Amendment Report

WITBERG WIND ENERGY FACILITY

Prepared for:

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1 EXECUTIVE SUMMARY

This study contains an appraisal of the amendments made for the proposed Witberg Wind Energy Facility and their likely impacts on the avian community, particularly the eagles. The avian component was previously reported on in 2012, following six site visits (Anchor Environmental 2012) and the use of the area specifically by juvenile Verreaux's Eagles, in 2014 over four site visits (Simmons and Martins 2015), including Collision-Risk Modelling (CRM: Percival 2013). The original 70 turbines of 80-m hub height (HH) proposed by the developer, Witberg Wind Power (Pty) Ltd, in 2012, was reduced on appeal to the minister to 27 turbines of 92-m HH following the CRM and public comment. The following changes are requested and their impacts on the avifauna assessed: (i) a decrease in the number of turbines to 25; (ii) a 30% increase in hub height of the turbines from 92-m to 120-m; and (iii) a 17% increase in rotor diameter from 116-m to 136-m. This may influence species there, both positively and negatively.

Literature surveys suggest that the effect of the changes proposed on the authorised project are expected to be mainly negative because of the statistically significant increase in collisions for higher turbines (Loss et al. 2013, Simmons et al. MS). However, the Collision-Risk model (CRM) based on site-specific avifaunal data suggested lower eagle fatalities (Percival 2018, 2019). This may affect a suite of collision-prone birds highlighted by Turpie et al. (2012) and Simmons and Martins (2015), particularly the Verreaux's Eagles that breed in the area. Thus, impacts with the blades of the wind turbines, and the associated power line network, are the biggest potential risks with turbines placed on the upland ridges or near foraging areas. Theoretically, if the rotor blade length is doubled, a four-fold greater risk area is created if the turbines are placed in areas used by the species of concern. If hub height is also increased then birds flying higher could be impacted. A meta-analysis from North America reported a strongly significant effect of increased hub height on proportionately more avian fatalities, in a large sample of wind farms with turbines up to 80-m hub height. Our statistical modelling using data from North America and including South African turbines (not Witberg wind farm data) with hub heights up to 92-m found that avian fatalities are forecast to double for turbines increasing from 92-m to 120-m hub height. However, to consider site specific data, a CRM was prepared by Dr S. Percival using the Band et al (2007) method. To implement the precautionary principle and since the CRM estimated 0.28 Verreaux's Eagle adult and juvenile fatalities annually (Percival 2018, 2019) with taller turbines, we conclude that by combining the two models we estimate that, on average, 0.56 Verreaux's Eagles *Aquila verreauxii* and 0.08 Booted Eagle *Aquila hieraetus* fatalities will occur per year. Further mitigations are required if the level of eagle fatalities exceeds 1.0 Verreaux's Eagle per year to reach acceptable levels. Potential mitigations recommended for risky turbines include black-blade painting and shut-down-on-demand.

Birdlife South Africa (BLSA) guidelines (Ralston-Paton 2017) dictate that turbines within 3.0-km of Verreaux's Eagle nests can only be justified with detailed avifaunal surveys. Our surveys show almost no use of the area around eagle nest 1 by the adult or juvenile eagles (7 flights in 333 hours of detailed monitoring in 2.5 years), suggesting very low risk to the birds there. However, BLSA do not allow turbines within 1.5 km of any eagle nests, and this has been complied with in the latest amended 25-turbine layout provided in August 2018.

The impact zone of the originally proposed facility lies in montane areas of the Karoo biome, an area that holds a suite of southern African endemic birds and some Red Data species (e.g. eagles, harriers and cranes). Previous surveys indicated that 11 collision-prone species (CPS) occur in the area of which five are Red Data species. The passage rate of the Verreaux's Eagles along the whole Witberg Ridge was high at 0.84 birds/hour. However, within the present 1.5-km buffers around each eagle nest a very low Passage Rate of 0.021 eagles/hour was recorded within the 3-km buffer.

In a follow-up site visit in February 2019, we ascertained that despite an extensive wild fire and a 2-year drought negatively influencing the habitat, the presence of eagles and their nests remained un-affected in either their number or position. Passage Rates had decreased to 0.21 eagles per hour.

Detailed construction and post-construction monitoring, is required to determine the effectiveness of the suggested mitigations. Operational-phase monitoring is essential to determine the actual impacts on birds and, therefore, the required mitigation measures and thresholds. Such an approach requires a flexible Adaptive Management Plan to be implemented during operation. This plan must allow for: (i) changes to be implemented within a time-frame of 3-4 weeks; (ii) the wind farm has agreed to follow the mitigation measures as suggested by the Minister of Environment; and (iii) in accordance with the Adaptive Management Plan and the Environmental Authorisation, appropriate mitigation measures, such as black-blade painting or curtailment during specific environmental conditions or during high risk periods will be implemented. If the data show that more than one Red Data species is killed per year on the wind farm, then additional appropriate technology needs to be implemented at that turbine, as set out in the original EA. If these recommendations, and those of BLSA are followed, we see no reason why the Witberg wind farm cannot be developed.

1.1 Consultant's Declaration of Independence

Dr Rob Simmons of Birds & Bats Unlimited is an independent consultant to Witberg Wind Power (Pty) Ltd. He has no business, financial, personal or other interest in the activity, application or appeal in respect of which he was appointed other than fair remuneration for work performed in connection with the activity, application or appeal. There are no circumstances that compromise the objectivity of this specialist performing such work.

