movements (Veltheim et al. 2019) as well as knowledge of adult movements between roosting and foraging habitat (Veltheim et al. 2022). Information in Veltheim et al. 2022 was also used to develop a buffer around a roost wetland identified during the Biosis investigations. • Potential presence of any flocking areas within 5 km to the wind farm was assessed using desktop data analysis (database records and literature), including knowledge of flocking areas (White 1987, Sheldon 2004) and flocking area home ranges derived from GPS tracking (Veltheim 2018). The proximity of nearest known flocking areas was also assessed. The suitability for the area to support Brolgas in the

Triggers	KGPH meets criteria	Assessment objectives	DSE 2012 Methodology	Summary of Biosis methodology *With reference to relevant report section*
				non-breeding season was also assessed. • An additional 300 m radius was applied around each breeding home range to avoid disturbance effects, for each known and potentially suitable wetland. A 300 m disturbance buffer was also added to a roost wetland identified during the investigations. *Section 5.2*
			Step Two: Develop a site-specific collision risk model for Brolgas utilising or moving through the radius of investigation *Objective: estimate the residual number of Brolga movements which have the potential to interact with wind turbines on the proposed site and estimate annual collision risk.* • DSE recommends use of peer-reviewed CRMs.	**Step Two** • Scenario CRM was undertaken for the Brolga in the project area, using Smales et al. (2013). *Section 5.3*
			Step Three: Use PVA to estimate the impact of the proposed development. *Objective: model the potential impact of the proposed wind farm on the Victorian Brolga population.*	**Step Three** • Scenario PVA was undertaken for the Brolga in the project area (McCarthy 2008) *Section 5.8*

Triggers	KGPH meets criteria	Assessment objectives	DSE 2012 Methodology	Summary of Biosis methodology ***With reference to relevant report section***
			Step Four: Identify appropriate compensation strategies to ensure a zero net impact on the Victorian Brolga population *Objective: identify and, as much as possible quantify, appropriate strategies to fully offset the predicted impact from Step Three.*	To be developed in discussion between Neoen and DEECA. Compensation plans for all other approved wind farms within the Brolga range have been provided in the context of a secondary consent, as part of a permit condition. Same process is expected to be applied to the Kentbruck Green Power Hub.Outline and feasibility of a Brolga compensation plan is included. *Section 6.4.1*

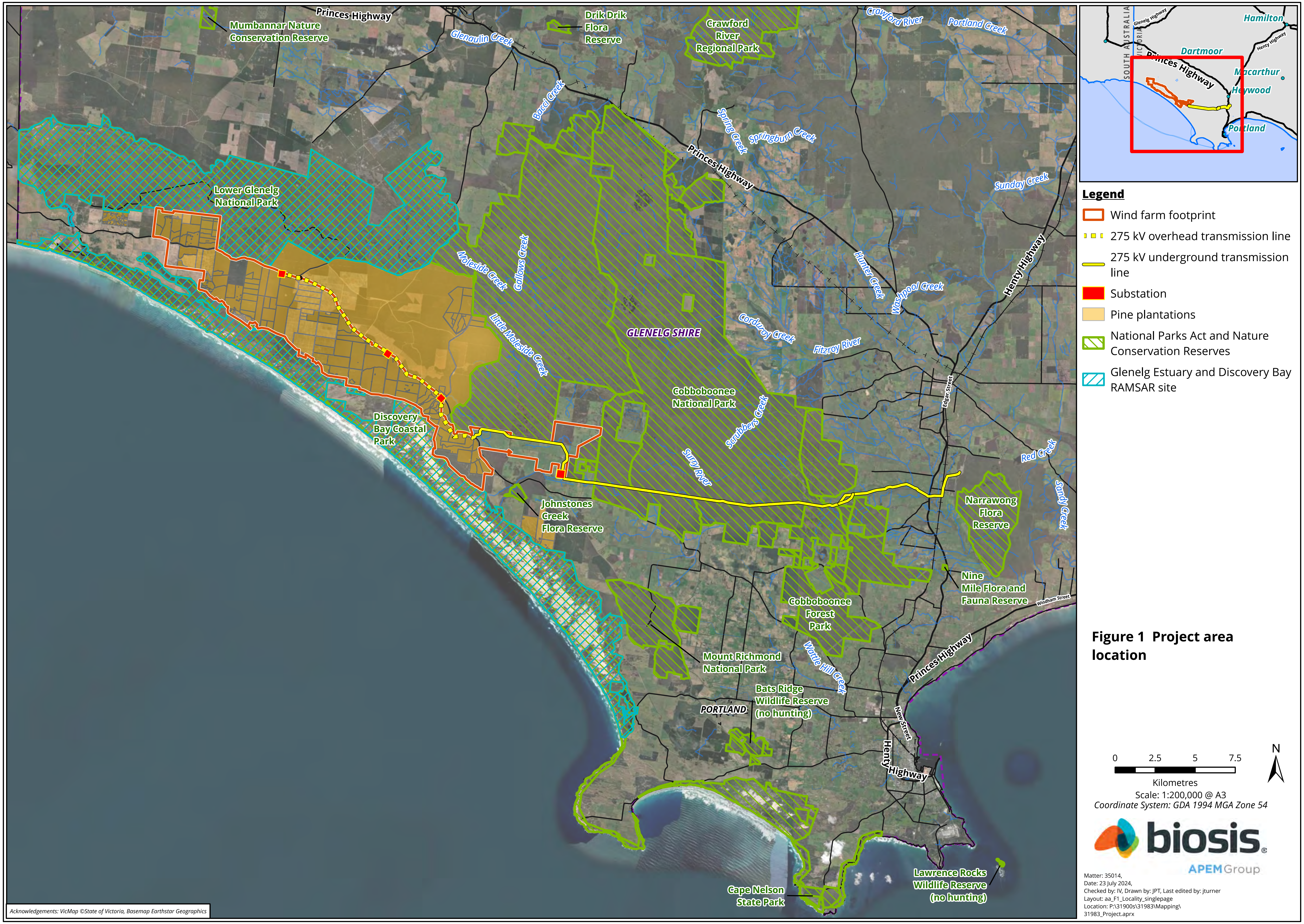

Figure 1 Project area location

1.4 Permits and personnel

Flora and fauna assessments undertaken by Biosis have been under provisions of the following permits and approvals:

- Research Permit/Management Authorisation and Permit to Take/Keep Protected Flora & Protected Fish issued by DEECA under the Victorian *Wildlife Act 1975*, FFG Act, *National Parks Act 1975* and *Crown Land (Reserves) Act 1978* (Permit Number 10008711).
- Permit to catch and release fish issued by the Victorian Fisheries Authority under the Victorian *Fisheries Act 1995* (Permit Number RP 1220, Personal File Number 13041).
- Approvals 30.17 and 19.18 issued by the Wildlife and Small Institutions Animal Ethics Committee of the Victorian Government Department of Economic Development, Jobs, Transport and Resources (DEDJTR).
- Scientific Procedures Fieldwork Licence issued by DEDJTR's Wildlife and Small Institutions Animal Ethics Committee (Licence Number 20020).

Biosis staff involved in field surveys and their qualifications are listed in Table 3.

Table 3 List of Biosis staff involved in Brolga field surveys

Name	Position and qualifications
Ian Smales	Principal Zoologist, MSc
Inka Veltheim	Senior Zoologist, BSc (Hons) PhD
Matt Gibson	Senior Ecologist, BAppSc
Daniel Gilmore	Senior Zoologist, BConEcol (Hons)
Mark Venosta	Senior Zoologist, BConEcol (Hons)
Katrina Sofo	Senior Zoologist, BSc, MEnv,
Kristin Campbell	Senior Zoologist, BEnvSc (Hons)
Caitlin Potts	Project Zoologist, BEnvSc (Hons)
Erin Baldwin	Project Zoologist, BEnvSc
Jules Farquhar	Zoologist, BEnvSc (Hons)
Wyn Russell	Zoologist, BEnvSc
John Muchan	Project Botanist, BEng (Hons)
Matt Jones	Research Assistant, BSc (EnvBio)

2 Brolga – species background

2.1 Population status, diet and lifecycle

Brolga *Antigone rubicunda* occurs in Australia and New Guinea (Marchant and Higgins 1996). The species is common in northern Australia but its numbers have declined in south-eastern Australia, including in Victoria (White 1987; Marchant and Higgins 1993). As a result, the species is listed as endangered in Victoria under the FFG Act. The south-eastern brolga population is estimated to total 1,000 individuals (Meine and Archibald 1996).

The distribution of Brolga in Victoria extends from the State's north-east to the south-west (Figure 2). Published information on the Victorian population estimates that it consists of 600–650 individuals, with 500–550 of these within the south-west and 50–100 within the north-east of the state (White 1987). More recent surveys have aimed at a better and more comprehensive understanding of the Brolga numbers in south-west Victoria, through undertaking systematic same day counts. In 2013 a total of 907 individuals were counted during the annual Department of Environment, Land, Water and Planning count (SWIFFT 2021) at Victorian and South Australian flocking areas. GPS tracking has shown that Brolgas move between sites in south-west Victoria and South Australia and are part of the same population. The number of breeding pairs is estimated to be 200–250 (SWIFFT 2021). South-west Victoria thus incorporates the core range of the Victorian Brolga population and the area occupied by the species includes breeding and locations at which Brolgas congregate during the non-breeding season (latter referred to as 'flocking areas' herein).

Brolgas are omnivorous and feed on crops, insects, small vertebrates such as frogs, crustaceans and plant matter, including wetland plant tubers (Marchant and Higgins 1993, DuGuesclin 2003). At flocking areas, where large numbers of brolgas congregate during the non-breeding season, brolgas mostly feed on grain after harvest or sowing. Brolgas use wetlands for nesting, foraging and roosting (Marchant and Higgins 1996), and are thus wetland-dependent throughout their annual life cycle. At both breeding and flocking areas, the species uses wetland and dryland habitat to forage in (Veltheim et al. 2019, King 2008). Wetlands are crucial for roosting and nesting and are also used for foraging.

Brolgas breed between July and November in shallow, temporary freshwater swamps, marshes, meadows and lakes (Corrick 1982, White 1987, Marchant & Higgins 1993) and can also breed in the shallow edges of stock dams (Herring 2018). Brolgas will re-nest if they fail, can nest in summer, and the breeding season may extend into March if conditions are favourable and if breeding wetlands have sufficient amount of water for nesting (Arnol et al. 1984). With the onset of summer and as the seasonally inundated wetlands dry, breeding pairs and their young move to flocking areas where they congregate in flocks from December to June (Arnol et al. 1984, White 1987, Marchant and Higgins 1993). Occasional birds may remain in proximity of breeding sites during the non-breeding season. Juveniles (<12 months old) will often accompany the breeding pair back to the breeding area at the commencement of the subsequent breeding season, but are chased away when the pair begin nesting and forming territories.

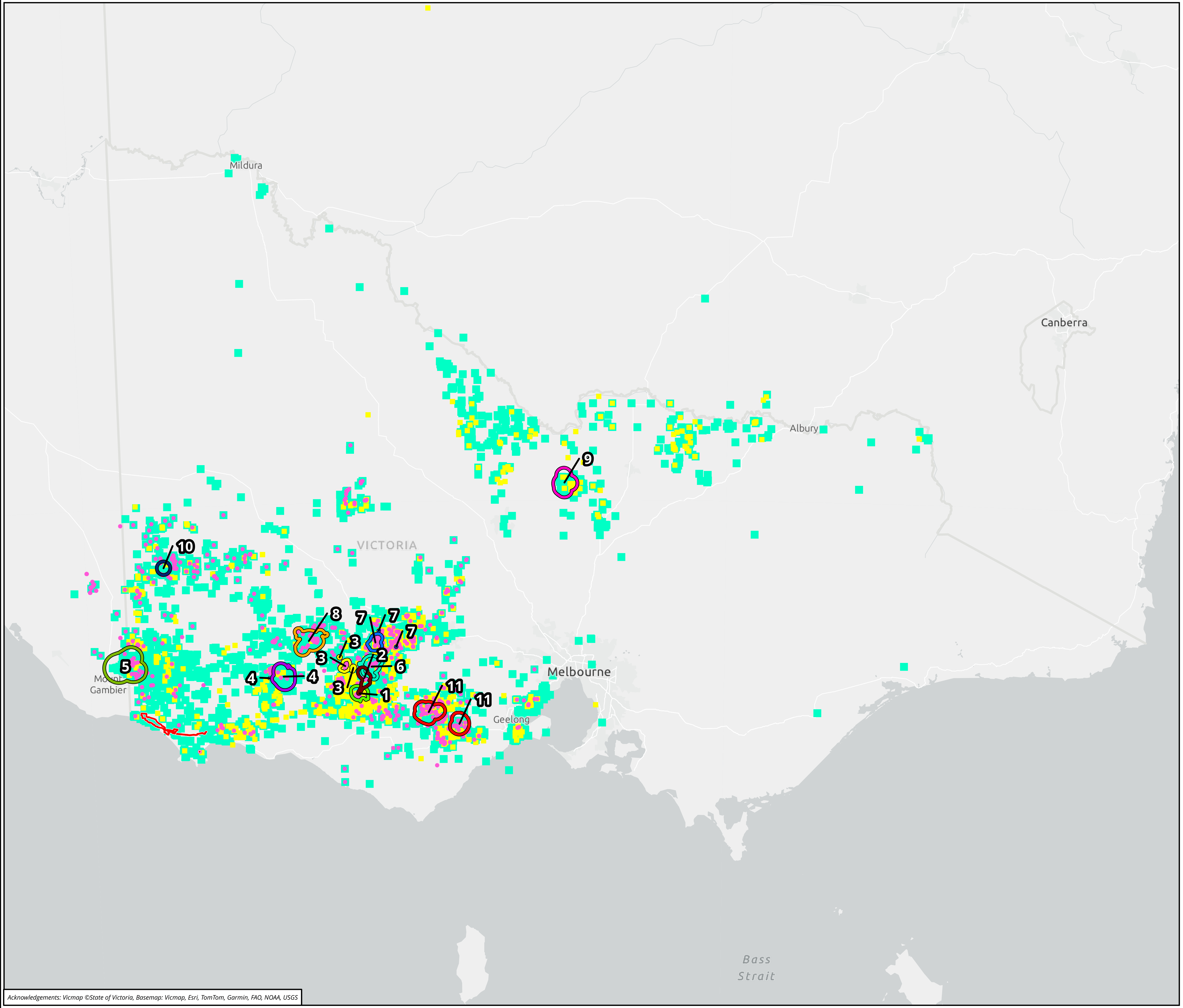

Figure 2 Brolga records and distribution in Victoria

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2.1.1 Movement behaviour

Brolgas establish breeding territories in what appear to be traditionally used sites, in other words breeding pairs seem to return to the same area each year and nest in the same, or a nearby wetland. Pairs are strongly territorial and in Victoria generally will not tolerate the presence of another breeding pair unless both territories are in a large and extensive wetland. Where multiple suitable breeding wetlands are within proximity of each other, pairs can breed within about one kilometre of each other and have overlapping home ranges (Fig. 2 in Veltheim et al. 2019). However, more commonly the nesting density in Victoria is low.

Observational and GPS-tracking studies have shown that nesting adults and their chicks generally stay close to the breeding wetland containing the nest or to a night roost wetland. Daily movements of adults can involve walking or flights to access suitable foraging patches, and can include territorial defence against neighbouring pairs. During nest building the pair will move together, but once eggs are laid they will share the incubating when one individual will sit on the nest and the other will forage nearby – either in the wetland or in non-wetland habitat. Once chicks hatch, the family tends to walk together, though adults may take occasional flights particularly to defend their breeding territory.

Unfledged chicks can be highly mobile and have been found to move 442 metres on average from their wetland night roost, with 95% of such movements being within 1369 metres from night roost (Veltheim et al. 2019). Chicks and the adult pair can move such distances to access foraging habitat or when switching night roosts within their breeding home range. The location of nests, night roosts and wetland depth and extent vary within and between seasons.

Observations of breeding brolgas by Brett Lane and Associates over the nesting and post-hatching period have shown that 54% of adult flights were within 400 metres of the breeding wetland and 86% within 1600 metres, with two flights being 3200 metres from the breeding wetland. GPS-tracking of Brolga has shown that brolgas can use multiple wetlands before chicks fledge (1–7 in Veltheim et al. 2019). Breeding home ranges vary greatly, from 70 hectares to 523 hectares and pairs and unfledged chicks and the breeding pair use multiple wetlands before chicks fledge (Veltheim et al. 2019).

In Victoria, Brolgas use a number of well-established and known flocking areas, which include 10 areas within south-west Victoria and two in north-east Victoria (Dingee and Corop) (White 1987, DuGuesclin 2003, DELWP 2020) (Figure 2). The flocking areas comprise of wetlands and agricultural fields (cropping and grazing) where brolgas use more permanent freshwater, stock dams and saline lakes as night and day roosts (Arnol et al. 1984, Sheldon 2004). Flocks roost communally at wetlands at night and move out to agricultural fields to feed in the morning, from first light to 30-45 minutes after sunrise. These foraging trips generally last 2-3 hours after sunrise and the flocks move back to a wetland roost to rest, loaf and preen (Veltheim 2018), returning back to foraging areas in the afternoon prior to moving to roost for the night, around sunset. Flocks thus make a minimum four movements (flights or walking) in a daily cycle, though they can move out to forage from a wetland roost more frequently during the day, particularly on cooler and overcast days (Veltheim 2018).

Throughout the flocking season, flocks use multiple wetland roosts thus moving in the landscape and shifting their centre of activity from week-to-week or month-to-month, resulting in large home ranges in flocking areas. Overall, GPS tracking has shown that the majority (95%) of brolga movement distances, between a nocturnal roost and a morning foraging area are within 5.2 kilometres of night wetland roosts throughout the year, across the breeding and non-breeding parts of their lifecycle (Veltheim et al. 2022). On average, adults moved shorter distances (0.69 kilometres) than juveniles (1.8 kilometres), when commuting from a night roost to a foraging area (Veltheim et al. 2022).

Brolga breeding sites are distributed throughout the species' Victorian range (Figure 2) and are generally located in areas with high density of shallow freshwater wetlands and reliable seasonal winter-spring rainfall.

These wetlands are at varying distances from flocking areas. Brolgas move between breeding and flocking areas in response to changes in environmental conditions (Marchant and Higgins 1996). As breeding wetlands dry, individuals move to flocking areas in late spring to early summer (November–December), returning to breeding wetlands as they fill because of increased rainfall in late autumn to early winter (May–June) (Arnol et al. 1984, Marchant and Higgins 1996). GPS-tracking has revealed Brolgas in south-west Victoria are partially migratory. Some individuals moved 96–111 kilometres on average, others moved shorter distances of 6–30 kilometres between breeding and flocking areas (Veltheim et al. 2022) and some breeding pairs remained at breeding areas throughout the year (Arnol et al. 1984, Veltheim et al. 2022). Pairs can remain at or near breeding territories if suitable wetland and foraging habitat is available. Figure 2 shows the Brolga breeding and flocking records (from VBA and Sheldon (2004)) and flocking areas (DELWP 2020), demonstrating the spatial distribution of these seasonally used areas by the species across its distributional range.

2.1.2 Threats

The main threats to Brolgas include on-going habitat loss of shallow freshwater breeding habitat mainly due to drainage for agriculture, collisions with fences and powerlines, and nest and chick predation (DuGuesclin 2003). Due to an increase in wind energy development within the Brolga's core range in south-western Victoria and concern that disturbance from, or collisions with, wind farm infrastructure may have a population level impact on the state's Brolga population, DEECA requires proponents to follow the Interim Brolga guidelines for assessing, avoiding, mitigating and offsetting of potential wind farm impacts on brolgas (DSE 2012).

3 Level One Assessment

The Level One Assessment aims to identify if a wind energy development poses a risk to Brolgas in Victoria, through a three-step methodology (Table 2) within a radius of investigation (ROI). The ROI includes the development footprint and a 10 kilometre area around it (DSE 2012).

The Project meets all Level One Assessment triggers (Table 2). Additionally, BLA (2018) recommended a Level One Assessment for the Brolga, based on an initial overview of bird and bat constraints to the Project. Biosis undertook a Level One Assessment in 2018 and 2019. Early stages of the Level One Assessment revealed presence of Brolgas within 10 kilometres of the Project and triggered a Level Two Assessment (DSE 2012). Biosis conducted further database searches, detailed field inspections and community liaison (targeted to areas of Brolga habitat within 5 kilometres of the Project) during Level Two Assessments in 2020 and 2021 (Section 4).

3.1 Methods

3.1.1 Step One: Database records

The following database searches were undertaken (results in Section 3.1.1):

- 10 kilometre threatened species VBA search by Brett Lane and Associates (BLA 2018) from the approximate centre line of the study area, in September 2018, considered in the Biosis 2018/2019 Level One Assessment.
- 5 km VBA search by Biosis as part of EES referral studies in May 2019 and 30 km NatureKit search in July 2019.

3.1.2 Step Two: Field inspection

A three-day field inspection on 9–11 November 2018 within 10 kilometres of the initial project area was undertaken to identify known and potential Brolga habitats visible from roads, including areas north of the Rennick pine plantations and west to Pick Swamp / Piccaninnie Ponds (results in Section 3.1.2).

3.1.3 Step Two: Local community consultation

Neoen hosted community sessions in 2018–2022 towns within the 10 km radius of investigation: Nelson ~5km, Mount Richmond ~5km, Portland ~30km and Heywood ~25km. These represent all the major communities around the project (see Chapter 6 EES for further detail).

Biosis held preliminary discussions with R. Hill (DEECA (previously) Casterton), A. Govanstone (retired DEECA officer from Portland), A. Moore (GTFP Plantation Manager) and R. Green (BirdLife SE South Australia; Avian Monitoring Services, Mount Gambier). These experts were not aware of any Brolga breeding or flocking sites additional to those documented in VBA records. During community consultation sessions held by Neoen in Portland, Mount Richmond and Nelson in December 2019, discussions were also had with some members of Portland Field Naturalists Club Inc. and local landowners.

Biosis engaged in further community consultation during Level Two Assessment (Section 4.1.5), which meet the criteria for Level One Assessment. Neoen additionally made the existing conditions report publicly available in late 2020 and received submissions, which included information on Brolga observations within the ROI.

3.2 Limitations

The BLA (2018) report had no details on the Brolga records, beyond information on the total number and the most recent record. BLA (2018) note limitations to the database search due to technical issues at the time of the request. A field inspection of short duration undertaken in November 2018, over a large area and limited by roadside access and visibility of all suitable areas, is likely to miss Brolgas. The Biosis 2019 VBA database search was limited to 5 kilometres, rather than 10 kilometres, however the 10 kilometre search area of BLA (2018) formed part of the overall Level One Assessment. The community consultation sessions only capture observations of attendees and Brolga occupancy of some areas within private land can be overlooked if other methods are not used to capture sightings. Although the local experts consulted in our assessment have good knowledge of their area they may not be aware of all Brolga sightings. Therefore, not all Brolga occurrence and location of habitats used within the ROI may have been captured in the assessment. Nonetheless, the assessment effort was sufficient to address the Level One Assessment requirements and to inform the need for a Level Two Assessment. The Level Two included further community consultation to gain a comprehensive understanding of current, historical and likely Brolga breeding site locations (see Section 4).

3.3 Results

3.3.1 Step One: Database records

The results of the Level One database searches are listed below:

- The BLA (2018) 10 kilometre VBA search identified (noting the limitations listed above (Section 3.2):
  - Four Brolga records.
  - Most recent record from 1997.
  - No breeding or flocking records.
- The Biosis 2018 5 kilometre VBA search identified:
  - 24 Brolga occurrence records.
  - Most recent record from 2011.
  - Four breeding records located at Little Moleside Creek (1978), Boggy Creek (1978), Jones Ridge (1984) and Beach Road, Nelson (1999).

The Biosis VBA and other database search records are shown in Figure 3.

An assessment of impacts based on a comparison of database records for the southern and eastern route transmission lines was added in October 2022 at Neoen's request (Appendix 6). The Biosis VBA search and other database search records for both of these transmission lines are shown in Appendix 6.

3.3.2 Step Two: Field inspection

During a three day field inspection on 9–11 November 2018, the only confirmed Brolga breeding site was at Pick Swamp / Piccaninnie Ponds, which was provided to Biosis by the Green Triangle Forest Products GTFP plantation manager. This site is outside of the Project area and beyond the 10 kilometre ROI.

3.3.3 Step Two: Local community consultation

Initial discussions and community consultations did not provide any data about Brolgas in the local area additional to what is contained in VBA database.

3.4 Summary and implications

The Project area and 10 kilometre ROI around it, contained a total of 24 Brolga occurrence records, including four breeding records, based on 2019 VBA database searches. Field inspection and community consultation provided no additional information on Brolga occurrence within 10 kilometres of the Project.

The Level One Assessment triggered the Level Two Assessment and met the Level One Assessment aim (Table 2):

- 'Identify the potential presence, number and location of any Brolgas or potential Brolga habitat within the radius of investigation for a proposed wind farm',

The need for Level Two Assessment was identified in the early stages of the Level One Assessment (breeding records within the ROI), and thus all further detailed work was undertaken as part of the Level Two Assessment, including field assessments, more detailed desktop assessments and targeted community consultation.

Legend

- Wind farm footprint
- 275kV overhead transmission line
- 275 kV underground transmission line
- Substation
- Project footprint 3km buffer
- Project footprint 5km buffer
- Project footprint 10km buffer

Brolga records (BirdLife) labelled by year

- Breeding
- Non-breeding

Brolga records (eBird) labelled by year

- Breeding (probable)
- Non-breeding

Brolga records (VBA) - labelled by year

- Breeding
- Non-breeding

Brolga records (Sheldon) - labelled by month/year and (bird count)

- Sheldon 2004 brolga flocking database records

Wetlands

- 1 - Flooded river flats
- 2 - Freshwater meadow
- 3 - Shallow freshwater marsh
- 4 - Deep freshwater marsh
- 5 - Permanent open freshwater
- 6 - Semi-permanent saline
- 7 - Permanent saline
- 20 - Sewage oxidation basin
- 21 - Salt evaporation basin
- 99 - No Category

Figure 3.1 Brolga database records

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Kilometres
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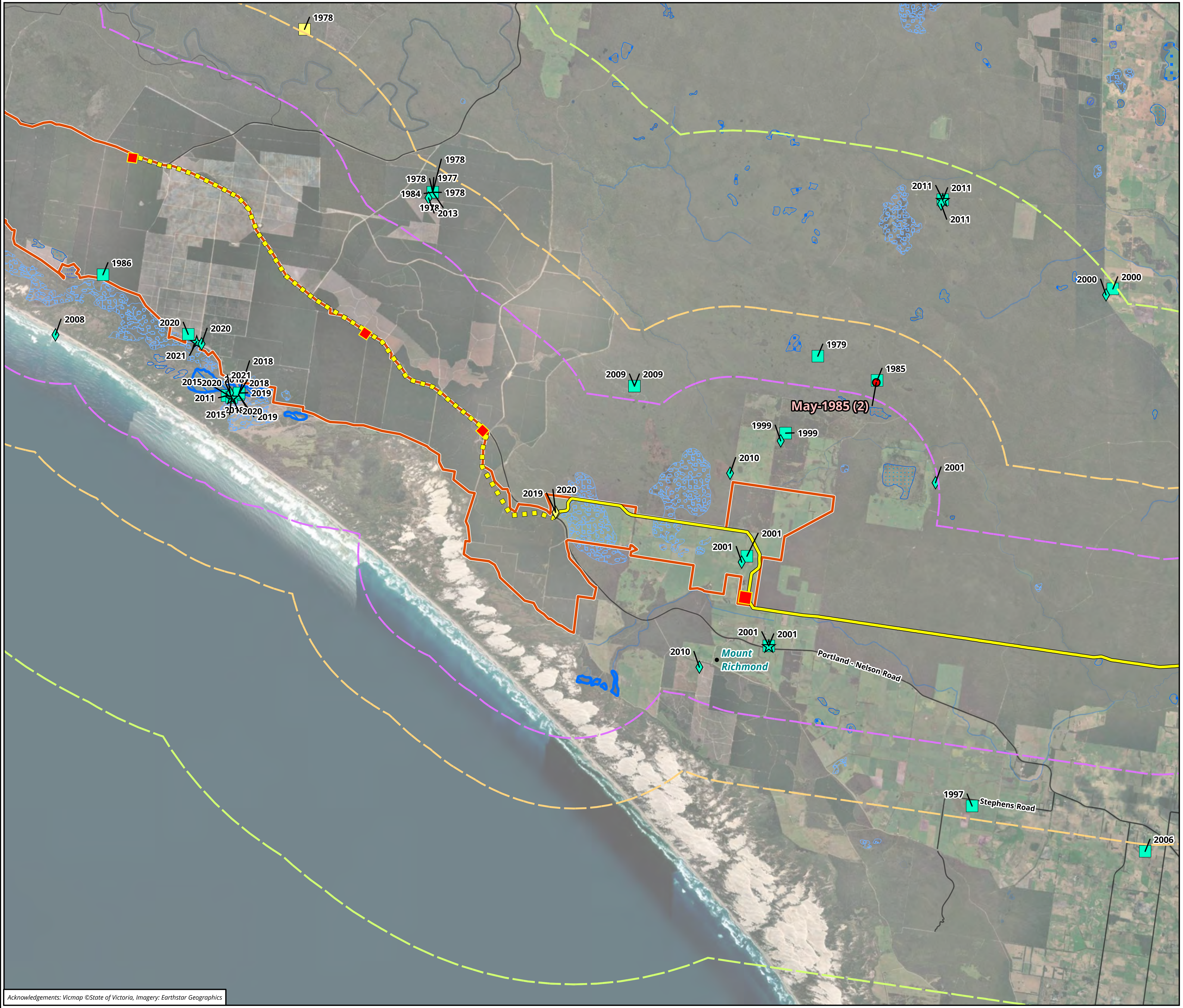

Legend

- Wind farm footprint
- 275kV overhead transmission line
- 275 kV underground transmission line
- Substation
- Project footprint 3km buffer
- Project footprint 5km buffer
- Project footprint 10km buffer

Brolga records (BirdLife) labelled by year
- Breeding
- Non-breeding

Brolga records (eBird) labelled by year
- Breeding (probable)
- Non-breeding

Brolga records (VBA) - labelled by year
- Breeding
- Non-breeding

Brolga records (Sheldon) - labelled by month/year and (bird count)
- Sheldon 2004 brolga flocking database records

Wetlands
- 1 - Flooded river flats
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- 6 - Semi-permanent saline
- 7 - Permanent saline
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- 21 - Salt evaporation basin
- 99 - No Category

Figure 3.2 Brolga database records

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Kilometres
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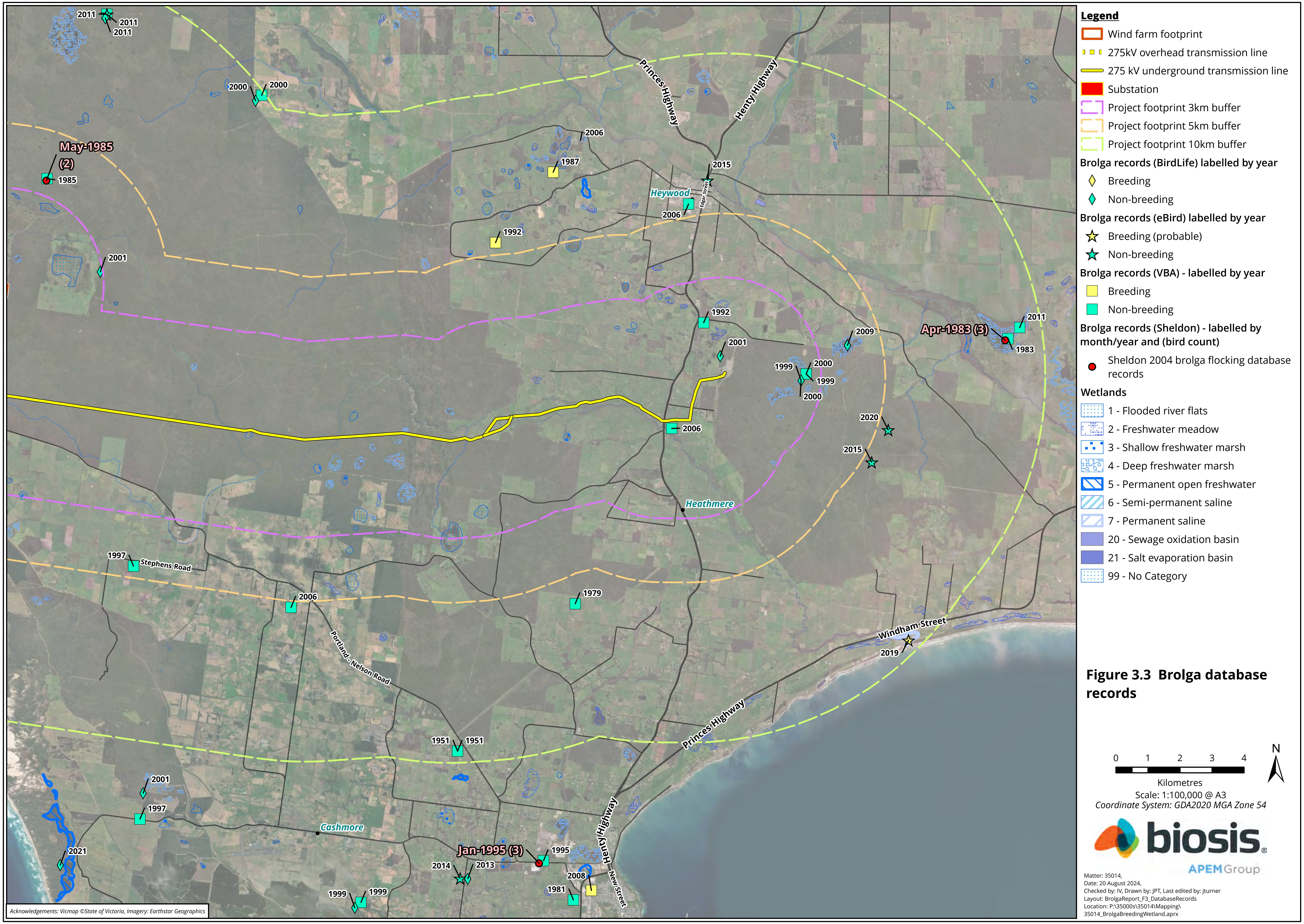

Figure 3.3 Brolga database records

4 Level Two Assessment

The Level Two Assessment aims to provide a comprehensive record of the location, nature and extent of Brolga habitats within the wind farm radius of investigation and to assess the potential for impacts arising from collision risk, indirect disturbance and barrier effects (Table 2) (DSE 2012). The Brolga guidelines (2012) outline suggested field investigation methodologies, including:

- Roaming surveys
- Aerial surveys
- Flight behaviour studies
- Gradient studies
- Time-activity budgets

The Brolga guidelines (2012) are not prescriptive regarding the choice of methods, although they recommend that a range of methods should be employed and should include one or more of those listed. The surveys should 'collect comprehensive data about the location, nature and extent of Brolga habitats, and patterns of habitat use and behaviour at breeding, flocking and foraging sites within the radius of investigation' (DSE 2012).

Early in the Level One Brolga assessment triggers for a Level Two assessment were identified (in 2018–2019), with all four triggers being potentially relevant for the project (see Table 2 for triggers and assessment objectives). At that point the project moved to a Level Two assessment. The Brolga guidelines (2012) require mitigation of potential wind energy development impacts through implementing turbine-free buffers for identified breeding and non-breeding (flocking) habitat. The default buffer is 5 kilometres of a flock roost site and 3.2 kilometres from breeding site, as defined in the Brolga guidelines (DSE 2012) (see Section 1.3.2 for definitions). Therefore, any such Brolga habitats within 5 kilometres of the Project boundary are considered to be at potential impact from the wind energy facility operations (turbines and all other infrastructure). BLA (2018) identified that if triggers were met, investigations would be needed to determine the presence of Brolga breeding or flocking sites at the wind farm and within 5 kilometres of proposed turbines.

4.1 Methods

Having identified the presence of brolgas with the 10 kilometre radius of investigation, Level Two Assessment was undertaken within 5 kilometres to address the main objectives of the Brolga guidelines (2012): to document Brolga habitat within the assumed potential wind farm impact zone of 3.2 kilometres within breeding sites and 5 kilometres of flock roost sites, to identify Brolga wetland habitat subject to turbine-free buffers.

The Biosis Level Two Assessment investigations in 2020 and 2021 focused on detailed field and desktop assessments to document location of Brolga habitat, flight behaviour, and the presence of breeding and any potential flocking sites within 5 kilometres of the Project footprint boundary. Desktop assessment for the potential presence of flocking sites beyond 5 kilometres was undertaken to understand the risk and potential impact of the Project to Brolgas using flocking sites during the non-breeding season and moving between breeding and flocking sites.

Biosis collected data on Brolga occurrence and habitat using the following methods (first three in this list are DSE (2012) recommended methods):

- **Roaming surveys – Brolga breeding season survey (2020)**.
- **Aerial surveys – Brolga breeding season survey (2020)**.
- **Flight behaviour studies (2020, 2021)** – bird utilisation surveys every alternate month April 2020 – Feb 2021, inclusive.
- **Database records (2021) – additional to Level One Assessment**
- **Local community consultation – targeted, additional to Level One Assessment**
- **Targeted flocking season survey (2020, 2021)**, December 2020 to June 2021 at a DELPWP-mapped wetland with frequent Brolga activity during the breeding season surveys.
- **Remote nest camera (2021)** deployed at a suspected nest site July-August 2021.
- **Additional targeted habitat assessment (2021)**.
- **Follow up targeted breeding season survey (2021)**.

Detailed methodology for each is described in the following sections.

4.1.1 Roaming surveys – Brolga breeding season

Wetlands surveyed

DEECA current wetland layer (Victorian Wetland Inventory (Current)) and VBA records were used to identify locations for roaming surveys. Potentially suitable mapped wetlands were accessed along roads and in private property where access was granted, within 5 kilometres of the Project area footprint (Figure 4).

Timing

Biosis undertook Brolga breeding season surveys in:

- July 2020 – three days
- September 2020 – three days
- November 2020 – four days

Surveys were conducted during the day, from morning to late afternoon.

Additional survey effort in high activity areas

The roaming survey effort was increased at two locations after incidental and flight observations as detailed below:

- Private property at Mt Kincaid Road, Gorae West private property, after an incidental record on 28 May 2020 prior to the formal start of breeding season roaming surveys, and flight observations to and from wetland 20522.
- Swan Lake after flight observations south west from wetland 20522 Mt Kincaid Road location.

Repeat surveys were taken at the following locations with frequent Brolga activity (Figure 4), including dawn and dusk surveys at high activity locations to identify roosting wetlands and record flight paths. Numbers for each site below correspond with the site numbers in Figure 4. Corresponding DEECA wetlands are also listed below:

- Private property Mt Kincaid Road, Gorae West (1); 20522, 20529. 20532, 20530, 20531, 20534, 20535.
- Kentbruck Settlement Road and Blacks Road (2); 20555, 20633, 20566, 20634.
- Martin's Lane, Gorae West (3).
- Swan Lake (4), wetland 20527.
- Private property on Johnsons Road, near McFarlanes Swamp (5).
- Corner Stephens and Hahns Road, Mt Richmond (6).

Incidental records

The assessment includes additional data from May 2020 to December 2020 incidental observations and targeted re-visits to locations where Brolgas were observed during the Brolga and other targeted fauna and flora, and bird utilisation surveys. Data on Brolgas was thus collected monthly, within suitable habitats and areas with high Brolga activity, most likely impacted by the Project.

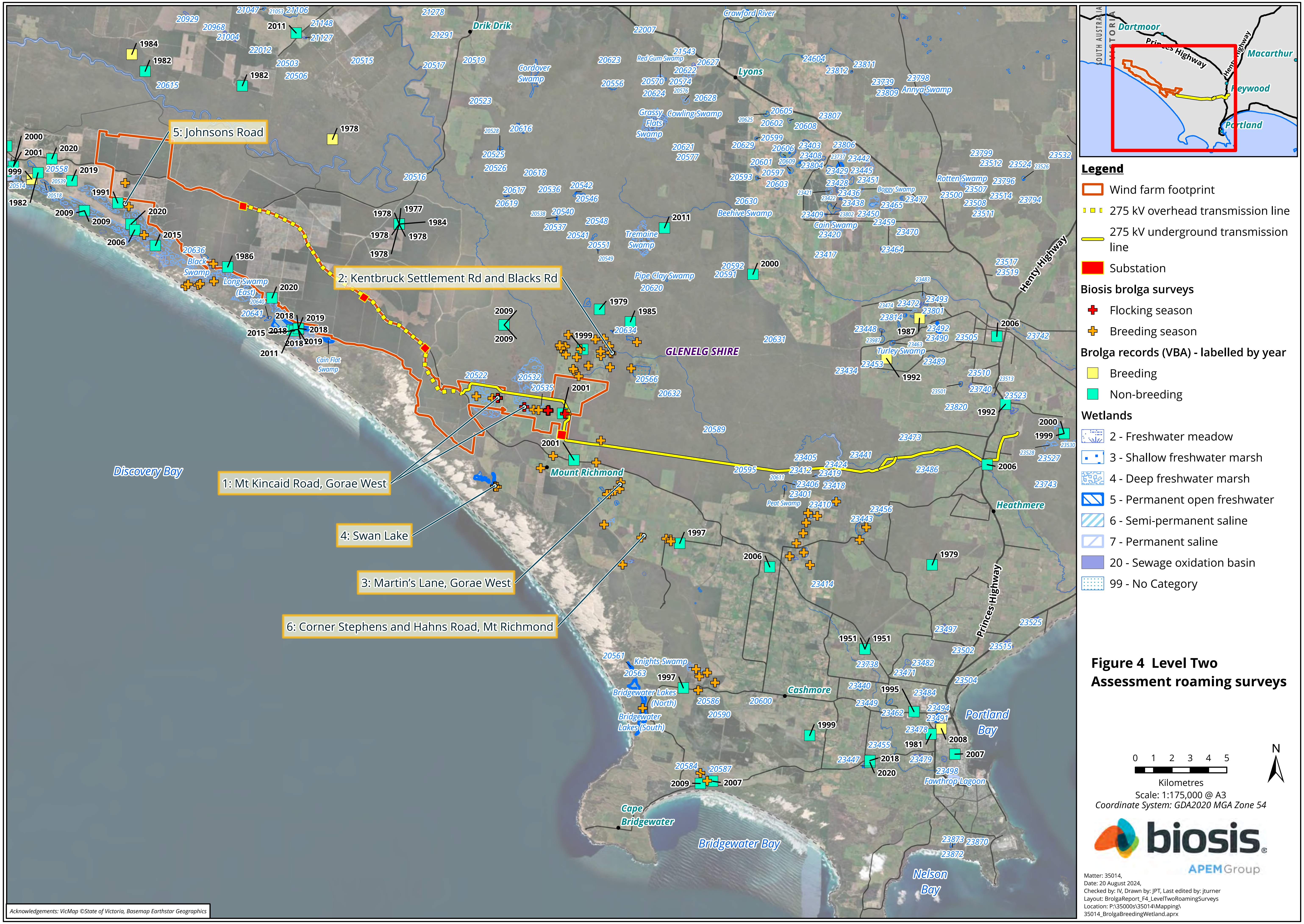

Figure 4 Level Two Assessment roaming surveys

4.1.2 Aerial surveys – Brolga breeding season

Aerial surveys during the late breeding season were undertaken on 30 November and 4 December 2020. This method can identify breeding sites, as Brolgas on nests and pairs with chicks can be readily observed from a plane.

Biosis used a single engine Cessna 182RG, high wing, four-seat plane with a pilot and zoologists experienced in undertaking Brolga surveys (Mark Venosta and Katrina Sofo, assisted by Wyn Russell). We followed the recommended survey methodology for conducting aerial surveys for breeding Brolgas provided in the Brolga guidelines (DSE 2012), as follows:

- Flight height of 500 feet and flight speed of 60–70 knots as far as coastal wind conditions allowed.
- East to west transects 500 metres apart within a 3 kilometre buffer of the wind farm footprint and the transmission line route options.
- Two observers, one in the left front seat and one on the right back seat, observing 250 metres to the north and the south of the transects.
- Observers scanned the landscape and all wetlands, dams, creeks and drainage lines with binoculars (10x42).
- Observers had an aerial map with wetlands (DEECA current wetland layer – Victorian Wetland Inventory (Current)) and numbered transects.
- Observations were entered into a GPS-enabled tablet, and their positions manually adjusted on the screen as required.

The aerial survey transects flown during the surveys are shown in Figure 5.

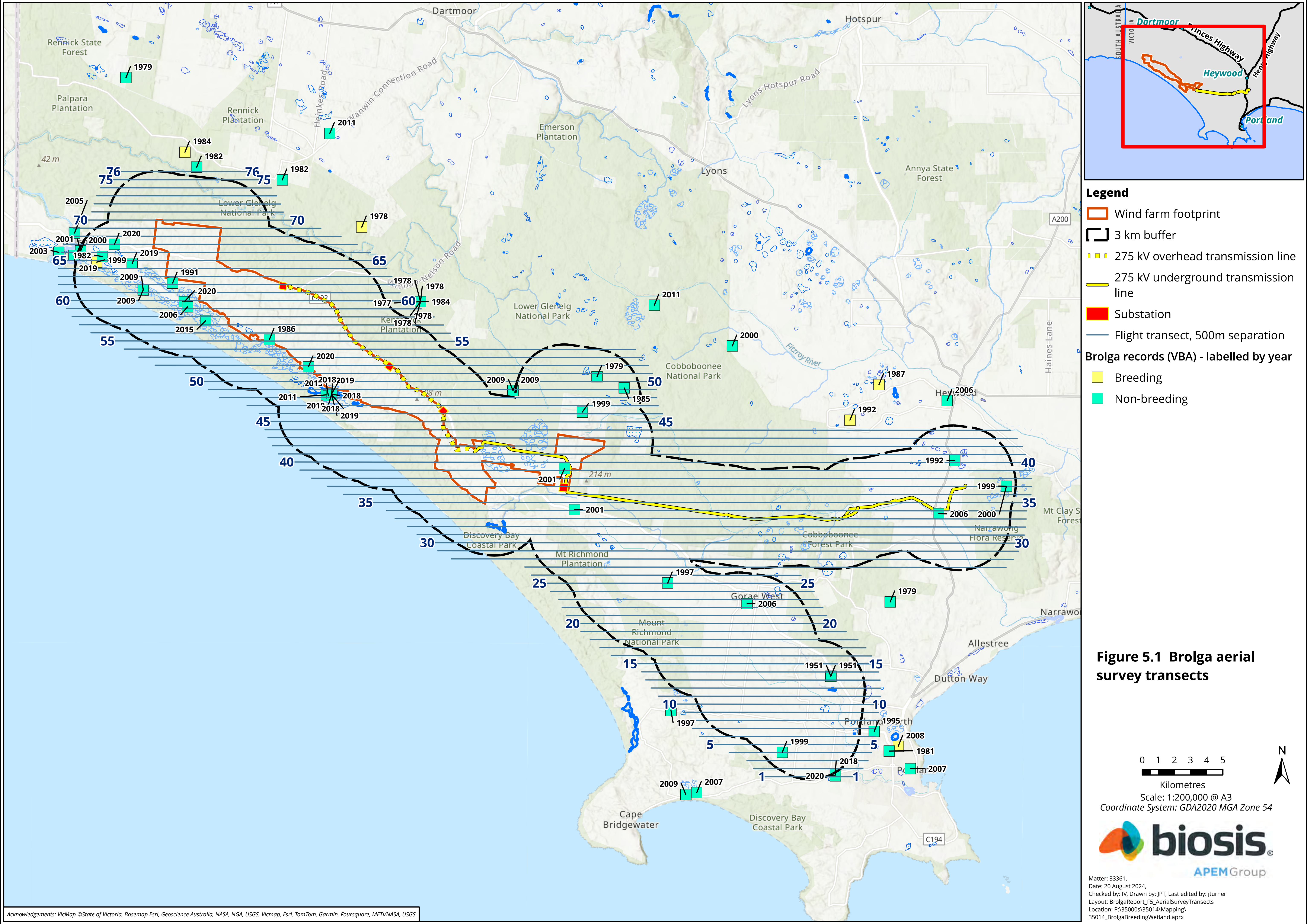

Figure 5.1 Brolga aerial survey transects

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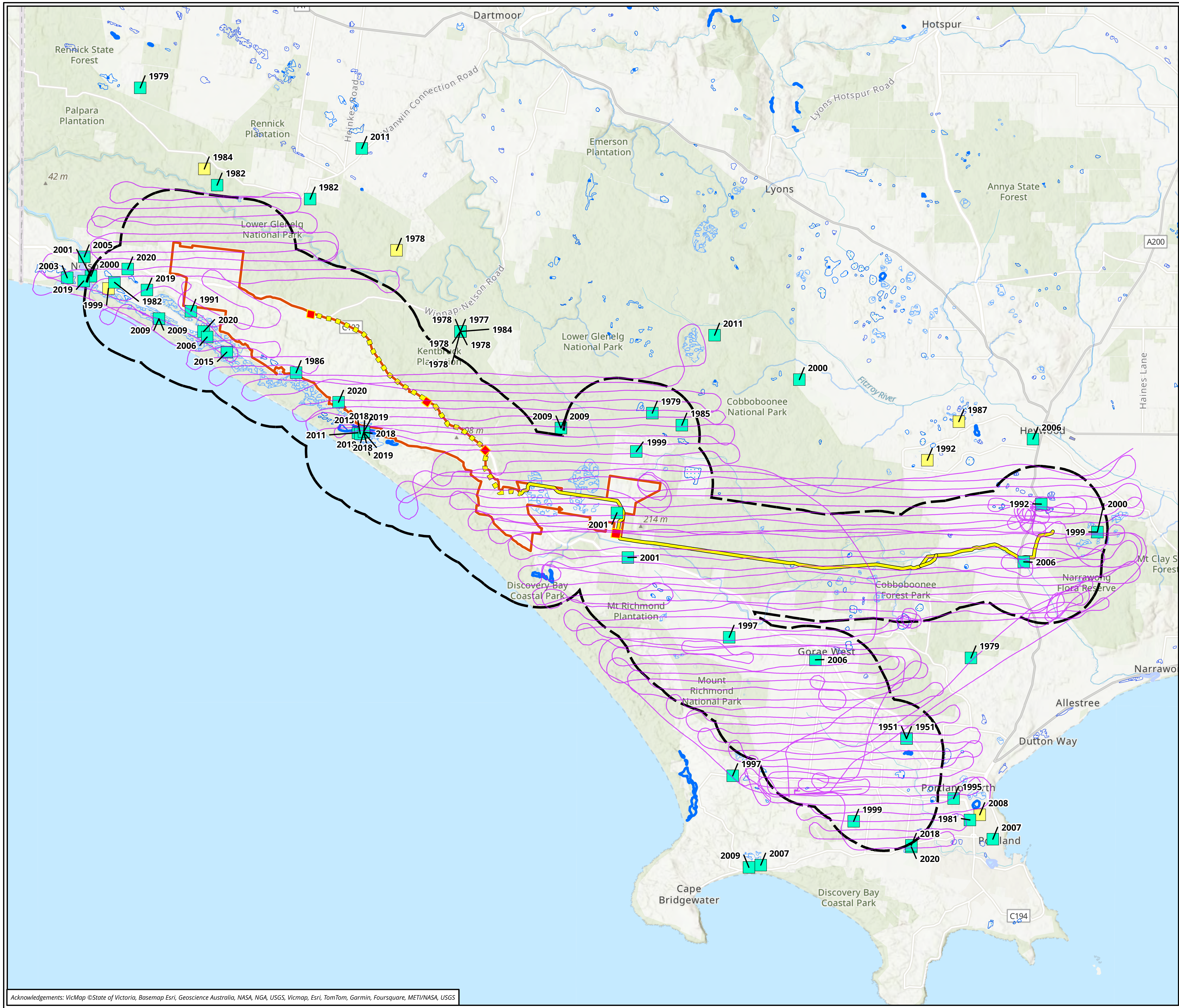

Legend

- Wind farm footprint
- 3 km buffer
- 275 kV overhead transmission line
- 275 kV underground transmission line
- Substation
- Survey effort (flight paths)

Brolga records (VBA) - labelled by year

- Breeding
- Non-breeding

Figure 5.2 Brolga aerial survey transects

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Coordinate System: GDA2020 MGA Zone 54

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Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_F5_AerialSurveyTransects
Location: P:\35000s\35014\Mapping\
35014_BrolgaBreedingWetland.aprx

4.1.3 Flight behaviour studies – Bird utilisation survey

Bird utilisation surveys (BUS) were undertaken in April 2020, June 2020, August 2020, October 2020, December 2020 and February 2021 to provide understanding of the avifauna presence in the project area and to inform any collision risk modelling undertaken (Smales et al. 2013). The replicate surveys were conducted across a ten-month period to representatively sample different seasons and capture the presence of migratory birds.

A total of 27 'point count' survey sites were selected across the project area. Point counts are a means of tallying all birds detected by sight and sound by a single observer located at a fixed position during a specified period. The BUS survey includes 17 'treatment' sites (T1 – T17) and ten 'control' sites (C1 – C10), as shown in (Figure 6). The survey (point count) sites were representative of locations for proposed turbines and sites of known threatened bird records.

Surveys were conducted three times at each point count site during each monitoring month. The three surveys were spread across 'morning' (start between 07:45 and 10:59), 'midday' (start between 11:00 and 13:59) and 'afternoon' (start between 14:00 and 17:15) surveys to capture the presence of the entire diurnal bird species assemblage at each site.

Point count surveys were conducted for 20 minutes by a zoologist, with the observer allowing an additional 5 minutes of time for birds to settle prior to commencing each survey. During the point count the observer recorded all birds sighted and associated variables including behaviour, flight height and distance from the observer. In addition to data collected during the 20-minute surveys, species heard during the survey and seen during the 5 minutes prior to the survey were also recorded.

A total of 12 of the 27 BUS survey sites were located near Brolga database records (T1, T2, T3, T11, T9, T15, T17, C3, C4, C7, C8 and C10) (Figure 6).

Flight path mapping

Biosis recorded flight observations during:

- Roaming surveys – Brolga breeding season survey (2020).
- Flight behaviour studies (2020, 2021) – bird utilisation survey.
- Targeted flocking season survey (2020, 2021), December 2020 to June 2021 at a DEECA-mapped wetland with frequent Brolga activity during the breeding season surveys.
- Additional targeted habitat assessment (2021).
- Follow up targeted breeding season survey (2021)

Flight path observations from a landholder at Mt Kincaid Rd, Gorae West were also documented and are presented in the results section of this report.

4.1.4 Database records – additional to Level One Assessment

Further database searches were undertaken:

- Database records within a 10-kilometre VBA search to understand occurrence and current and historical use of the area – date of search 8 July 2022.
- BirdLife Shorebirds2020 – date of search 12 June 2022. Database search areas included the Glenelg Estuary and the Discovery Bay Coastal Park.
- BirdLife BirdData – date of search 4 February 2022.

- eBird records within 10-kilometre radius of the Project – date of search 11 July 2022.
- Sheldon (2004) south-west Victorian Brolga flocking database within 10-kilometre radius of the Project.

Where Sheldon (2004) flocking database records overlapped with other database records, they were brought to the front in the mapping to clearly identify these records and distinguish them from other records.

Restricted database records were also considered, though will be excluded from the figures. The database searches were undertaken for the 'Original Layout' and included a southern transmission line (shown in Appendix 6). The figures in this report include data for the 'Original Layout' database searches.

4.1.5 Local community consultation – targeted, additional to Level One Assessment

Further to Level One Assessment community consultation, Biosis undertook additional local community consultation in 2020 and 2021. These consultations were targeted to areas with suitable Brolga habitat and overlapping infrastructure. Discussions also included a Portland Field Naturalists Club Inc. member and three landholders with suitable Brolga habitat.

