RE Future

Brewster Wind Farm

Application for Planning Permit

Appendix E – Brolga Assessment

August 2024

Final Report

Brolga Assessment (Level 1, 2 and 3) for the Brewster Wind Farm, Trawalla, Victoria

Prepared for

Brewster Wind Farm Pty Ltd

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Ecology and Heritage Partners Pty Ltd

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Ecology and Heritage Partners acknowledge the Traditional Owners of the country we live and work on, and we pay our respect to Elders past, present and emerging.

CONTENTS

1 INTRODUCTION

Ecology and Heritage Partners was commissioned by Brewster Wind Farm Pty Ltd to undertake detailed investigations to determine potential impacts to the State significant Brolga *Antigone rubicunda* associated with the proposed Brewster Wind Farm, located at Trawalla, Victoria (Figure 1).

Brewster Wind Farm Pty Ltd is proposing to develop a six-turbine windfarm approximately 14 kilometres east of the township of Beaufort (Figure 1b). The wind farm development boundary covers approximately 396 hectares and is bound by the Western Highway to the north, private property to the south, Kayleys Lane to the east and Spring Hill Creek to the west. It comprises three parcels of land; 295 Trawalla Road, Trawalla (6-A\PP2224); 7 Pin Oak Court, Trawalla (1\PS712949) and 54 Kayleys Lane, Brewster (2\PS712949).

The project is basing the application on four potential turbine model configurations, namely the V162 HH150 and HH166, and V172 HH150 and HH160. For the purpose of this report and potential impact implications pertaining to Brolga, the shortest and tallest Rotor Swept Area (RSA) heights were used (i.e. V172 HH150 bottom RSA of 64 metres, and V172 HH166 upper RSA of 252 metres).

Land within the wind farm development boundary is currently used for agriculture, with the entire area subject to agricultural disturbance, including stock grazing and cropping. Surrounding land use is consistent with the wind farm development boundary, being predominately agricultural, with scattered dams, sheds and rural dwellings present. The wind farm development boundary is generally flat, with several minor drainage lines intersecting the site.

Several waterbodies occur across the broader region, including:

- Dunn's Marsh (Site 139) - located 2.1 kilometres south-east;
- Lake Burrumbeet - located approximately 9.1 kilometres east;
- Spring Hill Creek - intersection the wind farm development boundary; and,
- Lake Goldsmith - located approximately 12 kilometres south-west.

There are no conservation reserves or significant wetlands (Ramsar or nationally-listed) located within, or in close proximity to, the wind farm development boundary.

According to the Victorian Department of Energy, Environment and Climate Action (DEECA) NatureKit Map (DEECA 2024a), the wind farm development boundary is located within the Victorian Volcanic Plain bioregion, Glenelg Hopkins Catchment Management Authority (CMA) and Pyrenees Shire Council.

A detailed Ecological Assessment has been undertaken for the proposed development, which details the ecological values present within and surrounding the study area and relevant environmental legislation and policy considerations for the proposed development (Ecology and Heritage Partners Pty Ltd 2024), with the exception of Brolga.

This report specifically addresses Brolga implications relating to the proposed Brewster Wind Farm, and presents the method and results of the Level 1, Level 2 and Level 3 Brolga investigations undertaken between 28 October 2020 and 22 December 2023 as per the *Interim Guidelines for the Assessment, Avoidance, Mitigation and Offsetting of Potential Wind Farm Impacts on the Victorian Brolga Population* (Interim Guidelines) (DSE 2012).

1.1 Consultation

DEECA was consulted throughout the pre-application process to inform the development of the project and discuss the survey design to ensure that a full understanding of potential Brolga impacts can be ascertained.

Table 1 summarises the stakeholder liaison activities that occurred during the pre-application process in relation to Brolga, and a summary of the outcomes of each consultation event.

Table 1. Stakeholder engagement activities undertaken in relation to ecological investigations.

Activity	Date	Matters Raised	Outcomes
Virtual Meeting with DELWP (Michael Juttner, Mitch Connolly, Mark Dold, Nathan McDonald, Nihal Altuntas, Monique Claasz).	08/12/2020	• Proposed development footprint; • Broad planning framework; • Ecological survey program; • Ecological survey findings to date;	• DELWP generally happy with proposed survey timing and schedule; • Proposed retention of all native vegetation within the wind farm development boundary;
Virtual Meeting with DELWP (Lisa Macauley, Nathan Macdonald, Bec Falk, Kirsty Miller, Michelle Butler, Maddi Marks)	10/11/2022	• Presence of additional Brolga breeding habitat.	• Further investigation into potential breeding habitat.
Virtual Meeting with DELWP (Lisa Macauley, Nathan Macdonald, Bec Falk, Kirsty Miller, Michelle Butler, Maddi Marks)	01/12/2022	• Summary of further field investigations; • Requirement for additional stakeholder consultation and Level 2 and 3 assessments.	• Stakeholder consultation to commence; • Level 2 and Level 3 assessments required.
Virtual Meeting with DEECA (Ezaz Sheikh, Lisa Macauley, Nathan Macdonald, Danielle Foster, Kirsty Miller, Michelle Butler,)	02/03/2023	• Summary of outcomes from the stakeholder consultation; • Confirmation of the presence and location of brolga breeding wetlands;	• Continuation of Level 2 and 3 Brolga assessment as per criteria in Interim Guidelines (DSE 2012);
Landowner Consultation Questionnaire Letterbox drop	06/12/2022 – 08/03/2023	• Landowner Consultation Questionnaire; • Presence of additional Brolga breeding habitat.	• Further investigation into potential breeding habitat.
DEECA Response to Brolga Assessment	23/08/2023	• Additional Stakeholder engagement required; • Additional site-specific data required to inform Level 3 assessment, and subsequent CRM and PVA.	• Detailed Level 1 and 2 Brolga Assessments to commence.
Updated Level 1 and 2 Brolga Assessment, and Home Range Analysis submitted to DEECA for review	16/04/2024	• Detailed Level 1 and 2 Assessment completed as per the Interim Guidelines (DSE 2012)	• DEECA confirmed Level 1 and 2 Assessments undertaken adequately. Endorsement to commence with Level 3 Assessment (03/05/2024). Effectiveness of proposed Home Range buffer to be determined on submission of Level 3 Results.

2 BROLGA

2.1 Species Summary

EPBC Act Status: Not listed

FFG Act Status: Endangered

The Brolga is one of two species within the family Gruidae (Cranes) found in Australia, which are often characterised by their large body, long legs, and longevity.

Plate 1. Brolga *Antigone rubicunda* and nest. Ecology and Heritage Partners Pty Ltd.

Species description

Brolga boasts predominately grey plumage, with distinctive coral red patches on the head and neck (Plate 1). Adults can reach a standing height of 1.8 metres, a weight between four and eight kilograms, and supports a wingspan approximately two metres wide. Adult male and female Brolga are largely indistinguishable in appearance, though the female is usually shorter (Marchant and Higgins 1993). The long, slender beak appears grey-green in adults, and their irises yellow-orange.

As omnivorous foragers, Brolga feed in wetlands, saltwater marshes, and farmland. The species is known for their intricate courtship dances, with Brolga holding both cultural and ecological significance.

Distribution, habitat, and Victorian population size

Nationally, the Brolga is a secure species, being widespread and abundant across north and north-east Australia, particularly in north-east Queensland, where the species has been recorded in the tens of thousands (Marchant and Higgins 1993).

In Victoria, Brolga distribution has declined since European settlement, primarily due to the loss of suitable habitat by agricultural development, drainage of suitable breeding wetlands, and predation of eggs and young by the introduced Red Fox *Vulpes vulpes*. Currently in Victoria, Brolga occur primarily in the south-west of the State, though movement and distribution vary between seasons.

The most recent Brolga population estimate for south-west Australia is 879 individuals (including 43 Brolga recorded at Boole Lagoon, approximately 20 kilometres west of the Victorian/South Australian border) (SWIFFT 2024). The 2024 survey found that 19% of the 586 birds that could be identified were young (less than two years old), suggesting good breeding success and recent favourable conditions (the average for the past 15 years is 13%). This increased breeding success and Brolga recruitment, similar to that observed in 2013, aligns with several years of La Niña conditions (SWIFFT 2024) (Table 2).

Table 2. Brolga population estimates of south-west Victoria.

Date	Estimated number of Brolga	Same day count	Source
24/03/2024	836 ^	Yes	https://www.swifft.net.au/cb_pages/sp_brolga.php (accessed on 13 June 2024)
22/4/2023	521	Yes, subset of flocking count*	
23/4/2022	552	Yes, subset of flocking count*	
27/3/2021	413	Yes, subset of flocking count*	
2020	-	No count undertaken	
4/2019	635	Partial	
4/2018	377	Partial	
4/2017	278	Partial	
4/2016	348	Partial	
4/2015	449	Partial	
4/2013	907	Yes	
2012	448	Partial	
2011	250	No	
2010	401	No	
2004	675	-	Sheldon (2004)
2002	402	-	DSE (2007)
1984	550-600	-	Arnol *et al.* (1984)

Note: *Counts were taken from a subset of the main flocking locations in south-west Victoria, namely Willaura, Penshurst, Lake Bolac, Streatham, Darlington, Camperdown, Cressy, and Strathdownie. 'Partial' counts were conducted at Dundonnell, Penshurst, Willaura, Strathdownie, Lake Bolac, Streatham, Boole Lagoon (S.A.) and Lake Wongan; ^ A total of 879 birds recorded on the day, with an additional 43 birds observed at Naracoorte, South Australia.

2.2 Brolga Assessment Framework

Due to the potential risk posed to Brolga by wind farms in Victoria, DEECA (formally the Department of Environment, Land, Water and Planning) developed the *Interim Guidelines for the Assessment, Avoidance, Mitigation and Offsetting of Potential Wind Farm Impacts on the Victorian Brolga Population* (Interim Guidelines) (DSE 2012).

The Interim Guidelines outline a conservative approach to assessing and managing the effects of both individual wind farms and the cumulative impacts of the wind industry on the Victoria Brolga population. The objective of the Interim Guidelines is to ensure that there is no 'net effect' of wind farms on the Brolga, with the goal of achieving a positive effect for the population as a whole. The guidelines identify key habitat features for Brolga which require consideration and protection–these being breeding sites and flocking sites (DSE 2012).

Based on advice received from DEECA (23 August 2023), the assessment of the potential impacts of the Brewster Wind Farm on the Victorian Brolga population was undertaken in accordance with the requirements of the Interim Guidelines (DSE 2012).

Applications to develop land for a wind energy facility must also assess flora and fauna listed under the FFG Act (i.e. Brolga) and EPBC Act, including significant habitat corridors, and movement corridors for these fauna under Clause 52.32 (Wind Energy Facility) of the Pyrenees Planning Scheme.

2.3 Interim Guidelines

The assessment method for Brolga under the Interim Guidelines follows a staged risk assessment process consistent with the AusWEA Interim Standards for Risk Assessment (AusWEA 2005). The method and results associated with each stage of the Brolga risk assessment process is provided in Section 3 (Level 1) and Section 4 (Level 2). It should be noted that investigations for Brolga focused within a 10-kilometre Radius of Investigation (ROI) area from the boundary of the wind farm. A summary of the Brolga assessment requirements in accordance with the Interim Guidelines and the relevant sections of the report that addresses these requirements are provided below (Table 3).

Table 3. Brolga Impact Assessment: Triggers and levels (DSE 2012).

Level	Step	DSE 2012 Triggers	Outcomes, actions and relevant report section
Level 1		The presence of Brolga within the ROI The presence of potential Brolga habitat within the ROI The location of the proposed development is within an area that may be used by Brolga during seasonal movements between breeding and flocking habitats	Level 1 Assessment triggered and completed (Section 3).
1	**1**	Desktop investigation into known and potential habitat areas for Brolga.	All biological databases analysed, including recent and historical records, to identify the extent of Brolga occurrence within the ROI (Section 3.2.1).
	2	Initial field inspection and community engagement	Initial site investigation completed (Section 3.2.3) Initial community consultation completed (Section 3.2.2). Community engagement continued throughout the Level 2 Assessment, with responses up until 22 December 2023 included in the analysis. Results across both Levels are included in Section 3.2.2.
Level 2		Records of breeding or flocking within the radius of investigation The proposed development is located in an area which may be used by Brolga 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 Brolga for diurnal movements between foraging and roosting sites The proposed location of new powerlines associated with the development may create new collision risks for Brolga.	Level 2 Assessment triggered and completed (Section 4).
2	**1**	Collect comprehensive data on the location, nature, and extent of Brolga habitat, and patterns of habitat use and	Extensive field investigations undertaken during Brolga breeding and non-breeding

Level	Step	DSE 2012 Triggers	Outcomes, actions and relevant report section
		behaviour at breeding, flocking and foraging sites within the ROI.	seasons in 2020, 2021, 2022, and 2023 to identify Brolga breeding locations within the ROI (Section 4.2). Aerial (drone) surveys of all waterbodies within the ROI (298 waterbodies) during the 2023 Brolga breeding season to identify potential Brolga foraging, breeding and flocking (Section 4.2.1), in addition to a Brolga habitat assessment (Section 4.2.2). Extensive site-specific breeding season Brolga flight movements (Section 4.2.3; 4.2.5) to inform the Level 3 Assessment.
Level 3		Qualitative risk assessment (AusWEA 2005)	Potential for impact to Brolga, Level 3 triggered (Section 5)
3	**1**	Avoid or mitigate all potential impacts to brolga breeding and flocking home ranges within the ROI with turbine-free buffer areas	Home range and turbine-free buffer prepared based on site-specific data. Turbine layout updated (Section 5.1)
	2	Develop a site-specific collision risk model (CRM) for Brolga utilising or moving through the ROI	CRM completed (Section 5.2)
	3	Use DELWP (Melbourne University) Brolga PVA to estimate the impact of the proposed development on the population	PVA completed (Section 5.3)
	4	Identify appropriate compensation strategies to ensure a *zero net impact on the Victorian Brolga population*	Brolga Compensation Plan proposed (Section 5.4)

2.3.1 Breeding Site definition

Brolga are known to build nests in wetlands with emergent vegetation, raising a mound of plant material. Nests are typically constructed in shallow areas of wetlands where a range of vegetative material is constructed into a platform approximately 1.5 metres in diameter (White 1987). Brolga nesting requires a wetland to hold water for a minimum of 120 days, allowing for:

- Nest building, egg laying, incubation [approximately 30 days (Merchant and Higgins 1993)]; and,
- Hatching and growth of young [90-100 days (Merchant and Higgins 1993; Herring 2001)];
    - Veltheim *et al.* (2019) found the total number of days prior to fledging in 11 chicks was between 18 and 53 days.

At about 90 days old, the chicks are less vulnerable to predation (i.e. foxes) and can walk to neighbouring wetlands (Herring 2001; Myers 2001).

The higher the quality of the wetland, the less likely Brolga will move out to forage in other areas, with food density and habitat quality impacting Brolga home range. Furthermore, dense vegetation, water depth and food availability were found to be the most critical habitat features for Brolga breeding success (Herring 2001, Myers 2011). Individual wetland condition is therefore likely to be the most important habitat feature for Brolga breeding success (Veltheim *et al.* 2019).

As per the Interim Guidelines (DSE 2012), a breeding site is defined as:

'the nest of a Brolga breeding pair and the perimeter of the surrounding wetland. A breeding site also includes wetlands with previous records of Brolga breeding nests from any relevant information source. A wetland remains a breeding site provided that it has not been permanently drained and/or planted with trees'.

2.3.2 *Flocking site definitions*

In Victoria, the non-breeding season for Brolga generally occurs between January – June (DSE 2012). During this time, groups of Brolga will flock together and move between waterbodies for the purpose of foraging. Occasionally, groups of Brolga may roost at a nearby waterbody for a period of time, and have been known to move up to five kilometres (Herring 2005).

During foraging activities away from the flock roost site, Brolgas can gather in large groups at roost sites at permanent or ephemeral freshwater or saline wetlands (including dams, swamps, etc.) to rest day or night. They will generally return to a flock roost sites to roost nocturnally.

One-off flocking records may correspond to daytime foraging away from traditional flocking sites and can often be associated with non-wetland habitats (i.e. pasture and cropped land). Therefore, traditional flocking sites are considered to have greater value for Brolga than one-off flocking sites, the former representing a key habitat resource that provides overnight roosting potential.

A flock roost site holds water for the majority of the summer and autumn flocking period and as Brolgas generally return to traditional flock roost sites each year the wetland should possess long term historical records of its use by large numbers of brolgas for nocturnal roosting during the flocking season.

The Interim Guidelines (DSE 2012) identify that a flock roost site must meet three required criteria (Table 4).

Table 4. Criteria used to identify a flock roost site (DSE 2012).

Criteria	Justification
More than one year of recording	To ensure the selection of traditional 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 by flocking Brolgas. The assumptions 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 traditionally for the majority of the flocking or non-breeding season.

3 LEVEL 1 ASSESSMENT

The Level 1 Assessment provides a preliminary determination of whether a proposed wind farm development represents any level of risk to the Victorian Brolga population. As the wind farm development boundary is located within the Victorian range of Brolga, as identified in Figure 1 of the Interim Guidelines (DSE 2012) and shown in Figure 2a and 2b through the presence of historical records of the species, a Level 1 Assessment is triggered. The findings of the Level 1 Assessment are used to decide whether a Level 2 Assessment is required as per the Interim Guidelines (DSE 2012).

The Level 1 Assessment was undertaken using a combination of desktop review, field assessments, and engagement with relevant stakeholders.

3.1 Method

3.1.1 Desktop Assessment

Relevant literature, online-resources and databases were reviewed to provide an assessment of Brolga breeding, flocking, and sighting records associated with the study area and Radius of investigation (ROI), which for Brolga is a 10-kilometre buffer of the project area boundary. The following information sources were reviewed:

- The Department of Energy, Environment and Climate Action (DEECA) NatureKit Map (DEECA 2024a);
- Brolga Movements and Spatial Requirements During Breeding, south-west Victoria. Ecology and Heritage Partners Pty Ltd, November 2013 (Ecology and Heritage Partners Pty Ltd 2013);
- Breeding home range movements of pre-fledged brolga chicks, *Antigone rubicundra* (Gruidae) in Victoria, Australia – Implications for wind farm planning and conservation (Veltheim *et al.* 2019);
- Birdlife New Atlas Bird Data for all Brolga records within 10 kilometres of the wind farm development boundary (BirdLife Australia 2024);
- Atlas of Living Australia (ALA) for Brolga records within 10 kilometres of the wind farm development boundary (ALA 2024);
- South West Brolga Flocking Database (Sheldon 2004);
- Review of previous data collected on Brolga flight and movement from south-west Victoria;
- The Victorian Biodiversity Atlas (VBA) for previously documented Brolga records within the ROI (DELWP 2024c); and,
- Aerial photography of the study area.

3.1.1.1 Accuracy of records

A number of Brolga breeding records within biological databases (i.e. VBA) are not associated with wetlands due to the inaccuracy of the record. DEECA provided a protocol for addressing historical Brolga breeding records that have an inaccuracy greater than 100 metres where the co-ordinates are not at a wetland. The following steps are to be applied in these circumstances:

- Attempt to confirm the record location using the location and observer details;
- Buffer the record according to the accuracy field;
- Attribute the record to the closest wetland within the accuracy buffer;
- If there are no wetlands within the accuracy buffer, disregard the record; and,
- If the accuracy attribute is greater than one kilometre, disregard the record.

3.1.2 Community Consultation

3.1.2.1 Landowner Questionnaire

Between 6 - 8 December 2022, all residents within three kilometres of the wind farm boundary were invited to participate in a landowner survey. All residences were followed up again on 14 December 2022. In total, a Landowner Consultation Questionnaire (hereafter referred to as the 'Questionnaire') was hand delivered or mailbox dropped to 23 separate residences and/or businesses within the three-kilometre buffer.

On 7 September 2023, all residents within 10 kilometres of the wind farm boundary (i.e. within the ROI) were invited to participate in consultation by means of the Questionnaire. The purpose of this landowner consultation was to expand the previous community consultation effort, and to obtain information on the availability of suitable breeding habitats within the entire ROI.

A reminder to landowners inviting them to complete the Questionnaire was mailed to residences on 25 October 2023. In total, the Questionnaire was mailed to more than 700 separate residences and/or businesses within the ROI on two separate occasions. A copy of the cover letter and Questionnaire is provided at Appendix 1 and Appendix 2, respectively. When requested, or further information required, a site visit and/or meeting was scheduled with the relevant landowner to follow up on their responses. Landowner meetings occurred on 12 September, 27 September, and 20 November 2023.

A final reminder to invite survey respondents to contribute further information was sent on 19 December 2023, with all responses received up until 22 December 2023 accepted and included in this assessment.

Several additional stakeholders (Birdlife Australia, Glenelg Hopkins Catchment Management Authority, regional DEECA offices, Pyrenees Shire Council and local Landcare and friends' groups) were contacted to ascertain the historical and current utilisation of Brolga, and the presence of potential habitats within the broader locality. Where no response was received by telephone, these groups were contacted via email.

It is noted that the quality of landowner survey data is likely to vary due to landowner interest and length of residency. However, the data provided through the consultation process may add additional information to the assessment not previously available via other methods. While not all landowners responded, or provided contact details for follow-up, it is unlikely that the data provided via community consultation is a comprehensive assessment of all Brolga breeding and flocking habitat within the ROI. However, coupled with detailed desktop interrogation via aerial imagery, the Level 1 Assessment is considered to adequately consider the potential for Brolga utilisation within the study area and ROI.

3.1.2.2 Community Information Sessions

Four information sessions were held at Beeripmo Community Centre, Beaufort (Table 5). An invitation to the sessions was mailed out to all residences within five kilometres of the wind farm parcel boundary on 26

September 2023. Subsequently, any resident who enquired about the event was also provided with the invitation.

A copy of the invitation letter is provided in Appendix 3.

In total, 21 residents attended the information sessions which included a presentation from RE Future, and allocated time for questions and answers with an ecologist from Ecology and Heritage Partners.

Table 5. Community Information Session details.

Date	Time	Number of resident attendees
10/10/2023	15:00 – 16:00	2
10/10/2023	17:30 – 19:30	5
15/10/2023	11:00 – 12:30	1*
15/10/2023	17:30 – 19:30	13

Note: * Community information session not attended by Ecology and Heritage Partners.

3.1.3 Field Inspections

3.1.3.1 Site Inspections

Site inspections were undertaken concurrently with roaming surveys across the ROI to determine the extent and quality of Brolga habitat within the ROI and to confirm the utilisation of potential nest sites. These surveys included:

- On-site roaming field surveys were undertaken by visually searching for Brolga and Brolga habitat at all potential wetland areas not subject to private land access limitations. Ground-based roaming surveys were undertaken between and including 2020 and 2023 Brolga breeding seasons;
    - Binoculars were used where appropriate, and historical Brolga breeding records were inspected on foot by suitably qualified Zoologists for suitability of breeding habitat; and,
- Targeted surveys for Brolga and Brolga habitat where coordinates were provided (i.e. through landowner consultation).

Initial site inspections were undertaken by Ecology and Heritage Partners between 28 and 30 October 2020, and 4 and 11 November 2020. On 12 September, 12 October, 11 and 14 November 2022, a second round of site inspections were undertaken for all wetlands as described above.

Additional site visits on 8 February and 8 March 2023 were undertaken on five landowner properties to ground-truth the presence of Brolga breeding sites as indicated through the landowner consultation process.

3.1.4 Habitat Quality Assessment

Habitat quality was assessed via a combination of roaming surveys and aerial (drone) investigations. Habitat quality was determined using the criteria detailed below, based on information on Brolga breeding habitats in Western Victoria (Marchant and Higgins 1993; Du Guesclin 2003).

High: Habitat components listed below are usually all present.

- Shallow freshwater marsh or shallow freshwater meadow less than 0.5 metres deep;
- Wetlands with large areas of aquatic and emergent vegetation (e.g. Annual herbs, rushes, Juncus spp. or tussock grass Poa spp.);
- Little or no signs of changed water regimes (e.g. drained wetlands);
- Little or no signs of disturbance (e.g. cultivation, native vegetation removal, grazing).

Moderate: Some habitat components are often missing although wetlands still provide some characteristics to provide nesting opportunities.

- Waterbody likely to hold water throughout breeding season (July-December) (i.e. permanent, or largely permanent);
- Water body with some aquatic and emergent vegetation (e.g. Annual herbs, rushes *Carex* spp. or *Juncus* spp. or tussock grass *Poa* spp.);
- Some changes to water regime may have occurred (drainage lines);
- Wetland shows some signs of disturbance (such as limited access to stock, cultivation, feral predators).

Low: Many habitat elements have been lost. Wetland habitats that are:

- Likely to be ephemeral or drained (only hold water for limited time of the year);
- Little or no aquatic or emergent vegetation;
- Changed water regime, little water present;
- Showing signs of disturbance (such as heavily grazed by stock, cultivated, feral predators).

During the site surveys the following data were recorded for each nest and/or Brolga located (Table 6).

Table 6. Data recorded at each nest site

Data	Format
Site/Pair ID	Number or label that will be used to identify the pair in future
Nest Location	Easting/Northing
Land Use Type	Grazing/cropping/other (provide details)
Wetland size	Hectares
Chick Present	Y/N
Location of Brolgas	Easting/Northing (if flushed/disturbed, note this)
Notes on nest, including condition, location etc.	-

3.2 Results

3.2.1 Desktop Assessment

The online biological databases that contain historical breeding and sighting records of Brolga include Birdlife New Atlas, Sheldons Brolga Database, and the Victorian Biodiversity Atlas. Figure 2a and 2b illustrate the location of the records from these resources.

The records contained within these resources are obtained via incidental observations or planned surveys, uploaded from a wide range of contributors. The purpose of the desktop assessment is to understand where Brolga have historically been recorded within the ROI and broader landscape, and where current breeding and flocking sites may occur.

In the instance where historical Brolga breeding records are not associated with wetlands due to the accuracy of the record, DEECA have previously provided a protocol for addressing the Brolga breeding records that have an inaccurate record of greater than 100 metres where the co-ordinates are not at a wetland. The following steps were applied in these circumstances:

- Attempt to confirm the record location using the location and observer details;
- Buffer the record according to the accuracy field;
- Attribute the record to the closest wetland within the accuracy buffer;
- If there are no wetlands within the accuracy buffer, disregard the record; and,
- If the accuracy attribute is greater than one kilometre, disregard the record.

3.2.1.1 Birdlife New Atlas

Managed by Birdlife Australia, this database is a collection of distribution and abundance records of bird species in Australia. The Birdlife New Atlas has been operational since 1998 and contains in excess of 7 million bird records.

Data extraction from the Birdlife New Atlas (2024) revealed nine non-breeding Brolga records within the ROI (Figure 2b). These records are all located around waterbodies between the north-east and south-east such as Dunn's Marsh, Black Swamp, Cockpit Lagoon and Lake Burrumbeet, as well as a single record to the south-west near Beaufort-Carngham Road (Figure 2b). There are no documented Brolga records to the north, south or west within the Birdlife New Atlas, and no breeding or flocking records of Brolga anywhere within the ROI (Birdlife Australia 2024).

3.2.1.2 Sheldons Brolga Database

Sheldon's Brolga Database revealed 23 Brolga records previously recorded within 10 kilometres of the wind farm development boundary (Figure 2b). No breeding records or flocking events were identified within 10 kilometres of the site from the Sheldon's Brolga Database.

3.2.1.3 Victorian Biodiversity Atlas (VBA)

The VBA is an online resource accessible to government agencies, environmental consultants, researchers, and the general public. Administered by DEECA, this database serves as a comprehensive repository of observations detailing the distribution and abundance of species across Victoria. Consolidating data from previous databases under the Department's purview, such as the Flora Information System, the Atlas of Victorian Wildlife, the Aquatic Fauna Database, and the Victoria Rare or Threatened Population Database, the VBA also incorporates information sourced from the Atlas of Living Australia. Individuals who register as contributors can submit records to the VBA, with a panel of taxonomic experts overseeing the review and validation of new entries.

<u>Breeding Records</u>

A search of the VBA revealed 213 Brolga records, totalling 431 observed Brolga within the ROI (DELWP 2024c). This is an average of 1.94 Brolga per record, dated between 1968 and 2023 (DELWP 2024c). Of these, 189 Brolga were recorded within four kilometres of the wind farm development boundary (Figure 2a), with 242 recorded between 4 and 10 kilometres from the wind farm boundary (Figure 2b).

The majority of the VBA records occur to the east, north and north-west of the wind farm development boundary (Figure 2b).

A search of the VBA identified 66 of the 431 records as Brolga breeding records within the ROI (Figure 2b), and of those, 23 are located within four kilometres of the wind farm development boundary (Figure 2a).

Every VBA Brolga breeding record within the ROI was analysed for suitability as a current Brolga breeding site, following the DEECA provided protocols for addressing historical Brolga breeding records, resulting in:

- Eighteen VBA Brolga breeding records, across 11 sites, are not attributable to wetland (Table 7; Figure 2b);
- Forty-eight VBA Brolga breeding records, across ten locations, are attributable to wetland (Table 8; Figure 2c);

Based on the definition of a Brolga breeding site as contained in the Interim Guidelines (DSE 2012), 10 Brolga breeding sites are considered likely to provide breeding habitat for Brolga currently or in the future based on historical records (Table 8).

A summary of Brolga breeding wetlands from the VBA that were *excluded* following the protocol outlined by DEECA (and summarised above) are presented in Table 7, and Brolga breeding VBA records that were *included* for further investigation are presented in Table 8.

Table 7. Analysis of excluded Brolga VBA breeding records.

Lat/Long	Year	# Brolga breeding records	Accuracy of observation (kms)	Distance to nearest wetland (kms)	Suitable for inclusion	Justification
143.5787, -37.4586	1989/90	2	0.0	0.54	No	No wetlands within the accuracy buffer
143.577, -37.4609	1989/90	2	0.0	0.63	No	No wetlands within the accuracy buffer
143.418, -37.4152	1977	1	9.0	0.18	No	Accuracy attribute greater than one kilometre
143.5013, -37.4152	1984	2	0.0	1.07	No	No wetlands within the accuracy buffer
143.4513, -37.3985	1984	1	0.0	0.54	No	No wetlands within the accuracy buffer
143.4507, -37.4005	1990	2	0.0	0.65	No	No wetlands within the accuracy buffer
143.468, -37.5146	1989/90	2	0.0	0.42	No	No wetlands within the accuracy buffer
143.468, -37.5152	1984	1	0.0	0.48	No	No wetlands within the accuracy buffer

Lat/Long	Year	# Brolga breeding records	Accuracy of observation (kms)	Distance to nearest wetland (kms)	Suitable for inclusion	Justification
143.4634, -37.5278	1993	3	0.0	0.24	No	No wetlands within the accuracy buffer
143.4594, -37.5459	1991	1	0.0	1.06	No	No wetlands within the accuracy buffer
143.4589, -37.5463	1991	1	0.0	1.13	No	No wetlands within the accuracy buffer

Table 8. Analysis of included Brolga VBA breeding records.

Site Number (Figure 2c)	Year	# Brolga breeding records	Accuracy of observation (kms)	Distance to nearest wetland (kms)	Suitable for inclusion	Justification
47	2000/01	4	0.0	0.00	Yes	Included in further investigation
61	2004	3	1.0	0.25	Yes	Included in further investigation
106	1979/81/87/ 88/89/89/90	16	0.0	0.00	Yes	Included in further investigation
114	1988/89/90	7	0.0	0.00	Yes	Included in further investigation
121	2022	4	0.0	0.00	Yes	Included in further investigation
139	1988/90, 2019	6	0.0	0.00	Yes	Included in further investigation
168	1984	1	0.0	0.00	Yes	Included in further investigation
194	1984	1	0.0	0.07	Yes	Included in further investigation
196	1770	2	0.0	0.00	Yes	Included in further investigation
222	1990	4	0.0	0.00	Yes	Included in further investigation

Flocking Records

A single record that contained an estimate of 40 Brolga is included within the VBA (DEECA 2024c). This observation was from June 2005 and located approximately 6.2 kilometres north-west of the wind farm development boundary within an agricultural paddock to the northeast of the intersection of Racecourse Road and Trawalla-Waterloo Road (Table 9).

Table 9. Records of 10 or more Brolga

Survey Type	Count (estimate)	Date	Accuracy of Record	Location Description	Lat/Longs	Source
General Observation	40	June 2005	0.9 km	Racecourse Road, NE of Beaufort	-37.4065; 143.447	VBA*

Note: * DEECA (2024c).

The closest wetlands to the record are Site 47 (260 metres east) and Site 61 (309 metres south) (Figure 2b). Both Site 47 and Site 61 have been included as Brolga breeding wetlands based on information received during landowner consultation and the database interrogation (Table 8).

There are no additional records contained within the VBA, Birdlife New Atlas data, Sheldon's database, or information collected via landowner consultation (Section 3.2.2) that suggest additional observations of 10 or more Brolga recorded at this location (inclusive of Site 47 and 61) during the flocking season, or that Brolga utilise this site (s) for flocking purposes.

A review of historical aerial photography at the location of the record (Google Earth 2024) does not indicate any evidence of historical inundation during the flocking (or breeding) seasons, with the site appearing to be used for agricultural (i.e. grazing) purposes as observed during the roaming surveys.

It is likely that the observation in Table 9 recorded an instance of a flock of Brolga foraging in or adjacent to the paddock away from a flock roost site, and in the absence of additional records or evidence of site utilisation by Brolga at this location, this record does not meet the criteria that defines a flock roost site as per the Interim Guidelines (DSE 2012) (Table 10).

Table 10. Criteria and results of a potential flock roost site. The site should meet all three criteria (DSE 2012).

Criteria	Justification	Result
More than one year of recording	To ensure the selection of traditional regularly used sites	Not triggered
One or more records of counts equal to or greater than 10 birds	To include sites which have been used often or traditionally by flocking Brolgas. The assumptions is made that if more than 10 birds are recorded on a wetland, flocking behaviour is likely.	One count of ten or more Brolga
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 traditionally for the majority of the flocking or non-breeding season.	Not triggered

3.2.2 Community Consultation

Landowners who participated in the consultation were questioned about the current and past land use of their property to provide a more complete picture of landscape. The surveys found the majority of participants had occupied their land for more than 25 years, with some multi-generational land managers. Grazing and cropping was the primary land use, and arable land the dominant land type. Little to no change to on-site waterbodies were documented in these responses.

