

**Evaluating risk of Brolga collisions
with powerlines for the proposed
Stockyard Hill Wind Farm**

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Biosis Research

**Report to Stockyard Hill Wind Farm Pty.
Ltd.**

**Evaluating risk of Brolga collisions
with powerlines for the proposed
Stockyard Hill Wind Farm**

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SUMMARY

Stockyard Hill Wind Farm Pty. Ltd. is in the process of developing the Stockyard Hill Wind Farm, near Skipton in Victoria. An assessment is provided here of the potential risk to Brolgas of collisions with a proposed powerline to connect the wind farm to the electricity grid. Brolgas are considered to be at risk during occupation of breeding locations near the northern portion of the powerline.

Available data about Brolgas and the powerline, along with information from investigations of the interactions of other crane species with powerlines, has been used to provide a methodology for the assessment. Due to various uncertainties in available information, a conservative approach has been adopted by incorporation of values that are more likely to overestimate risks than to underestimate them.

Results suggest that an approximate average of 0.0324 Brolgas per annum may collide with the proposed powerline.

Population Viability Analysis has used the results of this assessment and previous modelling of collisions with wind turbines at Stockyard Hill to determine implications to the Victorian Brolga population.

Measures to reduce the potential for powerline collisions and to mitigate the combined effects of turbine and powerline collisions are discussed.

1.0 INTRODUCTION

Stockyard Hill Wind Farm Pty. Ltd. is in the process of developing a wind energy facility named Stockyard Hill Wind Farm near Skipton in Victoria. In order to better assess the potential impact of this developments on the Brolga *Grus rubicundus*, studies by Brett Lane and Associates (2008) have collected data about the birds' utilisation of the wind farm area and the local region during 2007 and 2008. Additional contextual and historical information about Brolga use of the area has also been made available from databases held by the Department of Sustainability and Environment.

Biosis Research has been commissioned to use available information from those sources to provide an evaluation of the potential risks to Brolgas of collisions with powerlines proposed to be installed to connect the wind farm to the electricity grid. A number of recent and former Brolga breeding sites are close to the proposed powerline and they are largely concentrated toward its northern extremity near the proposed wind farm.

The Brolga is the only species of crane to inhabit Victoria and the population is listed as threatened in Victoria under the Flora and Fauna Guarantee Act and is assigned the conservation status of vulnerable by DSE (2007).

A separate report provides an assessment of the potential risks to Brolgas of collisions with wind turbines (Biosis Research 2008).

1.1 Process for assessment of collision risk for Brolgas

Assessment of the potential for Brolga mortalities to occur as a result of collisions with wind turbines and powerlines proposed for the Stockyard Hill Wind Farm, and of the consequent potential effect on the Victorian Brolga population, has been a collaborative process requiring a number of steps as outlined below.

Draft Guidelines for evaluation of the possible effects of wind farms in south-western Victoria have been under development by the Victorian Brolga Wind Farm Scientific Panel led by DSE, whilst the assessment for the proposed Stockyard Hill Wind Farm project has been underway. The assessment for Stockyard Hill has entailed liaison throughout with DSE and has followed the processes outlined in the Draft Guidelines.

The Victorian Brolga population is estimated at between 400 and 600 birds with the great majority of the population centred on the south-western volcanic plains. Habitat suitable for Brolgas has quite specific characteristics including shallow wetlands and meadows traditionally used for breeding and flocking. The birds also forage out from wetlands into low-lying pasture and cropped agricultural

land. Availability of suitable wetlands is heavily influenced by drought and, more permanently, by drainage works. Outside of the flocking season pairs of Brolgas are territorial and do not tolerate close proximity of other Brolgas. As a result of these factors Brolgas are relatively scarce and widely dispersed even in suitable areas of their range for much of the year. During the annual flocking season they congregate at a few key sites. As a consequence, there is limited capacity for ornithologists to obtain a large body of numerical data for Brolga utilisation from field observations.