Figure 6.1 Bird utilisation survey points

Scale: 1:100,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

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Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_F6_BUS
Location: P:\35000s\35014\Mapping\
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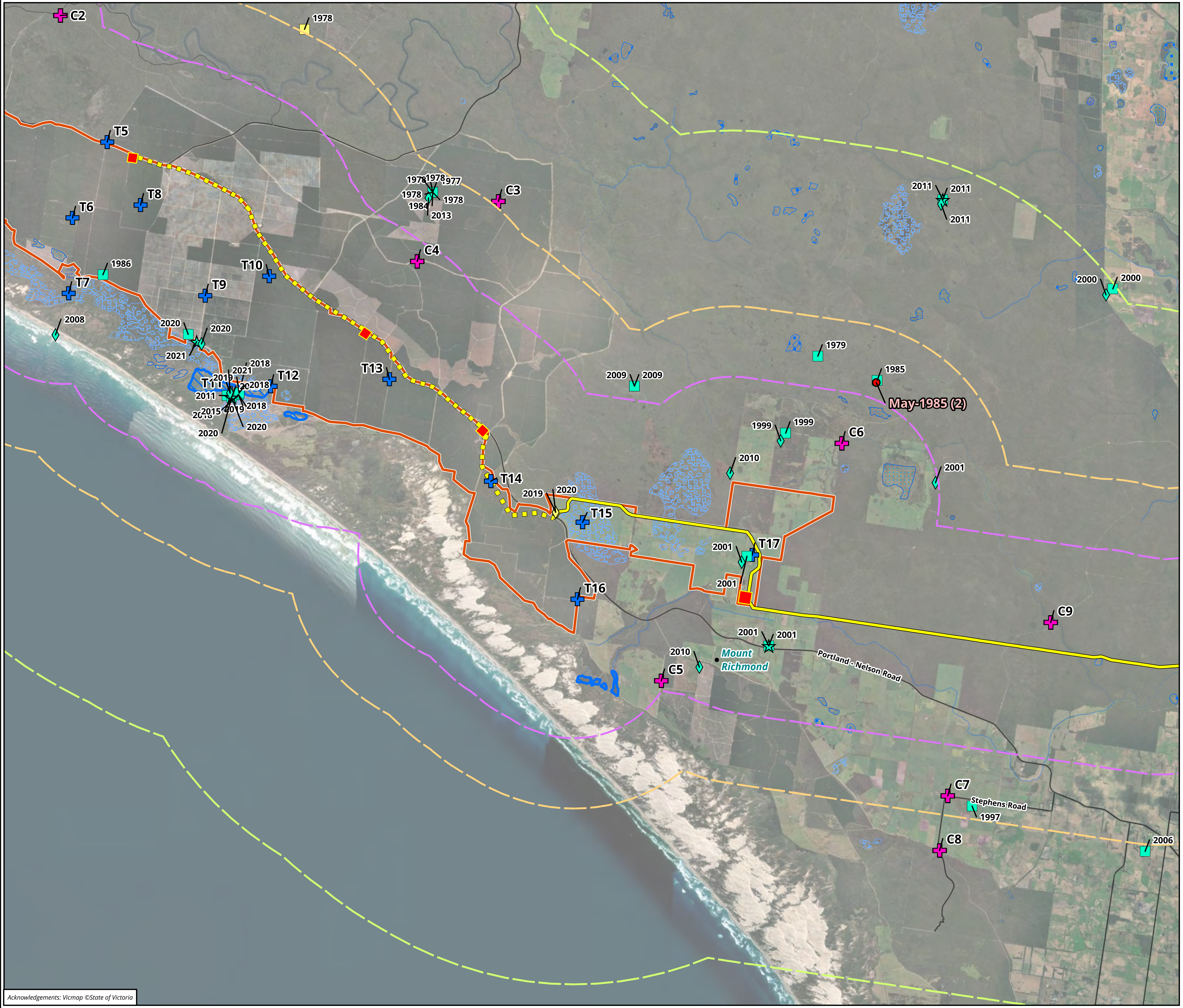

Legend

- Wind farm footprint
- 275 kV overhead transmission line
- 275 kV underground transmission line
- Substation

Survey sites

- Control
- Treatment

Brolga records (BirdLife) labelled by year

- Breeding
- Non-breeding

Brolga records (eBird) labelled by year

- Breeding (probable)
- Non-breeding

Brolga records (VBA) - labelled by year

- Breeding
- Non-breeding

Brolga records (Sheldon) - labelled by month/year and (bird count)

- Sheldon 2004 brolga flocking database records

Wetlands

- 1 - Flooded river flats
- 2 - Freshwater meadow
- 3 - Shallow freshwater marsh
- 4 - Deep freshwater marsh
- 5 - Permanent open freshwater
- 6 - Semi-permanent saline
- 7 - Permanent saline
- 20 - Sewage oxidation basin
- 21 - Salt evaporation basin
- 99 - No Category

Figure 6.2 Bird utilisation survey points

0 1 2 3 4

Kilometres

N

Scale: 1:100,000 @ A3

Coordinate System: GDA2020 MGA Zone 54

biosis APEM Group

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_F6_BUS
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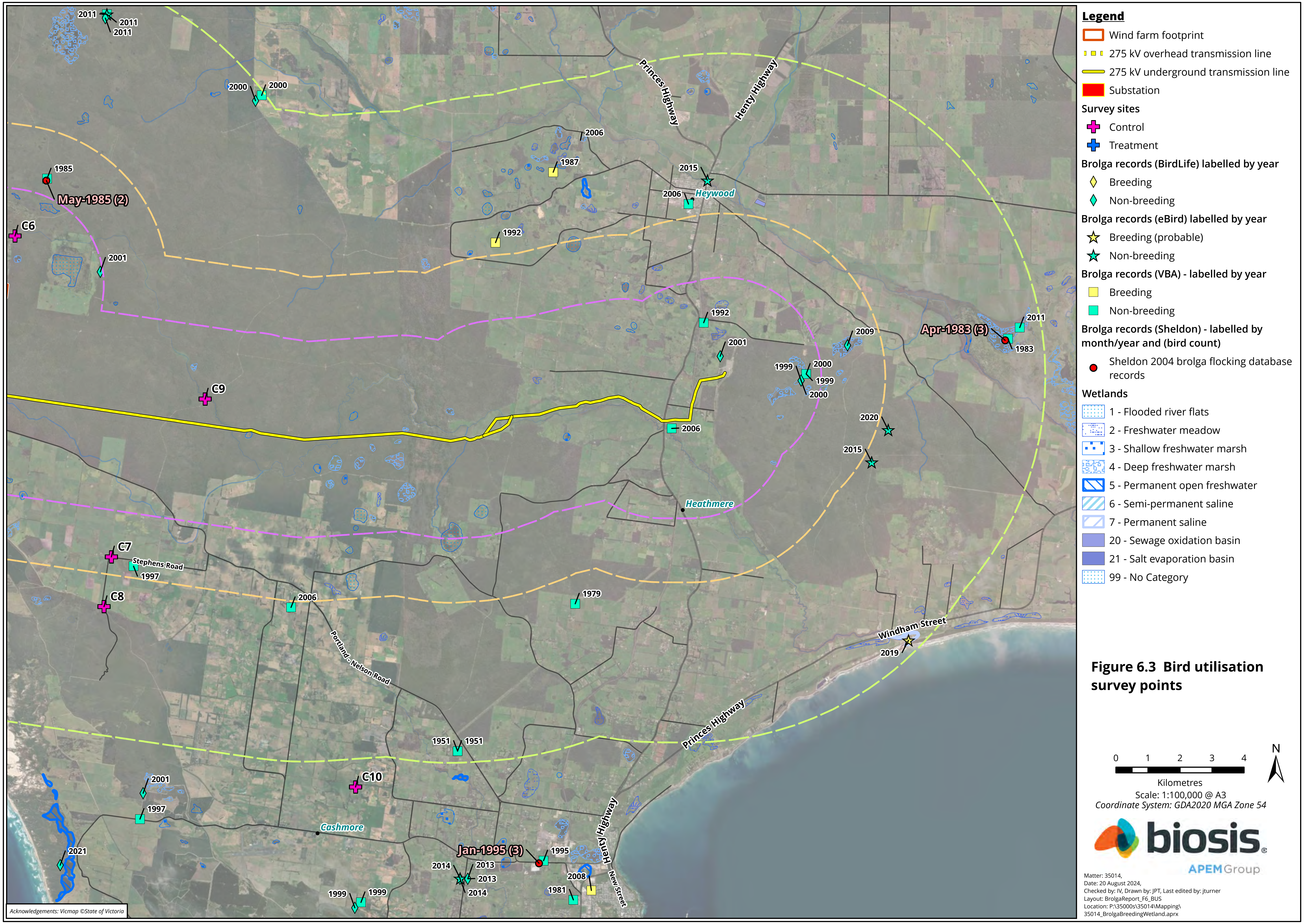

Figure 6.3 Bird utilisation survey points

4.1.6 Brolga flocking season survey

The nearest known flocking area to the Kentbruck Green Power Hub – Strathdownie (Kaladbro/Mingbool) – is approximately 50 to 70 kilometres north/north-west of the project area and can support up to 300 individuals annually during the flocking season (SWIFFT 2021) (Figure 2).

Brolgas flock from December to June (Arnol et al 1984) and move between wetland roosts and feeding areas 30-40 minutes before sunrise and after sunset (Marchant and Higgins 1993). Flocks also use wetland roosts from late morning to late afternoon (Marchant & Higgins 1993, Veltheim 2018). Surveys were therefore conducted monthly from December 2020 to June 2021 and included dawn, midday and dusk observations each month. Dawn surveys began 30 minutes before first light and continued until an hour after sunrise, midday surveys were done in the middle of the day for one hour and dusk surveys began an hour before sunset and continued until 30 minutes after last light or until it was too dark to see.

Flocking season survey was undertaken on the private property at Mt Kincaid Road, Gorae West, located north of the Portland-Nelson Road and south of the Lower Glenelg National Park (Figure 4), after multiple observations of Brolgas during the Biosis threatened species and bird utilisation surveys and due to overlapping planned wind farm infrastructure at that location. The aim of the flocking season surveys was to determine if this location was used by Brolga flocks (>10 individuals) and whether it would meet the DSE (2012) flock roost site criteria (Table 1) and be subject to flock roost turbine-free buffer.

4.1.7 Remote nest camera

A potential Brolga nest was found in June 2021, during the flocking season surveys. Two Reconyx white-flash remote cameras were deployed at the nest site 5 July–13 August 2021.

4.1.8 Additional targeted habitat assessment (2021)

Biosis undertook a further, detailed habitat assessment in the paddocks surrounding DEECA-mapped wetlands along Mt Kincaid Rd, Gorae West in October 2021. The survey team walked through the paddocks, documented wetland presence and assessed their suitability as Brolga breeding habitat.

4.1.9 Follow up targeted breeding season survey (2021)

A follow up survey of breeding pairs in the Mt Kincaid Rd, Gorae West nesting sites was conducted in November 2021, to record progress and status of pairs, nests, eggs and chicks.

4.2 Limitations

Brolga occurrence and habitat use can change daily, seasonally and annually. The species' roosting and foraging behaviour requires searching of wetlands and surrounding habitats at appropriate times of the day and year to record presence. Absence at suitable wetlands does not necessarily equate to absence of the species, particularly when surveys cover a single season or year and if suitable habitats are not surveyed repeatedly at different times of the day to capture roosting, foraging and breeding habitat, and movements between them. A variety of survey techniques and knowledge of the species' behaviour are required to increase confidence of likely presence in any given area, in wetland and non-wetland habitats.

Biosis employed a number of field survey techniques within 3–5 kilometres of the Project area, in 2020, with further targeted surveys in 2021 in areas of high activity. Survey efforts were focused on known and likely suitable habitat locations and the combined effort from the Brolga and other biodiversity surveys has provided a comprehensive and detailed understanding of known and likely Brolga use within 3–5 kilometres of the Project area where the species is most likely to be affected by the proposed wind farm and where habitat buffers would be needed to reduce potential impacts.

Due to lack of access to some private properties, which may have potential Brolga habitat, the presence of Brolgas and suitable habitat may have been missed. The aerial survey provides coverage of such areas though a single-season survey is unlikely to capture all likely breeding sites, as shown by further discoveries of breeding wetland through ground-based field surveys in the year after aerial surveys were conducted.

Limited field survey effort was undertaken in the agricultural area in the eastern part of the Project area, between the Boiler Swamp Road and the Heywood terminal, apart from roadside inspections. It is possible suitable habitat and records within this area were not completely captured. Community consultation and discussions with a local ornithologist were used to further understand presence of Brolgas and their habitat in this area.

Neoen community consultation covered communities within the 10 kilometre radius of investigation (including towns within 5–25 kilometres). Further consultation with a local ornithologist, Robert Farnes yielded additional breeding records. It is possible that some landholders with records were not in attendance at the community sessions and that some known or potential Brolga habitats are not captured by the Biosis Brolga assessment. However, a detailed understanding of occurrence and habitat use of Brolgas was obtained and given that Brolga breeding habitat within 3 kilometres of the Project area is limited to the agricultural area and Long Swamp and wetlands within the Discovery Bay Coastal Park it is likely that the great majority of suitable breeding habitat has been identified.

To account for the remaining uncertainty of suitable Brolga breeding wetland presence and the possibility of unaccounted potential breeding wetlands within 3 kilometres of the Project area, we have:

- Identified and mapped all wetlands found during the Biosis assessment, which were not included in the DEECA wetland layer.
- Undertaken a further desktop assessment of remaining wetlands to identify and map most likely suitable Brolga breeding wetlands not identified in the Level One and Level Two assessment – those included and not included in the DEECA wetland layer. We identified these wetlands using aerial photography interpretation, where wetland was clearly or most likely present based on:
  - Knowledge of other known Brolga breeding wetlands within 3 kilometres of the Project area.
  - Proximity to Brolga database records within known wetland to foraging area movement distance for breeding pairs and adults (Veltheim et al. 2019; Veltheim et al 2022).
  - Size, based on known breeding (nesting) and roosting wetland size from the current surveys and Veltheim et al. 2019 and references therein.

This methodology, findings and implications to buffer development are detailed in Section 5.

No Brolga flocking roost sites have been recorded within 10 kilometres of the Project area. Based on the Level One and Level Two assessment results, knowledge of south-west Victorian flocking areas and flock roost wetlands from historically (White 1987; Sheldon 2004) and GPS tracking (Veltheim 2018) we consider it unlikely that flock roost sites as defined in the Brolga guidelines are present within 5 kilometres of the Project area.

4.3 Results (Existing conditions) – Brolga occurrence within the project area

The findings from Level One and Level Two assessments, incorporating data from databases, community and landholder discussions and Biosis field surveys are summarised in this section and shown in Figure 7 and describe the existing conditions for this species, relevant to the Project.

Further detail from each level of assessment is provided in the following sub-sections, and divided into:

- Breeding
- Flocking
- Flight paths

The summary is intended to provide background and context to brolga habitats, which are subject to turbine-free buffer areas, and the number of breeding pairs used to inform the collision risk modelling.

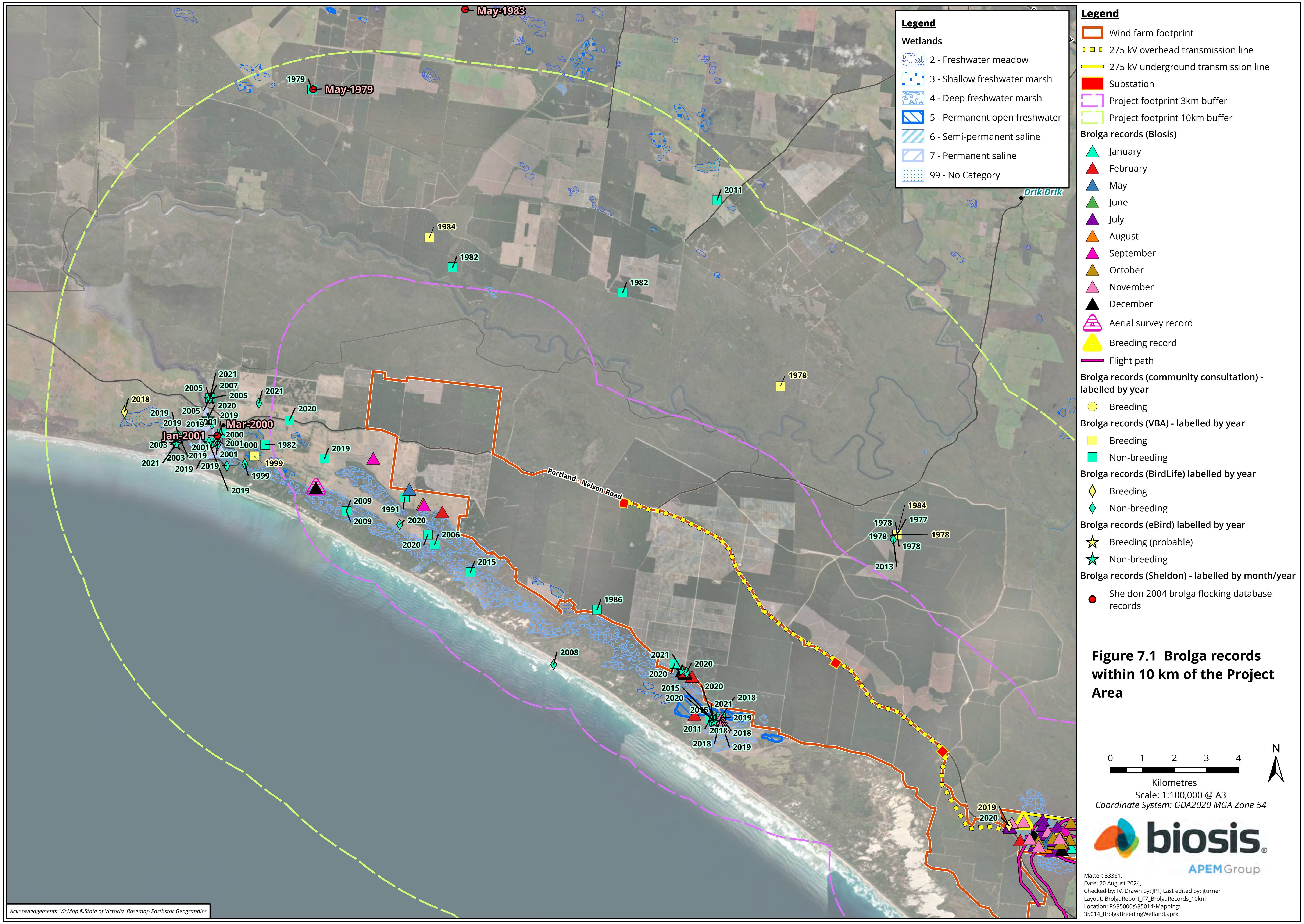

Figure 7.1 Brolga records within 10 km of the Project Area

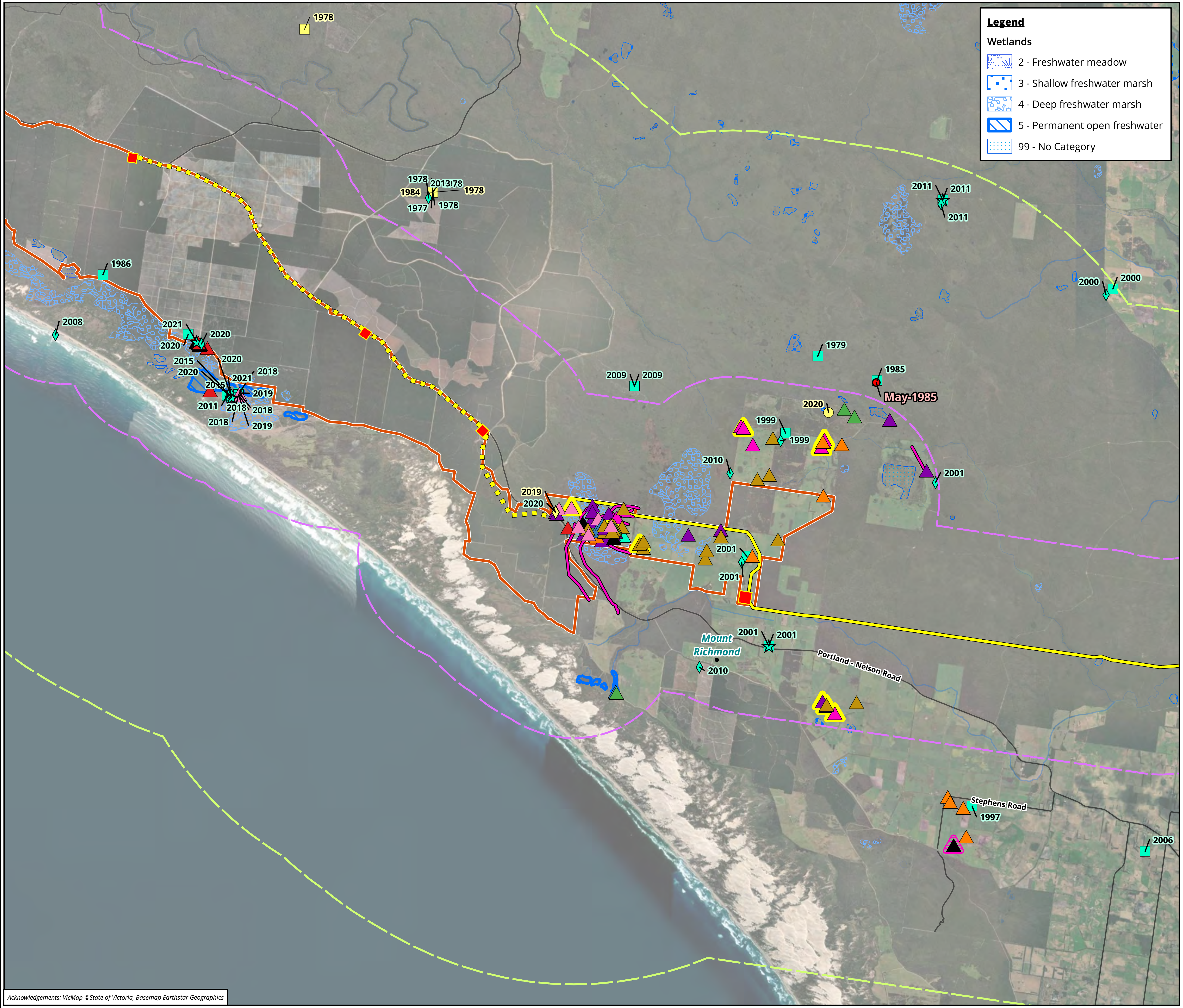

Figure 7.2 Brolga records within 10 km of the Project Area

biosis
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Matter: 33361,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
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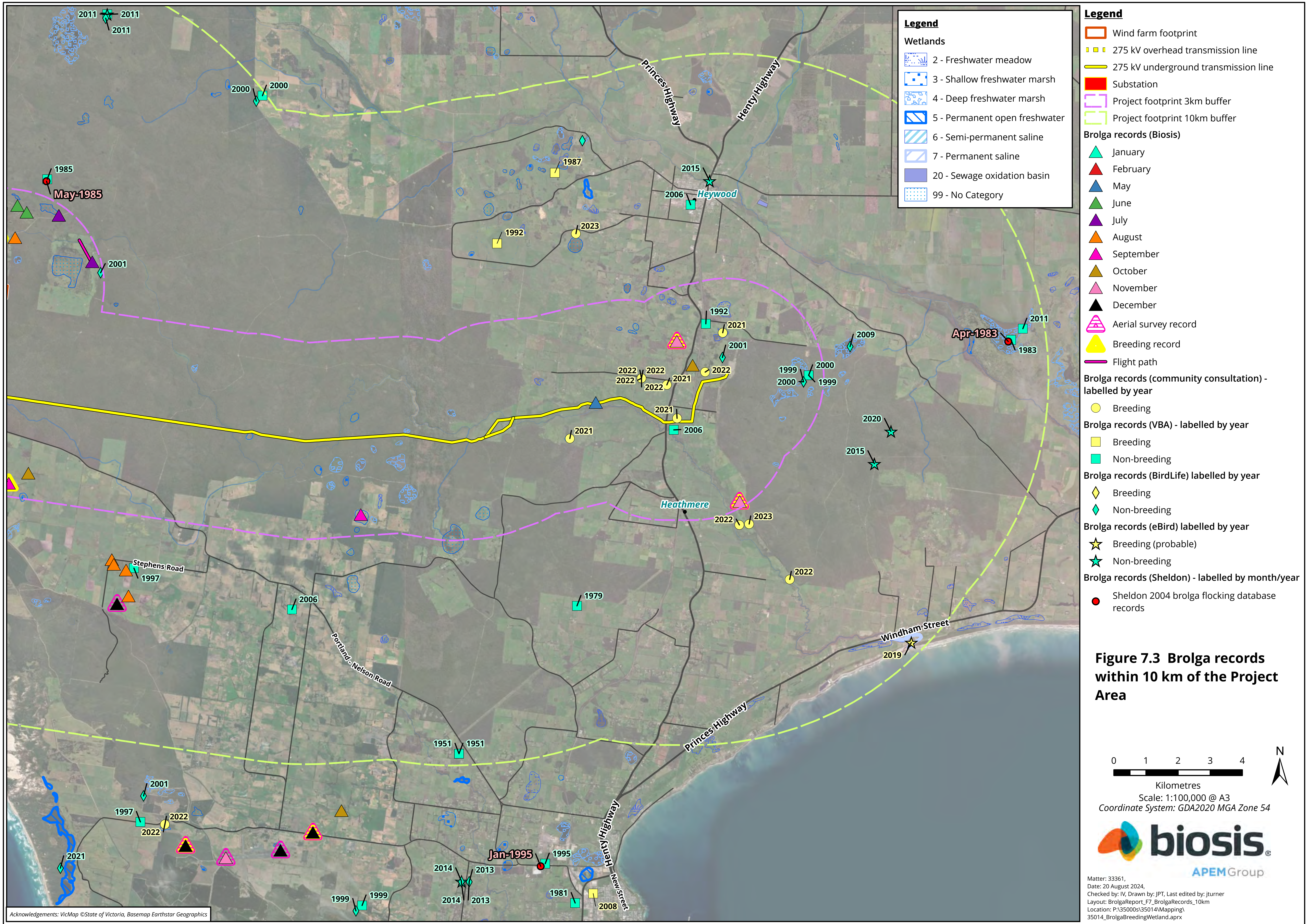


Figure 7.3 Brolga records within 10 km of the Project Area

4.3.1 Breeding

The Level One and Level Two assessments confirmed the presence of eleven (11) breeding pairs and identified the assumed presence of an additional three (3) pairs within 3 kilometres of the Project area (Figure 8). Two additional breeding records were added in 2023, after we obtained these from Robert Farnes.

Not all of these were confirmed breeding during the Biosis surveys. However, these pairs were assumed to be breeding pairs based on landholder and community member discussions, regular and frequent observations of adult pairs and pairs with juveniles during Biosis surveys or identified from database records (VBA, BirdLife BirdData, BirdLife Shorebird2020, eBird – multiple non-breeding and a single breeding record; see Table 4). We have also assumed the presence of a breeding pair between McFarlanes Swamp and Lake Mombeong near Nobles Rocks, due to extensive suitable habitat and as it is conceivable that a breeding pair could have a breeding territory at this location.

The breeding database record results within 3.2 km of the Project are listed below:

- VBA:
  - No breeding records.
- BirdLife Shorebird2020 data 2011–2022:
  - No breeding records.
- BirdLife BirdData:
  - One breeding record (Pair reference 4 in Table 4, Figure 8) with the following notes: "Recently fledged young; Adult pair with two well-grown, flighted but apparently dependent juveniles." Although a pair with fledged young can move away from their breeding territory, we have assumed this family group is likely to have a breeding territory near the record and have included it in the assessment. Additionally, a pair with flightless chicks was recorded during the Biosis surveys near this location (Table 4, Figure 8), which further supports the presence of a breeding site and territory.
- eBird:
  - No breeding records.

Confirmed and assumed breeding pairs were located at 16 locations (Table 4, Figure 8).

Table 4 Confirmed and assumed breeding sites within 3 kilometres of the Project area identified in the Level One and Level Two assessments.*

Pair reference number	Location	Status	Source of information
1	**McFarlanes Swamp/Long Swamp**	**Assumed** based on regular presence of a pair, and an observation of 3 individuals considered most likely to be a pair with a juvenile.	Database records (VBA, BirdLife, breeding activity not specified); Landholder conversations; Biosis BUS
2	**Nobles Rocks/Long Swamp**	**Assumed** based on extensive suitable habitat and database records within ~2 km (1986; 2015)	Nearby database records (VBA, BirdLife, breeding activity not specified); Visual habitat assessment during Biosis targeted surveys.
3	**Lake Mombeong/Long Swamp**	**Assumed** based on an observation of a pair with fledged young, and regular observations of a single individual.	Database records (VBA, BirdLife, eBird, breeding activity not specified); Biosis preliminary surveys 2018 and 2019; Biosis targeted surveys and BUS 2020.
4	**Gorae West 1 Cleared agricultural land in the far western end of Mt Kincaid Road**	**Confirmed** during Biosis surveys. **Pair, nest, eggs (**Plate 1**,** Plate 2**)**	Biosis 2021 additional surveys; nest found in June 2021 during flocking season surveys, remote camera confirmed brolga breeding activity. Nest under water in August 2021, nest relocated and with two eggs in October 2021, nest abandoned and empty, new nest in a different wetland with one egg in November 2021. BirdData record from 2019 also suggests a nest site present, with an observation of recently fledged young; adult pair with two well-grown but apparently flighted dependent juveniles.
5	**Gorae West 2 Cleared agricultural land in the western end of Mt Kincaid Road**	**Confirmed** during Biosis surveys. **Pair, nest, eggs** (Plate 3)	Biosis 2021 additional surveys; nest with two eggs found in October 2021, nest with two eggs still present November 2021.
6	**Gorae West 3 Cleared agricultural land in the western end of Mt Kincaid Road**	**Confirmed** during Biosis surveys. **Pair with two unfledged chicks**	Biosis 2021 additional surveys; Pair with two chicks 6-8 weeks old found in November 2021.
7	**Kentbruck Settlement Road corner of Blacks Road, breeding site assumed to be within Blue Gum plantation**	**Confirmed** during Biosis surveys. **Pair with two unfledged chicks** (Plate 4)	Biosis targeted breeding season surveys 2020. Breeding pair with two chicks approximately 2-3 weeks old. Historical breeding site within Blue Gum plantation, obtained through community consultation (local ornithologist).

Pair reference number	Location	Status	Source of information
8	**Martins Lane**	**Confirmed** during Biosis surveys **Pair with two unfledged chicks**	Biosis targeted breeding season surveys 2020.
9	**Heywood 1** Heywood Bushland Reserve	**Confirmed** during Biosis surveys. **Pair with 2 juveniles (2020 breeding season chicks)**	Biosis aerial surveys 2020. 2 adults and 2 juveniles (2020 breeding season chicks).
10	**Heywood 2** Coffeys Lane/Princes Hwy	**Confirmed** through community consultation	Community consultation (local ornithologist).
11	**Heywood 3** Golf Course Road	**Confirmed** through community consultation	Community consultation (local ornithologist).
12	**Heathmere 1** Surrey River flats	**Confirmed** during Biosis surveys. **Pair with 1 chick**	Biosis aerial surveys 2020. 2 adults and 1 chick at foot (2020 breeding season chick).
13	**Heathmere 2** Jarretts Road	**Confirmed** through community consultation	Community consultation (local ornithologist).
14	**Heathmere 3** Meaghers Road	**Confirmed** through community consultation	Community consultation (local ornithologist).
15	**Heywood 4** Coffeys Lane	**Confirmed** through community consultation	Community consultation (local ornithologist).
15	**Heywood 5** Between Princes Hwy and Rifle Range Rd	**Confirmed** through community consultation	Community consultation (local ornithologist).

*Outside of the 3 kilometre Project area radius an additional two pairs each with a single chick were also recorded east and west of the Portland airport during aerial surveys. A breeding site is likely to also be present near Mt Richmond (corner Hanns and Stephens Rd), where two adults and 2 first-year juveniles (2019 breeding season chicks) were recorded during Biosis surveys.

Plate 1 Brolga pair 4 on a nest 9 July 2021, recorded on a remote camera. This wetland is not mapped in the DEECA current wetland layer, but is immediately adjacent to the eastern boundary of wetland 20522 (Figure 8).

Plate 2 Brolga nest in a new location wetland of pair 4 with breeding pair observed on approach, 27 October 2021. The pair built a new nest in the same wetland after the first nest was flooded (nest observed under water 13 August 2021).

Plate 3 Pair 5 Brolga nest with two eggs, recorded on 20 November 2021, in an umapped wetland between DEECA mapped wetland ID 20522 and wetland ID 20532. Pair observed on approach to the wetland.

Plate 4 Brolga pair 7 with two 1-2 week old chicks walking west along Kentbruck-Settlement Road, near the corner of Blacks Road.

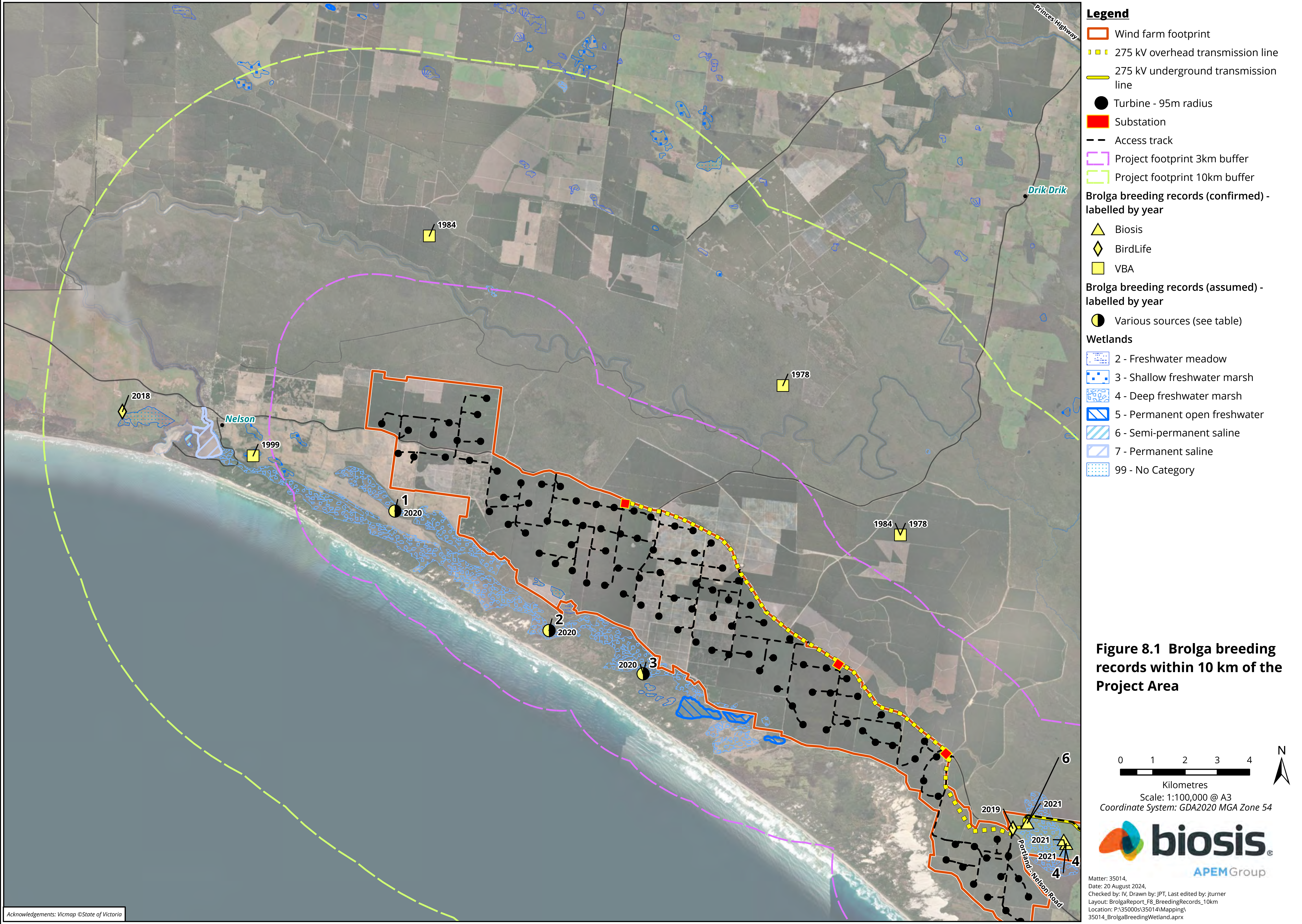


Figure 8.1 Brolga breeding records within 10 km of the Project Area

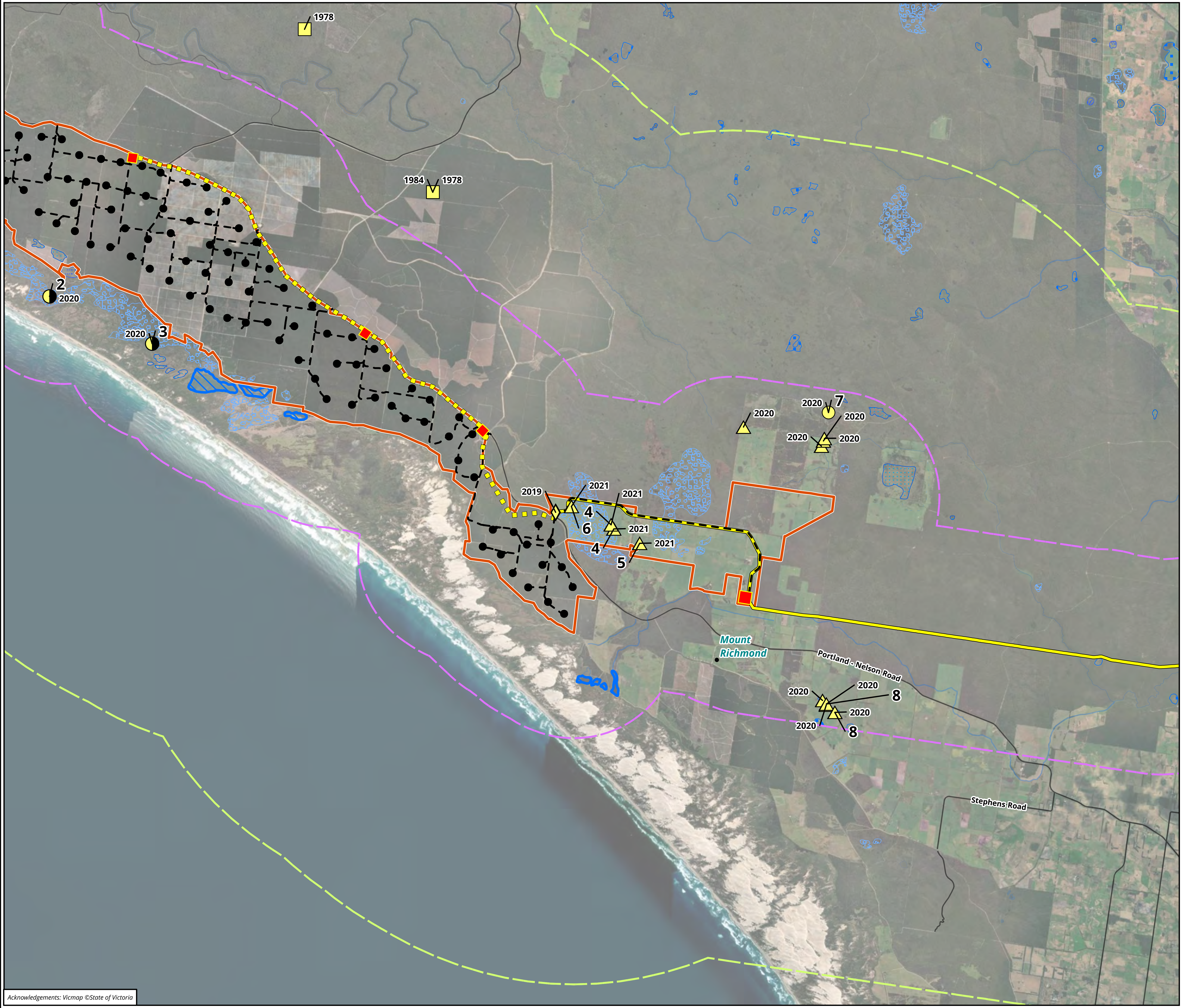


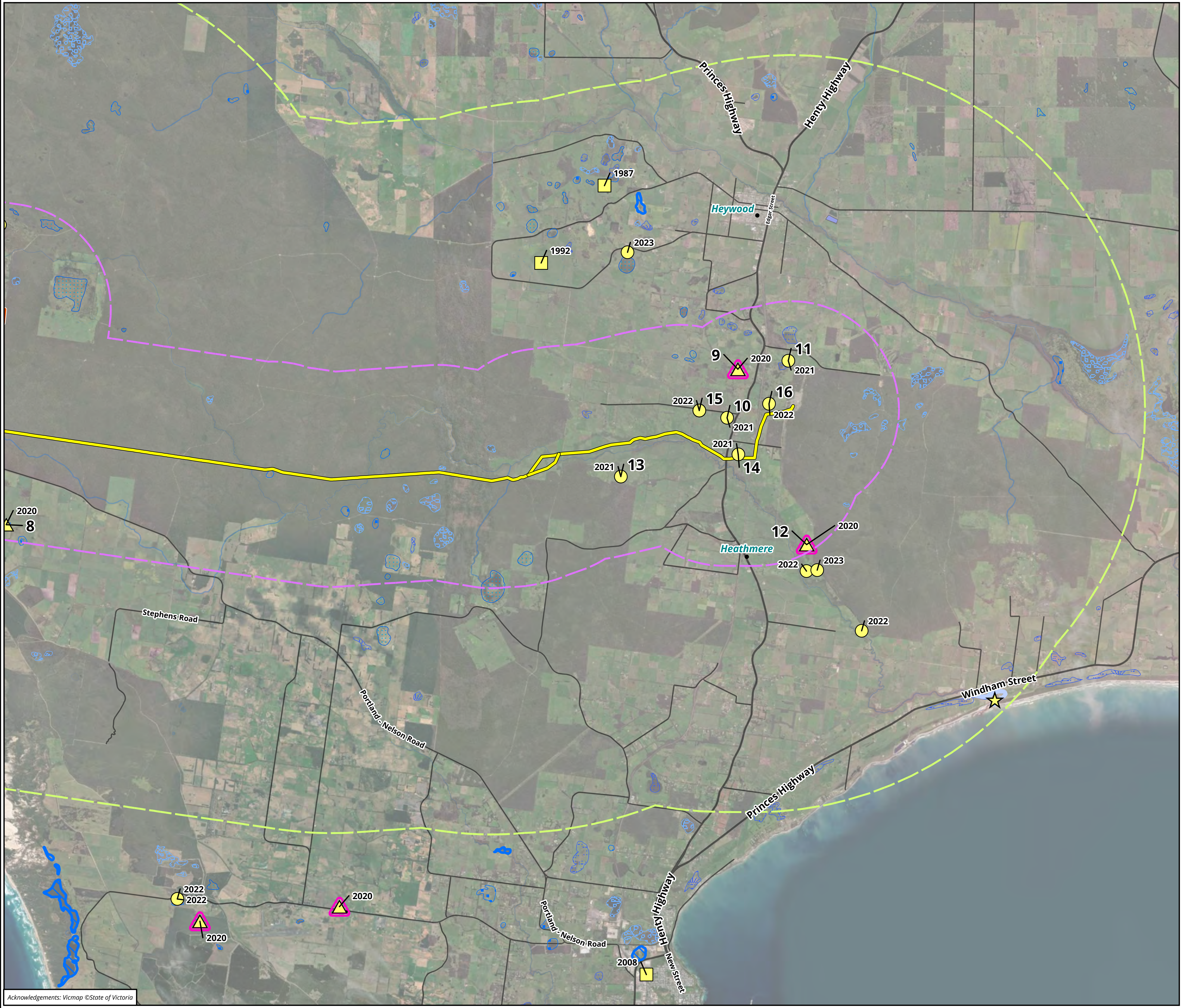
Figure 8.2 Brolga breeding records within 10 km of the Project Area

Scale: 1:100,000 @ A3

Coordinate System: GDA2020 MGA Zone 54

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_F8_BreedingRecords_10km
Location: P:\35000s\35014\Mapping\
35014_BrolgaBreedingWetland.aprx

Acknowledgements: Vicmap ©State of Victoria



Legend

Wind farm footprint
275 kV overhead transmission line
275 kV underground transmission line
Turbine - 95m radius
Substation
Access track
Project footprint 3km buffer
Project footprint 10km buffer

Brolga breeding records (confirmed) - labelled by year

Biosis
Biosis aerial survey record
eBird
VBA
Community consultation

Wetlands

2 - Freshwater meadow
3 - Shallow freshwater marsh
4 - Deep freshwater marsh
5 - Permanent open freshwater
6 - Semi-permanent saline
7 - Permanent saline
20 - Sewage oxidation basin
99 - No Category

Figure 8.3 Brolga breeding records within 10 km of the Project Area

0 1 2 3 4
Kilometres
Scale: 1:100,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

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APEM Group

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_F8_BreedingRecords_10km
Location: P:\35000s\35014\Mapping\
35014_BrolgaBreedingWetland.aprx

4.3.2 Flocking

No flock roost sites (see Table 1 for definition) were identified in the Level One or Level Two assessments. The nearest known flocking area to the Kentbruck Green Power Hub – Strathdownie (Kaladbro/Mingbool) – is approximately 50 to 70 kilometres north/north-west of the Project area (Figure 9), and can support up to 300 individuals annually during the flocking season (SWIFFT 2021). The next nearest site is Penshurst, approximately 100 kilometres north-east of the Project area and regularly holds some 200 individuals (SWIFFT 2021) (Figure 2). The Sheldon flocking database (2004) has five records within 10 kilometres of the Project area (Figure 9). None of these is a known flocking area (DELWP 2020), none has records of >10 Brolga from multiple months or years, or fit the flock roost site criteria (Table 1).

Table 5 Records in the Sheldon (2004) flocking database – none of these wetlands meets the flock roost site definition (see Table 1)

Flocking database ID	Number of individuals	Latitude	Longitude	Date	Wetland name	Location
182	2	-37.9583	141.042	1979 May	Unknown	4km south of Munbannar
233	3	-38.175	141.736	1983 April	Homerton Swamp	10.5km southeast of Heywood, north of the Fitzroy River
256	2	-38.1317	141.394	1985 May	Unknown	8.5km northeast of Mount Richmond. Settlement Road, Lower Glenelg National Park
1003	0	-38.0558	141.008	2000 March	OXBOW LAKE	South of Nelson
1060	0	-38.0558	141.008	2001 January	OXBOW LAKE	South of Nelson

The largest group recorded during the Biosis Level Two assessments was nine (9) individuals foraging in the western paddock of the Mt Kincaid Road cleared agricultural land, at the eastern part of the Project area. Another two (2) individuals were recorded simultaneously, approximately three kilometres east on the same property (Figure 7 Brolga records within 10 km of the Project). A single individual appeared to roost in a wetland in the western paddock, and a family group (2 adults, 2 juveniles) roosted at Swan Lake. However, no flocks (>10 individuals) used any of the assessed wetlands for nocturnal roosting and the pairs, family groups and individuals flew into this paddock as separate groups from different directions indicating they were not engaging in flocking behaviour. The wetlands within the Project area and a 10 kilometre radius around it do not meet any of the flock roost site criteria (Table 1, DSE 2012), based on existing database records and Biosis field survey findings.

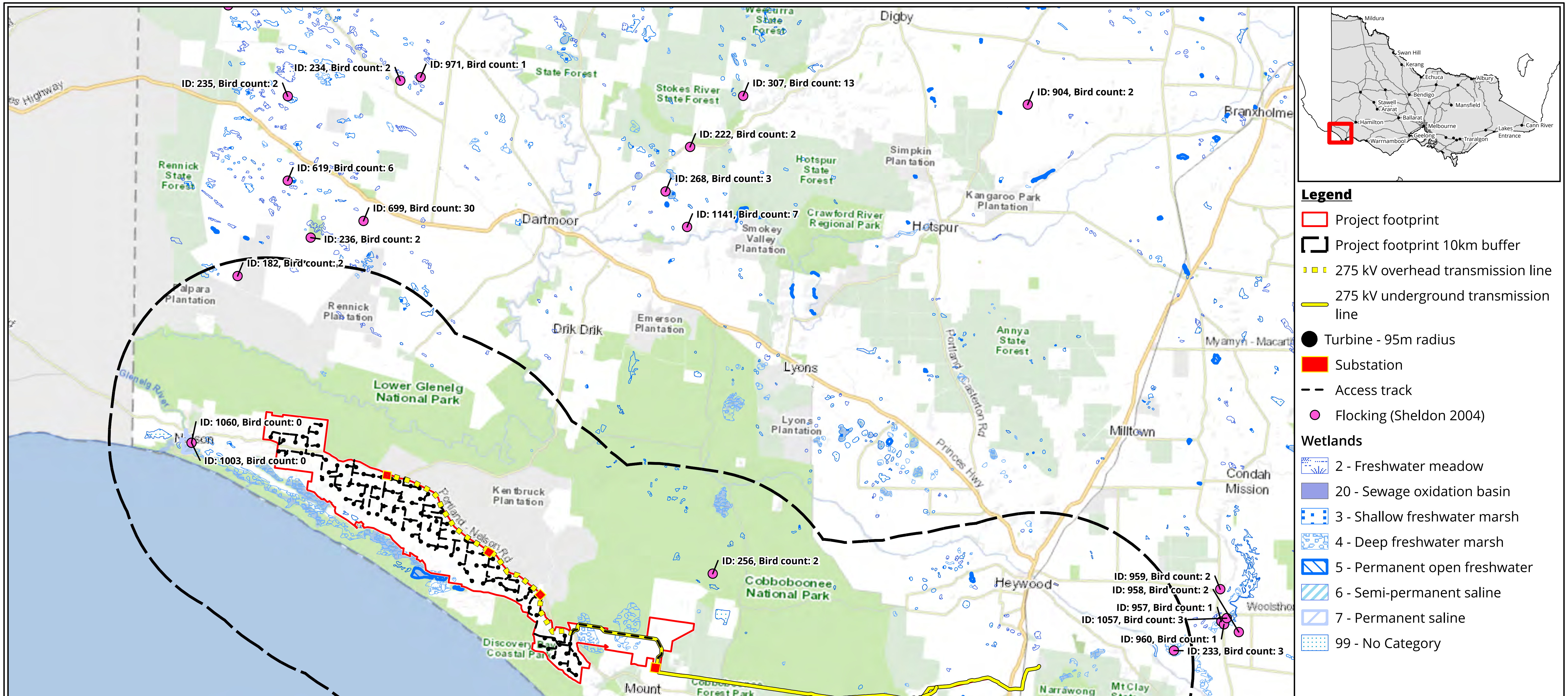


Figure 9 Brolga flocking database records within 10 km of the Project Area

Scale: 1:250,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

biosis
APEM Group

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_F9_FlockingRecords_10km
Location: P:\35000s\35014\Mapping\
35014_BrolgaBreedingWetland.aprx

4.3.3 Roosting

One roosting wetland was found, with an adult pair with two young flying between the western paddock of the Mt Kincaid Road and Swan Lake (Figure 10). Further targeted surveys found the family roosting at night at Swan Lake.

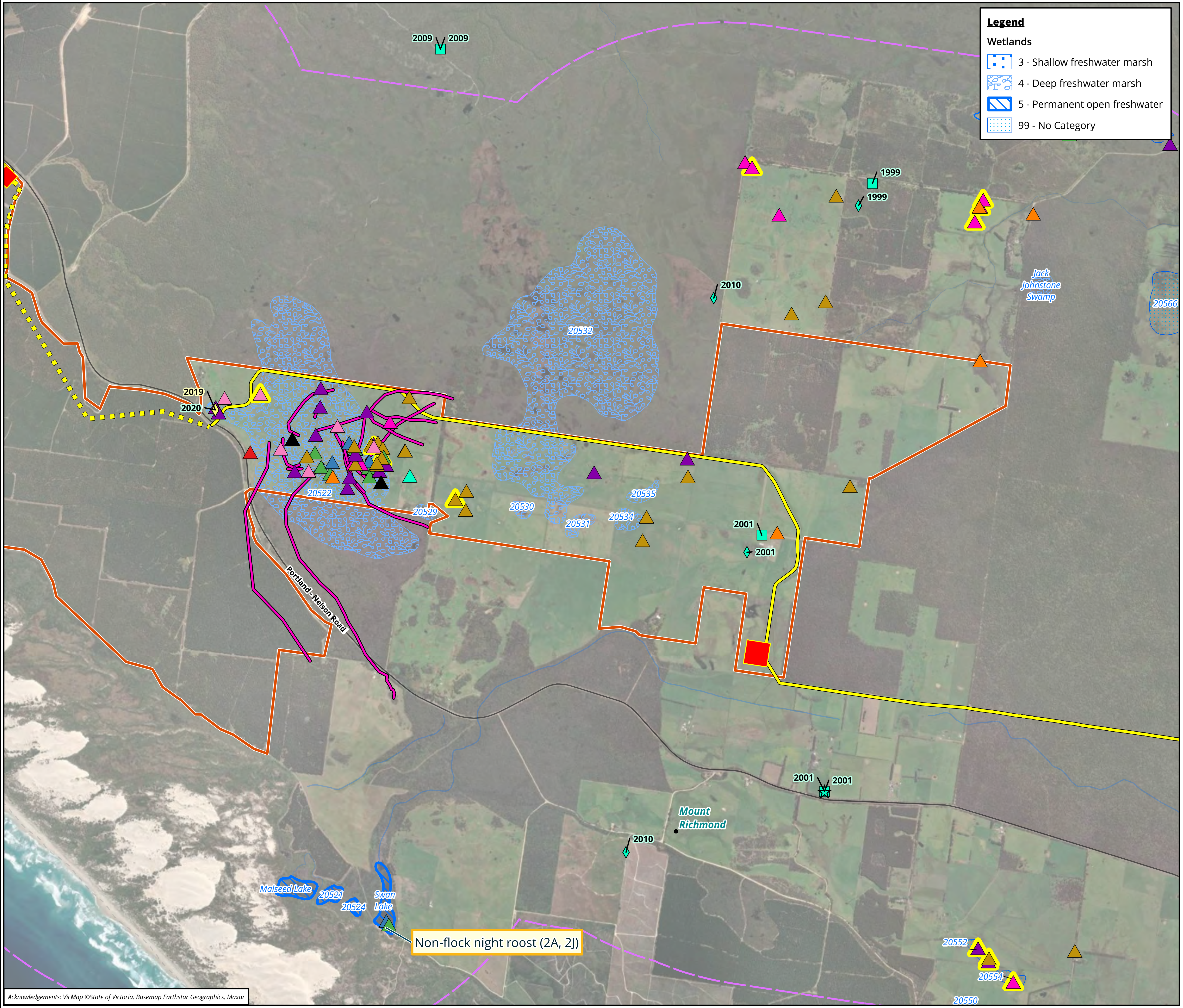
4.3.4 Flight paths

Biosis recorded flight observations from:

- Western part of the site, near Johnson's Road – pair (2 adults) soaring at 70 metres, flying south/south-west to north-east.
- Lake Mombeong – group of three flying east to west over the lake.
- Cleared paddocks around Mt Kincaid Rd, Gorae West – family group of four (2 adults, 2 juveniles) flightpath south-east to Swan Lake roost; individuals and pairs flying east-west and west-east at dusk and dawn; numerous flights throughout the day within the paddocks.

These are shown in Figure 7 and Figure 10.

The landholder at Mt Kincaid Rd, Gorae West reported that Brolgas fly to the property from south and south-west (27 October 2021). The landholder also reported Brolgas fly towards north and north-east from the eastern part of the property, through the cleared paddocks of the adjacent property towards the north. The adjacent landholder (north of Mt Kincaid Rd, west of Blacks Road, Gorae West) did not report Brolga sightings, but indicated they would not know how to identify the species.



Legend

- Wind farm footprint
- 275 kV overhead transmission line
- 275 kV underground transmission line
- Substation
- Project footprint 3km buffer
- Project footprint 10km buffer

Brolga records (Biosis)

- January
- February
- May
- June
- July
- August
- September
- October
- November
- December
- Breeding record
- Flight path

Brolga records (community consultation) - labelled by year

- Breeding

Brolga records (VBA) - labelled by year

- Breeding
- Non-breeding

Brolga records (BirdLife) labelled by year

- Breeding
- Non-breeding

Brolga records (eBird) labelled by year

- Breeding (probable)
- Non-breeding

Brolga records (Sheldon) - labelled by month/year

- Sheldon 2004 brolga flocking database records

Figure 10 Non-flock night roost

0 500 1,000 1,500

Metes

Scale: 1:35,000 @ A3

Coordinate System: GDA2020 MGA Zone 54

Matter: 33361,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_F10_NonFlockNightRoost_F7basemap
Location: P:\35000s\35014\Mapping\
35014_BrolgaBreedingWetland.aprx

5 Level Three Assessment

5.1 Introduction

The Level Three assessment objective is to avoid significant impacts on Brolga breeding and non-breeding habitat through design response and siting turbines away from these habitats, and to quantify residual risk. The project meets the Level Three Assessment trigger:

- Qualitative risk assessment (AusWEA 2005) of project following site design is greater than "low".

The Level Three Brolga assessment methodology requires a four-step approach as per the Brolga guidelines (DSE 2012):

- **Step One**: Avoid or mitigate all potential impacts to Brolga breeding and flocking home ranges within the radius of investigation with turbine-free buffer areas.
- **Step Two**: Develop a site-specific collision risk model for Brolgas utilising or moving through the radius of investigation.
- **Step Three**: Use PVA to estimate the impact of the proposed development.
- **Step Four**: Identify appropriate compensation strategies to ensure a zero net impact on the Victorian Brolga population.

5.2 Step One: avoid and mitigate potential impacts with turbine-free buffers

5.2.1 Data, information and justifications used in buffering methodology

The data used in habitat buffers is described in Section 4.3 and shown in the figures described in that section.

The Brolga guidelines (DSE 2012) provide the following guidance on methods for siting turbines away from breeding and non-breeding home ranges:

- Avoid the Brolga breeding home range (identified in the Level Two Assessment or use the generic guideline of 3.2 km).
- Avoid the Brolga non-breeding home range (identified in the Level Two Assessment or use the generic guideline of 5 km).
- Avoid an additional 300 m radius around each home range to avoid disturbance effects.

No non-breeding flocking roost sites, as defined in the Brolga guidelines (DSE 2012) (Section 1.3.2, Table 1), were identified during Level Two assessments and there are thus no flock roost home ranges required to be avoided by the Project.

A nocturnal roost site used by a family was found at Swan Lake (Figure 10). The Brolga guidelines do not provide guidance on avoiding potential impacts on non-flocking roost sites. We have applied a buffer around this wetland using current knowledge on Brolga behaviour and movements between roost and foraging habitat (Veltheim et al. 2022). Breeding sites were identified during Level Two assessments and incorporating turbine-free buffers into the design, aimed at avoidance of breeding home ranges, are applicable.

The guidelines recommend that the proponent should meet with DEECA to discuss turbine-free buffer design and for advice on considering the latest understanding on Brolga behaviour. If site-specific buffer distances are proposed, they should be agreed to by DEECA.

The general recommendation in the guidelines for proposing site-specific buffers is to collect site-based data on the location of breeding pairs, their nesting wetland and chicks. These data are aimed at collecting data to estimate Brolga breeding home range. Previous observational studies clearly demonstrate the challenge of collecting sufficient data for robust home range estimation, due to breeding success failures or breeding site abandonment. The result is generally an underestimation of this home range (Veltheim et al. 2019). Furthermore, Brolgas are generally wary and sensitive to disturbance, particularly when nesting and with young unfledged chicks, as eggs and chicks are most vulnerable to predation. Observational studies to collect site-specific data can potentially increase nest and chick predation and bias location data, and home range estimates.

More recent work using GPS-tracking of unfledged chicks collected data at a number of breeding territories in south-west Victoria, improving the knowledge of habitat requirements and home range of breeding Brolgas (Veltheim et al. 2019). Findings from this study can be applied more generally to understand likely extent of Brolga breeding home ranges by using the principles of movement and habitat use from the tracking results. This approach is thus far more preferable for deriving turbine-free buffers around breeding sites, given the more general applicability of this study findings, field observational studies' major limitations in collecting comparable data, and risk of potentially reducing Brolga breeding success.