1.2 Qualifications of Specialist Consultants

Dr Rob Simmons, of Birds & Bats Unlimited Environmental Consultants (http://www.birds-and-bats-unlimited.com/) was approached to undertake the specialist avifaunal addendum to the Avian Impact Assessments to determine the implications of changes in the number, size and blade swept areas of the wind turbines proposed at the Witberg Wind energy facility, Western Cape. Dr Simmons is an ecologist and ornithologist, with 30 years' experience in avian research and impact assessment work. He has published over 100 peer-reviewed papers and two books, (see http://www.fitzpatrick.uct.ac.za/fitz/staff/research/simmons for details). He was the State Ornithologist for Namibia's Ministry of Environment for 14-years and has undertaken more than 50 avian impact assessments in Angola, Namibia, South Africa and Lesotho. He also undertakes long-term research on threatened species (raptors, flamingos and terns) and their predators (cats) at the FitzPatrick Institute, UCT. He supervises PhD students studying the ecology of threatened raptors (harriers and vultures) and statistical approaches to recording avian impacts at wind farms.

Marlei Martins, co-director of Birds & Bats Unlimited, has eight years' consultancy experience in avian wind and solar farm impacts as well as environmental issues, and has been employed by several consultancy companies throughout South Africa because of her expertise in this field. She has published papers on her observations including a new species of raptor to South Africa (http://www.birds-and-bats-unlimited.com/).

2 TERMS OF REFERENCE

The Terms of Reference for the avian impact assessment are to:

Compile an addendum to the 2012 and 2015 specialist avian reports addressing the following:

- The implications of the proposed amendments in terms of the potential impact(s);
- A re-assessment of the significance (before and after mitigation) of the identified impact(s) in light of the proposed amendments (as required in terms of the 2014 EIA Regulations) for the construction and operational phases, including consideration of the following:
    - Cumulative impacts;
    - The nature, significance and consequence of the impact;
    - The extent and duration of the impact;
    - The probability of the impact occurring;
    - The degree to which the impact can be reversed;
    - The degree to which the impact may cause irreplaceable loss of resources;
    - The degree to which the impact can be avoided, managed or mitigated.

This addendum to the 2013 and 2015 reports should include an impact summary table outlining the findings of the re-assessment in terms of the above-mentioned assessment criteria.

- A statement as to whether the proposed amendments will result in a change to the significance of the impact assessed in the original EIA for the proposed project (and if so, how the significance would change);
- A detailed description of measures to ensure avoidance, management and mitigation of impacts associated with the proposed changes;
- An outline of the potential advantages and disadvantages of the proposed amendments in terms of potential impacts ;
- Provide confirmation as to whether the proposed amendments will require any changes or additions to the mitigation measures recommended in our original specialist report. If so, provide a detailed description of the recommended measures to ensure avoidance, management and mitigation of impacts associated with the proposed amendments.
- The re-assessment must take into account the findings of the 12 months pre-construction monitoring.

2.1 Study Area

The proposed wind farm lies 10-km west of Matjiesfontein in the Witteberg mountains at S33^{o} 17' E20^{o} 26'. The ridge along which the wind farm is proposed is ~25 km long. The substrate is rocky, and the topography of the WEF is highly undulating varying from 1179-m asl to the highest point at 1452-m asl. Two wind masts, and a Sentec communication tower are the only man-made structures currently on the WEF site (pers. obs.). The study area is dominated by high wind-swept ridges and the natural vegetation is dominated by Matjiesfontein Shale Renosterveld in the valleys, and Matjiesfontein Quartzite Fynbos on the ridges (Mucina and Rutherford 2006 pp 132, 179). It lies in the Nama-Karoo biome, with habitat elements of Fynbos (e.g. proteas) and Succulent Karoo on the higher slopes.

The proposed Witberg wind farm site is situated on the farms Jantjesfontein (Farm RE/164), Besten Weg (Farm 1/150 and Farm RE/150), Tweedside (Farm RE/151), Elandskrag/Elandsfontein (Farm RE/269 and Farm 1/269).

2.2 Background

The wind farm site at the Witberg, near Laingsburg in the western Karoo was proposed by Witberg Wind Power (Pty) Ltd. It was originally planned with 70 turbines. Following the EIA and pre-construction monitoring of the possible bird impacts (Avisense 2010, Anchor Environmental 2012) it was revealed that the area held three breeding pairs of Verreaux's Eagles *Aquila verreauxii* on the ridges, and a possible breeding Martial Eagle *Polemaetus bellicosus* pair north of the ridge. Buffers of 1.5-km and 2.5-km around the Verreaux's and Martial Eagle nests respectively were suggested (following the recommendations of Avisense 2010) which reduced the number of, and altered the placement of, turbines. Birdlife South Africa, and others, as interested and affected parties (I&APs), objected to the Environmental Authorization and called for Collision-Risk Modelling (CRM) to quantitatively assess the impact to the Verreaux's Eagles there, considering it too risky to have turbines so close to active nests. That was duly undertaken by Shoney Renewables (Percival 2013), based on flight paths collected by Anchor Environmental (2012). That CRM has since been updated twice (Percival 2018, 2019).