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

Records of Brolgas were obtained from the area encompassed by the proposed Stockyard Hill Wind Farm and adjacent areas during fieldwork undertaken by Brett Lane & Associates. From early in the assessment program it was recognised by DSE that collection of a large body of empirical data for Brolgas was not feasible. Thus field data collected for the project was obtained with the primary purpose of providing information about current Brolga use of the area as an adjunct to pre-existing records for the area. It also obtained some key information, such as records of Brolga flight heights, for which no previous information existed. Monitoring of Brolgas was naturally concentrated on areas used by the birds. Its results apply only to areas of habitat for the birds and are not indicative of their use of the great majority of the landscape of the proposed wind farm which is not suitable habitat for them.

Collision risk assessments for Brolgas have been undertaken on the basis of informed scenario modelling. The scenarios have been informed by general ornithological knowledge and published information about the biology of the south-western Victorian Brolga population; previous database records of Brolgas from the relevant area; and specific information obtained from the field by Brett Lane & Associates.

Algorithms and mathematical computations for some key inputs to collision risk modelling, such as for the lengths and heights of Brolga flights, were determined by Symbolix on the basis of data provided by Brett Lane & Associates. Due to uncertainties and the likelihood of variables that were not encompassed by the available field data, a level of conservatism was introduced by the use of an 80 percentile confidence boundary on values derived from the field data.

The rationale, parameters and values used for various scenarios for the different

seasonal activities of Brolgas are described in this powerline collision assessment report and turbine a collision assessment report prepared by Biosis Research. Predictions of mean annual numbers of Brolga fatalities that might occur under the scenarios modelled were calculated using the Biosis Research deterministic collision risk model.

Potential numbers of Brolga mortalities predicted by the model were provided to Dr Michael McCarthy of Melbourne University and input into a Brolga Population Viability Analysis model. This demographic model evaluated the effect of predicted mortalities on extinction risk for the Victorian Brolga population.

The collision risk model and population viability analysis are predictive mathematical models. All such models are mathematical representations designed to represent what might occur in reality. They are transparent in that every parameter and values used as inputs to the models are defined and explicit.

Collision risk modelling accounts for a range of factors that describe how wind turbines will function based on multiple specifications of their physical dimensions, geometry, movements and positioning in the landscape. It also accounts for the expected flights of Brolgas in the area of the wind farm including their frequency, heights and distance according to the birds' seasonal behaviours. Using this information the model provides forecasts for an annual average number of interactions between Brolgas and turbines that pose a risk of collision. A similar process has been applied to model risk of collisions with the powerline proposed to transfer electricity from the wind farm to the power grid, and is the subject of the present report.

Population viability analysis uses information about the demographic functioning of a wildlife population, including rates of survival, mortality, fecundity, immigration and emigration to evaluate the threats faced by the species in terms of its risks of extinction or decline. In the present case it has been used to evaluate the potential influence of mortalities that might occur due to the wind farm on extinction risk for the Victorian Brolga population.

1.2 Background to crane collisions with powerlines

Avian collisions with overhead electricity supply lines occur around the world and there is now a substantial literature about the issue. *An Annotated Bibliography of Avian Interactions with Utility Structures* covering the issue is online at http://www.energy.ca.gov/research/environmental/avian_bibliography/retrieve_advance1.php?findall=findall.

Substantial mortality due to collisions has been reported, particularly where powerlines intersect areas of concentrated bird activity, and especially affects larger-bodied species. Powerlines near wetlands that are heavily utilised by large waterbirds are prone to high rates of collision.

A few studies have been made of the problem as it relates to various species of cranes, some of which are closely related to the Brolga. However, no detailed investigation has been made of Brolga interactions with powerlines in Australia. Ideally, it would be useful to have information about the geography of collisions, frequency of collisions relative to powerline designs and correlations of collisions with habitats, age and sex of Brolgas involved in collisions.