The Project has developed and applied site-specific turbine-free buffers. Specific to the Project, it was clear that collecting a sufficient amount of site-based data for home range estimation and undertaking studies without disturbance was not possible, for the following reasons:

- In 2020, Biosis found one breeding pair with chicks using the Project area (Pair 7; Table 4; Figure 8). This pair was believed to have had a nest within the blue gum plantation, just outside of the Project footprint in the north-east part of the investigation area. Subsequent efforts to find the nest were unsuccessful, although the pair with chick/s was recorded several times within the Project area and outside of the blue gum plantation. These site-based data contributed to identifying the most likely extent of the pair's breeding home range, and the turbine-free buffer. It should be noted that through layout design changes, although this pair was initially within the proposed Project area, the observations are now outside of it (see Figure 8).
- In 2021, Biosis found three breeding pairs in the cleared agricultural land at t Kincaid Road, Gorae West (Pair 4, Pair 5, Pair 6; Table 4; Figure 8). Observing pairs without disturbance was difficult due to the linear nature of access points and the location of the nests. Additionally, while observing one pair with nest at a distance of about 400 metres, a second pair with two chicks was observed running > 1 kilometre away in the distance and clearly disturbed by the observer presence.

An additional reason for not collecting repeated observations for site-based data, particularly given the likelihood of disturbance and human presence thus biasing location data was:

- Home ranges derived from site based visual observations may underestimate the actual site use and home range size of breeding brolgas (Veltheim et al. 2019). This is mainly related to the much less frequent location data collection compared to tracking data and the possibility of not locating the pair and chicks on some occasions (Veltheim et al. 2019).

The decision was thus made not collect further data on the breeding pairs at Mt Kincaid Road, Gorae West in 2021, and instead use the small amount of site-based data on breeding pairs, nest locations and apply the knowledge of Brolga movement patterns at breeding sites, breeding home ranges and adult movements, to derive turbine-free buffer areas (Veltheim et al. 2019, Veltheim et al. 2022).

Two meetings in 2021 between Neoen, Umwelt, Biosis and DEECA were held to discuss this approach and to seek agreement from DEECA, as is required through the Brolga guidelines Level Three Assessment methodology (DSE 2012). Through these discussions, DEECA provided in-principle support for using the latest science and information on brolga breeding ecology. In response to comments to the draft KGPH EES Brolga impact assessment report (dated 8 February 2022), DEECA Barwon South West (BSW) acknowledged the difficulties in collecting site-based data, as outlined in this section. Additionally, DEECA BSW stated they support using the latest science and research in determining appropriate turbine free buffers. DEECA Barwon South West has indicated through the TRG process that the site-specific buffers proposed for this project appear to respond well to the objectives described in the Brolga guidelines (DSE 2012).

5.2.2 Project buffering in relation to Brolga guidelines

The Brolga guidelines recommend implementation of turbine-free buffers to avoid potential wind farm-related impacts on Brolga breeding and non-breeding habitats and an additional 300 metre buffer to avoid disturbance effects. The objectives are set out in the Brolga guidelines for both (p.8, DSE 2012):

Breeding habitat

> *"In the case of breeding habitat "turbine siting would be used to exclude any significant reduction in breeding success caused by turbines" (Brolga Scientific Panel 2008). This will be achieved by establishing turbine-free areas around all potential Brolga nesting sites sufficient to have no significant impact on the likelihood of successful reproduction."*

Non-breeding habitat

> *"At non-breeding or flocking sites, turbine-free buffers should be designed to exclude any significant impact on the survivorship of Brolgas whilst occupying that flocking site."*

In line with the Brolga guidelines objectives, The Project has applied turbine- and transmission line-free habitat buffers for:

- **Breeding sites – known, records**: wetlands with nest or chick observations.
  - This is in line with requirements of the Brolga guidelines to protect and define such sites as:

    "The nest of a Brolga breeding pair and the perimeter of the surrounding wetland. Also includes wetlands with previous records of Brolga nests from any relevant information source."

- **Breeding sites – suitable, no records:** wetlands assessed on-ground (field assessments) or using aerial photography interpretation with no known Brolga breeding observations.
  - This is not required in the Brolga guidelines. However, given the knowledge on Brolga ecology, including the Project site assessments and published information (including Veltheim et al. 2019) it was deemed likely that a number of wetlands with no Brolga records could support breeding Brolgas, demonstrated by additional assessments where breeding was confirmed in wetlands with no historical records. Habitat buffers were applied to wetlands assessed as most likely to meet this criteria.

- **Non-flock roost site – known, records**: wetland with nocturnal roosting observations of a Brolga family (2 adults, 2 juveniles).
  - The Brolga guidelines provide no definition or guidance on methods for identifying. or applying habitat buffers around non-flocking roost sites. We identified one non-flocking roost (Swan Lake) and applied a habitat buffer around it to meet the Brolga guidelines objective for flock roost sites of excluding any significant impact on the survivorship of Brolga whilst occupying an identified roost site.

- **Non-flock foraging site – known, records**: agricultural area with foraging observations of non-flocking Brolga (9 birds in total observed simultaneously).
  - The Brolga guidelines provide no definition or guidance on methods for identifying. or applying habitat buffers around non-flocking foraging sites. We identified one non-flock foraging site, which is fully incorporated within the breeding buffers.

The Project assessment did not identify any presence of flock roost sites and known flocking areas are 50–100 kilometres from the Project area. Therefore flock roost habitat buffers do not apply to the Project.

The Brolga guidelines do not explicitly specify requirements for turbine-free movement corridors or buffers around habitats that do not fall within the breeding and flock roost site definitions (e.g. a non-flock roost site) as discussed above. However, it is strongly advisable to mitigate for potential wind farm impacts in such areas where frequent Brolga activity occurs. Additionally, the Brolga guidelines only require proponents to locate buffers around known habitat where Brolga observations exist – identified through database searches or field studies. The Project has taken an approach to apply habitat buffers to all identified known and suitable breeding wetlands, a non-flocking night roost and along movement corridors. This has been undertaken to achieve the Brolga guidelines objectives avoid and minimise significant impacts to breeding and non-breeding Brolga throughout the Project area where the species does or is most likely to occur.

This approach to decisions on habitat buffer locations is described in further detail below, demonstrating alignment with Brolga guidelines requirements.

5.2.3 Locations for habitat buffers

Breeding sites – known, records

Applying breeding habitat buffers in line with the Brolga guidelines requires buffers around the six wetlands where Brolga breeding activity was recorded. The Brolga guidelines also state that new powerlines in turbine-free buffer zones should generally be excluded or placed underground. The Project has applied design changes responsive to the assessment findings. Neoen has updated the layout to replace the previous overhead section of the transmission line from Boiler Swamp Road to the Heywood terminal with an underground transmission line.

Turbine- and powerline-free buffers have been applied to the locations listed below, where turbines and powerlines overlapped with known Brolga habitat, areas of frequent Brolga activity and habitat most suitable for breeding (Figure 9).

- Wetland within a blue gum plantation in the north-east part of the project area. A pair with chicks was observed a number of times during the 2020 surveys at Kentbruck-Settlement Road and adjacent paddocks (Pair 7; Table 4; Figure 8).
- Three wetlands on private property at the western end of Mt Kincaid Road, Gorae West (Pair 4, Pair 5, Pair 6; Table 4; Figure 8).
- Two wetlands on private property near Heywood (Pair 15 and Pair 16; Table 4; Figure 8).

Breeding sites – suitable, no records:

The Project area contains suitable breeding habitat along Long Swamp and associated wetlands. No breeding records exist for these wetlands, but the habitat is suitable for supporting breeding Brolgas, and frequent activity was recorded around Lake Mombeong suggesting a breeding pair is present (Section 4.3.1).

To account for the remaining uncertainty of suitable Brolga breeding wetland presence and the possibility of unaccounted potential breeding wetlands within 3 kilometres of the Project area, we have:

- Identified and mapped all wetlands found during the Biosis assessment, which are not mapped in the DEECA wetland layer.
- Undertaken a further desktop assessment of remaining wetlands to identify and map most likely suitable Brolga breeding wetlands not identified in the Level One and Level Two assessment – those included and not included in the DEECA wetland layer. We identified these wetlands using aerial photography interpretation and the DEECA VicMap Hydro layer, where a suitable breeding wetland was clearly or most likely present based on:
  - Knowledge of other known Brolga breeding wetlands within 3 kilometres of the Project area.
  - Likely presence of water and similar to other known breeding wetlands, based on aerial imagery.
  - Proximity to Brolga database records, within known wetland to foraging area movement distance for breeding pairs and adults (Veltheim et al. 2019; Veltheim et al 2022).
  - Size, based on known breeding (nesting) and roosting wetland size from the current surveys and Veltheim et al. 2019 and references therein.
  - Knowledge of wetland suitability for breeding brolgas from published literature.

Turbine- and powerline-free buffers have been applied to the locations listed below (Figure 11), where turbines and powerlines overlap with most likely habitat to support breeding.

Suitable habitat with likely breeding activity, not recorded on databases or field surveys:

- Long Swamp and wetlands within its proximity.

Suitable habitat, breeding not recorded on databases or field surveys:

- Within 3 kilometres of the Project area, based on aerial photography interpretation.

Non-flock roost site – known, records

Non-flock roost site:

- Identified at Swan Lake during field surveys – family group of two adults and two juveniles.

Non-flock foraging site – known, records

A number of Brolgas used the paddocks at the western end of Mt Kincaid Road, Gorae West in January–February and May–December. The highest number recorded at any one time was nine Brolgas in the western and two at the eastern part of the property (Section 4.3.2). These included pairs and individuals foraging and moving independently, i.e. not in a cohesive flock. These Brolgas roosted away from the paddocks they foraged in. This area represents non-flocking foraging habitat. The Brolga guidelines provide no guidance or requirements on buffering non-flocking foraging habitat, where the birds roost away from such a foraging area. Brolga locations, foraging areas and flights of these individuals (Figure 8) are incorporated in breeding habitat buffers (Figure 11 - see 11.2) and thus the overall objectives of the Brolga guidelines for avoiding significant impacts through turbine-free buffering is achieved within this area.

Movement corridors

Frequent flights and foraging movements were recorded in the cleared agricultural land at Mt Kincaid Road, Gorae West. Movement corridors have been applied within the Project area to allow for barrier-free movement between foraging and roosting habitats, where these movement corridors were identified during field studies (4.3.4).

Movement corridors were identified during the field investigations (walking, foraging, flying individuals):

- Between paddocks in the western end of Mt Kincaid Road, Gorae West.
- East-west along the northern edge of the paddocks in the western and eastern end of Mt Kincaid Road, Gorae West within private property.
- Kentbruck Settlement Road between Blacks Road and the end of Kentbruck Settlement Road.

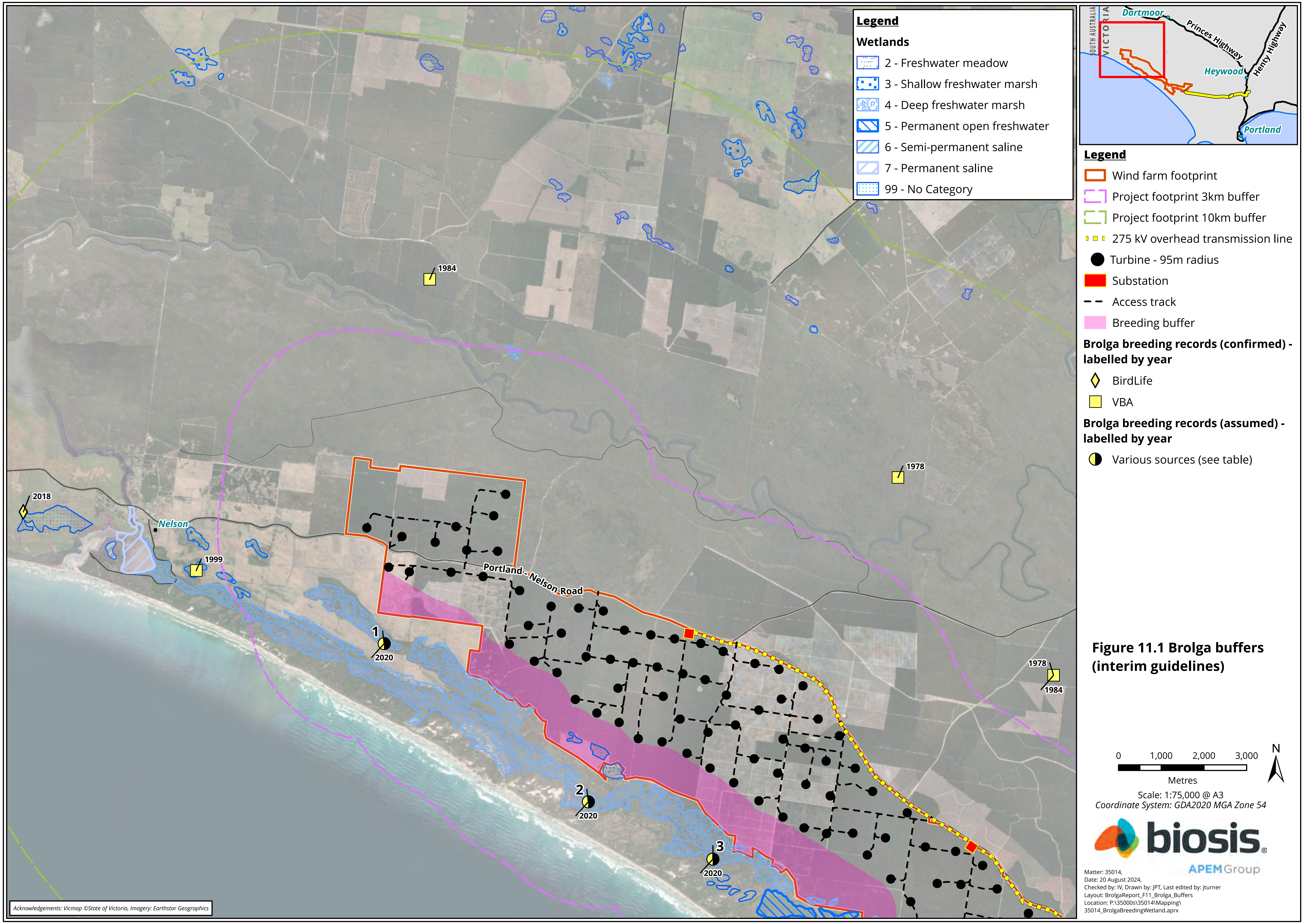


Figure 11.1 Brolga buffers (interim guidelines)

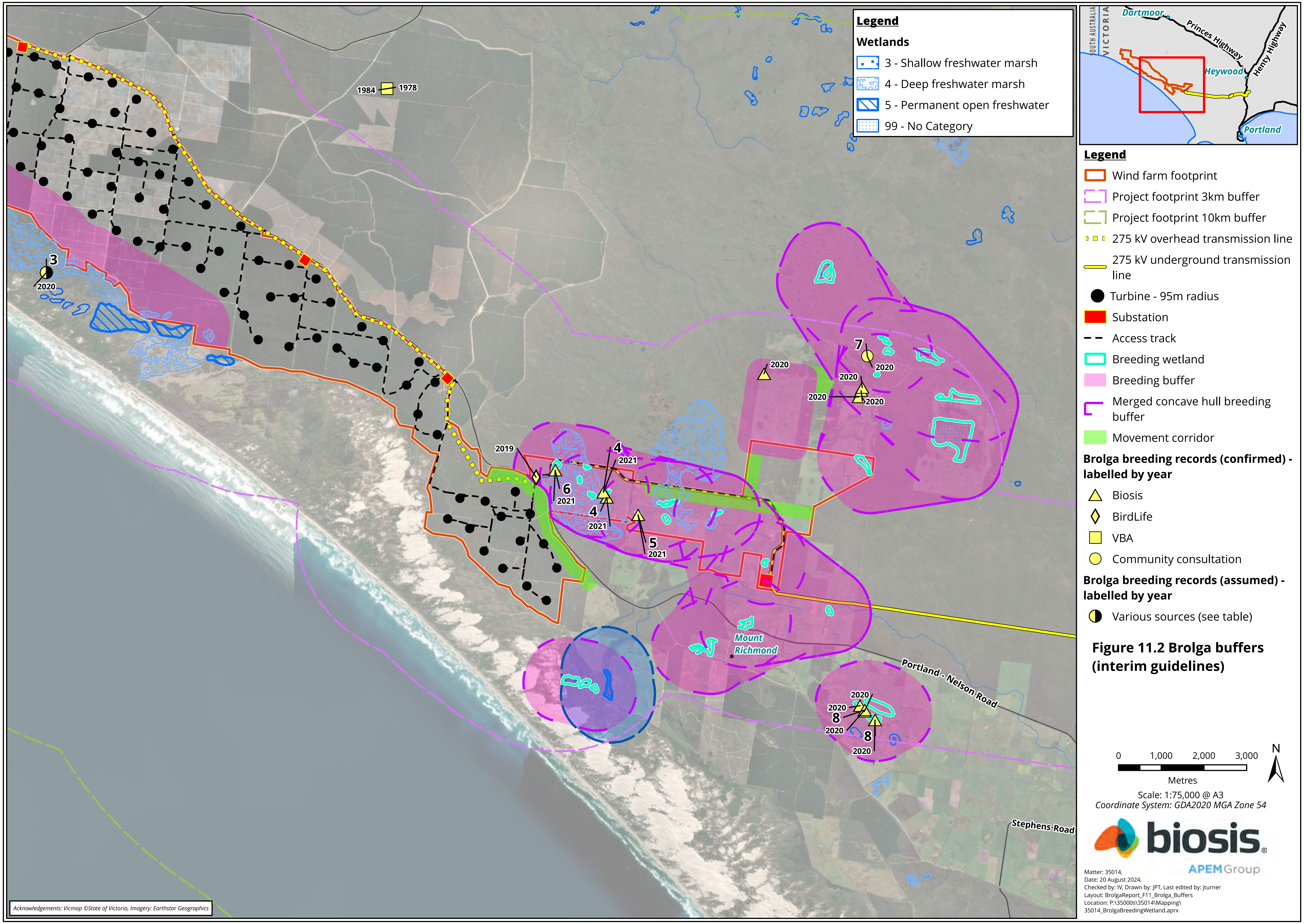


Figure 11.2 Brolga buffers (interim guidelines)

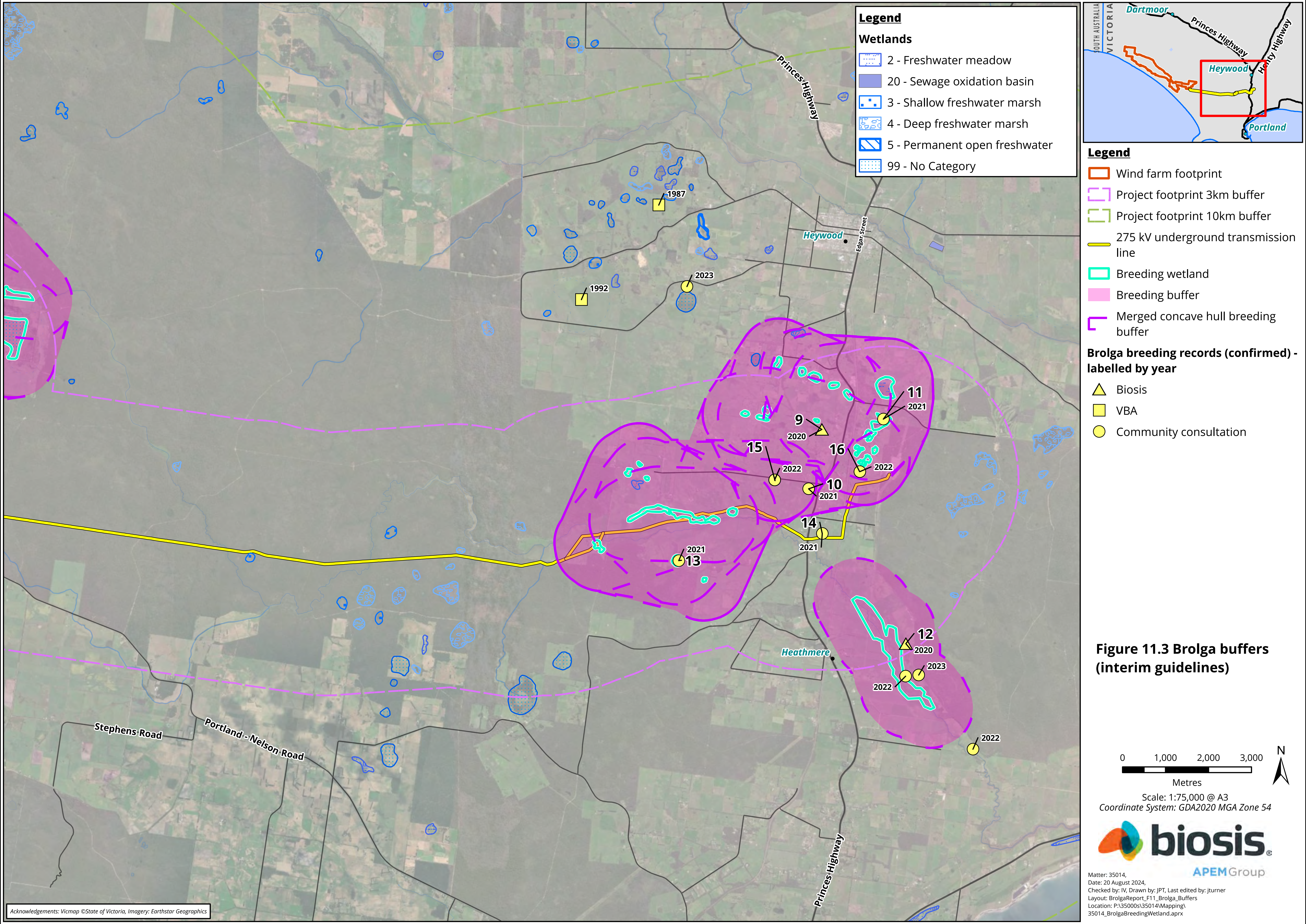


Figure 11.3 Brolga buffers (interim guidelines)

5.2.4 Buffer design methodology

The interim Brolga guidelines state the following objective for protecting Brolga habitats:

> "Siting turbines to avoid and minimise impacts on breeding and non-breeding habitats where Brolgas spend the vast majority of the year is an important strategy for avoiding potential wind farm impacts on Brolgas. In the case of breeding habitat "turbine siting would be used to exclude any significant reduction in breeding success caused by turbines" (Brolga Scientific Panel 2008). This will be achieved by establishing turbine-free areas around all potential Brolga nesting sites sufficient to have no significant impact on the likelihood of successful reproduction."
>
> "As a general recommendation, these guidelines recommend that a 3.2 km and 5 km radius turbine-free buffer from breeding sites and flock roost sites respectively, will adequately meet the objectives set for these habitats. However, recognising that the spatial requirements of Brolgas are not well understood, a proponent may propose to meet the objectives set for breeding and non-breeding habitats. Proposed buffer distances should meet with the satisfaction of the DSE."

The definitions relevant to the habitat buffers applied for the Project are provided below.

Successful reproduction is not defined in the Brolga guidelines, however it is understood this refers to successful fledging of young from a breeding site and has been treated here as such.

Breeding site for habitat buffering is defined as 'the nest of a Brolga breeding pair and the perimeter of the surrounding wetland. Also includes wetlands with previous records of Brolga nests from any relevant information source. A wetland remains a breeding site providing it has not been permanently drained and/or planted with trees. Wetlands that have been ploughed can still be breeding sites providing the wetland retains some level of filling'.

Roosting site is defined as a permanent or ephemeral freshwater or saline wetland (including dams, swamps etc) at which Brolgas have been observed to roost (nocturnally or diurnally) (Brolga guidelines p.13), however, the guidelines do not describe the point of buffering for flock roost sites, or mention using the perimeter as they do for the breeding sites.

Potential Brolga Habitat: Potential Brolga habitat includes but is not limited to permanent and ephemeral freshwater and saline wetlands, pastures and crop land within the recorded distribution of the Victorian Brolga population. Consideration should also be given to the airspace potentially occupied by Brolga during seasonal and daily movement along commuting routes.
In line with the Brolga guidelines objective above discussions with DEECA throughout the EES assessment process indicate that it is appropriate for the Project to use the latest information and science on Brolga breeding home range movements, based on GPS-tracking (Veltheim et al. 2019).

Information guiding buffer design

Breeding sites

The following information on Brolga movements, home ranges and habitat use was used to guide the buffer design for breeding sites (known and assumed).

At breeding sites, unfledged chicks are accompanied by adults. GPS-tracking of chicks has shown (Veltheim et al. 2019):

- Night roost locations were within mapped wetland perimeter.
- Some chicks (and therefore the Brolga families) used multiple wetlands and non-wetland foraging habitat prior to fledging, indicating these habitats are important for breeding success.
- Chicks moved 442 metres on average between wetland night roosts and day foraging areas, with 95% confidence interval of 403–481 metres and 99% confidence interval of 391–494 metres (CIs calculated from Veltheim et al. 2019).
- Chicks walked longer distances to move to more distant wetlands, up to 2 kilometres, with fewer frequency of such movements beyond 500 metres from wetland night roost.
- Brolga chick movement distances from nest sites were comparable to equivalent movements of Whooping Crane (*Grus americana*) and Black-crowned Crane (*Balearica pavonine*) families (adults and chicks) of 1.6–1.8 kilometres from nests, and unfledged Mississippi Sandhill (*G. c. pulla*) and Greater Sandhill (*G. c. tabida*) chicks, which have been recorded moving 1.6 kilometres and more than 2 kilometres (Veltheim et al. 2019 and references therein).
- Home ranges varied between 70–523 hectares.
- For the 95% utilisation distribution, representing the home range, close to 100% of all home ranges incorporated within a 2 kilometre circular buffer (from wetland roost centroid – from a single or multiple wetlands as described in Veltheim et al. 2019).
- For the 99% utilisation distribution, representing the home range, close to 100% of all home ranges incorporated within a 2.4 kilometre circular buffer (Veltheim et al. 2019).

Breeding sites and non-flock roost site

GPS-tracking of adult Brolga provides additional information on movements between wetland roosts and foraging areas (Veltheim et al. 2022), that can support buffer size recommendations for the breeding sites and the non-flock roost site:

- Throughout the annual lifecycle (breeding and non-breeding movements not separated) adults moved 690 metres on average between wetland night roosts and day foraging areas, with 95% confidence interval of 573–807 metres and 99% confidence interval of 536–843 metres.

Movement corridors

Guidance on disturbance distance recommendations outlined in the Brolga guidelines, and on Common Crane (*G. grus*) wind farm avoidance (Brett Lane and Associates 2017, Gerjets 2006) was used to inform movement corridor buffer width. The species has been recorded flying between 100–750 metres, with median distance of 300 metres in one study.

Buffer design method – justification summary

Identifying likely breeding home range

Suitable nesting and foraging wetlands and foraging habitat within a 2 kilometre radius of known, assumed and suitable nesting sites is likely to incorporate the majority of habitat used by chicks and breeding adults, based on knowledge of Brolga home ranges and roost to foraging habitat movements (Veltheim et al. 2019, Veltheim et al. 2022). The pre-fledged chick home ranges and roost to foraging habitat movements, and the adult movements in Veltheim et al. (2019, 2022) were calculated from locations within, rather than the perimeter of a wetland, and from a wetland centroid for chicks. Therefore, a 2 kilometre radius from the wetland perimeter is a very conservative and precautionary approach for identifying and buffering suitable wetlands that may be part of a pair's breeding home range. For the Project, it is considered to adequately protect breeding pairs from significant impacts. Identifying suitable wetlands for buffering within this radius is highly likely to incorporate the great majority of chick and breeding pair movements including distances walked to shift wetland roosts or foraging areas. The adult roost to foraging movement data (Veltheim et al. 2022) indicates that a 2 kilometre radius is also highly likely to contain the majority of flight and walking activity.

Determining likely foraging area surrounding suitable wetlands within likely home ranges

The majority of chick foraging movements at breeding sites were within 500 metres of wetland night roosts. The Brolga guidelines require the buffer to be applied from the wetland perimeter with an additional 300 metre disturbance buffer. We have added 100 metres to this, for consistency with a recent decision for another south-west Victorian wind energy project. A 900 metre buffer around each wetland is also highly likely to include the majority of adult breeding movements, at times when adults may not be accompanying a chick (e.g. during nest building, incubation and territory defence).

The Brolga guidelines provide no guidance on non-flock roost site buffer methodology. The Brolga family observed at the only non-flock roost site, roosting over night at Swan Lake, flew in and out of this wetland. No foraging was recorded and the family flew to the Mt Kincaid property to forage. The area surrounding Swan Lake contains little suitable Brolga foraging habitat as it is dominated by shrubby and woodland vegetation (Coastal Alkaline Scrub). A buffer of 1000 metres has been applied from the Swan Lake perimeter, based on published information on adult Brolga movements. This includes the average roost to foraging habitat adult movement distance of 690 metres (Veltheim et al. 2022). We have rounded this up to 700 metres and applied a 300 metre disturbance buffer, adding up to 1000 metres total buffer distance from the wetland perimeter.

Movement corridors

Little information exists to guide movement corridor protection and buffering. The Project has applied the Brolga guidelines disturbance distance, which is likely to avoid and minimise potential interactions or disturbance from the Project infrastructure. A number of 300 metre movement corridors have been applied, based on the median distance of Common Crane flights near turbines in a European study (Gerjets 2006).

Buffer design method – principles and individual breeding sites

The site-specific, turbine- and powerline-free buffers for the project have been designed and applied as follows and are shown in Figure 11.

Breeding sites – known and those determined as suitable (see Section 4.3.1)

Step 1 – Draw a 2 kilometre circular radius around the mapped breeding site wetland perimeter.

Step 2 – Identify and map all suitable breeding wetlands within the area mapped in Step 1 (Section 5.2.3). This included:

- DEECA-mapped wetlands considered suitable Brolga breeding habitat based on literature.
- Biosis-mapped wetlands:
  - Not identified in the DEECA-mapped wetland layer.
  - Two DEECA-mapped wetlands that have numerous deep drains through them and do not function as single large wetlands. Multiple smaller wetlands remain within these two DEECA-mapped wetlands.

Step 3 – Include a 600 metre radius foraging buffer around the perimeter of each wetland identified in Step 2.

Step 4 – Add a 300 metre radius disturbance buffer to the buffer in Step 3, resulting in a complete 900 metre habitat buffer.

Step 5 – Apply concave hull around the buffered wetlands from Step 4 within the area mapped in Step 1, to identify the buffered most likely breeding home range.

The buffers have been developed with data collected on breeding brolgas (pairs recorded with nest, eggs, and/or chicks) within the Project area and incorporate considerations for likely overlap and/or breeding territory boundaries based on these observations, and the known multiple wetland use within some breeding home ranges prior to chick fledging (Veltheim et al. 2019). They also incorporate likely other suitable breeding wetlands within 3 kilometres of the Project area (see Section 5.2.3),

All turbine free buffers are required to be free of turbine infrastructure, as outlined in the Brolga guidelines (DSE 2012) and will need to exclude all parts of turbine stands and blades. No part of turbines or turbine blades shall intersect with the breeding habitat buffers. All turbine infrastructure and new overhead transmission lines have been removed from buffers developed here.

The turbine- and overhead transmission line-buffers are shown in Figure 11 and the buffer development methodology for all wetlands identified as known or suitable breeding sites is provided in Appendix 3.

Known breeding sites

Pair 7:

- Wetland with a historical breeding record within the blue gum plantation and a sighting of a pair with two chicks on Kentbruck-Settlement Road in 2020 (Plate 1, Figure 8).
- 2 kilomtre radius was drawn around the nesting wetland (Figure 8, Appendix 2). All DEECA mapped wetlands considered suitable Brolga breeding habitat within this radius were included in the buffer. Detailed on-ground wetland was not possible due to lack of access and the DEECA-mapped wetland was considered sufficient to incorporate any possible uncertainty in these wetlands being suitable Brolga breeding habitat.
- 900 metre buffer was included around each of these wetlands within the 2 kilometre radius (Site 7 in Figure 8).
- Known locations within a breeding pair's home range – a buffer around a cleared paddock in the north of the project area, which abuts Kentbruck-Settlement Road. This area had a lot of Brolga activity, including a pair with chicks, indicating it is part of the breeding home range of breeding site 7 (Figure 8, observations of adult pair with chick/s in non-wetland habitat from 2020). The buffer incorporates the entire paddock, which constitutes foraging habitat, and an additional 300 m disturbance buffer from the northern edge of the road. The pair with chicks was observed walking on the road, which is thus included as a buffered movement corridor of 300 metres on either side of the road.

- Based on site observations the pair and chicks also used the Kentbruck-Settlement Road as a movement corridor (Plate 4) Additionally, the family foraged in a cleared paddock at the western end, and south of the road (Figure 7, Figure 8, Figure 11). The road and the paddock are therefore also incorporated into turbine free buffers. A 300 metre disturbance buffer was applied to the perimeter of the paddock and to Kentbruck-Settlement Road outer road edge on both sides of the road to be consistent with the Brolga guidelines 300 metre disturbance buffer distance.

Pair 4:

- Two wetlands at the western end of Mt Kincaid Road, Gorae West with a record of a breeding pair with a nest in July 2021 and eggs in October and November 2021 (Figure 8).
- 2 kilometre radius was drawn around the two nesting wetlands. All Biosis-mapped wetlands assessed as suitable Brolga breeding habitat were included within the buffer (Appendix 2). The DEECA-mapped wetlands within the agricultural area are heavily drained, modified and greatly reduced in extent (Plate 5, Appendix 2) and the refined assessment of wetland presence and suitability was used to map and incorporate suitable breeding wetlands into the buffer.
- 900 metre buffer was included around the two nesting wetlands and all identified suitable breeding wetlands within 2 kilometres of the nesting wetland.
- This was considered a reasonable and realistic buffer, due to the neighbouring breeding territories, which were within 1.1 km and 0.7 km of each other. Brolgas are highly territorial during breeding and will defend and chase other individuals away, though the edges of their breeding home ranges can sometimes overlap (Veltheim et al. 2019). The DEECA mapped wetland (20522) within this location are highly modified with drains through them. However, some smaller pockets of functioning wetlands with emergent aquatic vegetation remain. Biosis undertook detailed wetland mapping in this area to identify potential Brolga habitat, and these were included in the buffer. A breeding habitat buffer at this location also incorporates habitat with frequent and regular Brolga activity recorded in January–February and May–December, which included pairs with young (within 12 months of their life), pairs without young, and single individuals (Figure 8; Appendix 2).

Plate 5 Aerial photo of the area with DEECA-mapped wetland ID 20522 (Figure 4), showing the impact of drainage and its reduced extent. The area retains pockets of deeper inundated wetlands, some of which were assessed to be suitable Brolga breeding habitat (Section 4.1.8, Section 4.1.9, Appendix 2).

Pair 6:

- Wetland at the western end of Mt Kincaid Road, Gorae West, with a record of a breeding pair with two unfledged chicks in 2021. No nesting wetland identified as the family were observed using non-wetland habitat at the time. Nesting wetland location assumed, based on the observation and Biosis wetland habitat assessment. (A database record of a pair with fledged young in non-wetland habitat from 2019 less than 500 metres from the Biosis 2021 suggests Brolgas are also likely to have nested in this area previously).
- 2 kilometre radius was drawn around the assumed nesting wetland (Figure 8, Appendix 2). The limits of this pair's breeding home range is likely to be less than 1.1 km, where Pair 4 nested. Suitable breeding wetlands were assessed, mapped and included into the buffer as described for Pair 4 (Appendix 2).
- 900 metre buffer around the assumed nesting wetland , and a 900 metre buffer around all suitable breeding wetlands within a 2 kilometres of it.

Pair 5:

- Wetland at the western end of Mt Kincaid Road, Gorae West, with a record of a breeding pair with a nest and eggs in 2021 (Figure 8, Appendix 2).
- 2 kilometre radius was drawn around the nesting wetland (Figure 8) and suitable breeding wetlands were assessed, mapped and included into the buffer based on Biosis-mapped wetlands as described for Pair 4 (Appendix 2).
- 900 metre buffer around the nesting and a 900 metre buffer around all identified suitable breeding wetlands within 2 km of the nesting wetland (Figure 8, Appendix 2). Similarly to Pair 4the DEECA-mapped wetlands in this area (IDs 20532, 20530, 20531, 20534, 20535; labelled in Figure 4) are heavily modified, drained and reduced in extent (Appendix 2; Wetland 27). Thus Biosis assessed the current wetland extent and condition to determine their suitability as Brolga breeding habitat. It is possible that these wetlands could be part of this pair's breeding home range. Another non-breeding pair was recorded at the time at the eastern end of the private property and although no other active nests were found in October and November 2021, it is conceivable that another breeding territory could be present in some years.

Suitable breeding habitat with no database or field survey breeding records

- A breeding site buffer was applied to the entire Long Swamp and wetlands within its proximity, as suitable breeding habitat exists, and records indicate that at least one pair is highly likely to breed there (Figure 7, Figure 8).
- All DEECA-mapped suitable Brolga breeding wetlands within 2 kilometre radius were incorporated into the buffer.
- 900 m buffer was applied to all identified suitable breeding wetlands following the methodology outlined in this section for breeding sites. Frequent Brolga activity was recorded near Lake Mombeong (and includes a VBA record further indicating the location is likely regularly used).

- We applied the same methodology to buffer suitable breeding wetlands with no known breeding records, as for those with known breeding records within the remainder of the 3 kilometre radius of the Project. For each suitable breeding wetland, a 2 kilometre radius was drawn to identify all suitable breeding wetlands. A 900 metre buffer was then applied around the perimeter of each such wetland (Appendix 3). This goes beyond the Brolga guidelines requirements, which stipulate that wetlands with a breeding record should have a habitat buffer around them.

Movement corridors

- Movement corridors are included in areas where Brolga flight paths, foraging and walking were recorded during field studies (records and flight paths in Figure 7, Figure 10; movement corridor buffers in Figure 11). The buffer distance is based on recommendation within the Brolga guidelines (DSE 2012) to have a 300 metre setback from breeding and non-breeding Brolga home ranges and Gerjets 2006 as described above in this section. No guidance or recommendations are provided for width of movement corridor buffers, but we have followed the principles recommended for home ranges.
- 300 m buffer east-west through the private property at Mt Kincaid Road, Gorae West.
- 300 m buffer north-south through the eastern end of private property at Mt Kincaid Road, Gorae West and through a square block of Blue Gum plantation.
- 300 m buffer from each edge of Kentbruck-Settlement Road between the Blue Gum plantation breeding wetland buffer and the cleared paddock buffer, as a pair with chicks use this road to move between habitats.
- 300 m buffer from edge of pine into the pine plantation (between private property at Mt Kincaid Road, Gorae West where Brolgas forage, and Swan Lake night roost).

In response to TRG comments to the draft KGPH EES Brolga impact assessment report (dated 8 February 2022), DEECA Barwon South West (BSW) stated their support for movement corridors.

Non-flocking roost wetland

A buffer of 1000 metres has been applied to Swan Lake, from the wetland perimeter. A pair with 2 fledged young (<12 months old) regularly used Swan Lake to roost at night. No guidance exists on buffering of non-flocking roost wetlands. We have used published information on adult Brolga movements and applied the average roost to foraging habitat adult movement distance of 690 metres (Veltheim et al. 2022). We have rounded this up to 700 metres and applied a 300 metre disturbance buffer, adding up to 1000 metres total buffer distance from the wetland perimeter.

Plate 6 Aerial photo of Swan Lake where a family of 4 Brolga (a family of 2 adults, 2 fledged young <12 months old) roosted overnight in June 2020. The photo shows the lake full Some potential Brolga foraging area is exposed as water levels drop. The surrounding paddocks are used for stock grazing and provide less foraging opportunities in winter compared with cropped areas the family used at Mt Kincaid Rd, Gorae West.

5.3 Step Two: Approach to scenario collision risk modelling for Brolga

Level three assessment under the Brolga Interim Guidelines (DSE 2012) includes the use of quantified modelling of the risk of Brolgas colliding with turbines and use of the results of that in population viability analysis to determine a level of offsetting designed to achieve a zero net impact on the Victorian Brolga population.

5.3.1 Empirical information about Brolgas at the project site

Utilisation surveys for all bird species were undertaken to provide understanding of the bird fauna using the site and to inform potential collision risk modelling (Biosis 2022; Section 10). Flight activity data for birds were obtained during a systematic regime of fixed-time point counts. A total of 27 count sites across the proposed wind farm site and adjacent areas included 17 'treatment' sites (T) representative of locations for turbines and ten 'control' sites (C) that are not planned to be affected by the development (Biosis 2022; Figure 10a). Each point count was 20 minutes long. During the count the observer recorded all species sighted and documented the height from ground and distance from observer of bird flights. Replicate counts were be made to representatively sample different times of day, variable weather conditions and different seasons. Point count sessions were undertaken in every alternate month from April 2020 to February 2021, inclusive. A total of 418 point counts were made. Count locations were intentionally selected to include some sites of previous records of threatened birds, including Brolgas.

Systematic point counts, in which the flight activity of birds is measured in a defined area and a specified time period, can provide data for use in turbine collision risk modelling provided the data are sufficiently representative of the species flight activity for a full year and across the areas where turbines are proposed to be located.

During point counts Brolgas were recorded at four locations (sites T2, T15, C6, C7). Sites T2 and T15 are in areas where turbine-free buffers have now been applied around Brolga breeding sites. Sites C6 and C7 are outside the project area, although the Brolga pair with chicks observed at C6 were also observed within the project area and within a breeding buffer designated to protect this pair's presumed breeding wetland. The point count data includes 10 counts in which between one and four Brolgas were observed. They include 10 records of Brolgas in flight and 17 of them on the ground. The flight records include eight of Brolgas (of 1–3 individuals) flying at heights between 5 and 20 metres above the ground and one of two Brolgas flying at 70 metres high.

The number of observations of Brolga flights from point counts is not sufficient to provide a representative sample for Brolga flight activity across the wind farm area and for this reason the modelling detailed in this report was undertaken using informed scenarios for Brolga activities (see below). We note that the UK regulator, Natural England, recommends that 100 flight-height records of any species as a minimum to provide a representative proportion of bird flights for use in collision risk modelling (Natural England 2013).

Observations of Brolgas were made during other investigations for the project, including surveys to detect and obtain information about Brolga flocking and breeding activity. Those observations provide further information about Brolgas in the project area and vicinity, but due to the infrequency of Brolga flights, surveys were not aimed at obtaining quantified flight data and they therefore did not contribute data for use in collision risk modelling.

The empirical information from the formal point count surveys about Brolgas at the site was used to inform scenarios developed for the risk modelling detailed in this report.

5.3.2 Background to collision impact assessment for Brolgas at Kentbruck Wind Farm

The Victorian Brolga population is estimated at 600–650 birds (White 1987) with the great majority of the population centred on the south-western volcanic plains. More recent DEECA surveys recorded 907 individuals from south-west Victorian and South Australian flocking areas in 2013 (SWIFFT 2021).

Habitat suitable for Brolgas has quite specific characteristics including shallow wetlands and meadows traditionally used for breeding and flocking. The birds also forage outside wetlands in low-lying pasture and cropped agricultural land. Availability of suitable wetlands is heavily influenced by annual rainfall and, more permanently, by drainage of wetlands. Outside of the flocking season pairs of Brolgas are territorial and do not tolerate close proximity of other Brolgas. As a result of these factors Brolgas are relatively sparsely distributed in the landscape and, for much of the year are widely dispersed even within suitable areas of their range. During the annual flocking season they congregate at a few key sites where they roost and undertake key social activities. During this period of the year they commute daily between roost and foraging areas (usually agricultural paddocks).

Brolgas spend significant portions of their time on the ground. They obtain their food whilst walking and this activity occupies a large part of their activity cycle. Flights are relatively infrequent and are undertaken primarily when moving between locations of concentrated terrestrial activity, such as between a nest site and preferred foraging areas, between roosting and foraging areas and during displays, and between breeding and flocking areas with changing seasons and wetland availability. Thus long periods of field observation generally document few flights.

Wherever bird utilisation data are available from timed point count surveys, these provide numerical values for Brolga movements to inform the modelling process. Bird utilisation studies for the Kentbruck project obtained a small number of timed observations of Brolgas. As is usual for the species, the majority of records were of birds walking. Ten records were obtained of Brolgas in flight. The number of observations of Brolga flights is not considered sufficient to provide a representative sample for an entire annual cycle of Brolga flight activity. For this reason, the modelling was undertaken using informed scenarios for Brolga activities. A low number of Brolga flight observations and the consequent use of informed assumptions has been routine for collision risk assessment for this species for wind energy assessments in Victoria. The assumptions involved and the rationale underlying them are set out below.

The assessment of turbine and powerline collision risk for Brolgas has been undertaken on the basis of scenario modelling in which assumptions are based on empirical information for the species, including published and authoritative unpublished information about the biology of the south-western Victorian Brolga population and observations of Brolgas at the Project site and adjacent area.

As a consequence, the exercise here is reliant on assumptions used and the model's outputs are projections rather than predictions. The risk modelling exercise has been undertaken primarily to provide an *indication of risk to Brolgas if the assumptions apply*. The rationale for assumptions used is set out below, but it should be noted that a number assumptions are necessarily arbitrary and they may not accurately or precisely reflect real occurrences at the Project wind farm.

It is also noteworthy that empirical evidence from intensive monitoring over many years at multiple wind energy facilities within the Victorian distribution of the species (Moloney et al. 2019; DELWP 2020) indicates that collisions are extremely rare, noting one recent carcass detected at a south-west Victorian wind farm. Thus, at present, all turbine collision risk modelling undertaken for the species for all previous wind energy projects appears to have conservatively overestimated this risk and it is reasonable to assume that the modelling exercise here has done the same.

Turbine collision risk modelling accounts for a range of factors that describe how wind turbines will function based on multiple specifications of their physical dimensions, geometry, movements and positioning in the landscape. It also accounts for the expected flights of birds in the area of the wind farm including their frequency, heights and distance according to the birds' seasonal behaviours. Using this information and assuming any collision will be fatal, the model provides forecasts for an annual average number of Brolga fatalities due to interactions with turbines.

It was assumed that Brolga flights to and from breeding sites within 3.2 kilometres of the proposed overhead powerline are at some risk of collision and, since no quantified rate for such collisions is available for Brolgas, a rate was determined from published rates for powerline collisions of other crane species overseas. The 3.2 kilometre distance is drawn from the default breeding home range distance defined by the Brolga Guidelines (Figure 13).

The collision risk model was run for potential interaction with turbines only. Neoen has updated the current layout, placing the transmission line between Boiler Swamp Road and the Heywood terminal underground. The likely breeding pairs present in Long Swamp are all further than 3.2 kilometres. The overhead option collision risk model discussion is provided in Appendix 7.

Seasonal activities of Brolgas

The annual pattern of Brolgas activities that may place them at some risk of interaction with turbines differ and are modelled separately for the breeding and the non-breeding seasons.

Due to differences in the frequency and other characteristics of Brolga flights and of the number of birds that may be involved, a scenario has been modelled for each of these seasonal periods. An annual estimate of risk has been determined as the sum of the results for these modelled seasonal activities.

The annual breeding and non-breeding seasons for Brolgas in south-western Victoria each span approximately six months. These periods may vary for occasional birds in some years, but for the purposes of all modelling here an average of six months (183 days) has been used for each of the two annual seasons.

Turbine collision risk model

Projections of mean annual numbers of Brolga fatalities that might occur due to collisions with wind turbines, under the scenarios modelled were calculated using the Biosis Deterministic Collision Risk Model. The model was developed in 2002 and has been refined over time to incorporate new data and knowledge, and has been applied at a wide range of proposed wind farm sites in Australia. A full description of the model (Smales *et al.* 2013) is in Appendix 3.

Projections of mean annual numbers of Brolga fatalities that might occur due to collisions with an overhead powerline were also calculated using a defined set of assumptions.

Because the number of flights is different from the number of birds making those flights it is necessary to incorporate an estimate of the number of individuals that may use the site per annum into the model. Without that function results of modelling would be expressed in terms of the expected number of flights at risk per annum. The site-population value functions in the model to cap the projected number of collisions so that it does not exceed the number of individuals at potential risk and thereby to permit results to be expressed as a projected number of collisions.

Results are provided for three avoidance rates. Avoidance rate is the capacity for a bird to avoid a collision, whether that occurs due to a cognitive response on the part of a bird or not. Thus a 0.95 avoidance rate equates to one flight in 20 in which a bird takes no action to avoid a turbine, 0.98 avoidance rate equates to one flight in 50 in which a bird does not avoid a turbine, and 0.99 avoidance rate equates to one flight in 100 in which a bird does not avoid a turbine. Based on experience with a wide range of bird species, it is assumed that virtually all species have high capacity to avoid collision with the static components of turbines. Avoidance rate for these components is thus consistently considered to be 0.999 in all modelling. Various avoidance rates are modelled for the dynamic turbine components because it is not certain how adept Brolgas might be at evading collision with the moving rotor. For this reason, results are provided for 0.95, 0.98 and 0.99 avoidance rates for the dynamic components of turbines.

In the model, the turbine is decomposed into its static and dynamic components. The entire turbine (including the tower, nacelle and the rotor when stationary) represents the static component. The dynamic component is the volume swept by the leading edge of the rotor blades in the time it takes the species of interest to pass across the depth of the swept disk.

Static components (i.e. the stationary turbine) are considered to pose minimal collision risk as they are very likely to be seen and avoided by birds in flight. The sweeping rotor blades are considered to represent higher risk due to their speed and the likely difficulty of a bird in flight to avoid them. The model takes the static and dynamic elements into account by allocating different avoidance rates to them.

The risk assessment accounts for a combination of variables that are specific to the Project wind farm and to data for Brolgas from the vicinity of the farm. They include the following:

- The numbers of Brolga flights below rotor height, and for which just the lower portion of turbine towers present a collision risk.
- The numbers of Brolga flights at heights within the zone swept by turbine rotors, and for which the upper portion of towers, nacelles and rotors present a collision risk.
- The portion of the year that birds are within proximity of the wind farm site and that they may thus be at risk.
- The mean area (m^2 per turbine), of tower nacelle and stationary rotor blades of a wind generator that present a risk to birds. Thus, the mean area presented by a turbine is between the maximum (where the direction of the bird is perpendicular to the plane of the rotor sweep) and the minimum (where the direction of the bird is parallel to the plane of the rotor sweep). The mean presented area is determined from turbine specifications supplied to Biosis for specific make and model of turbine. It represents the average area presented to an incoming flight from any direction.
- The additional area (m^2 per turbine) presented by the movement of rotors during the potential flight of a bird through a turbine. This information is determined via a calculation involving species-specific, independent parameters of flight speed and body length and supplied turbine specifications.
- The model assumes that all turbines in the wind farm represent equal risk.
- A calculation of the average number of turbines a Brolga is likely to encounter in a given flight through the wind farm. This is based on the scattered configuration of turbines in the landscape and the total number of turbines proposed for the wind farm.

As per the Brolga Guidelines, a Brolga using a breeding wetland that is a default distance of 3.2 kilometres or more from the nearest turbine are considered to be adequately buffered from the risk of turbine collisions. Similarly, a flocking roost site (as defined by the Brolga Guidelines) is considered to be adequately buffered from the risk of turbine collisions if it is a minimum of 5 kilometres from the nearest turbine. No flocking sites are known or have been identified within 5 kilometres of the Project site. For the purposes of collision risk modelling, Brolgas at all known and potential breeding sites within 3.2 kilometres of the Project site have been included. The Brolga Guidelines allow for a proponent to propose reduced buffer areas if certain conditions are met. Turbine-free buffer distances designated for Project design purposes are discussed in Section 5.2.4 *Level Three assessment – Step One: turbine-free habitat buffers*. The rationale and input values used for each of the breeding- and non-breeding portions of the Brolga's annual cycle are outlined below.

Reporting measures

Model projections are provided in terms of mean number of collisions per annum. In the real event where collisions are fatal, deaths are measured in whole birds (not fractions of birds). The model provides a predicted annual average number of collisions, but the number of actual collisions that might occur in a given year can obviously vary in a distribution around an average, from zero to some maximum.

The model cannot forecast the frequency of collisions around a projected annual average and it is important to recognize that the number of any actual collisions that might occur can be expected to vary from year to year.

5.4 Scenario collision risk modelling for Brolgas

The following components were undertaken as part of the current assessment:

1. Collision risk modelling for a configuration of 105 turbines.

Specifics of the rationale and input values used for assessments of Project wind farm are set out below.

5.5 Scenario modelling of turbine collision risk for Brolgas

5.5.1 Turbines

Modelling was undertaken for a configuration of 105 turbines.

The collision risk model uses multiple dimensions and rotor speed to calculate the area presented by a turbine to a bird in flight. The basic specifications of the turbines are set out in Table 6.

Table 6 Basic specifications for turbines proposed for Project wind farm used for collision risk modelling

Basic specifications for turbines proposed for Kentbruck Green Power Hub	
Number of turbines	105
Hub centreline height	155 metres
Rotor diameter	190 metres
Upper blade tip height	250 metres
Lower blade tip height	60 metres
Nominal average rotor speed	6.5 rpm
Nominal annual percentage of downtime	2%

5.5.2 Brolga size & flight speed

A length of 1.96 metres, measured from museum specimens, is used in modelling for a Brolga in flight. Veltheim (2018) has provided the first documentary evidence for Brolga flight speed based on data from satellite tracked birds. Instantaneous in-flight speeds during seasonal movements varied from 37.0 km/h to 79.6 km/h with a mean speed of 57.7 km/h. This mean speed has been used in the modelling. In previous assessments no empirical data for the species was available and an average ground flight speed of 45 kilometres per hour, obtained from data for similar-sized crane species overseas (Alestram 1975; Bruderer and Boldt 2001), was used.

5.5.3 Brolga flight heights relative to turbine collision risk

Figure 12 shows the correlation between flight height and flight distance of Brolga movements in the non-breeding season (adapted and updated with permission from Nature Advisory Pty Ltd [formerly Brett Lane and Assoc.] 2008). It is recognised that non-breeding season data may not be a true representation of flights outside the non-breeding season. However, available data for Brolga flights during the breeding season was from a total of just 44 Brolga flights and no flights of 50 metres or higher were recorded. For the flocking season the data include a pool of 1700 Brolga flights with documented flight height estimates and they include flights that were up to 100 metres high. The flocking season data is thus more robust and, in respect of collision risk, is the more conservative.

At face value the plotted data for Brolga flight height against flight distance shows a projection of the relationship that may be misinterpreted. This is because the data points shown on the chart are not equally weighted as each point may represent more than one observation and the records do not show the number of Brolgas involved. For example the data point at 20 metres height and 1000 metres flight distance actually represents flights by two flocks of 15 and 40 Brolgas each. Other data points may represent a single flight by one individual. For this reason, a free linear regression curve has been fitted to incorporate all data and show weighting appropriately.

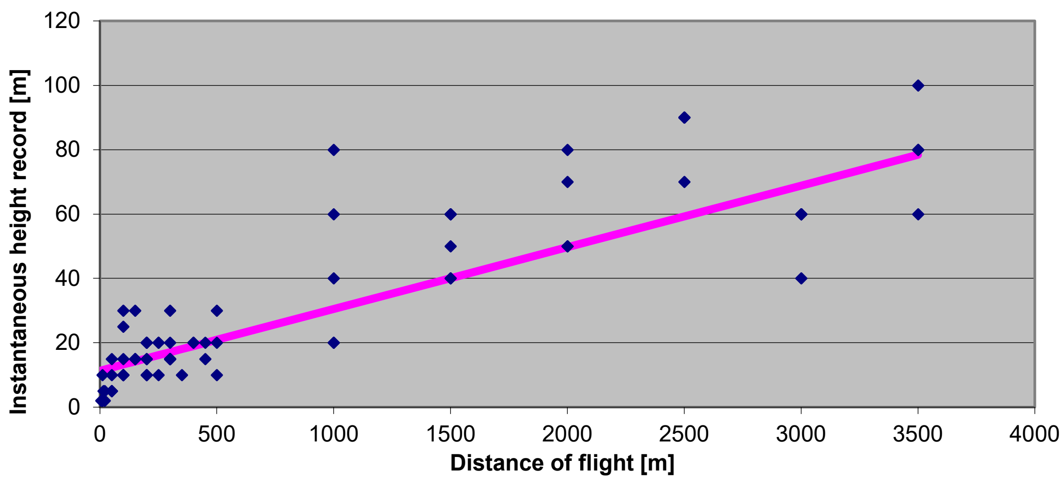


Figure 12 Brolga flight height relative to flight distance.

The regression line sits toward the lower edge of the data points because it includes a high proportion of flocks recorded at lower heights than individual birds. Regardless of weightings in the data, within the flight distances included, there is a positive relationship between flights at greater altitude and distance flown.

Because each Brolga breeding wetland is protected by a 900 metre wide turbine-free buffer, movements by birds using those sites must exceed the buffer distance before they may encounter a turbine. Turbines for the project are proposed to have rotors spanning the height between 60 and 240 metres from the ground. In the Figure 12 dataset the majority (~60%) of flight records that are longer than 900 metres are within the rotor-swept height zone. For the purposes of collision risk modelling, we have used the conservative assumption that 70% of all Brolga flights that might interact with a turbine will be within rotor-swept height while 30% of Brolga flights will be below that height.

5.5.4 Breeding season

Number of turbines presenting risk

It is assumed that during the breeding season it is possible for Brolgas to interact with the entire complement of turbines proposed for the whole wind farm. This assumption has potential to add to the estimate of risk given that the distance of movements by birds occupying a breeding home range are likely to be constrained to some degree based on Brolga movement behaviour at breeding sites and the distribution of suitable habitat in the assessment area. However, as there are seven breeding sites that are distributed around the wind farm site and the number of turbines that Brolgas using each of them might interact with varies, a simplifying assumption has been adopted and considers that all turbines pose a risk to all Brolgas present during the breeding season.