Turbine numbers were reduced to 27 as a result of that report and further consultation, and some were moved to other locations. However, the I&AP also pointed out that no juvenile eagles were present in the environment during these exercises, so it was further recommended that additional studies be undertaken to determine flight paths and patterns of juvenile eagles to assess the risks to them. Birds & Bats Unlimited undertook those assessments (2014) and found no activity of the juvenile eagle (or the adults) over the ridges ear-marked for possible turbine positions (Simmons and Martins 2015) for the proposed Witberg wind energy facility. While this may seem unusual so close to active eagle nests, we suspect that there are too few cliffs to allow for either slope soaring by the eagles (the hills here have a rounded topography) or for their main prey (Rock Hyrax) to exist. We, thus, suggested it was safe to construct turbines within 750-m of the nest No. 1 where the eastern-most turbine on the farm was proposed.

Subsequently, in 2018, new technology introduced taller turbines that generate more power than approved in the original Environmental Authorisation.

Specifically, the proposed amendments to the authorised wind farm include the following:

- Hub height increased (30%) from 92-m to up to 120-m;
- Rotor diameter increased (17%) from 116-m up to 136-m (blades increased from 58m to 78m);
- Increased power output up to 5.0MW per turbine;
- A decrease in the number of authorised turbines from 27 to 25;
- Re-micro-siting of the remaining turbines;
- Amendment of the layout including reduction of wind turbines and relocation to avoid sensitive areas, including the relocation of infrastructure to avoid sensitive areas (i.e. substation, powerline and construction camps);
- Extension of validity period by an additional two years.

The overall generation capacity has not changed and remains at 120MW. The layout, as defined in 2015, has changed slightly as depicted in Figure 1.

2.3 Methods

All the methods employed in the original EIA study (Turpie et al. 2012) and the follow up focussed study on the active nests (Simmons and Martins 2015) are detailed in those reports. Briefly, six equally-spaced visits were undertaken in 2011-2012 covering 213 hours, followed by another 4 visits (and 160 hours) in 2014-2015. This covered 2.5 years of monitoring, satisfying BLSA's 2-year monitoring requirements for Verreaux's Eagles (Ralston 2017). It is also close to the number of hours recommended per vantage point (72 h per year) given that there were 3 VPs on the Witberg ridge and a total of 373 hours of VP observations in the WEF over 2 years. A further 28 hours in 2019 (below) gives a total of 401 hours or 66.8 hours per VP per year - not far short of the 72 hours suggested by BLSA, before the guidelines were published. Thus, our methods during the monitoring undertaken largely comply with what is now recommended for Verreaux's Eagles (Ralston 2017), allowing us to reach robust conclusions across all seasons and multiple years.

Among the comments received during the public participation conducted in November-December 2018, was that the receiving environment may have changed since the last visit in 2015, and our results may thus be "out of date". We, therefore, undertook a 3-day site visit from 9-11 February 2019 to :

(i) survey all four large eagle nests (Verreaux's and Martial) known on the site,

(ii) undertake vantage point surveys along the top ridge for flying eagles,

iii) photograph all the known eagle nests,

iv) survey by foot different sections of the veld to determine differences from 2015,

(v) meet with the two land-owners (L. Hart and J. du Plessis) to discuss local conditions.

2.3.1 Limitations

The limitations of the original reports (Turpie et al. 2012, Simmons and Martins 2015) were covered therein. For the updates in 2019 the observations were designed to assess the receiving environment and the status of the eagle nests, so they are not the typical 12h VP observations for raptors or 18 h for the Verreaux's Eagles. The number of hours spent observing amounted to 28 h of surveys.

We also note that the 2011-2012 and 2014-2015 observations were undertaken when rainfall was average or close to average, thus we can expect typical eagles breeding patterns. Rainfall after 2015 was classed as drought conditions (http://www.weathersa.co.za/climate/historical-rain-maps) potentially hindering eagle breeding. A fire swept the area of the WEF in 2016 and would have reduced the primary productivity. Since our follow-up surveys were undertaken 3 years later, however, the land had a chance to recover, even with minimal rains.