3.2.2.1 Landowner Questionnaire 2020

A total of five Landowners located within the wind farm development boundary and nearby locality were initially contacted in late 2020 as part of the initial Level 1 Assessment (Figure 3).

Four landowners had not observed Brolga within the immediate vicinity of the wind farm development boundary for several years. However, sightings of Brolga from 2019/20 had been observed east of Lake Burrumbeet and within the vicinity of Waubra Wind Farm.

One Landowner stated that Brolga regularly foraged in a dam (Site 153 – Figure 2b). However, no breeding or flocking behaviour was observed by the landowner.

3.2.2.2 Landowner Questionnaire 2022

In December 2022, all landowners within 3 kilometres of the wind farm boundary comprising a total of 23 Landowners, were contacted to participate in the investigation via the Questionnaire, with the invitation made open for landowners to forward the Questionnaire to additional interested parties. A total of 15 responses to the Questionnaire were received, often representative of multiple family members or property owners (Figure 3). Landowner observations of Brolga are summarised below:

- Five landowners stated that they had not observed Brolga on their property;
- Five landowners reported Brolga sightings with no breeding observations;
- Five landowners reported Brolga breeding events on their property or on adjacent property; and,
- Zero landowners reported Brolga flocking events or groups of ten or more Brolga.

The results from the 2022 questionnaires and subsequent correspondence identified additional Brolga sightings within the ROI. Brolga breeding sites documented during landowner consultation included current and historic breeding records within Site 121 and Site 139. Photographs of Brolga and Brolga nests were also provided by landowners for these locations.

Four additional unconfirmed breeding locations were provided by landowners within four kilometres of the wind farm parcel boundary, which became the subject of investigation and additional field assessment undertaken on 8 February 2023, the results of which are detailed in Section 3.2.3 below.

3.2.2.3 Landowner Questionnaire 2023

The Questionnaire and associated cover letters were mailed out to all residences within the ROI on 7 September 2023, with an initial deadline of 22 September 2023. However, due in part to feedback from the responders, this deadline was extended. A reminder to complete the Questionnaire was mailed to the same database of residences on 25 October 2023. A request for any further information was sent to all survey respondents on 19 December 2023, which also advised the new deadline of 22 December 2023.

In total, the Questionnaire was mailed to more than 700 separate residences and/or businesses within the ROI on two occasions, and Ecology and Heritage Partners have accepted all responses received up until the date of this report.

A total of 32 Landowners responded to the questionnaire, often representative of multiple family members or property owners (Figure 3). Landowner observations of Brolga from the 2023 questionnaire are summarised below:

- 23 landowners (72%) had not previously responded during a previous survey period;
- 26 landowners (81%) reported Brolga sightings with no breeding observations;

- 13 landowners (41%) reported Brolga breeding events; and,
- Zero landowners reported traditional Brolga flocking as defined in the Interim Guidelines (DE 2012).

It was noted that one landowner reported '*up to ten Brolga usually later in spring*' at Site 139. On further investigation, this observation of 'up to 10 Brolga' is confirmed to have occurred during the breeding season, often consisting of multiple pairs of Brolga and their chicks within Site 139 (Dunn's Marsh). Although the observation does not qualify as a flocking observation (given it does not occur during the non-breeding season), it does indicate that Site 139 provides important foraging and breeding habitat for Brolga. Further commentary on Site 139 is provided in Section 3.2.3.2.

The results from the 2023 questionnaires and subsequent correspondence identified additional potential Brolga breeding locations within the ROI, namely Site 42, 47, 212, 227, and 297. Additional field assessments were also undertaken to ground-truth the extent of mapped wetland and habitat quality at Site 297 on 19 September 2023, and Site 121 on 27 September 2023. Sites 42, 47 and 212 were assessed from publicly accessible areas and aerial (drone) fly over. All five sites have been included as Brolga breeding wetlands given the presence of evidence of historical or current breeding, and the presence of wetland habitat.

Photographic and video documentation capturing Brolga activity was collected by some landowners sited within four kilometres of the wind farm boundary. These records were subsequently analysed in collaboration with the relevant landowners on 12 September and 20 November 2023, supplementing the broader community consultation sessions. In total, 13 Brolga flight instances were discussed during the meetings. Consensus on flight characteristics (i.e. location, direction, height) was reached during the meetings and via follow-up email correspondence. These records show Brolga flight behaviour and are further discussed in Section 4.2.4.

Engagement with other stakeholders (i.e. Glenelg Hopkins Catchment Management Authority, Pyrenees Shire Council and local Landcare and friends' groups) did not result in any additional Brolga breeding or flocking records that were not already available via desktop analysis and/or landowner consultation.

Information relating to Brolga observations and specific wetland investigations are detailed below.

3.2.3 Field Investigations

To suitably address Interim Guidelines (DSE 2012) Level 1 (Step Two): *Undertake field inspection*, and Level 2: *Obtain detailed information on the occurrence of Brolga within the ROI*, some repetition occurs in the following sections. Although these sections may contain overlapping information, they serve distinct purposes:

- Site inspections and roaming surveys provide a broad overview of all wetlands within the ROI visible from roadside and publicly accessible locations, which was repeated and improved with the use of drones during the aerial survey as detailed in Section 4.2.1 and 4.2.2.
- Ground-truthing of potential Brolga breeding wetlands were undertaken at select wetland sites, where roaming survey, and/or landowner consultation indicated suitability for such breeding activities. As a wetland remains a breeding site provided that it has not been permanently drained and/or planted with trees (DSE 2012), Brolga breeding wetlands identified through biological databases may not have required additional ground-truthing to persist as a confirmed breeding wetland (See Section 3.2.4) if aerial surveys or aerial photography indicated the suitable habitat was still present.

3.2.3.1 Roaming Surveys and Site Inspections

All wetlands within the ROI visible from roadside and publicly accessible locations (i.e. not subject to private land access limitations) were investigated during the breeding season in 2020 and 2022. In total, of 285 waterbodies identified in the ROI, 228 waterbodies (80%) were visually inspected during these roaming surveys (Table 11). The remaining 57 waterbodies were assessed via NearMap aerial photography due to site access restrictions.

The majority of observed waterbodies were shallow dams with no riparian, emergent or floating vegetation, or paddocks dominated by pasture grasses that contained no evidence of recent inundation. Most wetlands were located in areas that consistently and frequently undergo cultivation for either cropping or pasture establishment. Waterbodies were largely modified (i.e. subject to draining) and either lacked riparian and/or aquatic vegetation (i.e. emergent, submerged and fringing vegetation) or supported a low cover of aquatic vegetation.

A total of three wetlands (Site 47, Site 139 and Site 285) met the criteria for 'High Quality' habitat, and 19 wetlands met the criteria for 'Moderate' habitat quality. Moderate quality wetlands were dams or waterbodies that were located in an area of high agricultural activity and supported low levels of riparian and/or aquatic vegetation. The majority of waterbodies (i.e. 206) met the criteria for 'Low' quality habitat. Many of these waterbodies were dry at the time of the assessment and were located in modified areas subject to ongoing agricultural land uses and contained no riparian and/or emergent vegetation due to being channelised and/or drained.

Sites 114 and 194, which initially contained the two closest historical Brolga breeding records have been assessed as low quality as they are both highly modified due to agricultural disturbance, and at the time of the assessment, Site 194 was dry and did not contain any riparian and/or emergent vegetation. Site 114 was investigated on 8 March 2023 as part of ongoing investigations and was again assessed as low quality. The construction of the Western Highway significantly reduced the extent of this wetland, particularly the 2015/16 upgrade (i.e. post all Brolga breeding records). Site 114 now sits approximately 60 metres north of the Western Highway, and 105 metres south of the Western Highway access road in a degraded state (Plate 2; Plate 3). However, given the presence of historical breeding records and potential for future inundation, Sites 114, 194 and 196 still meet the criteria of a Brolga breeding site.

Site 121, which was added as a confirmed Brolga breeding site during the September 2022 Landowner consultation, was also assessed as low quality in 2020 due to modification from local agriculture and no water being present. However, Landowner photographs from 2 February 2022 clearly show the presence of water, fringing and emergent vegetation, typical of moderate habitat quality. On-ground assessments in 2023 later confirmed Site 121 to comprise High quality habitat (Section 4.2.2) (Table A1, Appendix 8).

A summary of the survey results and initial habitat assessment are presented in Table 11.

Table 11. Results of the roaming Brolga Habitat Assessment.

Habitat Quality	Habitat Quality based on Site Assessment	Habitat Quality based on Desktop Assessment
High	3 (0.4%)	0
Moderate	19 (5.8%)	4 (1.8%)

Habitat Quality	Habitat Quality based on Site Assessment	Habitat Quality based on Desktop Assessment
Low	206 (67.4%)	53 (24.6%)
Total	**228 (80%)**	**57 (20%)**

Plate 2. Site 114 facing the Western Highway (Ecology and Heritage Partners Pty Ltd (08/02/2023)

Plate 3. East of Site 114 with the raised Western Highway right of Plate (Ecology and Heritage Partners 08/02/2023)

3.2.3.2 Ground-truthing of potential Brolga breeding sites

Ground-truthing field surveys were undertaken at wetlands requiring further investigation as part of the Level 1 assessment to determine if Brolga had used the site for breeding. Potential sites included those identified through landowner consultation and roaming surveys.

Site 121

Included in the photographic and video documentation provided by Landowners was evidence of one pair of breeding Brolga at Site 121 in late 2022 (Section 3.2.2). A field assessment was undertaken to ground-truth the extent of mapped wetland and habitat quality at Site 121 on 27 September 2023. The Site was recorded as high quality, and confirmed as a suitable Brolga breeding wetland (see Section 3.2.4).

Site 124

Four Brolga were observed at Wetland 124 during bird utilisation surveys conducted between 29 November – 1 December 2021. The Brolga were sighted on 29 and 30 November 2021, with a separate incidental sighting on 2 December 2021 while driving past the wetland.

The four Brolga observed appeared to comprise a family of two adults and two juveniles, with no chicks present. Given the absence of Brolga from Wetland 124 during previous surveys, this indicates that the wetland was not being used for breeding purposes as fledging generally occurs at around 100 days, with juveniles staying with their parents for another breeding season if the parents do not re-nest (Marchant and Higgins 1993).

Wetland 124 was investigated as part of targeted field investigations from ongoing Landowner consultation on 8 February 2023.

No Brolga was observed, and no evidence of breeding was recorded at this location. Based on the absence of Brolga at Wetland 124 during all previous surveys undertaken for the project, as well as the absence of chicks during the opportunistic sightings, and the absence of any evidence of breeding at this site via landowner consultation and aerial (drone) surveys (Section 4.1.2), it is highly likely that Wetland 124 was being opportunistically utilised for foraging purposes, and does not support breeding habitat for Brolga.

Site 139

Five adult Brolga were observed on 8 February 2023 in the western portion of Site 139 (Dunn's Marsh), where Brolga sighting and breeding records had been previously recorded between 1989 and 2022. Four nests were also observed in this portion of the wetland (Table 12), though two of the nests were occupied by Black Swan *Cygnus atratus* with seven juveniles nearby at the time of the field inspection (Table 12). Given historic breeding at Site 139 within online databases, as well as landowner consultation information, Site 139 was assessed as a confirmed Brolga breeding wetland.

Table 12. Data recorded at site 139

Data	Result
Site/Pair ID	Site 139
Nest Locations (Eastings/Northings)	725880/5849248 725660/5849077 725351/5849454 725319/5849398
Land Use Type	Grazing
Wetland size	320
Chick Present	N
Location of Brolgas	8/2/2023: Four adult Brolgas observed at 726020/5849675, which flew to 725495/5849203, before returning to original location as the site was surveyed.
Notes on nest, including condition, location etc.	Four nests observed, all high quality within high quality habitat. This western portion of Dunn's Marsh also supported Black Swan, including seven juveniles.

Plate 4. Nest recorded at Site 139 (Western portion of Dunn's Marsh) Ecology and Heritage Partners Pty Ltd (08/02/2023).

Plate 5. Nest recorded at Site 139 (Western portion of Dunn's Marsh) Ecology and Heritage Partners Pty Ltd (08/02/2023).

Site 285

Two adult Brolga were sighted at Site 285 on 8 February 2023, where three large nests were found amidst high-quality Brolga habitat (Plate 6 and Plate 7) (Table 13). The landowner affirmed that they had previously witnessed only one breeding pair utilising the wetland during any given breeding season. Following landowner reports and ongoing consultation, up to seven Brolga were observed at Site 285.

Despite the presence of three nests at Site 285, their varied heights and close proximity indicated that a second and third nest had been constructed in response to high rainfall events in the 2022 breeding season.

Plate 6. Nest recorded at Site 285 Ecology and Heritage Partners Pty Ltd (08/02/2023).

Plate 7. Nest recorded at Site 285 Ecology and Heritage Partners Pty Ltd (08/02/2023

Table 13. Data recorded at site 285

Data	Result
Site/Pair ID	Site 285
Nest Locations (Eastings/Northings)	720312/5854379 720313/5854348 720313/5854322
Land Use Type	Cropping
Wetland size (hectares)	5.2
Chick Present	N
Location of Brolgas	Two adult Brolgas observed at 720353/5854383, which flew north-east to Site 258.
Notes on nest, including condition, location etc.	Three nests observed, all high quality within high quality habitat.

Site 298

Included in the photographic and video documentation provided by Landowners were two large nests located at Site 298, on the southern edge of the wind farm parcel boundary, dated 21 January 2023 (Figure 2a). A pair

of Brolga and a chick have also been photographed foraging in this wetland in January 2023. Ecology and Heritage Partners have surveyed this location for potential breeding Brolga across multiple breeding seasons with no evidence recorded that Brolga have, or are utilising the wetland for breeding purposes (Table 14).

During the breeding seasons, the wetland was inundated with no Brolga observed. Further, Black Swan has been observed utilising habitat within or immediately adjacent to the wetland during November 2022 and August 2023 (Table 14) (Plate 8, Plate 9).

Table 14. Site 298 field assessments.

Date	No. Brolga Observed	Other notable species
30 September 2020	0	-
21 October 2021	0	-
12 August 2022	0	-
12 September 2022	0	-
11 November 2022	0	Black Swan
27 August 2023	0	Black Swan

Based on landowner information, it is accepted that one Brolga pair successfully bred in Site 121 located to the south of Site 298 during the 2022/23 Brolga breeding season (Figure 2a).

With the absence of Brolga observations at Site 298 across multiple breeding seasons, the proximity of known breeding sites, and the observation of similar nest builders at the site (i.e. Black Swan) during the breeding season, the presence of Brolga at Site 298 in January 2023 is most likely due to the breeding pair at Site 121 visiting for foraging purposes. Further, although the record of the observation at Site 298 is logged within the VBA, it is not noted as a breeding record (DEECA 2024a), and in the absence of any evidence that Brolga breeding has occurred at this location, Site 298 is not classified as a breeding site.

A habitat assessment was undertaken for Site 298, resulting in a Moderate habitat suitability for Brolga (Table 15). The habitat quality assessment is detailed in Section 3.14, Section 4.2.2 and illustrated in Appendix 8.

Plate 8. Black Swan *Cygnus atratus* recorded at Site 298. Ecology and Heritage Partners Pty Ltd (11/11/2022).

Plate 9. Site 298. Ecology and Heritage Partners Pty Ltd (27/08/2023).

Table 15. Data recorded at Site 298

Data	Result
Site/Pair ID	Site 298
Nest Locations (Eastings/Northings)	No nests observed
Land Use Type	Pasture/Cropping
Wetland size (hectares)	2.1
Chick Present	N
Location of Brolgas	No Brolga observed
Notes on nest, including condition, location etc.	Moderate quality habitat. Black Swan observed on site.

Other wetlands within the Wind Farm Parcel Boundary

Throughout the field work program, several site inspections have been undertaken at wetlands within the wind farm parcel boundary to confirm the presence or absence of Brolga breeding activity.

Based on the results of the site assessments, and condition of wetlands within the wind farm parcel boundary, there is no evidence that Brolga have, or are utilising any of these wetlands for breeding purposes (Table 16).

Table 16. Field observations for additional wetlands within the Parcel Boundary.

Wetland ID	Date	No. Brolga Observed	Comments
154	**30 September 2020**	0	Low quality. No nests in or along adjacent drainage line.
	12 September 2022	0	As above.
	27 August 2023	0	As above.
215	**30 September 2020**	0	Drainage line, not inundated. Adjacent dam – almost dry. No nests.
	1 October 2021	0	Some water in dam.
	21 October 2021	0	Some water in dam.
	29 November 2021	0	Some water in dam.
	27 August 2023	0	-
234	**30 September 2020**	0	Highly modified. Mostly drained into dam on eastern edge. No nests.
	1 October 2021	0	As above.
	21 October 2021	0	As above.
	12 September 2022	0	As above.
	27 August 2023	0	As above.
269	**30 September 2020**	0	Heavily disturbed and pugged by cattle. No nests.
	1 October 2021	0	As above.
	21 October 2021	0	As above.
	12 August 2022	0	As above.

Wetland ID	Date	No. Brolga Observed	Comments
	12 September 2022	0	As above.
	11 November 2022	0	As above.
	27 August 2023		As above.
296	**30 September 2020**	0	Low quality. No nests in or along adjacent drainage line.
	12 September 2022	0	Low quality. No nests in or along adjacent drainage line.
	27 August 2023	0	Low quality. No nests in or along adjacent drainage line.

3.2.4 Level 1 Confirmed Breeding Wetlands

Based on the findings of the Level 1 Brolga Assessment, including ongoing desktop analysis, site inspections and ground-truthing assessments, as well as extensive consultation with landowners, a total of 14 breeding wetlands as defined by the Interim Guidelines (DSE 2012) were identified within the ROI (Table 17). Of these, eight of these are located within four kilometres of the wind farm development boundary (Figure 2b).

A summary of all Brolga breeding wetlands included in further analysis, and respective capture methodology, is presented in Table 17.

Table 17. Confirmed Brolga breeding wetlands within the ROI based on Level 1 Assessment

#	Site Number	# Brolga nests	Distance to wind farm boundary (kms)	Distance to nearest turbine (kms)	Direction	Capture Methodology
1	**42**	1	7.6	8.07	North-West	Landowner
2	**47**	5	6.21	6.67	North-West	VBA / Landowner
3	**61**	1	5.06	5.54	North-West	VBA
4	**114**	7	2.01	2.51	West	VBA
5	**121**	1	0.8	1.46	South	Landowner
6	**139**	10	2.0	2.97	South-East	VBA / Landowner / Targeted survey
7	**168**	1	8.34	8.62	South	VBA
8	**194**	1	1.66	2.83	North-East	VBA
9	**196**	2	3.24	4.44	North-East	VBA
10	**212**	1	7.27	8.68	South-East	Landowner
11	**222**	4	3.74	4.97	North-East	VBA

#	Site Number	# Brolga nests	Distance to wind farm boundary (kms)	Distance to nearest turbine (kms)	Direction	Capture Methodology
12	**227**	1	8.04	9.06	South	Landowner
13	**285**	3	1.62	2.31	North-West	Landowner / Targeted survey
14	**297**	1	1.42	2.17	South-West	Landowner

3.3 Conclusion

Based on the findings of the Level 1 Brolga assessment, a total of 14 breeding wetlands are confirmed to be present within the ROI. No Brolga flocking sites as defined in the Interim Guidelines (DSE 2012) were identified during the desktop assessment, landowner questionnaire or community consultations, and there is no evidence that the ROI supports wetlands used for flock roost sites. The nearest identified flocking site is located at Lake Goldsmith, approximately 12.7 kilometres south-west of the wind farm development boundary.

The summary of the results of the Level 1 Assessment against the triggers for a Level 2 Brolga Assessment (DSE 2012) are detailed in Table 18.

Table 18. Triggers used to determine if a Level 2 Brolga Assessment is required (DSE 2012).

Trigger	Justification	Result
Records of breeding or flocking habitats within the radius of investigation	Sixteen Brolga breeding records within the ROI were identified through biological databases and through the community consultation processes. No records of Brolga flocking (as defined in the Interim Guidelines [DSE 2012]) within the ROI were identified through biological databases or community consultation.	**Triggered**
The proposed development is located in an area which may be used by Brolga moving seasonally between breeding and foraging sites, and may potentially create a barrier effect reducing movements between these habitats	Given the confirmed presence of Brolga breeding wetlands north-west, north-east and south of the Brewster Wind Farm, there is potential for Brolga to move seasonally across the project area.	**Triggered**
The proposed development is located in an area which may be used by Brolgas for diurnal movements between foraging and roosting sites	Given the absence of known flocking sites within the ROI, there is a low likelihood that the species enters the study area for diurnal movements between foraging and roosting sites during the flocking season. The nearest known flocking site is located at Lake Goldsmith	Unlikely
The proposed location of new powerlines associated with the development may create new collision risks for Brolga.	The proposed action includes a new powerline of approximately 400 metres in length across Spring Hill Creek that may create a collision risk to Brolga.	**Triggered**

Based on the results of the Level 1 investigation, as per the criteria detailed in the Interim Guidelines (DSE 2012), a Level 2 assessment is triggered due to:

- The confirmed presence of Brolga breeding records within the ROI, with 14 breeding sites confirmed within 10 kilometres of the wind farm development boundary;
- The wind farm development boundary is located within an area which may be used seasonally by Brolga for diurnal movements between breeding and foraging sites; and,
- The proposed development of a new overhead powerline (approx. 400 metres across Spring Hill Creek) associated with the development may create collision risks for Brolga.

4 LEVEL 2 ASSESSMENT

A Level 2 Brolga Assessment was conducted in accordance with survey methodology detailed in the Interim Guidelines (DSE 2012). Specifically, the objective was to collect data on the location, extent and condition of Brolga habitats, and patterns of habitat use and behaviour at breeding and foraging sites within the area of investigation (if and where Brolga are observed).

Initial investigations to undertake the Level 2 Assessment criteria were undertaken between October 2020 and March 2023. Additional Level 2 investigations were undertaken between September and December 2023.

4.1 Methodology

Data for the Level 2 Assessment can be collected via a range of methodologies, including additional ground-truthing of sites, aerial surveys, habitat assessments, flight behaviour studies and gradient studies, where possible (DSE 2012). The following methods were undertaken:

- Observational surveys, including:
    - A comprehensive aerial (drone) survey of waterbodies within the ROI for evidence of breeding Brolga, where drone flight was actionable;
    - Updated habitat assessment of all waterbodies within the ROI; and,
    - Ground-truthing of potential Brolga breeding sites.
- Site-specific Brolga flight behaviour studies at confirmed breeding wetlands during the 2023 breeding season.

4.1.1 Aerial Surveys

Ecology and Heritage Partners employed Australian UAV Pty Ltd (AUAV) in conjunction with Catchment Health Engineering (CHE) to undertake aerial surveys via drone for all waterbodies within the ROI. Waterbodies were identified through:

- DEECA wetland mapping layer;
- Additional waterbodies identified during previous roaming surveys;
- Additional waterbodies identified through landowner consultation process; and,
- Additional waterbodies identified via drone survey (i.e. farm dams, wetlands in addition to those identified above).

Video footage and photographs were taken of each wetland assessed during the aerial surveys. In total, 298 waterbodies were identified within the ROI through the above methods. Overall, 292 waterbodies (97.9%) were successfully aerially investigated and analysed via drone for evidence of Brolga activity, as well as an up-to-date review of habitat quality during the 2023 breeding season.

An additional six waterbodies could not be accessed during the aerial surveys as:

- Four of the waterbodies (Sites 39, 170, 224, and 286) were inaccessible via drone flight due to topography and weather constraints. These sites occur on the outer range of the ROI, located approximately 8.7, 9.3, 9.5, and 9.8 kilometres from the wind farm, respectively; and,
- Two waterbodies (Sites 158 and 198) are located on Langi Kal Kal Prison property, approximately 4.3-kilometres north-west of the project area, and are designated 'no-fly' zones.

Importantly, Site 106 (Bittern Lagoon) is also located within the Langi Kal Kal Prison property and was identified as a potential Brolga breeding record through the VBA and Questionnaire. As such, the Prison was contacted via email and permission granted for a Zoologist to inspect the site for the Brolga. A Brolga breeding pair was identified at Site 106, and follow-up flight investigations were undertaken during the breeding season (See Section 4.2.1). The Prison also advised that despite Brolga presence on Site 106, no Brolga had been historically observed on either of the other two locations (Site 158 and 198) within the Prison boundary.

Drone surveys were carried out between 7 September and 15 September 2023 by licenced drone operators (AUAV and CHE) and conducted in accordance with the requirements of the *Civil Aviation Safety Regulations 1998*.

A suitably qualified and experienced Zoologist was either present with the drone operator during the drone flight or was present within the ROI, being on-call to the drone operator during the time of the drone flights. This allowed for real-time assessment of the waterbodies for presence of Brolga and/or breeding activity (i.e. nests).

4.1.2 Flight Behaviour Studies

Once the 2023 Brolga breeding sites within the ROI had been identified, using a combination of aerial (drone) surveys, landowner consultation, and targeted surveys, extensive Brolga flight behaviour surveys were undertaken for each site.

Four Brolga breeding pairs were identified (including two pairs at Site 139, and one pair each at Site 106 and Site 141) during the aerial surveys, with subsequent flight behaviour studies undertaken between 6 September and 12 December 2023. Surveys were undertaken between 0710 and 1945 hours.

Each survey was scheduled for a minimum of 20 minutes, though some spanned for up to 95 minutes if Brolga were present and flight behaviour was ongoing or likely. A suitability qualified and experienced zoologist rotated through the sites, often visiting the site multiple times per day to cover a wide range of times and conditions. Observations within the same site were undertaken at least two hours apart so that any single observation could be considered independent of any previous observations.

Flight behaviour studies were undertaken by visually watching Brolga at known breeding locations. Surveys were undertaken, with binoculars where appropriate, from:

- Private land where access was provided by the Landowner; and,
- Areas not subject to private land access limitations.

The following data was collected for each flight during the survey (Table 19).

Table 19. Data recorded during flight behaviour studies

Data	Format
Survey Info:	
Site/Pair ID:	As previously recorded
Date:	
Survey Start Time & End Time:	Recording Survey duration even if no bird is observed may allow accounting for false absences better.
Chick present?	Y/N
Precipitation:	Clear / Cloudy / Light Rain / Heavy Rain
Temperature:	Degrees
Observations:	
Bird 1: Observed Time:	
Observed Location:	Easting / Northing
Flight Direction	
Flight Distance	
Flight Height	
Flight Destination	Easting/ Northing
Behaviour or other notes:	Time spent grazing, nesting etc.
Bird 2: Observed Time:	
Observed Location:	Easting/Northing
Flight Direction	
Flight Distance	
Flight Height	
Flight Destination	Easting/ Northing
With Bird 1?	Y/N
Behaviour or other notes:	Time spent grazing, nesting etc.

4.2 Results

4.2.1 Aerial Surveys

Extensive field surveys were undertaken during the breeding and non-breeding seasons between 2020 and 2023 to document the extent of Brolga activity and current and historical spatial patterns of activity within the ROI. Field investigations occurred during various weather conditions, including low and high rainfall (La Niña conditions in southern Australia).

Aerial (drone) surveys across 292 waterbodies recorded evidence of four breeding pairs of Brolga within the ROI during the 2023 breeding season at three sites:

- Site 139 (two breeding pairs);
- Site 106; and,

- Site 141.

No additional wetlands actively being used for breeding during the 2023 breeding season were identified through aerial surveys, desktop analysis or landowner/community consultation.

Note that Sites 106 and 141 are additional breeding wetlands that were not identified during the Level 1 assessment.

Imagery of each wetland as captured during the aerial surveys is provided in Appendix 8.

4.2.1.1 Aerial (drone) surveys - Site 106

Known as 'Bittern Lagoon' and located on the Langi Kal Kal Prison property but outside the Prison wall, Site 106 was surveyed via drone with permission from the relevant authorities who advised that Brolga were seen on Site 106 but not Site 158 or Site 198. Two Brolga and one chick was recorded on 13 September 2023, foraging along the southern edge of the wetland (Table 20).

Table 20. Data recorded at Site 106

Data	Result
Site/Pair ID	Site 106
Nest Locations (Eastings/Northings)	721300/5857645
Land Use Type	Bittern Lagoon/Langi Kal Kal Prison property
Wetland size (hectares)	37.29
Chick Present	Y
Location of Brolgas	Two adult Brolgas and chick observed along southern edge
Notes on nest, including condition, location etc.	High-quality Brolga habitat, Brolga stayed nearby nest (3-metre radius).

4.2.1.2 Aerial (drone) surveys – Site 141

During aerial surveys on 13 September 2023, one Brolga was observed upon a nest along the south-east edge of Site 141, located approximately 8.7 kilometres north-east of the wind farm parcel boundary (Table 21). Black Swan were also present at the site. Up to two Brolga were observed on site until last seen late November 2023. Despite not observing any chicks, Site 141 has been considered a Brolga breeding site within the ROI.

Table 21. Data recorded at Site 141

Data	Result
Site/Pair ID	Site 141
Nest Locations (Eastings/Northings)	731208/5858031
Land Use Type	Cropping/wind farm
Wetland size (hectares)	40.98
Chick Present	N
Location of Brolgas	One adult Brolga observed on nest
Notes on nest, including condition, location etc.	Nest located approximately 500 metres from turbine (Waubra Wind Farm).

4.2.1.3 Level 2 Confirmed Brolga breeding wetlands

With the addition of Site 106 and 141, the total number of Brolga breeding wetlands within the ROI after the Level 2 assessment is 16 breeding wetlands (Table 22). Importantly, Table 22 is a definitive list of Brolga breeding in the ROI as determined through the Level 1 and Level 2 assessment, and supersedes Table 17.

Table 22. Confirmed Brolga breeding wetlands within the ROI based on Level 2 Assessment

#	Site Number	# Brolga nests	Distance to wind farm boundary (kms)	Distance to nearest turbine (kms)	Direction	Capture Methodology
1	**42**	1	7.6	8.07	North-West	Landowner
2	**47**	5	6.21	6.67	North-West	VBA / Landowner
3	**61**	1	5.06	5.54	North-West	VBA
4	**106**	4	4.4	4.97	North	Drone
5	**114**	7	2.01	2.51	West	VBA
6	**121**	1	0.8	1.46	South	Landowner
7	**139**	10	2.0	2.97	South-East	VBA / Landowner / Targeted survey
8	**141**	1	8.7	9.57	North-East	Drone
9	**168**	1	8.34	8.62	South	VBA
10	**194**	1	1.66	2.83	North-East	VBA
11	**196**	2	3.24	4.44	North-East	VBA
12	**212**	1	7.27	8.68	South-East	Landowner
13	**222**	4	3.74	4.97	North-East	VBA
14	**227**	1	8.04	9.06	South	Landowner
15	**285**	3	1.62	2.31	North-West	Landowner / Targeted survey
16	**297**	1	1.42	2.17	South-West	Landowner

4.2.2 *Brolga Habitat Assessment*

Building on from the initial habitat quality assessments that were undertaken via roaming surveys and existing aerial imagery (see Section 3.1.4), this section details the additional investigations of habitat across 292 waterbodies undertaken via drone survey, which included a reassessment of all wetlands previously surveyed. A full breakdown of the definitive habitat assessment (i.e. this section of the report) is presented in Table A1 and Appendix 8.

4.2.2.1 Aerial (drone) Assessment

The aerial (drone) survey results broadly aligned with previous habitat assessment efforts (Table 11; Section 3.2.3), finding the majority of waterbodies (73.8%) within the ROI to be of low habitat quality for Brolga (Table A1). Importantly, 17 waterbodies (5.7%) were classified as high-quality, highlighting the presence of optimal breeding habitat for Brolga within the ROI.

A summary of the habitat assessment results, undertaken as part of Level 2 assessment which supersedes the habitat assessment in Level 1 (Table 11) and provides a definitive list of Brolga habitat quality within the ROI at the time of writing, is presented in Table 23.

Table 23. Summary of results of the aerial habitat assessment.

Habitat Quality	Number of wetlands assessed based on drone survey (as percentage)	Number of wetlands assessed based on desktop assessment (as percentage) *	Total number of wetlands (as percentage)
High	17 (5.7%)	0	17 (5.7%)
Moderate	61 (20.5%)	0	61 (20.5%)
Low	214 (71.8%)	6 (2.0%)	220 (73.8%)

***Four of the six sites requiring desktop assessment are located more than 8.5 kilometres from the wind farm boundary, with the remaining two sites located on Langi Kal Kal prison property (3.75 and 4.07 kilometres from the wind farm boundary) with no recorded Brolga activity (Langi Kal Kal Prison pers. comms.)**

4.2.3 *Flight Behaviour Studies*

Between 6 September and 12 December 2023, 142 separate Brolga flight behaviour data points were collected across multiple sites, primarily the four breeding pairs located at the three known Brolga breeding sites, spanning over 67 hours of survey time. Of the 142 data points, 63 (44%) observed Brolga present at the breeding wetland. The frequency of Brolga observation decreased towards the end of the breeding season (i.e. December) with only three of the final 22 surveys (14%) positively observing the species. This decrease aligns with the growth and fledging of the Brolga chicks discussed in the following sections.

Of the 142 surveys, 124 surveys were conducted at three confirmed 2023 Brolga breeding sites, these sites are detailed in Table 24. Eighteen surveys were opportunistically undertaken at three additional sites (Sites 47, 59 and 61) if Brolga were observed between sites, or when advised of Brolga presence by landowners. However, surveys at Sites 47, 59 and 61 did not result in any observed Brolga flights.

Table 24. Confirmed Brolga breeding wetlands within the ROI (2023 only)

Site Number	# 2023 Brolga breeding pairs	# surveys conducted at site	Distance to wind farm boundary (kms)	Direction from wind farm boundary
106	1	29	4.4	North
139	2	55	2.0	South-East
141	1	40	8.8	North-East

Where multiple Brolga were observed flying together and exhibiting the same flight behaviour – starting and landing within metres of each other, these flights were not considered to be independent of each other, and have not been assessed as independent flight events.

A total of 22 Brolga flights were recorded during the 2023 flight behaviour studies across 11 independent flight events (Table 25; Table 26; Figure 4). The majority of flights were captured to and from Site 139. One flight was recorded from Site 141, with no flights captured from Site 106.

Table 25. Brolga flight observations.