There is evidence from some species of cranes that incidence of collisions may differ between low voltage distribution lines and larger, higher voltage powerlines. A difference between types of powerlines has been documented in a study of Sarus Cranes *Grus antigone* in India (Sundar and Choudhury 2005). The Sarus Crane is the species most closely related to the Brolga. Values from their study indicate that supply lines were responsible for about 8.5 times more fatalities per kilometre than high tension powerlines. Other authors have reported similar trends for Grey-crowned Cranes and Wattled Cranes in South Africa (McCann and Wilkins 1995), while the reverse was documented for Sandhill Cranes in the U.S.A. (Ward and Anderson 1992) and Blue Cranes (McCann and Wilkins 1995).

Information about Brolga flight heights (Brett Lane & Associates 2008) suggests that they fly within the height zone of low voltage distribution lines much more often than at other heights and distribution lines are likely to be involved in more Brolga collisions than higher powerlines. Distribution lines are often of one or two strands and may be less easily seen than multiple, larger diameter wires on higher tension powerlines.

Upper-most lightning ground wires on high tension lines are also apparently dangerous because they are of smaller diameter than the power transmission wires lower on the structure. They may thus be less easily seen as birds climb to pass over the more visible lower wires.

Large birds, like cranes, may die as a result of electrocution or from traumatic injury resulting from impact of collision if they come into contact with electricity lines. However, unlike some other groups of birds, cranes do not routinely perch on power poles or wires and electrocution is likely to occur only as a result of a flying Brolga colliding with wires. There is also a body of experience indicating that single-strand distribution lines result in substantially more crane mortalities than do transmission lines with multiple wires. Electrocution is much less likely to occur in single-stand lines than in transmission lines with multiple wires.

While non-fatal collisions may occur in the absence of electrocution and thus electrocution may be a secondary event that results in death of a bird that otherwise might not have occurred, all such events involve in-flight collision. Electrocution can be minimised by design of powerlines, however for the purposes of evaluating the impacts of powerlines on Brolgas, no distinction is made here between electrocution and collision that does not involve electrocution.

1.3 Approach to assessment of Brolga powerline collisions

Brolgas are known to occasionally fatally collide with powerlines in Victoria, although published documentation of this is limited and is not recent (White 1987; Goldstraw and du Guesclin 1991). There is no empirical data about Brolga collisions with powerlines in south-western Victoria that might provide a basis for quantifying them. In the absence of empirical data, an approach has been devised to assess potential risk that is based on available information. This includes:

- Data from the local Brolga population quantifying numbers of flights made by individual Brolgas per annum at breeding site and nearby flocking sites and the lengths of those flights (Brett Lane and Associates 2008);
- data from the local Brolga population quantifying the number of birds using breeding sites per annum (Brett Lane and Associates 2008);
- distances from core of breeding territories and a single intermittently used flocking site to the nearest location of the proposed powerline for all Brolga sites within five kilometres of the powerline (Brett Lane pers. comm. 2008); and,
- a collision rate for powerline crossings, based on studies of other crane species reported in the international literature.

The approach adopted has been developed in consultation with DSE in south-western Victoria, Dr. Michael McCarthy of the University of Melbourne and Dr. Stuart Muir of Symbolix.

The annual cycle of Brolgas in south-western Victoria encompasses the breeding season, and, for most birds, a period of ‘migration’ to flocking locations where they reside for a period, and subsequent return ‘migration’ to breeding sites. Breeding and flocking occurs at discrete locations within relatively local regions where distances between them may be measured in tens of kilometres or less. Brolgas are known to occur in proximity to the proposed powerline for the

Stockyard Hill Wind Farm only whilst at breeding sites.

Models for assessment of the impacts on bird populations of collisions with wind turbines have been fully developed and are widely applied in risk assessment. A search has failed to locate any extant mathematical models designed to evaluate the risks of collisions with powerlines, despite the fact that the problem has been widely investigated for numerous bird species around the world. This may, in part, be due to perceived difficulties associated with the fact that powerlines are static which means that all variables to be modelled relate to the vagaries of bird behaviours and, unlike wind turbines, none relate to the movements of the structures themselves. The assessment used here may be limited by assumptions it incorporates and a more sophisticated model could potentially be developed when better information about Brolga interactions is available from field studies.