Number of individuals at risk

For the breeding season, the number of Brolgas at risk relates to the number of breeding sites occupied by birds. Targeted project investigations and a review of all available sources of data for Brolga breeding sites indicates that seven locations where Brolga have been documented to breed, or are likely to do so, exist within 3.2 kilometres of Project wind farm. The seven sites, numbered as in Figure 8, are as follows:

1. **MacFarlane's Swamp**/Long Swamp
2. **Nobles Rocks**/Long Swamp
3. **Lake Mombeong**/Long Swamp
4. **Gorae West** Cleared agricultural land in the western end of Mt Kincaid Road
5. **Gorae West** Cleared agricultural land in the western end of Mt Kincaid Road
6. **Gorae West** Cleared agricultural land in the far western end of Mt Kincaid Road
7. **Kentbruck Settlement Road** corner of Blacks Road, breeding site within Blue Gum plantation

The number of wetlands where breeding might occur within this distance is substantially limited by the surrounding pine plantations and the coast and it is considered unlikely that any more than these breeding wetlands exist within the relevant distance of the wind farm. Site 8 (Figure 8) is greater than 3.2 kilometres from the wind farm. The seven sites include three documented in the course of project studies on private agricultural property at Gorae West and one within Blue Gum plantation also at Gorae West. A further three sites been included for conservatism as we are not aware of Brolgas having bred there but suitable habitat is present and much of the area is difficult to access and study and frequent Brolga activity during the breeding season was recorded at two of these locations (Long Swamp near Johnsons Road and Lake Mombeong). These are at wetlands within the Long Swamp complex in Discovery Bay Coastal Park between Lake Mombeong and MacFarlane's Swamp. Fieldwork for the project indicated it is possible that all seven breeding sites may have been occupied during a single breeding season, hence, for the purposes of the modelling exercise an average of seven breeding pairs (14 adult birds) along with juveniles are considered likely to be present in any given year at the relevant wetlands.

The number of juveniles has been derived as follows. Chicks of a given breeding season are at minimal risk of collisions in that season because they generally are not fledged until late in the breeding season. However, many fledged juveniles remain with parents for up to 11 months (Marchant & Higgins 1993) and thus may be at risk in a substantial portion of their second season. The ratio of juveniles and sub-adults to adults in the south-west Victorian population is drawn from two sources. The first is the ratio of immature birds to adults in annual, simultaneous population counts at all traditional flocking sites in Victoria recorded by SWIFFT (accessed 26 October 2021). The ratio from those sites has been documented for each of nine years between

2009 and 2021. The second, is the percentage of juveniles and subadults from annual, simultaneous population counts at the two traditional flocking sites closest to the Kentbruck area where birds from there are considered most likely to flock, at Kaladbro Swamp and Penshurst. Count data for these two sites has been obtained in each of nine years from 2012 to 2021. The percentage of juveniles and subadults documented at all flocking sites has varied from 3% to 18% of the counted population and the mean was 10%. The mean percentage of juveniles and subadults documented at Kaladbro Swamp and Penshurst has been 10% and 7%, respectively. It is apparent that, overall, higher fledging success, and thus a greater proportion of juveniles and subadults in the population, correlates with years of higher rainfall and longer wetting of breeding habitats (I. Veltheim pers. obs.). In the limited monitoring of Brolga breeding for the KGPH Project fledging success was higher than the long-term average and the ratio recorded was 18%. In view of these local results, modelling was undertaken for a mean value of 10% and also for an upper, conservative value of 18% (results for 18% value are in Appendix 5). Respectively, these equate to annual averages of 1.4 juveniles (10%) and 2.5 (18%) accompanying 14. We have therefore modelled for totals of 15.4 and 16.5 birds at risk per annum. The discussions of rationale and calculations below relate to the mean ratio of 10% of the population being juveniles and subadults which is based on long-term empirical data. The rationale and methods of calculations for a ratio of 18% are identical. Results and comparison of these two scenarios are provided in Appendix5.

We have no basis on which to differentiate risk to adults and first-year juveniles, so risk prediction for the two age-classes is directly proportional to the ratio of adults to juveniles in the population.

Numbers of flights at risk

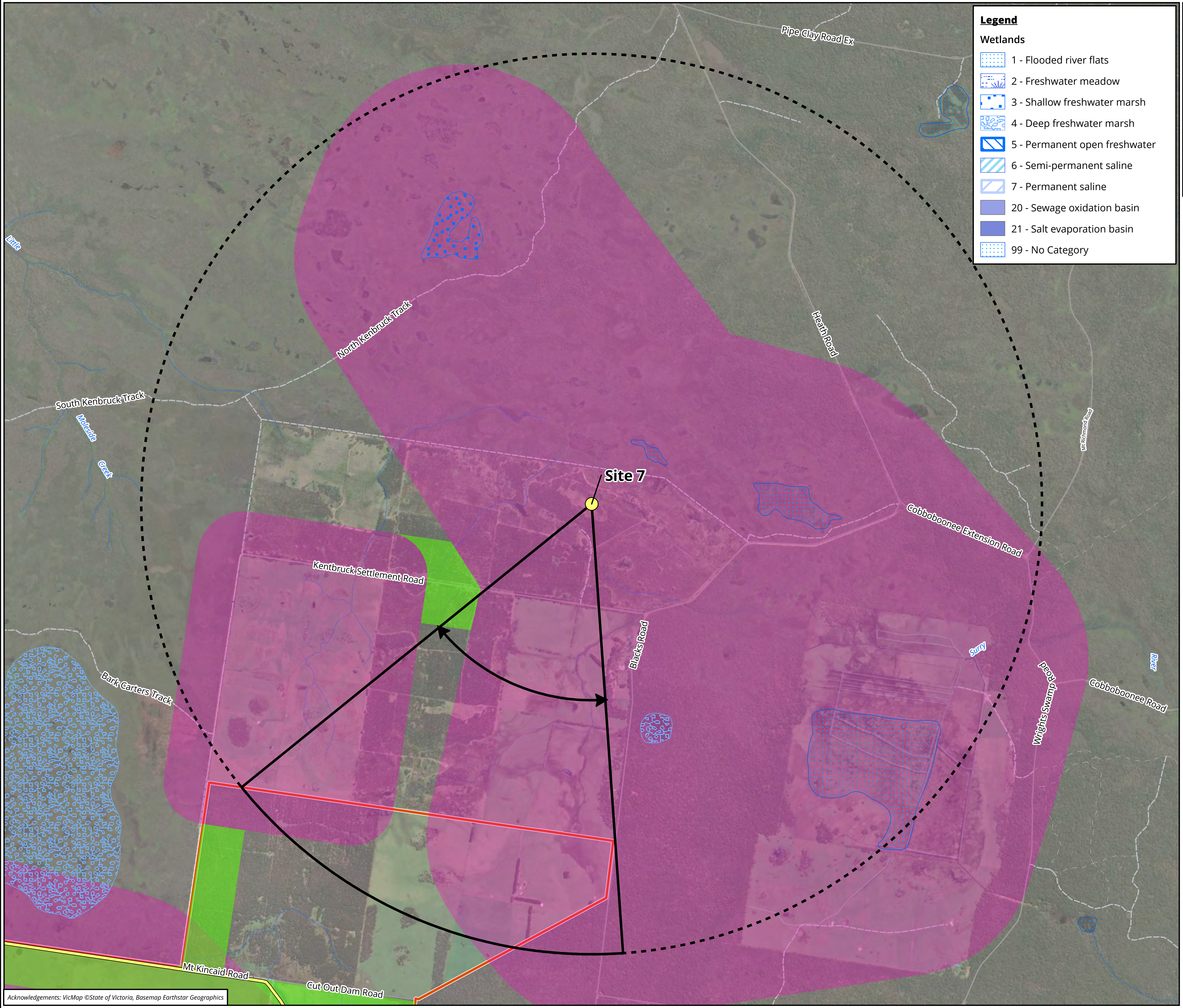
The seven wetlands within 3.2 kilometres of turbines at the Project wind farm where Brolgas have been documented to breed, or are considered likely to do so, have each been buffered by a turbine-free zone that extends a minimum of 900 metres wide around the perimeter of the wetland and contain multiple wetlands that breeding Brolgas may use, until chicks fledge. This distance around each individual wetland and nearby wetlands is as set out as described in Section 5.2. It comprises a 600 metre distance foraging buffer, a further 300 metre distance and movement corridors between nearby wetlands (up to 2 km), intended to minimise disturbance of breeding Brolgas. The buffer methodology uses principles of movement and habitat use within breeding home ranges (Section 5.2.4, Veltheim et al. 2019).

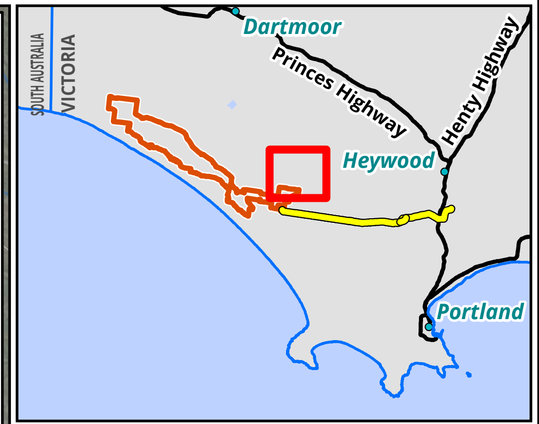
Brolga flights within the buffered area are at no risk of collision with any turbine. Veltheim (2018) and Veltheim *et al.* (2019) studied movements of Brolgas within breeding sites. Data for the birds' movements used for determining the size of breeding home-ranges were obtained from satellite tracking of pre-fledged juveniles rather than adults or fledged juveniles that are capable of flight. Pre-fledged chicks are accompanied by adult birds (Marchant and Higgins 1993; Veltheim 2018), so results of the tracking study provide a sound basis for understanding the breeding home-range sizes of Brolgas, but it is also recognised that adults may range outside of the breeding home-range and the tracking study did not collect data for flights that adult birds may make beyond a breeding home-range. For the purposes of the modelling exercise, it is assumed that on average each adult and fully fledged juvenile Brolga makes one flight out from its breeding wetland beyond the buffered area and one return flight (total of 2 flights) on each of the 183 days of the breeding season. We thus assume that each Brolga may make a total of 366 flights that include portions outside of the turbine-free buffer area during the course of a breeding season. This is considered to be a conservative overestimate because there is no empirical data indicating that Brolgas routinely make such flights.

It is acknowledged that flights are not likely to be uniformly distributed, particularly as habitats vary considerably and some, like pine plantations are not hospitable for the species, however there are no available data for Brolgas using relevant breeding wetlands to indicate that they preferentially fly in any particular direction, so in the model it is assumed that flight directions are uniformly distributed throughout all 360 degrees of the compass. Hence, the number of their flights that have potential to interact with turbines is prescribed by the arc encompassing the proportion of all flights that are in the direction of the wind farm. The method of calculating this arc is illustrated in (Figure 13). The proportion of all flights that are not in the directions of the wind farm are at no risk of colliding with any turbines. The proportion of flights that may be in the direction of the wind farm is thus individually unique to each breeding wetland and was calculated for each of the seven breeding wetlands on the assumption that all of them will be occupied by breeding Brolgas every year. The arc that is directed from a wetland towards the wind farm varied among the seven wetlands from 46 to 300 compass degrees. In turn, these equate to between 13% and 83% of all flights that could be towards turbines. Using the specific arc and relevant percentage of flights for each of the seven breeding wetlands provides a sum total of 3172 Brolga flights-at-risk per breeding season. As noted above, 30% of the total (951) flights are modelled as being below turbine rotor-swept height, while 70% (2220) are modelled as being within rotor-swept height (see *Brolga flight heights relative to collision risk*, above), for the breeding season per annum.

'Migration' flights

Brolgas tend to aggregate into large flocks concentrated on a number of particular wetlands outside the breeding season and many (but not necessarily all) birds move from breeding territories to join these flocks. Prior to the subsequent breeding season, pairs of birds move back to breeding wetlands. While these movements do not constitute 'migrations' in the true ecological sense, 'migration flights' a term of convenience. As per the Brolga Guidelines, two seasonal movements for each adult and fledged juvenile bird have been added to the breeding season modelling to account for these flights. That is 2 x 15.4 = 30.8 (rounded to 31) per annum. As these are long-distance flights it is assumed that all of them are at rotor-swept height. Recognising that it is not possible to determine directionality of these flights, it has been assumed that all of them could encounter turbines.





Legend

- Wind farm footprint
- 275 kV underground transmission line
- Site ID (Breeding pair)
- Brolga flight distance 3.2km
- Arc of flights intersecting with wind farm
- Breeding buffer
- Movement corridor

Figure 13 Arc calculation methodology: turbines

0 500 1,000
Meters
Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

biosis
APEM Group

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_F13_BrolgaBreedingWetlandsMethodology
Location: P:\35000s\35014\Mapping\
35014_BrolgaBreedingWetland.aprx

Breeding season summary

For each of seven Brolga breeding sites during each breeding season the following averages have been assumed:

- The breeding season includes 183 days of the year
- An average for each breeding site of 2.2 (2 adults and a proportion of juveniles) Brolgas make flights that may extend beyond the turbine-free buffered areas
- Each Brolga makes two flights per day that may extend beyond the turbine-free buffered area

For each Brolga breeding site during each breeding season the modelling accounts for an average of 805 flights [183 days x 2.2 birds x 2 flights] reaching beyond the turbine-free buffered area.

The seven breeding sites vary somewhat in their geographic locations relative to the proposed turbine array. As a consequence, the portion of Brolga flights from them that may encounter turbines also varies. This factor, combined with the percentage breakdown of flights that are considered likely to be below-, or within rotor-swept-height, means that the total number of flights used for turbine collision risk modelling also varies between the breeding sites. As per section 2.4.4, an additional total of 31 have been added to the breeding season modelling to account for 'migration season' flights. It is assumed that all of those are at rotor-swept height. The allocations of flights for the seven breeding sites, along with the combined total of flights for the breeding season, are shown in Table 7.

Table 7 Breeding season Brolga flights at risk of turbine collisions for each of seven breeding sites used in risk modelling (based on average of 2.2. Brolgas making 2 flights per day that extend beyond turbine-free buffers, over 183 days)

Wetland	Portion of flights toward turbines [portion of 360]	Total flights with potential to encounter turbines	Total flights at risk within RSH (total flights x 0.7)	Total flights at risk below RSH (total flights x 0.3)
1. MacFarlane's Swamp	0.50	403	282	121
2. Nobles Rocks	0.50	403	282	121
3. Lake Mombeong	0.50	403	282	121
4. Gorae West 1	0.83	671	470	201
5. Gorae West 2	0.78	631	442	189
6. Gorae West 3	0.69	559	391	168
7. Kentbruck Settlement Road	0.13	103	72	31
		3172	2220	951
migration' flights			31	
			2315	**951**

5.5.5 Non-breeding season

During the non-breeding portion of the year all factors related to turbines are the same as those used in the model for the breeding season. Factors that alter for the purposes of collision risk modelling relate to the activities of Brolgas.

Flocking

During the non-breeding period Brolgas tend to aggregate into flocks centred on traditionally used wetlands where the birds roost overnight. The Brolga Guidelines provide criteria for defining a flock roost site. Brolgas commonly move out from a night roost into the surrounding landscape to forage during daylight hours. Traditional flocking areas in Victoria are mapped by DELWP (2020). All such flocking sites are distant from the project area and Brolgas using them will be at no risk as a result of the project. As a consequence of this separation distance, there is no requirement to consider collision risk for flocking Brolgas during the non-breeding season.

Resident Brolgas

While most Brolgas tend to flock during the non-breeding period, some individuals may remain in the region of their breeding sites during this part of the year (Veltheim et al. 2022) and thus within the Project area. For this reason, modelling has been undertaken for some birds that may be at risk of collisions during this period. While most Brolgas are likely to move out of the local area to join flocks at traditional flocking areas, for the purposes of this assessment it is assumed that half of the birds modelled as present during an average breeding season will remain in the vicinity throughout each non-breeding season. In the absence of empirical data about the number of birds and the flights they may make, this assumption is considered to be conservative in light of results the of surveys for the Project and discussions with local landholders.

Brolgas that remain in the local area and do not move to flocking areas during the non-breeding season, are not known to be constrained to defined home-ranges. However, they still use wetlands as night roosts, which are generally the central point of their activities from where they move to forage in non-wetland habitats.

As a consequence of these assumptions, modelling for the non-breeding season accounts for half the number of Brolga flights at risk of collisions with turbines as during the-breeding season. The total number of migration flights per annum have been accounted for in the assessment of the breeding season (above; Section 5.5.4), and in the case of birds that remain in the local area, no migration flights would occur. Hence no migration flights are required to be added for the non-breeding season.

Non-breeding season summary

Modelling for the non-breeding season provides simply for an average of half the number of Brolgas and their flights that are modelled for the breeding season. It has thus accounted for an annual average total of 1586 flights at risk of turbine collision (3172/2) of which 30% (476) are below turbine rotor-swept height, and 70% (1110) are within rotor-swept height.

5.6 Overhead powerline collision risk for Brolgas

Empirical evidence exists for occasional fatal Brolga collisions with powerlines (Goldstraw & du Guesclin 1991). Discussions by Biosis staff with local landowners and a local field naturalist revealed their incidental knowledge of four instances of such collisions in the local area over a period of approximately 35 years, however the overall frequency at which such collisions occur is unknown.

The Kentbruck project includes one overhead powerlines:

- A 275 kV powerline running parallel to a portion of the Portland Nelson Road transmitting electricity to the Project substation at Gorae West.

The overhead transmission line is planned to use monopoles that will generally be between 40 and 50 metres high and spaced between 200 and 400 metres apart. The poles may be double or single circuit and have one or two overhead earthing/communication lines.

International data suggests that earth wires are likely to represent greater collision risk to cranes than conductor wires (Stehn and Wassenich 2008). This is because these wires are above the conductors and are thinner and probably more difficult for birds to detect.

The powerline route proposed to run beside Portland Nelson Road is not within 3.2 kilometres of any identified Brolga breeding wetland and collision risk modelling is thus not applicable to it. We have assumed that Brolgas migrating between breeding and non-breeding areas fly above the powerline height (>50 metres).

The Boiler Swamp Road to Heywood Terminal transmission line is proposed to be placed underground. The underground portion poses no collision risk for Brolgas. A scenario model for the overhead option is provided in Appendix 7.

5.7 Assessment of collision risk for Brolga

Results of modelling scenarios for turbine collision risk for Brolgas at the Project wind farm are set out below. Results are tabulated for each of the annual breeding season (including annual 'migration' flights); for birds that may be resident during the annual non-breeding period; and for Brolgas using the area where there may be some risk of collisions with the proposed overhead transmission line. The sum of these provides an estimated annual average number of Brolga collisions with turbines and the transmission line that might occur under the scenarios modelled.

5.7.1 Results of turbine collision risk modelling

Turbine collision risk results are provided for three potential avoidance rates for the dynamic components of turbines.

The results indicate a low risk of collisions under the scenarios modelled. At the time of writing there is no strong empirical basis for suggesting a precise avoidance rate for Brolgas in south-western Victoria, noting one recent carcass detected at a Victorian wind farm, it is likely that turbine avoidance capacity of Brolgas is very high and close to 100%. Investigations of turbine collision avoidance rates for a wide variety of bird taxa indicate that virtually all are above 95%, with most being above 98% and many as high as 99.9% (e.g. Cook *et al.* 2012; 2014). As described in Section 5.5.4, in order to assess for two different success rates for fledging (one in which the ratio of juveniles and subadults equates to an average of 10% of the population and another in which it equates to 18% of the population) turbine collision risk modelling was undertaken for average totals of 15.4 and 16.5 Brolgas at risk. Appendix 5 provides modelled results and comparison of these two scenarios.

Table 8 Projected number of Brolga collisions with turbines (60m blade clearance) for an average of 15.4 birds at risk per annum

Projected annual number of Brolga collisions with turbines			
Turbine avoidance rate	**0.95**	**0.98**	**0.99**
Breeding season (incl. migration flights)	0.14	0.06	0.03
Non-breeding season	0.07	0.03	0.02
Annual average total	**0.21**	**0.09**	**0.05**

5.7.2 Discussion of collision modelling results

Results for three turbine avoidance have been modelled and are provided here for consistency with results that have been evaluated for other wind energy projects in Victoria. Many hundreds of intensive searches for Brolga carcasses using purpose-trained dogs have been completed under operating turbines at multiple wind farms within the species south-western Victorian distribution. Wind farms with a total of more than 730 turbines operate within the range of the Victorian Brolga population (https://en.wikipedia.org/wiki/List_of_wind_farms_in_Victoria [accessed 23 July 2023]). To-date there is one documented case of Brolga collisions with turbines in Victoria , despite the fact that Brolgas remain present and mobile through the landscape. This suggests that Brolgas have a very high capacity to avoid turbine collisions. Previous quantified collision risk modelling and the present modelling assume that a level of collision risk for Brolgas does exist. Evidence to-date from operational wind farms indicates that the risk is very low and that the projections for all avoidance rates provided here and in previous collision risk modelling for the species may well be higher than is likely to occur in reality. With this in mind, we consider that, although the capacity for Brolgas to avoid collisions with wind turbines may not be perfect (i.e. 1.0 or 100%), it is clearly very high. For this reason, we consider that the modelled result for an avoidance rate of 0.99 is likely to be closer to reality than those for lower avoidance rates.

As noted throughout this report, in the absence of empirical data the risk modelling exercise is a theoretical one and is based on assumptions that are detailed here. There is no available data quantifying the incidence of powerline collisions by Brolgas. Modelling of that risk is intentionally conservative and, for consistency, follows an approach that has been applied for assessment of such collisions by Brolgas for wind energy projects since 2009 (Biosis Research 2009).

5.7.3 Comparative risk modelling for turbines with lower ground clearance

The 60 metre lower blade tip height proposed for the project is substantially higher than that of turbines installed or proposed for other onshore wind energy facilities in south-eastern Australia. For this reason, collision risk modelling was undertaken to compare the risk of collisions for turbines with a lower blade tip height of 60 metres above the ground as proposed to be installed by the project, with turbines with a lower blade tip height of 45 metres above the ground which are similar to other contemporary onshore wind energy facilities.

The comparative modelling exercise altered the tower and hub heights but maintained all other specifications of turbines, including all dimensions of rotors, unchanged. The change in rotor height required alteration to the proportion of Brolga flights that would be below rotor height and within rotor height. These proportions were calculated as set out in section 5.5.3 and with reference to Brolga flight height data plotted in Figure 3.

The 45 metre blade/ground clearance means that a greater proportion of Brolga flights would be within rotor height and, based on values shown in Figure 3 the comparative modelling was undertaken on the assumption that 80% of all Brolga flights that might interact with a turbine will be within rotor-swept height while 20% of Brolga flights would be below that height (modelling, above, for 60 metre for blade/ground clearance used 70% and 30% for these parameters respectively).

All other values used for the comparative modelling were held constant and unchanged from those used in modelling of turbines with 60 metre blade/ground clearance described above.

Results of collision risk modelling for the lower rotor height are set out in Table 9. Results shown in italics differ from the results for the scenario using 60 metre blade/ground clearance. A comparison of

Table 8 and Table 9 indicates that the risk associated with a configuration using turbines with a 45 metre blade/ground clearance is slightly higher than for the configuration using 60 metres, as proposed for the project. The difference is not large primarily because, while a 10% change in the proportions of Brolga flights below, and within rotor swept height was used, the absolute numbers of Brolga flights in either height band is low (Figure 3).

Table 9 Projected number of Brolga collisions with turbines (45m blade clearance) per annum

Projected annual number of Brolga collisions with turbines			
Turbine avoidance rate	**0.95**	**0.98**	**0.99**
Breeding season (incl. migration flights)	*0.16*	*0.07*	0.03
Non-breeding season	*0.08*	0.03	0.02
Annual average total	***0.24***	***0.10***	**0.05**

5.8 Step Three: population viability analysis

On the basis of results of collision risk modelling for Brolgas provided here, an evaluation of the potential effects on the south-western Victorian Brolga population was undertaken by Prof. Michael McCarthy School of BioSciences, The University of Melbourne. The assessment used the population viability analysis (PVA) prepared for this purpose (McCarthy 2008). The Project-specific PVA is reported in full in Appendix 2 (McCarthy 2022).

On the basis of natural survivorship rates for juveniles, two-year-olds and adult Brolgas, the PVA process simulates the trajectory of the population over a predetermined time period to first ascertain the likelihood of it reaching quasi-extinction in the absence of any effects of the Project. It then simulates the trajectory with the added effects of collision fatalities determined by the collision risk modelling. A summary of the PVA assessment is as follows.

Simulations were run over a 25-year time period. The exact size of the south-western Victorian Brolga population is not known with certainty, but estimates in recent years have been determined from a number of attempts at simultaneous counts when the majority of the birds are centred on key flocking sites. Given variation in count results for different years the PVA was run for populations of two starting (current) sizes, one of 625 individuals and another of 907 birds (DSE report of simultaneous flock counts in April 2013).

Results of the PVA indicate that it is likely that a population that currently consists of 625 birds will decline to number approximately 556 within 25 years if it experiences no mortalities due to the Project and for a population that currently consists of 907 birds will decline to number approximately 807 within 25 years if it experiences no mortalities due to the Project. These projected declines are dependent upon values used in the analyses for demographic rates of annual average survivorship and reproduction and coefficients of variation associated with them. The values used were informed by empirical information for Brolga. Simulations were based on 1,000,000 stochastic iterations for each set of parameters.

When modelled mortalities due to the Project are added to the simulations the resultant estimates of population size are as detailed in Table 10. The PVA predicts that the south-west Victorian population (currently 625-907 birds) would decline by 11% over 25 years under existing conditions, or slightly faster (between 11% and 12% over 25 years) if the proposed wind farm is additional source of mortality at rates projected by the collision risk modelling.

Table 10 Expected minimum population (EMP) size of the south-west Victorian Brolga population for each of the three different turbine avoidance rates when the initial population size was 625 or 907 Brolgas. Values here are for a Project with underground transmission line between Boiler Swamp Road and Heywood.

PVA projections of expected minimum population (EMP) size over 25 years, and the reduction in EMP due to collisions		
	Minimum population size	**Maximum population size**
Initial SW Vic population	625	907
PVA population estimate with no collision mortality due to project	556	807
PVA population estimate with collision mortality due to project (95% avoidance rate)	553	805
PVA population estimate with collision mortality due to project (98% avoidance rate)	554	806
PVA population estimate with collision mortality due to project (99% avoidance rate)	555	807

The PVA indicates that a zero net impact upon the population – as required by the Brolga Guidelines – can be achieved by management to increase recruitment into the population by approximately one juvenile over every two years.

As noted previously, the collision risk modelling provided here – and hence also the PVA – is essentially a hypothetical exercise. Mounting empirical evidence from wind farms suggests that Brolga collisions with turbines are extremely rare events and thus that the modelling here is likely to be overly conservative. We also consider that assumptions used for the frequency of powerline collisions are conservative. Nonetheless, the exercise has been undertaken in order to meet requirements of the Brolga Guidelines. Results of the PVA quantify effects on the Brolga population as required for a Level Three Assessment under the Brolga Guidelines.

6 Impact assessment and mitigation

The Brolga is not listed under the EPBC Act. It is listed under the FFG Act as endangered in Victoria and an Action Statement has been prepared for it (DuGuesclin 2003). The threat category for this species has recently changed from vulnerable to the higher endangered category. The VBA contains records of this species within the 10 kilometre search area, including breeding records from eight locations.

Based on the Biosis field surveys and local knowledge, the number of mature individuals is estimated to be 28, or 14 breeding pairs, within the investigation area. This total number will fluctuate from year to year, depending on breeding wetland suitability, breeding success and the number of pairs that return with previous year's young, prior to setting up breeding territories. Some of the highest percentage of juveniles in flocking season counts in Victoria are about 18% (SWIFFT 2021), representing overall annual recruitment success. Based on this, the approximate highest numbers of fledged individuals (<12 months old) expected in the investigation area could be as high as 4–5 annually. However, juvenile recruitment on average would be expected to be around 10%, which is the mean percentage of juveniles in Victorian flocks over an approximately 10-year period.

During the field investigations in 2020, the number of juveniles for the investigation area was at the upper end of the Victorian long-term recruitment percentages (about 17%). The field investigations found two pairs with two chicks each, and 3 juveniles from the 2019 breeding season and estimated 16 adults present during the 2020 investigations. Based on the average 10% and maximum 18% recruitment rate in south-west Victoria, the investigation area could hold 30–31 Brolgas on average (28 adults; 2–3 juveniles) and at times up to 32–34 Brolgas in years of high breeding success (28 adults; 4–5 juveniles). This total is 3-6% of the estimated south-west Victorian population (based on 550 in White 1987 and 907 in SWIFFT 2021) and 6–7% of the estimated 200–250 breeding pairs (SWIFFT 2021) in south-west Victoria.

Brolgas move seasonally from breeding to flocking areas (Arnol et al. 1984, White 1987). The flocking areas are well-documented (White 1987, Veltheim 2020) and the nearest one to the Kentbruck Green Power Hub is the Strathdownie (Kaladbro/Mingbool) area, which is approximately 50 to 70 kilometres north/north-west of the project area and most likely the one used by Brolgas breeding within the investigation area. The Biosis field surveys indicate most Brolgas depart the investigation area after the breeding season and return at the end of the flocking season. Therefore, regular seasonal movements between December and May in and out of the area are expected. Brolgas undertake such flights mostly at 11:00–14:00, they may stop over between 1–5 wetlands while undertaking these flights, and can reach breeding or flocking areas within 1–2 days (Veltheim 2018).

Local movements of five kilometres, prior to the breeding season, were observed during the Biosis surveys, with a pair and two juveniles flying between a day foraging area within farmland and a night roost at Swan Lake in late May and mid-June. Most local movements would be expected to be within five kilometres and much less once pairs are on breeding territories, which vary in size from 70 hectares to 523 hectares with the majority of movements contained within two kilometres of the centre of night roosts (Veltheim 2018, Veltheim et al. 2019).

The main concern for Brolgas within the project area is potential collision with turbines; and power lines and with guy wires supporting meteorological masts. Abandonment of breeding sites due to potential disturbance from infrastructure and construction and maintenance activities is also a possibility. The species is prone to power line and fence collisions (DuGuesclin 2003) and collisions from wind farm infrastructure are a concern for the threatened Victorian population (DSE 2012). Four powerline collisions have recently been reported in the Portland district (Farnes 2019, Farnes pers. comm.) and a local landholder at Mt Kincaid Rd, Gorae West has recorded a single powerline collision on their property. The Brolgas were found a range of transmission line types – from single to multiple line powerlines. Despite substantial targeted search effort at multiple operational wind farms within the species range (Moloney et al. 2019; DELWP 2020), a single mortality has been recorded from an operational wind farm to date.

During the Biosis bird utilisation surveys, Brolgas were seen flying at heights of 2, 10, 20 and 70 metres. During targeted surveys Brolgas were recorded flying at heights within 5 metres (n = 9), within 5–35 metres (n = 5) and at 50 metres (n = 2). These results indicate that individuals will at times fly at rotor swept height, and more commonly at the height of power lines when undertaking local movements. The family group observed flying from farmland south towards Swan Lake in the eastern part of the project area flew around the pine plantation at approximately canopy height. Brolgas could occasionally fly over the pine plantation, and have been observed doing so in south-western Victoria (I. Veltheim pers. obs.), and are likely to sometimes fly at turbine height. The greatest risk of any turbine or powerline collisions are expected to be in areas of higher frequency activity and areas supporting higher numbers of Brolgas such as the farmland in the north-eastern part of the project area. This area of farmland had frequent Brolga activity with up to 11 individuals recorded, and with Brolgas flying in and out at dusk, dawn and throughout the day. Other locations with frequent Brolga activity include the farmland in the eastern part of the project area where a pair was observed, and on the edge of native heathland vegetation and cleared pine immediately north of Lake Mombeong where a single Brolga was seen foraging. Collision risk and potential disturbance risk from turbines and power lines should be mitigated and managed at these locations.

Guidelines currently exist to assess, avoid, mitigate and offset potential wind farm impacts on the Victorian Brolga population (DSE 2012). New standards for assessing and mitigating wind farm impacts on Brolgas were released in draft in late 2020 (DELWP 2020). Both the DSE (2012) guidelines and the DEWLP (2020) draft standards set out methodology for assessing, avoiding and mitigating wind farm impacts on the Victorian Brolga population through applying breeding and flocking habitat buffers. The new standards (DELWP 2020) have not yet been finalised, and the draft was released for public comment after the project field surveys commenced. Thus, Biosis used the assessment methodology outlined in the guidelines (DSE 2012) and Level One, Level Two and Level Three Assessments step one, two and three (Sections 5) were completed.

This section provides an impact assessment and recommended mitigation measures under each sub-heading, with cross-reference to the bat and bird adaptive management plan.

6.1 Wind farm

Wetland habitat, including breeding habitat will not be removed and is not likely to be impacted by the project, as long as any potential impacts to groundwater, surface water and sediment run-off from construction are managed (see below). Therefore effects on habitat conditions and destruction of habitat are unlikely. The project does not involve direct removal of individuals. Some level of uncertainty exists with potential disturbance effects of wind farms on Brolgas and cranes more generally. However, wind energy facility infrastructure is considered to potentially cause disturbance to Brolgas (DSE 2012) and avoidance by Brolgas of wetland habitat in the vicinity of operating turbines is possible. Mechanisms for minimising disturbance through the use of buffer zones that are free of wind energy infrastructure are components of the assessment approach (DSE 2012).

There is a low to moderate likelihood of individual Brolga flight paths intersecting with Kentbruck Green Power Hub infrastructure such as turbines and power lines, given the distribution of potential and known habitat south, north and east of the project area, the frequency of Brolga activity and local movements in the farmland areas in the east and west during their seasonal presence in the area, as well as regular seasonal movements in and out of the region. Some mortality may occur and is more likely to occur due to collisions with an overhead transmission line than with turbines but the magnitude of either is uncertain. The only new overhead transmission line will be the section along Portland-Nelson Road, which should be marked to increase its visibility to Brolgas and other bird species. The overhead transmission line collision risk and impact has now been substantially reduced in the updated layout through moving the transmission line between the wind farm site and Heywood Terminal Station underground.

If the assessment methodology of DSE (2012) is determined to be applicable to the Project, the potential impacts of collisions may be explored with the use of quantified collision risk modelling. Existing government guidance for assessment and mitigation of possible effects on Brolgas does not address the potential for birds to collide with the guy wires supporting meteorological masts. It is recommended that guy wires should be permanently marked with commercially available bird flight diverter markers so they are more visible to Brolgas.

Any disturbance or mortality impacts would be expected to be confined to the extent of the investigation area for the duration of the wind farm's operational life of 25 years, where and when approximately 2% of the south-west Victorian Brolga population is present.

6.2 Transmission line

The overhead transmission line, along the Portland-Nelson Road is planned to use monopoles that will generally be between 40 and 50 metres high and spaced between 200 and 400 metres apart. The poles may be double or single circuit and have one or two overhead earthing/communication lines. The section of transmission line through the Mt Kincaid, Gorae West private property and through Cobboboonee National Park section will be underground from the eastern end of the national park to Heywood subterminal station and won't have collision risk impacts to Brolgas. Placing the transmission line underground as proposed, will eliminate impact to eight breeding sites within 1-3 kilometres of the new easement.

Brolgas are known to occasionally collide fatally with power lines (Herring 2001, DuGuesclin 2003, Herring 2005, Veltheim 2017, Farnes 2019, I. Veltheim pers. obs.). Based on observations, and anecdotal reports, juveniles are particularly at risk, especially when power lines are in proximity to a breeding wetland, although adults can also collide with power lines (Veltheim 2017, I. Veltheim pers. obs.).

A powerline at or below the pine canopy height would be unlikely to pose a collision risk to the Brolga. An internal reticulation overhead transmission line is also proposed to be constructed parallel to the Portland-Nelson Road. There is currently uncertainty about how the transmission height relates to the height of the pines and this would change based of coupes being harvested. The transmission line could pose a collision risk to Brolgas where its height sits between the top of the pine tree canopy and the bottom turbine blade tip. As well as being within the flight height range of birds (including Brolgas) undertaking local flights, a transmission line above the canopy height could pose collision risk when birds attempt to avoid blades and fly underneath them. There is no suitable wetland habitat that would suggest frequent and regular local flights south-north between Long Swamp and associated wetlands north of the Portland-Nelson Road. Long Swamp is ≥3.5 kilometres and McFarlane's is 7 kilometres from the Portland-Nelson Rd transmission line. The flights crossing the proposed powerline along Portland-Nelson Road would most likely consist of seasonal migratory movements between breeding and non-breeding (flocking) areas. Such longer distance flights are likely to be at greater height than the overhead transmission line. A conservative approach has been taken here, with the assumption that collision risk exists when Brolgas undertake such movements, and the Portland-Nelson Road transmission line has been included in the collision risk model.

The use of marker devices fitted to the proposed overhead wires may also be applicable to reduce the potential collision risk for birds, including Brolgas.

The duration of an impact and effect from a power line within this farmland is a minimum 25 years of the wind farm's proposed operational lifetime.

6.3 Potential for direct impacts

Direct impacts for the Brolga are most likely to occur through turbine and power line related fatal injury or mortality. Moloney et al. 2019; and DELWP 2020 note that Brolga collisions with turbines have not been documented to date. However a single mortality has recently been recorded at an operating wind farm in south-west Victoria and risk assessments for wind energy projects within the species range consider that such collisions may occur and occasional collisions with power lines are known to occur. One Brolga carcass has recently been detected at a south-west Victorian wind farm. Collisions may occur when individuals move seasonally between breeding areas within the investigation area and non-breeding areas (November–January; May–June) and when they are moving locally (May–December).

Section 5 of this report sets out scenario collision risk modelling based on information obtained by the project about the local Brolga population and a set of explicit assumptions. As noted above, the modelling is a hypothetical exercise that is reliant on the assumptions used and selection of those used a conservative approach in dealing with uncertainty with a view to over-estimation of potential risk. On the basis that the powerline connecting the Project to the external is underground and Brolgas in flight have a 95% turbine avoidance rate and that other relevant assumptions hold, the modelling projects that an average of approximately one Brolga may collide with the combined project turbine array every four to five years.

Population viability analysis set out in Appendix 4 was undertaken for results of collision risk assessment. The PVA estimates the expected minimum population size in the absence and presence of wind turbines and powerlines for turbines with overhead transmission line from Boiler Swamp Road to Heywood. The total number of turbines for the Project has been reduced to 105 for collision risk modelling presented here, and the transmission line is now proposed underground, substantially reducing the collision risk and impact on the expected minimum population size. The population viability analysis will be re-run to provide an indication of both the level of effect this might have on the extinction risk for the south-eastern Australian Brolga population and a level of positive management that would be required to achieve a zero net impact on the population. This is expected to be approximately one extra juvenile.

The project will not remove wetland habitat, thus no direct impact on habitat is likely.

6.4 Potential for indirect impacts

Effects of noise and disturbance from turbines on Brolgas are unknown, but considered possible as cranes are known to be sensitive to disturbance (Shenk and Ringelman 1992, Meine and Archibald 1996) and there are some reports of wind farm avoidance behaviour by other species of cranes (e.g. Gerjets 2005). If turbines are excluded from important habitats, indirect impacts during operation are unlikely. Noise, traffic and artificial light during construction and operation may have an impact if important habitats are affected, particularly during the breeding season. The potential spread of weeds, pathogens and pest animals as part of the project construction and operation is unlikely if construction environmental management plans and controls are in place and adhered to.

Breeding pairs and families with unfledged chicks may occur within the Project area along the edge of Long Swamp and in the modified agricultural areas in the east – around Gorae West, Mt Richmond and between Boiler Swamp Road and Heywood. Infrastructure within breeding sites that may impact on Brolgas during operation has been excluded. Disturbance from road, turbine track, substation and underground transmission line works in these areas may occur during construction if and when breeding pairs are present.

The Brolga breeding season generally extends from July to November (Arnol et al. 1984, Herring 2001), though pairs can be present at their breeding territories for two months either side of these months and the breeding season can extend to March-April in some years depending on rainfall and wetland water levels (Veltheim et al. 2019). Flocks form during the non-breeding season between December and June when pairs and their chicks move from breeding to non-breeding flocking areas (Arnol et al. 1984, White 1987, Marchant and Higgins 1993, Sheldon 2004).

Construction activity that is too close to breeding wetlands may disturb breeding Brolgas, through visual disturbance and noise caused by vehicle traffic, presence and operation of plant such as cranes and presence of humans on foot. Such disturbance can result in pairs moving away from nests, disrupting incubation and separating chicks from adults, which can potentially impact on breeding success. Brolgas avoid buildings within breeding home ranges, which may relate to disturbance and frequent human activity around buildings (Veltheim et al. 2019).

Summary of recommended actions to avoid and minimise indirect impacts during construction and operation are provided below, with further detail outlined in this section:

- Construction should not occur within Brolga breeding habitat buffers during the known breeding season (July–November) or if breeding activity is recorded within the buffers outside of these months.
- Adaptive management and monitoring will be implemented for the construction and operational phase of the Project to avoid and monitor any impacts to breeding Brolgas. This will include any additional construction-specific buffers if deemed necessary.

Construction activity should not proceed within Brolga breeding buffers when pairs are present and engaging in breeding activity (mating displays, nest building, incubating, with unfledged chicks), until chicks fledge and the families dispersed from the buffers. If a new site is found within 3 kilometres of the Project footprint, a breeding buffer should be determined and construction activity should stop within the new breeding buffer. The breeding buffer should be developed using the methodology outlined in Section 5.2.2. Construction activity should also not occur within the breeding buffers during the breeding season (July–November) even if Brolgas have not been observed during pre-clearance surveys, to ensure construction does not prevent Brolgas from breeding in those areas in any given season. Monitoring of pairs and breeding activity should occur throughout the breeding season and when breeding Brolgas are present, as part of the BBAMP adaptive management implementation. Start of construction should be determined by the end of breeding season defined as the fledging of chicks and dispersal of pairs and families from the breeding buffers.

Currently, the disturbance response of breeding Brolgas to construction activities including visual and noise impacts, is unknown due to lack of data. Additionally, we are not aware of published literature on other species of cranes to inform set-back distances to avoid construction-related disturbance to breeding pairs, particularly in the context of wind farms. Buffers of 800 metres within nesting sites during the breeding season have been recommended for Sandhill Cranes, whereby all forestry activities are excluded (including harvest, salvage, hauling, and road construction) (Gill, C. N.D.). This distance is comparable to the Project's Brolga breeding buffers, which extend to 900 metres from suitable breeding wetland habitat. This distance could be used as a starting point for construction activity buffers, noting the uncertainty of the level of disturbance such activities may have on breeding pairs and breeding success and noting that in one case during the Biosis surveys a pair with two chicks showed signs of being disturbed at a distance of >1 kilometres (Section 5.2). Site characteristics and visual line of sight of breeding pairs to construction areas will be important in finalising construction set-back distances, as breeding activity and behaviour of Brolgas is affected when individuals sight vehicles (moving or stationary) or humans on foot in proximity to breeding habitat. The need for, and specific details of any additional construction set-back distances will be implemented through the adaptive management plan actions (Biosis 2023).

Construction of turbines and other infrastructure that are closer than the set-back distance from breeding wetlands will be scheduled to occur only during the non-breeding period of the year (January–June) and/or when chicks have fledged and breeding pairs and families are no longer present. Noting the exact timing of the breeding period can vary annually and breeding can occur outside of the generally accepted July–November breeding season, the non-breeding period of the year will be determined by the presence and activity of breeding pairs. All known and potentially suitable breeding wetlands should be monitored, from an appropriate distance, during construction activities to monitor the presence and breeding activity of pairs.

Recognising that Brolga presence and numbers may vary annually, adaptive mitigation and management approach during construction will be adopted. This should include pre-construction clearance surveys at all known and suitable breeding wetlands and the breeding habitat buffers identified here. The adaptive management during construction should include monthly monitoring of known and suitable wetlands with triggers to cease construction if breeding Brolgas are detected in the proximity of such wetlands. All monitoring should be conducted at a distance that does not cause undue disturbance to the breeding pair. A minimum 400 metres is recommended where-ever possible, based on observations of Brolga behaviour (I.Veltheim pers. obs.) and recommendations for other breeding crane species (Kong et al. 2020; Gill, C. N.D.).

Much of the Project is within a pine plantation. The great majority of the turbines and other infrastructure are thus distant from known and suitable Brolga breeding sites and within environments unsuitable for the species. Construction should be able to proceed across the majority of the site without causing disturbance to breeding Brolgas through the adoption of the above listed recommendations.

The substation is located within a breeding buffer. We understand that frequent access will be part of the construction and operation of the wind farm, with access required several times a week throughout the Project's lifetime. In this area:

- Avoidance is not possible because that entire section of site is covered by buffers and access is required through the area to connect the project.
- Best endeavours will be used to schedule primary installation works for the substation during non-breeding season but testing and commissioning works may be required during breeding season.
- Operation of a substation requires constant maintenance with maintenance intervals for pieces of equipment ranging from daily to 15 yearly. Daily and weekly activities are typically low impact visual and physical checks. The Project will endeavour to schedule higher impact long lead time major maintenance items outside the Brolga Breeding season.

The substation should be accessed from Portland-Nelson Road via Blacks Road and Mt Kincaid Road to completely avoid disturbance to known breeding pairs further west within the Mt Kincaid Road private property. A potentially suitable breeding wetland is located within 1 kilometre of the substation. If a pair is observed during construction or operation of the wind farm, adaptive measures would need to be implemented to monitor the pair, breeding activity and breeding success and to avoid and minimise potential disturbance impacts. Such measures should be incorporated into a site construction environmental management plan (EMP). Both the construction EMP and the bat and bird adaptive management plan should incorporate monitoring for the wetland within proximity of the substation.

6.4.1 Cumulative impacts – Brolga compensation plan for net zero impact

Offset options

Step Four of the Brolga guidelines (DSE 2012) outlines management options for offsetting modelled mortality for each individual wind farm, to manage potential cumulative impacts of wind farm development on Brolgas in south-west Victoria. The Brolga guidelines objective is to ensure a zero net impact on the Victorian Brolga population, by increasing fecundity or reducing mortality.

The Project is required to design and implement a Brolga compensation plan (BCP) to offset modelled mortalities. The Brolga guidelines offset options include:

- Reducing mortalities from powerline collisions.
- Protection and enhancement of breeding sites, to enhance breeding success (i.e. increase the number of fledged chicks recruiting into the population).

Monitoring and evaluating the BCP success can be achieved through quantifying fledgling success from restored and managed wetlands. Quantifying reduction in mortality from powerline collision avoidance is likely to be more difficult. Additionally, the PVA provides guidance on the number of individual fledglings required to achieve net zero through increasing fecundity, which can be achieved through creating and managing suitable Brolga breeding habitat. The Project BCP will therefore be developed to restore and manage wetland habitat to increase breeding success, to add individuals to the population to compensate for losses through predicted collisions due to the Project operation.

Powerline marking is known to reduce collisions for other crane species and will also be incorporated into the plan to avoid and minimise bird losses from collisions with new powerlines.

All new transmission lines, such as the proposed section along Portland-Nelson Road will be marked with commercially available bird flight diverter markers to increase its visibility to Brolgas and to reduce potential transmission line collisions. Options to install near-ultraviolet light to reduce collisions should be considered where transmission lines are in high risk locations, as this method has shown to reduce Sandhill Crane (*Antigone canadensis*) collisions by 98% (Dwyer et al. 2019).

BCPs have previously been developed and approved for the Dundonnell Wind Farm and Golden Plains Wind Farm and developed for the Willatook Wind Farm. The outlined for the KGPH Project incorporates the same considerations for developing a BCP for this wind farm.

Brolga compensation plan development

The Brolga compensation plan will be developed in consultation with DEECA, the Glenelg-Hopkins Catchment Management Authority and landholders participating in wetland restoration and management. The proponent proposes to form an expert group, including DEECA representatives to guide the BCP implementation. This is in line with other approved wind farm BCPs (e.g. Golden Plains Wind Farm).

The detailed plan will be developed in accordance with the relevant condition in the Incorporated Document that accompanies the planning scheme amendment. Endorsement of the BCP would be sought from the relevant authorities, such as the Minister for Planning, under secondary consent.

as a secondary consent. This section includes discussion on items to include in the BCP. In summary, the plan will include:

- Aim and objectives.
- Monitoring, evaluation and reporting framework.

- Incorporated site management plans used to inform landholder agreements.

BCP aim and objective

The BCP aim is to compensate each modelled mortality to ensure no net loss of individuals from the Victorian Brolga population. Loss of adults has the greatest impact on the population. Predicted 0.21 Brolgas would collide annually at 95% avoidance rate for the Project. The BCP needs to add one juvenile for approximately every two years of the Project operation to compensate for the predicted collision mortality. This can be achieved by wetland restoration and management that increases the number of chicks fledging, which recruit as breeding adults into the Victorian Brolga population.

Therefore, for 30 years of operation, the BCP objectives are to:

> Add 15 juveniles to replace estimated 7 individuals removed from the population due to predicted collision impacts of the Project operations. This will be achieved by restoring and/or managing breeding habitat that results in breeding pairs fledging additional young.

The BCP may include additional objectives related to selection, management and monitoring of selected compensation sites.

Project BCP feasibility – wetland restoration and management

High rainfall years in Victoria in 2010–2011 and 2021–2023 have increased suitable Brolga breeding habitat throughout their south-west Victorian range. Flock counts after these years have recorded higher than average (>10%) juveniles indicating the increased wetland habitat resulted in higher than average number of chicks fledging.

Restoring and managing wetlands to return flows and water holding capacity is known to increase the amount and suitability of breeding habitat for Brolgas (NGT 2023; Herring 2018). Such restoration can attract breeding pairs and nesting (NGT 2023) and successful fledging (I. Veltheim pers. obs. 2010, 2011). Brolgas can attempt to breed and hatch chicks within 1-2 years after wetland restoration (NGT 2022; I. Veltheim pers. obs. 2010) and chicks can successfully fledge when appropriate water levels are maintained for approximately 6 months (Herring 2017) to support Brolgas from nest building to chick fledging.

Such fast responses of Brolga nesting attempts are likely to occur when wetland availability is limited and breeding suitability poor at or near known breeding areas, for example in drier than normal years. Young pairs (2–3 years old) looking for nesting sites are most likely to find new, restored wetlands and attempt breeding. Young birds recruiting into the population are likely to take longer (3–5 years) than adults for their first breeding attempt and to successfully fledge chicks (I.Veltheim pers. obs. 2010, 2022).

The BCP needs to implement a wetland restoration and management program to successfully fledge 15 chicks in 30 years of the Project's operational life.

Currently no systematically collected data exists on what factors contribute to a wetland successfully fledging a chick, how and why fledging success varies between years. Some Brolga are successful every year (I. Veltheim pers. obs. 2024, based on annual landholder records), others are successful once every few years and some rarely successfully fledge chicks.

Many factors at site-based scale that contribute to high breeding success are unknown, such as the experience of the breeding pair, predation and water holding capacity. However, the south-west Victorian flock counts after years of average to higher than average rainfall indicate that more chicks fledge when there are more wetlands and when they retain water for the whole breeding season (approximately 6 months to allow nest building to chick fledging). Greater number of two-chick clutches also successfully fledge in such years (e.g. Veltheim et al. 2019)

The feasibility of the Project BCP is therefore based on assumptions and some information known to contribute to breeding success (Herring 2018, Veltheim et al. 2019). The BCP will have higher likelihood of achieving the objective by including these factors into the plan and wetland management actions.

- Water levels maintained at suitable levels for approximately 6 months, or until chick fledges.
- Wetland contains dense emergent vegetation.
- Sites consist of a:
  - Single large wetland; or
  - Wetland complex: large and smaller wetlands or multiple smaller wetlands. Where feasible, wetlands complexes should include wetlands of varying depths to maximise the suitability of wetlands for nesting with varying rainfall years.

The feasibility of the BCP to successfully fledge 15 chicks in 30 years of the Project operational life assumes the following:

- No Brolgas breed successfully in the first 5–7 years of the program.
  - Includes time to engage a delivery partner to implement the BCP, find suitable site, engage in DEECA, expert team and landholder consultation, and formalising landholder agreements.
  - Includes wetland habitat time to fully restored hydrological regime and sufficient emergent aquatic vegetation for nesting material and cover.Assumes that Brolgas will find the wetlands within 1-3 years of restored hydrological regime and vegetation cover, based on information from restored wetlands in south-western Victoria.
  - Considers the higher likelihood that most restored wetlands will be settled by young adults of breeding age recruiting into the population (2–4 years old) rather than older adults with established breeding wetlands and home ranges. Young, less experienced pairs may take longer to breed successfully compared with older, more experienced, pairs.Considers the above variability and uncertainty of wetlands incorporated into home ranges by established older adult pairs and younger adults searching for nesting wetlands. If a wetland is used for nesting by an established older pair, successful breeding could occur within 1–2 years of completing restoration works.
  - Adult lifespan is approximately 10 years (based on annual DEECA flock observations of banded Brolgas)
  - Assumes likely 1 year of no breeding each 10 years, assuming loss of one individual from a pair, and re-pairing or new pair establishing a nest site.
- Breeding success between pairs and breeding sites are highly variable. The plan considers an average of 4.5 chicks assuming four scenarios (noting these are not based on data, but represent some possible variability in breeding success per pair at different sites, and represent observations of breeding success at some south-western Victorian Brolga breeding sites):
  - 1 chick every year.
  - 1 chick every second year.
  - 2 chicks over 10 years.
  - 1 chick over 10 years.

This would add up to 18 chicks from 4 sites over 10 years, equivalent to 18% breeding success. The Brolga flock counts in south-west Victoria have recorded an average of 10% breeding success over a 10 year period, with 17%–18% in higher rainfall years. A managed wetland could be assumed to be as productive as non-managed wetlands in higher rainfall years. An average of 4.5 fledged chicks over a 10 year period is therefore considered to be a reasonable estimate in the absence of systematic data on individual and landscape-scale breeding success.

If we assume that no Brolga breed in the first 5–7 years of the BCP implementation, this would total 10.5–11.25 fledged chicks (11–12 rounded up) from a single site within a 30 year period. The Project requires 15 fledged chicks to compensate for modelled losses. Based on the assumptions above, two sites comprising of a large wetland or a wetland complex would produce 22–24 fledged chicks. Given the current lack of understanding and uncertainty about what contributes to successful breeding and the number of chicks fledging over a given period of time from any one wetland or breeding home range, the BCP should include a minimum of 2 wetland and/or wetland complex sites to compensate for the predicted losses due to collisions. The BCP will implement monitoring and adaptive management to revise and adjust the number of sites to achieve the compensation target if required.

A large proportion of shallow wetland habitat suitable for Brolga breeding has been modified and drained in south-west Victoria. This includes 79% of shallow marshes and 14% of freshwater meadows throughout this region (Corrick 1982). Thus, the western Victorian region includes great potential for wetland restoration and it is highly likely that suitable sites for the Project BCP can be sourced. Wetland restoration in the region to date, including for wind farm BCPs provides high confidence for finding landholders willing to participate in such a program (e.g. Dundonnell Wind Farm BCP, Golden Plains Wind Farm BCP). Cost-effective restoration options such as blocking drains have been shown to be successful and feasible.

Criteria for BCP wetland selection

Criteria to meet the breeding ecological requirements of the Brolga should be followed when selecting suitable BCP wetlands, to maximise the likelihood of meeting the BCP objectives to successfully fledge 15 Brolgas over 30 years. These criteria will be developed in consultation with DEECA and species experts and with experts with Brolga breeding wetland restoration track record.

The criteria should include (with relevant criteria as outlined in the Golden Plains BCP and Willatook BCP; and additional criteria from published literature):

- Wetland type (historical or current) – known suitable breeding habitat such as shallow marsh or freshwater meadow.
- History of drainage and alteration.
- Breeding records at, or within proximity to, the site (e.g. sites with records within the last 40–50 years with a likelihood of breeding established at such sites). Wetlands within 2 kilometres of a record are likely to be most successful in attracting breeding pairs, based on Brolga breeding home range Brolga movement distances (Veltheim et al. 2019). Wetlands within approximately 10 kilometres of a known breeding pair are likely to attract the new breeding pairs (immature birds once they reach breeding age) – due to the male young of breeding pairs establishing nesting territories near their natal wetland (I. Veltheim pers. obs.).
- Wetland size and landscape context – one large wetlands, or several smaller wetlands are likely to increase breeding success. Restoring a wetlands within 1–2 kilometres of existing known breeding wetlands or restoring wetlands near historical records as described above is likely to maximise breeding success.

- Wetlands within 20–40 kilometres of flocking areas are likely to attract new breeding pairs (immature birds once they reach breeding age), as immature birds pair up at flocking areas and will search for wetlands to set up a breeding territory.
- Adequate catchment water yield to ensure regular (at least one in every three years) substantial filling given expected annual differences in future rainfall (to take account of future climate change projections).
- The availability of any artificial top-up water supplies, if deemed necessary to provide suitable conditions to maximise breeding success.
- Infrastructure to allow for adding or releasing water to maintain optimal water levels for successful breeding.
- The ability of the wetland to hold water for approximately 5–6 months, to support pairs from nest building, to incubation and chick fledging.
- The compatibility of land uses surrounding the wetlands with requirements for Brolga breeding, including water supply, catchment inputs, disturbance levels and structures that may impact survival (e.g. transmission lines, fences).
- Landholder considerations, such as willingness to set aside wetland and water for conservation purposes, and to provide on-title security (e.g. s. 69 agreement) for the life of the project.

Hydrological considerations

The hydrological considerations will be assessed by an expert, such as a hydrologist, for each potentially suitable wetland restoration site to establish that each site fulfils the criteria required to optimise Brolga breeding success. This will include assessing catchment yield, depth and length of inundation based on the wetland characteristics and annual rainfall variability.

Land tenure and security

An agreement between the landholder and DEECA will be required to protect and manage the BCP wetland/s as Brolga breeding sites. This could be achieved through section 69 of the *Conservation Forests and Lands Act 1986* and include a site-specific management plan that all parties agree to. The agreement will be on-title with a continued obligation to implement BCP for the entire plan time period in the event the property ownership is transferred.

Monitoring, evaluation and reporting

The Brolga guidelines require monitoring the implementation of an offset measure, where there is no current information about its effectiveness. A monitoring, evaluation and reporting framework will be developed for the BCP in consultation with DEECA. The framework should allow adaptive management in response to monitoring findings to ensure the BCP aim and objectives are met. Annual reporting and periodic reviews (e.g. every 5 years) should form part of the framework to evaluate if the BCP is meeting its intended objectives and to establish what actions may be required to review and adjust the BCP if required.