Flight Event # (Figure 4)	Date (2023)	Site	Time	# Brolga	# Juveniles
1	25 Sep	139^	1250	1	0
2	1 Nov	139^	0925-1100	1	0
3	1 Nov	139^	0925-1100	2	1
4	1 Nov	139^	0925-1100	2	1
5	1 Nov	139^	0925-1100	1	0
6	1 Nov	139^	0925-1100	1	0
7	1 Nov	139^	0925-1100	2	0
8	1 Nov	139^	0925-1100	2	0
9	1 Nov	139^	0925-1100	3	1
10	21 Nov	139^	1825	2	0
11	13 Nov	141	1415	2	0

Note: ^Record pertains to one of the two breeding pairs

The Brolga flight behaviour survey effort varied over the course of the 2023 breeding season, with the most intensive surveying between October and November (Section 4.2.4). This survey effort, and documented Brolga behaviour, aligns with the expected behaviour of the species in south-west Victoria.

Table 26. Brolga flight observations

Flight # (Figure 4)	Site	No. Brolga	Direction	Flight height (m)	Total flight distance (m)	Maximum distance from breeding wetland (m)	Start Location	Destination	Notes
1	139	1	W	3	204	0	E edge 139	Within 139	Brolga foraging in small area for most of the survey. Late in the survey, it took off (3 m height), did a wide arc and then flew west.
2	139	1	N- NE	5	166	187	NE edge of 139	Paddock	Brolga observed in paddock W of Modesty Lane. <5m off ground (possibly juvenile). Flew N.
3	139	3	W- NW	20	718	222	NE edge of 139	Paddock	Brolga flew off (approx. 20m height) from fence line behind house, headed NW before an arc due W.
4	139	3	NE	20	1662	1180	Paddock	Site 243	Brolga (that flew West (Flight #3) flew towards observer, then headed NE (20m height) to Site 243.
5	139	1	E-NE	30	1236	1290	NE edge of 139	Site 261	Brolga near fence line behind property flew E circling higher until approx. 30m height. Brolga then flew NE to Site 261.
6	139	1	NE	20	1218	1325	Paddock	Site 261	Brolga in paddock flew NE circling higher until approx. 30m height. Brolga then flew NE to Site 261 (Shortly after Flight #5).
7	139	2	SE	20	1164	1300	Site 261	Paddock at the NE edge of 139	Brolga flew SE circling up to 20m height, landing along fence line approx. 300m behind property. Brolga were calling and foraging approx. 30m radius.
8	139	2	NE	50	1262	1315	NE edge of 139	SW edge of Site 261	Brolga flew off progressively circling higher (large circles) until approx. 50m height, calling consistently. Brolga then flew over Modesty Lane, headed NE to Site 261.
9	139	4	SW-W	70	698	1120	Site 261	Paddock	Brolga arced SW over plantation, landing in paddock.

Flight # (Figure 4)	Site	No. Brolga	Direction	Flight height (m)	Total flight distance (m)	Maximum distance from breeding wetland (m)	Start Location	Destination	Notes
10	139	2	SW	10	116	273	S edge of 139	Paddock	Brolga foraging S edge of 139 within 30m radius. Brolga flew up and arced SW on edge of wetland near fence line with hay bales. Flight was 100m approx. and between 5-10m height. Brolga proceeded to do a courtship dance for 10min before foraging further up hill in grazed land with hay bales out of 139.
11	141	2	NW	5	690	690	Northern edge of Site 131	NE edge of 141	Brolga flying into NE edge of 141 to forage.

Analysis of home range data (using 'maximum distance from breeding wetland') indicated that all Brolga movement observed during site-specific investigations are contained within 523.2 metres for 90% of their movements, 1,132 metres for 92.5% of movements, and 1,268 metres for 95% of movements whilst incubating, brooding, and rearing chicks (Table 27). Our results broadly align with Veltheim *et al.* (2019), which found that 95% of Brolga flights during the breeding season were less than 1,369 metres.

Table 27. Summary of Brolga flight behaviour data

Metric	Flight Height*	Total Flight Distance ^	Starting distance from breeding wetland	Maximum flight distance from breeding wetland
Range (metres)	3-70	116-1662	0-886	**0 - 1325**
Mean	23	872.64	176.27	**182.57**
50th percentile (metres)	20	1163	153	**40.0**
90th percentile (metres)	50	1262	178	**523.2**
92.5th percentile (metres)	55	1362	355	**1132.0**
95th percentile (metres)	60	1462	532	**1268.0**
97.5th percentile (metres)	65	1562	709	**1306.0**
99th percentile (metres)	68	1622	815.2	**1318.6**

Note: * Estimated height from the ground; ^ Total flight distance includes the portion of the flight that occurred within the breeding wetland.

The below sections describe the flight behaviour at each site.

4.2.3.1 Confirmed Brolga breeding wetlands in 2023

Site 106

For the purpose of flight data collection during the 2023 breeding season, 29 surveys spanning a minimum of 20 minutes were undertaken at Site 106. The breeding pair was first observed on 13 September 2023 via drone, with one of the Brolga observed sitting on a nest along the southern edge of the wetland. Brolga were recorded at the wetland during 15 of the surveys (52%), with the chick first identified on 27 September 2023, and during a total of six surveys (21%).

Despite extensive effort, no Brolga flight behaviour was observed for this site, with the birds only recorded walking and foraging along the eastern and southern boundaries of the wetland when present. A summary of their behaviour is detailed in Table 28.

Table 28. Brolga recorded behaviour at Site 106

Brolga Behaviour	Occasions (percent of observed time)*
Not observed	14 (48%)
Sitting on nest (no movement)	1 (3%)
Foraging <5 metre radius	7 (24%)
Foraging 5-30 metre radius	6 (21%)
Foraging 31-100 metre radius	0 (0%)
Foraging >100 metre radius	1 (3%)
Flight	0 (0%)

Note: * May not equate to 100% due to rounding

Site 139

For the purpose of flight data collection during the 2023 breeding season, 55 surveys spanning a minimum of 20 minutes each were undertaken at Site 139. Two pairs of Brolga were confirmed to be using Site 139 for breeding, one pair on the eastern edge near Modesty Lane, and one pair on the western edge abutting agricultural land. These nests were located approximately 2.2 kilometres apart, though are located within the same wetland. Both breeding pairs were observed to be successful, with a chick observed at each nest between September and December 2023.

Over the 55 surveys, a total of 29 hours and 42 minutes were spent observing Site 139. Brolga were observed at the wetland during 24 surveys (44%) however surveys positive for the species typically lasted longer, resulting in 14 hours and 25 minutes (48%) of direct Brolga observation at the site. Clear evidence of a chick was recorded on four occasions (7%), however three or more Brolga were recorded at a breeding site on 10 occasions (18%), which is potentially a product of the chick's growth and distance of observer from the Brolga (i.e. chick becoming similar size to the female towards the end of the breeding season).

The Brolga flight events captured were predominately along the north-east, east, and south-east borders of Site 139 (i.e. abutting Modesty Lane) (Figure 4). It is likely that the eastern-most breeding pair and chick are responsible for most of the flight data, however at least one flight event (four Brolga) suggests the two breeding pairs potentially meeting up (Table 25) (Figure 4).

The Brolga flight events captured at Site 139 are detailed in Table 29 and illustrated in Figure 4. The majority of the flights from Site 139 were into adjacent pasture for foraging activity, and/or towards Site 261, located to the north-west over the Western Highway. Where flights and or precise landing locations were obscured by trees/windrows or other landscape features, these flights were followed via vehicle at the first opportunity, with Brolga later observed (usually within 5 minutes) foraging within pasture at the edge of Site 261. The location of the Brolga where foraging was assumed to be the end of the flight path, with flight distance calculated to the location where the Brolga were observed.

Table 29. Brolga recorded behaviour at Site 139

Brolga Behaviour	Occasions (percent of observed time)
Not observed	31 (56%)
Sitting on nest (no movement)	4 (7%)
Foraging <5 metre radius	1 (2%)
Foraging 5-30 metre radius	10 (18%)
Foraging 31-100 metre radius	3 (5%)
Foraging >100 metre radius	0 (0%)
Brolga Flights	20* (15%)

Note: * 10 flight events comprising 20 Brolga

Site 141

For the purpose of flight data collection during the 2023 breeding season, 40 surveys spanning a minimum of 20 minutes were undertaken at Site 141. One Brolga was first observed on 14 September 2023 via drone, sitting on a nest along the south-east edge of the wetland. Up to two Brolga were recorded at the wetland on 20 occasions, however given the vantage point and on-site biomass, it was difficult to confirm the presence of a chick.

Despite extensive effort, one flight event comprising two Brolga was observed during the flight behaviour assessments (Table 25). Brolga were otherwise recorded foraging along the northern and western boundaries of the wetland. A summary of their behaviour is detailed in Table 30.

Table 30. Brolga recorded behaviour at Site 141

Brolga Behaviour	Occasions (percent of observed time)
Not observed	20 (50%)
Sitting on nest (no movement)	1 (3%)
Foraging <5 metre radius	3 (8%)
Foraging 5-30 metre radius	13 (33%)
Foraging 31-100 metre radius	2 (5%)
Foraging >100 metre radius	0 (0%)
Flight	2* (3%)

Note: * 1 flight event comprising 2 Brolga

4.2.4 Summary of Brolga Behaviour Observations

Throughout the 2023 Brolga breeding season, spanning between September and December, the flight behaviour studies also recorded other Brolga behaviours including nesting, and foraging distances. These observations illustrate the change in observable behaviour over the course of the survey period (Graph 1 and Graph 2).

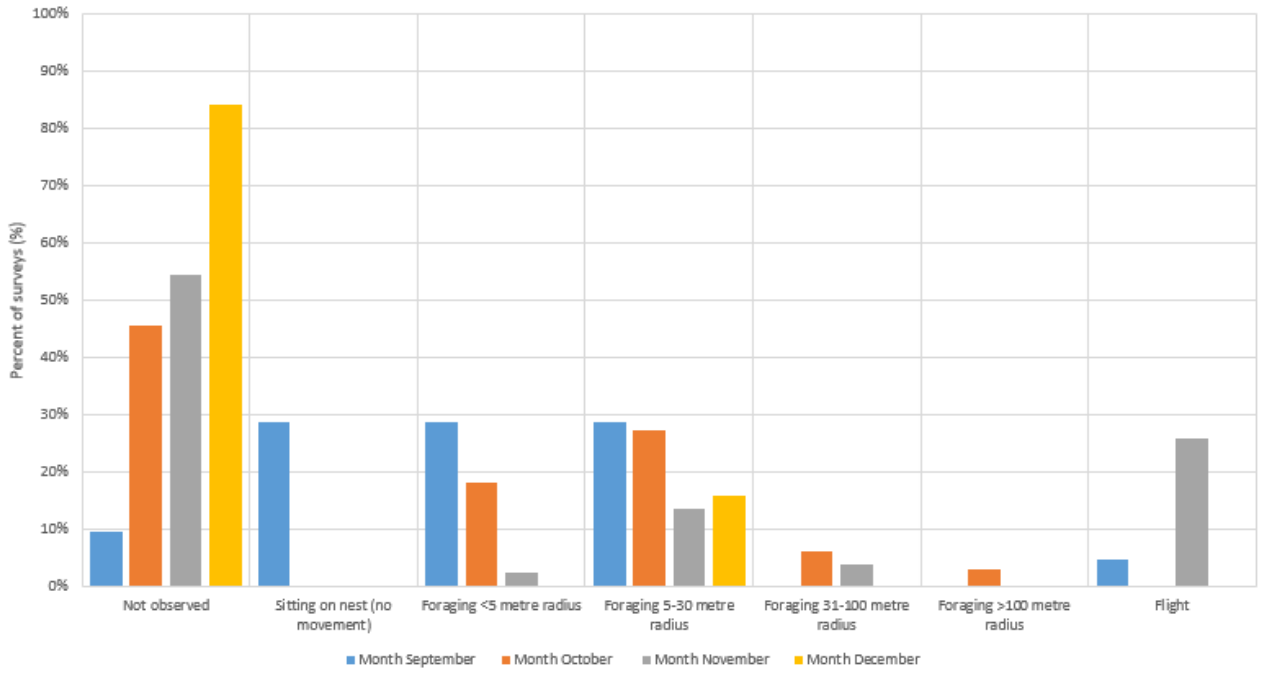
In September, Brolga were frequently observed either on the nest or foraging within a small (<30 metre) radius of the nest. One flight was observed at Site 139, however this was a short (<250 metre) flight by a single Brolga which did not reach above five metres height off the ground. The individual began and finished the flight wholly within the wetland (Figure 4).

October marked a shift as Brolga foraging distances increased from the nest, aligning with the observations of unfledged chicks at Site 106 and 139.

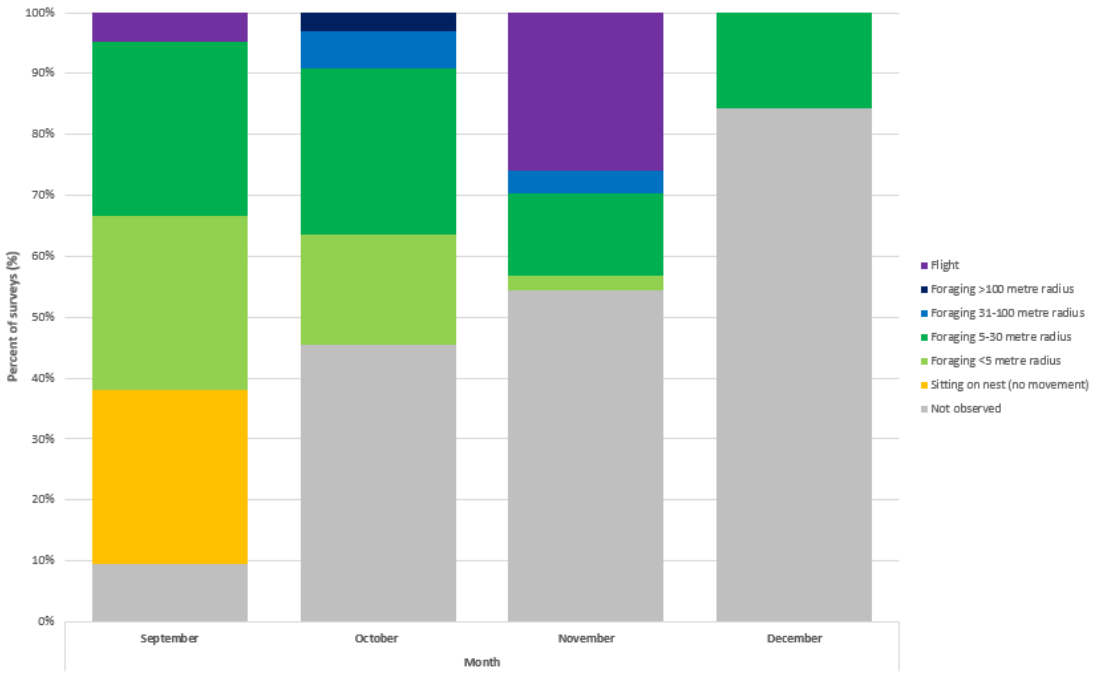
November witnessed a surge in Brolga flight events, coinciding with a decreased presence at confirmed breeding nests, likely indicative of juvenile birds becoming strong enough to travel to other habitats for foraging.

By December, a notable absence of Brolga at nest sites suggested an extended utilisation of foraging habitats. Brolga were spending longer at adjacent foraging resources, rather than being confined to the nest site.

Graph 1 illustrates the percentage of observed time that Brolga were undertaking a behaviour, colour coded by each of the four months of survey. Graph 2 illustrates each distinct month and uses colour coding to show the percentage of observed time that Brolga were undertaking that behaviour within the specified month.



Graph 1. Brolga activity separated by observed behaviour and coloured by month



Graph 2. Brolga activity separated by month and coloured by observed behaviour.

4.2.5 Non-breeding season flights

Some pairs of Brolga may remain in the vicinity of their breeding territory rather than moving to a flocking site during the non-breeding season (DSE 2012). Information provided during the landowner consultation process indicates that Brolga have been observed flying within and nearby the wind farm development boundary during the non-breeding season. As no flocking sites have been identified within the ROI as part of the Brolga Level 1 and Level 2 assessments, no site specific non-breeding season flight data has been recorded. However, Brolga movement and dispersal during the non-breeding season is likely to be an indicator of typical movements by Brolga during this period, and these movements (i.e. flights) can be considered in determining the residual risk of the proposed development to the Brolga population (DSE 2012).

The following section (Section 4.2.5.1) details the non-breeding season Brolga flights that were obtained during the landowner consultation process. The subsequent two sections (Sections 4.2.5.2 and 4.2.5.3) estimates the maximum number of non-breeding season Brolga flights to and from Lake Goldsmith and Dunn's Marsh (Site 139) that would be expected to occur within the locality, based on the number of pairs that would be expected to be present at Brolga breeding sites within the ROI.

Lake Goldsmith is the closest confirmed traditional flocking site to the wind farm boundary, while Dunn's Marsh has the potential to be used as non-breeding roosting habitat for Brolga that do not disperse to Lake Goldsmith (or any other traditional flocking site) during the non-breeding season.

4.2.5.1 Landowner Observations

As part of the Landowner consultation described in Section 3.2.2, photographic and video evidence of Brolga flights were presented to Ecology and Heritage Partners for analysis. These flights are detailed in Table 31.

Table 31. Brolga observations by Landowners

Date	Time	# Brolga	# Chicks	Flight Direction	Estimated Flight Distance (kilometres)	Flight Height (metres)	Flight Destination
19/02/2022	0951	3	0	NW	3.5 – 4	30-160	Brolga observed flying toward Site 285, likely from Site 124 or 139
19/02/2022	0951	2	0	NW	3.5 – 4	30-160	As above, though these two peeling off to stop at Site 121
February/March 2022	-	2	0	E	3	25-30	From near Site 121 towards Site 139
February/March 2023	-	2	0	S	3	20-25	From within wind farm boundary towards Site 297
21/01/2022	0801	2	1	-	-	-	Two adult Brolga and one juvenile foraging, likely at Site 269
20/04/2023	-	4	0	E/SE	3	20-30	From within wind farm boundary towards Site 139
April 2023	-	4	0	E/SE/S	3	20-30	From within wind farm boundary, headed E, then SE, then S towards Trawalla East Road
April 2023	dusk	4	0	E	2	20-30	Near to Site 121, headed to Site 139
27/05/2023	-	8	0	E/SE	3	30-40	Observed near W end of Site 139
May/June 2023	-	4	0	S/NE	1.5	10-20	From within wind farm boundary arcing NE
01/08/2023 *	-	6	0	SW	1.5	20	Observed flying into wind farm boundary from N
July/August 2023 *	-	6	0	W	1.5	20-25	Observed flying low
July/August 2023 *	-	6	0	N	1.5	20-25	Observed flying low

Note: * Although these flights are recorded as being undertaken near the commencement of the breeding season, given the absence of key flight data (confirmed start and end location, accurate flight distance, distance from breeding wetland etc), these flight data have not been incorporated into the breeding season flight data detailed in Section 4.2.3.

4.2.5.2 Non-breeding season flights to and from Lake Goldsmith

Lake Goldsmith, being the closest confirmed traditional flocking site at approximately 12 kilometres south-west of the wind farm parcel boundary, has a high potential of being utilised by Brolga observed within the ROI during the non-breeding season as a flock roost site, and therefore, potential flights to and from Lake Goldsmith that intersect the wind farm development boundary must be considered.

For the purposes of this assessment, it is assumed that the breeding pair at each breeding wetland will fly to Lake Goldsmith at the end of each breeding season, and back to the breeding wetland at the commencement of the next breeding season. Where the windfarm boundary is within 500 metres of the direct flight route between Lake Goldsmith and the breeding site, a potential flight interaction is assumed.

Figure 2d illustrates the relationship between Lake Goldsmith and the confirmed Brolga breeding locations within the ROI. Table 32 details the non-breeding season Brolga flights considered as part of the potential migration from breeding sites within the ROI to Lake Goldsmith.

Table 32. Potential Brolga flights between the ROI and Lake Goldsmith.

#	Breeding Site	Brolga breeding pairs per 10 years #	Total flights over the wind farm boundary per year	Notes
1	**42**	1	0	Pathway does not intersect wind farm boundary
2	**47**	1	0	Pathway does not intersect wind farm boundary
3	**61**	1	0	Pathway does not intersect wind farm boundary
4	**106**	7	0	Pathway does not intersect wind farm boundary
5	**114**	1	0	Pathway does not intersect wind farm boundary
6	**121**	7	0	Pathway does not intersect wind farm boundary
7	**139**	20	0	Pathway does not intersect wind farm boundary
8	**141**	1	0.4	Four flights per ten years: Two Brolga making one flight to and from Site 141
9	**168**	1	0	Pathway does not intersect wind farm boundary
10	**194**	1	0.4	Four flights per ten years: Two Brolga making one flight to and from Site 141
11	**196**	1	0.4	Four flights per ten years: Two Brolga making one flight to and from Site 141
12	**212**	1	0	Pathway does not intersect wind farm boundary
13	**222**	1	0.4	Four flights per ten years: Two Brolga making one flight to and from Site 141
14	**227**	1	0	Pathway does not intersect wind farm boundary
15	**285**	7	0	Pathway does not intersect wind farm boundary
16	**297**	1	0	Pathway does not intersect wind farm boundary
Total		**53**	**1.6**	

Note: # based on landowner consultation and/or historical VBA data

Overall, we expect 1.6 Brolga flights to intersect the wind farm development boundary per year for the purposes of non-breeding season flight behaviour to and from Lake Goldsmith from confirmed breeding wetlands.

4.2.5.3 Non-breeding season flights to and from Dunn's Marsh (Site 139)

Importantly, Site 139 can also be considered an important Brolga habitat and resource in the local landscape, considering the observed breeding success, observed flights during recent seasons, and landowner consultation. Based off the conservative estimate for the number of Brolga breeding pairs in the ROI per 10 year period, in the event that Dunn's Marsh is used as non-breeding roosting habitat for Brolga that do not disperse to Lake Goldsmith (or any other traditional flocking site) during the non-breeding season, we expect a maximum of 10.6 Brolga present in the ROI during the non-breeding season (Table 33).

Table 33. Estimated Brolga numbers present within the ROI.

Site Number	Estimated total no. Brolga per year calculated from a 10-year average#	Cumulative total number of Brolga
42	0.2	0.2
47	0.2	0.4
61	0.2	0.6
106	1.4	2.0
114	0.2	2.2
121	1.4	3.6
139	4	7.6
141	0.2	7.8
168	0.2	8.0
194	0.2	8.2
196	0.2	8.4
212	0.2	8.6
222	0.2	8.8
227	0.2	9.0
285	1.4	10.4
297	0.2	10.6
Total		**10.6**

Note: # based on landowner consultation

The Brolga non-breeding season typically spans between January and June (DSE 2012), for the purposes of this assessment, we have assumed a six-month period between 1 January 2024 and 30 June 2024, for a total 182 calendar days. Therefore, at maximum, we expect 10.6 Brolga to fly to Site 139 on 1929.2 occasions, and from Site 139 on 1929.2 occasions, for a total 3858.4 non-breeding season Brolga flights interacting with Site 139.

We have broken the landscape surrounding Site 139 into eight equal quadrants, namely north-west, north, north-east, east, south-east, south, south-west, and west. Given the documented Brolga breeding records, and the availability of suitable foraging habitat broadly across the ROI in all directions, we have assumed equal probability that Brolga will fly in any direction with Site 139 a reference (i.e. 12.5% chance Brolga will arrive or depart Site 139 from each of the eight aforementioned cardinal directions).

Next, we conservatively expect that 50% of flights will be greater than 2.5 kilometres. As such, 12.5% of 3858.4 is equal to 482.3, and the wind farm (nearest turbine being 2.97 kilometres from Site 139) may expect 50% of these flights, equal to 241.2. Therefore, 241.2 non-breeding season Brolga flights are expected to intersect the wind farm development each year, being north-west of Site 139 with the nearest turbine 2.97 kilometres from Site 139.

4.2.5.4 Summary of non-breeding season flights

No Brolga flocking sites have been identified within the ROI as part of the Brolga Level 1 and Level 2 assessments, however information provided during the landowner consultation process indicated that Brolga were present within and nearby the wind farm development boundary during the non-breeding season. Through landowner consultation and desktop assessment, the following non-breeding flight data have been estimated:

- We expect 1.6 Brolga flights to intersect the wind farm development boundary per year for the purposes of non-breeding season flight behaviour to/from Lake Goldsmith to/from confirmed breeding wetlands within the ROI; and,
- We expect 241.2 Brolga flights to intersect the wind farm development boundary per year, assuming presence of an average 10.6 Brolga within the ROI and equal distribution to/from Site 139.

Overall, we expect 243 non-breeding season Brolga flights to intersect the wind farm development boundary each year (Table 34).

Details on how non-breeding flight data has been incorporated into the Collision Risk Model (CRM) is detailed in Appendix 4.

Table 34. Estimated Brolga intersects with the wind farm boundary during the non-breeding season.

Site	Number of Brolga expected to intersect the wind farm boundary per year during the non-breeding season
Lake Goldsmith	1.6
Site 139	241.2
Total	**243**

4.3 Conclusion

The Level 2 Brolga assessment:

- Recorded a total of 16 Brolga breeding wetlands are present within the ROI;

- Updated Brolga habitat quality assessment for all waterbodies within the ROI, primarily via aerial (drone) surveys; and,
- Collected extensive Brolga flight behaviour data at three sites (Site 106, 139, 141) supporting four breeding pairs of Brolga:
    - Total flight distance recorded ranged between 116 – 1,662 metres;
    - Maximum flight distance from breeding wetland ranged between 0 – 1,325 metres; and,
    - Flight height ranged between 3 – 70 metres.
- Determined the number of non-breeding season Brolga flights in the vicinity of the proposed wind farm.

Based on the results of the Level 2 Brolga assessment:

- No Brolga flocking behaviour has been observed or recorded within the ROI.
    - Based on historical records and Ecology and Heritage Partners' ongoing investigations, the focus of this assessment and mitigation measures are on Brolga breeding habitat. The nearest identified flocking site is located at Lake Goldsmith, approximately 12 kilometres south-west of the wind farm development boundary.

The summary of the results of the Level 2 Assessment against the triggers for a Level 3 Brolga Assessment (DSE 2012) are detailed in Table 35.

Table 35. Triggers used to determine if a Level 3 Brolga Assessment is required (DSE 2012).

Trigger	Justification	Result
Qualitative risk assessment (AusWEA 2005) of project site design is greater than 'low'	A conservative estimate for the potential impact to Brolga indicate a residual risk greater than low from the operation of the proposed wind farm.	**Triggered**

5 LEVEL 3 ASSESSMENT

The Level 3 Assessment comprises four steps (DSE 2012), detailed below, to identify suitable mitigation measures for the proposed Brewster Wind Warm.

5.1 Step One: Avoid or mitigate all potential impacts to Brolga breeding and flocking home ranges with turbine-free buffer areas

The Interim Guidelines (DSE 2012) require that turbine free buffers be designed to avoid any significant impacts on Brolga within their breeding and non-breeding home ranges.

No flocking sites were found to occur within the ROI of the proposed Brewster Wind Farm boundary. Therefore, the home range analysis and associated turbine-free buffers apply to Brolga breeding sites only, whereby 'turbine siting would be used to exclude any significant reduction in breeding success caused by turbines' (DSE 2012).

5.1.1 Home Range Data Collection Method

As part of the Level 2 Assessment, Ecology and Heritage Partners confirmed the location of Brolga breeding sites during the 2023 breeding season using a combination of aerial (drone) surveys, landowner consultation, and targeted surveys, with extensive Brolga flight behaviour surveys undertaken, and time activity budgets determined for each breeding pair. The methodology for these investigations is detailed in Section 4.1 of this report

Data collection was undertaken via visual observation, with the location of Brolga recorded onto high resolution aerial photography on a GPS-enabled mobile device. Other parameters recorded are detailed in Table 19. Where precise data was unavailable, location data and movement distance has been rounded to the nearest five metres.

Where multiple Brolga were observed flying or foraging together and exhibiting the same behaviour (i.e. starting and landing within metres of each other), these movements were not considered to be independent of each other and have not been assessed as individual movements (i.e. where two Brolga were observed flying/foraging together, this has been assessed as one flight/movement).

All Brolga observations (flight and non-flight data) contributed towards the home range analysis, with the home range determined through interrogation of the 'maximum distance from wetland' value recorded during each observation.

5.1.2 Home Range Analysis

Brolgas spend a substantial amount of their time on the ground. Brolga feed while foraging on-ground and this activity occupies a large part of their daily activity cycle/time budget. Flights are relatively infrequent – particularly prior to the fledging of chicks, with flights during the breeding season undertaken primarily when moving between locations of concentrated terrestrial activity such as between a nesting site and a preferred foraging area, between foraging areas and during displays. Therefore, long periods of Brolga monitoring generally document few flights.

Between 6 September and 12 December 2023, 142 separate Brolga flight behaviour and time activity data points were collected across multiple sites, primarily the four breeding pairs located at the three known Brolga breeding sites, spanning over 67 hours of survey time. Of the 142 data points, 63 (44%) observed Brolga present at the breeding wetland. The frequency of Brolga observation decreased towards the end of the breeding season (i.e. December) with only three of the final 22 surveys (14%) positively observing the species.

A total of 11 independent flight events were recorded during the 2023 flight behaviour studies (Table 36; Figure 4). The majority of flights were captured to and from Site 139 (Figure 4). One flight was recorded from Site 141, with no flights captured from Site 106. A detailed analysis of flight data is provided in Section 4.2.3.

An additional 54 non-flight Brolga observations were made during the Level 2 assessments, with observations ranging from no movement (i.e. sitting on the nest), to foraging at various distances within, or from the perimeter of the breeding wetland.

A summary of Brolga behaviour observed during the 2023 breeding season from 65 total observations (11 flight observations, and 54 non-flight observations) is provided in Table 36.

Table 36. Summary of Brolga observational data and maximum distance from breeding wetland

Brolga Behaviour *	# Observations	Observation %	Cumulative %
Wholly within breeding wetland	14	21.5%	21.5%
Foraging <5 metre radius	9	13.8%	35.3%
Foraging 5-30 metre radius	3	4.6%	39.9%
Foraging 31-100 metre radius	15	23.1%	63%
Foraging 101>250 metre radius	13	20.0%	83%
Flight	11	17%	100%
Total	**65**		

Note: * Denotes the maximum distance from the perimeter of the breeding wetland.

The Level 2 assessments recorded a minimum distance of 0 metres from the breeding wetland, a maximum distance of 1,325 metres, with a mean distance of 182.57 metres (Appendix 7) (Table 37).

Analysis of home range data (using 'maximum distance from wetland') indicates that all Brolga movements observed during site specific investigations are contained within 523.20 metres for 90% of their movements, 1,132 metres for 92.5% of movements, and 1,268 metres for 95% of their movements whilst incubating, brooding and rearing chicks (Table 37).

Table 37. Home Range Analysis Summary

	Mean	50th Percentile	90th Percentile	92.5th Percentile	95th Percentile	97.5th Percentile	99th Percentile
Distance (metres) *	182.57	40.0	523.2	1,132.0	1,268.0	1306.0	1318.6

Note: * Denotes the maximum distance from the perimeter of the breeding wetland.

The presence of five flights, each over 1,180 metres (from a total number of 65 observations) from Site 139 to Site 261 or Site 243 (Table 26) for foraging purposes explains the substantial increase in the maximum distance from the breeding wetland beyond the 90th percentile as shown in Table 37.

Brolga breeding home ranges are known to vary depending on local habitat quality, resource availability and seasonal conditions. Given the high quality of habitat present within Site 106, 139 and 141 and the number of Brolga observations made at these sites, the data collected is considered to be representative of Brolga with a stable home range at these wetlands.

For breeding sites where breeding did not occur during the 2023 breeding season, or where insufficient data was collated, the home range as determined through data collected at the above sites is considered to provide a suitable, conservative estimate of the home range.

5.1.3 Turbine-free Buffer

Turbine-free buffers should be designed to remove any significant impact on Brolgas within their breeding and non-breeding home ranges (DSE 2012).

As a general recommendation, a 3.2 kilometre turbine-free buffer around Brolga breeding sites is considered adequate to meet the objectives of the Interim Guidelines (DSE 2012). However, the Interim Guidelines also allow for a proponent to propose reduced buffer areas (based on the collation of site-specific data) provided they can be shown to meet the objectives set for breeding and non-breeding habitats (i.e. to avoid any significant reduction in breeding success caused by turbines).

Further, the Interim Guidelines require individual wind farms to have, at a minimum, a *zero net impact* on the Victoria Brolga population (DSE 2012). As such, the recommendations outlined in the Interim Guidelines are:

1. Avoid and mitigate impacts to the extent that is practicable;
2. Assess and estimate residual risk via collision risk modelling and population viability analyses; and,
3. Establish a suitable compensation strategy to ensure a net-zero or positive outcome (completely offset unavoidable effects).

5.1.3.1 Home Range Assessment

It is noted that the majority of site-specific observations that contribute towards the home range distances at the upper end of the home range percentiles (as per Table 37) are flights to and from the breeding wetland at Site 139 and foraging habitat at Site 261 (Figure 4). Importantly, these flights from Site 139 to Site 261 do not go through, or towards the wind farm.

The closest breeding wetland to the wind farm (Site 121) occurs in the property immediately south of the wind farm development boundary. Although Brolga did not breed in Site 121 during the 2023 breeding season, evidence from landowner observations indicates that when present, the breeding pair from Site 121 have been known to forage at Site 298. Site 298, located within the wind farm development boundary is situated approximately 1.04 kilometres from Site 121 (Figure 2a).

A home-range that encompasses the area of Brolga activity between the breeding wetlands and known foraging habitat will avoid and mitigate impacts to Brolga whilst breeding.

The distance between known breeding wetlands (for those breeding wetlands within close proximity to the windfarm) and known foraging habitat are:

- Site 121: 1,040 kilometres to Site 298 for foraging;
- Site 139: 1,107 kilometres to Site 143 for foraging;
- Site 139: 1,160 kilometres to Site 261 for foraging.

Based on the data, a home range that encompasses all movements within the 90th percentile would result in a home range of 523.20 metres (Table 37) which does not provide a buffer around known foraging habitats.