A Population Viability Analysis (PVA) has been developed as a means to assess potential effects of wind farms on the viability of the south-western Victorian Brolga population (McCarthy 2008). PVA modelling also provides a mechanism to evaluate positive effects of various mitigation options against predicted negative effects on the population. Results of this collision risk assessment have been provided for input to the PVA model.

2.0 METHODS

2.1 Brolga population and movements

Investigations of Brolga utilisation for Stockyard Hill Wind Farm are detailed in Brett Lane and Associates (2008). That work provided data and analyses of the numbers of Brolgas occupying breeding sites and numbers of flights made by individual Brolgas at breeding and flocking sites and the lengths of those flights.

Estimates of the numbers flights made by Brolgas per breeding season and a derived mean number of flights per bird are as provided by Brett Lane (pers. comm.).

Data for the lengths of Brolga flights was used to calculate the mean percentage of all flights that would be long enough to reach or cross the powerline, given it runs in a straight line past a breeding or flocking site at a specified minimum distance. While the longest flight recorded during the field investigation was 3.2 kilometres, this may have been limited by the capacity of observers to record movements of Brolgas beyond a certain distance (Brett Lane pers. comm.). However the data for the numbers of flights of all distances recorded during breeding and flocking periods allow extrapolation using a 'decay curve' which indicates that flights rarely, if ever, exceeded five kilometres in length.

2.2 Proximity to proposed powerline

The distance from the core breeding location to the nearest point on the powerline was determined for each recorded breeding or flocking site located within five kilometres of the proposed powerline by Brett Lane (pers. comm.). A total of 19 breeding locations and a single flocking site were included in the pool of sites that fitted the criteria.

The mean shortest distance from the core of each breeding territory to the proposed powerline was calculated for each of the 19 breeding territories.

Since empirical data for Brolga activity in and near the site have been obtained only during 2007 and 2008, it is possible that they are not truly representative of longer timeframes encompassing different conditions. With this in mind, confidence limits have been placed on values derived from Brolga movement data (Symbolix 2008) and the 80% confidence bound has been applied to data to determine input values used for modelling. This is considered appropriate to cover a range of realistic variables that might occur.

2.3 Determining collision rate for powerline crossings

Brolgas are known to occasionally fatally collide with powerlines in Victoria, although published documentation of this is limited and is not recent (White 1987; Goldstraw and du Guesclin 1991). There is no empirical data about Brolga collisions with powerlines in south-western Victoria that might provide a basis for quantifying the frequency of collisions relative to the number of powerline crossings the birds make.

In the absence of information for Brolgas, a review of international literature about collisions by other species of cranes has been made. There is a substantial literature about bird collisions with powerlines, however there are relatively few rigorous studies that have attempted to quantify rates of collision and fewer still of them have investigated effects on cranes.

Two published studies provide calculated rates or values from which rates could be calculated for the number of powerline crossings that resulted in collisions. Janss and Ferrer (2000) studied the Common Crane and Morkill and Anderson (1991) studied the Sandhill Crane. These investigations were both substantial and encompassed thousands of potential interactions by cranes with powerlines. These studies of cranes that provide quantified rates of collision with powerlines have been used to provide 'benchmark' values for the purposes of evaluating possible collision rates for Brolgas.

2.4 Calculating risk

The potential number of Brolga mortalities per annum that might result from collisions with powerlines was calculated for breeding sites and one flocking site as set out below and shown in Figure 1.

Breeding sites

For breeding seasons, the average number of individual Brolgas present in breeding territories and that had capacity to fly far enough to reach or cross the powerline was multiplied by the mean number flights made by an individual bird per breeding season, as supplied from Brolga movement data collected and provided by Brett Lane & Assoc. (2008). This provided an annual average total for the number of Brolga flights per breeding season.