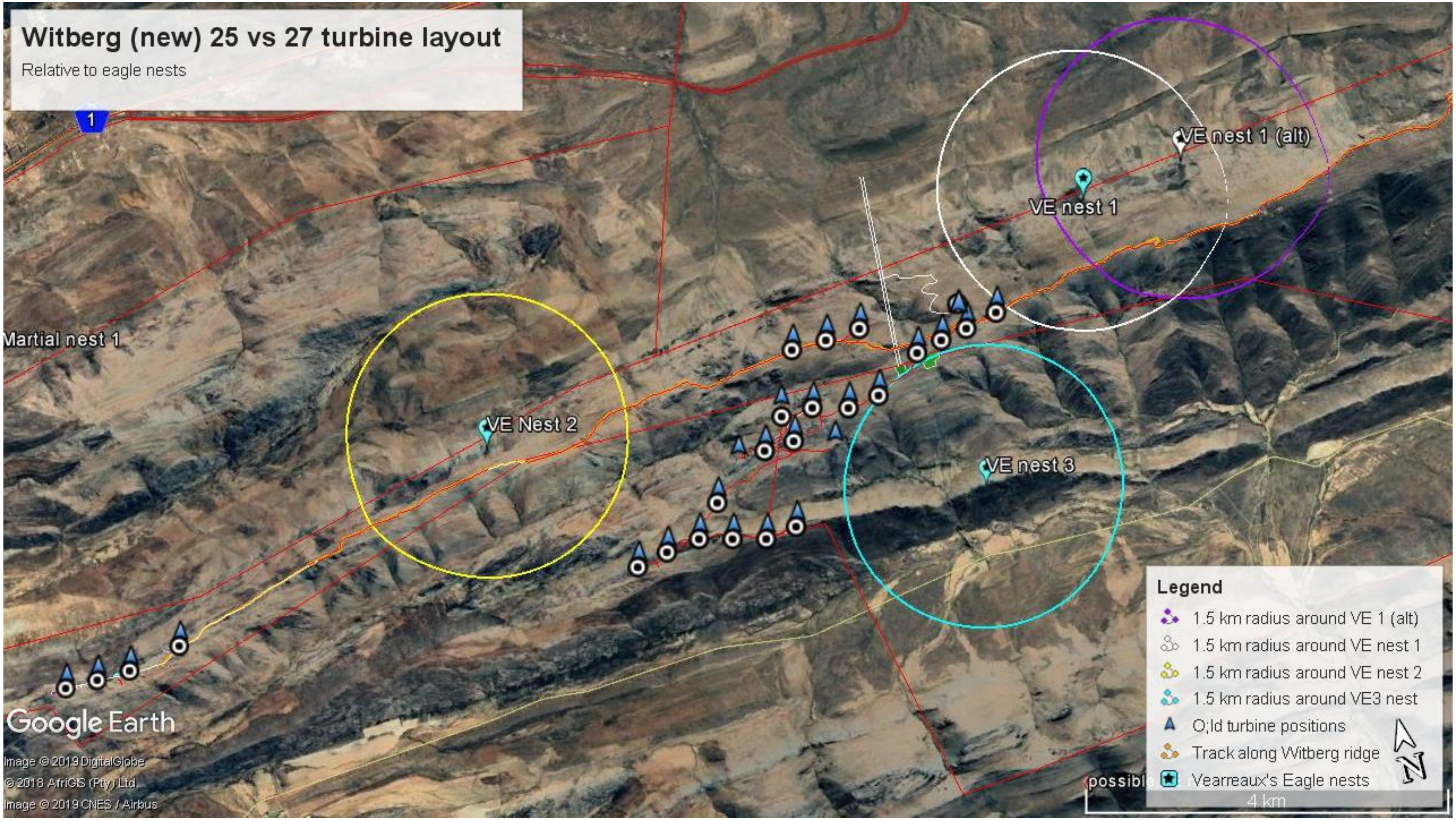

Figure 1: Turbine layout design compared: The authorised turbine design with 27 turbines (= blue arrows), relative to the new (August 2018) turbine layout of 25 turbines (= white circles) as supplied by Witberg Wind Power. All 25 turbines (and substation and lay-down areas in green) lie outside the 1.5-km radius circle shown around all known Verreaux's Eagle (VE) nests. Almost no eagle flights were recorded, even within 3-km of the nests, during all 333-h of monitoring, including the fledging period at VE nest 1.

3 SUMMARY OF FINDINGS OF THE ORIGINAL EIA REPORT

The original Witberg EIA avian pre-construction report assessed the possible impacts to birds (Turpie et al. 2012), updating the first Scoping Report by Avisense (2010). Twelve priority collision-prone species were recorded on, or around, the Witberg ridge including five Red Data species (Table 1). These species may be impacted by turbine placements – either by direct impact or disturbance and displacement. The collision-prone species included: 11 raptors (four Red Data), and one crane (Red Data) (Table 1). Of the Red Data species, the Blue Crane had a very low likelihood of occurrence on the site (Table 1), and were, therefore, deemed unlikely to be negatively affected by the turbines. Too few data were available for the other priority species to be gauged.

Table 1: Twelve priority collision-prone species and five Red Data species (Taylor et al. 2015) identified in previous avian EIA reports for Witberg (Avisense 2010, Turpie et al. 2012). Flight height is taken from field measures in the Turpie et al. (2012) and Simmons and Martins (2015). Passage Rates (bird flights per hour) were available only for Verreaux's Eagles from Simmons and Martins (2015). Reporting Rate taken from SABAP2 sourced on 3 July 2018 for three pentads along the Witberg Ridge (n = 7 full protocol cards).

				Susceptibility:	
Common Name and *Scientific Name*	**Red-list status**	**Reporting Rate***	**Passage Rate ** (mean ± 1SD)**	**Collision Rank *****	**Flight height*******
Verreaux's Eagle *Aquila verreauxii*	**Vulnerable**	**50%**	**0.84 ± 0.4**	**2**	**76%**
Martial Eagle *Polemaetus bellicosus*	**Endangered**	**3.5%**		**5**	**14%**
Black Harrier *Circus maurus*	**Endangered**	**10%**		**6**	**50%**
Blue Crane *Anthropoides paradiseus*	**Near Threatened**	**0.0%**		**11**	**n.d.**
Lanner Falcon *Falco biarmicus*	**Vulnerable**	**14.3%**		**22**	**100%**
Cape Eagle Owl *Bubo capensis*	-	**0.0%**		**41**	**n.d.**
Jackal Buzzard *Buteo rufofuscus*	-	**60.0%**		**42**	**73%**
Booted Eagle *Aquila pennatus*	-	**30%**		**55**	**51%**
Yellow-billed Kite *Milvus parasiticus*	-	**n.d.**		**60**	**0%**
Steppe Buzzard *Buteo buteo vulpinus*	-	**n.d.**		**67**	**50%**
Pale Chanting Goshawk *Melierax canorus*	-	**40%**		**73**	**33%**
African Harrier Hawk *Polyboroides typus*	-	**10%**		**85**	**50%**

* Reporting Rate is a measure of the frequency of occurrence (as reported by Avisense 2010 from 57 bird atlas cards, updated in June 2018 for this report from SABAP2).