As such, a home-range of 1,160 metres – incorporating all movements within the 93.3rd percentile of all Brolga observations has been applied. Specifically, the home range incorporates:

- The known movement of Brolga from Site 121 (closest to the wind farm boundary) to known foraging habitat located within Site 298. There is no evidence that additional foraging habitat is located beyond Site 298 within or immediately beyond the wind farm boundary to the north or west that Brolga breeding at Site 121 would be expected to visit for foraging purposes (Table 16);
- The known movement of Brolga from Site 139 to foraging habitats located at Site 261 and 243; and,
- A corridor between wetlands known to provide breeding and/or foraging habitat for the local Brolga population during the breeding season (i.e. to and from Sites 121 and 139, and 139 and 243 and 261).

5.1.3.2 Disturbance Setback

The Brolga Scientific Panel (Interim Guidelines; DSE 2012) recommend an additional disturbance setback of 300 metres around each breeding and non-breeding Brolga home range.

5.1.3.3 Turbine-free Buffer

For the Brewster Wind Farm Project, a turbine-free buffer of 1,460 metres will be implemented. This is based on a home range of 1,160 metres, and the addition of a 300 metre buffer to avoid disturbance effects as per the Interim Guidelines (DSE 2012) (Figure 5a; Figure 5b; Figure 6).

Importantly, the proposed turbine-free buffer is of a distance that incorporates the longest flight distance as per the 'maximum distance from wetland' flight data recorded during the Level 2 Brolga investigations (Table 26), and creates a turbine-free corridor between wetlands known to provide breeding and/or foraging habitat for the local Brolga population during the breeding season (Figure 5a; Figure 5b; Figure 6).

5.1.4 Wind Farm Design Considerations

The design of the current wind farm layout was driven by the following design objectives:

- Avoiding and mitigating potential impacts to Brolga breeding sites as much as practicable;
- Maximise setbacks to existing dwellings
- Minimising impacts to other known flora and fauna values;
- Avoid areas of cultural heritage sensitivity;

- Comply with minimum wind turbine separation distances; and,
- Comply with the requirements of participating landowners.

The design seeks to maximise setbacks to existing dwellings to minimise amenity impacts for nearby residents, in particular due to shadow flicker and noise emissions. While there is no exact distance at which wind farm noise and shadow flicker cease to have an impact on the amenity of nearby dwellings, distances of between 1,250 metres and 1,500 metres are generally sufficient to ensure that a wind farm safely complies with the relevant regulations. The siting of Turbine 1 (T1) has been revised 51 metres south from its previous location to adhere to this objective.

The design seeks to comply with minimum wind turbine separation distances to reduce the impact that downwind turbulence will have on the overall efficiency of the wind farm. While there is no exact distance at which wind turbines cease to interact with one another, distances in excess of ten rotor diameters are generally considered sufficient to ensure that downwind turbulence does not have a significant impact on the energy production of a wind farm. Importantly, in the case of the current wind farm a compromised target separation distance of six rotor diameters, or 1,032 metres, was adopted in order to assist with meeting the other stated design objectives.

The design seeks to avoid and mitigate potential impacts to Brolga breeding habitat and the known population of Brolga that is present within the locality. Dunn's Marsh (Site 139) and Site 121 are known sites that Brolga frequent for breeding purposes, and as such, the distance between turbine locations and those wetlands has been maximised, whilst having consideration to the above design constraints.

5.1.5 Proposed Turbine Layout

The current planning application for the proposed Brewster Wind Farm is based on a revised layout consisting of 6 wind turbine generators (Figure 5a). A previously proposed 7th turbine – located approximately 1.14 kilometres from the nearest breeding wetland (Site 121) has been removed to avoid and minimise potential impact to Brolga as determined by site-specific Brolga activity, and to enable the implementation of the turbine-free buffer as determined via the site-specific investigations.

A second turbine (T2) previously located 1,450 metres from Site 121 has been re-sited 11 metres to be located outside of the 1,460 metre turbine-free buffer (Figure 5a).

On review of the updated turbine layout and design response to the site conditions, in accordance with the objectives of the Interim Guidelines (DSE 2012), it is considered that the proposed project and design of turbine-free buffers will not result in a significant impact to brolga within their breeding and non-breeding habitats, as turbines have been sited to exclude any significant reduction on breeding success, and facilitate unimpeded access to foraging habitats located within proximity to breeding wetlands (Table 38).

Table 38. Summary of turbine-free buffers to mitigate impacts to Brolga breeding sites

Site*	Breeding record source	Distance to closest turbine	Buffer justification
42	Landowner	8.07 km NW	Turbine not obstructing movement corridors between breeding sites within 3.2 kilometres of each other. Nearest turbine situated further than the generic buffer distance of 3.2 km (DSE 2012).
47	VBA / Landowner	6.67 km NW	Turbine not obstructing movement corridors between breeding sites within 3.2 kilometres of each other. Nearest turbine situated further than the generic buffer distance of 3.2 km (DSE 2012).
61	VBA	5.54 km NW	Turbine not obstructing movement corridors between breeding sites within 3.2 kilometres of each other. Nearest turbine situated further than the generic buffer distance of 3.2 km (DSE 2012).
106	Aerial Survey	4.97 km N	Turbine not obstructing movement corridors between breeding sites within 3.2 kilometres of each other. Nearest turbine situated further than the generic buffer distance of 3.2 km (DSE 2012).
114	VBA	2.5 km W	Turbine not obstructing movement corridors between breeding sites within 3.2 kilometres of each other (i.e. between sites 114 and 121 or 139). Nearest turbine situated further than the 1,460 metre buffer from the breeding site.
121	Landowner	1.461 km S	Turbine not obstructing movement corridors between breeding sites within 3.2 kilometres of each other (i.e. between sites 121 and 114 or 285). Nearest turbine situated further than the 1,460 metre buffer from the breeding site.
139	VBA / Landowner	3.2 km SE	Turbine not obstructing movement corridors between breeding sites within 3.2 kilometres of each other (i.e. between sites 139 and 121, 114 or 285). Nearest turbine situated at the generic buffer distance of 3.2 km (DSE 2012).
141	Aerial Survey	9.57 km NE	Turbine not obstructing movement corridors between breeding sites within 3.2 kilometres of each other. Nearest turbine situated further than the generic buffer distance of 3.2 km (DSE 2012).
168	VBA	8.62 km S	Turbine not obstructing movement corridors between breeding sites within 3.2 kilometres of each other. Nearest turbine situated further than the generic buffer distance of 3.2 km (DSE 2012).
194	VBA	2.8 km E	Turbine not obstructing movement corridors between breeding sites within 3.2 kilometres of each other. Nearest turbine situated further than the 1,460 metres metre buffer from the breeding site.
196	VBA	4.4 km E	Turbine not obstructing movement corridors between breeding sites within 3.2 kilometres of each other. Nearest turbine situated further than the generic buffer distance of 3.2 km (DSE 2012).
212	Landowner	8.68 km SE	Turbine not obstructing movement corridors between breeding sites within 3.2 kilometres of each other. Nearest turbine situated further than the generic buffer distance of 3.2 km (DSE 2012).
222	VBA	4.97 km NE	Turbine not obstructing movement corridors between breeding sites within 3.2 kilometres of each other. Nearest turbine situated further than the generic buffer distance of 3.2 km (DSE 2012).
227	Landowner	9.06 km S	Turbine not obstructing movement corridors between breeding sites within 3.2 kilometres of each other. Nearest turbine situated further than the generic buffer distance of 3.2 km (DSE 2012).

Site*	Breeding record source	Distance to closest turbine	Buffer justification
285	Landowner / Targeted survey	2.36 km north-west	Turbine not obstructing movement corridors between breeding sites within 3.2 kilometres of each other (i.e. between sites 285 and 114, 121 or 139). Nearest turbine situated further than the 1,460 metre buffer from the breeding site.
297	Landowner	2.17 km SW	Turbine not obstructing movement corridors between breeding sites within 3.2 kilometres of each other (i.e. between sites 285 and 114, 121 or 139). Nearest turbine situated further than the 1,460 metre buffer from the breeding site.

5.2 Step Two: Site-specific Collision Risk Model (CRM)

The objective of collision risk modelling as detailed in the Interim Guidelines (DSE 2012) is to estimate the potential impacts of the turbine layout to the species, whereby *'The objective of CRM is to estimate the residual number of Brolga movements which have the potential to interact with wind turbines on the proposed site and from this estimate the annual collision risk'* (DSE 2012).

Ecology and Heritage Partners engaged Nature Advisory and Symbolix Pty Ltd to prepare the CRM for the Brewster Wind Farm, using the infrastructure layout of the Brewster Wind Farm as shown in Figure 5a, the range between the largest and smallest potential turbine specifications for the turbine models that may be used for the development (Table 39), the location and extent of all confirmed 16 breeding sites located within the ROI (Figure 2c), and information on the number of breeding pairs utilising each breeding wetland as determined through the Level 1 and Level 2 assessments (Table 32).

Table 39. Summary of maximum and minimum proposed turbine specifications informing the RSA

Turbine parameters	Model 1	Model 2
Model	Vestas V172	Vestas V172
Rotor diameter (m)	172	172
Hub Height (m)	150	166
Rotation period (s)	4.3 – 12.1 RPM	4.3 – 12.1 RPM
Maximum chord (m)	4.3	4.3
Number of Blades	3	3
Blade Height Maximum (m)	236	252
Blade Height Minimum (m)	64	80

The CRM (Appendix 5) also includes an assessment of collision risk associated with non-breeding season flights, as well as the newly proposed powerline to be constructed over Spring Hill Creek (See Figure 2d).

The detailed report supplied by Nature Advisory (2024), including the CRM as prepared by Symbolix (2024), is provided in Appendix 5, which includes a summary of the parameters input to inform the CRM. A summary of results are provided below.

5.2.1 *Summary of CRM Results*

5.2.1.1 Turbine Collision Risk

Under a 90% avoidance rate scenario an average of 0.0042 collisions were estimated per breeding season and 0.0056 per non-breeding season (Table 40) assuming a flat scenario and 5.3 breeding pairs per year (i.e. the most conservative model input assumptions). This is the highest impact predicted and would amount to 0.2 Brolga collisions over the life of the wind farm (30 years), equivalent to one collision every 150 years.

Under the 95% avoidance scenario, the average rate of collisions per year were estimated to be 0.0021 per breeding season, and 0.0028 per non-breeding season, equivalent to one Brolga collision every 300 years. However, as a conservative measure, the 90% avoidance rate is assumed to apply to the wind farm.

Table 40. Turbine Collision risk modelling for Brewster wind farm

Avoidance (%)	Scenario	Collisions/year (Breeding Season)	Collisions/year (Non-breeding Season	Expected collisions (30 years)	30 year 95% prediction interval
90	Flat	0.0042	0.0056	0.2	[0, 2]
92	Flat	0.0033	0.0044	0.2	[0, 1]
95	Flat	0.0021	0.0028	0.1	[0, 1]
90	Variable	0.0066	0.0022	0.2	[0, 2]
92	Variable	0.0053	0.0018	0.2	[0, 1]
95	Variable	0.0033	0.0011	0.1	[0, 1]

5.2.1.2 Power Line Collision Risk

Using an avoidance rate of 'zero', based on the assumption that Brolga cannot detect, and therefore avoid powerlines, the overall collision risk of the power line is expected to be a maximum of 0.0030 collisions per year (one every 333 years), using the flat scenario. Over the life of the wind farm this would result in 0.1 expected collisions of Brolga with the power line (Table 41).

Table 41. Power Line Collision risk modelling for Brewster wind farm

Avoidance (%)	Collisions/year (Breeding Season)	Collisions/year (Non-breeding Season	Expected collisions (30 years)	30 year 95% prediction interval
Flat	0.0002	0.0028	0.1	[0, 1]
Variable	0.0005	0.0004	0.0	[0, 1]

5.3 Step Three: Population Viability Analysis (PVA)

The Interim Guidelines (DSE 2012) requires a PVA be undertaken as step three of the Level 3 Assessment. The School of Biosciences at The University of Melbourne developed the PVA for the Brolga population of south-east Australia and was commissioned by Ecology and Heritage Partners to undertake this analysis.

The PVA is a widely recognised and utilised modelling technique employed to forecast the future trajectory of a plant or animal population. In this context, it aims to estimate the probability of a reduction in the Brolga population size to a point where the recovery of the population becomes difficult due to the population declining to a critically low level.

The University of Melbourne applied the Victorian Brolga PVA to the CRM results (Section 5.2). The detailed PVA report (University of Melbourne 2024) is provided as Appendix 6. A summary of results is provided below.

5.3.1 Summary of PVA Results

The results of the PVA for Brewster wind farm using the most conservative scenario predict a reduction in the expected minimum population (EMP) of the Brolga of no more than 0.2 birds over the 30-year period of the wind farm, compared to the baseline scenario (no additional turbines or powerlines constructed at the proposed Brewster Wind Farm) (Table 42; Appendix 6) (University of Melbourne 2024).

Table 42. Expected reduction in the minimum Brolga population size

Brolga population Size (scenario)	90% avoidance	92% avoidance	95% avoidance
625 (flat)	548.1 (0.2)	548.2 (0.1)	548.2 (0.1)
625 (variable)	548.2 (0.1)	548.2 (0.1)	548.3 (<0.1)
907 (flat)	796.6 (0.1)	796.6 (0.1)	796.7 (0.1)
907 (variable)	796.6 (0.1)	796.6 (0.1)	796.7 (<0.1)

It is noted that the most recent estimate of the Victorian south-west Brolga population is 836 birds (Table 2). This estimate is within the range of the population scenarios investigated within the PVA, being substantially closer to the highest previous population estimate (in 2013) of 907 than the conservative estimate of the current assumed population size of 625 Brolga. Therefore, the current estimated population size is within the range of the upper and lower scenarios estimated within the PVA, with the estimate of a reduction in the EMP of the Brolga of 0.2 birds over the 30-year period of the wind farm more likely to be an over-estimate than an under-estimate.

5.4 Step Four: Achieving Zero Net Impact

The Interim Guidelines (DSE 2012) require that any impact on the Victorian Brolga population proposed by the PVA (Section 5.3) must be 'fully offset'. For the proposed Brewster Wind Farm, 'fully offset' equivalates to an additional 0.2 juveniles being added to the breeding Brolga population over the 30-year lifespan of the wind farm.

RE Future Pty Ltd will develop a Brolga Compensation Plan that will outline a strategic approach to ensure the achievement of this objective.

5.4.1 Voluntary Brolga Compensation Plan

The compensation plan will establish an agreed framework for monitoring, evaluation and reporting (MER), which will be executed to ensure a surplus of successfully fledged young individuals capable of replacing any

Brolga population that may be impacted. The MER framework will be developed in consultation with DEECA to ensure success of the plan over the lifespan of the wind farm.

It is proposed that the location of any wetland proposed to be monitored, restored and/or managed will be agreed between RE Future Pty Ltd and DEECA as part of the post-approval requirements for the project.

5.5 Conclusion

Based on the findings of the Level 3 assessment undertaken for the Brewster Wind Farm as per the criteria detailed in the Interim Guidelines (DSE 2012):

- A total of 16 Brolga breeding sites are located within 10 kilometres of the windfarm (Figure 2c);
- A minimum turbine free buffer of 1,460 metres has been applied around each breeding site. Based on the development plan:
    - The closest breeding site (Site 121) to a turbine is located at a distance of 1.461 kilometres; and,
    - All other breeding sites are located at least 2.17 kilometres from the nearest turbine.
- The CRM predicts that the wind farm will result in an average of 0.0128 Brolga collisions per year under the most conservative scenario (including powerline collision risk);
- Using the most conservative scenario, the PVA predicts a reduction in the expected minimum population (EMP) of the Brolga of 0.2 birds over the 30-year period of the wind farm;
- Brewster Wind Farm Pty Ltd propose to develop a Voluntary Brolga Compensation Plan that will outline a strategic approach to ensure there will be 'zero net impact' to the Victorian Brolga population.

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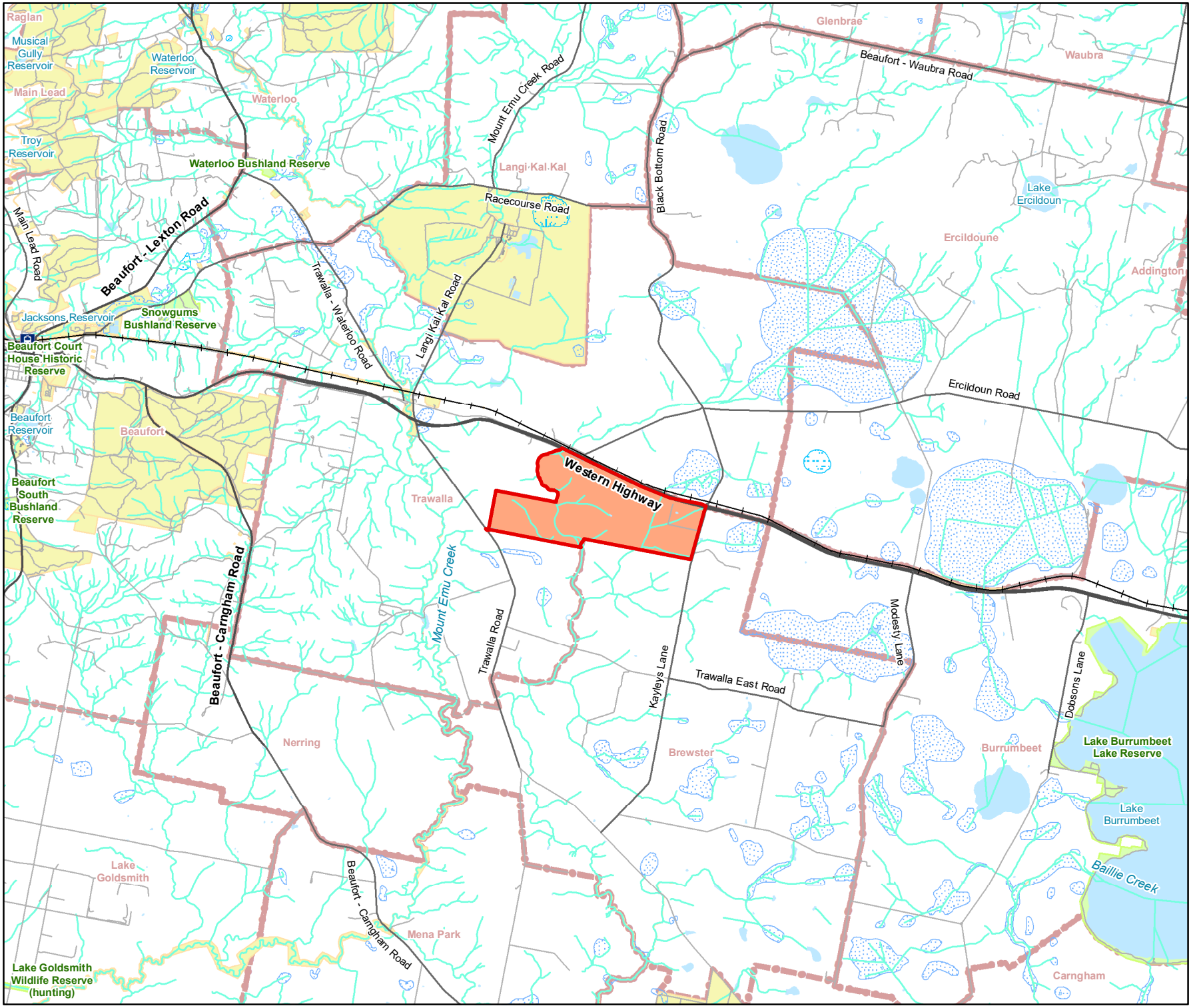
FIGURES



Legend

- Wind Farm Parcel Boundary
- Railway
- Major Road
- Collector Road
- Minor Road
- Proposed Road
- Minor Watercourse
- Permanent Waterbody
- Land Subject to Inundation
- Wetland/Swamp
- Parks and Reserves
- Crown Land
- Localities

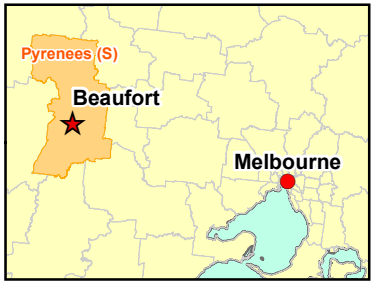


Figure 1

Location of the study area

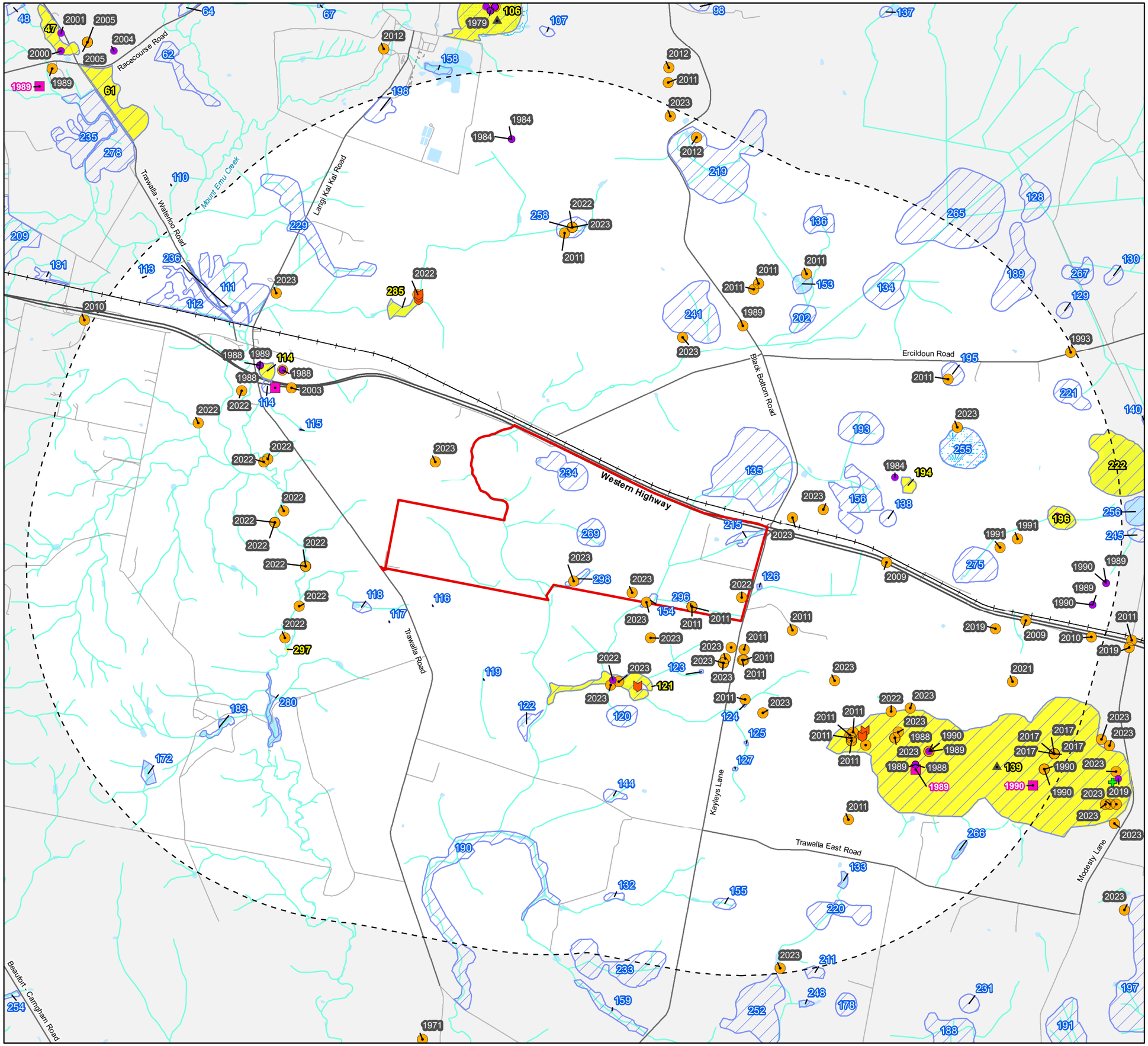
Brolga Impact Assessment for Brewster Wind Farm, Beaufort

0 1,000 2,000

Metres

Map Scale: 1:100,000 @ A4
Coordinate System: GDA 1994 MGA Zone 54

ecology & heritage partners



Legend

- Wind Farm Parcel Boundary
- Brolga records (VBA 2023)
- Brolga breeding records (VBA 2023)
- Brolga Records (Sheldons Flocking Database)
- Brolga records (Birdlife Australia)
- Water bodies
- Permanent Waterbody
- Wetland/Swamp
- Confirmed Brolga breeding locations

Landowner observations (February 2023)

- Brolga breeding record (confirmed)

Aerial/roaming surveys (September 2023)

- Brolga breeding record (confirmed)

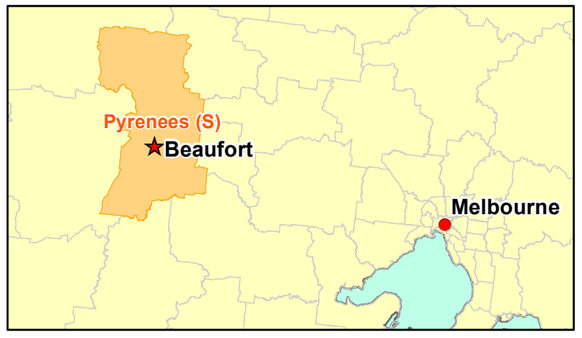


Figure 2a

Previously documented Brolga records within 4km of the study area

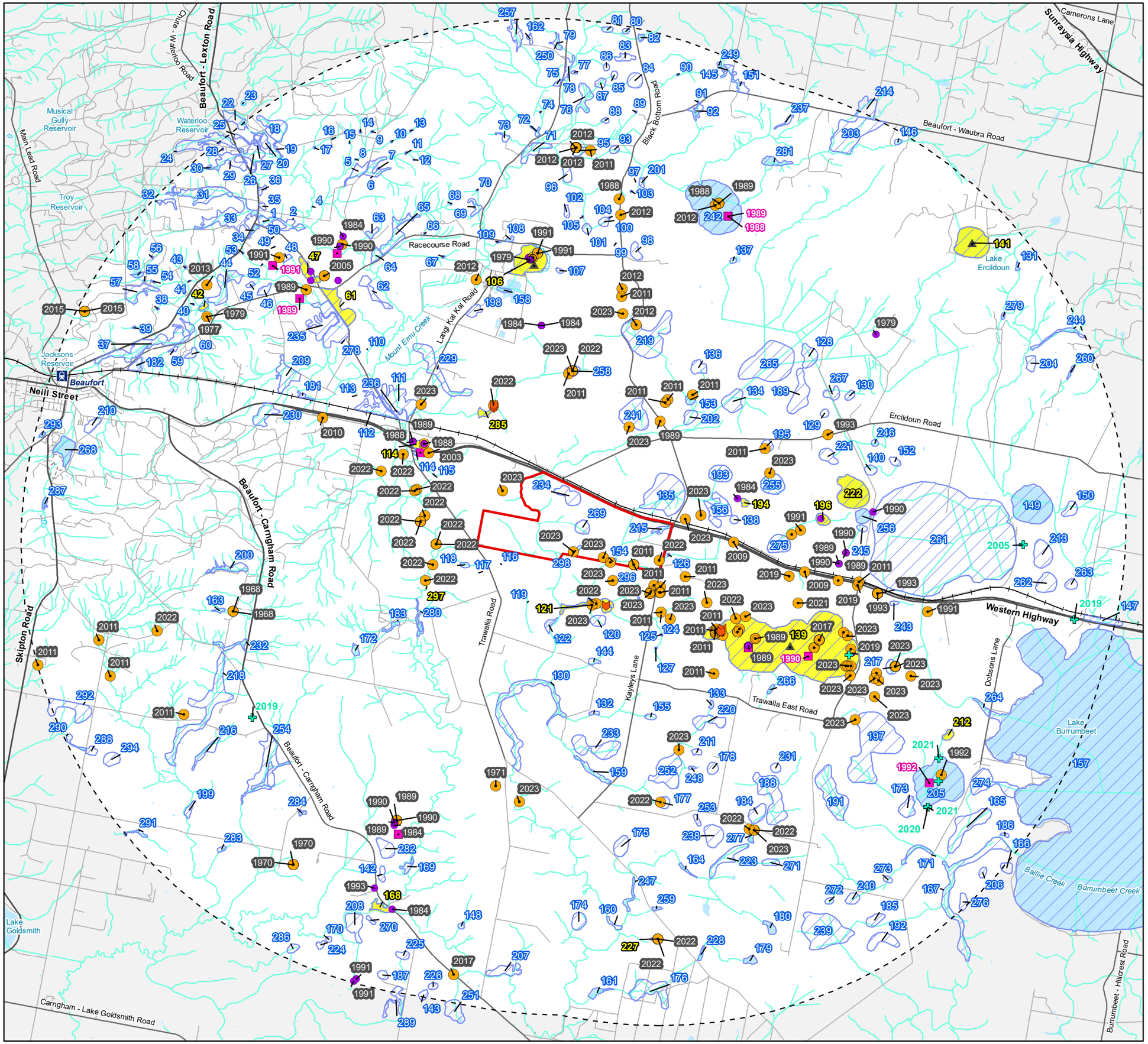
Brolga Impact Assessment for Brewster Wind Farm, Beaufort

0 1 2

Kilometres

Map Scale: 1:41,000 @ A3
Coordinate System: GDA 1994 MGA Zone 54

ecology & heritage partners



Legend

- Wind Farm Parcel Boundary
- Brolga records (VBA 2023)
- Brolga breeding records (VBA 2023)
- Brolga Records (Sheldons Flocking Database)
- Brolga records (Birdlife Australia)
- Water bodies
- Permanent Waterbody
- Wetland/Swamp
- Confirmed Brolga breeding locations

Landowner observations (February 2023)

- Brolga breeding record (confirmed)

Aerial/roaming surveys (September 2023)

- Brolga breeding record (confirmed)

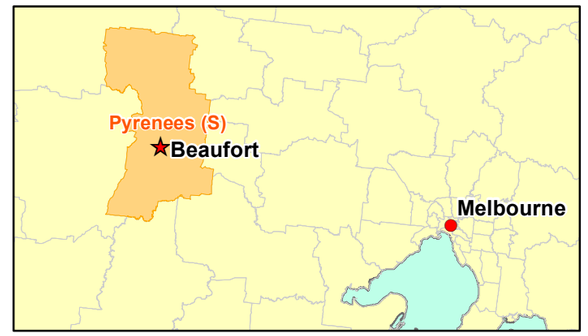


Figure 2b

Previously documented Brolga records within 10km of the study area

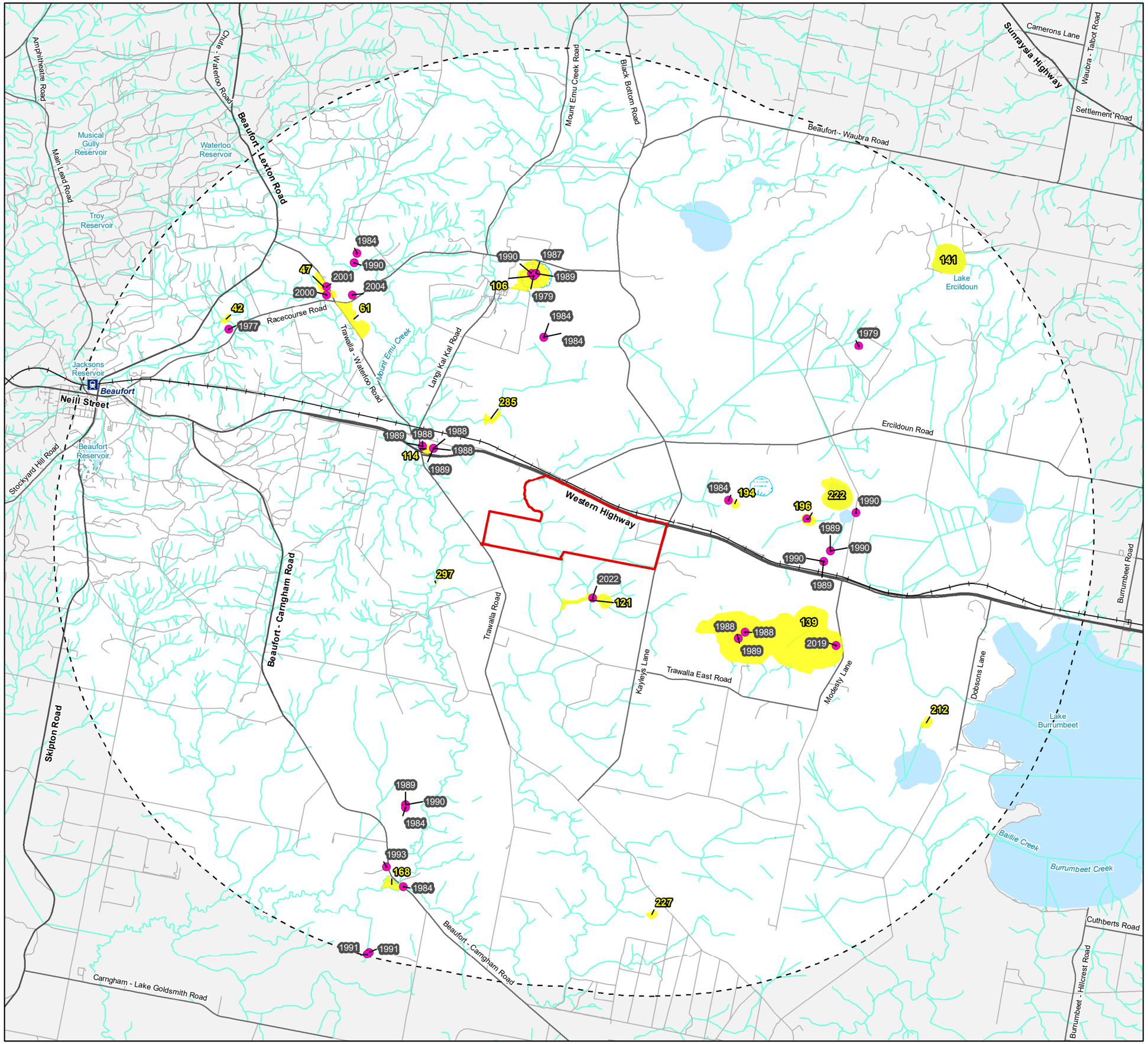
Brolga Impact Assessment for Brewster Wind Farm, Beaufort

0 2 4

Kilometres

Map Scale: 1:80,000 @ A3
Coordinate System: GDA 1994 MGA Zone 54

ecology & heritage partners



Legend

- Wind Farm Parcel Boundary
- Confirmed Brolga breeding locations
- Brolga breeding records (VBA 2023)