There are records of a total of 19 Brolga breeding territories within five kilometres of the proposed powerline. Most of these are historical sites and records indicate that relatively few are occupied in any given year. Brolgas used six of these territories in 2007/2008. For the purposes of determining an average annual population that has potential to encounter the powerline, we have assumed

that an average of eight breeding territories might be occupied per annual breeding season.

The mean annual breeding population for eight sites would be 16.8 birds. This is comprised of 16 adult birds and an annual average of 0.8 juveniles. The number of juveniles has been derived as follows. Chicks of a given breeding season are at minimal risk in that season because they generally are not fledged until late in the breeding season. However, many fledged juveniles remain with parents for up to 11 months (Marchant & Higgins 1993) and thus may be at risk in a substantial portion of their second season. Population ratio of juveniles to adults is estimated at 0.05 (Herring 2001 *in* McCarthy 2008). There is thus an expected average of 0.8 juveniles that are likely to be in company with 16 adults per annum. Thus we have an average total of 16.8 birds at risk per annum. We have no basis on which to differentiate risk for adults and first-year juveniles, so risk prediction for the two age-classes is directly proportional to ratio of adults to juveniles in the population.

Records of Brolga movements indicate that, on average each bird makes 220 flights during a breeding season.

The percentage of Brolga flights that might reach or cross the powerline for each territory is shown in the right hand column of Table 1, below.

Table 1. Geometric values for each Brolga breeding territory used to determine percentage of flights with potential to encounter the proposed powerline.

Site	Distance to powerline from territory centre	Percentage of flights greater than the apothem	Ratio of available space involving crossing a power line	% of flights crossing the powerline route
1	1750	13.19%	32.12%	4.24%
2	1590	14.67%	33.49%	4.91%
3	2100	10.54%	29.23%	3.08%
4	420	37.62%	44.98%	16.92%
5	2190	9.97%	28.50%	2.84%
6	1230	18.87%	36.72%	6.93%
7	1050	21.59%	38.42%	8.29%
8	190	50.19%	47.65%	23.92%
9	1040	21.75%	38.52%	8.38%
10	1340	17.44%	35.71%	6.23%
11	1170	19.72%	37.28%	7.35%
12	1430	16.37%	34.90%	5.71%
13	1180	19.58%	37.19%	7.28%
14	450	36.44%	44.64%	16.27%
15	1910	11.89%	30.78%	3.66%
16	1270	18.34%	36.35%	6.67%
17	2320	9.20%	27.47%	2.53%
18	2530	8.10%	25.83%	2.09%
19	1000	22.43%	38.91%	8.73%

For the 19 territories, the mean percentage of flights that might encounter the powerline is 7.69%, with 95% confidence that the average is less than 10.29%.

Flocking sites

No traditional and routine flocking sites are known from within 5 kilometres of the powerline route. However, temporary short-term flocking has been recorded occasionally at other locations. One such intermittent flocking site is centred 1.83 kilometres from the powerline at Witteran Swamps. Eight Brolgas were recorded there in February 1996, 12 birds were there in March 1996 and 8 birds were recorded there again in 1997. There is no documentation of its use before or since.

Because no data are available for Brolga movements at any intermittent flocking events, modelling has been undertaken using data recorded at traditional flocking

sites by Brett Lane & Assoc. (2008) as surrogate measures of numbers and heights of Brolga flights that might occur during one-off flocking events. The frequency and duration of flocking events at the single location near the powerline has been modelled on the basis of those observed in the past twenty years at Lake Goldsmith.

For the purpose of this assessment we have assumed that it is used intermittently on average by 12 birds, each of which makes four foraging flights per day for 21 days, once every five years.

Using the processes to determine proportion of flocking Brolga flights that might reach or cross the powerline route, as outlined for breeding sites, an estimated 3.94% of Brolga flights will do so.

Calculation of flights at risk

The total number of Brolga flights per breeding season and per flocking occasion was multiplied by the percentage of flights that were of sufficient length to reach or cross the mean distance to the powerline, given that it runs in a straight line past the breeding site at a specified minimum distance.