6.5 Operational phase monitoring, impact mitigation and adaptive management

Risk of collisions and disturbance to Brolgas is largely avoided through the turbine- and powerline-free buffers around known and most likely suitable habitat Brolgas may use within 3 kilometres of the Project. Some residual risk remains, which is estimated through the collision risk modelling exercise. The PVA modelling quantifies population level impact based on the CRM results, whereby the PVA outputs can be used to offset modelled mortalities for a net-zero population impact as required through the Brolga guidelines (DSE 2012) assessment process.

Monitoring to assess the Project impacts on Brolgas and mitigation to compensate impacts will consist of three distinct regimes of monitoring:

Environmental construction management plan

- Construction phase monitoring.

Bird and Bat adaptive management plan

- Operational phase monitoring – to assess collision and disturbance impacts:
  - Mortality monitoring in areas with wind farm infrastructure (turbines and powerlines).
  - Occupancy monitoring at breeding sites and suitable breeding wetlands.
  - Occupancy monitoring of all suitable wetlands that could support flocks during the flocking season.

Brolga compensation plan

- Brolga compensation plan monitoring – to monitor fledging success to assess BCP effectiveness in compensating any predicted losses from collision impacts.

Construction and operational phase monitoring will be undertaken as part of bird and bat adaptive management plan and as described in that plan. The Biosis Draft bird and bat adaptive management plan (BBAMP) for Kentbruck Green Power Hub (Biosis 2024) outlines triggers for reporting and provides a framework for adaptive management in response to monitoring and reporting. The BBAMP mortality monitoring findings for Brolga relate directly to the BCP, its aims and objectives and its requirements for compensation measures dependent on annual mortality estimates. The BCP will include a description of the mechanisms that link between the BBAMP and BCP, including how findings of monitoring and of triggers prescribed in the BBAMP will be used for updating the BCP based on these findings as required.

The BBAMP outlines:

- Measures for monitoring turbine and powerline impacts of the operational wind farm for Brolga.
- Potential operational measures to minimise impacts on the Brolga.

Operational phase collision impact will be monitored through mortality monitoring, as is routinely required for operational wind farms (see Section 8 BBAMP).

The BBAMP contains a section describing, comparing and analysing potential operational project measures to minimise collision impacts on birds and bats (Section 7 BBAMP). The infrastructure-free habitat buffers avoid and minimise collision risk around the important habitats identified in the Brolga impact assessment. Residual risk has been quantified through estimating remaining potential collision risk (Section 5.5). The residual risk assessed by CRM incorporates estimated flights beyond the buffers and flights during the seasonal migration between breeding and non-breeding areas. Any residual risk representing estimated losses of Brolgas from the population will be compensated through wetland management to achieve fledging of additional Brolgas to recruit into the population as breeding adults.

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Appendix 1 Level Two Assessment results details

A.1.1 Aerial surveys – Brolga breeding season

A total of eight Brolga observations were recorded during the aerial surveys, with a total number of 20 birds seen. This included four breeding pairs with either fledged juveniles (<12 months old) or unfledged chicks. Two of these breeding pairs were observed at wetlands near Heywood/Heathmere and two near the Portland airport at Cashmore (Figure 8 Brolga breeding sites within 10 km of the Project). No Brolgas were recorded within the Project footprint.

All observations are listed below and shown in Figure 7:

30/11/2020

- 2 adults and 2 juveniles
- 2 adults and 1 juvenile
- 2 adults

4/12/2020

- 2 adults – standing next to a dam, no nest observed
- 2 adults and 1 juvenile – chick of 2020
- 1 adult – standing in wetland
- 2 adults and 1 chick – chick at foot, recently hatched
- 2 adults

A.1.2 Community and landholder liaison

Initial discussions and community consultations did not provide any data about Brolgas in the local area additional to what is contained in VBA and BirdLife Australia databases. Further discussions with landholders indicate Brolgas regularly occur within the agricultural land on the eastern and western parts of the Project area, Mt Richmond and near Cashmore. Locations of the landholder and community member observations are nearby existing database records (Figure 7 Brolga records within 10 km of the Project). Brolgas were also recorded at these locations during the Biosis surveys. Discussions with a local ornithologist indicate a number of breeding pairs are present.

Findings from these discussions from are summarised below:

Project area west (landholder), in the vicinity of Johnsons Road:

- Usually a pair present, and a group of three has been seen. Also often heard calling.
- Observations mostly in autumn and winter.
- Seen west and south between the land and the coast, observed on the cleared paddocks including top and bottom paddocks.
- Observations in late morning or early afternoon.
- Seen flying along the swamp, heading west most of the time. Also seen heading inland and across the pine plantation and calling from a south-east direction from the swamp.

Based on these landholder observations, a breeding pair is assumed to be present (Section 4.1.1)

Project area east (landholder), in the vicinity of Mt Kincaid Road, Gorae West:

- Property was cleared of native vegetation in the 1950s-1960s, ploughed and sown to pasture.
- Majority of the paddocks have been ploughed.
- Brolgas present, numbers vary from year to year.
- No breeding observed in over 35 years (no nests, no chicks). Landholder arrived in 1983, took control of the property in 1985.
- Has sown barley for two most recent years (autumn 2019, 2020) in one of the western paddocks (N.B. Biosis observed Brolga foraging in the barley paddock in 2020). Currently sown to rape and turnip and barley has self-sown amongst the rape in 2021. The area of this crop is 100-200 acres.
- Has observed cockchafer beetle grubs in his paddocks (N.B. Brolgas feed on the beetle grubs, I. Veltheim pers.obs.).
- Sees Brolgas fly in from south and south-east.
- Has seen Brolgas fly north to north-east from the eastern end of the property. Has not seen Brolgas fly north or west, or over the woodland habitats.
- Sees Brolgas move around, and not always in the western paddock. For example:
  - Saw none in September 2021 when rounding up sheep.
  - Observed a group of three between the shearing shed and the house on 26th October 2021, stating one was half to two-thirds the size of the other two. Upon further conversations, the landholder considered the smallest bird to be two-thirds of the size of the other two.

- Has observed and photographed Brolga near his house. Has seen Brolgas at this location in October-December 2020.
- Has found one Brolga dead under a powerline near the house, within the >35 years of owning the land.

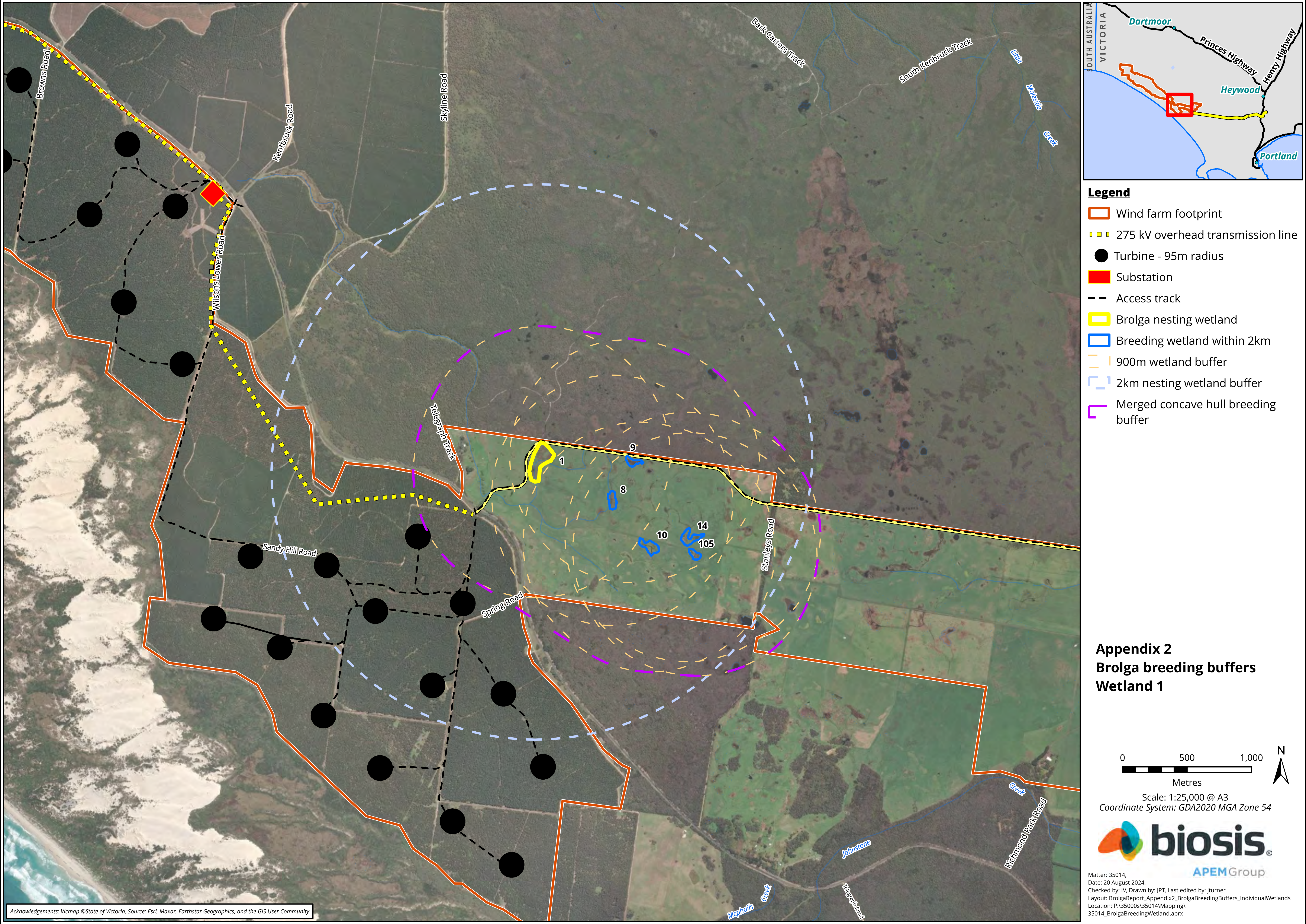
Project area east (landholder), north of Mt Kincaid Road, west of Blacks Road Gorae West:

- Has not seen Brolgas, but noted they would not be able to identify them.

Mt Richmond area (landholder), between Cashmore and Gorae West:

- Sees Brolgas on the property.
- Recorded breeding at a neighbour's property.

Appendix 2 Individual wetland buffer diagrams



Legend

- Wind farm footprint
- 275 kV overhead transmission line
- Turbine - 95m radius
- Substation
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 1

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

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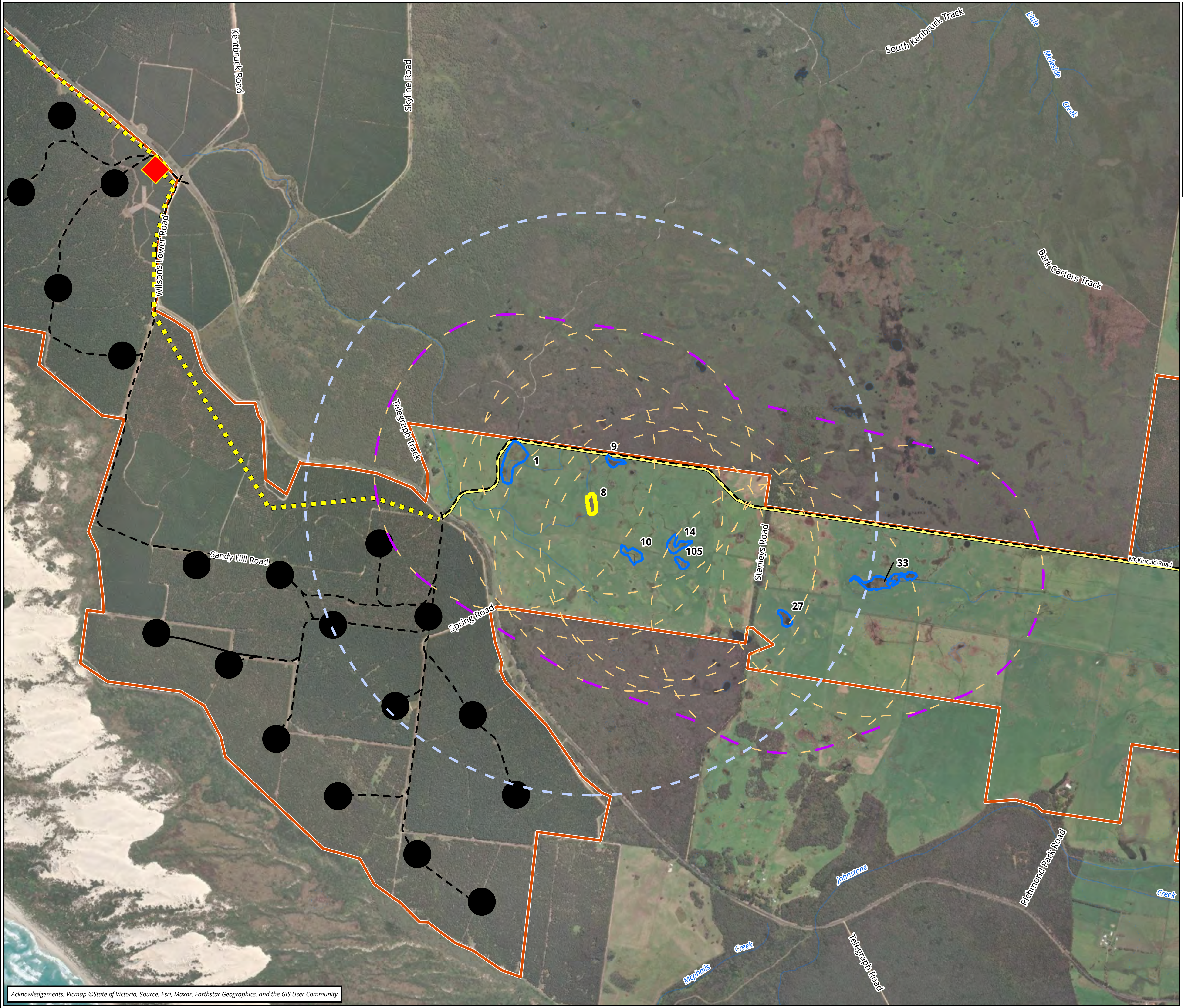
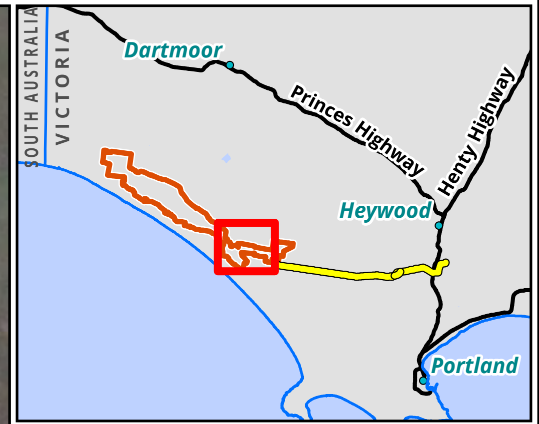
Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_Appendix2_BrolgaBreedingBuffers_IndividualWetlands
Location: P:\35000s\35014\Mapping\
35014_BrolgaBreedingWetland.aprx





Legend

- Wind farm footprint
- 275 kV overhead transmission line
- Turbine - 95m radius
- Substation
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 8

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

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Matter: 35014,
Date: 20 August 2024,
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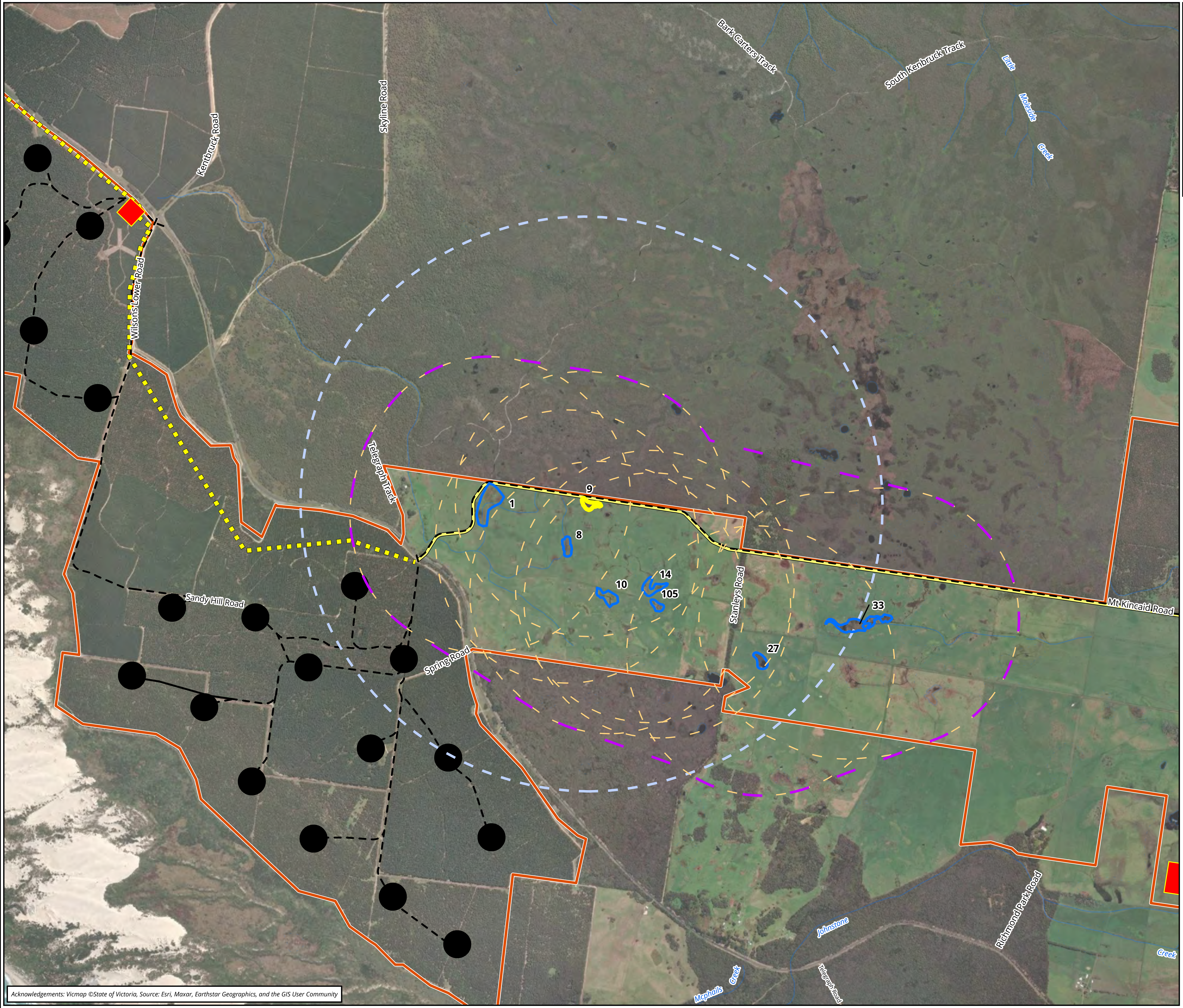

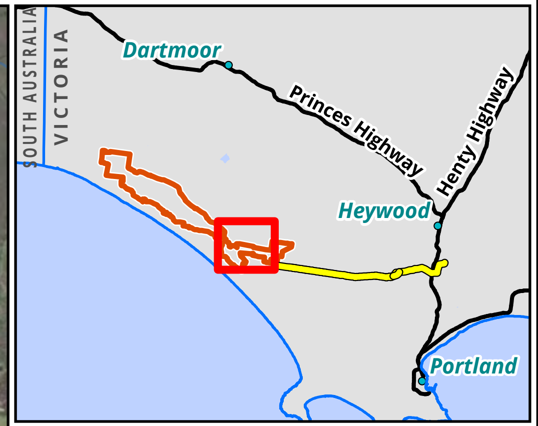

Legend

- Wind farm footprint
- 275 kV overhead transmission line
- Turbine - 95m radius
- Substation
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 9

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

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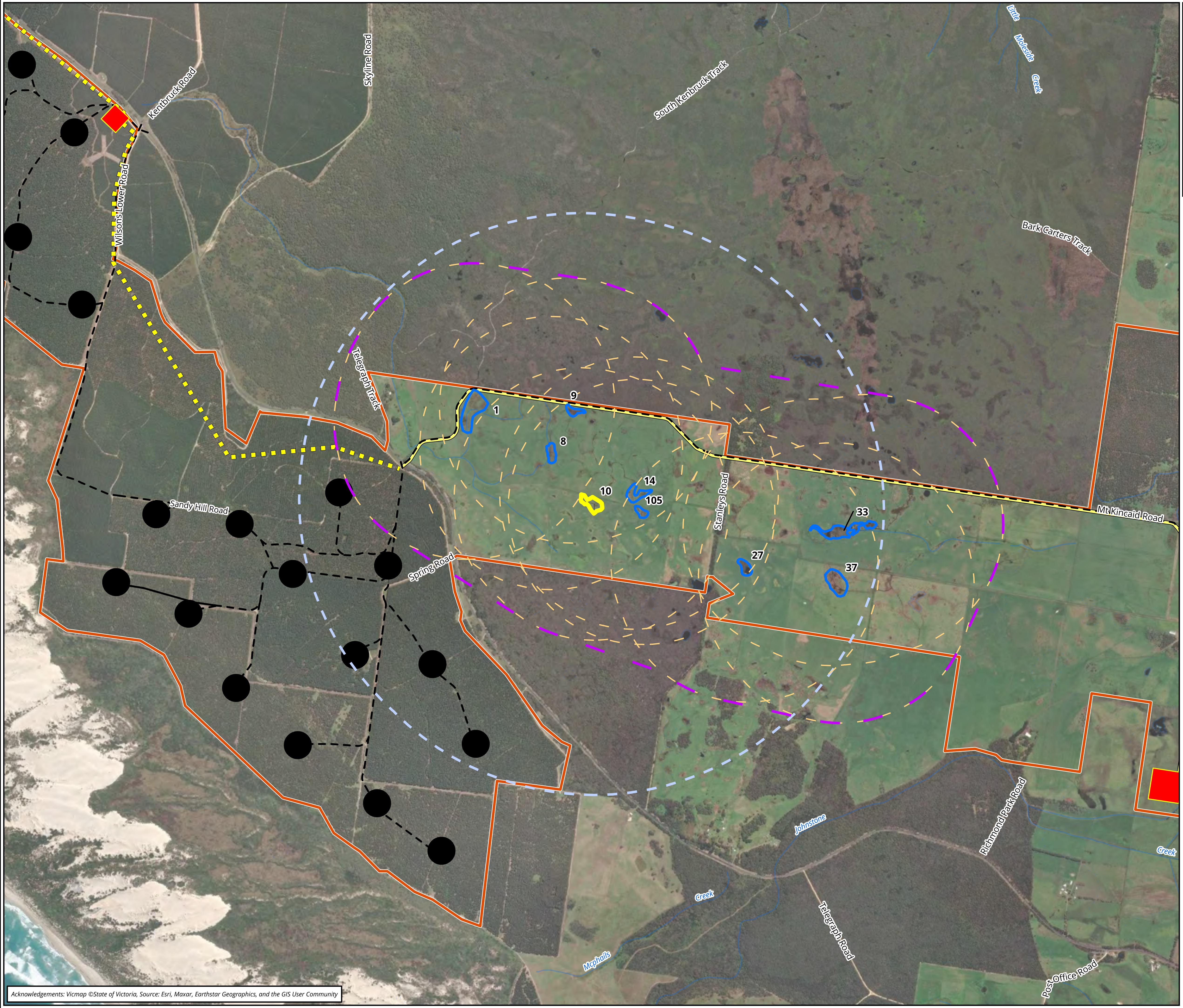

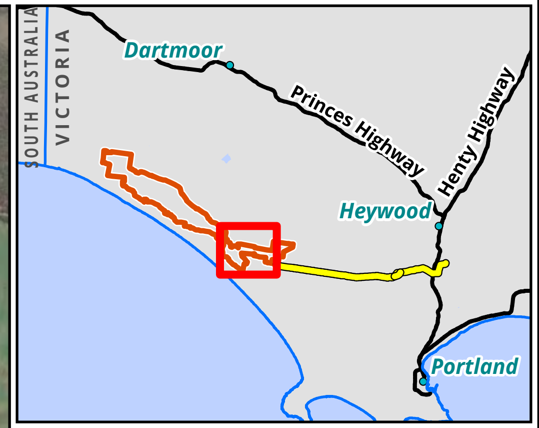

Legend

- Wind farm footprint
- 275 kV overhead transmission line
- 275 kV underground transmission line
- Turbine - 95m radius
- Substation
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 10

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

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Matter: 35014,
Date: 20 August 2024,
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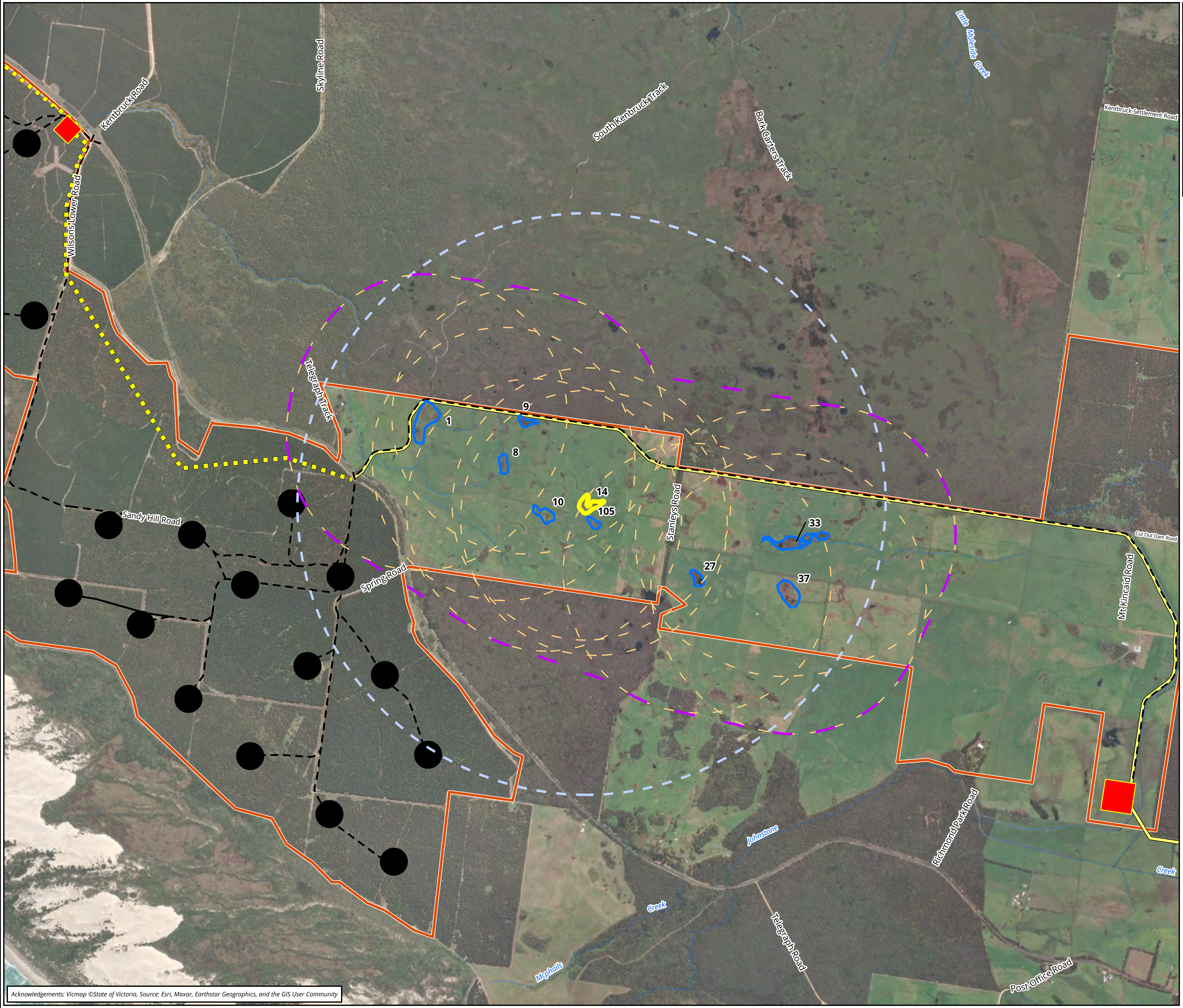

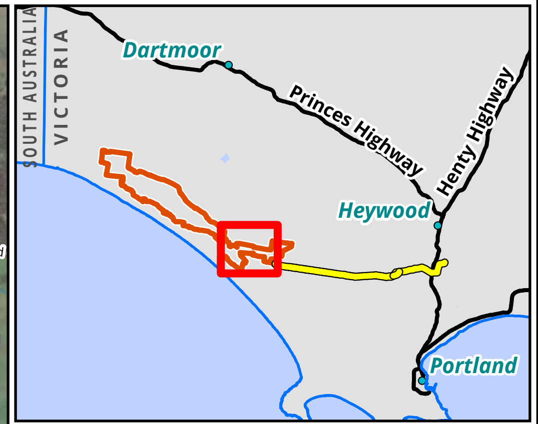

Legend

- Wind farm footprint
- 275 kV overhead transmission line
- 275 kV underground transmission line
- Turbine - 95m radius
- Substation
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 14

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

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Matter: 35014,
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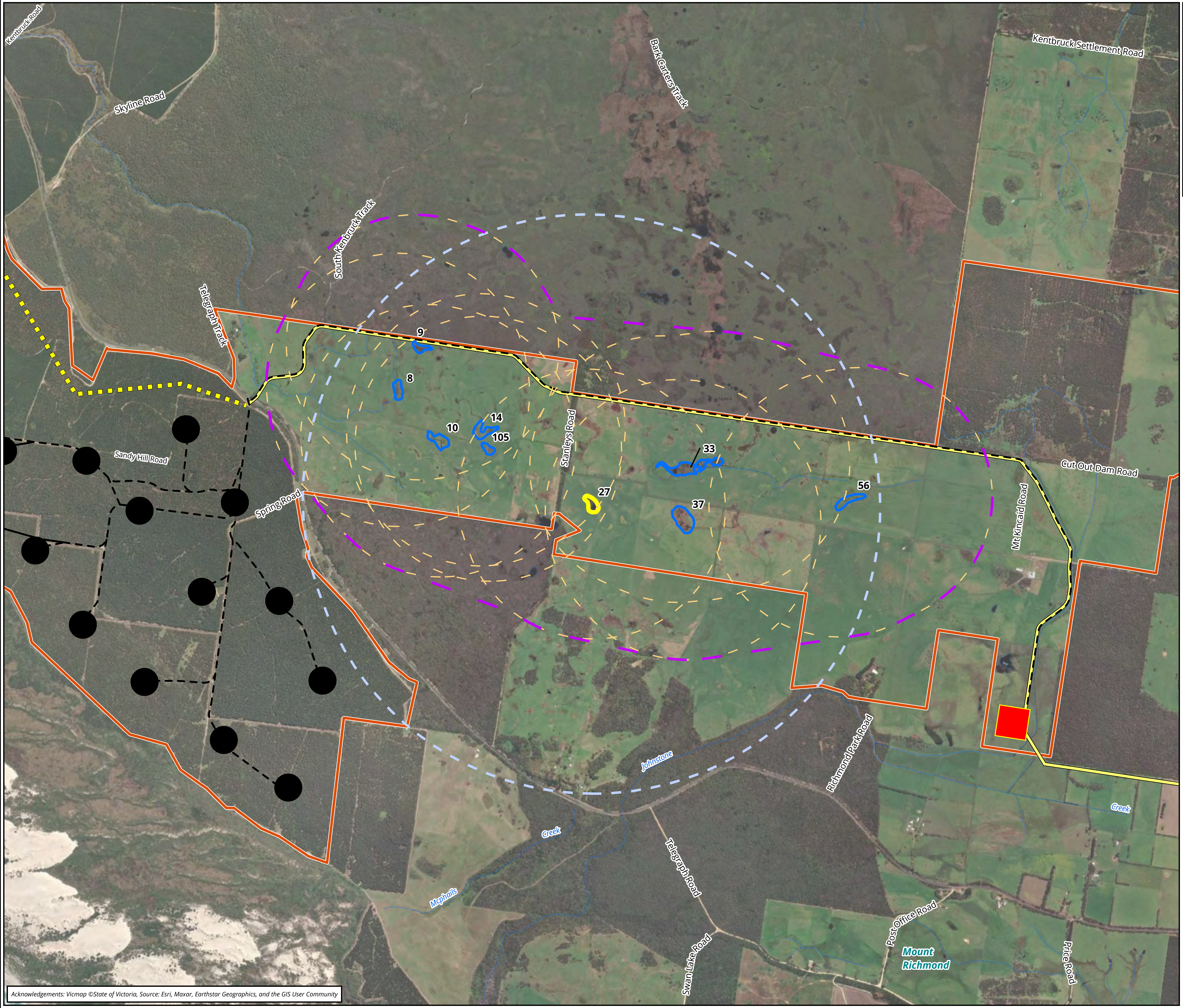

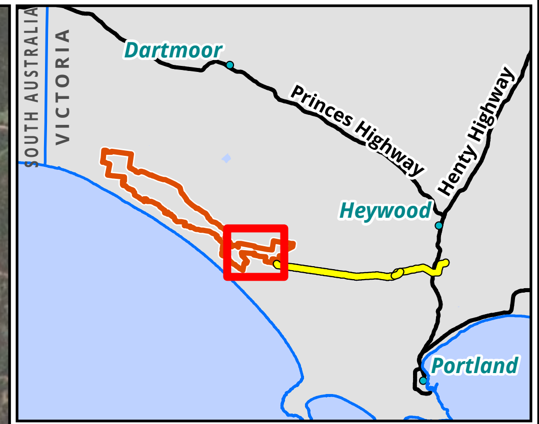

Legend

- Wind farm footprint
- 275 kV overhead transmission line
- 275 kV underground transmission line
- Turbine - 95m radius
- Substation
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 27

0 500 1,000

Metres

N

Scale: 1:25,000 @ A3

Coordinate System: GDA2020 MGA Zone 54

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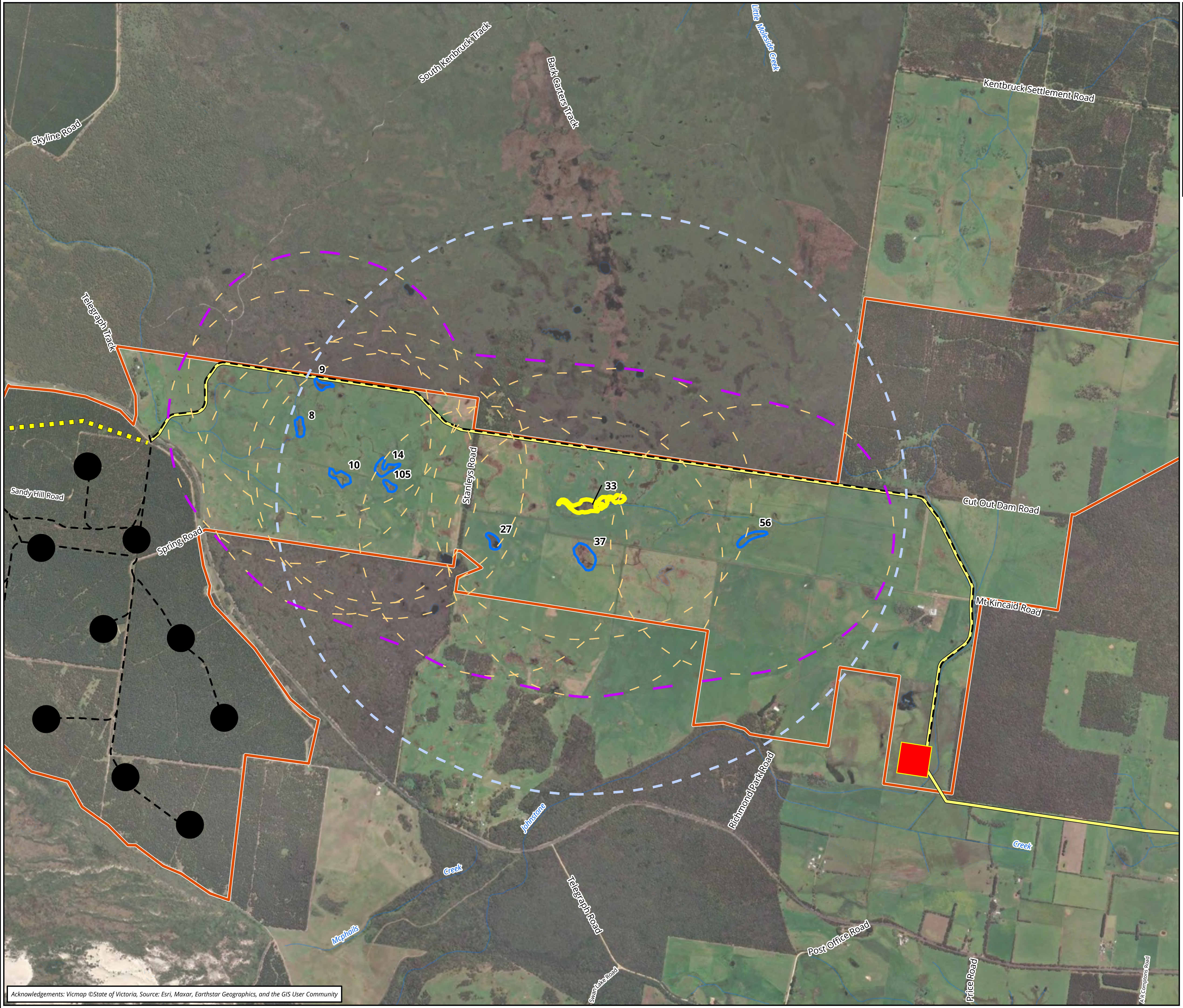

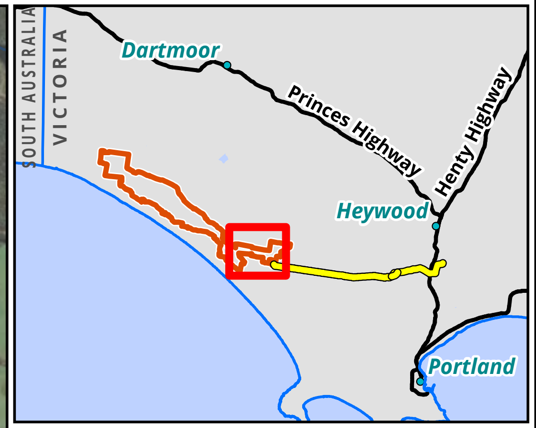

Legend

- Wind farm footprint
- 275 kV overhead transmission line
- 275 kV underground transmission line
- Turbine - 95m radius
- Substation
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 33

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
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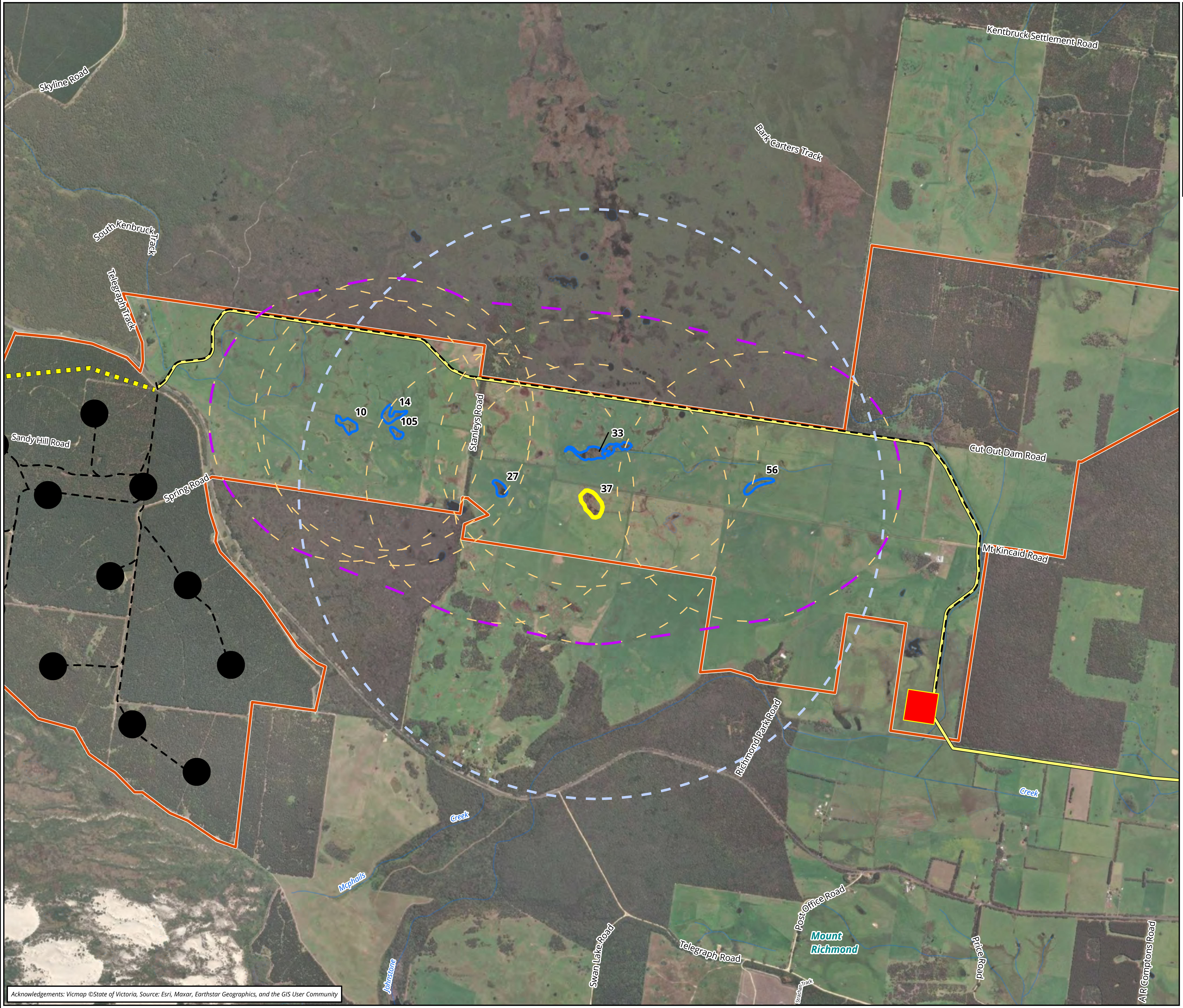

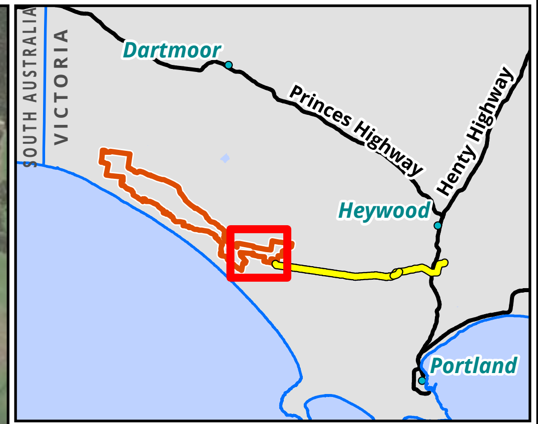

Legend

- Wind farm footprint
- 275 kV overhead transmission line
- 275 kV underground transmission line
- Turbine - 95m radius
- Substation
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 37

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

Matter: 35014,
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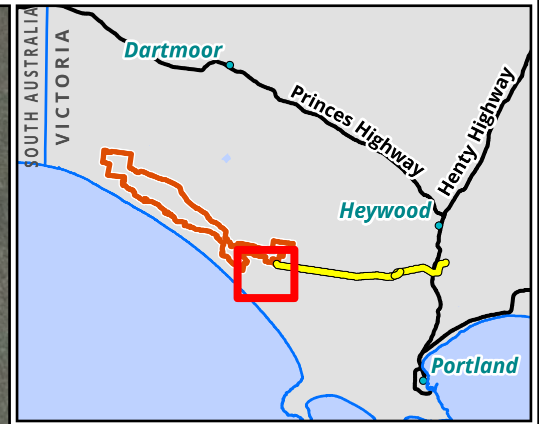

Legend

- Wind farm footprint
- 275 kV underground transmission line
- Turbine - 95m radius
- Substation
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 47

0 500 1,000

Metres

N

Scale: 1:25,000 @ A3

Coordinate System: GDA2020 MGA Zone 54

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
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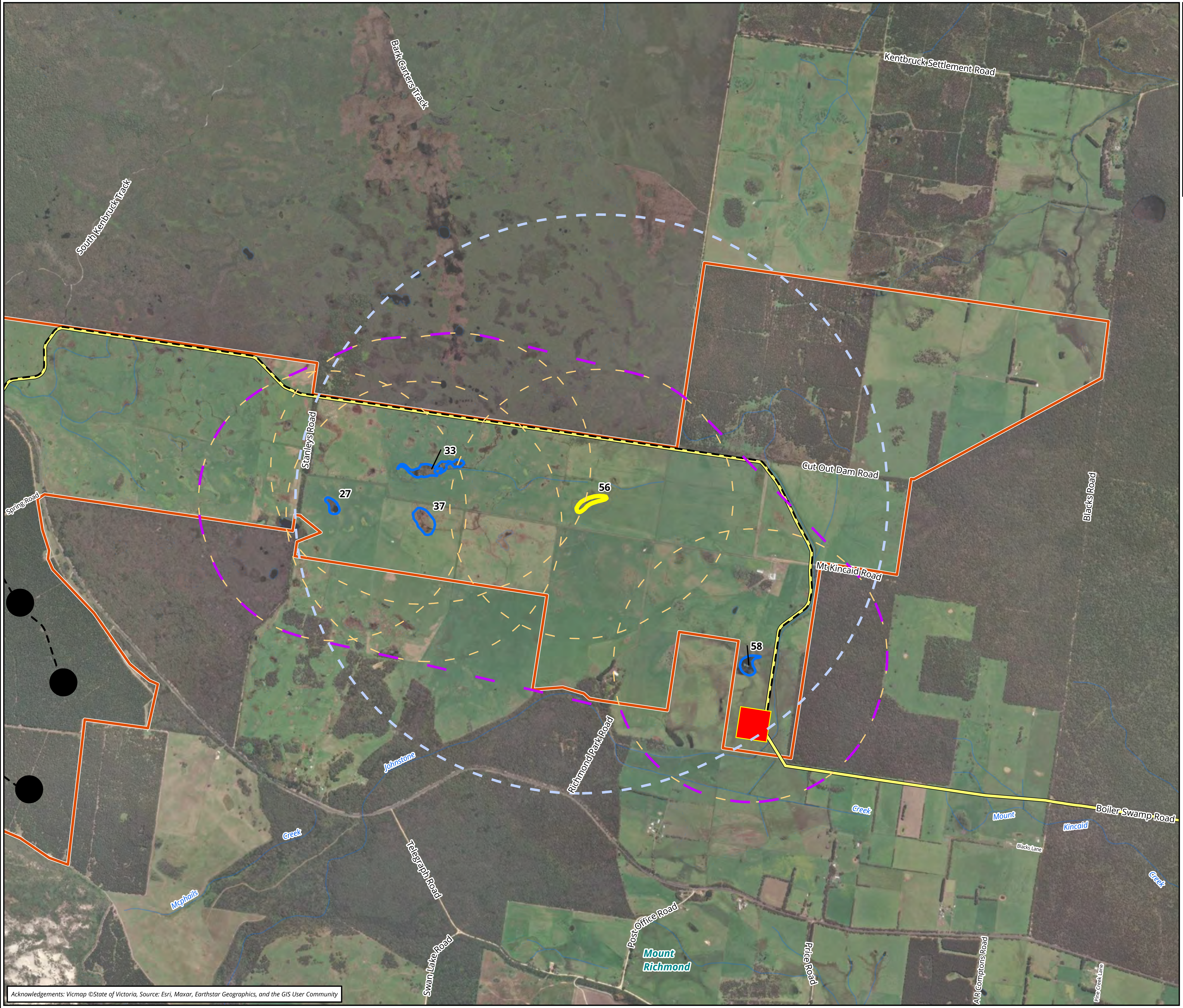

Legend

- Wind farm footprint
- 275 kV underground transmission line
- Turbine - 95m radius
- Substation
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 56

0 500 1,000
Metres

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

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Matter: 35014,
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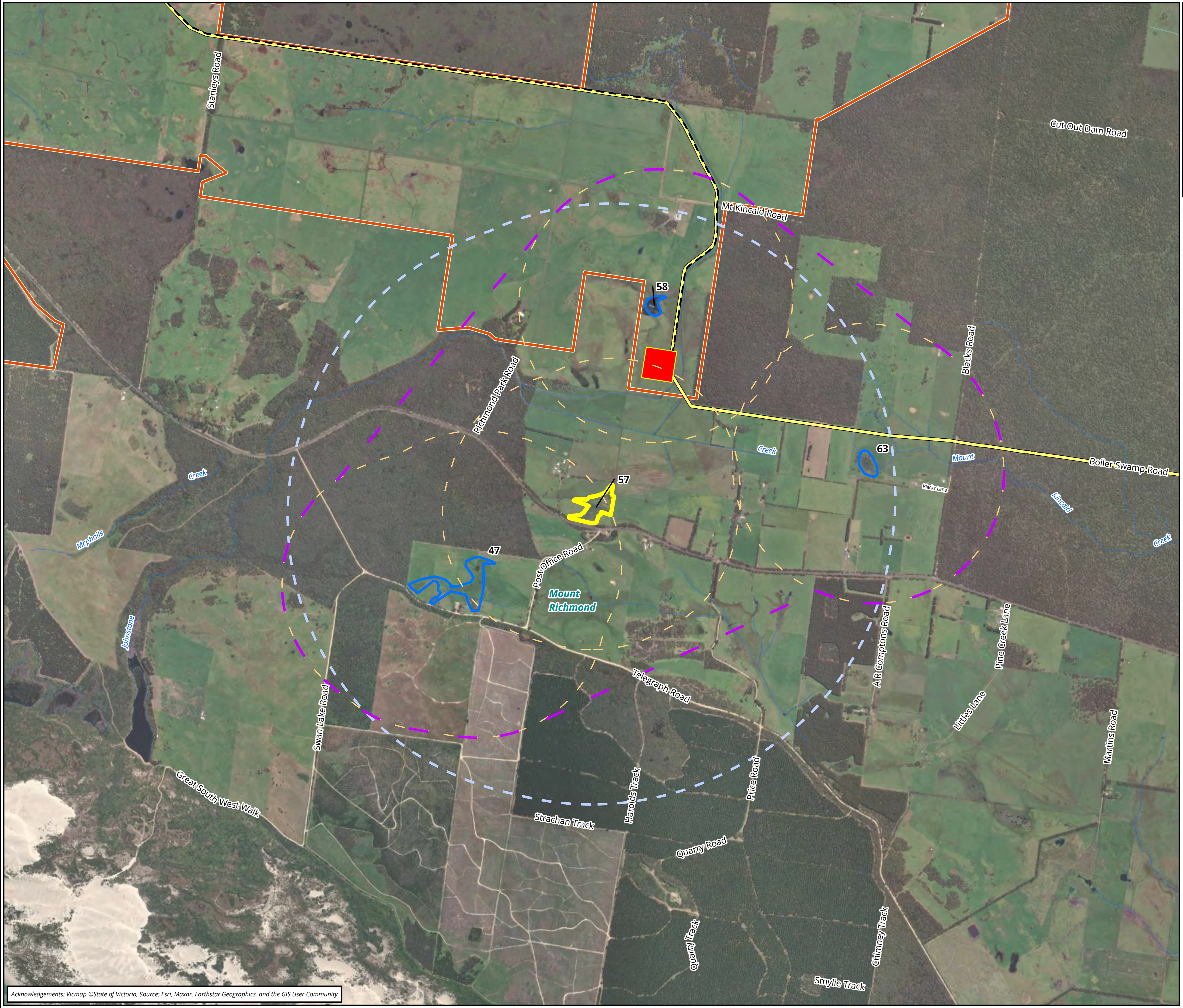

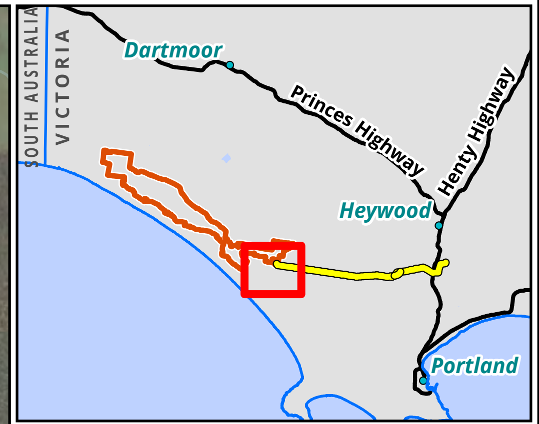

Legend

- Wind farm footprint
- 275 kV underground transmission line
- Substation
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 57

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

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APEM Group

Matter: 35014,
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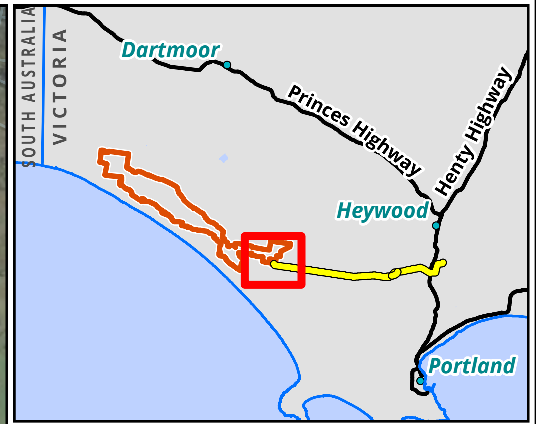

Legend

- Wind farm footprint
- 275 kV underground transmission line
- Substation
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 58

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

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APEM Group

Matter: 35014,
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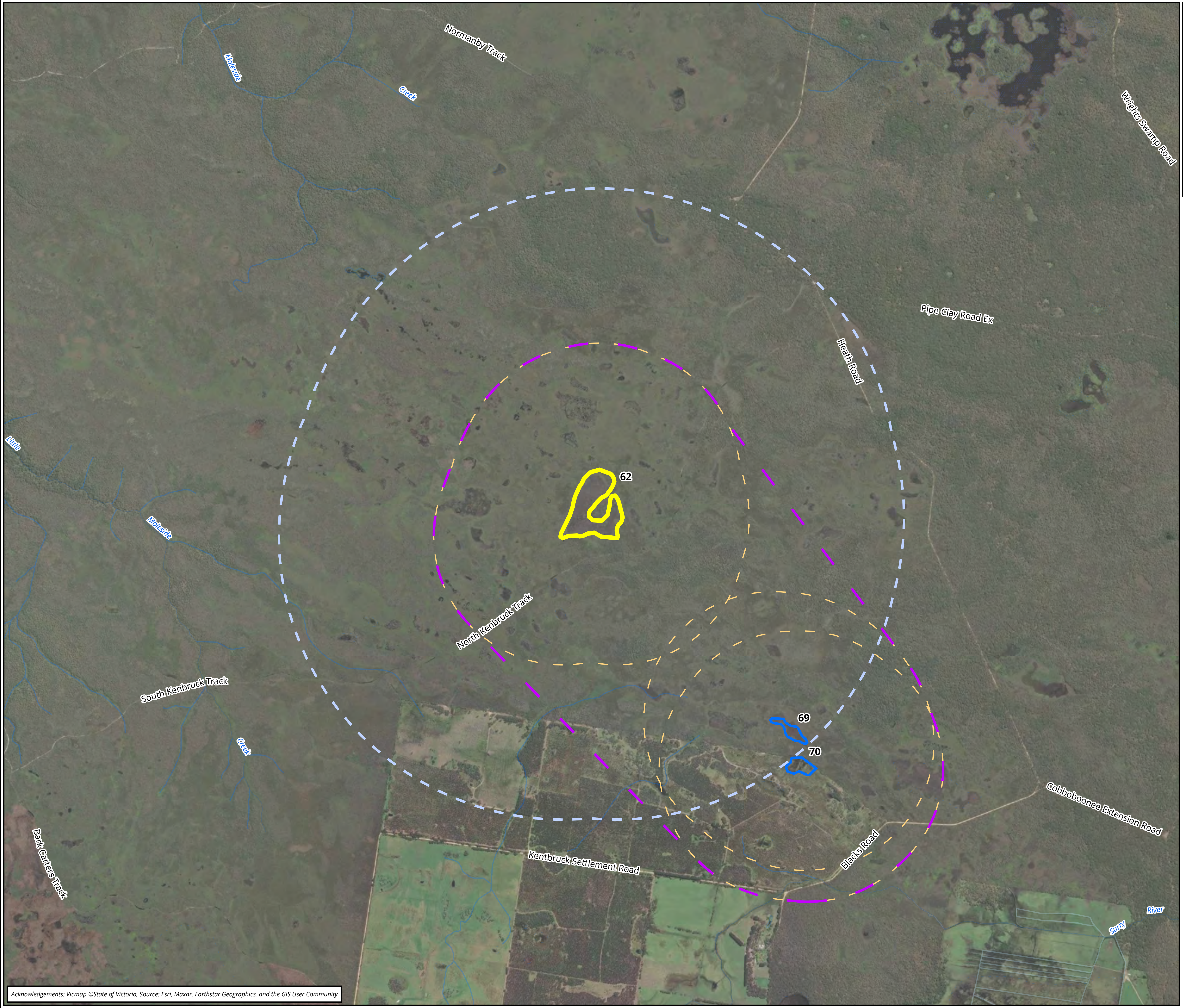