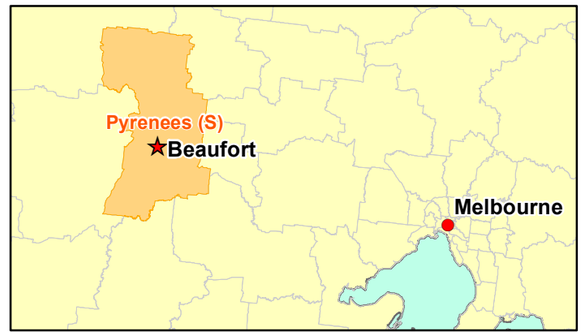


Figure 2c

Confirmed Brolga breeding locations and previously documented Brolga breeding records

Brolga Impact Assessment for Brewster Wind Farm, Beaufort

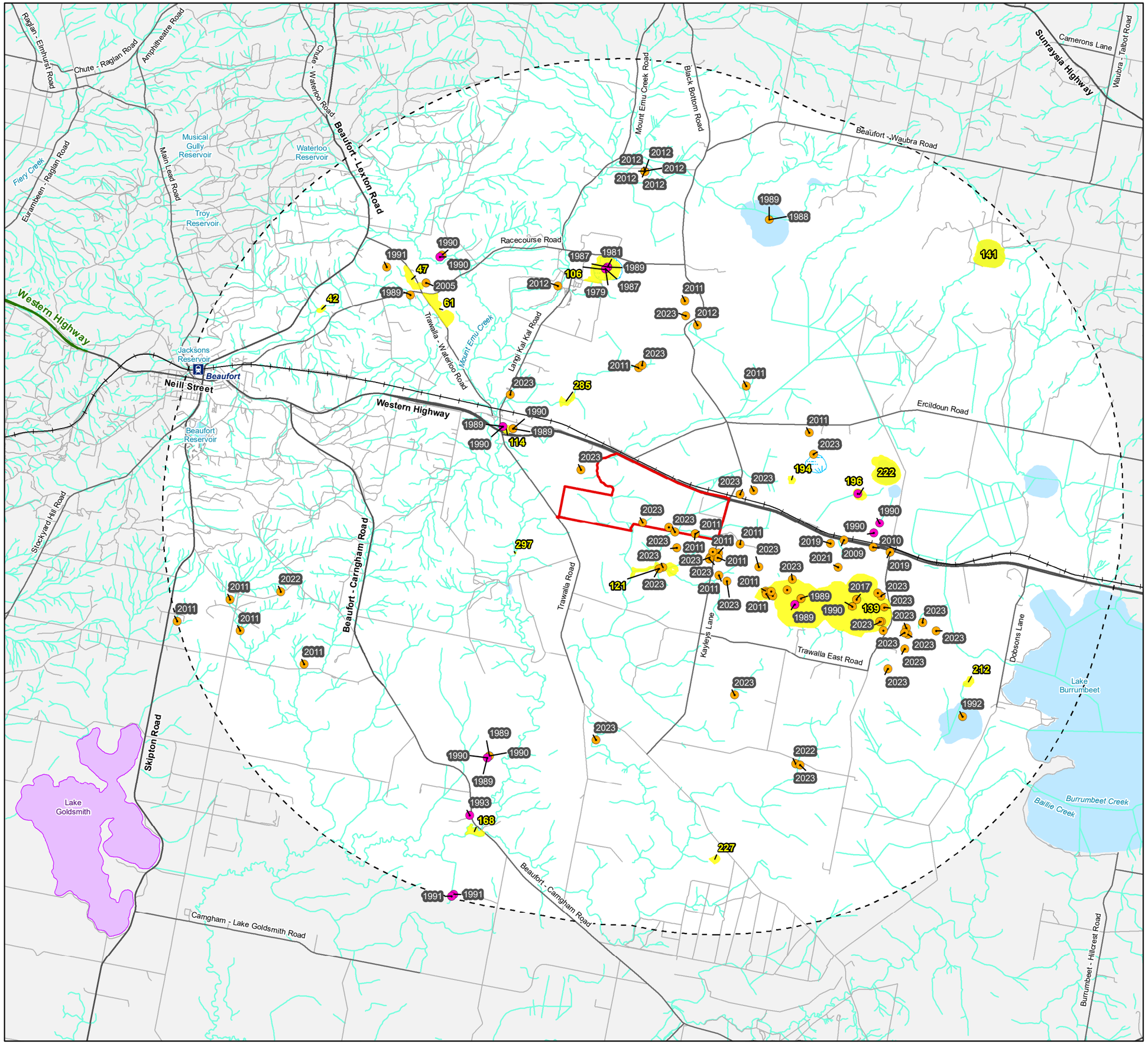
N

0 2 4

Kilometres

Map Scale: 1:85,000 @ A3
Coordinate System: GDA 1994 MGA Zone 54

ecology & heritage partners



Legend

- Wind Farm Parcel Boundary
- 10km buffer
- Lake Goldsmith
- Confirmed Brolga breeding locations

Records between January and June (VBA 2023)

- Brolga records
- Brolga breeding records

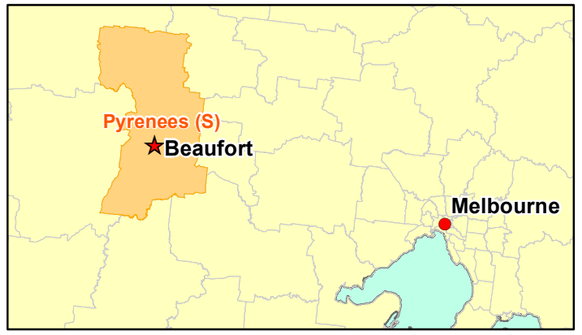


Figure 2d

Confirmed Brolga breeding locations and previously documented Brolga records (January to June)

Brolga Impact Assessment for Brewster Wind Farm, Beaufort

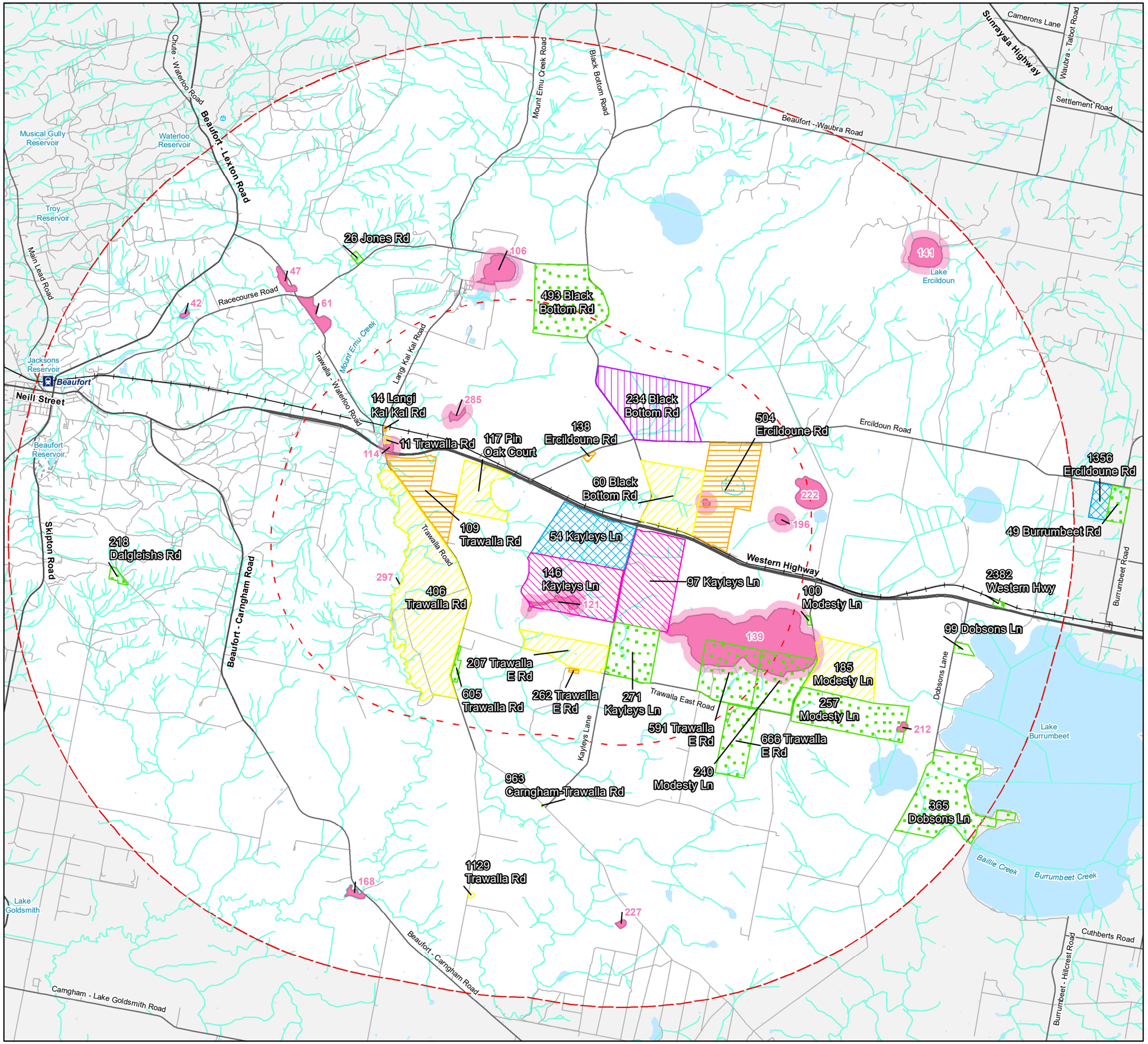
N

0 2 4

Kilometres

Map Scale: 1:92,000 @ A3
Coordinate System: GDA 1994 MGA Zone 54

ecology & heritage partners



Legend

- 4km buffer
- 10km buffer
- Current Wetland with confirmed Brolga breeding

Landowner Consultation

- 2020
- 2020 and 2022
- 2020, 2022 and 2023
- 2022
- 2022 and 2023
- 2023

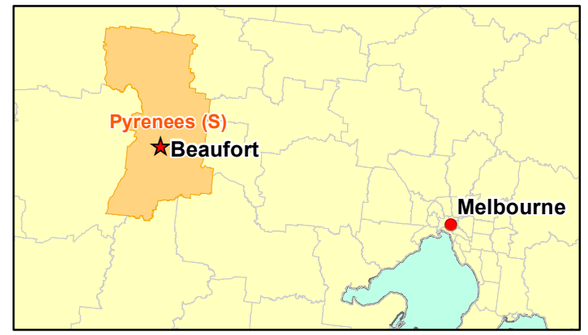


Figure 3

Comfirmed Brolga breeding records and landowner consultation

Brolga Impact Assessment for Brewster Wind Farm, Beaufort

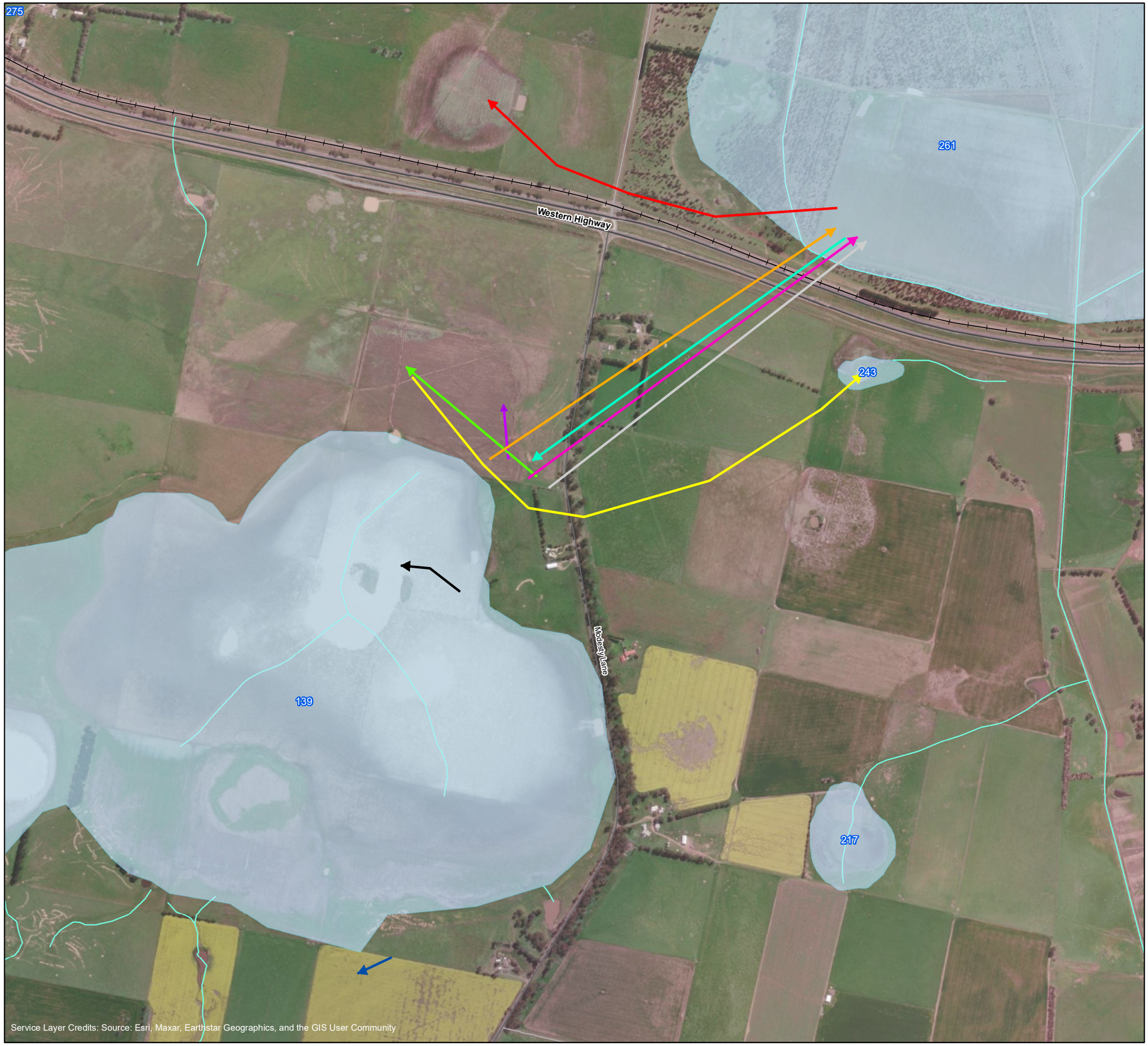
N

0 2 4

Kilometres

Map Scale: 1:83,000 @ A3
Coordinate System: GDA 1994 MGA Zone 54

ecology & heritage partners



Legend

- Wind Farm Parcel Boundary (overview map)
- Water bodies

Flight event

- Flight 1 (1 Brolga)
- Flight 2 (1 Brolga)
- Flight 3 (3 Brolga)
- Flight 4 (3 Brolga)
- Flight 5 (1 Brolga)
- Flight 6 (1 Brolga)
- Flight 7 (2 Brolga)
- Flight 8 (2 Brolga)
- Flight 9 (4 Brolga)
- Flight 10 (2 Brolga)

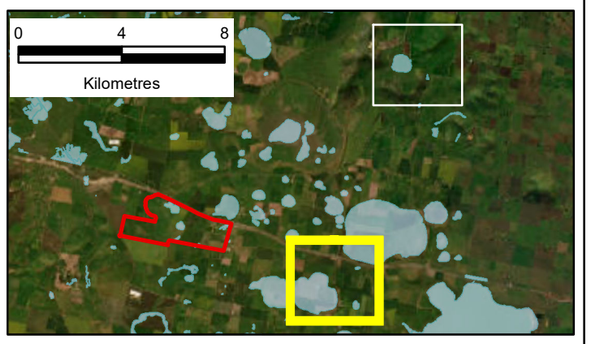


Figure 4a

Brolga flight events

Brolga Impact Assessment for Brewster Wind Farm, Beaufort

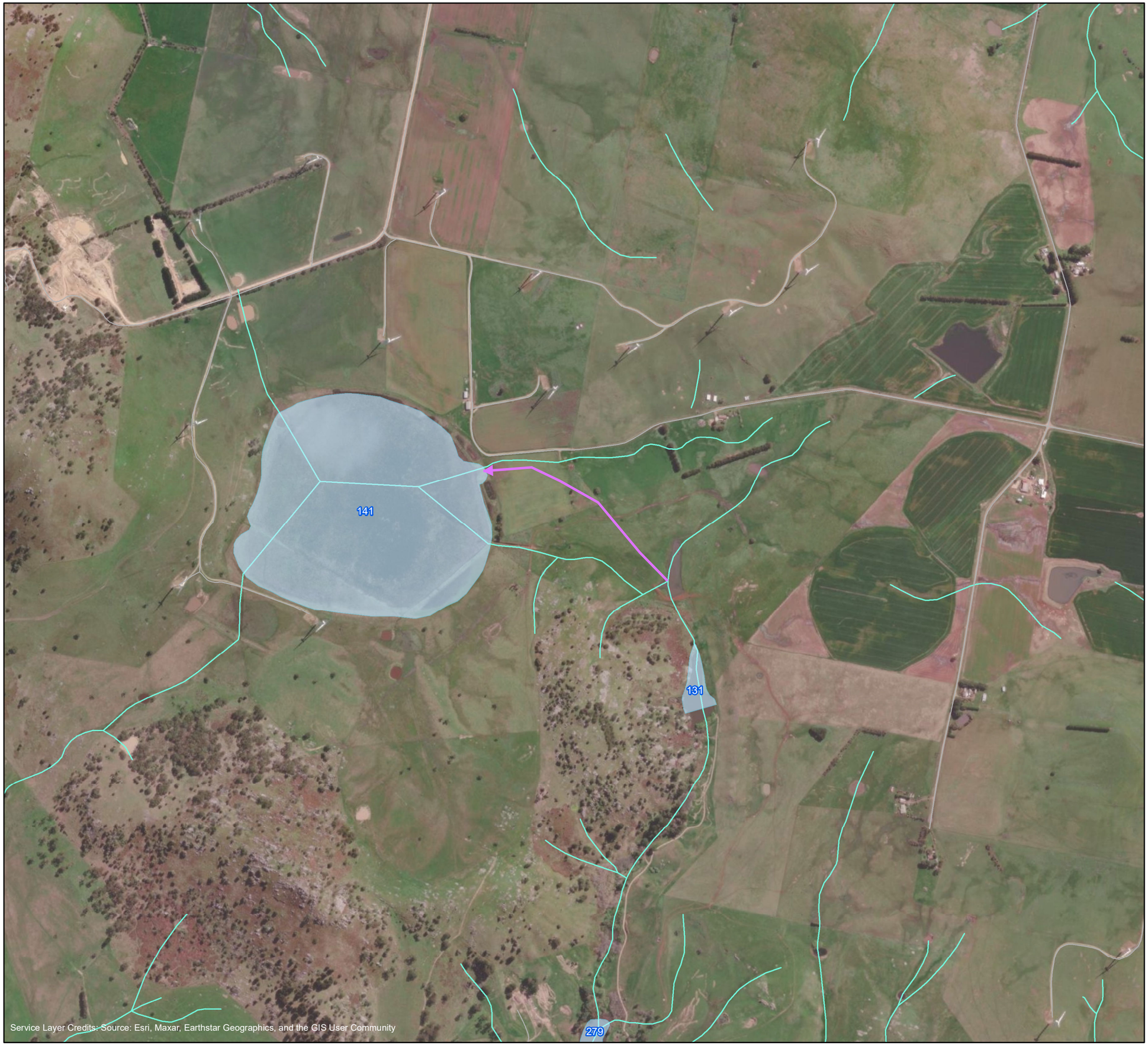
0 250 500

Metres

Map Scale: 1:11,000 @ A3

Coordinate System: GDA 1994 MGA Zone 54

ecology & heritage partners



Legend

- Wind Farm Parcel Boundary (overview map)
- Water bodies

Flight event

- Flight 11 (2 Brolga)

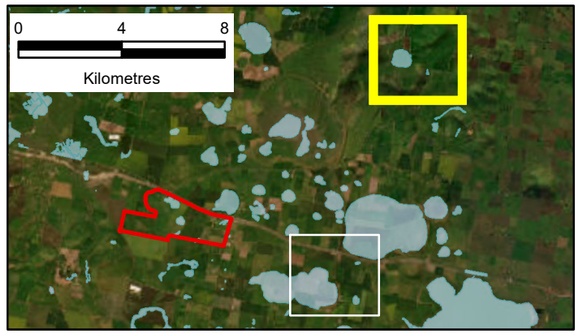


Figure 4b

Brolga flight events

Brolga Impact Assessment for Brewster Wind Farm, Beaufort

0 250 500

Metres

Map Scale: 1:11,000 @ A3

Coordinate System: GDA 1994 MGA Zone 54

ecology & heritage partners

Legend

- Wind Farm Parcel Boundary
- Water bodies
- Permanent Waterbody
- Wetland/Swamp
- Confirmed Brolga breeding locations
- Turbine location including foundation area

Turbine-free buffers

- Home Range (1,160 metres)
- Additional buffer distance (DSE 2012) (300 metres)

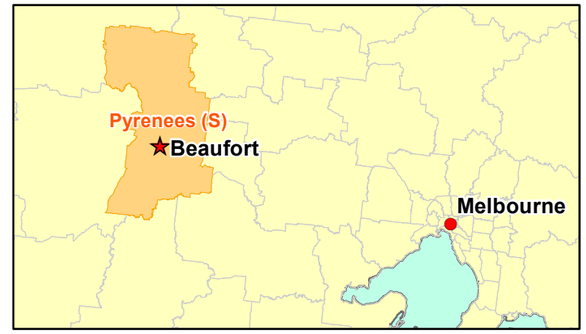


Figure 5a

Brolga breeding wetlands within 4km of the study area and turbine-free buffers

Brolga Impact Assessment for Brewster Wind Farm, Beaufort

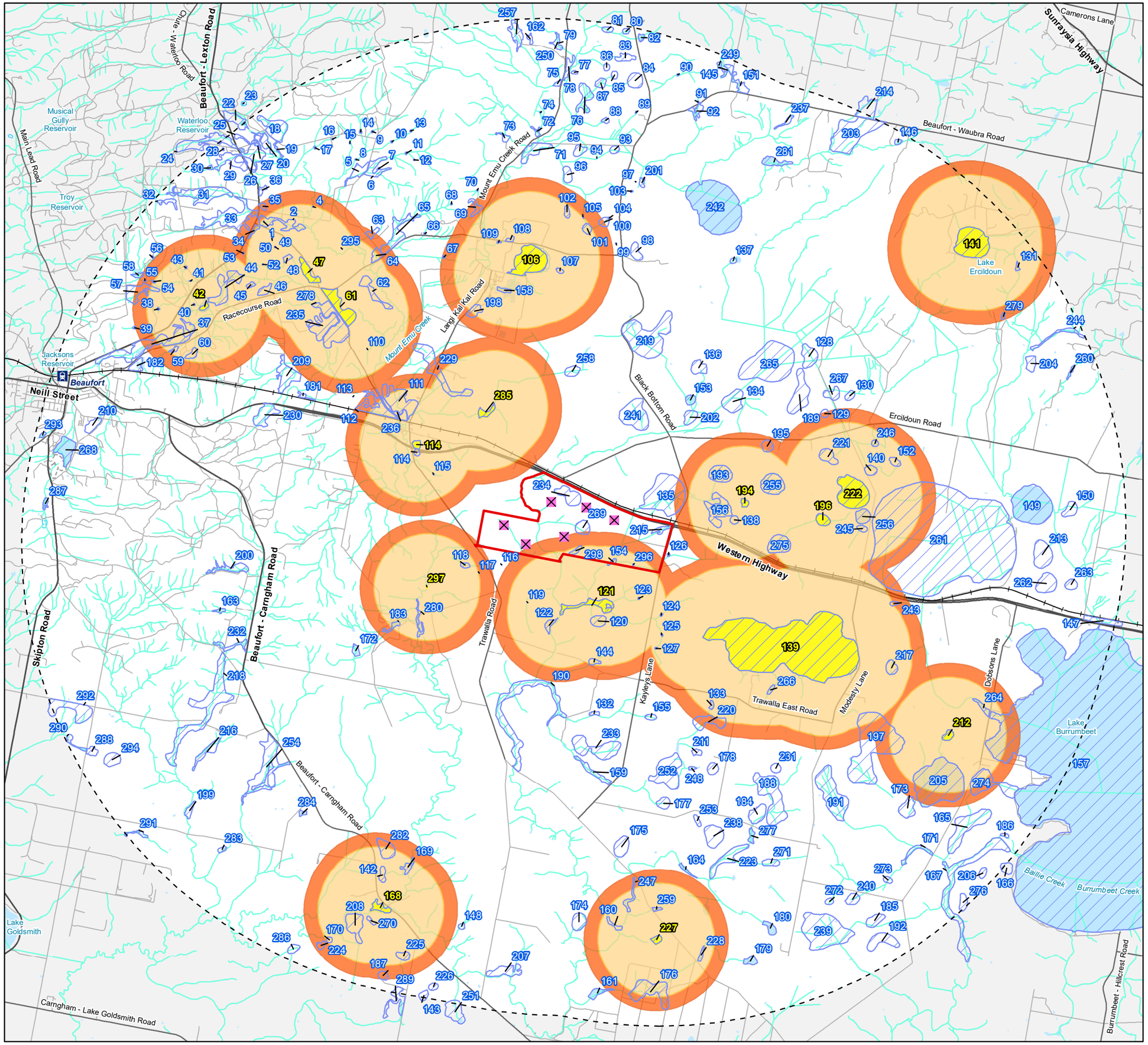
N

0 1 2

Kilometres

Map Scale: 1:41,000 @ A3
Coordinate System: GDA 1994 MGA Zone 54

ecology & heritage partners



Legend

- Wind Farm Parcel Boundary
- Water bodies
- Permanent Waterbody
- Wetland/Swamp
- Confirmed Brolga breeding locations
- Turbine location including foundation area

Turbine-free buffers

- Home Range (1,160 metres)
- Additional buffer distance (DSE 2012) (300 metres)

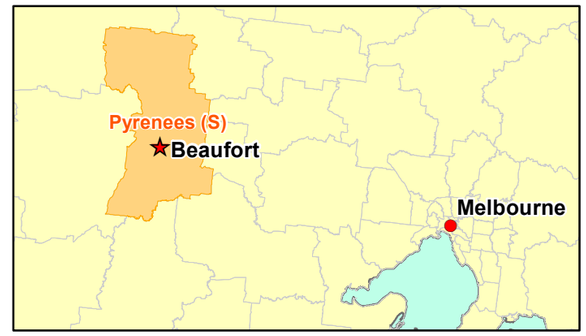


Figure 5b

Brolga breeding wetlands within 10km of the study area and turbine-free buffers

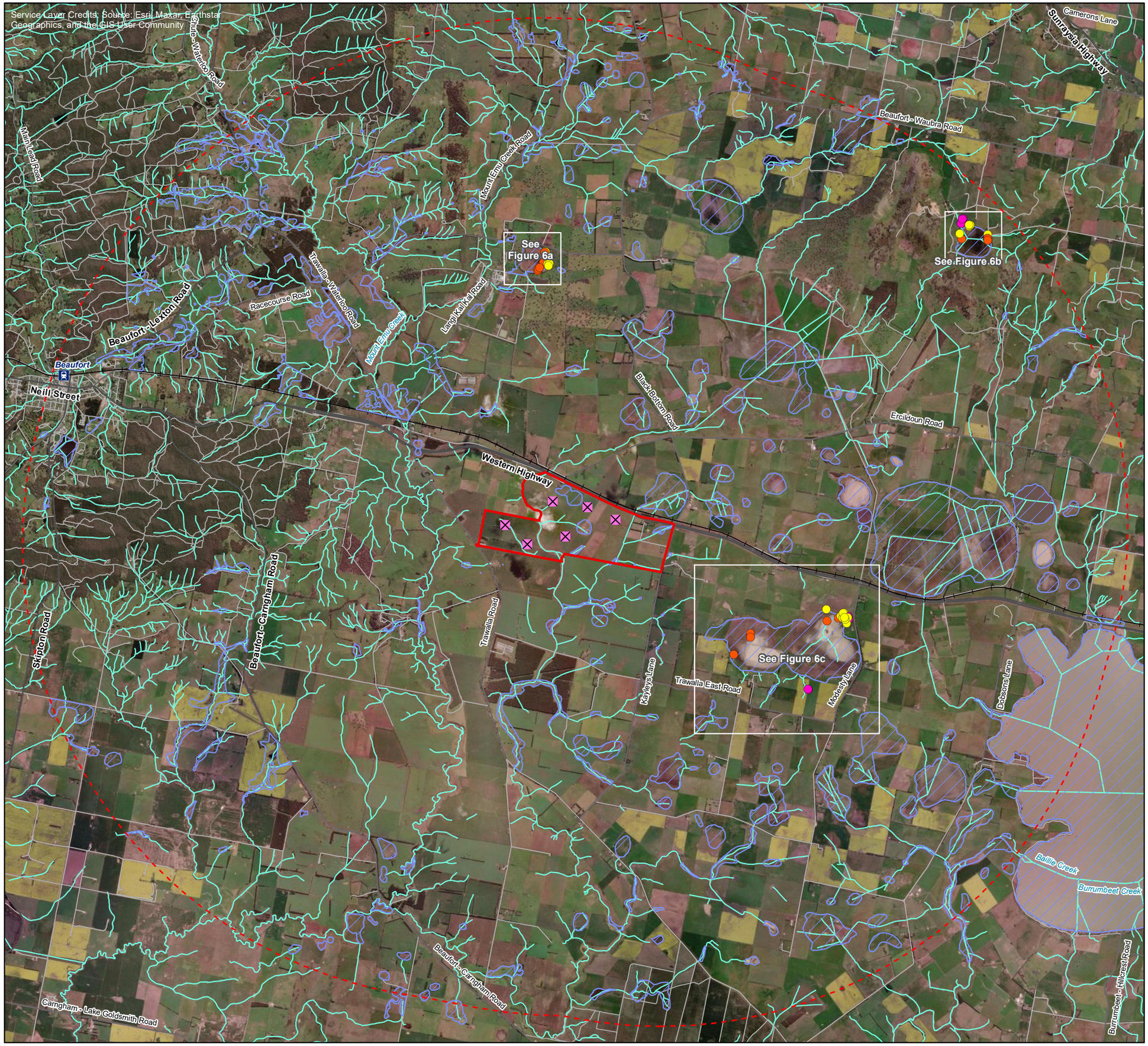
Brolga Impact Assessment for Brewster Wind Farm, Beaufort

0 2 4

Kilometres

Map Scale: 1:80,000 @ A3
Coordinate System: GDA 1994 MGA Zone 54

ecology & heritage partners



Legend

- Wind Farm Parcel Boundary
- 10km buffer
- Turbine location including foundation area
- Water bodies

Maximum distance to breeding wetland:

- 0 metres
- 1-100 metres
- 101-250 metres

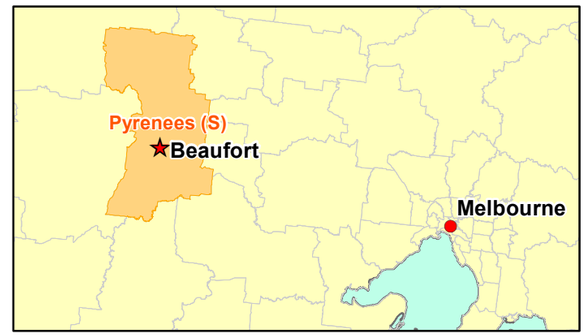


Figure 6 Overview

Brolga observations within 10km of the study area

Brolga Impact Assessment for Brewster Wind Farm, Beaufort

0 2,000 4,000

Metres

Map Scale: 1:80,000 @ A3
Coordinate System: GDA 1994 MGA Zone 54

ecology & heritage partners

Legend

- Water bodies

Maximum distance to breeding wetland:

- 0 metres
- 1-100 metres

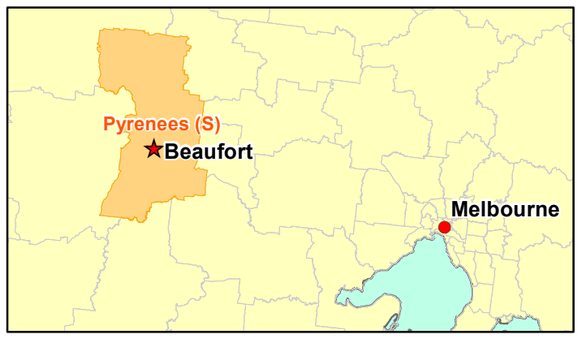


Figure 6a

Brolga observations within 10km of the study area

Brolga Impact Assessment for Brewster Wind Farm, Beaufort

N

0 100 200

Metres

Map Scale: 1:4,000 @ A3
Coordinate System: GDA 1994 MGA Zone 54

ecology & heritage partners

Service Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Legend

Water bodies

Maximum distance to breeding wetland:

- 0 metres
- 1-100 metres
- 101-250 metres

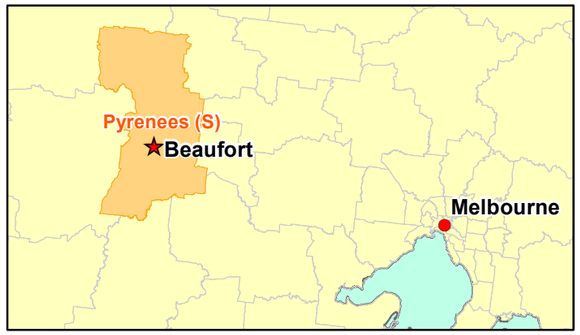


Figure 6b

Brolga observations within 10km of the study area

Brolga Impact Assessment for Brewster Wind Farm, Beaufort

N

0 100 200

Metres

Map Scale: 1:4,000 @ A3
Coordinate System: GDA 1994 MGA Zone 54

ecology & heritage partners

Legend

- Water bodies

Maximum distance to breeding wetland:

- 0 metres
- 1-100 metres
- 101-250 metres

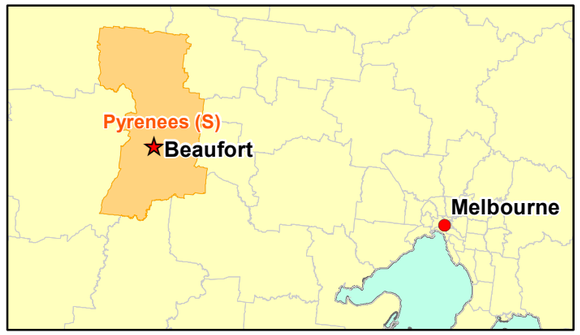


Figure 6c

Brolga observations within 10km of the study area

Brolga Impact Assessment for Brewster Wind Farm, Beaufort

N

0 330 660

Metres

Map Scale: 1:13,000 @ A3
Coordinate System: GDA 1994 MGA Zone 54

ecology & heritage partners

APPENDIX 1 – LANDOWNER COVER LETTER

Dear Landowner,

Re: Landowner Consultation Questionnaire for the proposed Brewster Wind Farm

Ecology and Heritage Partners have been engaged by Brewster Wind Farm Pty Ltd to undertake a series of ecological investigations to inform the planning application for the proposed Brewster Wind Farm.