This calculation provides an annual average number of Brolga flights that might cross the powerline route.

Finally, the annual average number of Brolga flights that might cross the powerline route was multiplied by a proportion of powerline crossings that might result in a collision.

On the assumption that every powerline collision results in a fatality, the final value is considered to represent a potential number of Brolga mortalities that could occur per annum.

Based on values provided by Morkill and Anderson (1991), we have calculated that they recorded 2.5 collisions per 100,000 powerline crossings by Sandhill Cranes (2.5×10^{-5} collisions per crossing). Janss and Ferrer (2000) provide estimate values ranging from 1.9 to 4.76 collisions per 100,000 powerline crossings by Common Cranes (from 1.9×10^{-5} to 4.76×10^{-5} collisions per crossing).

These published studies of cranes are the closest comparable information available for evaluation of the situation for Brolgas. However, we do not know how closely Brolga behaviour conforms with that of these other species. In order to provide a conservation approach we have chosen to use 1 collision per 10,000 powerline crossings (1.0×10^{-4} collisions per crossing) for our evaluation of risk to Brolgas

3.0 RESULTS

Following the methods outlined above we have the following equations to determine a potential annual number of Brolga fatalities that might occur as a result of collisions with the proposed powerline:

Breeding sites

16.8 birds in the population x 220 flights per bird x 7.69% of flights that could cross the powerline route x 1.0×10^{-4} collisions per powerline crossing.

The result for breeding sites is 0.0284 potential Brolga fatalities per annum.

Flocking site

12 birds in the population x 84 flights per bird x 3.94% of flights that could cross the powerline route x 1.0×10^{-4} collisions per powerline crossing.

The result for flocking site is 0.0040 potential Brolga fatalities per annum.

Combined total Brolga mortality estimate

The result for the combination of breeding sites and the single flocking site is 0.0324 potential Brolga fatalities per annum, which equates to approximately one Brolga per 30 years.

The annual average value predicted by the model is a forecast over the long-term and the model does not have capacity to predict the frequency distribution of such events. It would be perfectly within the bounds of probability and the average prediction of the model, that no Brolgas might be killed over a period very much longer than 30 years or equally that multiple birds might be killed in a single year. The value of the model's prediction is that, based on the assumptions used, it allows an evaluation to be made of the long-term average of impacts on the species.

4.0 POPULATION VIABILITY ANALYSIS

A species-specific Population Viability Analysis (PVA) model has been developed for the Victorian Brolga population (McCarthy 2008). Using inputs from turbine collision risk modelling (Biosis Research 2008) and results contained in the present report for powerline collisions, it has now been applied to assess impacts of the proposed Stockyard Hill Wind Farm on the Brolga population (McCarthy 2009).

It is intended that any reduction of the Brolga population resulting from development of the Stockyard Hill Wind Farm will be mitigated by management actions so that there will be, at most, a zero net impact on the population (DSE 2008). The present assessment indicates that the annual Brolga mortality associated with the proposed powerline may be in the order of 0.0324 birds. The modelled estimates of annual deaths due to collisions with wind turbines range from 0.196 to 0.026, and an estimate of 0.101 is considered to be ecologically reasonable (Biosis Research 2008).

Based on demographics of the Victorian Brolga population, assuming 600 birds, and assuming an upper limit of 0.2 Brolga deaths per annum due to collision with turbines, and 0.0324 deaths per annum from powerline collisions, McCarthy (2009) has calculated that this combined predicted loss of birds due to turbine and powerline collisions at Stockyard Hill equates to an addition to the population's annual mortality rate of less than 0.039% per annum. PVA modelling suggests that an increased rate of annual recruitment to the adult population of approximately 1% would be sufficient to mitigate mortality due to the predicted collisions.