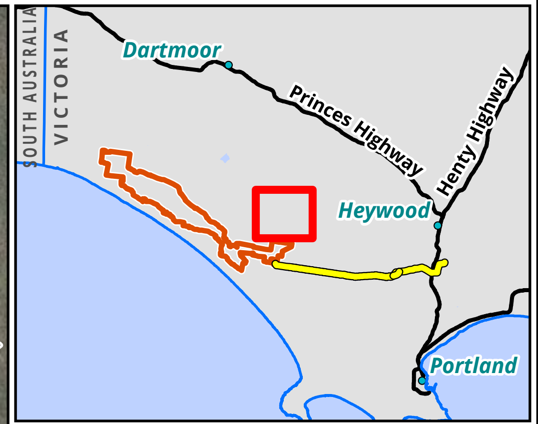

Legend

- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 62

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

Matter: 35014,
Date: 20 August 2024,
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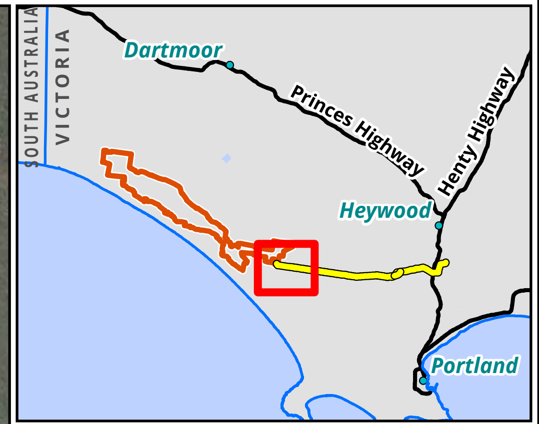

Legend

- Wind farm footprint
- 275 kV underground transmission line
- Substation
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 63

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
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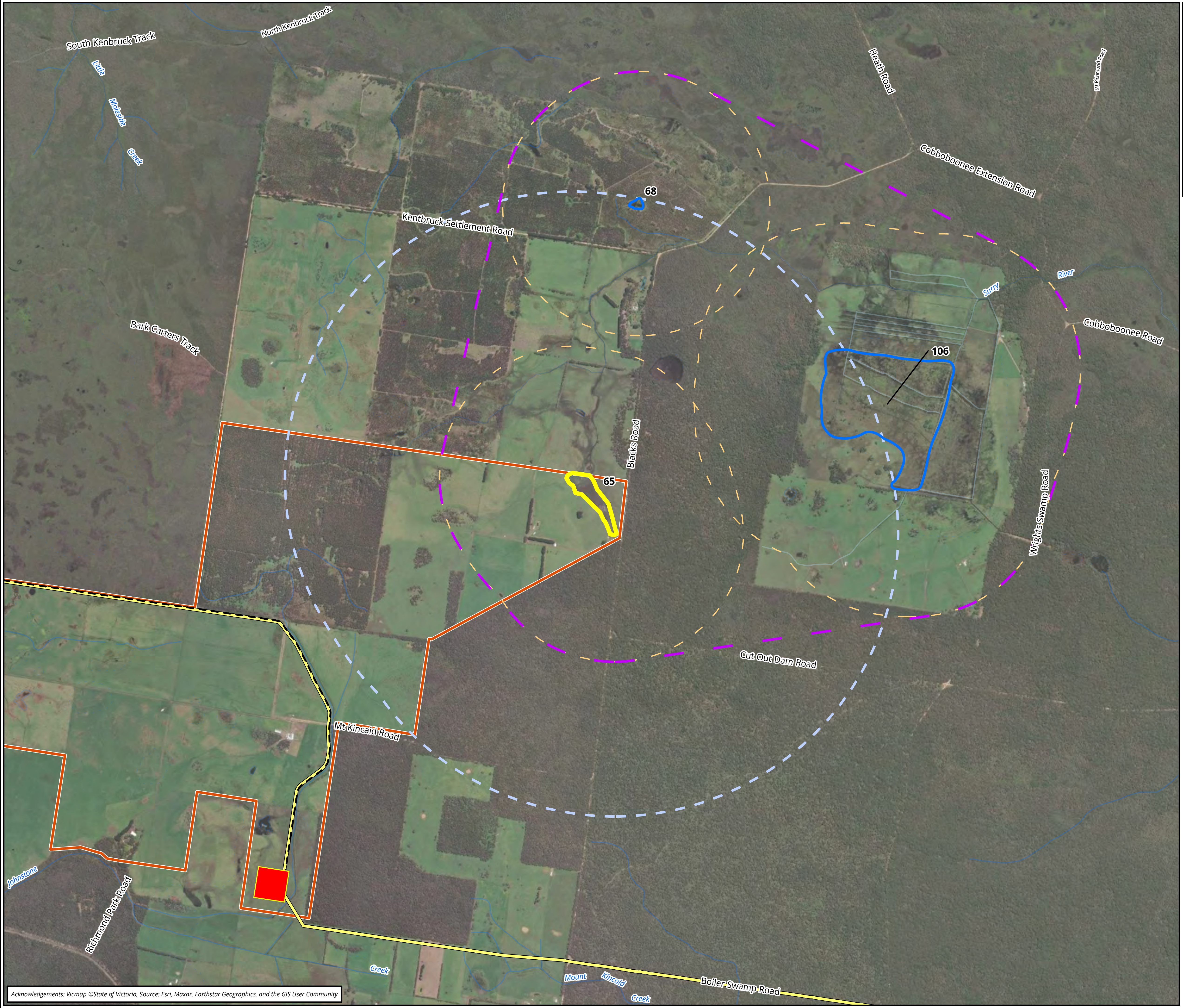

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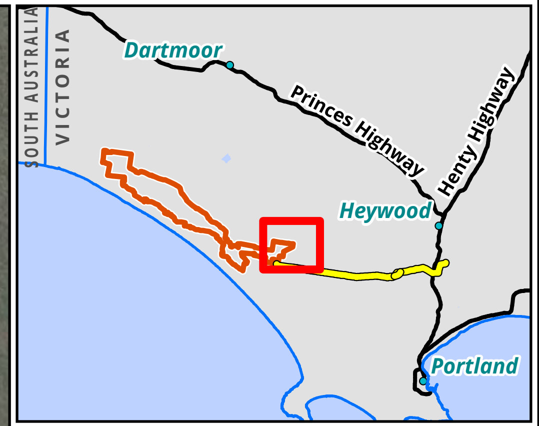

Legend

- Wind farm footprint
- 275 kV underground transmission line
- Substation
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 65

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

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Matter: 35014,
Date: 20 August 2024,
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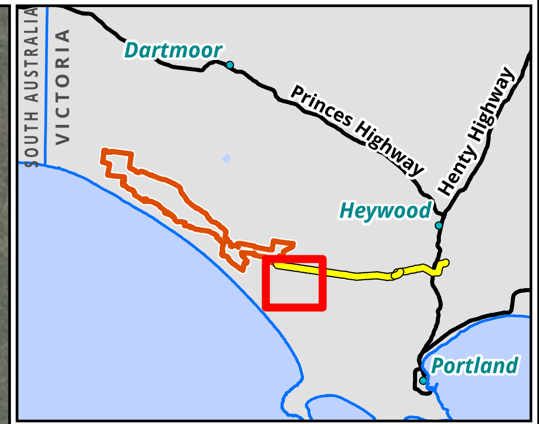

Legend

- Wind farm footprint
- 275 kV underground transmission line
- Substation
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 67

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
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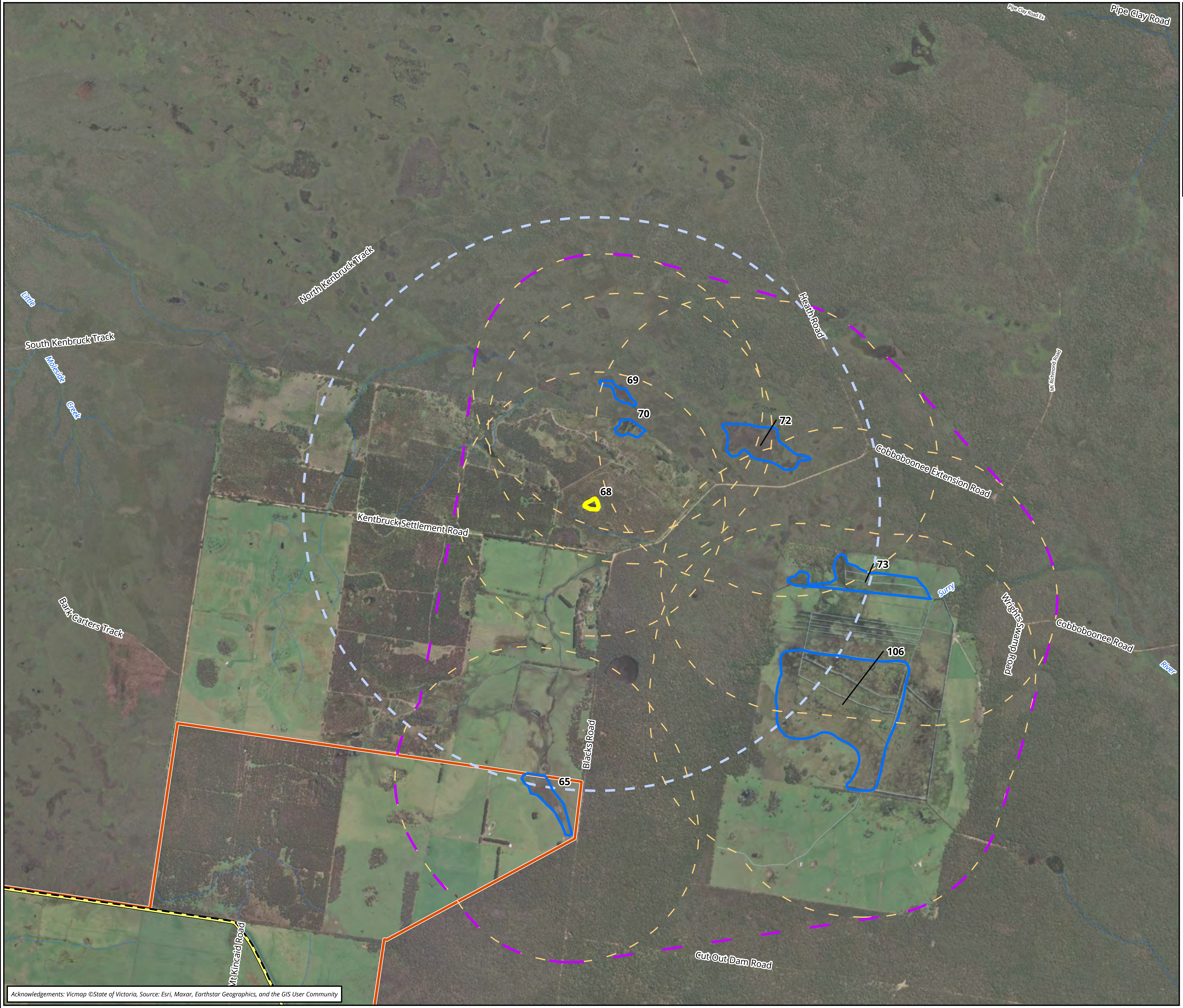

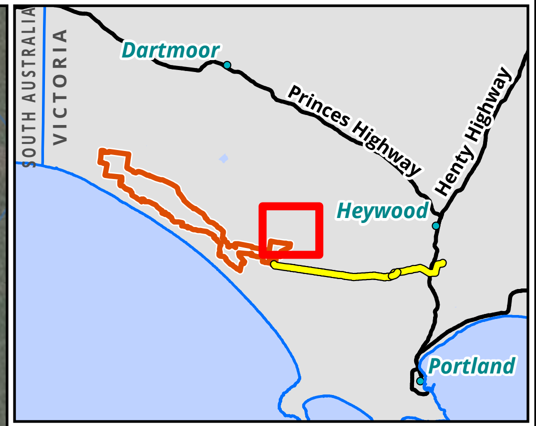

Legend

- Wind farm footprint
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 68

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

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APEM Group

Matter: 35014,
Date: 20 August 2024,
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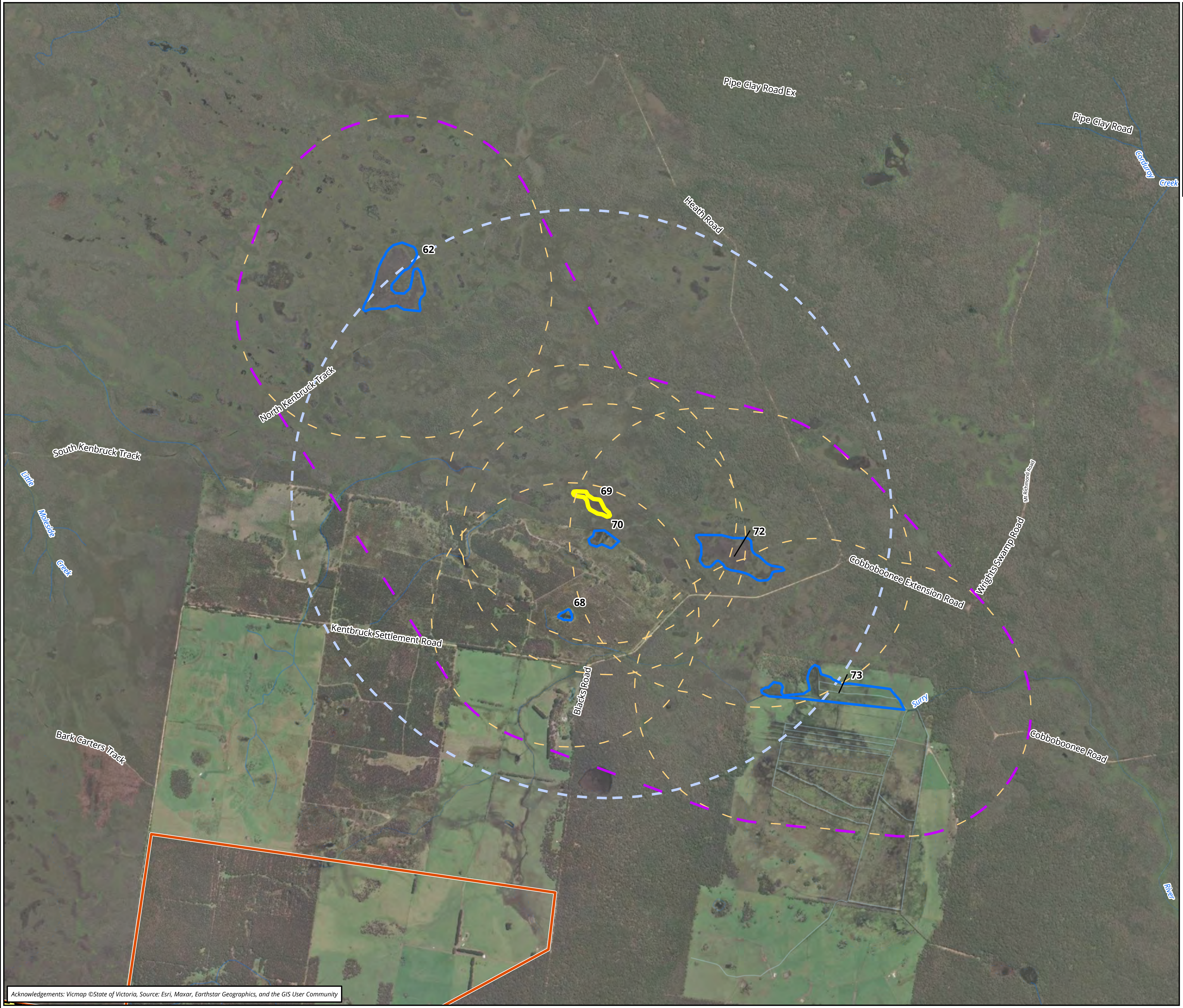

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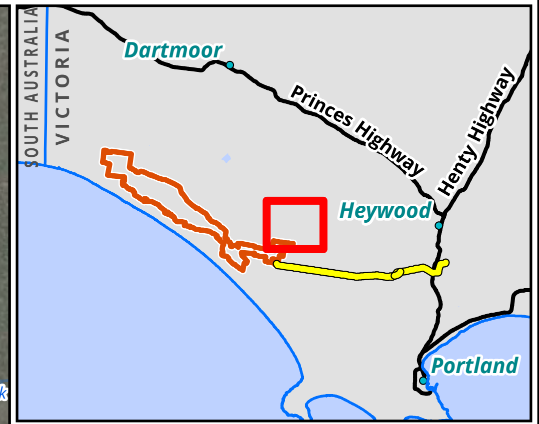


Legend

- Wind farm footprint
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

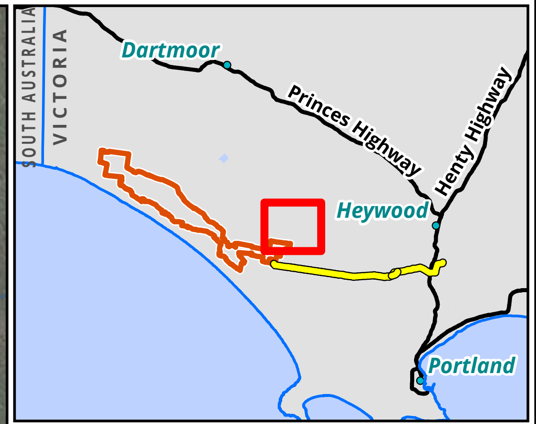
Appendix 2
Brolga breeding buffers
Wetland 69

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_Appendix2_BrolgaBreedingBuffers_IndividualWetlands
Location: P:\35000s\35014\Mapping\
35014_BrolgaBreedingWetland.aprx

Acknowledgements: Vicmap ©State of Victoria, Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Legend

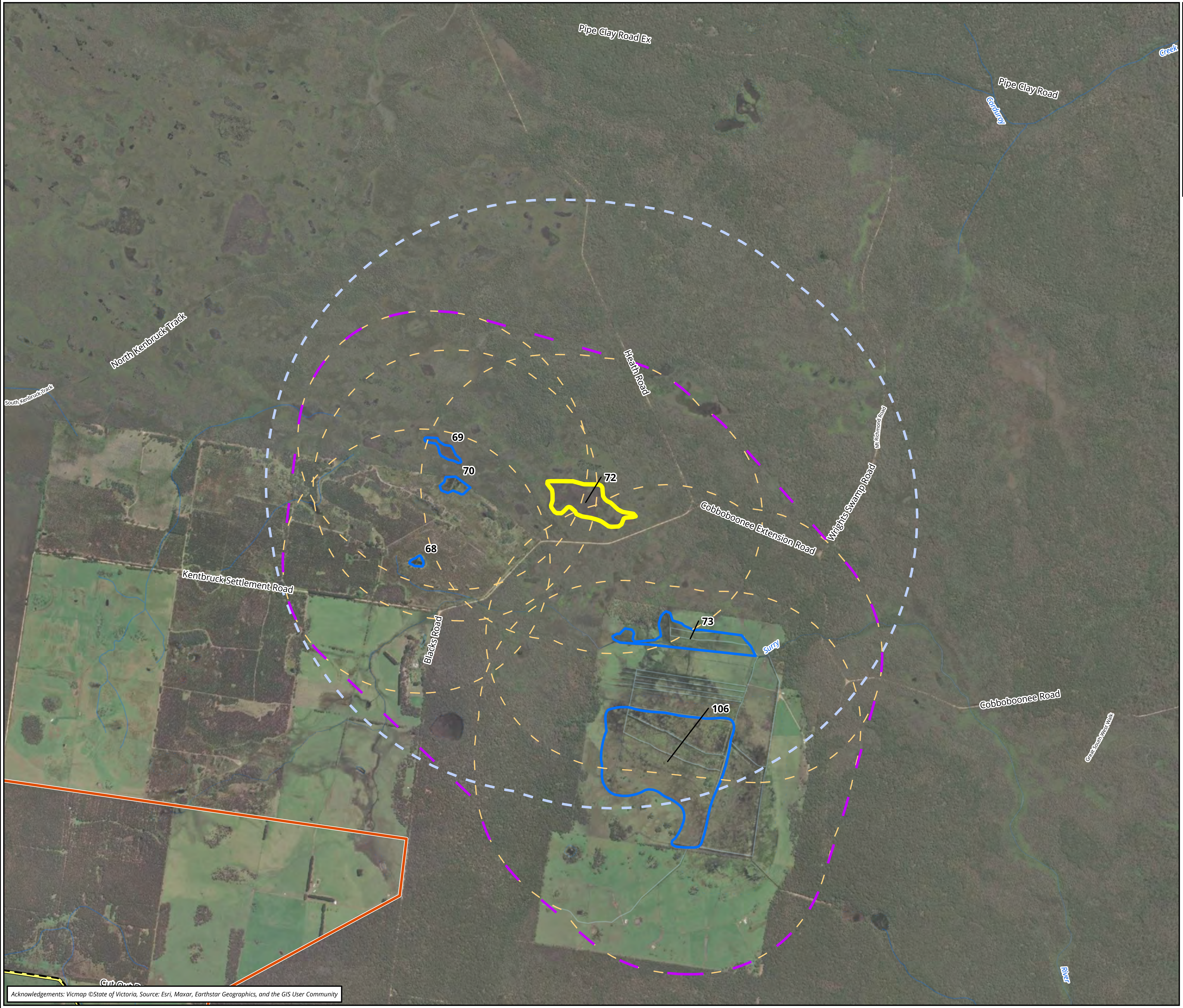
- Wind farm footprint
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

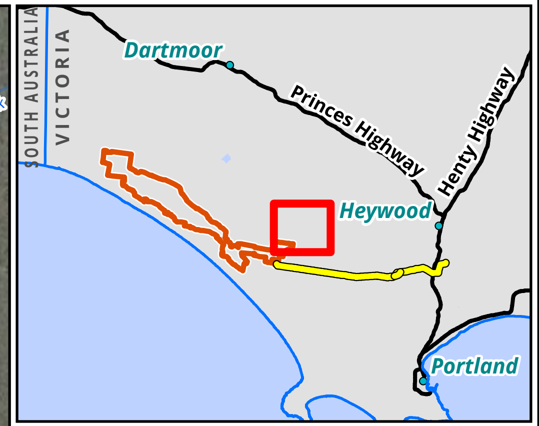
Appendix 2
Brolga breeding buffers
Wetland 70

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_Appendix2_BrolgaBreedingBuffers_IndividualWetlands
Location: P:\35000s\35014\Mapping\
35014_BrolgaBreedingWetland.aprx





Legend

- Wind farm footprint
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 72

0 500 1,000

Metres

N

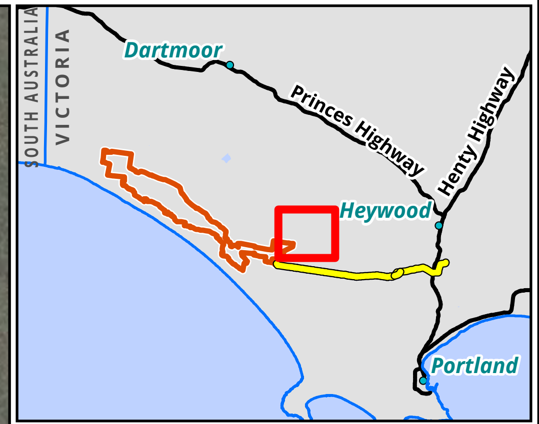
Scale: 1:25,000 @ A3

Coordinate System: GDA2020 MGA Zone 54

biosis

APEM Group

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_Appendix2_BrolgaBreedingBuffers_IndividualWetlands
Location: P:\35000s\35014\Mapping\
35014_BrolgaBreedingWetland.aprx



Legend

- Wind farm footprint
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 73

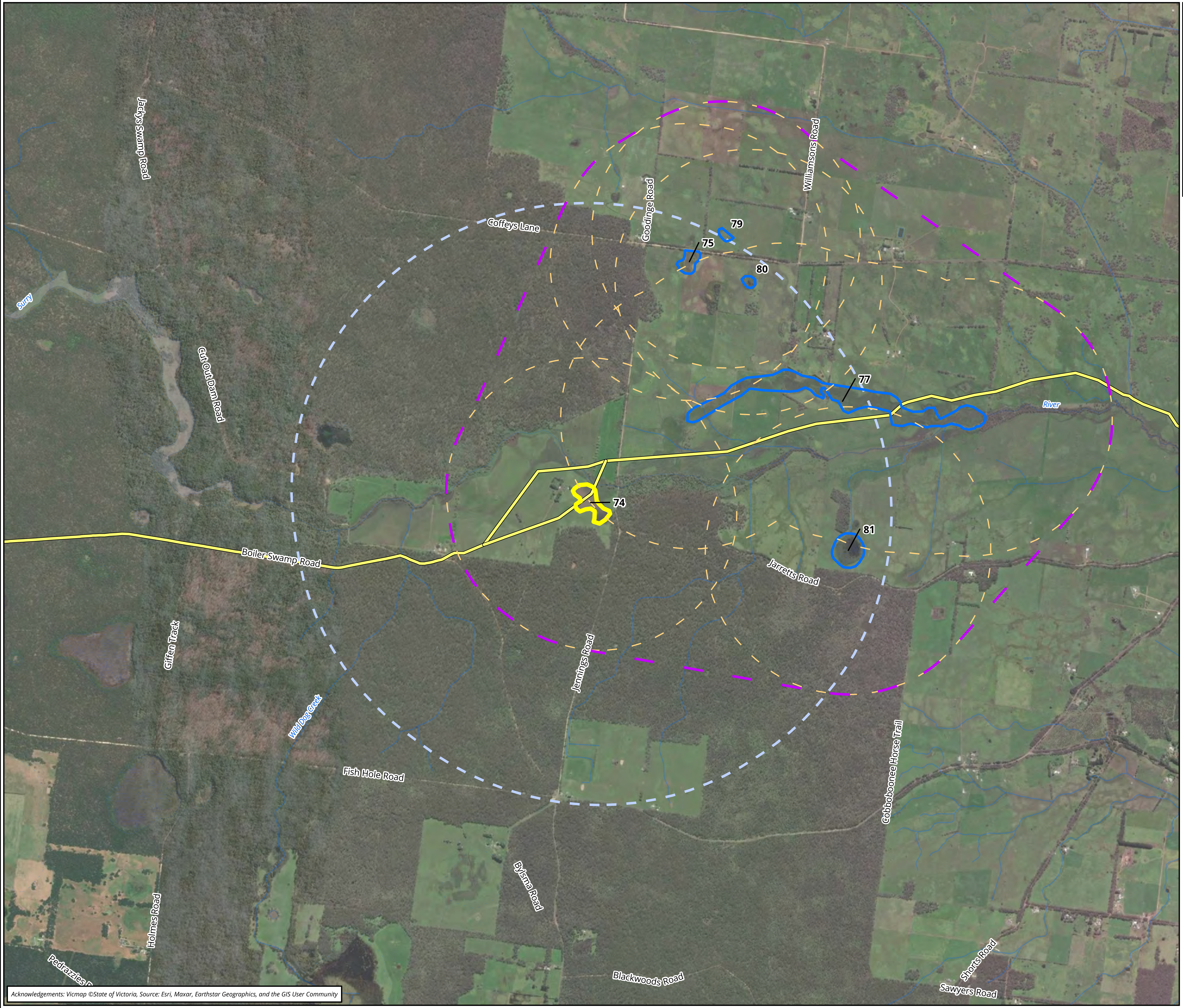
0 500 1,000
Metres
N

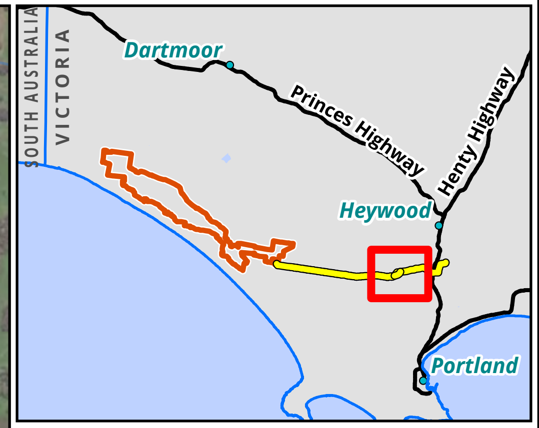
Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

biosis
APEM Group

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_Appendix2_BrolgaBreedingBuffers_IndividualWetlands
Location: P:\35000s\35014\Mapping\
35014_BrolgaBreedingWetland.aprx

Acknowledgements: Vicmap ©State of Victoria, Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community





Legend

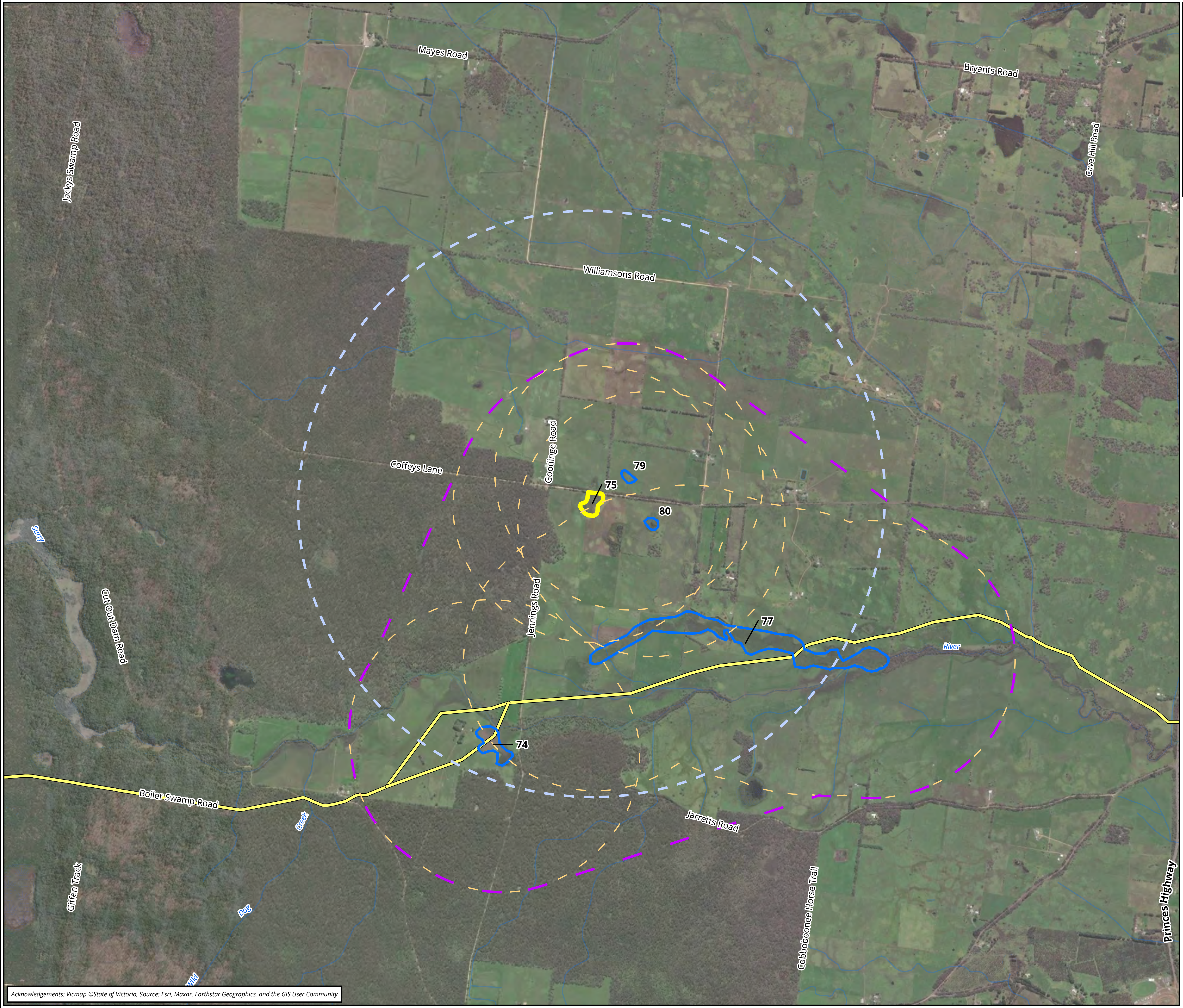
- 275 kV underground transmission line
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 74

0 500 1,000
Metres
Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

biosis
APEM Group

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_Appendix2_BrolgaBreedingBuffers_IndividualWetlands
Location: P:\35000s\35014\Mapping\
35014_BrolgaBreedingWetland.aprx



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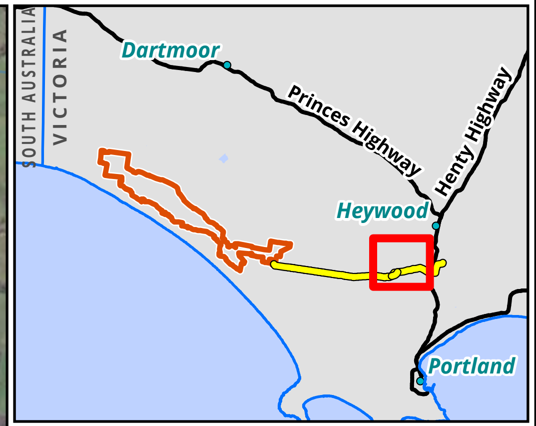

Legend

- 275 kV underground transmission line
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 75

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

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APEM Group

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_Appendix2_BrolgaBreedingBuffers_IndividualWetlands
Location: P:\35000s\35014\Mapping\
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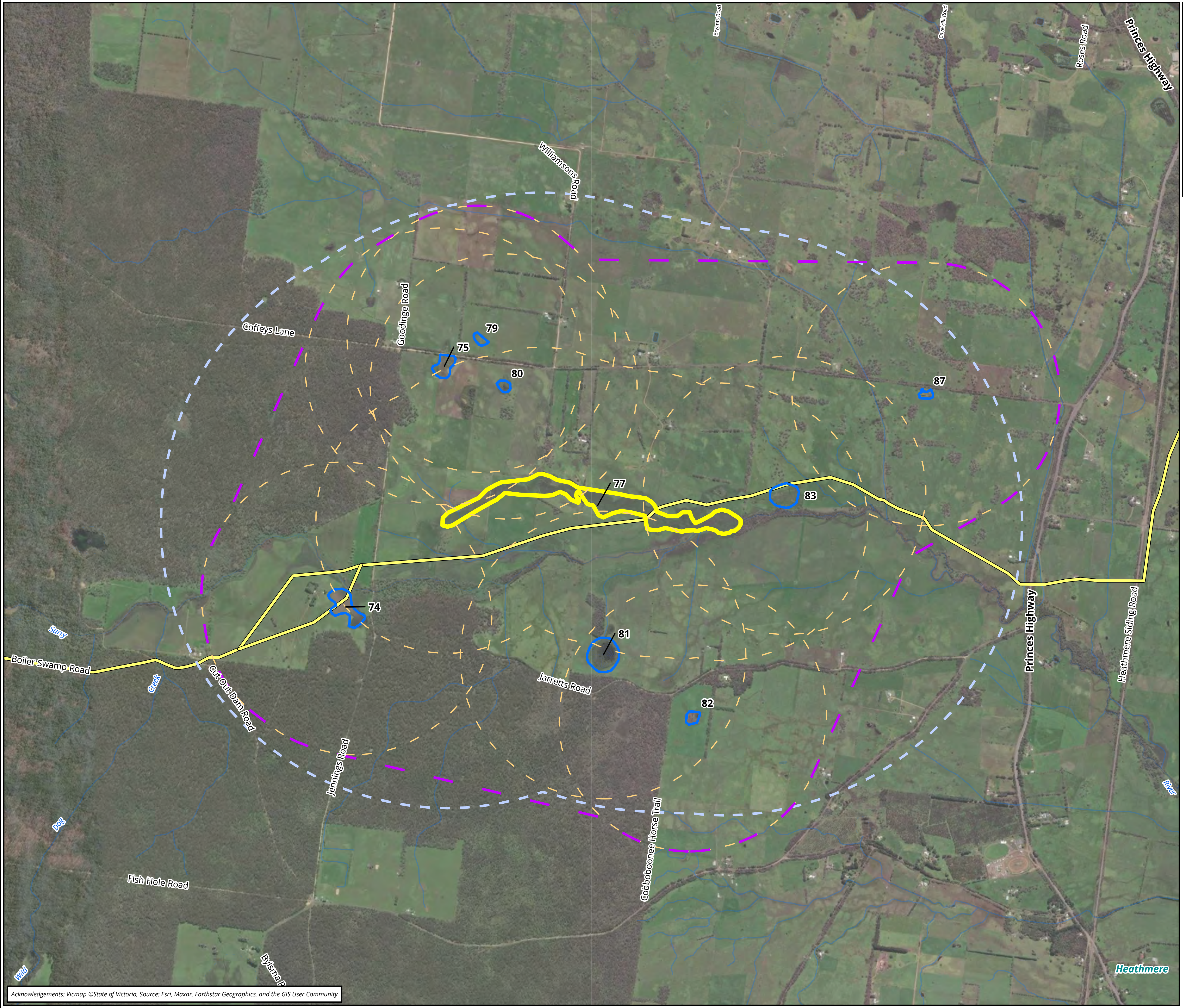

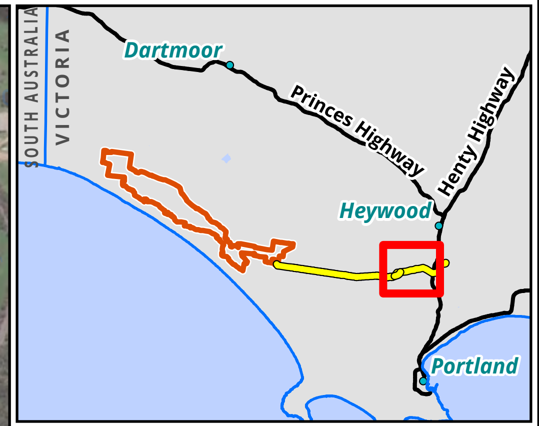

Legend

- 275 kV underground transmission line
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 77

0 500 1,000
Metres

N

Scale: 1:25,000 @ A3

Coordinate System: GDA2020 MGA Zone 54

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APEM Group

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_Appendix2_BrolgaBreedingBuffers_IndividualWetlands
Location: P:\35000s\35014\Mapping\
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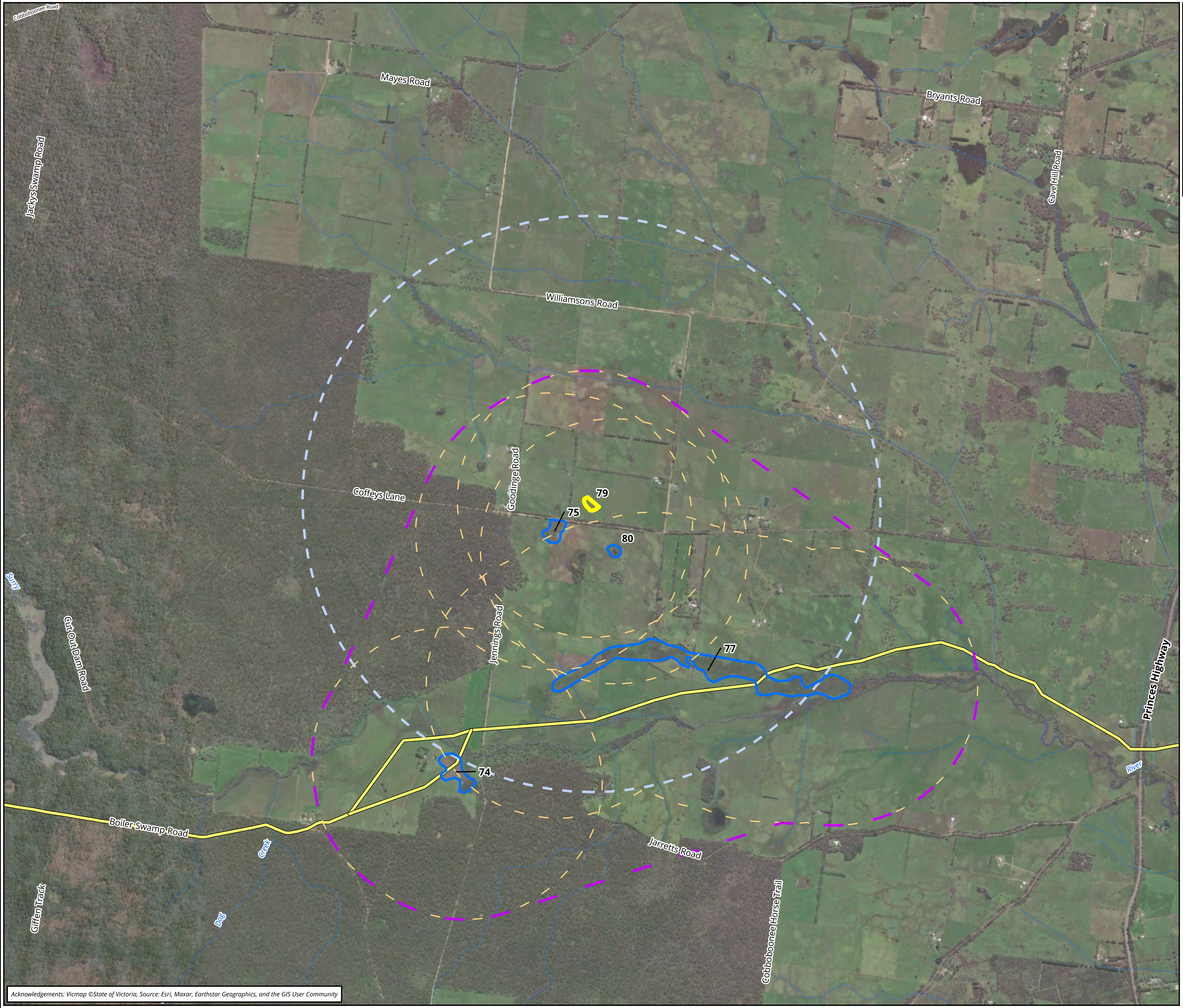

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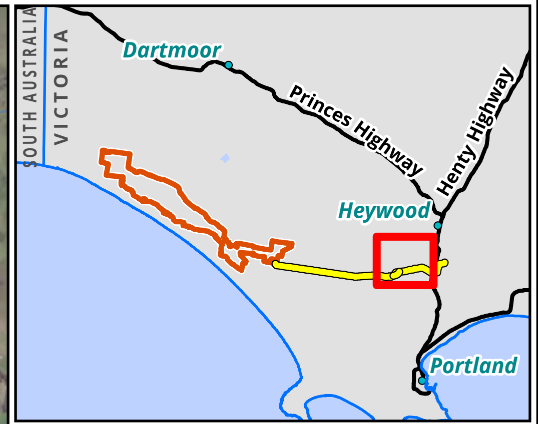

Legend

- 275 kV underground transmission line
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 79

0 500 1,000
Metres

N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

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APEM Group

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_Appendix2_BrolgaBreedingBuffers_IndividualWetlands
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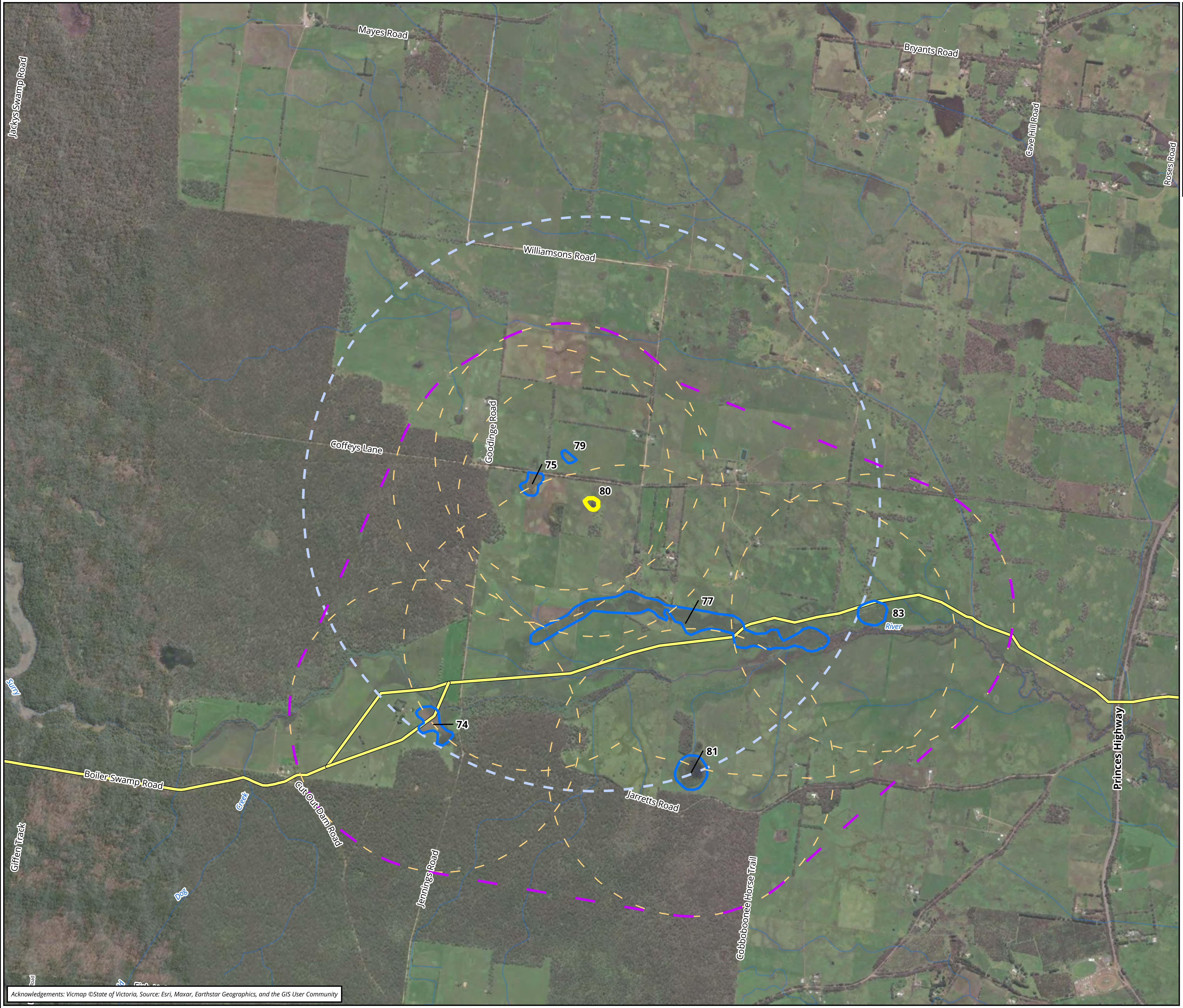

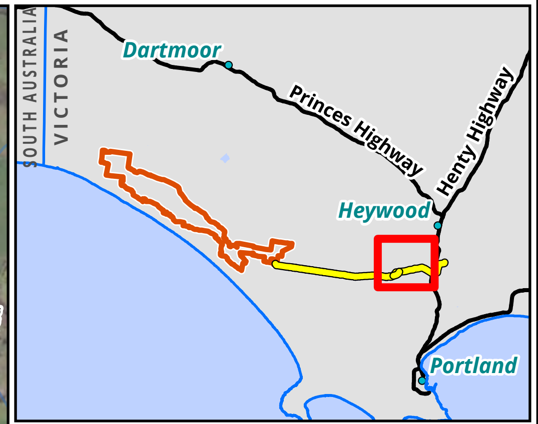

Legend

- 275 kV underground transmission line
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 80

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

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Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_Appendix2_BrolgaBreedingBuffers_IndividualWetlands
Location: P:\35000s\35014\Mapping\
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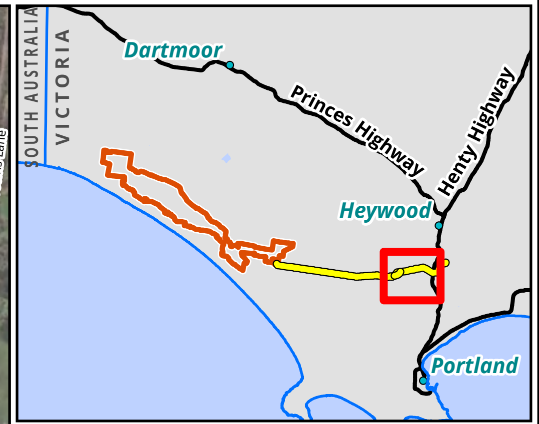

Legend

- 275 kV underground transmission line
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 81

0 500 1,000

Metres

N

Scale: 1:25,000 @ A3

Coordinate System: GDA2020 MGA Zone 54

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Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_Appendix2_BrolgaBreedingBuffers_IndividualWetlands
Location: P:\35000s\35014\Mapping\
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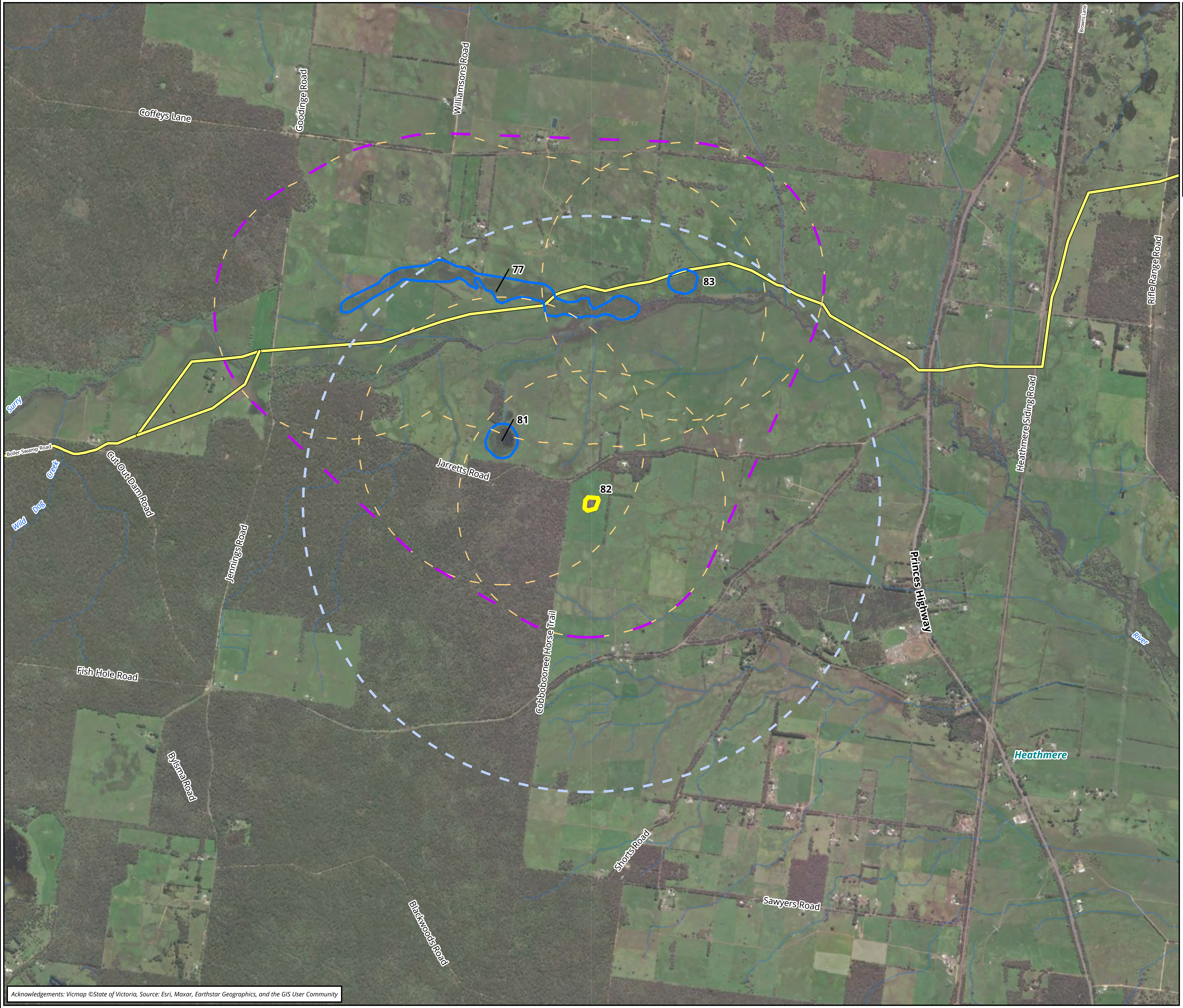

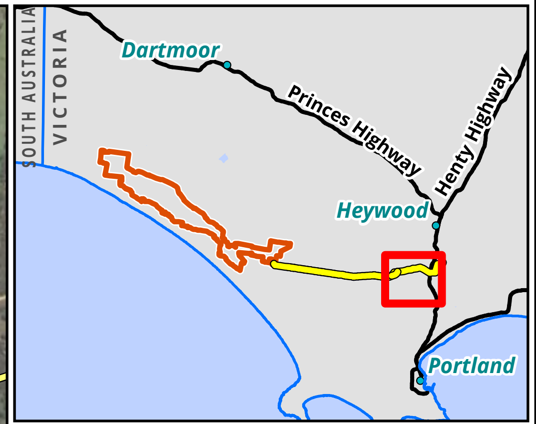

Legend

- 275 kV underground transmission line
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 82

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_Appendix2_BrolgaBreedingBuffers_IndividualWetlands
Location: P:\35000s\35014\Mapping\
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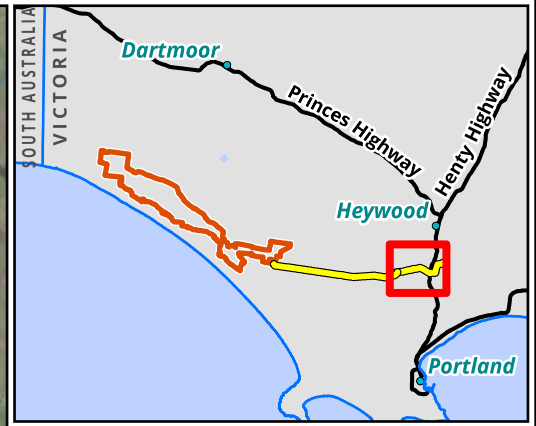

Legend

- 275 kV underground transmission line
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 83

0 500 1,000
Metres

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

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APEM Group

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_Appendix2_BrolgaBreedingBuffers_IndividualWetlands
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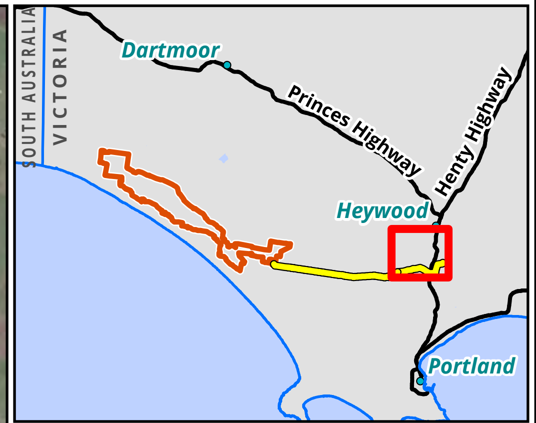

Legend

- 275 kV underground transmission line
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 84

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

biosis
APEM Group

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_Appendix2_BrolgaBreedingBuffers_IndividualWetlands
Location: P:\35000s\35014\Mapping\
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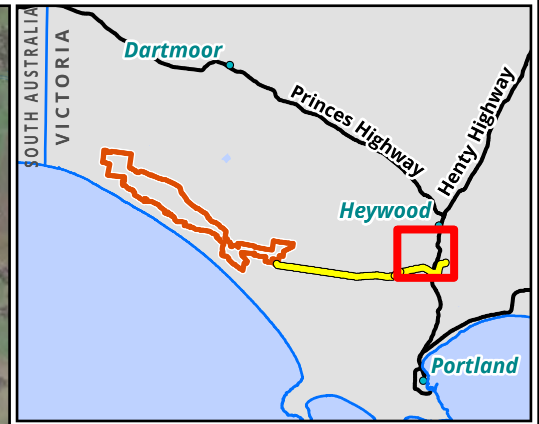

Legend

- 275 kV underground transmission line
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 85

0 500 1,000

Metres

N

Scale: 1:25,000 @ A3

Coordinate System: GDA2020 MGA Zone 54

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
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Location: P:\35000s\35014\Mapping\
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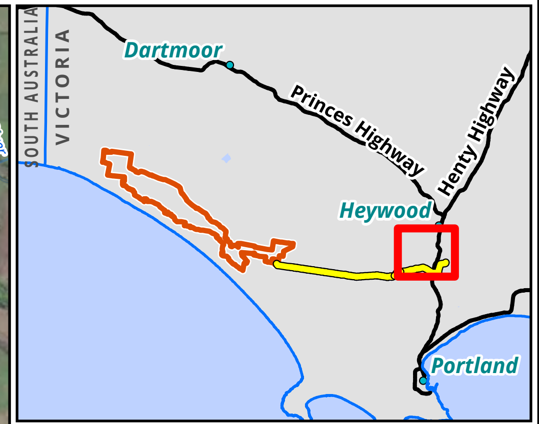
Acknowledgements: Vicmap ©State of Victoria, Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Legend

- 275 kV underground transmission line
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 86

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
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Location: P:\35000s\35014\Mapping\
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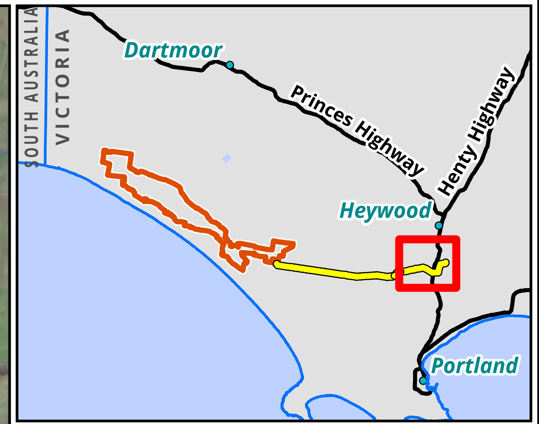


Legend

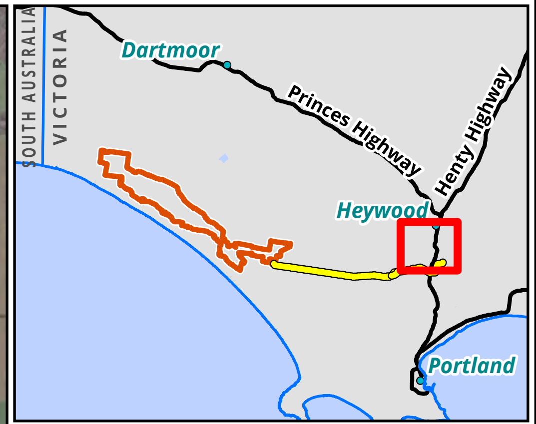
- 275 kV underground transmission line
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 87

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_Appendix2_BrolgaBreedingBuffers_IndividualWetlands
Location: P:\35000s\35014\Mapping\
35014_BrolgaBreedingWetland.aprx