As part of our ecological investigations, we are seeking to better understand the potential presence and location of ecological habitats and other values located within the broader locality, and invite you to participate in the process via our questionnaire.

Alternatively, we are happy to hear from you directly, and welcome an email or a phone call via the details below.

Information provided by you will remain confidential, and will ultimately assist in informing the design and operation of the proposed wind farm, and also ensure any mitigation measures implemented are appropriate, and directly respond to relevant ecological considerations.

Kind regards,

Mr. Shannon LeBel

Associate Ecologist - Ecology and Heritage Partners Pty Ltd

Phone: 0407 459 263

Email: slebel@ehpartners.com.au

07 September 2023

Dear Landowner,

Re: Ecological Investigation for the Proposed Brewster Wind Farm

As part of the ecological assessment for the proposed Brewster Wind Farm we are undertaking another season of ecological surveys to supplement the information we have gathered in previous years about the environmental values of the project site and its surrounds.

There are two important features of these surveys that we would like to draw your attention to. Firstly, as part of the assessment of the potential risk posed to brolga, over the coming weeks we will be conducting drone surveys of all wetlands within 10 km of the site of the proposed wind farm. Please note that these surveys are being carried out by licenced drone operators and conducted in accordance with the requirements of the *Civil Aviation Safety Regulations 1998*. According to the *Civil Aviation Safety Regulations 1998*, licenced drone operators are authorised to fly their aircraft over private property provided they do not encroach within 30 m of a person or in such a way that poses a risk to other persons or their property. Please also note that any information collected as part of these surveys will be used for no other purpose than to inform the ecological assessment of the proposed Brewster Wind Farm, and that it is being collected in accordance with the provisions of the Commonwealth Privacy Act 1988. However, if you would like us to refrain from conducting aerial surveys of wetlands located on your property, or if you would like to seek further information about them, please contact us by phone or email.

The second feature of the ecological surveys that we would like to draw your attention to is the landowner questionnaire we are distributing with this letter. As part of our ongoing ecological investigations, we are seeking to better understand the potential presence and location of ecological values located on your property and the broader locality and would like to invite you to participate in the process via our questionnaire. Information provided by you will remain confidential and will ultimately assist in informing the design and operation of the proposed wind farm, and will also ensure that any mitigation measures implemented are appropriate to the environmental values that are present in the local area. Please post your response back to us by **Friday 22 September 2023** to ensure your feedback is received in time to be reviewed and considered as part of the proposed operation and mitigation phases of the project. To be sure, we will continue to accept questionnaire responses mailed after that date, however we cannot guarantee that we will be able to incorporate any relevant findings into our assessment if they are posted after this date. Alternatively, we are happy to hear from you directly, and welcome an email or a phone call via the details below. Also, you are welcome to send through a photo or scan of your questionnaire responses to the details below rather than sending through by mail, if preferred.

If you have any further questions or queries about the information contained in this letter, please feel free to contact us via the details below. If you would like more information about the proposed Brewster Wind Farm in general, please see the project website at www.brewsterwindfarm.com.au or contact RE Future by telephone on 0498 810 177 or by email at info@brewsterwindfarm.com.au.

Thank you for your consideration of our questionnaire, and we look forward to receiving your feedback.

Kind regards,

David Heaton
Consultant Zoologist - Ecology and Heritage Partners Pty Ltd
Phone: 0438 178 934
Email: dheaton@ehpartners.com.au

APPENDIX 2 – LANDOWNER QUESTIONNAIRE

ecology & heritage partners

www.ehpartners.com.au

Landowner Consultation Questionnaire

The aim of the following survey is to enable Ecology and Heritage Partners to develop a broad-scale understanding of the environment within the general locality of the proposed Brewster Wind Farm through acquiring information on land use, management practices, and the potential presence of Brolga within the broader vicinity. This information will assist by informing the design and operation of the proposed Brewster Wind Farm.

Date: _____

Landholder's Name: _____

Property Address: _____

_____

What is the primary use for your land? (i.e. cropping, grazing, mixed alternating)

_____

What broad land types exist on your land? (i.e. arable, stony, aquatic, mixed, cleared)

_____

How long have you owned or farmed the land?

_____

Are you aware of feral animals on your land? (i.e. rabbits and warrens, foxes, deer etc.)

_____

Do you manage feral animals of your land? (Please circle one)

Yes / No

Do you have any wetlands/waterbodies on your property? If so, how many/what type
(i.e. farm dams, creek/stream, ephemeral wetlands)

_____

_____

Have there been any changes to waterbodies/wetlands within your property? When and why did these changes occur? (i.e. drainage for cropping purposes)

_____

_____

Are you aware of any threatened or protected fauna species on your land? If so, please indicate the number of individuals, approximate date / year, and frequency of sightings when applicable.
(i.e. 2-3 Wedge-tailed eagles observed up to 5 times during spring/summer)

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

If you have observed Brolga on your property, please indicate where (using Lat/Longs from Google Maps), when and how many Brolga you have seen on your property.

Number of Brolga observed together	Date of observation	Frequency of observation	Lat/Longs from Google Maps

Have you observed Brolga breeding on your property (i.e. nest sites)? If so, where (using lat/longs from Google Maps), when, and how often (i.e. breeding 3 years out of 10)?

_____

_____

_____

Have you observed any Brolga 'flocking' on your property? If so, where (using lat/longs from Google Maps), when, and how many Brolga?

_____

_____

_____

Any other comments related to Brolga, birds or bats?

_____

_____

_____

Are you happy for Ecology and Heritage Partners to call you to discuss your answers to the questionnaire in more detail? If so, please provide you best contact number and time to call:

Contact name:_____

Contact number:_____

Best time to call:_____

Please forward your completed responses
plus any relevant photography or Google Maps screenshots to:

230 Latrobe Terrace, Geelong West VIC 3218

or email reply to *dheaton@ehpartners.com.au*
Please also use the below contact information for any queries relating to this questionnaire

David Heaton | Consultant Zoologist / Bushfire Consultant

Ecology and Heritage Partners (Geelong)
T 1300 839 325 | M 0438 178 934 | dheaton@ehpartners.com.au | www.ehpartners.com.au

Ecology and Heritage Partners acknowledge the Traditional Owners of the country we live and work on, and we pay our respect to Elders past, present and emerging.

APPENDIX 3 – COMMUNITY INFORMATION SESSION INVITE

PO Box 739
Geelong, Victoria
Australia 3220

www.refuture.com.au

26 September 2023

Dear Resident,

PROPOSED BREWSTER WIND FARM – COMMUNITY INFORMATION SESSIONS

I am writing to invite you to join us at one of our upcoming community information sessions about the proposed Brewster Wind Farm. These information sessions will provide attendees with an opportunity to find out more about the proposed wind farm, as well as ask questions directly of RE Future representatives.

Venue: Beeripmo Community Centre, Beaufort.

Dates and times:

- Tuesday, 10 October from 3:00 pm – 4:30 pm;
- Tuesday, 10 October from 5:30 pm – 7:00 pm;
- Sunday, 15 October from 11:00 am – 12:30 pm; and
- Sunday, 15 October from 3:00 pm – 4:30 pm.

Please note that if there is sufficient interest we will happily organize further sessions in the coming months.

Session format: Our plan is to start with a short presentation about the wind farm followed by a question-and-answer session afterwards. However, we will be flexible if those present wish to discuss a particular topic at length or wish to skip straight to questions and answers. Please note that the maximum group size will be ten participants per timeslot—this small group setting will allow for a more detailed discussion and personalised attention to your questions.

Registration: Please register by emailing your name, phone number and preferred timeslot to info@brewsterwindfarm.com.au, or alternatively by calling us on 0498 810 177. So that we can tailor the session to your specific interests, please submit any questions or topics you'd like us to cover when you register. Light refreshments will be provided so please also let us know if you have any dietary requirements.

Further information: If you would like further information about these information sessions, or would like to make a general enquiry about the Brewster Wind Farm, please contact us by telephone on 0498 810 177 or by email at info@brewsterwindfarm.com.au.

We thank you in advance for your time and look forward to responding to your questions at one of our upcoming information sessions.

Yours sincerely,

Severin Staalesen
Project Director

APPENDIX 4 – SYMBOLIX LETTER

symbolix

making your data work harder

To: Shannon LeBel
Ecology and Heritage Partners
Via email

Ref #: BLABREW20240307
Date: 07 March 2024
CC: Inka Kulik - Nature Advisory

Re: Brewster Wind Farm Brolga Collision Risk Model

This letter outlines the approach to modelling Collision Risk to Brolga (*Antigone rubicunda*) at the proposed Brewster Wind Farm site. Brewster Wind Farm, in central western Victoria, includes up to 6 proposed wind turbines with associated power line infrastructure. Brolga are known to breed in the region, and therefore modelling is required to determine the risk that wind farm infrastructure poses to the species that might use nearby wetlands.

A preliminary Collision Risk Model (CRM) was prepared by Symbolix in April 2023 (Symbolix 2023), which presented the collision risk based on:

- Six wetlands identified as potential Brolga breeding sites by Ecology and Heritage Partners (EHP) during the Level 1 and Level 2 Brolga Assessment (i.e. desktop assessment, targeted Brolga surveys and habitat assessments).
- At least three, but as many as five pairs of Brolga utilising these wetlands for breeding, with breeding frequency estimated from the Level 1 Assessment Landowner Liaison.
- Brolga flight behaviour (i.e. models of flight height given distance and direction) provided by Nature Advisory (NA).
- Collision risk modelling using the Nature Advisory-Band (NA-BAND) model, with both flat and variable utilisation across the site.

We understand that EHP have conducted additional Brolga surveys at the proposed site following the initial Brolga CRM. The additional surveys included observations of breeding Brolga at new wetlands and incidental observations on site between the breeding and flocking seasons. As such, updates to the model inputs and ecological scenarios are required.

We outline here the proposed approach for updating the model to account for non-breeding/non-flocking incidental observations and for incorporation of EHPs flight behaviour data collected on site.

Brolga Collision Risk Modelling

Collision risk modelling (CRM) requires a step-wise risk model (Reason 1997), where the total risk is the probabilistic combination of the risk of each step in the process. The process can be summarised by the equation:

$$N_{\text{collision}} = F \times P(I|F) \times P(C|I) \times (1 - \text{AR}) \tag{1}$$

where:

- $N_{\text{collision}}$ is the estimated number of flights ending in collision over some time period
- F is the estimated activity rate of flights in the area over some time period
- $P(I|F)$ is the probability of a flight interacting with a infrastructure, given a flight in the study region
- $P(C|I)$ is the probability of collision, given an interaction occurs
- AR is the avoidance rate

The probability of collision given interaction (the fourth dot point above) is generated using the exact model published in Band, Madders, and Whitfield (2007) and Band (2012). The probability of interaction component in NA-BAND uses spatial statistics to estimate the probability of interaction for each turbine, allowing flights to interact with any number of turbines.

For Brolga, we use a modified approach which assumes that flights are centred on wetlands during the breeding season and can radiate from there in any direction.

The **probability of interaction** $P(I|F)$ during the breeding season is therefore given by:

$$P(I|F) = P(\text{wetland occupied}) \times P(\text{direction}) \times P(\text{distance}) \times P(\text{height}|\text{distance}) \tag{2}$$

where:

- $P(\text{wetland occupied})$ is the probability that a given wetland will be occupied in a given year.
- $P(\text{direction})$ is the proportion of flights which travel in the right direction to interact with windfarm infrastructure. This is a geometric calculation of the ratio between the angle subtended by the infrastructure and the 360 degree circle around the wetland (assuming that Brolga might fly in any direction).
- $P(\text{distance})$ is the probability that a flight will travel far enough to reach the infrastructure from any wetland.
- $P(\text{height}|\text{distance})$ is the probability that the flight will be at a height in which they can collide with the infrastructure, given that it travelled the requisite distance.

CRM inputs

Probability of interaction

To build a CRM based on the above equation, we need the following inputs to calculate the probability of a flight interacting with the wind farm infrastructure. This is done seperately for the breeding and non-breeding season.

Breeding season site utilisation

The first term in the model, the probability that a given wetland will be occupied in a given year (P(wetland occupied)) is derived from the Level 1 and Level 2 Brolga Assessment (i.e. desktop assessment, targeted Brolga surveys and habitat assessments). The assessments use breeding records to identify the number and location of wetlands being used by Brolga during the breeding season, and landowner liaison to estimate the breeding frequency within each of these wetlands. This produces an estimate of the number of flights available to interact with the wind farm infrastructure in the breeding season.

EHP originally identified six wetlands where breeding was occurring, with differing frequencies across wetlands. Following further surveys, the CRM will be updated to include 16 breeding wetlands. The additional wetlands will alter the number of flights and the probability of interaction with the wind farm infrastructure. This will be updated for both the flat utilisation scenario (a breeding pair is equally likely to utilise any of the 16 wetlands) and the variable breeding scenario (each wetland has a separate probability of usage).

The annual number of breeding season flights available to interact with the wind farm infrastructure is calculated using the number of breeding pairs, the estimated number of flights each make per day, the breeding season length and the probability that the flight will reach the wind farm infrastructure at a risk height (flight behaviour modelling described below).

Non-breeding site utilisation

Based on the updated assessment, we understand that EHP have evidence of non-breeding activity on site for which the collision risk was not assessed in the original model. Based on EHPs field and desktop assessment, EHP have estimated the number of non-breeding flights per day and the duration of the non-breeding season Brolga are likely to be active on site.

The annual number of non-breeding seasons flights available to interact with the wind farm infrastructure is calculated using the total non-breeding population size utilising the site, the number of flights per day in the non-breeding season, the length of the non-breeding season on site, the number of flocks per year and the probability that the flight will reach the wind farm infrastructure at a risk height.

Flight behaviour (direction, distance and height of flight)

Data collected on flight behaviour (i.e. the direction, distance and height of each flight observed) is used to calculate the probability of a flight reaching the wind farm infrastructure and the probability of the flight being at rotor or power line height. The preliminary CRM utilised flight data provided by NA from several sites through south-west Victoria (Brett Lane & Associates 2018). The distribution of flight height at a given distance is taken from combined breeding and flocking season data (obtained by NA) from sites in south-west Victoria (Brett Lane & Associates 2018). These data include the distance and height for a total of 667 flights collected.

Breeding and flocking season was not a significant factor in the relationship between flight height and distance so the data sets were combined to increase the size of the dataset. As such, these data are suitable for use for estimating the probability of interaction during the breeding and non-breeding season.

During the most recent surveys, EHP have recorded flight behaviour data for 11 flights at the proposed Brewster Wind Farm site.

Prior to updating the CRM, we will compare the flight behaviour collected at Brewster with the NA data. If they are comparable (i.e. there is no significant differences between the height and distance distributions), these data can be combined. If there are significant differences, we would recommend using the NA data alone. Although there may be site-specific differences in flight behaviour, too few flights have been recorded at Brewster alone to produce a robust model.

Probability of collision

From the above, we can calculate $P(I|F)$ at any point in the landscape (which we can assume is flat or model it as variable across the site). The probability of interaction at any point in the landscape is the sum of $P(I|F)$ over all wetlands. For Brewster Wind Farm, this approach was applied to estimate the probability of interaction with turbines and with the associated power lines and has been applied to assess collision risk for Moorabool Wind Farm, Dundonnell Wind Farm, and Golden Plains Wind Farm (Victoria).

The probability of collision given an interaction and the annual estimate of collision will be estimated separately for each of the breeding and non-breeding season flights using the NA-BAND model. The probability of collision after interaction is a geometric calculation using Band, Madders, and Whitfield (2007) and Band (2012).

An important note is that the NA-BAND model has no assumption about the likelihood that an individual bird would be replaced in the local area if it is struck. The model estimates the number of flights that are at risk of collision under the assumption that any breeding resident bird is immediately replaced. Therefore, our estimate of flight collisions is likely to be higher than the actual individual collision rate.

References

Band. 2012. "Using a Collision Risk Model to Assess Bird Collision Risks for Offshore Wind Farms." SOSS report, The Crown Estate. http://www.bto.org/sites/default/files/u28/downloads/Projects/Final_Report_SOSS02_Band1ModelGuidance.pdf.

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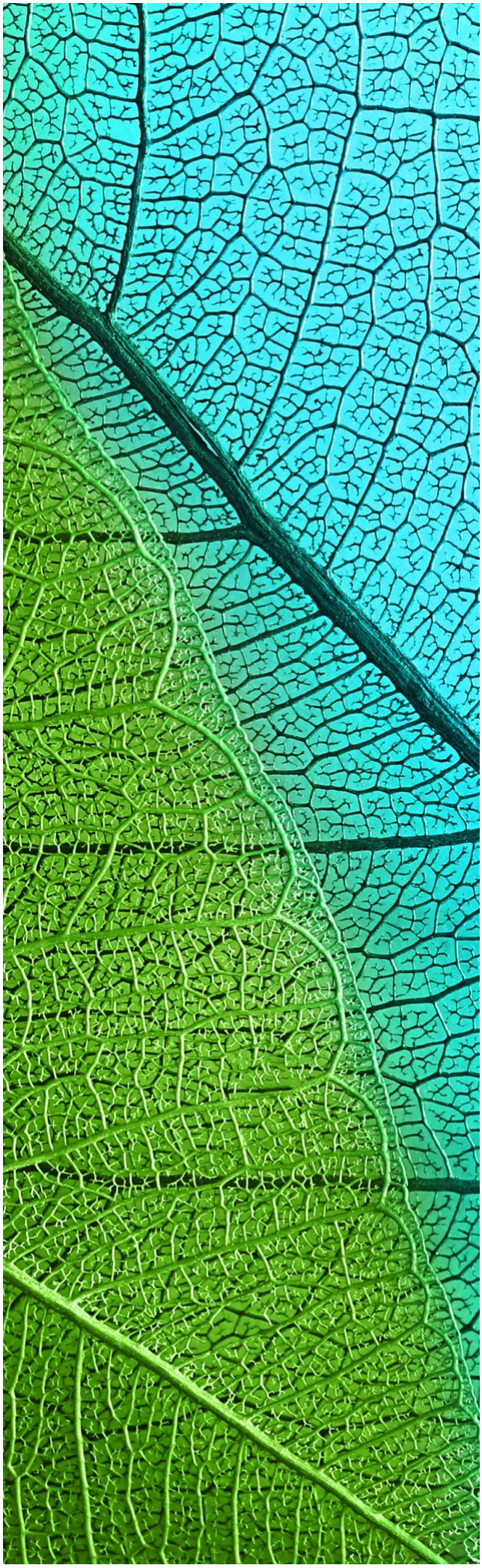
APPENDIX 5 – COLLISION RISK MODEL



Brewster Wind Farm

Brolga
Collision Risk Model

Prepared for
Ecology and Heritage Partners

June 2024
Report No. 22334.1 (1.2)

Nature Advisory
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Appendices

1. Introduction

Nature Advisory Pty Ltd (NA) has been asked by Ecology and Heritage Partners (EHP) to undertake a Collision Risk Model (CRM) of impacts on the Brolga (*Antigone rubicunda*) from the proposed Brewster Wind Farm in south-western Victoria using the Nature Advisory CRM. All Brolga field surveys and literature review have been undertaken by and provided by EHP.

The Victorian Interim Brolga Guidelines (DSE 2012) indicate that the objective of collision risk modelling is: "to estimate the residual number of Brolga movements which have the potential to interact with wind turbines on the proposed site and from this estimate the annual collision risk."

A description of how the Nature Advisory turbine bird collision risk model works and of how it derives the estimated collision rate is described in detail in the Appendix to this report by Symbolix Pty Ltd, which developed and maintains the NA CRM. An overview of how the model works and its results provided in this report.

The NA CRM used two components, described below:

- An estimate of the rate of movement of Brolga within the site based on the predicted activity levels of Brolga around all breeding and roosting sites within 10km kilometres of the wind farm converted to a probability distribution of Brolga activity across the wind farm site (see Appendix for more detail).
- An estimate of the interaction of Brolga estimated to fly over the site with turbines using the collision risk model developed for Scottish Natural Heritage (Band et al. 2007; Band 2012) for a range of potential avoidance rates.

The combination of the spatial probability of occurrence and number of flights across the site, together with a rate of turbine interaction (for a range of avoidance rates) enables the collision risk associated with different wind turbine layouts to be compared. The collision risk is equivalent to number of flights at risk of collision and assumes lost birds will be immediately replaced. In this respect, it is a conservative model, more likely to over-estimate than under-estimate collision risk.

This report summarises the model inputs and the results of the CRM from the Appendix. No further interpretation is provided but the results can be used for the next step in the level three assessment of the Victorian Interim Brolga Guidelines, namely the Population Viability Assessment.

2. Model Inputs

Details of the turbines to be used were provided by the proponent and factored into the application of the model.

The **turbine specifications** are summarised below. Two turbine models are used.

- A total of 6 turbines
- Model: Vestas V 172
- Rotor diameter: 172 metres
- Hub height: 150/166 metres
- Rotation period: 4.3 to 12.1 rpm
- Maximum chord: 4.3 metres
- Pitch (degrees): -5° – 95° (averaged at 6)
- Number of blades: 3
- Maximum blade height: 236/252 metres
- Minimum blade height: 64/80 metres

It is assumed that all turbines are operating 24 hours per day, 365 days per year, including all daylight hours when Brolgas are active. This assumption makes the model additionally conservative for a precautionary approach.

Key inputs in relation to Brolga movements from and back to breeding wetlands are described in the Appendix and these have informed the turbine and powerline collision risk modelling.

Notably, the modelling has factored in the movements at RSA height of Brolga around breeding sites, as well as a residual level of movement during the non-breeding or flocking season.

The **breeding season** scenario has been developed based on observations of flights from and back to 31 breeding sites by Nature Advisory (formerly Brett Lane & Associates) in the last 16 years. The scenario involved the following assumptions.

- A total of 16 potential breeding wetlands have been identified during level one and Level two Brolga assessments undertaken by Ecology and Heritage Partners (see Figure 1).
- 3.5 to 5.3 pairs of Brolga are assumed to use these breeding wetlands with a maximum of 10.6 individuals remaining on site during the on-breeding season
- Two scenarios were explored:
    - Flat utilisation across the site (equal chance of any of the 16 wetlands being used for breeding)
    - Variable utilisation based on level 1 assessment results, with only site 139 used as a non-breeding roost
- Each member of the breeding pair makes a flight into the country around the breeding site once per day (a total therefore of two outward and two inward flights per day), in accordance with the distance and height distributions documented in the Appendix.
- A proportion of the flights are at a height and distance where turbine interaction is possible, being from 64 metres above the ground.

- An average breeding event of 130 days for each pair comprising 30 days of incubation and 100 days of chick rearing until fledging (Marchant & Higgins 1993).

The final assumption is conservative. The duration of occupation of a breeding site (and therefore the number of assumed flights by that pair from the breeding site) has been estimated by Nature Advisory (unpubl. records) as averaging 50 days as most breeding attempts fail due to predation of eggs or chicks by foxes, or the rapid drying of the breeding wetland.

One wetland (Site 139) within the 10km radius of investigation was also identified as a **non-breeding** roost site, where individuals may remain during the non-breeding or 'flocking' season. Additionally, some birds migrate yearly to known flocking sites and the number of these migratory flights across the wind farm were estimated (see below).

The following **Brolga bird parameters** have been used for the collision risk model:

- Length: 1.65 metres
- Wingspan: 2 metres
- Flight speed: 16.7 metres/second
- Behaviour: Flapping
- Breeding season length: 130 days
- Breeding pairs (minimum): 3.5
- Breeding pairs (maximum): 5.3
- Brolga per breeding pair: 2.1
- Flights per day (breeding/non-breeding season): 2
- Non-breeding season length (days): 182
- Brolga on site during the non-breeding season: 10.6
- Intersecting migration flights (p/year): 1.6

Three **avoidance rates** were modelled: 90%, 92% and 95% for the turbines and no avoidance rate for the power line collision assuming that Brolga cannot see these and are thus not avoiding them. Determining an appropriate wind turbine avoidance rate for the Brolga is challenging given the lack of past interactions between Brolga and wind turbines frequently enough for data gathering.

3. Results of Collision Risk Modelling

3.1. Turbine Collision Risk

Under the 90% avoidance rate scenario an average of 0.0042 collisions were estimated per breeding season and 0.0056 per non-breeding season(Table 1) assuming a flat scenario and 5.3 breeding pairs per year (i.e. the most conservative model input assumptions). This is the highest impact predicted and would amount to 0.2 Brolga collisions over the life of the wind farm (30 years), equivalent to one collision every 150 years. For the reasons explained earlier, this is more likely an over-estimate than an under-estimate.

Table 1: Turbine collision risk modelling results

Avoidance	Scenario	Collisions/ breeding season	Collisions/ non-breeding season	Expected collisions (30 years)
90%	flat	0.0042	0.0056	0.2
92%	flat	0.0033	0.0044	0.2
95%	flat	0.0021	0.0028	0.1
90%	variable	0.0066	0.0022	0.2
92%	variable	0.0053	0.0018	0.2
95%	variable	0.0033	0.0011	0.1

3.2. Power Line Collision Risk

The overall collision risk of the power line is expected to be a maximum of 0.0030 collisions per year (one every 333 years), using the flat scenario. Over the life of the wind farm this would result in 0.1 collisions of Brolga with the power line (Table 2).

Table 2: Power line collision risk modelling results

Scenario	Collisions/ breeding season	Collisions/ non-breeding season	Expected collisions (30 years)
flat	0.0002	0.0028	0.1
variable	0.0005	0.0004	0.0

4. References

Band, W, Madders, M, and Whitfield, DP. 2007. Developing field and analytical methods to assess avian collision risk at wind farms. In: de Lucas, M., Janss, G.F.E. & Ferrer, M. (eds.) Birds and Wind Farms: Risk Assessment and Mitigation, pp. 259-275. Quercus Books: Madrid.

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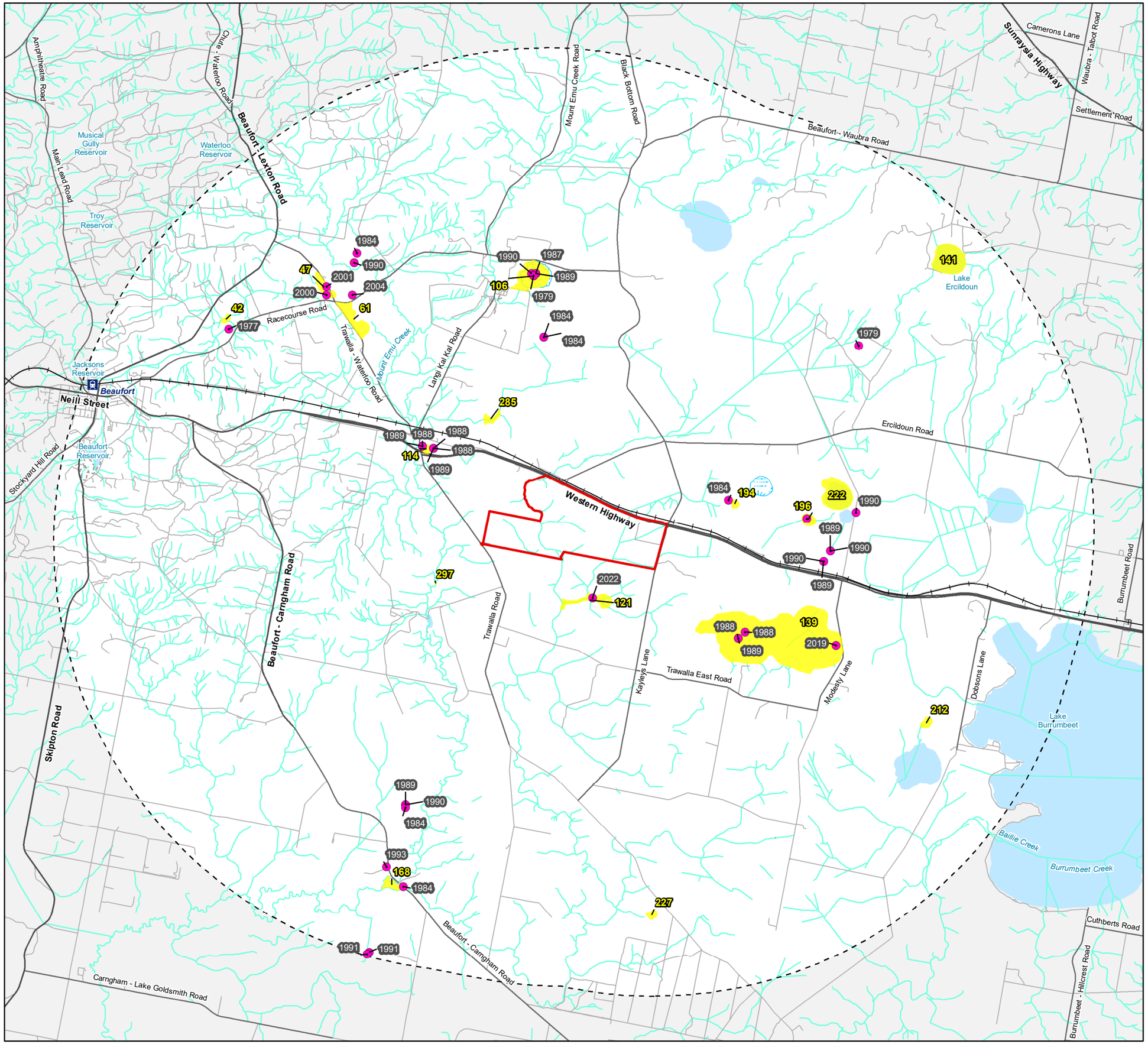

Figure 1

Confirmed Brolga breeding locations and previously documented Brolga breeding records

Brolga Impact Assessment for Brewster Wind Farm, Beaufort

0 2 4

Kilometres

Map Scale: 1:85,000 @ A3
Coordinate System: GDA 1994 MGA Zone 54

ecology & heritage partners

Appendix 1: Brewster Wind Farm Collision Risk Modelling (Symbolix 2023)

Brewster Wind Farm Collision Risk Modelling

Ver. 2.9

Submitted to Nature Advisory

symbolix

making your data work harder

Data and model used under licence from Nature Advisory.

Nature Advisory
Trusted ecology experts

Website: www.symbolix.com.au

Twitter: @SymbolixAU

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Acknowledgements

Symbolix would like to acknowledge and thank the following people for their valuable insights, contributions and feedback in the preparation of this report and its contained analyses.

- Shannon LeBel - Ecology and Heritage Partners
- Inga Kulik - Nature Advisory

Version Control

Version	Status	Date	Approved For Release	Issued To
0.9	For ecologist review	2023-04-17	E.Stark	I.Kulik
1.0	For submission to EHP	2023-01-05	E.Stark	I.Kulik
1.9	Updated with new data	2024-05-21	E.Stark	S.LeBel (EHP)
1.9	For client submission	2024-05-24	E.Stark	S.LeBel (EHP)
2.0	For client submission	2024-05-30	E.Stark	S.LeBel (EHP)
2.9	Updated turbine layout	2024-06-13	E.Stark	S.LeBel (EHP)

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1 Executive summary

Brewster Wind Farm, in central western Victoria, includes up to 6 proposed wind turbines with associated power line infrastructure. Brolga (*Antigone rubicunda*) are known to breed in the region, and therefore modelling is required to determine the risk that wind farm infrastructure poses to breeding pairs that might use nearby wetlands. This document summarises the estimated annual collision rate of Brolga at the proposed Brewster Wind Farm, including from both turbines and power line infrastructure. This information satisfies the requirements of step two of the Level Three assessment under the 'Interim guidelines for the assessment, avoidance, mitigation and offsetting of potential wind farm impacts on the Victorian Brolga population, 2011.

Turbine and power line collision risk was estimated using an avian collision risk model, based directly on Band, Madders, and Whitfield (2007) and Band (2012). This collision risk modelling report presents the results of the Nature Advisory Bird Collision Risk Model, developed for Nature Advisory Pty Ltd by Symbolix Pty Ltd. The Nature Advisory (NA) application (NA-BAND) updates the model to accept spatial data inputs. This modification extends Band, Madders, and Whitfield (2007) and Band (2012) to more correctly calculate the probably that a flight will interact with a turbine (if a flight occurs on-site) for each sites. The probability of collision after interaction is a geometric calculation using Band, Madders, and Whitfield (2007) and Band (2012). The NA-BAND model has previously been applied and peer reviewed as part of the approvals process for a number of Australian Wind Farms, for example Golden Plains Wind Farm (Victoria). For full details see Section 2.

A total of 16 wetlands were identified as potential Brolga breeding and non-breeding roost sites by Ecology and Heritage Partners (EHP) during the Level 1 and Level 2 Brolga Assessment (i.e. desktop assessment, targeted Brolga surveys and habitat assessments). These assessments indicate that at least 3.5, but as many as 5.3 pairs of Brolga utilise these wetlands for breeding, with an maximum of 10.6 individuals remaining on site during the non-breeding season. Based on the Level 1 Assessment undertaken by EHP (desktop analysis and Landowner Liaison) the number of breeding pairs and frequency of breeding in each of these wetlands and utilisation over the non-breeding season was estimated. From this, we explored two scenarios of wetland occupancy:

1. Flat utilisation across the site (i.e. an equal chance of any of the 16 wetlands being used for breeding)
2. Variable breeding utilisation based on the level 1 assessment result, with only site 139 used as a non-breeding roost.