** Passage Rate (number of birds/h) is a measure of the number of flights per hour of the priority species

*** Collision rank is taken from BLSA assessment (Ralston-Paton et al. 2017). Smaller numbers denote higher collision-risk.

**** Flight height is an estimate of the proportion of time spent at rotor-swept heights (adapted from Turpie et al 2012). Tip Height categories "Medium" [40-120] and "High" [120-150m] in Turpie et al (2012) were combined to mimic the blade swept areas that are proposed in the Amendments of 58-m to 198-m to provide an estimate only.

The threatened species that remain vulnerable to impacts include:

- **Verreaux's Eagle** *Aquila verreauxii* – a *Vulnerable* red data species (Taylor et al. 2015) and No. 2 in the priority list of collision-prone species (Ralston et al. 2017). This species, with a reporting rate of 50% on atlas cards has a 100% chance of occurring on site as it breeds there (Simmons and Martins 2015, Photo 1). Three nests are known on site and at least one is active every year. In 2019, the VE1 nest had been active as judged by "whitewash" around the nest, and VE2 nest was not active, and no eagles were present. The VE3 nest, that was removed on Elandsfontein, had not been re-built but a pair were observed perched above it and actively hunting along this east-west ridge. They may have relocated 3.5 km south in the Witberg Nature Reserve.
- **Martial Eagle** *Polemaetus bellicosus* – an *Endangered* species (Taylor et al. 2015) and No. 5 in the list of collision-prone species. This species had a 3-4% chance of occurring on site and has bred on the pylons below the ridge on the karoo plains (Avisense 2010). An adult bird was present on the same transmission line in February 2019, but neither nest appeared to be used. A 3-km buffer around either nest does not impact on the present placement of the 25 turbines planned**;**
- **Black Harrier** *Circus maurus* – an *Endangered* species (Taylor et al 2015, IUCN 2018) and No. 6 in the list of collision-prone species. This species has a 10% chance of occurring on the Witberg Ridge and may breed in the area (Simmons and Martins 2015).
- **Lanner Falcon** *Falco biarmicus* – a *Vulnerable* species (Taylor et al. 2015) and No. 22 in the list of collision-prone species. This species had a 13-14% chance of occurring on site (Avisense 2010).

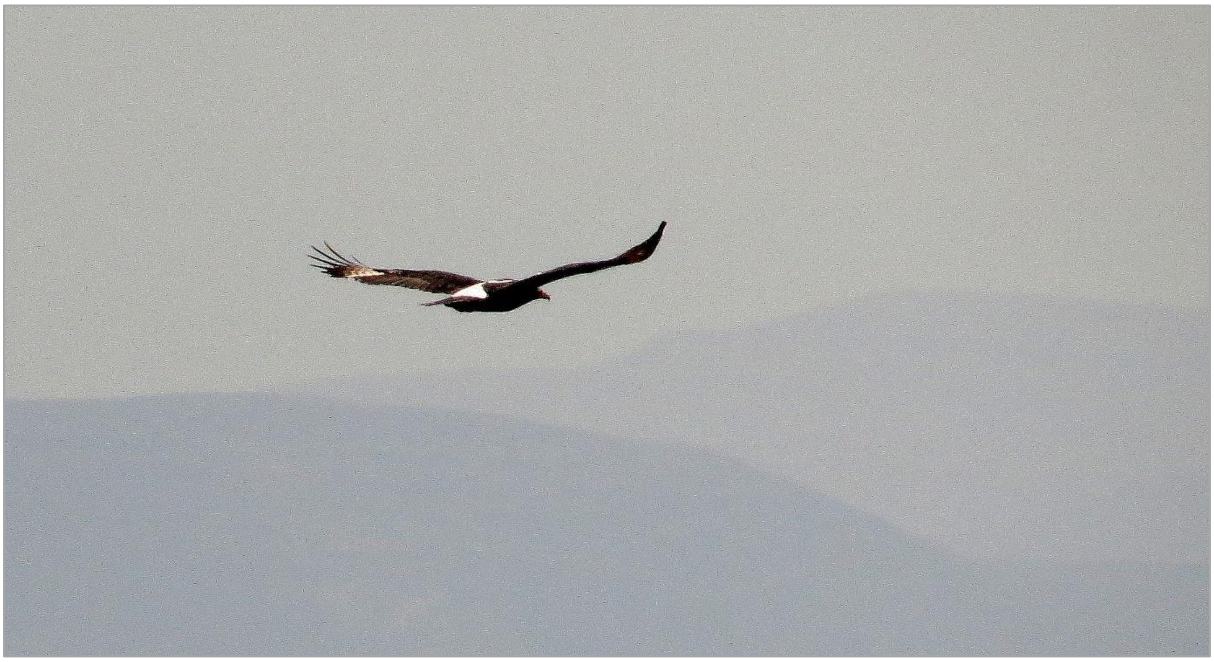

Photo 1: Verreaux's Eagles were seen daily in the study site and three nests were known in 2014, but only one was ever active during our site visits, despite three pairs being present (Turpie et al. 2012, Simmons and Martins 2015). One nest had been illegally removed from the Elandsfontein farm, probably by the farmer between site visits, and we recommended that an undertaking is put into place with farmers do not interfere with the eagles in any way. A pair were seen here in February 2019. This undertaking must form part of the environmental authorisation (Simmons and Martins 2015).