Legend

- 275 kV underground transmission line
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 89

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

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APEM Group

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_Appendix2_BrolgaBreedingBuffers_IndividualWetlands
Location: P:\35000s\35014\Mapping\
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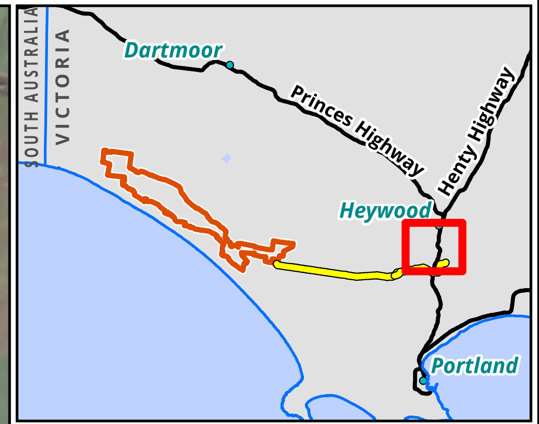

Legend

- 275 kV underground transmission line
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 90

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

biosis
APEM Group

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_Appendix2_BrolgaBreedingBuffers_IndividualWetlands
Location: P:\35000s\35014\Mapping\
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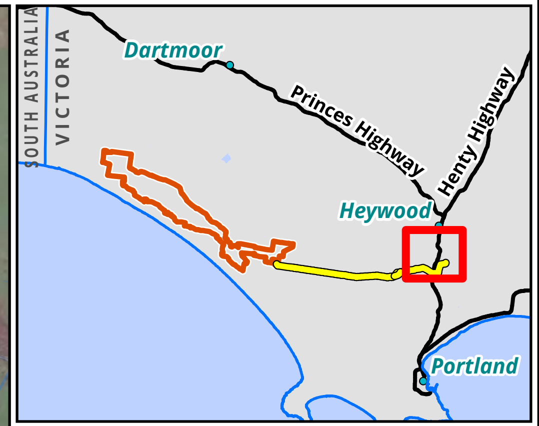

Legend

- 275 kV underground transmission line
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 91

0 500 1,000

Metres

N

Scale: 1:25,000 @ A3

Coordinate System: GDA2020 MGA Zone 54

biosis

APEM Group

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
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Location: P:\35000s\35014\Mapping\
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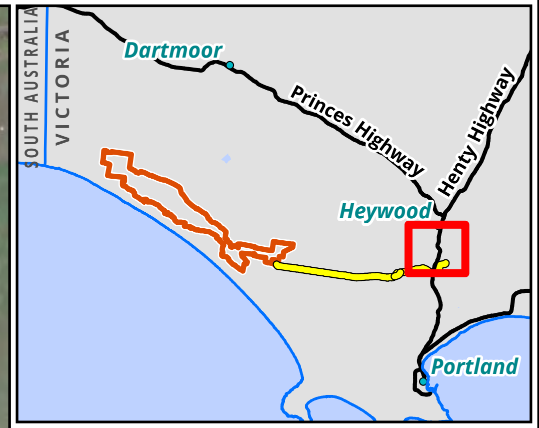

Legend

- 275 kV underground transmission line
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 93

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

biosis
APEM Group

Matter: 35014,
Date: 20 August 2024,
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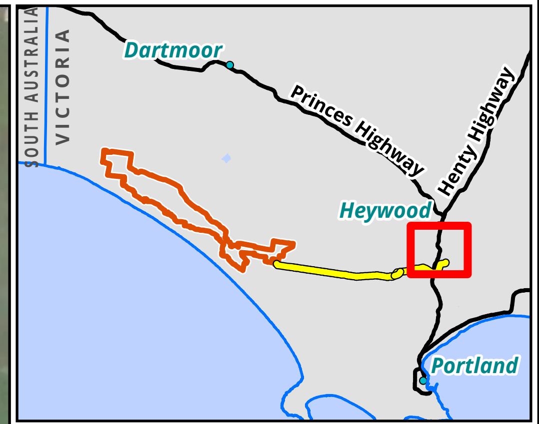

Legend

- 275 kV underground transmission line
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 94

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

biosis.
APEM Group

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
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Location: P:\35000s\35014\Mapping\
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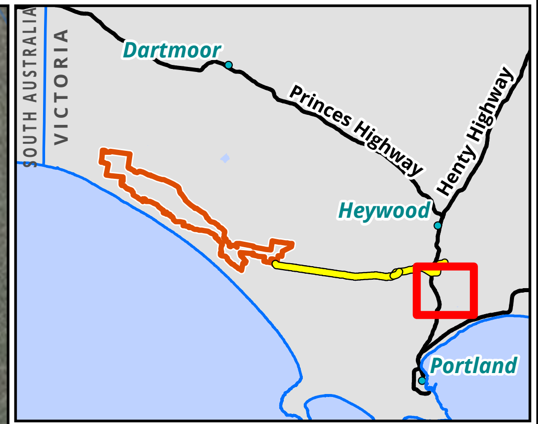

Legend

- 275 kV underground transmission line
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer

Appendix 2
Brolga breeding buffers
Wetland 95

0 500 1,000

Metres

N

Scale: 1:25,000 @ A3

Coordinate System: GDA2020 MGA Zone 54

biosis

APEM Group

Matter: 35014,
Date: 20 August 2024,
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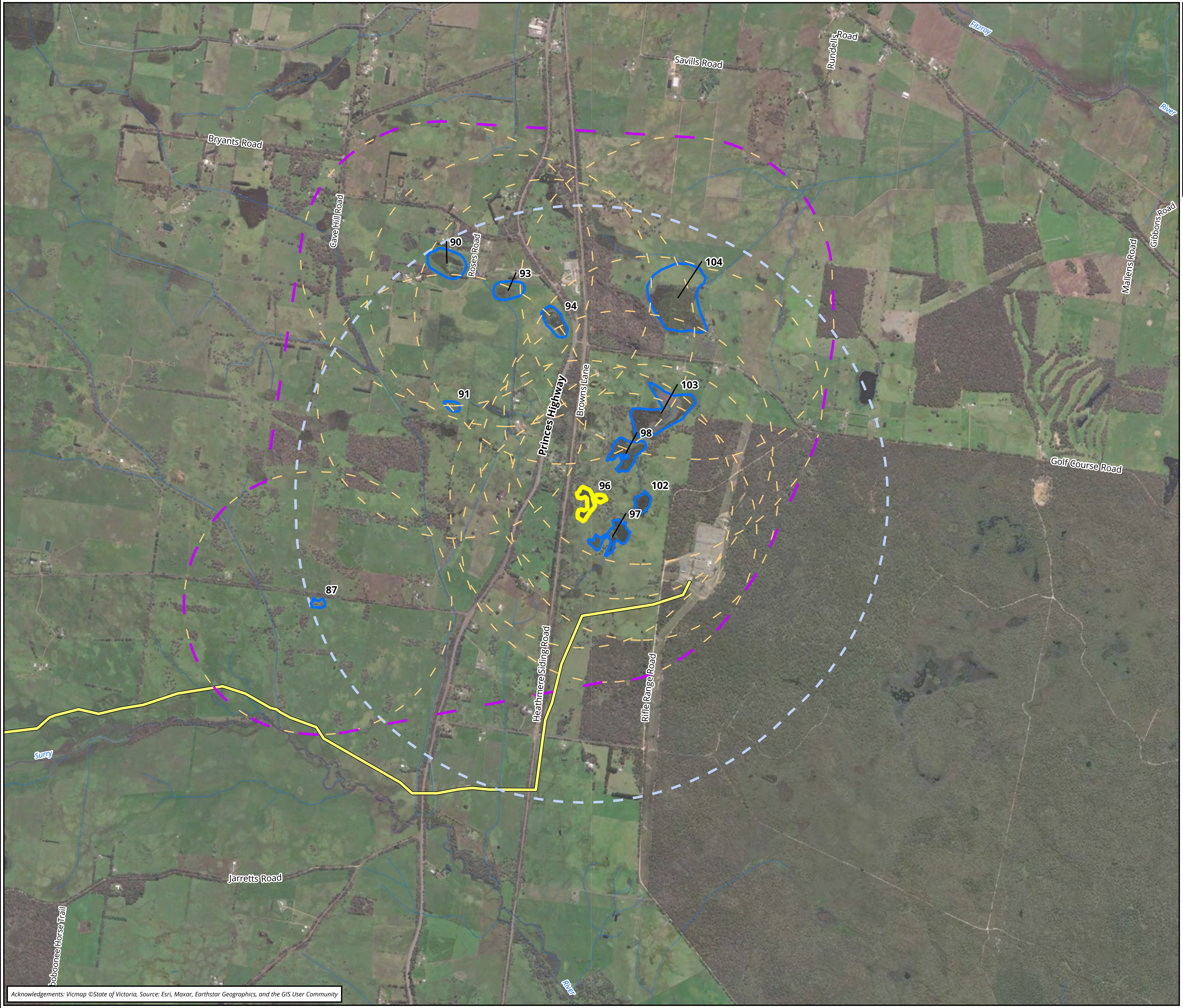

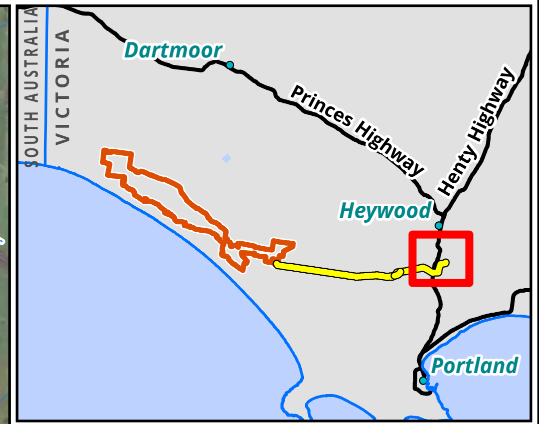

Legend

- 275 kV underground transmission line
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 96

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

biosis APEM Group

Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_Appendix2_BrolgaBreedingBuffers_IndividualWetlands
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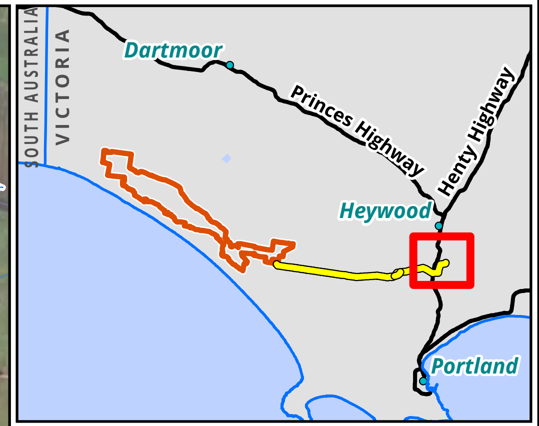

Legend

- 275 kV underground transmission line
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 97

0 500 1,000

Metres

N

Scale: 1:25,000 @ A3

Coordinate System: GDA2020 MGA Zone 54

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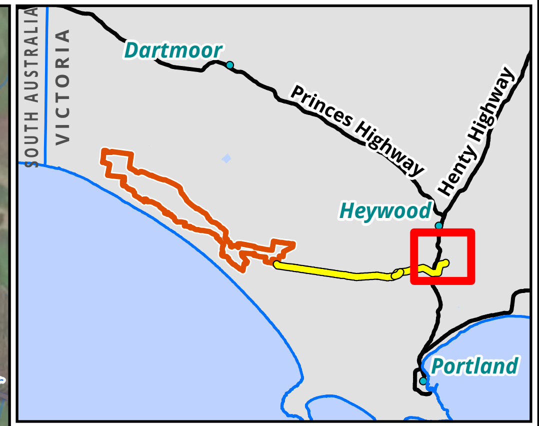

Legend

- 275 kV underground transmission line
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 98

0 500 1,000

Metres

N

Scale: 1:25,000 @ A3

Coordinate System: GDA2020 MGA Zone 54

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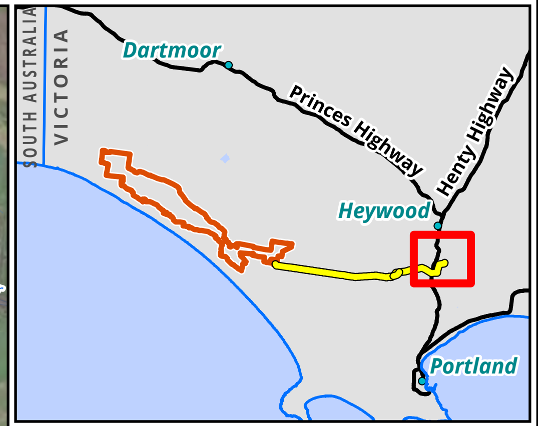

Legend

- 275 kV underground transmission line
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 102

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

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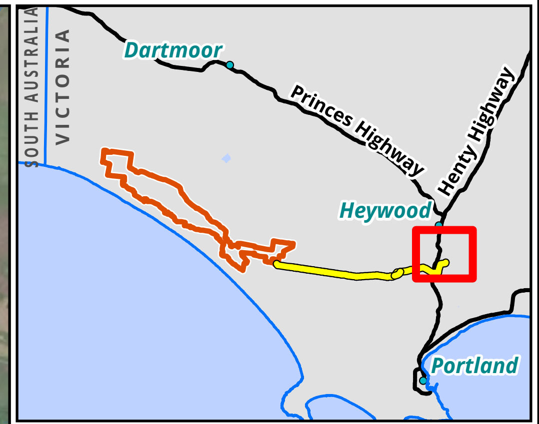

Legend

- 275 kV underground transmission line
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 103

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

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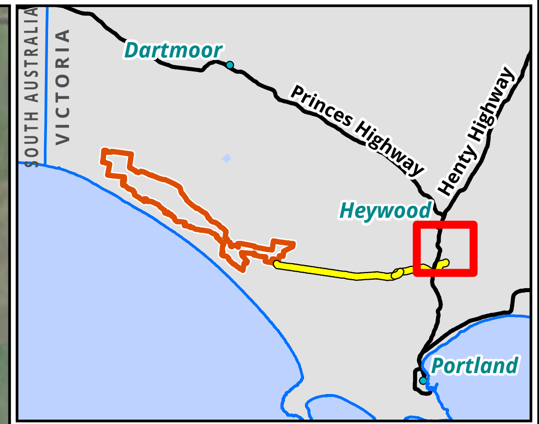

Legend

- 275 kV underground transmission line
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 104

0 500 1,000

Metres

N

Scale: 1:25,000 @ A3

Coordinate System: GDA2020 MGA Zone 54

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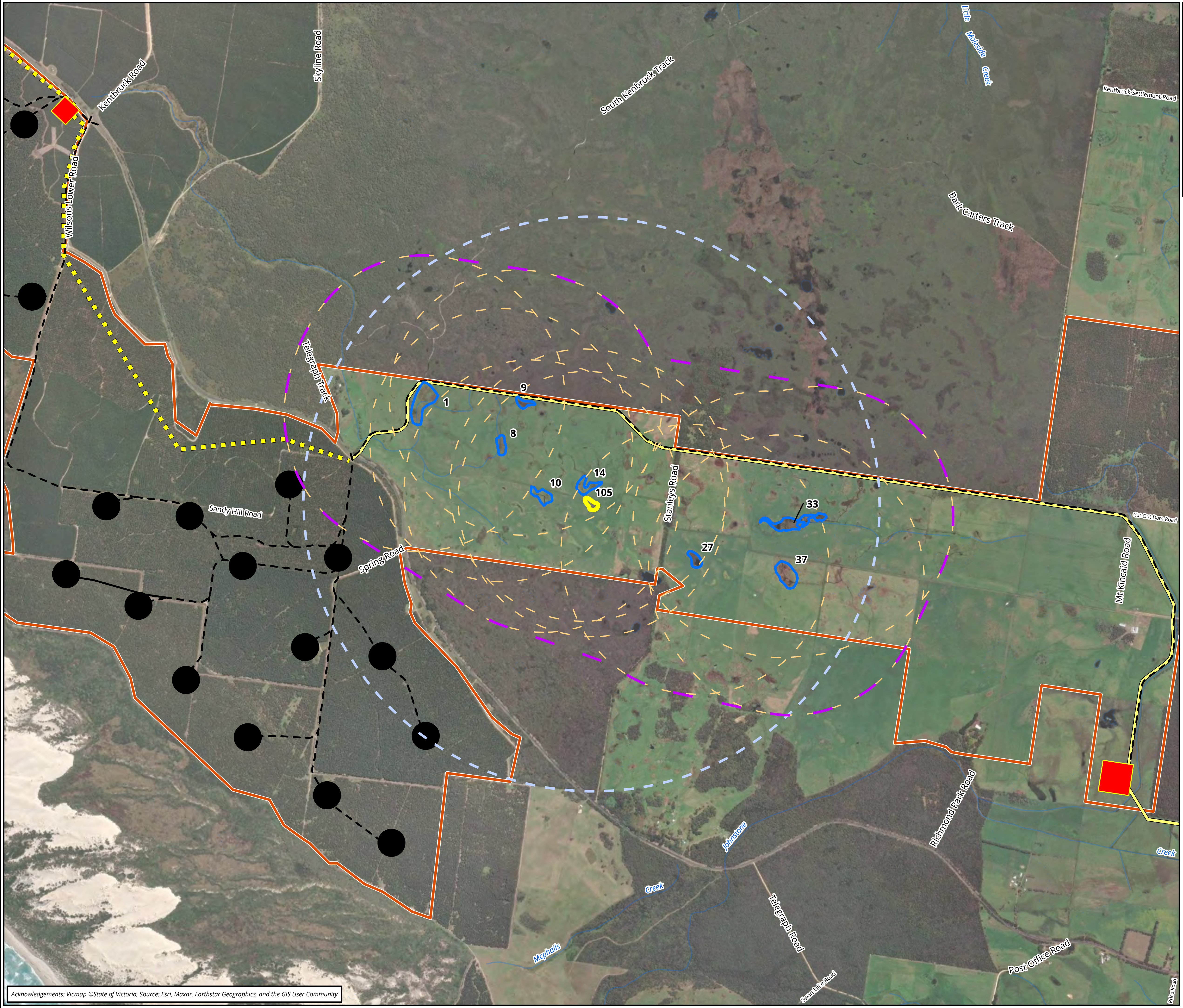
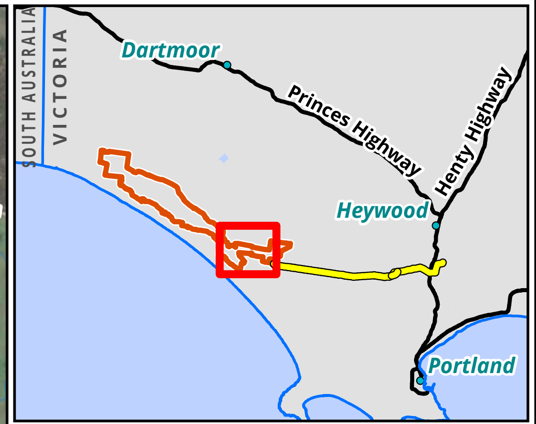
Appendix 2
Brolga breeding buffers
Wetland 105





Legend

- Wind farm footprint
- 275 kV overhead transmission line
- 275 kV underground transmission line
- Turbine - 95m radius
- Substation
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
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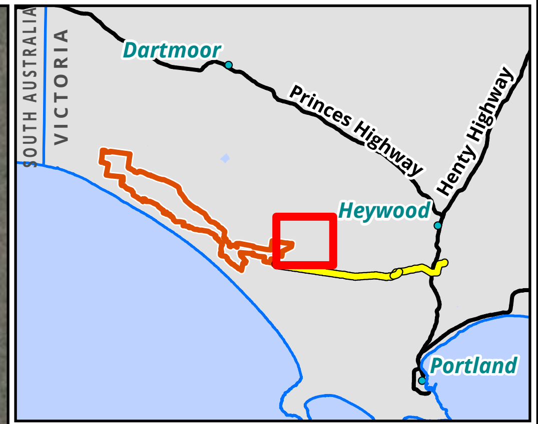

Legend

- Wind farm footprint
- 275 kV underground transmission line
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 106

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
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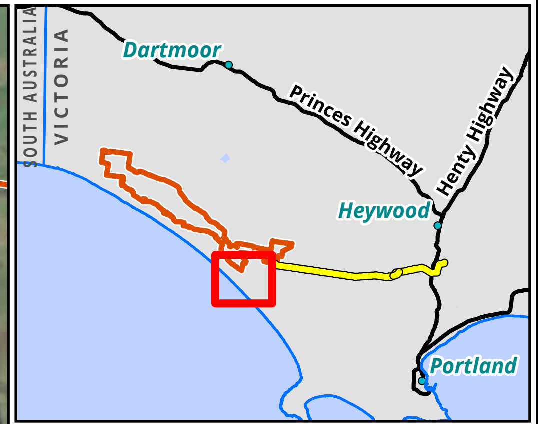

Legend

- Wind farm footprint
- Turbine - 95m radius
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 107

0 500 1,000
Metres
N

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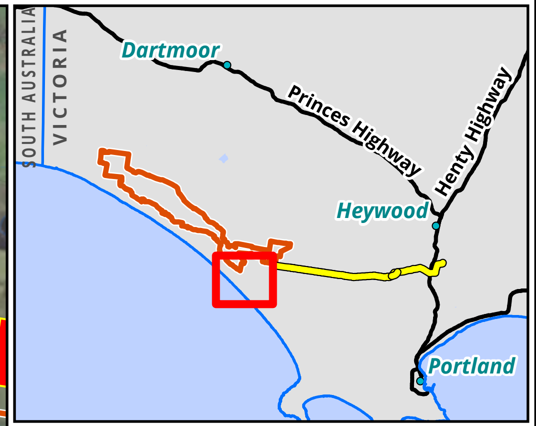

Legend

- Wind farm footprint
- Turbine - 95m radius
- Substation
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 108

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
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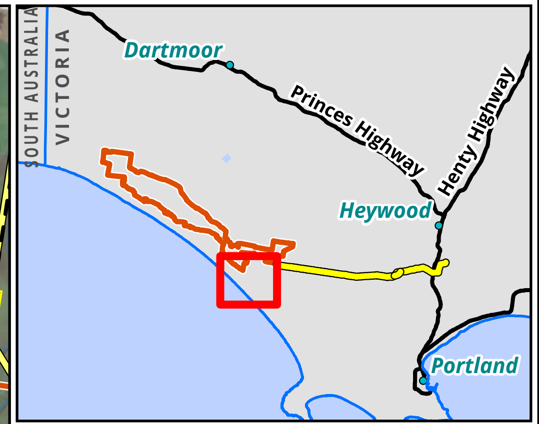

Legend

- Wind farm footprint
- 275 kV underground transmission line
- Turbine - 95m radius
- Substation
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 109

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
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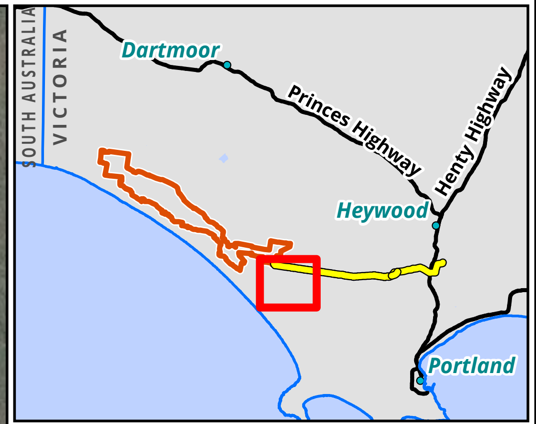

Legend

- Wind farm footprint
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- Substation
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 111

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
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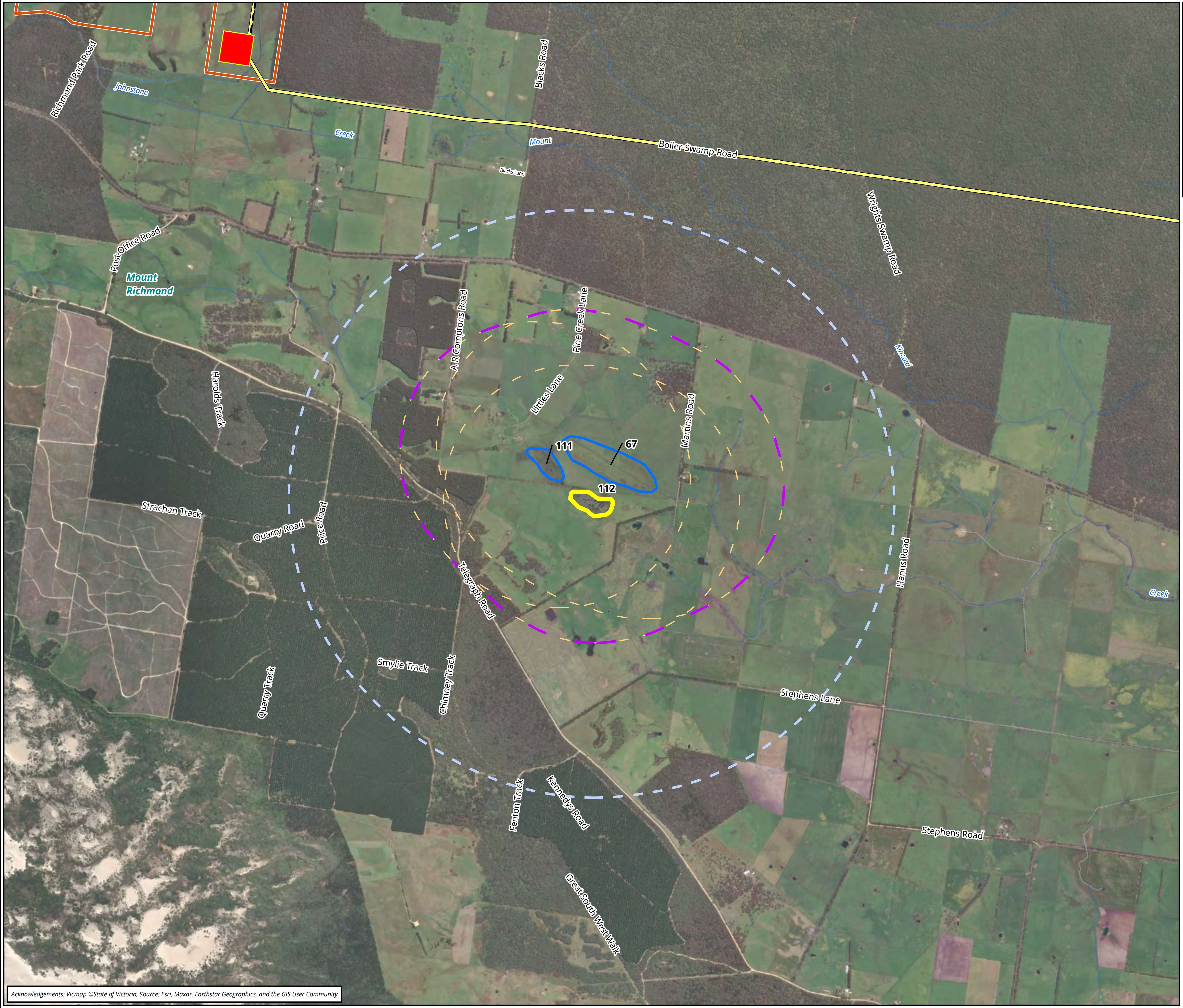

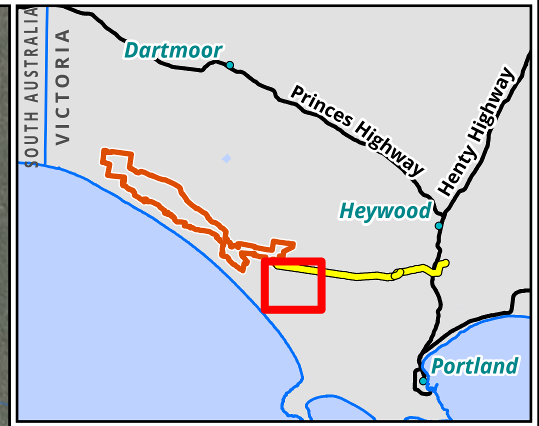

Legend

- Wind farm footprint
- 275 kV underground transmission line
- Substation
- Access track
- Brolga nesting wetland
- Breeding wetland within 2km
- 900m wetland buffer
- 2km nesting wetland buffer
- Merged concave hull breeding buffer

Appendix 2
Brolga breeding buffers
Wetland 112

0 500 1,000
Metres
N

Scale: 1:25,000 @ A3
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Appendix 3 Collision Risk Model published description

Wildlife Society Bulletin 37(1):59–65; 2013; DOI: 10.1002/wsb.257

Wind Energy and Wildlife Conservation

A Description of the Biosis Model to Assess Risk of Bird Collisions With Wind Turbines

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ABSTRACT We describe the model of Biosis Propriety Limited for quantifying potential risk to birds of collisions with wind turbines. The description follows the sequence of the model's processes from input parameters, through modules of the model itself. Aspects of the model that differentiate it from similar models are the primary focus of the description. These include its capacity to evaluate risk for multi-directional flights by its calculation of a mean presented area of a turbine; its use of bird flight data to determine annual flux of movements; a mathematical solution to a typical number of turbines that might be encountered in a given bird flight; capacity to assess wind-farm configurations ranging from turbines scattered in the landscape to linear rows of turbines; and the option of assigning different avoidance rates to structural elements of turbines that pose more or less risk. We also integrate estimates of the population of birds at risk with data for numbers of their flights to predict a number of individual birds that are at risk of collision. Our model has been widely applied in assessments of potential wind-energy developments in Australia. We provide a case history of the model's application to 2 eagle species and its performance relative to empirical experience of collisions by those species.

KEY WORDS bird, collision, model, risk, turbine, wind energy.

A number of mathematical models have been developed for the purposes of either describing the interaction of a bird with a wind turbine or to predict the risks of bird collisions with turbines (Tucker 1996*a*, *b*; Podolsky 2003, 2005; Bolker et al. 2006; Band et al. 2007). Tucker (1996*a*, *b*) and Band et al. (2007) detailed their models in the peer-reviewed literature. The collision risk model developed by Biosis Propriety Limited has been widely used to assess wind-energy developments in Australia since 2002, but it has not previously been described in detail. Given high levels of interest in effects of wind turbines on fauna, we believe it is important for the model to be accessible.

Our model provides a predicted number of collisions between turbines and a local or migrating population of birds. It has the potential to be modified to accommodate Monte-Carlo simulation, although at its core it uses a deterministic approach. It is modular by design, and allows various customizations, depending upon the unique configuration of the wind facility and characteristics of the taxa modeled.

The initial calculation involves species-specific parameters for speed and size of birds and specifications of the turbine, including its dimensions and rotational speed of its blades. Using these parameters, we derive the mean area of turbine presented to a bird in flight. This allows the model to accommodate flight approaches from any potential direction. Alternatively, unidirectional flights can be modeled by using the relevant turbine surface area presented to birds approaching from a given direction.

Data for bird flights are collected at the wind-farm site according to a specific and consistent field methodology. These data are used to determine the flux (density) of bird flights. When combined with turbine specifications, this yields the probability of collision during a single flight–turbine interaction. The density flux approach has not been used for this application previously.

The number of movements at risk of collision with one turbine is then scaled according to a typical number of turbines that a bird might encounter in a given flight. This is further refined by a metric for the capacity of the particular species to avoid collisions. Where a population census or estimate is available for the number of birds that may be at risk, a further deduction is used to attribute the number of flights-at-risk to individuals, and hence provide a final model output as the number of individuals at risk of collisions. The ability to transform from flights-at-risk to individuals-at-risk has been uniquely developed and applied as a routine component of our model.

DESCRIPTION OF THE MODEL

The model requires data for input parameters and, using these, functions in a sequence of modules (Fig. 1).

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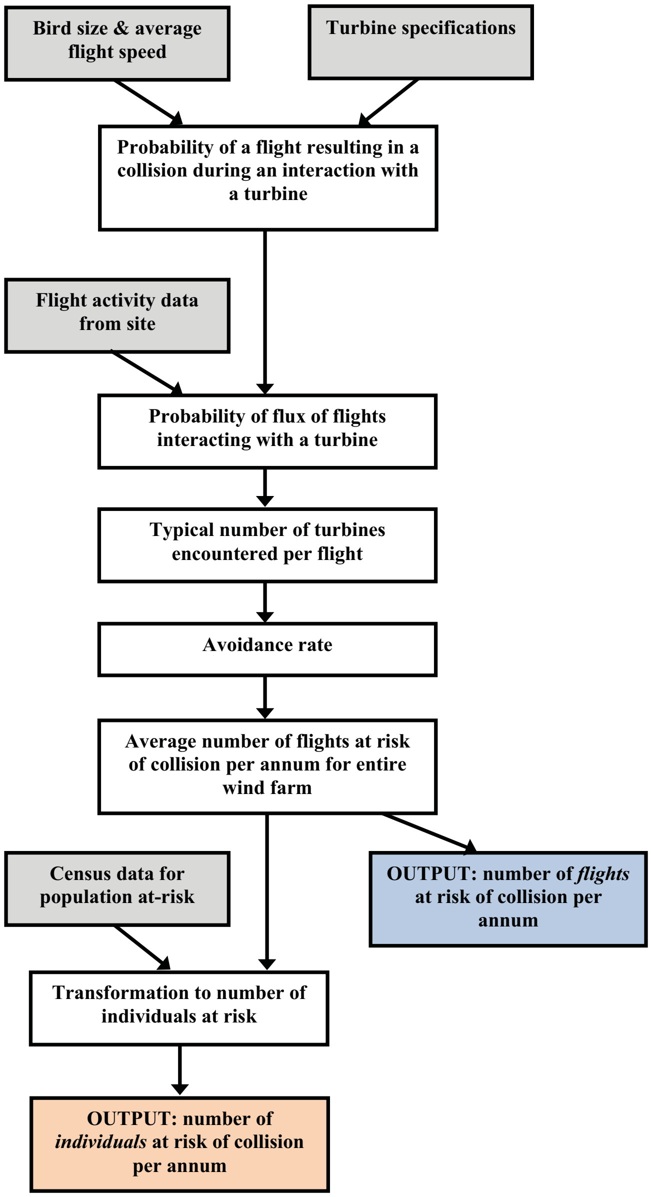

Figure 1. Overview of the collision risk model that quantifies risk to birds of colliding with wind turbines, showing input parameters (gray boxes), modules, and sequence.

Model Inputs

Turbine parameters.—The primary risk faced by a flying bird, whether it may strike or be struck by a turbine, is that the machine presents a potential obstacle in its path. Ultimately this equates to the surface area of the turbine presented to the bird from whatever its angle of approach. Other models, such as probably Band et al. (2007), use individualistic representations of birds. Our model uses a projection of the presented area onto all possible flight angles. For this reason, multiple dimensions of turbine components and rotor speed for the particular type of turbine are used as input values to the risk model. Turbine specifications are as provided by the machine's manufacturer.

The modeled wind turbine consists of 2 fundamental components representing potentially different risks. We refer to these as the static and dynamic components (Fig. 2). The static areas of a turbine include all surfaces of the entire machine comprising a tower, which in current turbines is a simple taper with known base and top diameters; a rectangular nacelle housing the generator; a hemi-spherical hub; and rotor blades that taper in 2 planes. The dynamic component is the area swept by the leading edges of rotor blades during the time that a bird would take to pass through the rotor-swept zone.

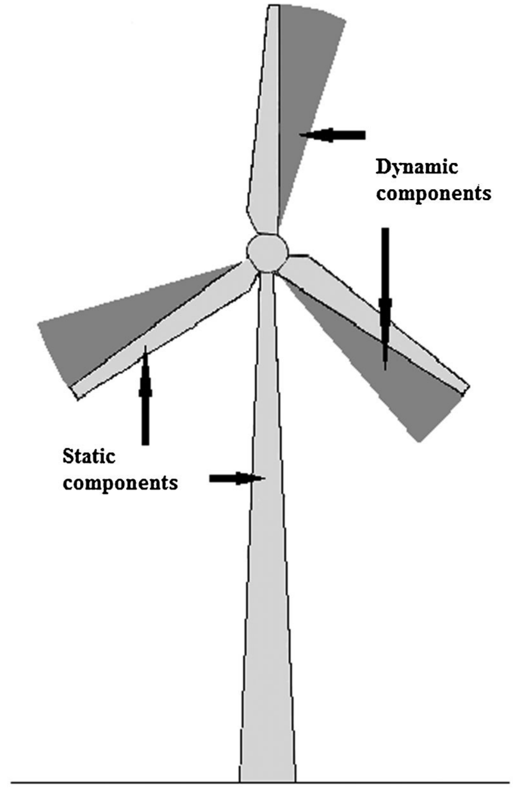

Figure 2. Schematic indication of the static and dynamic components of a wind turbine that may be encountered by a flying bird. The dynamic component is the area swept by rotor blades during the time that a bird of a particular species would take to pass through the rotor-swept zone.

Size and flight speed of birds.—For each taxon, the model requires values for the total length of the bird in flight, from bill tip to tip of the tail or outstretched legs, and the average speed of the species' flights. We obtained bird lengths either from museum specimens or from standard ornithological texts.

Accurate determinations of bird flight speeds can be complex and difficult to obtain (Videler 2005, Pennycuick 2008) and published data are not available for most species. However, published radar studies (e.g., Bruderer 1995, Bruderer and Boldt 2001) provide ranges of flight speeds for a variety of species, including congenerics with similar morphologies and ecological traits to a number of species we have assessed. Use of radar to collect bird flight data at the wind-farm site may provide flight speeds for species of interest. We consider that average ground speed (as opposed to air speed) is appropriate for modeling of multidirectional movements of birds.

Bird flight data.—The model requires data from the wind-farm site for the number of flights made by species of interest within a measured time and volume of airspace. Movement data may be obtained from fixed-time point counts using a methodology adapted from Reynolds et al. (1980), incorporating an effective detection range (Buckland et al. 1993). It may be collected by human observers or by using horizontal and vertical radar combined with call recording or visual species identification (e.g., Gauthreaux and Belser 2003, Desholm et al. 2006). Data represent the number of flights that birds make within a cylinder of airspace that is centered horizontally on the observer and the height of which is the maximum reached by rotor blades of the turbines. The data collection regime is designed with the aim of providing a representative sample of flight activity across the local range of diel, seasonal, and other environmental variables.

Model Modules

Probability of a single flight interacting with a turbine.—In some situations, such as during highly directional migratory passage, the presented area of turbines is determined from the angle of the birds' flight relative to the compass orientation of turbines. However, for the great majority of species (including temporary or permanent residents at an on-shore wind farm) this does not apply, and flights can be expected to approach turbines from any direction. For this situation, all dimensions of the turbine contribute to the area with which a flying bird might collide and the model uses a simple integration to determine a mean presented area. This represents a substantial advance over other collision risk models that depend on the assumption of a specific angle of approach as a bird encounters a turbine (e.g., Tucker 1996*a*, *b*; Bolker et al. 2006; Band et al. 2007).

We calculate the area presented by the static components of a turbine using a conservative assumption that none of them overlap or obscure any others. The area of each component is calculated individually, and these are then summed to determine a total static area for the turbine. Static areas are calculated from the simple length $\times$ width dimensions of all components visible by line of sight. These are then projected onto an arbitrary approach direction (effectively scaling by the cosine of the approach angle). For example, viewed directly from one side, only the side panel of the nacelle is visible. However, approached from 45° to the turbine, both the front and side panels are visible, and are thus scaled by $\cos(45) \varrho 1/\sqrt{2}$ to match that particular angle of view.

We calculate the dynamic area, swept during the movement of blades, from the dimensions of the stationary blades and the distance they travel at their average speed during the time taken by a bird to fly through the rotor-swept area. We assume that all flights involve forward movement, so the swept-area is derived from the length and speed of the particular species of bird, in combination with the thickness of the sweeping blade.

Each rotor blade is tapered in 2 planes. Thus the thickness of the blades, used to determine the time taken for a bird to cross through the swept area, is actually a function of the point in the rotor radius at which an individual bird's flight intersects the swept area. This presents a complication that we overcome by defining an effective blade, which is a simple rectangular cross-section that sweeps out precisely the same volume of space as the physical blade. In doing so, we calculate a constant thickness of blade that accounts for the fact that the thinner tips actually sweep far more space than the thicker base of the blade. This ensures also that our flux calculation is not compromised by introduction of a spatial variation at odds with other aspects of the model.

A further input parameter is the percentage of time per annum when rotors are not turning due to inappropriate wind speeds and routine turbine maintenance. Prior to commissioning of a wind farm, wind speed data are usually gathered and the expected percentage of downtime due to inappropriate wind speeds is determined. During downtime periods the rotor simply stops turning; and so risks associated with dynamic components only are reduced by this percentage of time, while all static components of the turbine remain as potential obstacles to flying birds.

Combining all presented areas of the turbine.—Modeling for multidirectional bird movements requires no dependence on approach angles nor on complexities of interactions between flight direction and wind direction. We thus reduce the turbine to its mean presented area. This is solved by the equation

$$\frac{1}{\pi}\int_0^{\pi} A(\theta)\, \mathrm{d}\theta$$

where A is the presented area of the turbine as a function of approach angle θ. We solve this numerically using a trapezoidal integrator (Press et al. 1992).

Probability of multiple flights interacting with a turbine.—Because counts of bird flights have been made across the wind-farm site and there is no obligatory relationship between point-count locations and particular sites proposed for turbines, we combine the data collected from all point counts. This provides a measure of flight activity, which is assumed to be constant across the site. Thus the field data reduce to a single ratio value for the subject species, which is the sum of all flights documented during all counts divided by the total time of observations. This equates to a maximum likelihood estimation of the mean of an assumed Poisson distribution.

To calculate a number of flights at risk of collision, we first reduce documented bird movements (M) to a measure of flux (F) using the equation

$$F = \frac{M}{T_{\mathrm{obs}} A_{\mathrm{obs}}}$$

where T_{obs} is the combined total time of all point counts and A_{obs} is the area of the vertical plane dissecting the observation cylinder. This flux is a measure of bird movements per time per square meter of vertical airspace. The third dimension, volume of airspace, is redundant (or tacit) due to the assumption that, unless involved in a collision, flight paths do not end arbitrarily in space.

We next multiply activity measure by the number of minutes in which the species is active during the 24-hour diel period, T, and the total presented area of the turbine, A. For year-round resident species, the "active minutes" are calculated for the entire year, while for seasonal or migratory species, they are calculated for the portion of the year that the species is present at the site. This then gives a measure of risk to the bird movements, $M_{\text{risk}} = \text{FTA}$.

Because the flight data are a measure of movements by the species in question and do not discriminate the number of individuals making the movements, the measure (M_{risk}) quantifies the total movements-at-risk for the species and does not reflect risk to individual birds.

To determine a risk rate from total of recorded movements-at-risk, it is necessary to extrapolate to a total number of expected bird movements per annum, M_{yearly}. We calculate this from the flight data, extrapolating the movements to a yearly total through the equation

$$M_{\text{yearly}} = M \frac{T_{\text{yearly}}}{T_{\text{obs}}}$$

We then deduce a probability of flights at risk of collision as $M_{\text{risk}}/M_{\text{yearly}}$. Note that T_{year} is the total time in a year, and not the diel activity period of the species, which has already been factored into the calculation of movements at risk.

The resultant value is now a probability of flights being at risk of collision with a single turbine. To this point, no account is taken of the bird's own ability to avert a collision. This is modified later through use of an avoidance factor.

Estimating number of turbines encountered per flight.—Every turbine is presumed to represent some risk for birds, so the total number of turbines proposed for the wind farm is an input to the model. Turbine layout of modern wind farms is primarily determined by the wind resource and turbines are micro-sited accordingly. Consequently, the machines are usually scattered on the landscape. Older wind farms had turbines arrayed in rows, and occasional modern facilities may be linear where they follow a single topographic feature.

To account for the number of turbines with which a single flight might interact, it would be necessary either to know precisely the route of every flight or to make informed assumptions about flight paths. The manner in which turbines are arrayed in the landscape is important to ascertain a typical number of turbines that a bird might encounter in a given flight. This number differs according to whether turbines are in a scattered array or a single row, and these require different calculations.

For a row of turbines, the likely number of encounters can be visualized by considering a row of N turbines in plan view and a flight path at angle Φ to the row. A flight directly along the line of turbines (Φ') will interact with all N turbines. As the angle of flight relative to the row increases toward 90°, flight paths have potential to interact with fewer turbines until an angle (Φ'') is reached at which the path has potential to interact with a maximum of one turbine.

For a single row of turbines, we define the piecewise smooth function, which gives the number of turbines for a given angle of crossing with,

$$n_{\text{interaction}} = \begin{cases} N, & \text{if } \theta \leq \phi\prime \\ \cot(\theta), & \text{if } \phi' < \theta \leq \phi'' \\ 1, & \text{if } \phi'' < \theta \leq \frac{\pi}{2} \end{cases}$$

This gives us an expected number of interactions as

$$\langle n_{\text{interaction}} \rangle = \frac{2}{\pi} \left[N \arctan\left(\frac{1}{N}\right) + \frac{\pi}{4} - \ln\left(\sqrt{2}\sin\left(\arctan\left(\frac{1}{N}\right)\right)\right)\right]$$

For scattered turbine arrays it is not realistic to assume that a bird will encounter all turbines in the wind farm in a given flight. We assume each flight has potential to cross between any 2 points on the outer edges of the farm. Given the size of most on-shore wind farms, this is a reasonable assumption for typical species of concern, such as raptors. When multiple flight paths are drawn randomly across the plan view of a wind farm, some paths may be circuitous and have potential to encounter many turbines, while others will pass through a small portion of the site and have potential to encounter relatively few turbines.

To deduce an average number of turbines likely to be encountered by any flight we use a topological, non-affine mapping technique. This spatial transformation can be illustrated as follows: if we were to throw a lasso around the perimeter of the site and shorten it to its minimum, we would find that all the turbines had collected in a circle. A straight flight path through this "lassoed" site is mathematically equivalent to a random walk across the unconstrained layout. The average of all flight paths crossing the center of this remapped farm will intersect with $\sqrt{N}$ turbines (where N is the total no. of turbines in the wind farm). This value is used in the model for the number of turbines that might be encountered per flight within a scattered turbine array.

For arrays that are neither entirely scattered nor linear, the model employs a simple weighted average of the values for fully scattered and entirely linear arrays.

Application of turbine avoidance capacity.—Birds have substantial ability to avoid obstacles; therefore, it is necessary to incorporate this capacity into the model. In common with other workers (Percival et al. 1999), we use "avoidance" in specific reference to behavior on the part of a bird that averts a potential collision with a turbine. The "avoidance rate" equates to the proportion of flights that might otherwise have involved interaction with a turbine but where the bird alters course and the flight does not result in a collision. For the purposes of the model it is of no consequence whether or not this is a result of a cognitive response by the bird to the presence of the turbine.

Turbine avoidance remains little-studied for any species, and empirical information about actual avoidance can be obtained for a given site only by studying the responses of birds in the presence of operational turbines (Chamberlain et al. 2006). One recent investigation has compared flight behaviors of 2 species of eagles in the presence of turbines at

2 operating wind farms with their behaviors at a site without turbines (Hull and Muir 2013).

Avoidance rate is incorporated into the model by scaling the movements at risk by $(1 - v)$, where v is a measure of the bird's ability to avoid objects. In this scenario, $v = 0$ corresponds to a blind, non-responsive projectile, and $v = 1$ represents a perfectly responsive bird able to avoid any object.

A novel feature of our model is its capacity to apply different avoidance values to the static and dynamic portions of a turbine. As noted by Martin (2011), birds are known to collide with both stationary and moving parts of turbines. This aspect of our model allows for differences in capacity of birds to detect and avoid the large, static components of modern turbines relative to their capacity to detect and avoid the small and fast-moving leading edges of rotor blades.

Size of population at risk.—When information about the size of the population at-risk is available, this can be factored directly into our model to provide results in the form of an expected number of individuals at risk of collision per annum. This is an important consideration because an input measured in terms of bird movements cannot provide an output in terms of individual birds. This aspect appears to have been largely overlooked by other workers, although Chamberlain et al. (2006) alluded to the use of a number of flights only, without incorporation of the number of individuals, as a potential issue in evaluation of collision estimates provided by the Band model (Band et al. 2007).

To deduce a predicted number of individual birds that are at risk of collision, a valid estimate is required of the number of individuals that may interact with turbines at the wind farm in the course of a year. If it is not feasible to obtain this for a species, then the output of the collision risk model will necessarily be the number of flights-at-risk per annum. Although this metric is not predictive of the number of individuals that might collide, it permits risk to be compared for various designs of a wind farm or between one facility and another. In rare cases, such as where there is a single migration passage through the site per annum, the number of movements may equate with the number of individual birds that are at risk. The great majority of risk modeling we have undertaken has been for raptors that are year-round residents. Due to their territoriality and relatively low densities, our studies at wind-farm sites have been able to ascertain the number of individuals using a site per annum, including both resident adults and juveniles, with a high level of confidence. For some other species, such as cranes (Gruidae), we have undertaken home-range studies to determine numbers present during the breeding season, and we have obtained local census data to estimate numbers of individuals that might encounter turbines during non-breeding seasons.

Given a population estimate, the number of flights at risk is attributed equally to the relevant number of individuals through the simple relation $M_{\text{individuals}} = \text{Yearly Movements/Population}$. We can then attribute individual mortality through

$$\text{mortality} = \text{Population}\left(1 - \frac{\text{Movements At Risk}}{\text{Yearly Movements}}\right)^{M_{\text{individuals}}}$$

MODEL VALIDATION

The model we describe here has been used to assess potential turbine collision risk for numerous species of birds for 23 commercial-scale wind farms proposed in Australia and one in Fiji. Eleven of these facilities have subsequently been built and are now operational. The model's projections have been used by regulatory authorities in determination of approval or modification to wind-farm designs for a range of species of concern. These include taxa as diverse as the orange-bellied parrot (*Neophema chrysogaster*), wedge-tailed eagle (*Aquila audax*), brolga (*Grus rubicunda*), and the large and readily observable Pacific fruit-bat (*Pteropus tonganus*) in Fiji.

The model's performance can be validated only when it can be compared with post-construction mortality data that are sufficient to permit calculation of an actual annual mortality rate and a 95% confidence interval for that rate. Conditions of regulatory approval for most wind farms that have been built to-date in Australia have varied considerably between state jurisdictions and over time. Generally they have not required rigorous investigation or public reporting of avian collisions that occur during operation. We have thus had limited opportunity to validate our model against empirical information for actual collisions. However, where these are available, we can compare the model's predicted average estimates with the measured confidence interval for actual mortalities to assess its predictive capacity. We present one such case study below.

Comparing the Model's Predictions With Empirical Data—A Case History

Substantial investigations have been undertaken at Bluff Point and Studland Bay wind farms in northwestern Tasmania entailing a number of studies of wedge-tailed eagle and white-bellied sea-eagle (*Haliaeetus leucogaster*). These have included utilization surveys designed to measure eagle activity before and after development of the wind farm; collision monitoring; eagle breeding success; eagle behaviors and movements relative to turbines and observers; and investigations and trials aimed at reduction of collisions (Hull et al. 2013). Commissioning of turbines began at Bluff Point Wind Farm in 2002 and at Studland Bay Wind Farm in 2007. Bluff Point Wind Farm consisted of 37 Vestas V66 turbines in a scattered array on an area of 1,524 ha. Studland Bay Wind Farm was situated 3 km south of Bluff Point and comprised 25 Vesta V90 turbines in a scattered array over an area of 1,410 ha. Both wind farms were close to the coast of northwestern Tasmania and resident white-bellied sea-eagles and Tasmanian subspecies of wedge-tailed eagle (*A. a. fleayi*) occurred at both sites.

Monitoring Eagle Flights

Movement data for both species were collected during point counts at Bluff Point Wind Farm site in 3 years prior to construction of turbines and in 4 years after they commenced operating. At Studland Bay, they were collected in 6 years prior to turbine construction and in 3 years after turbines commenced operation. As prescribed by regulatory authorities, point counts were undertaken in the austral autumn and spring. Ten replicate point counts were made in each season at 18 locations per wind farm. There were 545 point counts undertaken at Bluff Point between 1999 and 2007 and 854 point counts at Studland Bay between 1999 and 2009.

Collision Risk Model Results

We used the model to estimate risk based on movement data collected prior to construction for populations of 6 wedge-tailed eagles and 4 white-bellied sea-eagles at-risk per annum at each of the 2 wind farms.

State regulatory authorities have required that the collision risk model be re-run with the accumulated sum of eagle movement data obtained during the entire period of both pre-construction and operation of the 2 wind farms spanning the period from 1999 to 2009 (Table 1). We modeled static avoidance rate at 99% in all cases.

Documented Eagle Collisions

Carcass monitoring surveys were conducted at the Bluff Point and Studland Bay wind farms since they commenced operating. Fences to exclude mammalian scavengers were maintained at 27% of turbines across the 2 sites. All turbines, both fenced and unfenced, were searched routinely within a 100-m radius of the tower base. Search frequency was initially informed by trials to determine rates of loss to scavengers and of observers' capacity to detect carcasses. Since 2007, searches were carried out twice weekly during periods that may have represented higher risk to the species (i.e., eagle display period Jun–Aug, inclusive; and eagle fledging period mid-Dec–Feb, inclusive) and fortnightly outside these periods (Hull et al. 2013). Assessment of the extent of undetected eagle collisions (Hydro Tasmania 2012; Hull et al. 2013) concluded that it is unlikely that significant numbers of eagle carcasses were missed because they are conspicuous; the search zone around turbines was adequate to detect eagle carcasses where they will fall after colliding with turbines (Hull and Muir 2010); personnel on site had capacity to detect carcasses that may have been moved from the formal search zones; eagle carcasses in vegetation were found not to decompose readily and, even when scavenged, remains were identifiable; avian scavengers did not remove all evidence of carcasses and, although mammalian scavengers could remove carcasses, this was controlled at the subset of fenced turbines; survey intensity was informed by predetermined scavenger removal rates; and, although a small number of eagles survived collision with a turbine, in all documented cases such birds were unable to fly and are likely to have been detected because both scavenger exclusion and farm fences prevented them from leaving the site.

Table 1. Modeled mean annual turbine collision estimates for 2 eagle species based on movement data collected over the span of pre-construction and operation of 2 wind farms in northwestern Tasmania, Australia, from 1999 to 2009. Estimates are shown for 4 potential dynamic avoidance rates. Static avoidance rate was modeled at 99% in all cases

	White-bellied sea-eagle		Wedge-tailed eagle	
Dynamic avoidance rate (%)	Bluff Point	Studland Bay	Bluff Point	Studland Bay
90	0.9	0.8	2.7	1.9
95	0.5	0.4	1.5	1.1
98	0.2	0.2	0.7	0.5
99	0.1	0.1	0.4	0.3

Comparison of Collision Risk Model Estimates With Actual Mortality Rates

Given constraints of statistically low collision numbers, the model's estimates of annual collisions, based on the combined total of movement data from pre-construction and operation of the 2 wind farms from 1999 until 2009 (Table 1), compare well with actual mortality of the 2 eagle species at both wind farms (Table 2). The model's estimate of the number of wedge-tailed eagle collisions per annum at Bluff Point at a 95% avoidance rate was 1.5, which is the same as the mean number of documented mortalities per annum. Estimates provided for this case by model iterations for 90% and 95% avoidance rates fell within the 95% confidence interval of measured mortality rates. The model's estimates for number of collisions at a 95% avoidance rate for white-bellied sea-eagles at Bluff Point (0.5) and for wedge-tailed eagles at Studland Bay (1.1; Table 1) also closely approximated the mean numbers of documented mortalities per annum for the 2 species (0.4 and 1.0, respectively; Table 2). For those cases, the model's estimates for the range of avoidance rates between 90% and 99% fell within the 95% confidence interval of measured mortality rates. No white-bellied sea-eagle collisions have yet been reported from Studland Bay so, to date, the model's estimates are higher than actual experience for that species there.

MANAGEMENT IMPLICATIONS

We consider that there are 2 different, although not mutually exclusive, applications for modeling of bird collision risks at prospective wind farms. These are to provide projections of long-term effects of a particular wind-energy facility on key bird species; and to determine relative risks for key species that are associated with different wind-farm sites, different portions of large wind farms, and different types of turbines and/or turbine configurations.

In many respects, we consider the latter use of collision risk modeling is the most important contribution it offers. This application provides a tool for planning of wind farms to avoid, reduce, or mitigate potential risks to birds. The model we describe here has now been used in such an iterative manner for a number of prospective sites to evaluate relative risks to key species posed by different types, sizes, numbers, and layouts of turbines.

The integration in our model of data for numbers of bird flights with numbers of birds in the population at-risk is key to the accurate prediction of potential numbers of collisions. This aspect appears not to have been adequately considered previously but has real implications to the appropriate determination of actual risks posed by a wind farm. Our model's use of bird flight data to determine annual flux of movements; a mathematical solution to the typical number of turbines that might be encountered in a bird flight; capacity to assess wind-farm configurations ranging from turbines scattered in the landscape to linear rows of turbines; and the option of assigning different avoidance rates to components

Table 2. Average annual mortality rate and variance for 2 eagle species based on carcasses detected at 2 wind farms in northwestern Tasmania, Australia

	White-bellied sea-eagle		Wedge-tailed eagle	
Wind farm	**Mean annual mortality**	**Annual variance (95% CI)**	**Mean annual mortality**	**Annual variance (95% CI)**
Bluff Point 2002–2012	0.4	0.1–1.0	1.5	0.8–2.6
Studland Bay 2007–2012	0.0	0.0–0.7	1.0	0.3–2.2

of turbines that pose more or less risk, all represent refinements designed to improve the predictive capacity of turbine collision risk modeling.

In the cases outlined here, where long-term mortality data sets have permitted validation of the model's collision estimates at given avoidance rates, the two have closely approximated each other. We will seek further opportunities to compare the results of our model with empirical mortality information from operating wind farms, with a view to wider application of the model.