An important note is that the NA-BAND model estimates the number of flights that are at risk of collision under the assumption that any breeding resident Brolga is immediately replaced. Therefore our estimate of flight collisions is likely to be higher than the actual individual collision rate. This document presents an overview of the model methodology, the inputs used, and scenario results.

1.1 Summary of turbine collision risk

Table 1 summarises the output of the turbine collision risk model for turbine layout provided by EHP. We present here both the 'flat' and 'variable' utilisation scenarios, with avoidance rates of 90%, 92% and 95%.

Table 1: Turbine collision risk modelling results.

Avoidance	Scenario	Collisions/breeding season	Collisions/non-breeding season	Expected coll. (30 yrs)	30 yr 95% pred. interval
0.90	flat	0.0042	0.0056	0.2	[0, 2]
0.92	flat	0.0033	0.0044	0.2	[0, 1]
0.95	flat	0.0021	0.0028	0.1	[0, 1]
0.90	variable	0.0066	0.0022	0.2	[0, 2]
0.92	variable	0.0053	0.0018	0.2	[0, 1]
0.95	variable	0.0033	0.0011	0.1	[0, 1]

Using these parameters, the most conservative annual collision rate (assuming 90% avoidance and equal use of wetlands) is 0.0042 collisions per year in the breeding season and 0.0056 collisions per year in the non-breeding season. This could manifest as between zero and two Brolgas struck in the life of the wind farm (30 years), breeding season and non-breeding seasons combined. This assumes an estimate of 5.3 breeding pairs utilising the area each year. The numbers in the final column of Table 1, and in the above paragraph, represent 95% prediction bounds.

1.2 Summary of power line collision risk

Table 2 summarises the output of the power line collision risk model for the power line layouts provided by EHP. We present here both the 'flat' and 'variable' utilisation scenarios, with avoidance rates of zero, based on the assumption that Brolga cannot detect, and therefore cannot avoid, power lines.

Table 2: Power line collision risk modelling results.

Scenario	Collisions/breeding season	Collisions/non-breeding season	Expected coll. (30 yrs)	30 yr 95% pred. interval
flat	0.0002	0.0028	0.1	[0, 1]
variable	0.0005	0.0004	0.0	[0, 1]

Using these parameters, the annual rate (assuming no avoidance) is zero collisions per breeding season and zero per non-breeding season, regardless of the utilisation scenario used. This is most likely to manifest to 0.1 Brolgas struck in the life of the wind farm (30 years). This

assumes a worst case of 5.3 breeding pairs utilising the site and accounts for Brolgas potentially having a different flight height if they fly out over the power line and then back over the power line to to return to the wetland.

2 Methods

2.1 Collision risk model

Collision risk modelling (CRM) requires a step-wise risk model (Reason (1997)), where the total risk is the probabilistic combination of the risk of each step in the process. The process can be summarised by the equation:

$$N_{\text{collision}} = F \times P(I|F) \times P(C|I) \times (1 - \text{AR}) \tag{1}$$

where:

- $N_{\text{collision}}$ is the estimated number of flights ending in collision over some time period
- F is the estimated activity rate of flights in the area over some time period
- $P(I|F)$ is the probability of a flight interacting with a infrastructure, given a flight in the study region
- $P(C|I)$ is the probability of collision, given an interaction occurs
- AR is the avoidance rate

The probability of collision given interaction (the fourth dot point above) is generated using the exact model published in Band, Madders, and Whitfield (2007) and Band (2012)).

The probability of interaction component in Band, Madders, and Whitfield (2007) and Band (2012) (the third dot point above) includes an unreasonable assumption that every flight interacts with every turbine. The NA-BAND model uses spatial statistics to estimate the probability of interaction for each turbine, removing the reliance on the Band, Madders, and Whitfield (2007) and Band (2012) assumption. This use of Band (2012) with spatial input parameters has been peer reviewed in Australia as part of the approvals process for sites such as Dundonnell and Golden Plains Wind Farms.

2.2 Probability of interaction of a flight with windfarm infrastructure

In the Brolga breeding and non-breeding season we assumed that flights are centred on wetlands and can radiate from there in any direction. The **probability of interaction** $P(I|F)$ is given by:

$$P(I|F) = P(\text{wetland occupied}) \times P(\text{direction}) \times P(\text{distance}) \times P(\text{height}|\text{distance}) \tag{2}$$

where:

- P(wetland occupied) is the probability that a given wetland will be occupied in a given year.
- P(direction) is the proportion of flights which travel in the right direction to interact with windfarm infrastructure. This is a geometric calculation of the ratio between the angle subtended by the infrastructure and the 360 degree circle around the wetland (assuming that Brolga might fly in any direction).
- P(distance) is the probability that a flight will travel far enough to reach the infrastructure from any wetland.
- P(height|distance) is the probability that the flight will be at a height in which they can collide with the infrastructure, given that it travelled the requisite distance.

For modelling of Brolga flight characteristics (height and distance of flights), the distribution of flight distance and height is taken from NA breeding and non-breeding data from a range of sites through south-west Victoria (Brett Lane & Associates 2018).

Breeding and non-breeding season was not a significant factor in the relationship between flight height and distance so the data sets were combined to increase the size of the dataset. As there was a difference between the distribution of flight distances in the breeding compared with the non-breeding season, the probability that a flight will travel far enough to reach the infrastructure from any wetland was modelled per season.

2.3 Application for turbines and power lines

When applying this collision risk model to predict collision with powerlines, equation (2) still holds, but the geometrical calculations relate to the linear power line structure instead of the wind turbine, i.e.

- P(height|distance) is the probability that a flight will occur within the minimum and maximum height at which the power line might occur. Powerline height was deemed to be between 15-22m.
- We estimated P(height) in two ways:
  - The first predicts the heights through a linear fit based on the shortest distances between wetland and power line only.
  - The second uses an adjusted distance to account for the fact that a flight could start from the source (wetland) or from the destination (e.g. beyond the powerline). This correction tends to generate more credible flight height predictions in case of two-way movements.
  - We present the results from the second method only because there is no difference between the two results.
  - This was done for both the breeding and non-breeding season

2.4 Probability of wetland occupancy

Ecology and Heritage Partners (EHP) undertook a Level 1 and Level 2 Brolga Assessment (i.e. desktop assessment, targeted Brolga surveys and habitat assessments). The desktop assessment included collation of Brolga breeding records from the Victorian Biodiversity Atlas (VBA), Birdlife Australia, Sheldons Brolga Flocking Database and opportunistic sightings by local landowners. Additionally, EHP undertook habitat assessments and roaming surveys across the site. From these surveys, 16 wetlands were identified as potential breeding location for Brolga (Shannon Le Bel, EHP, *pers. comm.*). The site was also identified as a non-breeding roost site, where individuals may remain during the non-breeding or 'flocking' season. Additionally, some birds migrate yearly to known flocking sites, for which the number of these migratory flights across the wind farm were estimated. See Figure 1 for their locations.

Landowner liaison provided an estimation of the breeding frequency within each of these wetlands. Whilst some wetlands were used regularly by breeding Brolgas (with at least one breeding observation per year), others had been used as little as once in the past 10 years. We therefore used this to explore two ecological breeding scenarios:

- **Flat**: in a given year, a breeding pair is equally likely to utilise any of the 16 wetlands.
- **Variable**: the number of years in which breeding has been observed and the number of pairs observed was used to calculate a frequency of breeding for each wetland.

Increasing the probability that a wetland is being utilised increases the probability of interaction with the wind farm infrastructure. Table 3 displays the probabilities of occupancy under this scenario.

For the non-breeding season, Site 139 is believed to be the only non-breeding roost site. As such, the variable scenario is the most accurate estimate for the non-breeding season. We present a flat utilisation rate for the non-breeding season for completeness.

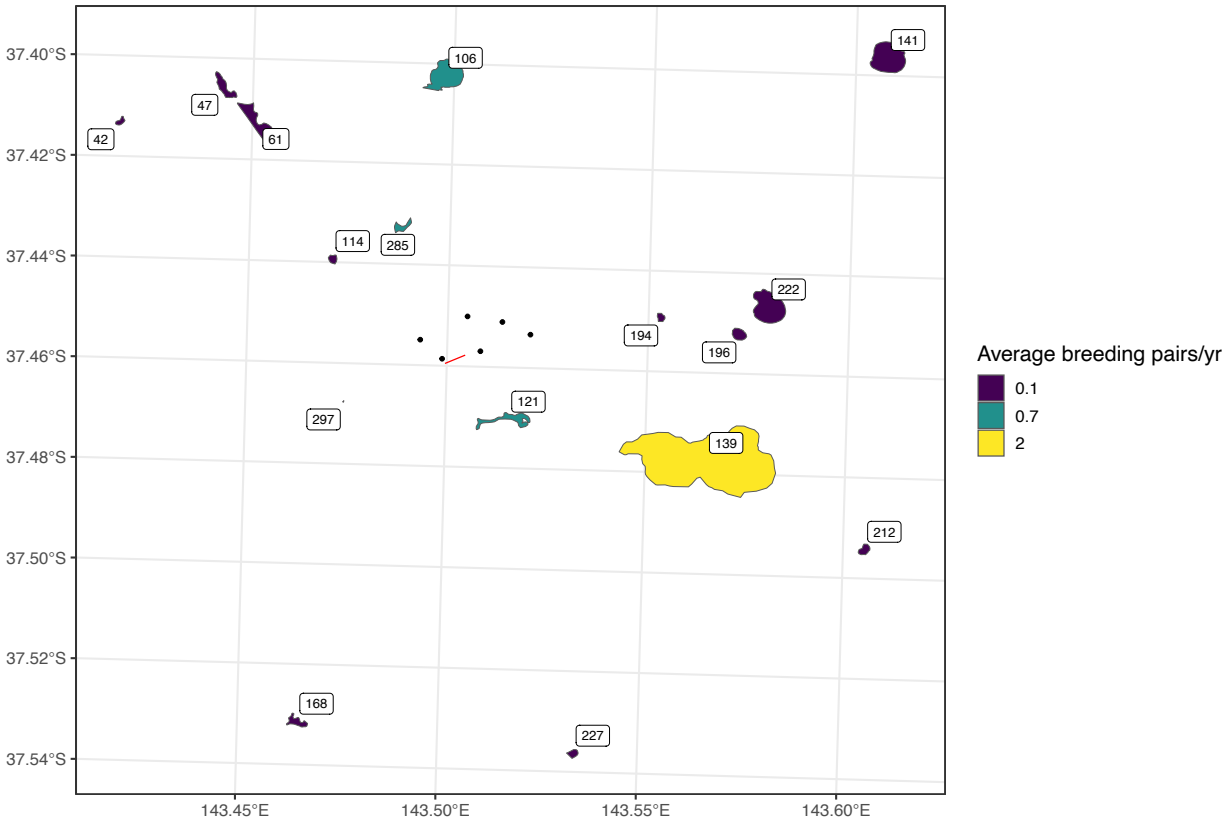

Figure 1: Breeding wetlands identified across the site, with turbine locations (black dots) for reference.

Table 3: Probability of wetland occupancy under the variable breeding scenarios.

Wetland ID	Average breeding pairs / year	P(breeding utilisation)	Maximum non-breeding individuals / year	P(non-breeding utilisation)
121	0.7	0.163	0.0	0
139	2.0	0.233	10.6	1
114	0.1	0.023	0.0	0
285	0.7	0.163	0.0	0
194	0.1	0.023	0.0	0
196	0.1	0.023	0.0	0
222	0.1	0.023	0.0	0
42	0.1	0.023	0.0	0
47	0.1	0.023	0.0	0
61	0.1	0.023	0.0	0
141	0.1	0.023	0.0	0
106	0.7	0.163	0.0	0
212	0.1	0.023	0.0	0
227	0.1	0.023	0.0	0
297	0.1	0.023	0.0	0
168	0.1	0.023	0.0	0

2.5 Probability of a flight reaching the windfarm infrastrucutre

The distribution of flight distance is taken from combined NA breeding data from a range of sites through south-west Victoria (Brett Lane & Associates 2018). The dataset was small (163 records) but demonstrates a clear preference for shorter flights (up to one kilometre). EHP also provided flight data taken from the site (n = 11), which were compared with the larger dataset.

We fit a gamma distribution to the data, with and without the Brewster data, which allowed us to infer the probability that a flight would travel a given distance (i.e. the $P(\text{distance})$ component), even if no observations were recorded at that distance. Inclusion of the Brewster data produced a worst fitting model. As there are too few flights recorded at Brewster to understand if any difference in the flight distances at this site compared with all other sites, we excluded it from the models. A histogram of observed distances is given in Figure 2.

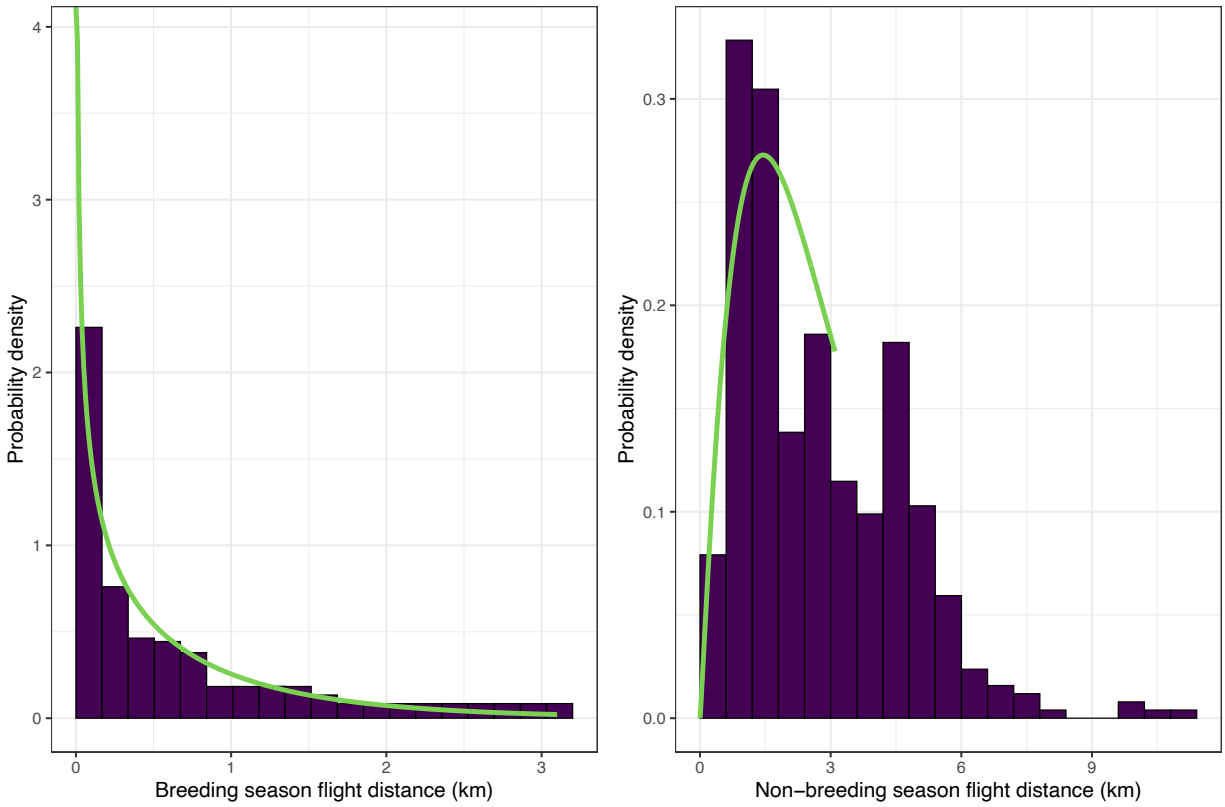

Figure 2: Empiricial flight distance distribution (histogram) and fitted gamma probability density function (curve) for the breeding (left) and non-breeding (right) season.

2.6 Probability of flying at rotor or power line height

The dataset of breeding season observations used in the previous section also contains flight height data. The dataset used for the distance distribution included 67 records for which height data was also recorded. To supplement this data, we included matched flight and height data from 547 flocking season flights at Dundonnell Wind Farm, also provided by NA. As

seen in Figure 3 there is a clear linear relationship between flight height and distance (if we pre-transform both variables using the natural log function). We fit linear models to quantify this relationship. Testing breeding/non-breeding as a factor showed no significant difference between the two seasons (thereby justifying our combining of the data).

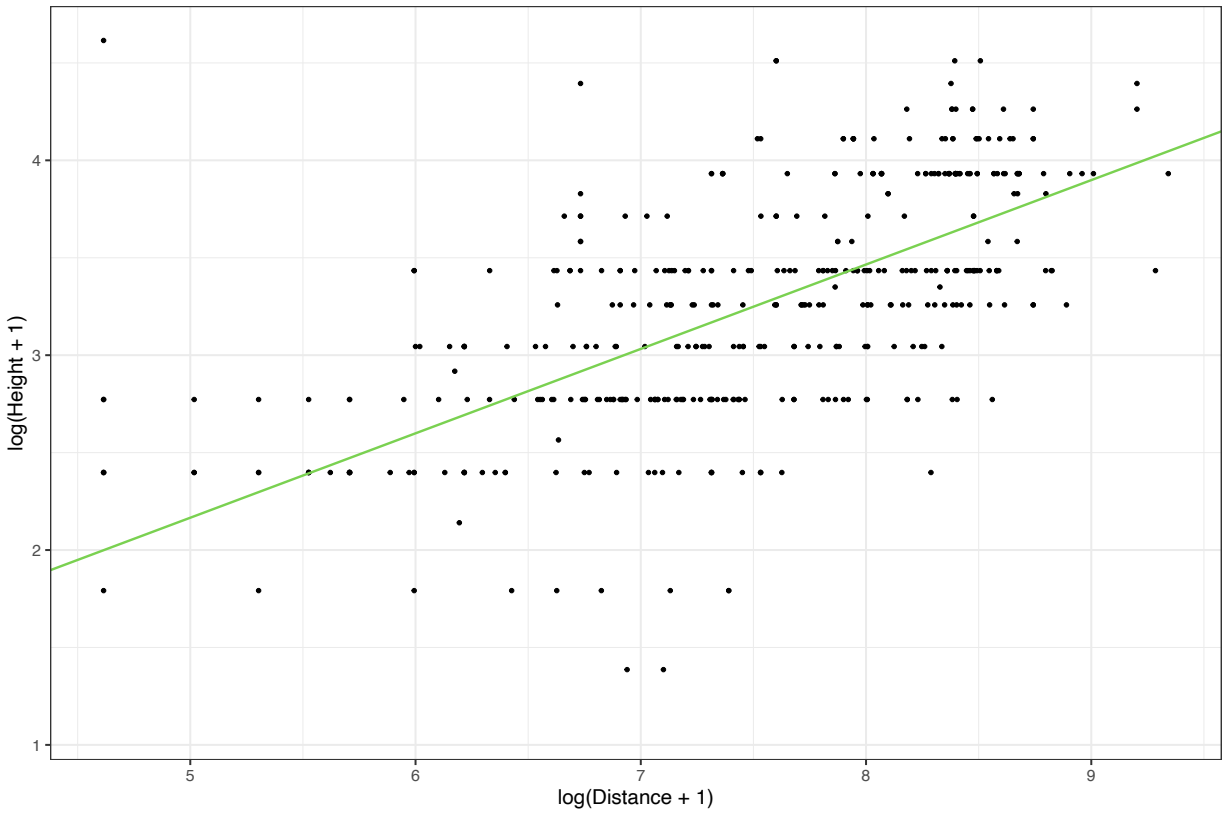

Figure 3: Relationship between flight height and distance. The pre-transformed units of height are metres, and distance is in kilometres.

The linear model allowed us to predict the expected height at a given flight distance, but to estimate the probability that a flight will occur in the rotor swept height or power line range we also need to consider the variability of the data around this expected value (i.e. we want to know the distribution of model residuals).

At any given distance, the probability of seeing a given flight height is described by the percentiles of the distribution of the residuals around the modelled value. $P(\text{height}|\text{distance})$ is the proportion of this distribution that falls in the height range (see Table 4) of the infrastructure being modelled.

2.7 Calulation of the probability of interaction

From the above methods we now have:

- The probability that a wetland is occupied is taken from our breeding and non-breeding season scenario models.
- The probability of direction (at any point on the site) is taken by assuming that a turbine is placed there for the (breeding and breeding season separately), and then using geometry to calculate the angle.
- The probability of travelling the requisite distance is taken from the gamma distribution fit to empirical data.
- The probability of being at the rotor swept height or power line height, given distance, is taken from the log-log linear model fit to empirical data.

We therefore have all the components to calculate $P(I|F)$ at any point in the landscape. The probability of interaction at any point in the landscape is the sum of $P(I|F)$ over all wetlands. This was done for the breeding and non-breeding season seperately.

2.8 Probability of collision given turbine interaction

Turbine collision risk was estimated using an avian collision risk model, based directly on Band, Madders, and Whitfield (2007) and Band (2012). The NA application (NA-BAND) updates the model to accept spatial data inputs. This modification extends Band, Madders, and Whitfield (2007) to more correctly calculate the probably that a flight will interact with a turbine (if a flight occurs on-site) for general sites. The probability of collision after interaction is a geometric calculation using Band, Madders, and Whitfield (2007) and Band (2012). The NA-BAND model has previously been applied to assess collision risk for Moorabool Wind Farm, Dundonnell Wind Farm, and Golden Plains Wind Farm (Victoria).

An important note is that the NA-BAND model has no assumption about the likelihood that an individual bird would be replaced in the local area if it is struck. The model estimates the number of flights that are at risk of collision under the assumption that any breeding resident bird is immediately replaced. Therefore, out estimate of flight collisions is likely to be higher than the actual individual collision rate.

The NA-BAND model requires a number of turbine-related and bird-related inputs, which are summarised in Table 4 and 5 respectively.

Table 4: Turbine parameter inputs for the NA-BAND model.

Turbine parameters	Value
Model	Vestas V172
Rotor diameter (m)	188
Hub Height (m)	166
Rotation period (s)	5
Maximum chord (m)	4.3
Pitch (degrees)	Averaged at 6
Number of Blades	3
Blade Height Maximum (m)	252
Blade Height Minimum (m)	64

Table 5: Bird parameter inputs for the NA-BAND model.

Bird parameter	Value
Length (m)	1.65
Wingspan (m)	2
Flight speed (m/s)	16.7
Flapping (0 = flapping, 1 = gliding)	0
Breeding season length (days)	130
Breeding pairs (minimum)	3.5
Breeding pairs (maximum)	5.3
Brolga per breeding pair	2.1
Flights per day (breeding/non-breeding season)	2
Non-breeding season length (days)	182
Brolga on-site during the non-breeding seaosn	10.6
Intersecting migration flights (p/year)	1.6

3 Data preparation

Datasets were provided by NA and EHP, including:

- Turbine physical parameters
- Brolga physical parameters
- Distance data
- Height given distance data
- Turbine layout data
- Wetland location data
- Brolga breeding information

3.1 Pre-processing

The following data pre-processing steps were performed:

- Wetland spatial data was filtered to the 16 relevant wetlands.
- For the height modelling, the response variable was taken to be the mean of the minimum and maximum height of each observation.
- For the distance modelling, flights with unspecified end points were set to be right-censored.
- Information on the number of years Brolga were observed breeding in each wetland at Brewster WF in the last 10 years, and the number of pairs typically seen in each wetland was used to calculate a probability of wetland utilisation.
- Information on the site utilisation during the non-breeding season.

3.2 Dataset summary

Table 6 summarises the parameters, data sources, and model input values for the collision risk model.

Table 6: Collision risk model data inputs.

Variable	Input data	Data source	Model input value
Number of flights	Scenario for Brolga breeding and non-breeding flights, based on estimate of 3.5 - 5.3 breeding pairs in the region and a maximum of 10.6 individuals reamining on site in the non-breeding season, making an average of two flights daily. Breeding attempts were assumed to last an average of 130 days, with the non-breeding season being 182 days. We have assumed there is no flocking on site (S. LeBel, pers. comm.).	Regional population and activity estimates provided by EHP based on historical records, landowner liaison and habitat surveys at Brewster Wind Farm. The number of birds per breeding pair uses the juvenile to adult ratio of 0.05 (Herring (2001), in McCarthy (2008)).	A minimum of 1911 and a maximum of 2893.8 flights per breeding season. Additionally, a maximum of 3860 flights per non-breeding season.

P(wetland occupied)	16 wetlands were identified as potential breeding sites, with one being used during the non-breeding season. Flat scenarios were run using an equal probability of useage. Additionally,a variable scenario was run, in which each wetland included a unique probability of utilisation based on previous records	Spatial layer provided by Nature Advisory and observational records provided by EHP.	For the flat scenario scenario each wetland had an 0.06% chance of utilisation. For the the variable utilisation scenario, each had a unique probability of utilisation provided in Table 3.
P(distance)	A gamma distribution was fit seperately to the breeding and non-breeding season flight distance data to estimate the probability that a flight from a wetland will travel (at least) the distance to a given turbine.	Breeding and non-breeding season survey data provided by Nature Advisory.	A probability was generated for each suitable wetland and each turbine location for the breeding and non-breeding season. The total probability is the sum of these values.

P(height|distance)	We fit a linear (log-log) model to predict the expected height for a given flight distance, breeding and non-breeding season combined. The proportion of flights within rotor swept height was then calculated by the proportion of the residuals within this range at the given distance.	Nature Advisory provided regional breeding and non-breeding season flight data with both heights and distances rom other Victorian sites. The rotor swept height was assumed to be 64 to 252 metres, as provided by EHP. The power line height was assumed to be 15 to 22 metres above ground, as provided by EHP	A value was calculated for each turbine/wetland combination and each wetland to the single power line.
AR (avoidance rate)			Turbine collision models used avoidance rates of 0.90, 0.92 and 0.95. power line collision models used an avoidance rate of zero (based on the assumption that Brolga cannot see and therefore cannot avoid power lines.

4 Results

4.1 Turbine collision risk

Figure 4 and Figure 5 shows the risk of Brolga flight interaction with turbines, under the current turbine layout. Comparatively higher risk areas are shown in yellow and green, while lower risk areas are in blue and purple. For reference, we include the number of breeding pairs or non-breeding individuals per year observed in each wetland. We see here that there are slightly higher risk closer to the wetlands with higher breeding and non-breeding frequency (i.e. Site 139), extending out towards the turbines.

Table 7 shows the collision risk modelling results for turbines. Under the 90% avoidance scenario and variable utilisation, we expect on average 0.0066 collisions per year during the breeding season (based on 5.3 breeding pairs) and 0.0022 collisions per year during the non-breeding season, over the 30 year lifetime of the farm.

The plausible range of cumulative mortalities over a 30 year period (assuming 90% avoidance) is shown in Figure 6. These counts represent the potential yearly manifestation of the long-term rate. We present the variable utilisation model as it is the more conservative estimate. There is a 95% chance that the expectation would manifest as between 0 and 2 collisions across the life time of the windfarm, breeding and non-breeding seasons combined. In other terms, there is a 20.26% chance of one turbine collision in the life of the wind farm. This is using the variable utilisation model as it is the more conservative estimate.

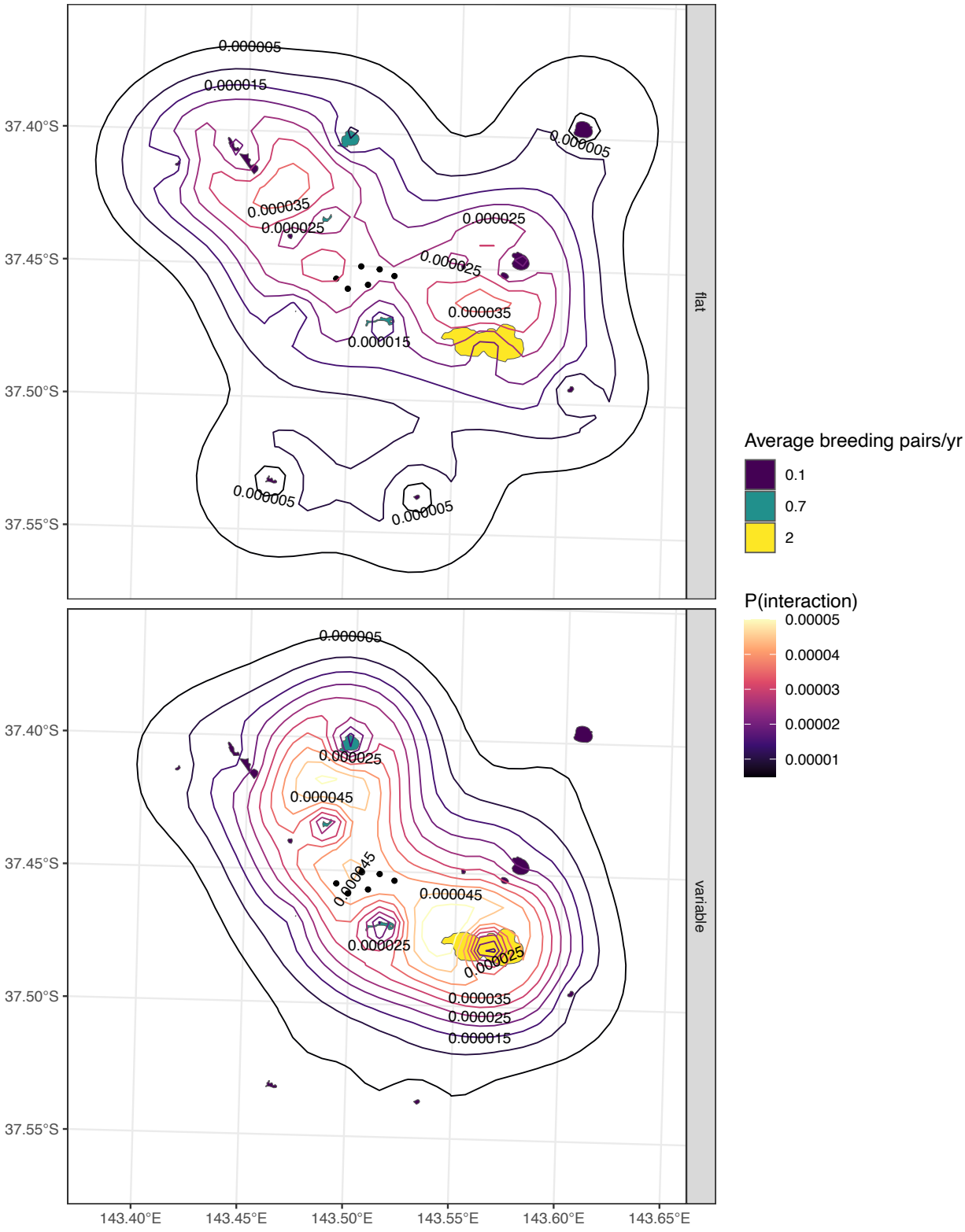

Figure 4: Contour plot of the probability of interaction with the proposed turbines during the breeding season. Turbine locations are shown with black dots. Contour lines (or isolines) provide a visualisation of the two-dimensional probability functons.

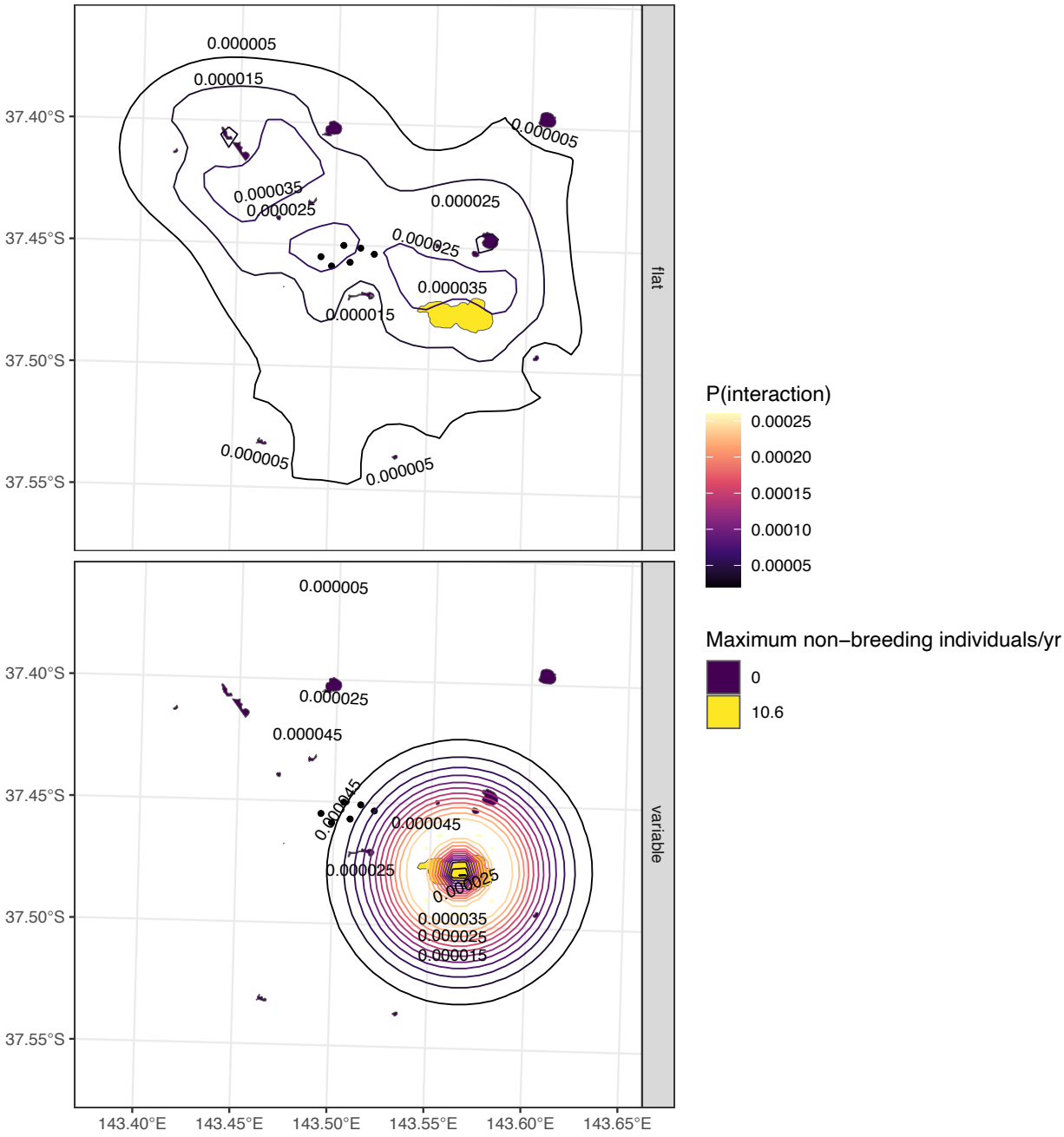

Figure 5: Contour plot of the probability of interaction with the proposed turbines during the non-breeding season. Turbine locations are shown with black dots. Contour lines (or isolines) provide a visualisation of the two-dimensional probability functons.