These are the priority species threatened by the proposed wind farm facility at Witberg and require special attention. Two additional species that are not threatened species in South Africa (Taylor et al. 2015), but are vulnerable to collision with wind farms are:

- **Booted Eagle** *Aquila pennatus* – ranked 55th in the Top 100 collision-prone birds (Ralston-Paton et al. 2017). This species was recorded on 30% of all SABAP2 cards and is known to breed within the wind farm site. It is designated Red Data status in Namibia (Simmons et al. 2015);
- **Jackal Buzzard** *Buteo rufofuscus* – ranked 42nd in the Top 100 collision-prone birds (Ralston-Paton et al. 2017). This species was recorded on 60% of all SABAP2 cards and, therefore, has a high chance of occurring.

Thus, of the 12 collision-prone species at the proposed Witberg wind farm, the six species above require an assessment of impacts. Some, such as the Martial Eagle, however, have too few flights to allow us to determine their risk of collision, and this species rarely occurs over the ridges.

The biggest potential avian impact issues on the Witberg site relate to the three Verreaux's Eagle nests (Figure 1). Birdlife South Africa (BLSA) guidelines stipulate:

> "**A buffer of 3 km is recommended around all nests** (including alternate nests). This is intended to reduce the risk of collisions and disturbance. This is a precautionary buffer and may be reduced (or increased) based on the results of rigorous avifaunal surveys, but nest buffers should never be less than 1.5 km (Ralston-Paton 2017)."

Because the exact positions are important for avoidance and planning purposes, we give the exact GPS locations in Table 2.

Table 2: all known positions of Verreaux's Eagle nest on the Witberg Ridge 2011-2014.

Nest site	Latitude	Longitude	Notes
VE nest 1 (new in 2014)	S 33°16'35.18"	E 20°29'9.15"	Bantam nest
VE nest 1 alt	S 33°16'30.89"	E 20°29'48.39"	Bantam nest alternative 1.03-km east of new nest (found Aug 2011 by Lucia Rodrigues)
VE nest 2	S 33°17'9.45"	E 20°24'48.93"	Besterweg nest (3 nest sites, one above the other)
VE nest 3 (southern-most nest)	S 33°18'2.23"	E 20°28'3.56"	Elandsfontein or Elandskrag (nest illegally removed)

The 1.5-km buffer referred to (Ralston-Paton 2017) is shown in Figure 2. This also has ecological significance because Percival (2013) shows that Witberg Verreaux's Eagle flight densities drop off at 1.5-km, meaning most flights are expected inside this buffer.

Note also, that the fact that VE nest 3 was illegally removed (Simmons and Martins 2015) does not mean the nest site no longer exists. The pair, possibly also persecuted, will be replaced by another pair which will very likely build a nest in a similar position. Thus, their absence in 2014 does not mean a 1.5-km buffer is not required. The post-construction monitoring must take careful cognisance of this area, and report any further attempts to disrupt the breeding of this site. We would recommend a concealed trail camera is erected to record all eagle (and human) activity at this site.

The summer 2019 site visit covering 3 days (9-11 February) revealed the following:

(a) the habitat has been negatively affected by a combination of a large fire in February 2016 and two years of drought; both farmers (L Hart and J du Plessis pers. comm.) said that the drought was one of the worst in their memory;
(b) fewer smaller bird species were recorded on both the Witberg Ridge (4 spp) and the surrounding plains (13 spp);
(c) nevertheless, eagles were present: An adult Martial Eagle was present on the transmission line pylons 3.5 km north of the proposed WEF and at least one of the two Verreaux's Eagle (VE) nests on the north-facing ridge had been active this year (VE nest 1 and VE nest 1 alt., east) as judged by fresh "white-wash" (faeces). Both were photographed (Photos 2 and 3).
(d) The VE nest 3 on Elandsfontein was still absent – no nests have been re-built on this southern-most cliff-face: however
(e) The pair of eagles were recorded perched above the nest site and hunting along the southern ridge that runs east-west from Mr. du Plessis' farm house. This pair may have relocated their nest to the Witberg Nature Reserve 3.5 km south east of the Witberg nest.

We conclude that despite the baseline habitat being negatively affected by the 2016 fire (covering 6600 ha) and 2-years of drought, the raptor component has not changed from the time of the original EA and, thus, the extension of the validity of the EA is well founded.

Photo 2: A Verreaux's Eagle pair (above) were seen perched above the Elandsfontein nest area in February 2019, but their nest has not been re-built on the cliff face here. By contrast, the Verreaux's nest VE1 at the east end of the ridge had clearly been used during the year as evidenced by large amount of white-wash around the nest (right).