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Appendix 4 Population viability analysis

Results for Brolga PVA at Kentbruck

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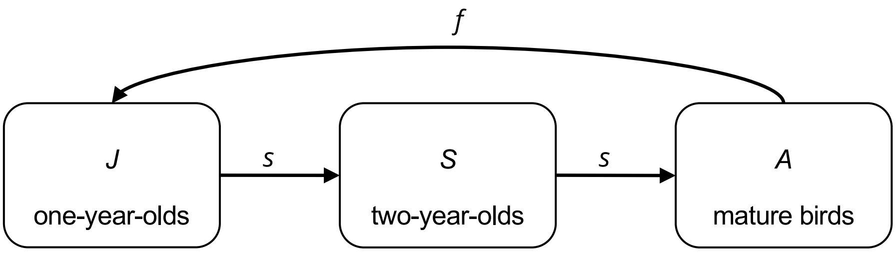
This report documents a population viability analysis (PVA) of brolga to predict the impacts of a proposed wind farm at Kentbruck, using updated predictions of deaths of brolgas from collisions with powerlines and turbines as provided by Biosis. The predictions of impacts on the brolga population in south-western Victoria are based on three different avoidance rates (95%, 98%, 99%) and for two different scenarios – one in which collisions with powerlines are eliminated by putting the powerline underground. These correspond to 0.21, 0.09 and 0.05 collisions per year for the three avoidance rates in the absence of collisions with powerlines, and 1.07, 0.95 and 0.91 collisions per year in the scenario with powerline collisions. These annual rates were converted to a per-capita annual rate by assuming the population size of brolga is 625 birds. The same scenarios were also run assuming the initial population size was 907 birds (DSE report of simultaneous flock counts in April 2013). The expected minimum population size (EMP) was calculated for each of these scenarios, and compared to the EMP in the absence of the wind farm development.

The population viability analysis was based on an age-structured model, with individuals classified as being one year old birds (juveniles), two year-old birds (sub-adults) and mature birds (adults). Let *J*, *S* and *A* be the abundances in each of these age classes. The per capita fecundity rate (*f*) and survival rate (*s*) define the transitions among these age classes, which can be represented diagrammatically:



The fecundity rate *f* is the product of the probability that an adult breeds, the average number of chicks produced, and the survival of any chicks to one year of age. The transitions between age classes can be defined by a matrix (**M**):

$$\mathbf{M} = \begin{bmatrix} 0 & 0 & f \\ s & 0 & 0 \\ 0 & s & s \end{bmatrix}$$

Estimation of the parameters *s* and *f* is problematic for brolga because mark-resighting data are not available. However, estimates can be derived from the observed ratio of immature (one-year-old and two-year-old birds) to mature birds and assumptions about the population trend with particular assumptions. If the population is stable (abundances of each of the age classes are the same from year to year):

$J = f\,A$,
$S = s\,J$, and
$A = s\,(S + A)$.

Solving these equations leads to:

$f = (1 - s) / s^2$, and
$s = \sqrt{(R + 1)} / (R + 1)$,

where R equals the ratio of immature to mature birds $((J + S) / A)$. Therefore, if $R = 0.05$, which is approximately the case for contemporary populations in southeastern Australia (Herring 2001), $s = 0.976$ and $f = 0.025$, which are used as the standard set of parameter values. The estimate of s can be compared to predictions from an allometric model (McCarthy et al. 2008, but with additional data on cranes: Bennett and Bennett 1990, Link et al. 2003, Masatomi et al. 2007) that predicts the annual survival rate of adult birds from body mass. Based on a body mass of 6 kg, the predicted annual survival rate of cranes is 0.91 with a 95% credible interval of [0.77, 0.96]. Therefore, the estimate based on age structure is higher than might be expected for a crane of this size but not inconceivably so. Nevertheless, a survival rate less than 0.976 may be possible, and in fact may be likely.

The population growth rate based on the matrix model can be obtained by eigenanalysis of the transition matrix **M**, and is the (real) solution to the cubic equation:

$\lambda^3 - s\,\lambda^2 - f\,s^2 = 0.$

A closed form solution can be obtained, but it is unhelpfully complicated (result not shown). However, the solution can be approximated using a first-order Taylor series expansion around the point $f = 0$, leading to $\lambda \approx s + f$. The next term in the expansion is $-f^2/s$, which is small when f is small and s is large. Therefore, $\lambda \approx s + f$ is a good approximation if $f \approx 0$ and $s \approx 1$, which is the case for the brolga. This means that reductions in the population growth rate due to decreased survival of brolgas can be approximately compensated by an increase in fecundity of the same magnitude.

Initial abundances in the simulation were set at 79 1-year-olds, 75 2-year olds, and 753 adults, reflecting the 2013 simultaneous flock counts, or 54 1-year-olds, 52 2-year olds, and 519 adults when assuming an initial population size of 625 birds. The numerous younger birds (17% of the population) suggests that annual recruitment rate has been approximately 10% in the two years prior to the survey following high rainfall. Assuming annual survival of 0.976, and a reproduction rate of 2.5% on average to obtain a stable population size, this suggests large variation in reproduction – a value of 100% for the CV seems plausible. This value was chosen for the CV for fecundity, and 50% was chosen for the CV of mortality (which translates to small variation in survival).

Simulations were based on 1,000,000 stochastic iterations for each set of parameters with analyses done within the statistical programming language R. This model is structurally identical to the previous analyses conducted in RAMAS/GIS (Akçakaya and Root 2002).

Results

In the absence of losses to wind turbines and powerlines, the expected minimum population size over the next 25 years was 555.5 brolgas when the initial population size was 625 brolgas, and was 807.3 when the initial population size was 907 brolgas. Impacts of the turbines and powerlines can be compared to these values (Tables 1).

Table 1. Expected minimum population (EMP) size of the south-west Victorian brolga population for each of the three different turbine avoidance rates when the initial population size was 625 or 907 brolgas. The reduction in the EMP compared to the absence of turbines is given in brackets.

	Expected minimum population (EMP) size over 25 years, and the reduction in EMP due to collisions (in brackets).

Initial brolga population size	Collision scenario	95% avoidance rate	98% avoidance rate	99% avoidance rate
625 birds	With powerline collisions	541.9 (13.6)	543.5 (12.0)	544.1 (11.4)
	Without powerline collisions	553.0 (2.5)	554.4 (1.1)	554.8 (0.7)
907 birds	With powerline collisions	793.8 (13.5)	795.4 (11.9)	796.0 (11.3)
	Without powerline collisions	804.8 (2.5)	806.2 (1.1)	806.6 (0.7)

The expected minimum population size (EMP) is a useful metric of the risk of decline. It is calculated from stochastic simulations of the model. The smallest population size in each of the simulations is recorded. The EMP is the average of these, representing the average amount that a quasi-extinction risk curve is above extinction (McCarthy 1996; McCarthy and Thompson 2001).

The linear approximation of the population growth rate ($\lambda = f + s$) indicates the number of births that would be required to offset mortality events from collisions. Because fecundity and survival have approximately additive effects on growth rate, each mortality event would need to be mitigated by an extra bird being raised to adulthood. This might be achieved by improving breeding habitats or reducing collision with other infrastructure such as powerlines or fences (Beaulaurier 1981; Alonso et al. 1994; Brown & Drewien 1995). For example, with a 95% avoidance rate, the expected number of extra deaths is 1.07 birds per year with the aboveground powerline scenario. If survival of juveniles to adulthood is j, then the required number of extra juveniles can be calculated as $1.07/j$. Assuming that j is larger than ~0.55, then two extra juveniles per year (rounded up) would be sufficient to compensate for the extra mortality. If $j = 0.75$, then an average of 1.4 extra juveniles per year is required to compensate for the death of 1.07 birds per year. Given uncertainty about j (see above), then a requirement for two extra juveniles per year might be prudent.

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Glossary of acronyms

CV	coefficient of variation, equal to the standard deviation divided by the mean.
EMP	expected minimum population size; a measure of risk of decline of a population.
PVA	population viability analysis; a model-based analysis of the risk of decline of populations.

Appendix 5 Collision risk model results for higher portion of juveniles in the local Brolga population

As described in Section 5.5.4, breeding success data for the south-western Victorian population of Brolgas indicates the long-term average ratio of post-fledging juveniles in the population is approximately 10%. This accounts for variation between years in which the ratio may be higher or lower than the average.

In the limited monitoring of Brolga breeding for the KGPH Project, fledging success was higher than the long-term average and the ratio of juveniles to adults recorded was 18%. In view of these local results, turbine collision risk modelling was undertaken for ratios of 10% and 18% of juveniles in the population. Respectively, these equate to annual averages of 1.4 (10%) and 2.5 (18%) juveniles accompanying 14 adults. We have therefore modelled for totals of 15.4 and 16.5 birds at risk per annum. In the body of this report collision risk modelling and its results are provided for the population long-term average ratio of 10% (i.e. an annual total local population of 15.4 birds). Here we provide collision risk modelling results for a local population in which the ratio of juveniles to adults is 18% (i.e. an annual total local population of 16.5 birds). The rationale and methods of calculations for running collision risk modelling for this value are identical to those described in the body of the report.

Results and comparison of these two scenarios are provided in tables below. The results differ very little and it is necessary to show them to three decimal places simply to show differences between them. This should not be interpreted as a level of precision in the results. For the purposes of evaluating the potential for Brolga collisions to affect the viability or functioning of the population, the difference between the scenarios for different ratios of juveniles are immaterial and as the PVA (Appendix 3) uses rounded values it has no capacity to discriminate between the results for the very minor differences between results presented here.

Table A4.1 - Projected number of Brolga collisions with turbines (60m blade clearance) for an average of 16.5 birds at risk per annum

Projected annual number of Brolga collisions with turbines			
Turbine avoidance rate	**0.95**	**0.98**	**0.99**
Breeding season (incl. migration flights)	0.143	0.059	0.032
Non-breeding season	0.071	0.030	0.016
Annual average total	**0.214**	**0.089**	**0.048**

Table A4.2 - Projected number of Brolga collisions with turbines (60m blade clearance) for an average of 15.4 birds at risk per annum

Projected annual number of Brolga collisions with turbines			
Turbine avoidance rate	**0.95**	**0.98**	**0.99**
Breeding season (incl. migration flights)	0.133	0.056	0.030

Projected annual number of Brolga collisions with turbines			
Non-breeding season	0.067	0.028	0.015
Annual average total	**0.200**	**0.084**	**0.045**

Appendix 6 Assessment of the southern and eastern powerline options based on database records

Assessment of impacts on Brolgas for the southern and eastern powerline options based on database records.

- Option One: underground route - Heywood
  The Option One route generally extends between the eastern boundary of the proposed wind farm site and the existing Heywood Terminal Station located inside the western boundary of the Narrawong Flora Reserve / Mount Clay State Forest (on land owned by AusNet). This transmission line connection option is approximately 26.6 kilometres long. Within Cobboboonee National Park and Cobboboonee Forest Park, the transmission line would be located beneath Boiler Swamp Road (for a distance of approximately 17.6 kilometres) which bisects the Parks in an east to west direction. The underground section would be constructed within a 6.5 metre construction footprint, with cabling buried at a depth of approximately 1.25 metres beneath the existing road. Construction would be mostly via trenching, with horizontal directional drilling (HDD) used in several locations to avoid impacts on waterways, including the Surrey River. After exiting Cobboboonee Forest Park the underground line would continue for 1.2 kilometres through freehold agricultural land to the Surrey River. To the east of the Surrey River, the transmission line would continue underground, either trenched or directionally drilled to avoid native vegetation and road and rail crossings, for 7.8 kilometres until its connection point to the Heywood Terminal Station.
- Option Two: Overhead only route - Portland
  The overhead route (also referred to as the 'Portland' Option or the 'Southern' Option) connects the project from the eastern end to the existing Heywood–Portland 500 kV transmission line, involving construction of a new Terminal Station. The line would pass south-east towards Portland through private property in the Mount Richmond and Gorae West localities. A decision was made during field assessment for the project to discontinue the assessment of this option and focus on Option 1. This decision was made with consideration of land access, visual impact, vegetation removal and community concerns. As a result, only limited field-based ecological information is available for Option 2, in comparison with the detailed studies conducted for Option 1.

NeoEn required an additional impact assessment of the southern transmission line option in comparison to the potential impacts of the eastern transmission line. The southern transmission line alignment traverses south-east from the Gorae West part of the Project area towards Portland, terminates at Cashmore, and would be overhead along the entire route. The eastern transmission line runs underground from Gorae West, through the Cobbobonee National Park, with an overhead section from the eastern end of Cobbobonee National Park to Heywood.

As the Brolga assessment identified no flocking areas (DELWP 2020) or flock roost sites (DSE 2012) within 10 kilometres of the Project area boundary, this assessment was confined to 3.2 kilometre radius from the southern and eastern transmission line routes and focused on identifying potential breeding sites.

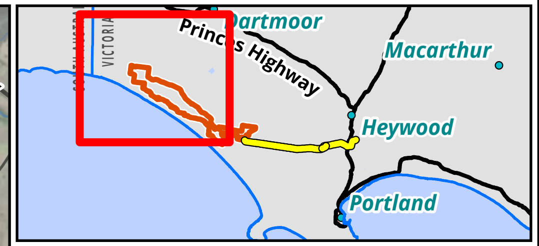
The database search results are shown in Table A6.1

Table A6.1 Comparison of Brolga records in database searches within 3.2 kilometres of the Project area

Record	Southern route	Eastern route
Non-breeding	**16**	**8**
VBA	10	5
BirdLife	6	3
Breeding	**1**	
BirdLife	1	

The southern route has an overall higher number of records (17) than the eastern route (8) and includes one database breeding record. Inferring potential impacts of the transmission lines based solely on database records has major limitations. The absence of records is often not indicative of absence of the species, or breeding records, but is generally related to survey effort and lack of data submissions from a particular area. The Biosis field surveys and community consultation found six (6) Brolga breeding records along the overhead section of the eastern route, that were not in the database searches. Similarly, two (2) confirmed breeding sites were found along the eastern survey, which was not subjected to the same amount of field survey effort as the eastern transmission line route. Another breeding site is likely to be present near Stephen's Road along the southern transmission route, where a family group including a pair and juveniles were recorded.

Notwithstanding these limitations of database records and unequal survey effort, any reduction in the length of an overhead powerline is recommended, to reduce collision impacts on locally breeding Brolgas and on other locally occurring threatened avifauna. The eastern route achieves this reduced transmission line length compared to the southern transmission line. Although fewer Brolga breeding pairs were recorded along the southern route, it was not surveyed as intensively as the eastern transmission line and the southern transmission line would not be a recommended option in favour of the eastern powerline. The eastern powerline is likely to have an impact on locally breeding Brolga pairs within 3.2 kilometres of the route (see Section 5.6.5) and the recommendation would be to bury it to avoid collision impacts on the species. If the southern transmission line is the preferred option, further detailed and targeted breeding season surveys would be required to understand its full impact on the Brolga within the Project area.



Legend

- Wind farm footprint
- Northern transmission line
- Southern transmission line (July 2020)
- Project footprint 3km buffer
- Project footprint 5km buffer
- Project footprint 10km buffer

Brolga records (BirdLife) labelled by year
- Breeding
- Non-breeding

Brolga records (eBird) labelled by year
- Breeding (probable)
- Non-breeding

Brolga records (VBA) - labelled by year
- Breeding
- Non-breeding

Brolga records (Sheldon) - labelled by month/year and (bird count)
- Sheldon 2004 brolga flocking database records

Wetlands
- 1 - Flooded river flats
- 2 - Freshwater meadow
- 3 - Shallow freshwater marsh
- 4 - Deep freshwater marsh
- 5 - Permanent open freshwater
- 6 - Semi-permanent saline
- 7 - Permanent saline
- 20 - Sewage oxidation basin
- 21 - Salt evaporation basin
- 99 - No Category

Appendix 6.1 Brolga database records – including southern transmission line option

0 1 2 3 4
Kilometres
Scale: 1:100,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

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Matter: 35014,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_Appendix6_supersededNov2023_F4_DatabaseRecords_STL
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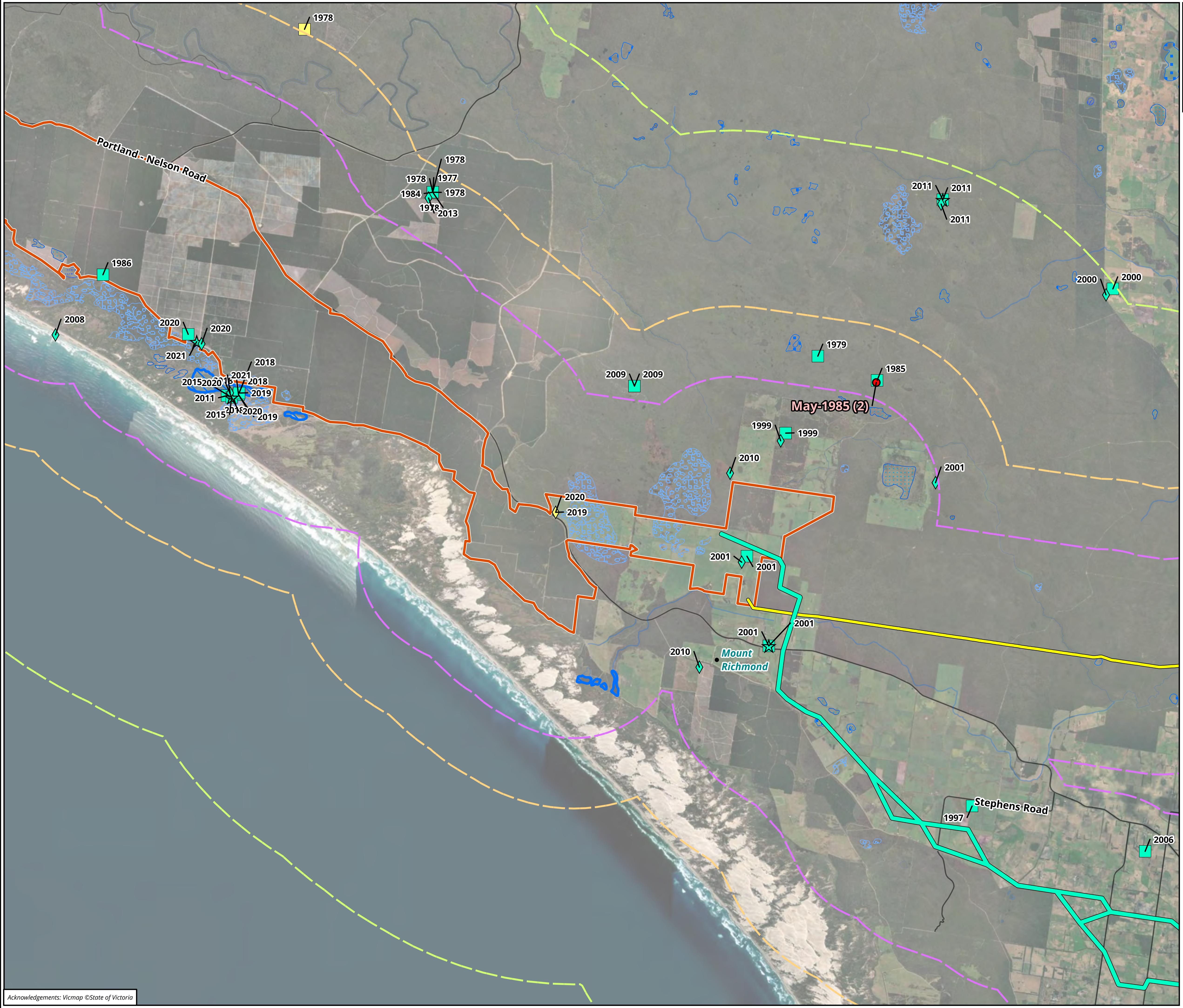

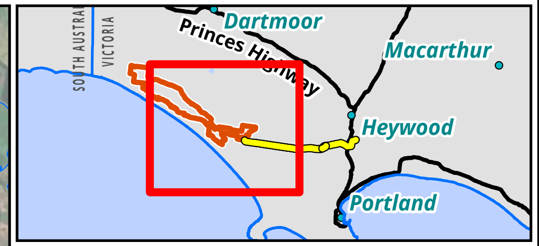

Legend

- Wind farm footprint
- Northern transmission line
- Southern transmission line (July 2020)
- Project footprint 3km buffer
- Project footprint 5km buffer
- Project footprint 10km buffer

Brolga records (BirdLife) labelled by year

- Breeding
- Non-breeding

Brolga records (eBird) labelled by year

- Breeding (probable)
- Non-breeding

Brolga records (VBA) - labelled by year

- Breeding
- Non-breeding

Brolga records (Sheldon) - labelled by month/year and (bird count)

- Sheldon 2004 brolga flocking database records

Wetlands

- 1 - Flooded river flats
- 2 - Freshwater meadow
- 3 - Shallow freshwater marsh
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- 21 - Salt evaporation basin
- 99 - No Category

Appendix 6.2 Brolga database records – including southern transmission line option

0 1 2 3 4
Kilometres
Scale: 1:100,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

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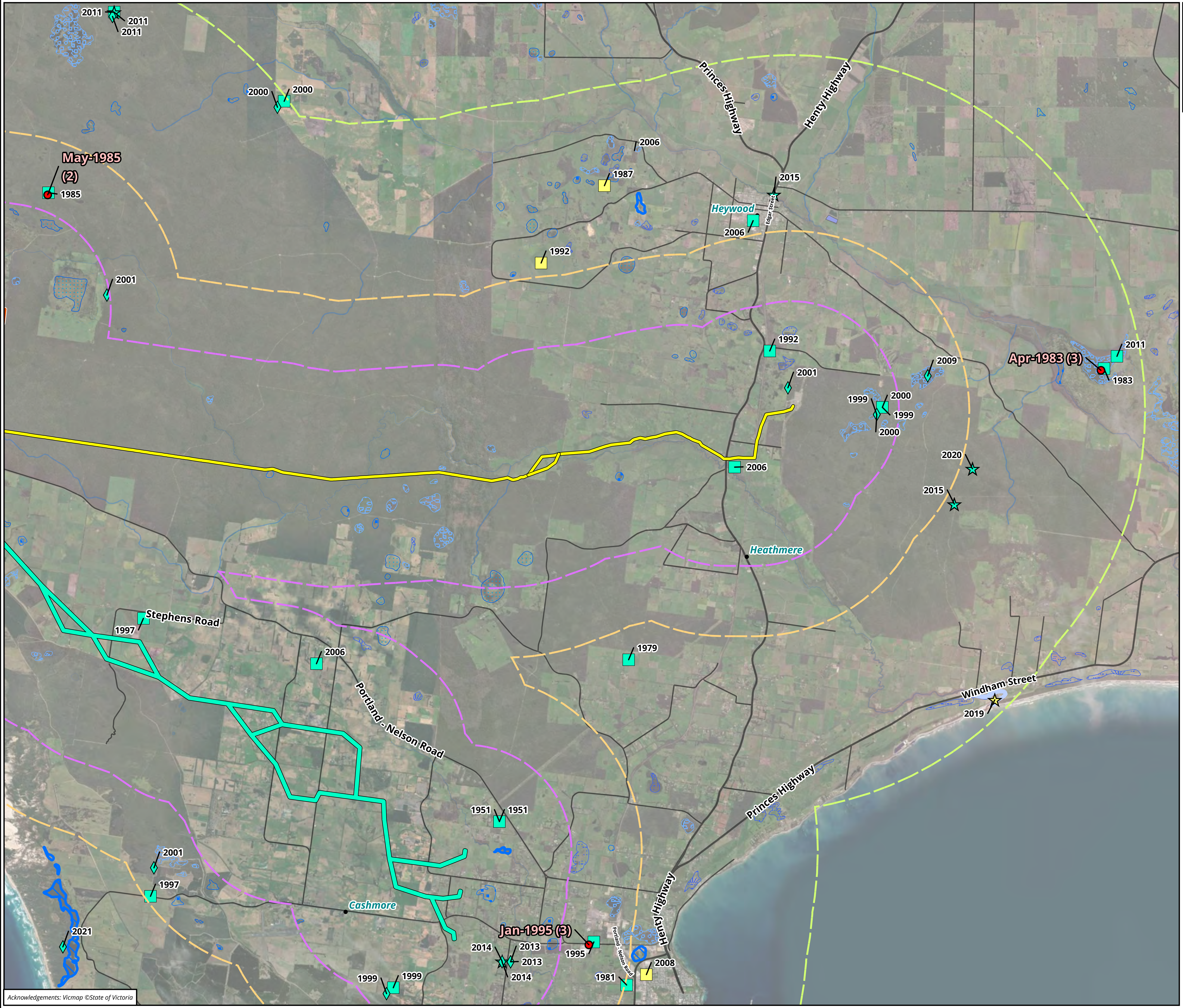

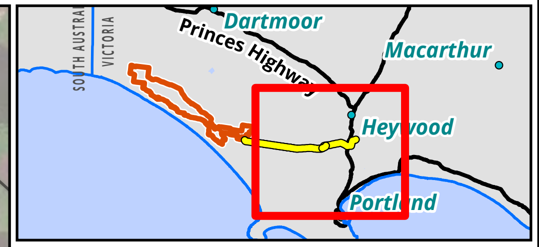

Legend

- Wind farm footprint
- Northern transmission line
- Southern transmission line (July 2020)
- Project footprint 3km buffer
- Project footprint 5km buffer
- Project footprint 10km buffer

Brolga records (BirdLife) labelled by year
- Breeding
- Non-breeding

Brolga records (eBird) labelled by year
- Breeding (probable)
- Non-breeding

Brolga records (VBA) - labelled by year
- Breeding
- Non-breeding

Brolga records (Sheldon) - labelled by month/year and (bird count)
- Sheldon 2004 brolga flocking database records

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- 99 - No Category

Appendix 6.3 Brolga database records – including southern transmission line option

0 1 2 3 4
Kilometres
Scale: 1:100,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

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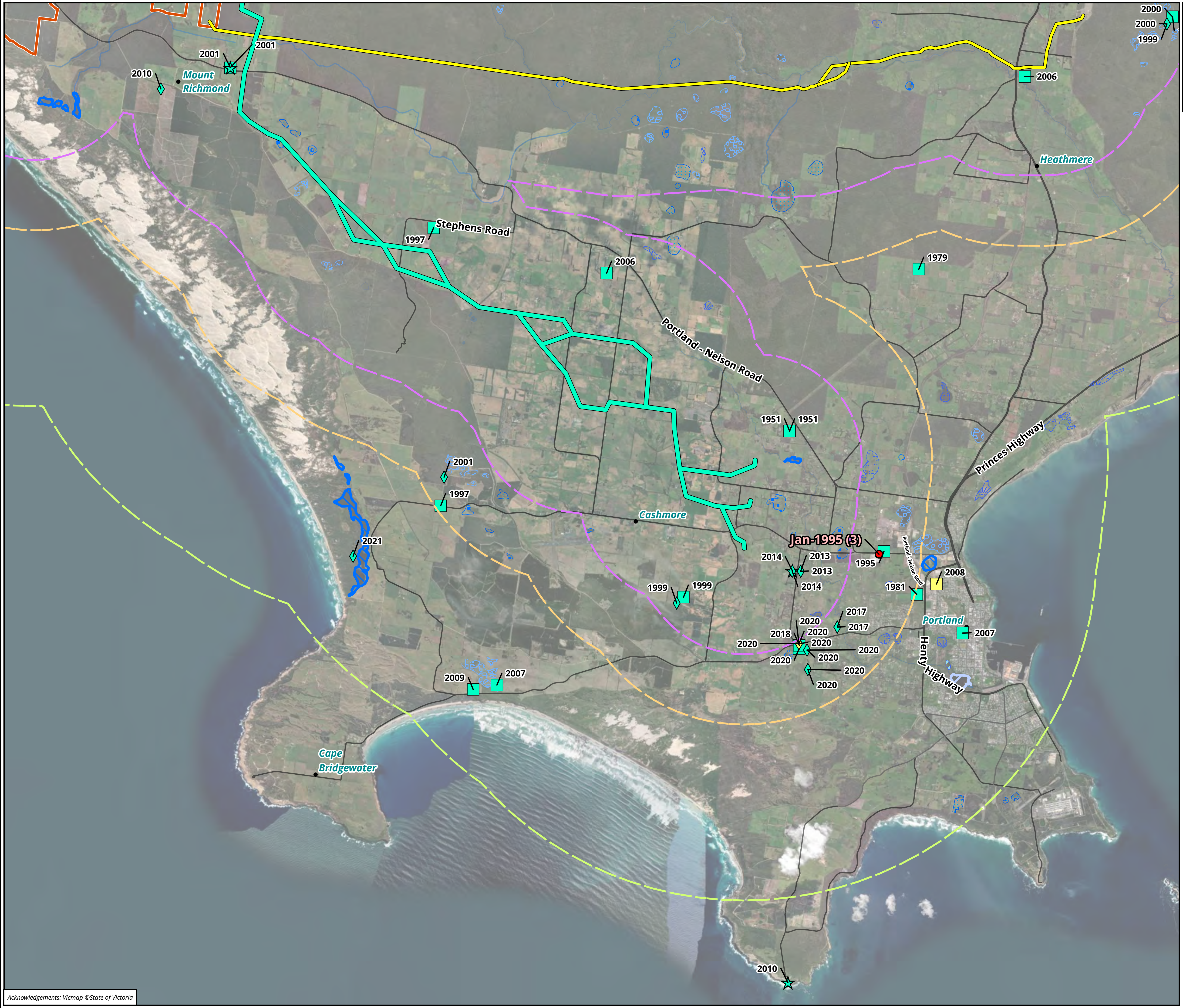

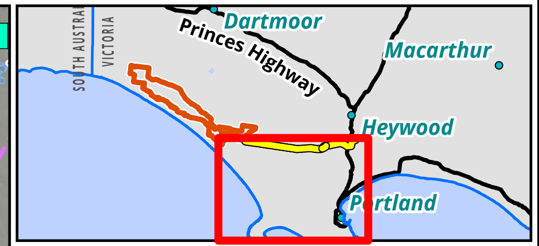

Legend

- Wind farm footprint
- Northern transmission line
- Southern transmission line (July 2020)
- Project footprint 3km buffer
- Project footprint 5km buffer
- Project footprint 10km buffer

Brolga records (BirdLife) labelled by year
- Breeding
- Non-breeding

Brolga records (eBird) labelled by year
- Breeding (probable)
- Non-breeding

Brolga records (VBA) - labelled by year
- Breeding
- Non-breeding

Brolga records (Sheldon) - labelled by month/year and (bird count)
- Sheldon 2004 brolga flocking database records

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Appendix 6.4 Brolga database records – including southern transmission line option

0 1 2 3 4
Kilometres
Scale: 1:100,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

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35014_BrolgaBreedingWetland.aprx

Appendix 7 Impact assessment for overhead powerline to Heywood Terminal

This Appendix 7 outlines the Project overhead transmission line option between Boiler Swamp Road and the Heywood terminal.

A7.1 Step One: avoid and mitigate potential impacts with turbine-free buffers

A7.1.1 Overhead powerline linking between Boiler Swamp Road and Heywood Terminal

Six breeding records are located along the overhead powerline section connecting to the Heywood terminal, identified through the Biosis aerial surveys and discussions with a local ornithologist:

- Three records within 1 km.
- Two records within 1.5 km.
- One record within 3 km.

Pairs with and without fledged young using these breeding wetlands, and moving between flocking areas further north and the breeding sites, may fly across the powerline and thus a collision risk exists. Juveniles colliding may consequently impact on a pair's breeding success. Brolgas, and cranes in general, are known to collide fatally with overhead powerlines (DuGuesclin 2003).

Avoiding and mitigating potential powerline collisions can be done through:

- Excluding overhead powerlines within likely breeding home ranges
- Placing powerlines underground
- Re-routing away from known or likely regular flight paths
- Near-ultraviolet light (e.g. Dwyer et al. 2019)
- Marking powerlines with bird flight diverter markers

Excluding overhead powerlines and placing them underground avoids collision risk completely. Thus, good environmental impact mitigation strategy should avoid construction of new powerlines in Brolga habitats and where new powerlines are located across likely flight paths, or placing them underground. The Brolga guidelines require turbine free buffers, with a recommendation to exclude new powerlines, or place them underground (Level Three, Step One; Glossary in DELWP 2011). The guidelines are less clear and prescriptive on requirements to avoid and mitigate powerline collision risk, and lack clear and explicit guidance on this.

Based on existing knowledge and evidence on powerline collisions of brolgas and other crane species, new overhead powerlines should be excluded from brolga habitats where they may pose collision risk and increase mortality. To avoid collision risk for breeding brolgas and their young. the preferred construction option for the powerline from the Cobboboonee National Park to the Haywood subterminal station would be to bury it underground.

The Brolga breeding territories are likely to have various degrees of overlap within the proposed new overhead powerline footprint, given their close proximity. No site-based data was collected from this part of the Project area. However, any method of habitat buffering (DSE 2012, Veltheim et al. 2019) would overlap with the majority of, or the entire, overhead powerline footprint. Alternative routes north or south are unlikely to avoid or minimise collision risk as suitable brolga habitat occurs throughout the cleared agricultural land with wetlands. If a new overhead powerline is constructed, mitigation should involve powerline marking, which has been demonstrated to reduce fatal collision for cranes.

A recommendation to reduce collision risk from a new powerline at this location is to bury it underground if possible. Re-routing at the eastern end of the project area, between Cobbobonee National Park and the Heywood terminal is not recommended, as the collision risk to the north and south will remain due to presence of brolga breeding pairs and habitat north and south of the current powerline alignment. If an overhead powerline is constructed, it should be marked with commercially available bird flight diverter markers so it is more visible to Brolgas. Options to install near-ultraviolet light to reduce collisions should be considered, as this method has shown to reduce Sandhill Crane (*Antigone canadensis*) collisions by 98% (Dwyer et al. 2019).

A7.2 Step Two: Approach to scenario collision risk modelling for Brolga

A7.2.1 Background to collision impact assessment for Brolgas at Kentbruck Wind Farm

Powerline collision risk model

For consistency with assessments undertaken for previous energy projects, the risk of Brolgas colliding with a proposed new overhead powerline exporting electricity from the Project wind farm to Heywood have been evaluated using the principles and methods outlined in Biosis Research (2009).

Brolgas are known to occasionally fatally collide with powerlines in Victoria, although published documentation of this is limited and is not recent (White 1987; Goldstraw and du Guesclin 1991). There are no empirical data about Brolga collisions with powerlines in south-western Victoria that might provide a basis for quantifying them. While there is a substantial international literature about bird collisions with powerlines (see review of Bernardino et al. 2018), there are relatively few rigorous studies that have attempted to quantify rates of collision and fewer still of them have investigated effects on cranes. In the absence of empirical data for Brolgas, the approach to assess potential risk is based on the annual cycle of Brolga activities and behaviours and specific information including the following:

- Alignment location information for overhead powerlines for the Project wind farm.
- Information about the average per annum number of Brolgas that may use breeding sites in proximity to the proposed overhead powerline.
- Assumptions about the number flights per annum from breeding sites that have potential to reach and interact with the powerline.
- A collision rate for powerline crossings, based on studies of other crane species reported in the international literature.

A7.3 Scenario collision risk modelling for Brolgas

The following components were undertaken as part of the current assessment:

1. Modelling for the potential flights of Brolgas at risk of collisions with turbines and the external overhead transmission line during the annual breeding season; and
2. Modelling for the potential flights of Brolgas at risk of collisions with turbines and the external overhead transmission line during the annual non-breeding season.

Specifics of the rationale and input values used for assessments of Project wind farm are set out below.

A7.4 Scenario modelling of overhead powerline collision risk for Brolgas

Empirical evidence exists for occasional fatal Brolga collisions with powerlines (Goldstraw & du Guesclin 1991). Discussions by Biosis staff with local landowners and a local field naturalist revealed their incidental knowledge of four instances of such collisions in the local area over a period of approximately 35 years, however the overall frequency at which such collisions occur is unknown.

The Kentbruck project includes two overhead powerlines:

- an internal powerline running parallel to a portion of the Portland Nelson Road transmitting electricity to the Project substation at Gorae West.
- a 275 kV transmission line to export electricity from the wind farm to the external grid

As for modelling of turbine collision risk, modelling the risk of Brolga collisions with these powerlines has been undertaken for birds using breeding sites that are within 3.2 kilometres of the powerline routes.

The internal powerline route proposed to run beside Portland Nelson Road is not within 3.2 kilometres of any identified Brolga breeding wetland and collision risk modelling is thus not applicable to it.

The alignment and design of the 220 kV export transmission line runs from the eastern end of the proposed wind farm at Gorae West to Heywood Terminal Station. The majority of this transmission line will be located underground and a short eastern portion will be overhead across private properties to the Heywood Terminal Station. The underground portion poses no collision risk for Brolgas. Collision risk is considered here for the relatively short portion of the line that is proposed to be overhead. The KGPH Project is assessing the potential to underground the entire export transmission line and in that event, it will pose no collision risk for Brolgas. Modelling detailed below is based on the conservative assumption that the eastern portion of the export transmission line will be overhead.

There are some records of Brolgas using breeding sites within 3.2 km of the proposed 275 kV overhead transmission line and thus a collision risk assessment is provided here for Brolgas within that zone.

A7.4.1 Transmission line

The overhead transmission line is planned to use monopoles that will generally be between 40 and 50 metres high and spaced between 200 and 400 metres apart. The poles may be double or single circuit and have one or two overhead earthing/communication lines.

International data suggests that earth wires are likely to represent greater collision risk to cranes than conductor wires (Stehn and Wassenich 2008). This is because these wires are above the conductors and are thinner and probably more difficult for birds to detect.

A7.4.2 Brolga flight heights relative to transmission line collision risk

A relationship between Brolga flight distance and flight height is indicated (see section 2.3) and has utility in assessment of collision risk for turbines because turbines components occupy a substantial span of vertical airspace. By comparison, transmission wires are extremely thin and occupy a very narrow height band. It is feasible that Brolgas flying from a point that is a greater distance from the transmission line are likely to be higher and thus more likely to pass over it. However, for the purposes of this modelling a conservative approach has been adopted and assumes that all flights that may travel from a breeding wetland may be at risk of colliding with the transmission line. This assumption also addresses the possibility that Brolgas may always respond to the presence of an overhead transmission line by attempting to fly over, rather than under its wires.

A7.4.3 Breeding season

There are six wetlands on private agricultural land where local ornithologists and Biosis aerial surveys have documented Brolgas breeding within 3.2 km of the proposed overhead transmission line. Historical database records of Brolgas also exist for four of these locations. During fieldwork for the project, Biosis observed Brolgas at two of these locations. The six sites, numbered as in map Figure 1, are as follows:

9. Heywood Bushland Reserve

10. Coffeys Lane/Princes Hwy

11. Golf Course Road

12. Surrey River flats

13. Jarretts Road

14. Meaghers Road

The distances between the six wetlands and the closest point of the overhead transmission line vary from approximately 3 kilometres (site 12) to less than 100 metres (site 14). These distances would appear to position the transmission line within routine daily flight distances of Brolgas using these breeding sites. Site 8 (Figure 9 Brolga flocking records within 10 km of the Project) is a little more than 3.2 kilometres from the proposed underground portion of the export transmission line and very much further from the overhead portion of it.

Number of individuals at risk

As a conservative measure it is assumed that a pair of Brolgas will occupy each of the six wetlands every breeding season and that the average number of fledged juveniles per pair will be 10% of the number of adult birds, as detailed for turbine risk modelling. There is thus an expectation that there will be an annual average of 1.2 juveniles accompanying 12 adults per annum. We have therefore modelled for a mean total of 13.2 birds at risk of collision with the overhead transmission line per annum. This average allows for years in which higher or lower numbers of Brolgas may be present and at some risk.

Numbers of flights at risk

In its glossary the Brolga Guidelines says *"Turbine-free buffer zones are recommended to remove potential impacts of wind farm development on breeding and non-breeding Brolga habitats. Within these areas new powerlines should generally be excluded or placed underground."* Thus, while new powerlines are not recommended within turbine-free buffers, there is no general requirement for overhead transmission lines to be buffered from Brolga breeding wetlands. As a consequence of the lack of a constraint due to distance (as applies to buffered turbines), all Brolga flights that have capacity to reach the transmission line are considered to have inherent risk of collisions regardless of the distance between a particular breeding wetland and the transmission line. It is thus assumed that on average each adult and fully fledged juvenile Brolga makes six flights on each of the 183 days of the breeding season. We thus assume that each Brolga may make a total of 1098 flights during the course of a breeding season.

It is acknowledged that flights are not likely to be uniformly distributed, particularly as habitats within 3.2 km of the various wetlands near the transmission line vary considerably, however, as for consideration of turbine collision risk, there are no available data to indicate that the birds preferentially fly in any particular direction, so in the model it is assumed that flight directions are uniformly distributed throughout all 360 degrees of the compass. Hence, the number of their flights that have potential to interact with turbines is prescribed by the arc encompassing the proportion of all flights that are in the direction of the overhead transmission line. The method of calculating this arc is illustrated in Figure 12. The proportion of all flights that are not in the directions of the overhead transmission line are at no risk of colliding with it. The proportion of flights that may be in the direction of the overhead transmission line is thus individually unique to each breeding wetland and was calculated for each of the six breeding wetlands on the assumption that all of them will be occupied by Brolgas every year. The arc that is directed from a wetland towards the wind farm varied among the six wetlands from 52 to 282 compass degrees. In turn, these equate to between 14% and 78% of all flights that could be towards turbines. Using the specific arc and relevant percentage of flights for each of the six breeding wetlands provides a sum total of 6884 Brolga flights-at-risk per breeding season.

Migration season period

Brolgas tend to aggregate into large flocks concentrated on a number of particular wetlands outside the breeding season and many (but not necessarily all) birds move from breeding territories to join these flocks. Prior to the subsequent breeding season, pairs of birds move back to breeding wetlands, and are sometimes accompanied by the juvenile (<12 months old). As per the Brolga Guidelines, two seasonal movements for each adult and fledged juvenile bird have been added to the breeding season modelling to account for these flights. That is 2 x 13.2 = 26.4. Recognising that it is not possible to determine directionality of these flights, it has been assumed that all of them could encounter the transmission line.

Breeding season summary

For each of six Brolga breeding sites during each breeding season the following averages have been assumed:

- The breeding season includes 183 days of the year
- An average of 13.2 Brolgas are present
- Each Brolga makes 6 flights per day of sufficient length to reach the transmission line if they fly in that direction

The six breeding sites vary in their geographic locations relative to the proposed overhead transmission line. As a consequence, the portion of Brolga flights from them that may encounter the line also varies as outlined in Section 3.3.2. The allocations of flights for the six breeding sites is shown in Table A7.1.

Table A7.1 - Breeding season Brolga flights at risk of transmission line collisions for each of six breeding sites used in risk modelling

Wetland	Portion of flights toward transmission line [portion of 360°]	Total flights with potential risk of collision
9. Heywood Bushland Reserve	0.37	886
10. Coffeys Lane/Princes Hwy	0.58	1409
11. Golf Course Road	0.14	349
12. Surrey River flats	0.50	40
13. Jarretts Road	0.47	1141
14. Meaghers Road	0.78	1892
Subtotal of routine daily flights		*5717*
'migration' flights		26
		5743

A further two seasonal movements for each adult and fledged juvenile bird have been added to the breeding season modelling to account for 'migration season' flights (13.2 birds x 2 flights = 26.4, rounded to 26) and making for a total of **5743** flights at risk during an average breeding season.

A7.4.4 Non-breeding season

Flocking

As noted above (section 2.5.1) there are no known Brolga flocking sites within the region and there is thus no requirement to consider powerline collision risk for flocking Brolgas during the non-breeding season.

Resident Brolgas

For the reasons described in section 2.5.2, modelling has been undertaken for some birds that may remain in the landscape of the project area and be at risk of powerline collisions during this period. In the absence of empirical data about the number of birds and the flights they may make, this portion of the modelling is necessarily reliant on arbitrary assumptions that are considered to be reasonable. We have modelled for an average of six Brolgas (i.e. half the number of adult Brolgas modelled as present during each breeding season) to remain in the local area during the non-breeding period.

Non-breeding season summary

Using the rationale for this period as set out in Section 5.5.5, modelling for the non-breeding season accounts for half the number of Brolga flights at risk of collisions with the overhead transmission line as during the breeding season. Hence, **2872** Brolga flights at risk of collision with the transmission per annum have been included in the modelling.

A7.4.5 Modelled Brolga interactions with overhead transmission line

In the absence of any empirical data quantifying transmission line collision rates for Brolgas, we have based this assessment on values provided for Sandhill Cranes by Morkill and Anderson (1991) and for Common Cranes by Janss and Ferrer (2000). A number of studies of powerline collisions by crane species have been published since those works, but they remain the references that quantify the frequency of collisions relative to the number of flights that interacted with transmission lines.

From Morkill and Anderson (1991), we have calculated that they recorded 2.5 collisions per 100,000 powerline crossings by Sandhill Cranes (2.5×10^{-5} collisions per crossing, or approximately 1 collision per 40,000 crossings). Janss and Ferrer (2000) provide estimate values ranging from 1.9 to 4.76 collisions per 100,000 powerline crossings by Common Cranes (between 1.9×10^{-5} to 4.76×10^{-5} collisions per crossing, or between approximately 1 collision per 52,600 crossings and 1 per 21,000 crossings).

These published studies of cranes are the closest comparable information available for evaluation of the situation for Brolgas. However, as we do not know how closely Brolga behaviour conforms to that of these other species we have adopted a conservative approach in which 1 collision may occur per 10,000 transmission line crossings (1.0×10^{-4} collisions per crossing) for our evaluation of risk to Brolgas.

Following the methods outlined above we have used the following factors to determine a potential annual number of Brolga fatalities that might occur as a result of collisions with the proposed overhead transmission line:

- **Breeding season** (including migration flights): subtotal of 5743 flights p.a.) that could encounter the transmission line.
- **Non-breeding season** subtotal of 2872 flights p.a.) that could encounter the transmission line.

The annual average **total of all Brolga flights** per annum that might encounter the transmission line is thus **8615**.

On the basis that one collision may occur once in every 10,000 crossings of the transmission line, we have the following equation:

8615 flights x 1.0 x 10^{-4} collisions per transmission line crossing = **0.86** transmission line collisions per annum.

A7.5 Assessment of collision risk for Brolga

A7.5.1 Results of overhead transmission line collision risk modelling

Under the assumptions used for modelling of potential Brolga collisions with the proposed overhead transmission line, the result projects an annual average of **0.86** collisions.

A7.5.2 Combined results of turbine & overhead transmission line collision risk modelling

The overall annual projections of collision risk for turbines and the transmission line combined are shown in Table A7.2. Results are shown for each of three turbine avoidance rates. For each avoidance rate, the result is shown as the projected annual collision rate.

Table A7.2 – Projections of combined collision risk for turbines and transmission line

Projected annual number of Brolga collisions with turbines & transmission line			
Avoidance rate	**collision rate per annum at 95% avoidance rate**	**collision rate per annum at 98% avoidance rate**	**collision rate per annum at 99% avoidance rate**
Average annual turbine collision rate	0.21	0.09	0.05
Average annual powerline collision rate	0.86	0.86	0.86
Projected number of Brolga collisions with turbines & transmission line combined	**1.07**	**0.95**	**0.91**

A7.5.3 Discussion of collision modelling results

The primary contribution to the potential for collisions as modelled, is due to collisions with the proposed overhead transmission line. If the entire export transmission line is underground and has no overhead component, the overall collision risk for Brolgas would be substantially reduced and the modelled results set out in Table 8 for risk of collisions with turbines only would apply.

As noted throughout this report, in the absence of empirical data the risk modelling exercise is a theoretical one and is based on assumptions that are detailed here. There is no available data quantifying the incidence of powerline collisions by Brolgas. Modelling of that risk is intentionally conservative and, for consistency, follows an approach that has been applied for assessment of such collisions by Brolgas for wind energy projects since 2009 (Biosis Research 2009). In particular, the assumption that Brolga collisions with transmission lines may occur at a rate of 1 per 10,000 flights across a transmission line is higher than the greatest empirical rate available for other crane species (see section 3.5). If the greatest rate reported for Common Crane of 1 per 21,000 flights across a transmission line (Janss and Ferrer 2000) was to be adopted, the risk level for Brolgas for the current project would be less than half the rates reported here.

A7.6 Impact assessment for overhead transmission line to Heywood

The overhead transmission line, along the Portland-Nelson Road and from Cobboboonee National Park to Heywood, is planned to use monopoles that will generally be between 40 and 50 metres high and spaced between 200 and 400 metres apart. The poles may be double or single circuit and have one or two overhead earthing/communication lines. The section of transmission line through the Mt Kincaid, Gorae West private property and through Cobboboonee National Park with an overhead section from the eastern end of the national park to Heywood subterminal station.

Brolgas are known to occasionally collide fatally with power lines (Herring 2001, DuGuesclin 2003, Herring 2005, Veltheim 2017, Farnes 2019, I. Veltheim pers. obs.). Based on observations, and anecdotal reports, juveniles are particularly at risk, especially when power lines are in proximity to a breeding wetland, although adults can also collide with power lines (Veltheim 2017, I. Veltheim pers. obs.). The main potential powerline-related impact on Brolgas is likely to occur along the overhead transmission section from Cobboboonee National Park to Heywood terminal station, where six breeding sites are within >1 km to 3 km of the proposed transmission line.

The magnitude of impact is likely to be greater than potential turbine collision risk, given it is a known threat and as Brolgas are likely to undertake frequent local flights in and out of this area on a daily basis at breeding sites, and on a twice-annual basis when moving between breeding and flocking areas. Juveniles may fly through the area more frequently once the breeding pairs nest.

A powerline at or below the pine canopy height would be unlikely to pose a collision risk to the Brolga. An internal reticulation overhead transmission line is also proposed to be constructed parallel to the Portland-Nelson Road. There is currently uncertainty about how the transmission height relates to the height of the pines. We understand the transmission line is higher than the tree line (at 36 m top height of steel poles) and below the bottom of the turbine rotor swept area. This could pose a collision risk to birds, including Brolgas, where the powerline height sits between the top of the pine tree canopy and the bottom turbine blade tip. As well as being within the flight height range of birds (including Brolgas) undertaking local flights, a transmission line above the canopy height could pose collision risk when birds attempt to avoid blades and fly underneath them. The Portland-Nelson Road is unlikely to pose a similar risk to Brolgas, however, as the Cobboboonee National Park to Heywood section. There is no suitable wetland habitat that would suggest frequent and regular local flights south-north between Long Swamp and associated wetlands north of the Portland-Nelson Road. Flights crossing the proposed powerline along Portland-Nelson Road would most likely consist of seasonal migratory movements between breeding and non-breeding (flocking) areas. Such longer distance flights are likely to be at greater height than the overhead transmission line. A conservative approach has been taken here, with the assumption that collision risk exists when Brolgas undertake such movements, and the Portland-Nelson Road transmission line has been included in the collision risk model.

Burying transmission lines is preferable and recommended wherever possible, to avoid and minimise transmission line collision risk. The use of marker devices fitted to the proposed overhead wires may also be applicable to reduce the potential collision risk for birds, including Brolgas.

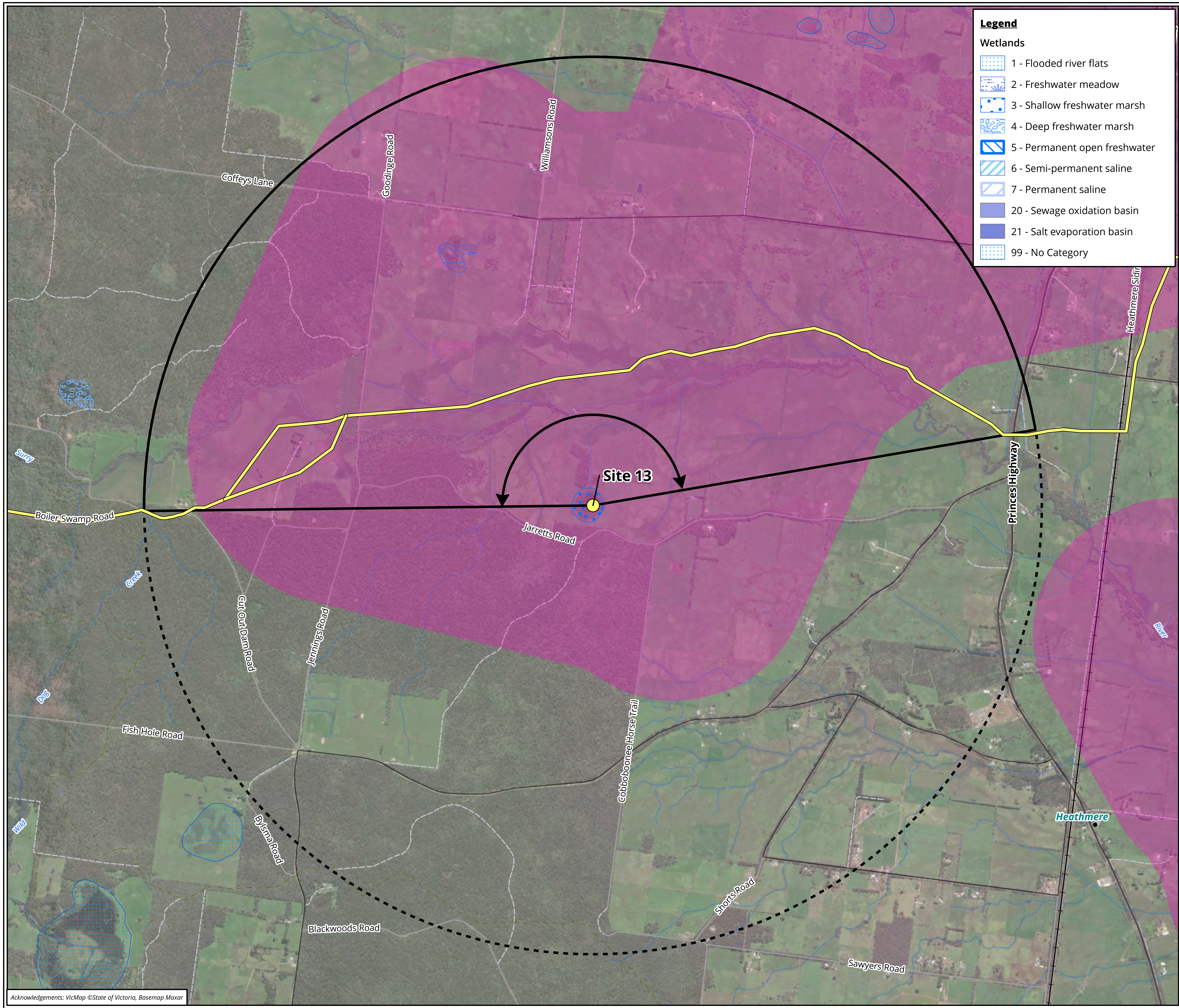
The duration of an impact and effect from a power line within this farmland is a minimum 25 years of the wind farm's proposed operational lifetime.

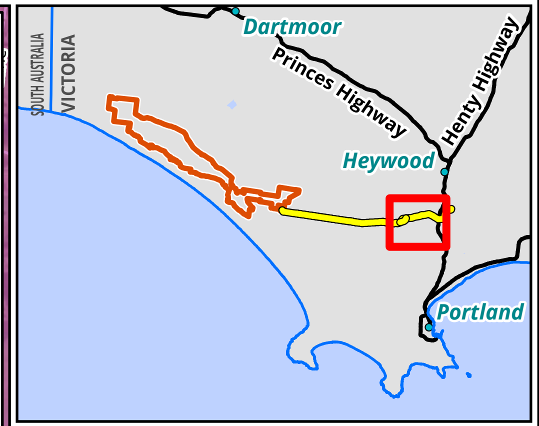
A7.6.1 Potential for direct impacts

Direct impacts for the Brolga are most likely to occur through turbine and power line related fatal injury or mortality. Moloney et al. 2019; and DELWP 2020 note that Brolga collisions with turbines have not been documented to date. However a single mortality has recently been recorded at an operating wind farm in south-west Victoria and risk assessments for wind energy projects within the species range consider that such collisions may occur and occasional collisions with power lines are known to occur. One Brolga carcass has recently been detected at a south-west Victorian wind farm. Collisions may occur when individuals move seasonally between breeding areas within the investigation area and non-breeding areas (November–January; May–June) and when they are moving locally (May–December).

Section 5 of this report sets out scenario collision risk modelling based on information obtained by the project about the local Brolga population and a set of explicit assumptions. As noted above, the modelling is a hypothetical exercise that is reliant on the assumptions used and selection of those used a conservative approach in dealing with uncertainty with a view to over-estimation of potential risk. If relevant assumptions hold, the modelling projects that approximately one Brolga per annum may collide with the combined project turbine array and overhead powerline. Population viability analysis suggests that, depending on the size of the south-eastern Australian Brolga population, over a 25-year operation of the project, collisions may result in an overall reduction of the of between 11 and 14 individuals. The PVA indicates that a zero net impact upon the population – as required by the Brolga Guidelines – can be achieved by management to increase recruitment into the population by between one and two birds per annum.

The project will not remove wetland habitat, thus no direct impact on habitat is likely.





Legend

- Wind farm footprint
- 275 kV underground transmission line
- Site ID (Breeding pair)
- Brolga flight distance 3.2km
- Arc of flights intersecting with wind farm
- Breeding buffer

Appendix 7
Arc calculation methodology: transmission line

0 500 1,000
Meters
N
Scale: 1:25,000 @ A3
Coordinate System: GDA2020 MGA Zone 54

biosis
APEM Group

Matter: 33361,
Date: 20 August 2024,
Checked by: IV, Drawn by: JPT, Last edited by: jturner
Layout: BrolgaReport_Appendix7_BrolgaBreedingWetlandsMethodology
Location: P:\35000s\35014\Mapping\
35014_BrolgaBreedingWetland.aprx

Appendix 8 GIS data sources used in Figures

Layer name	Client data package name
Wind farm footprint	240305_Umwelt_TWilliamson_WindFarmLayout_Transfer
275 kv overhead transmission line	240305_Umwelt_TWilliamson_WindFarmLayout_Transfer
275 kv underground transmission line (wind farm area)	240305_Umwelt_TWilliamson_WindFarmLayout_Transfer
275 kv underground transmission line (Boiler swamp road - Heywood)	230731_Umwelt_TWilliamson_ProjectDataPackage_Transfer
Substation	240305_Umwelt_TWilliamson_WindFarmLayout_Transfer
Access tracks	Kentbruck_Update_061123
Turbine - 95m radius	Kentbruck_Update_061123
Southern transmission line	20200709 Grid route options_July2020