Table 7: Turbine collision risk modelling results.

Avoidance	Scenario	Collisions/breeding season	Collisions/non-breeding season	Expected coll. (30 yrs)	30 yr 95% pred. interval
0.90	flat	0.0042	0.0056	0.2	[0, 2]
0.92	flat	0.0033	0.0044	0.2	[0, 1]
0.95	flat	0.0021	0.0028	0.1	[0, 1]
0.90	variable	0.0066	0.0022	0.2	[0, 2]
0.92	variable	0.0053	0.0018	0.2	[0, 1]
0.95	variable	0.0033	0.0011	0.1	[0, 1]

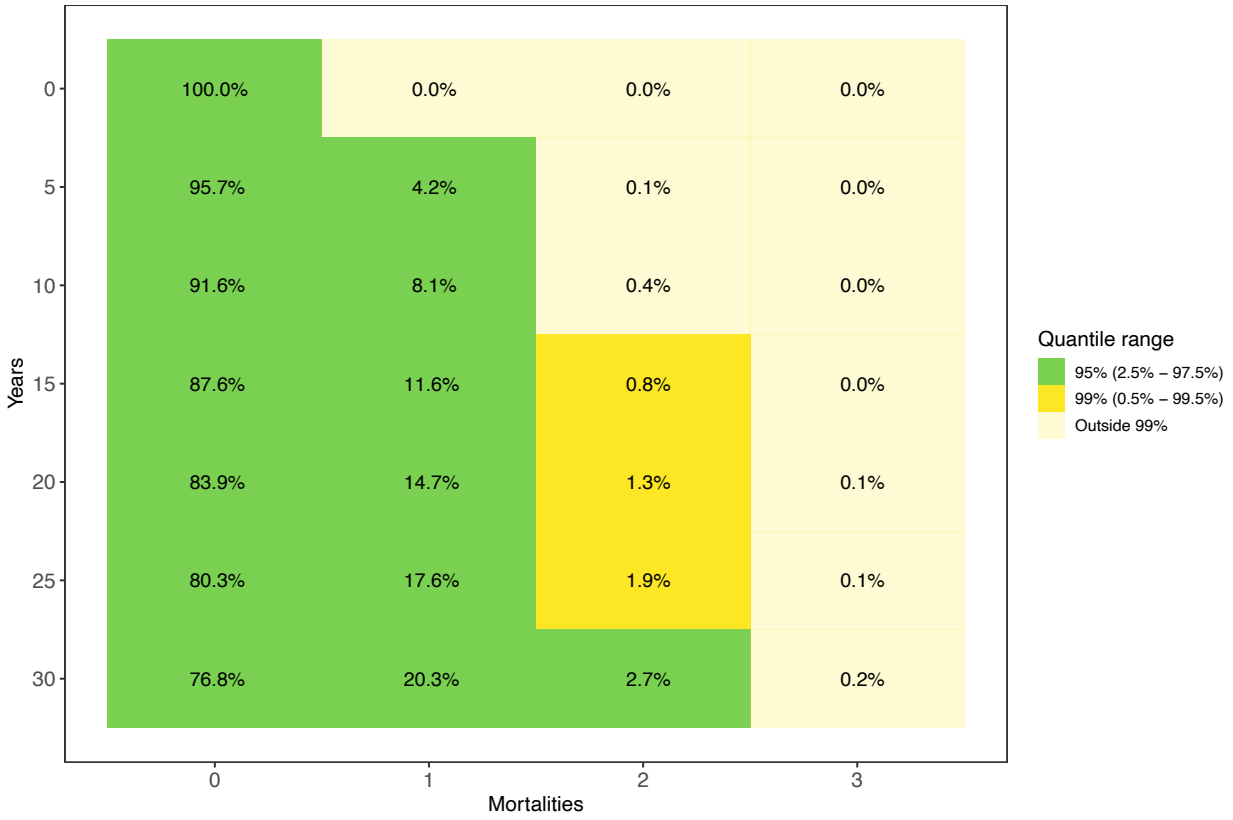

Figure 6: Plausible range of cumulative turbine mortalities. The most conservative model is visualised here, assuming 90% avoidance, flat utilisation across the site and a maximum of five breeding pairs utilising the identified breeding wetlands.

4.2 Power line collision risk

Figure 7 and Figure 8 shows the risk of brolga flight interaction with the proposed single power line, breeding and non-breeding season respectively. As with the turbine contour map, comparatively higher risk areas are shown in yellow and green, while lower risk areas are in blue and purple. For reference, we include the number of breeding pairs or non-breeding individuals per year observed in each wetland.

Table 8 shows the collision risk modelling results for the powerline. We expect on average 0.0005 collisions per year during in the breeding season and 0.0004 collisions per year during in the non-breeding season over the 30 year lifetime of the farm, with no avoidance.

Over 30 years, the expectation of the model is 0 collisions in total (breeding season and non-breeding season). There is only a 2.75% chance of one power line collision in the life of the wind farm, regardless of site utilisation.

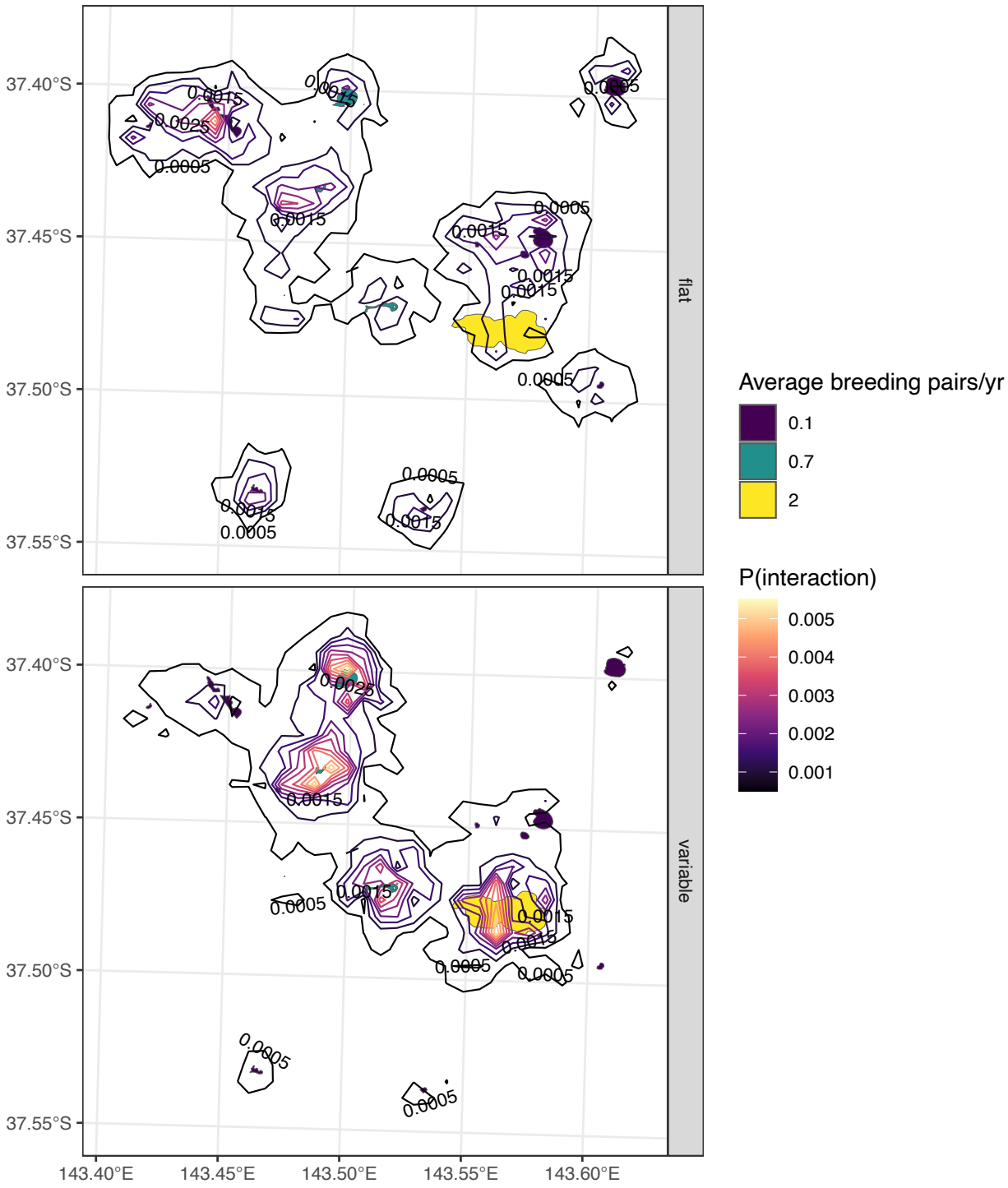

Figure 7: Contour plot of the probability of interaction with the proposed power line during the breeding season. Turbine locations are shown with black dots. Contour lines (or isolines) provide a visualisation of the two-dimensional probability functons.

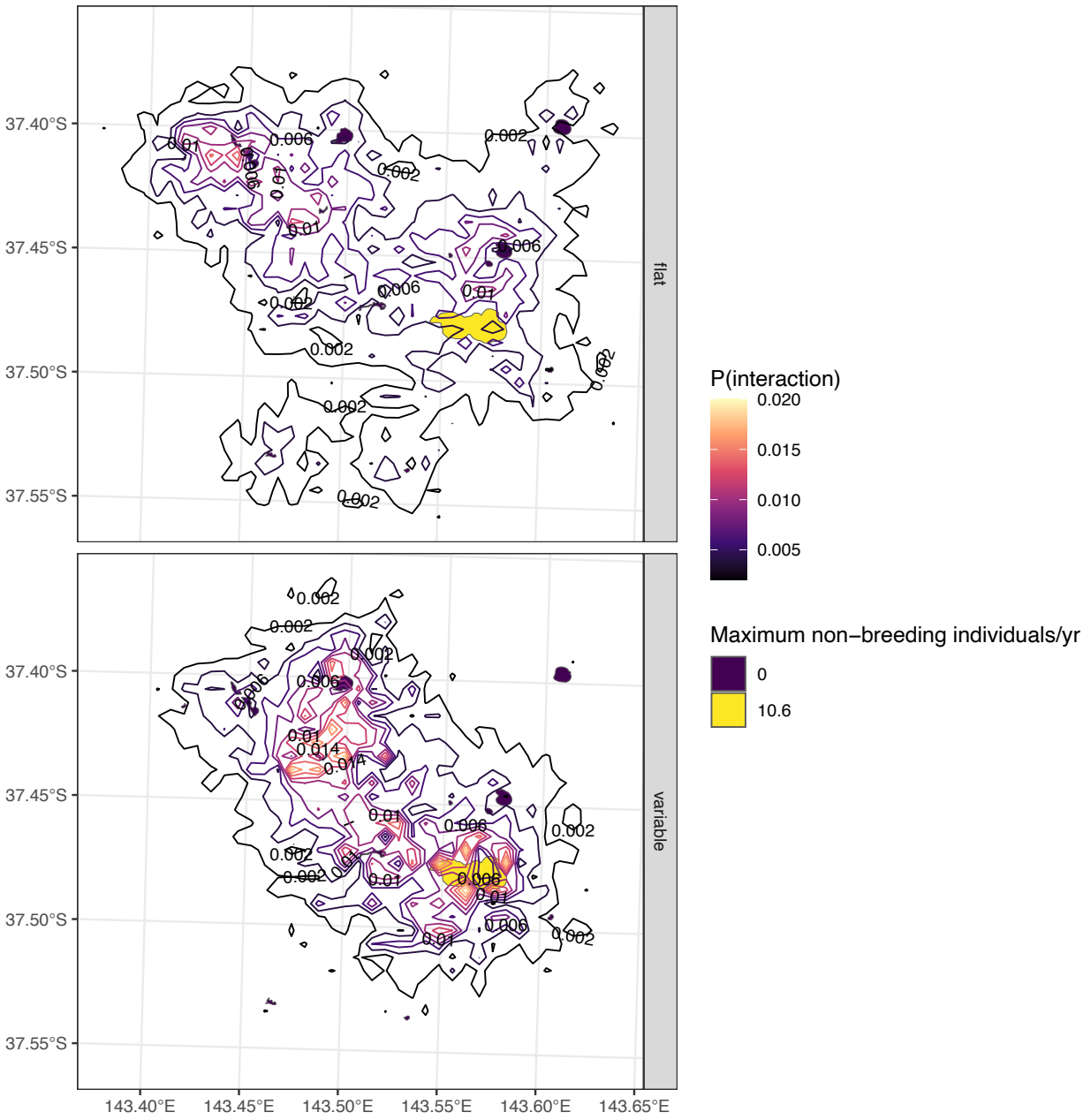

Figure 8: Contour plot of the probability of interaction with the proposed power line during the nonbreeding season. Turbine locations are shown with black dots. Contour lines (or isolines) provide a visualisation of the two-dimensional probability functons.

Table 8: Power line collision risk modelling results.

Scenario	Collisions/breeding season	Collisions/non-breeding season	Expected coll. (30 yrs)	30 yr 95% pred. interval
flat	0.0002	0.0028	0.1	[0, 1]
variable	0.0005	0.0004	0.0	[0, 1]

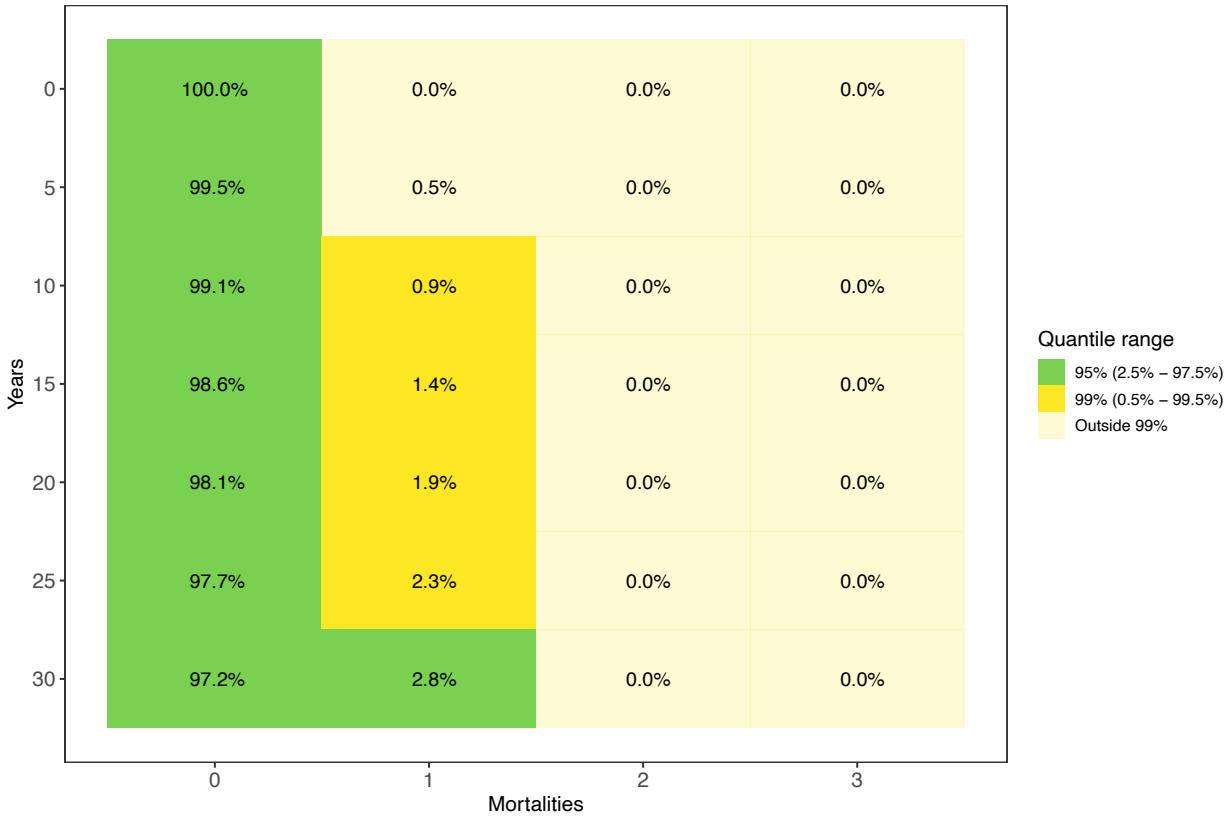

Figure 9: Plausible range of cumulative power line mortalities. The most conservative model is visualised here, assuming no avoidance, flat utilisation across the site and a maximum of five breeding pairs utilising the identified breeding wetlands.

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APPENDIX 6 – POPULATION VIABILITY ANALYSIS

Results for Brolga PVA for the Brewster Windfarm

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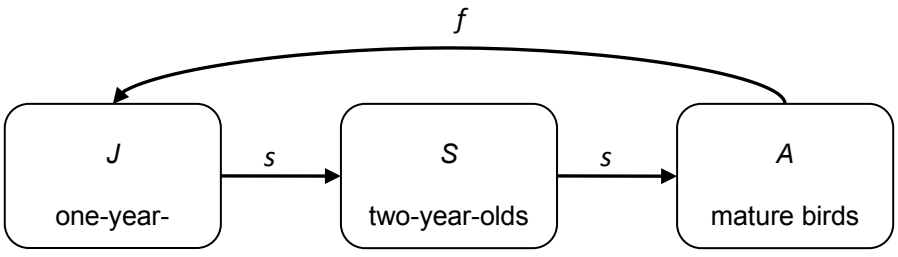
7 June 2024

This report documents a population viability analysis (PVA) of brolga to predict the impacts of the proposed Brewster wind farm following updated collision risk modelling. The report uses projections of the number of annual collisions with turbines and powerlines. The predictions of impacts on the brolga population in south-western Victoria are based on three different avoidance rates (90%, 92%, 95%) and two different wetland utilisation patterns (flat with equal use of the wetlands, and variable based on the level 1 risk assessment reported in the Brewster Wind Farm Collision Risk Modelling by Symbolix). These correspond to 0.0127, 0.0107, 0.0079 collisions per year for the flat scenario (including 0.003 collisions per year with powerlines), and 0.0097, 0.0080, 0.0053 collisions per year for the variable scenario (including 0.0009 collisions per year with powerlines). These annual rates were converted to a per-capita annual rate by assuming the population size of brolga is 625 birds. The dynamics of the brolga population were simulated for a period of 30 years. 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 windfarm collisions.

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 in the last two years has been approximately 10% in the last couple of years 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 2,000,000 stochastic iterations for each set of parameters with analyses done within the statistical programming language R.

Results

In the absence of losses to wind turbines and powerlines, the expected minimum population size over the next 30 years was 548.3 brolgas when the initial population size was 625 brolgas, and was 796.8 when the initial population size was 907 brolgas. Impacts of the turbines and powerlines can be compared to these values (Tables 1). For all scenarios, the impact on EMP was predicted to be ≤0.2 over the 30 years. Changes in the EMP near 0.1 are near the limit of precision of the stochastic simulations with 2 million iterations.

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 brolgas or 907 brolgas. Results are shown for the flat and variable scenarios, corresponding to different wetland ustilisation patterns. 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 and scenario	90% avoidance rate	92% avoidance rate	95% avoidance rate
625 birds (flat)	548.1 (0.2)	548.2 (0.1)	548.2 (0.1)
625 birds (variable)	548.2 (0.1)	548.2 (0.1)	548.3 (<0.1)
907 birds (flat)	796.6 (0.1)	796.6 (0.1)	796.7 (0.1)
907 birds (variable)	796.6 (0.1)	796.6 (0.1)	796.7 (<0.1)

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 degree by which a quasi-extinction risk curve is from 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 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 improvement to breeding habitats or reduced collision with other infrastructure such as existing 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 substantially less than 1 bird over the 30-year period. If survival of juveniles to adulthood is *j* and the expected number of deaths is *d*, then the required number of extra juveniles can be calculated as *d*/*j*, which remains less than one bird for the parameters considered in this report.

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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 7 – BROLGA OBSERVATIONS

ecology & heritage partners

Site	No. Brolga	Direction	Height (m)	Total Flight Distance (m)	Maximum distance from breeding wetland (m)	Location	Notes
139	1	W	3	204	0	E edge 139	Brolga foraging in small area for most of the survey. Late in the survey, it took off (3 m height), did a wide arc and then flew west.
139	1	N- NE	5	166	187	NE edge of 139	Brolga observed in paddock W of Modesty Lane. <5m off ground (possibly juvenile). Flew N
139	3	W- NW	20	718	222	NE edge of 139	Brolga flew off (20m height 19approx.) from fence line behind house headed NW before an arc due W
139	3	NE	20	1662	1180	Paddock	Brolga (that flew West (Flight #3) flew towards observer, then headed NE (20m height) to Site 243
139	1	E-NE	30	1236	1290	NE edge of 139	Brolga near fence line behind property flew E circling higher until approx. 30m height. Brolga then flew NE to Site 261.
139	1	NE	20	1218	1325	Paddock	Brolga in paddock flew NE circling higher until approx. 30m height. Brolga then flew NE to Site 261 (Shortly after Flight #5)
139	2	SE	20	1164	1300	Site 261	Brolga flew SE circling up to 20m height, landing along fence line approx. 300m behind property. Brolga were calling and foraging approx. 30m radius.
139	2	NE	50	1262	1315	NE edge of 139	Brolga flew off progressively circling higher (large circles) until approx. 50m height, calling consistently. Brolga then flew over Modesty Lane, headed NE to Site 261.
139	4	SW-W	70	698	1120	Site 261	Brolga arced SW over plantation, landing in paddock.
139	2	SW	10	116	273	S edge of 139	Brolga foraging S edge of 139 within 30m radius. Brolga flew up and arced SW on edge of wetland near fence line with hay bales. Flight was 100m approx. and between 5-10m high. Brolga proceeded to do a courtship dance for 10min before foraging further up hill in grazed land with hay bales out of 139
141	2	NW	5	690	690	Northern edge of Site 131	Brolga flying into NE edge of 141 to forage.
139	1		0		0	Eastern edge	One Brolga sitting on nest for entire 20 min

Site	No. Brolga	Direction	Height (m)	Total Flight Distance (m)	Maximum distance from breeding wetland (m)	Location	Notes
141	1		0		0	Southern edge	Brolga did not leave nest during survey, approx. 50m from active turbine
139	1		0		0	Western edge	One Brolga sitting on nest for whole 20 min
139	1		0		0	Western edge	Brolga 1.5km + away, difficult to see but did not leave nest for 20min
141	2		0		0	Two Brolga foraging southwest edge	Two Brolga far edge, foraging within 10m radius
106	2		0		0	Northern edge	Two Brolga seen, far edge of wetland. Foraging same location, no movement
139	3		0		110	Northern edge	Two adult Brolga with chick foraging together along fence line. Easily seen form roadside approx. 300m away
106	3		0		5	Southern edge	Two Brolga plus one chick, foraging southern edge of wetland, half in shadow of treeline. Didn't move more than a 3-metre radius throughout survey.
106	2		0		5	Southern edge	Two Brolga foraging southern edge of wetland, half in shadow of treeline. Didn't move more than a 3-metre radius throughout survey.
106	2		0		5	Eastern edge	Two Brolga foraging within 3m radius, Approx. 100m from where previously seen. No chick seen.
141	1		0		5	Approx. 120m away from nest location.	One Brolga foraging within 3m radius throughout survey. Masked Lapwing observed on the Brolga nest
139	1		0		5	One Brolga on western edge	One Brolga foraging within 3m radius throughout survey
139	2		0		5	Western edge	Two Brolga foraging in a small area for the duration of the survey.

Site	No. Brolga	Direction	Height (m)	Total Flight Distance (m)	Maximum distance from breeding wetland (m)	Location	Notes
141	2		0		5	In line with the southern turbine.	Two Brolga near the fenceline of the paddock with the wetland, almost in line with the southern turbine. One was resting on the ground for the duration of the survey. The second remained very close, either preening or foraging within 5m of the mate.
141	2		0		5	Western edge.	Two Brolga foraging,
141	2		0		0	North-east edge	Two Brolga foraging/wading approx. 10m apart on north-east edge of 141 entire 30 minutes
106	3		0		0	Northern edge of wetland	Three Brolga still present, though stayed within 5m radius during entire survey
106	2		0		5	Northern edge	Two Brolga foraging in tall vegetation N edge
141	2		0		40	Western edge.	One Brolga flapped wings and ran 20-30m to chase off Purple Swamphen, while the other Brolga stayed.
106	3		0		40	Southern edge	Two Brolga far edge, foraging within 20m radius, chick seen
106	2		0		40	Eastern edge	Two Brolga, eastern edge. Too far to see chick. Foraging in tall veg on tree line/ fence line within 5m radius
139	3		0		30	Western half of wetland	Two Brolga and one chick observed walking/foraging within a 15 metre radius, along the fenceline/property line within western portion of Dunn's Marsh.
106	2		0		40	Eastern edge	Two Brolga seen eastern edge, same area as yesterday, foraging in the rain. No chick seen but veg high. Brolga behaviour suggested chick present
141	2		0		50	North-east edge	Two Brolga foraging approx. 10m apart on north edge of 141 entire 20 minutes
139	2		0		30	Near to nest	Two Brolga, did not leave 15m radius
106	2		0		40	Southern edge	Two adult Brolga foraging approx. 30m apart. No chick seen in the high veg. Slowly walked closer together. Brolga didn't not move out of 30m radius during survey

Site	No. Brolga	Direction	Height (m)	Total Flight Distance (m)	Maximum distance from breeding wetland (m)	Location	Notes
141	2		0		50	Eastern edge	Two Brolga eastern edge 20m radius foraging
106	3		0		30	Eastern edge	Two Brolga foraging in reeds within 10m radius. No chick seen likely due to high vegetation. Pair appeared to do less foraging over time, instead ducking down as if on nest or with young. Presence of young confirmed from eastern boundary
106	2		0		40	Southern edge	Light rain, two adult Brolga observed far edge of wetland, minimal movement during survey
106	3		0		200	Northern edge	Two Brolga and chick. Chick looking much more mature, almost size of female. Walked/foraged SE 200m
139	2		0		100	Northern edge	Two Brolga approx. 30m East from where seen 4 hours ago along same fence line. No movement during survey
139	2		0		110	North edge	Two Brolga in distance, difficult to see, no flights
139	3		0		80	Northern edge	Two Brolga and chick foraging and walking along fence line near to centre of wetland. Brolga walked 50+m indication that chick is growing stronger. Took cover in mound with high veg
139	3		0		60	Northern edge	Two Brolga and chick foraging within 15m along fence line, chick present
106	2		0		0	South Eastern edge	Two Brolga foraging within 2m radius. Adults then sat in long grass for 15min before foraging again. Adults did not move more than 2m. No chick present.
141	2		0		50	North edge	Two Brolga one on ground in grass and one standing, North edge. No movement and no chicks observed
141	2		0		220	East edge	Two Brolga standing close to fence on North east edge, only upper body observed above crops. Movement within 2m radius
141	2		0		170	North-East edge	Two Brolga seen foraging in south direction from the Northeast edge. Within 30m radius. No chick observed

Site	No. Brolga	Direction	Height (m)	Total Flight Distance (m)	Maximum distance from breeding wetland (m)	Location	Notes
139	2		0		240	North-East edge	Two Brolga foraging Northeast edge along fence line, heading south. Lost sight of Brolga behind property (on modesty lane). No chicks observed
141	2		0		50	North edge	Two Brolga foraging north edge, within 10m radius. No chick present
139	2		0		0	Western edge	Two adult Brolga foraging approx. 10m apart on Western edge heading Northwest. Approx. 50m radius. No chick observed
141	2		0		50	North-east edge	Two Brolga foraging/wading approx. 10m apart on north-east edge of 141 entire 20 minutes
139	2		0		50	North-East edge	Two Brolga foraging Northeast edge 20m off fence line. Within 10m radius. No chick observed
141	2		0		50	Northeast edge	Two Brolga north eastern edge foraging within 30m radius . No chick present
141	2		0		200	South East edge	Two Brolga in long grass. After 22min Brolga walked further North <20m foraging. No chick present
141	2		0		150	Southern edge	Two Brolga foraging from the South edge moving West. Moved approx. 80m, Brolga always 10m apart from each other. No chick present even when in short open grass.
141	2		0		150	North-east edge	Two Brolga foraging Northeast edge against fence line. Machinery started in crops close by. Brolga agitated by this. Two separated, one northwest in long grass, other brolga went South. Both Brolga met up further north when machinery got close again, they both ventured South approx 50m. No flights and no chicks recorded.
139	8		0		150	East edge	8 Brolga foraging east edge (behind dam next to Modesty lane) heading west (wetlands behind property). No juveniles. All 8 Brolga within 20m radius of each other.

Site	No. Brolga	Direction	Height (m)	Total Flight Distance (m)	Maximum distance from breeding wetland (m)	Location	Notes
139	3		0		150	South edge	Two Brolga plus chick foraging along fence line on South side heading West. Chick in front with adult female. Brolga continued Southwest across paddock >50m until out of sight. Possible nest observed towards nth side of main water body. Compacted mud mound.
139	2		0		0	Southwest edge	(Glenn's property) Two Brolga. Same location No chicks
139	2		0		100	North edge	Two Brolga foraging northern edge against fence line (within 20m radius). No chicks observed.
139	2		0		250	Southwest edge	Two Brolga foraging Southwest edge outside 139 in dry hay bale paddock on hill slope. Within 15m radius. No chicks observed
141	2		0		0	North-east edge	Two Brolga foraging/preening approx. <5m apart on north-east edge of 141 entire 45 minutes
106	3		0		0	South edge	Three Brolga foraging south edge 10m radius

APPENDIX 8 – AERIAL DRONE SURVEY RESULTS

Table A1. Wetland Brolga habitat quality scores.

Wetland Site	Habitat Quality	Wetland Site Cont.	Habitat Quality Cont.	Wetland Site Cont. II	Habitat Quality Cont. II
1	Moderate	101	Low	201	Low
2	High	102	Low	202	Moderate
3	High	103	Low	203	Moderate
4	Low	104	Moderate	204	Low
5	Low	105	Low	205	Low
6	Low	106	High	206	Low
7	Moderate	107	Low	207	Low
8	Low	108	Low	208	Low
9	Moderate	109	Low	209	Moderate
10	Moderate	110	Low	210	Moderate
11	Low	111	Low	211	Low
12	Low	112	Moderate	212	Low
13	Moderate	113	Low	213	Low
14	Moderate	114	Moderate	214	Moderate
15	Low	115	Moderate	215	Low
16	Low	116	Low	216	Low
17	Moderate	117	Low	217	Low
18	Low	118	Low	218	Low
19	Low	119	Low	219	Low
20	Low	120	Low	220	Low
21	Low	121	High	221	Moderate
22	Low	122	Low	222	Moderate
23	Low	123	Low	223	Low
24	Low	124	Low	224	No access
25	Low	125	Low	225	Low
26	High	126	Low	226	Moderate
27	Moderate	127	Low	227	Low
28	Low	128	Moderate	228	Low
29	Low	129	Low	229	Low
30	Low	130	Moderate	230	Low
31	Moderate	131	Low	231	Low
32	Low	132	Low	232	Low

Wetland Site	Habitat Quality	Wetland Site Cont.	Habitat Quality Cont.	Wetland Site Cont. II	Habitat Quality Cont. II
33	Low	133	Low	233	Low
34	Moderate	134	Low	234	Moderate
35	Low	135	Low	235	Low
36	Low	136	Low	236	Low
37	Low	137	Moderate	237	Moderate
38	Moderate	138	Low	238	Low
39	No access	139	High	239	Low
40	Low	140	Low	240	Low
41	Low	141	High	241	Low
42	Low	142	Low	242	Moderate
43	Low	143	Low	243	Low
44	Low	144	Low	244	Moderate
45	Moderate	145	High	245	Low
46	Low	146	Low	246	Low
47	Low	147	Low	247	Low
48	Low	148	Low	248	Moderate
49	Low	149	Low	249	Low
50	Low	150	Low	250	Moderate
51	Low	151	Low	251	Low
52	Low	152	Low	252	Moderate
53	Low	153	Low	253	Low
54	Low	154	Low	254	High
55	Low	155	Low	255	High
56	Moderate	156	Low	256	High
57	Low	157	Low	257	Moderate
58	High	158	No access	258	Moderate
59	Moderate	159	Low	259	Low
60	Moderate	160	Low	260	Low
61	Moderate	161	Low	261	Moderate
62	Low	162	Low	262	Moderate
63	Low	163	Low	263	Low
64	Moderate	164	Low	264	Moderate
65	Low	165	Low	265	Moderate
66	Low	166	Low	266	Low
67	Low	167	Low	267	Moderate
68	Low	168	Moderate	268	Low

Wetland Site	Habitat Quality	Wetland Site Cont.	Habitat Quality Cont.	Wetland Site Cont. II	Habitat Quality Cont. II
69	Low	169	Low	269	Low
70	Low	170	No access	270	Low
71	Low	171	Low	271	Low
72	Low	172	Low	272	Low
73	Moderate	173	Low	273	Low
74	Low	174	Low	274	Low
75	Low	175	Low	275	Low
76	Low	176	Low	276	Low
77	Low	177	Low	277	Low
78	Low	178	Low	278	Low
79	Moderate	179	Low	279	Low
80	Low	180	Low	280	High
81	Low	181	Moderate	281	Low
82	Moderate	182	Low	282	Moderate
83	Low	183	High	283	Low
84	Low	184	Low	284	High
85	Low	185	Low	285	High
86	Low	186	Moderate	286	No access
87	Low	187	Low	287	Moderate
88	Low	188	Low	288	Moderate
89	Low	189	High	289	Low
90	Low	190	Low	290	Low
91	Low	191	Low	291	Low
92	Low	192	Low	292	Low
93	Low	193	Low	293	Moderate
94	Low	194	Moderate	294	Low
95	Low	195	Moderate	295	Low
96	Low	196	Moderate	296	Low
97	Low	197	Low	297	Moderate
98	Low	198	No access	298	Moderate
99	Low	199	Low	-	-
100	Low	200	Low	-	-