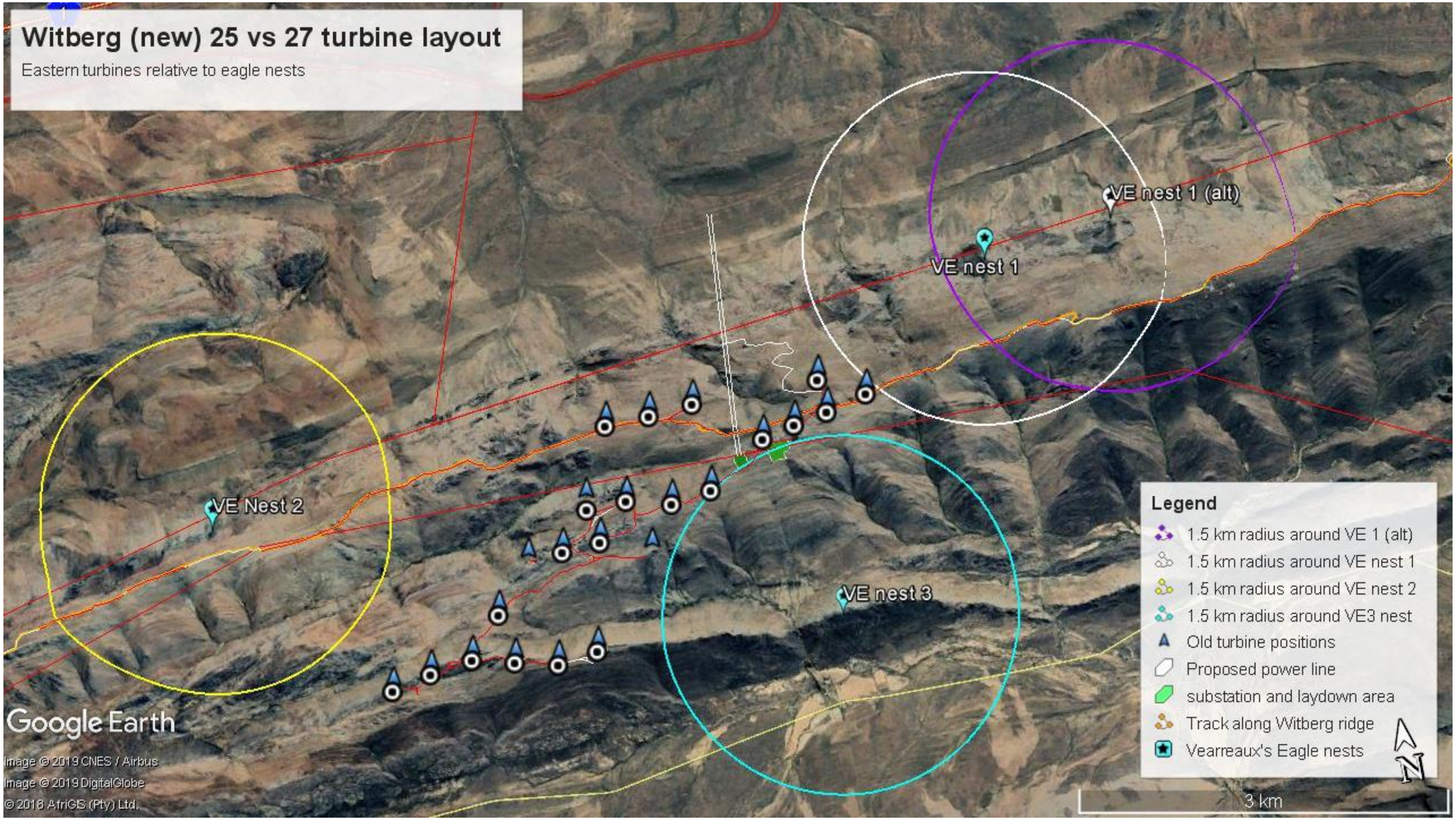

Figure 2: Detail of the eastern area of the turbine layout for 25 turbines (= white circles) for the August 2018 design, relative to known Verreaux's Eagle nests. The old authorized layout turbines (blue arrows) indicate that the turbines located in the 1.5km VE Buffers - the area of greatest potential use by the breeding Verreaux's Eagles- have been moved further away from the Verreaux's Eagle nests.