The expected loss of Brolgas due to collisions equates to approximately one adult bird every five years. Obviously, as mentioned by McCarthy (2009), the increase required to compensate for the expected loss is also small and unlikely to be measured with precision. Within the Victorian population of approximately 600 birds, this level of impact is very small and would be completely masked by natural demographic variability. Nonetheless, it is the intent that there should be no impact on this vulnerable population and the present work is aimed at informing decisions to ensure that this is achieved.

5.0 REDUCTION OF IMPACTS & MITIGATION MEASURES

A variety of potential management actions could be instigated to effectively mitigate Brolga mortalities due to collisions with turbines and powerlines.

5.1 Effectiveness of marking powerline wires

Some types of line markers designed to increase the visibility of wires, have been shown to substantially reduce incidence of collision. Morkill and Anderson (1991) measured reactions of Sandhill Cranes to marked and unmarked lines, rather than differences in mortality rates. Markers were 30 cm yellow balls with black stripe positioned at 100 m intervals. Cranes were significantly more likely to increase altitude in response to marked versus unmarked lines and initiated their change in height further away from the lines.

Alonso et al. (1994) measured differences in mortality rates of Common Cranes at marked and unmarked powerlines. Markers were red PVC spirals 1 m long and 30 cm maximum diameter positioned on groundwires at 10 m intervals. They found that collisions by all bird species decreased by 61% after the installation of markers. Their sample size for cranes appears too small for the difference to be statistically significant but collisions were lower for marked lines.

Janss and Ferrer (1998) measured differences in mortality rates of various bird species for three different line markers. Results for Common Crane were only recorded with white PVC spirals 1 m long and 30 cm max diameter positioned on groundwires at 10 m intervals. Results were ‘convincing (eight dead under unmarked spans, one under marked span) but not significant’.

It is expected that appropriate marking of powerline wires will also reduce the frequency of Brolga collisions with lines, but that has not been tested for this species and we do not know by how much they might be reduced.

5.2 Potential for line-marking at Stockyard Hill

The assessment here of potential collisions with the proposed powerline has been undertaken for unmarked powerlines. To reduce the incidence of collisions, it is recommended that the uppermost wires should be marked in the sectors of this line that pass through each breeding site within a five kilometre radius of the powerline and known to have been occupied by Brolgas within the past ten years.

Mitigation of the residual effects of collisions on the population may be

achievable by marking of additional powerlines. In the study of Sarus Cranes by Sundar and Choudhury (2005), collisions with low voltage distribution lines occurred many times more frequently per unit of powerline length than they did with larger, higher voltage lines. Marking lines near well-used flocking sites anywhere within the population's range is likely to be more effective in reducing collision risk than at breeding sites because much larger concentrations of Brolgas utilise flocking locations.

Without information about the actual value of line marking for Brolgas, the exact amount of lines that should be marked cannot be determined with precision. The best approach therefore will be to mark sufficient length of powerlines in relevant locations to be sure of over-mitigating. Using the rule of thumb that collisions with distribution lines can be expected to occur more frequently than they do with the new high voltage powerline, it is reasonable to assume that marking a length of low voltage lines in the existing distribution network equivalent to the length of the new high voltage line in proximity to breeding and/or flocking sites will more than mitigate for mortalities caused by collisions with turbines and the new powerline. Advice should be sought from DSE about locations where powerline marking is likely to be most effective.

5.3 Alternative mitigation options

Burying powerlines would be a complete resolution to powerline collision risk at key locations. It may be applicable to some existing distribution lines in close proximity to Brolga flocking or breeding sites.

Alternatives to marking or placing powerlines underground could take the form of reduction of introduced predators of Brolgas, reservation of additional Brolga habitat or improved management of existing habitat, such as management of water at key sites in favour of Brolgas. Such measures might be of greater benefit to the Brolga population than measures to reduce powerline collisions, but quantifying the effects on the population would be difficult and would not be directly measurable against the effects of powerline collisions.

Instigation of any of these potential mitigation measures would be at the discretion of relevant authorities and guidance from DSE should be sought in planning any of them.

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