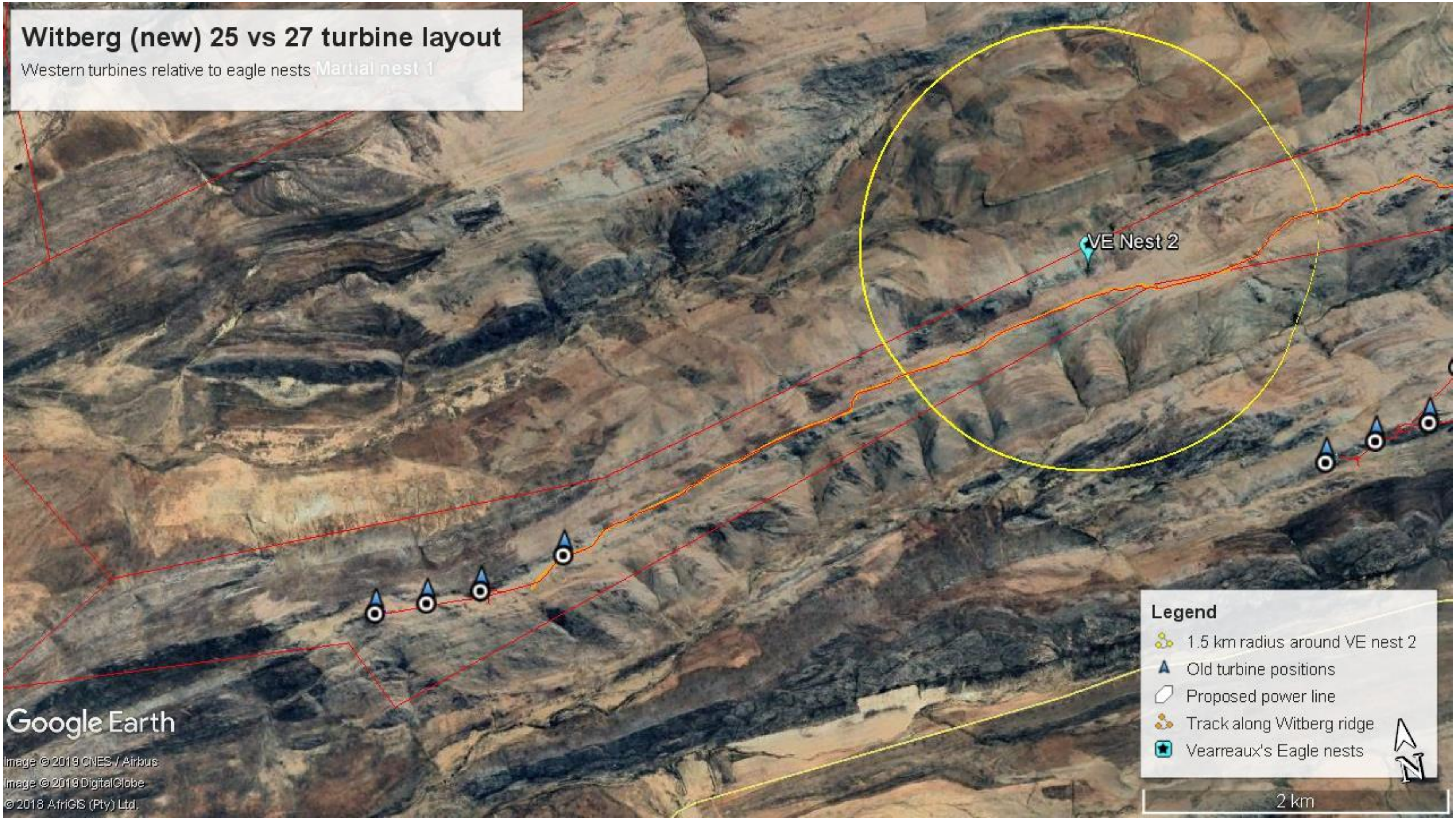

Figure 3: Detail of the western area of the turbine layout for the 25 turbines (= white circles) for the August 2018 design, relative to known Verreaux's Eagle and Booted Eagle nests. The authorized 27 wind turbine layout (blue arrows) are shown. All occur outside the 1.5-km circles, - the area of greatest potential use by the breeding Verreaux's Eagles.

4 REVIEW OF POTENTIAL AVIAN IMPACTS DUE TO CHANGES IN TURBINE NUMBERS AND DIMENSIONS

4.1 Interactions between wind energy facilities and birds

Literature reviews (e.g. Kingsley & Whittam 2005, Drewitt & Langston 2006, 2008, Kuvlevsky et al. 2007, Loss et al. 2013) and personal communications (S. Loss and P. Whitfield pers comm.) are excellent summaries of avoidance, displacements and impacts, due to wind farms in other parts of the world. Few data exist for southern Africa on the impacts of operational wind farms, partly because of the recent advent of operational farms (the first came on line in 2010), and partly because of non-disclosure agreements with clients. However, Birdlife South Africa have collated data on annual mortality at eight operational farms in South Africa (Ralston-Paton et al. 2017).

What will be assessed here is the likely change in risk to the birds passing through the wind farm where the following is altered:

- the number of turbines reduced to 25;
- the locations have been changed slightly from the 27 turbine layout, by densifying those wind turbines in the East;
- all turbines now lay outside the 1.5 km-buffer recommended as no-go for Verreaux's Eagles (Ralston-Paton 2017); that is, that no turbines can be placed in this buffer because of the negative impact they may have on the breeding Verreaux's Eagles;
- the hub height is increased from 80-m (original) to 92-m (authorised) to a range between 92m up to 120-m (proposed);
- the rotor diameter is increased from 116-m (authorised) to a range between 116m up to 136-m.

There are three major ways wind farms can influence birds:

a) **displacement and disturbance** (birds avoid the area, through the disturbance caused by the operation of the turbines);
b) **habitat loss and fragmentation** (the infrastructure and building phase directly destroys or divides habitat); and
c) **direct mortality** (birds are struck by the turbines and die).

The final report (Simmons and Martins 2015) covered all three points.

We can summarise **general** findings on bird-wind farm interactions as follows:

- On average 5.25 bird fatalities/turbine/year in the USA (range 2.92 - 7.85 birds killed); (Loss et al. 2013);

- Collisions in South Africa average 4.1 birds/turbine/year, (reviewed below);
- A few turbines are responsible for most deaths (Simmons and Martins 2019);
- Some wind farms on migration routes, and those employing lattice turbine towers, suffer high mortality rates (Loss et al. 2013) so, poorly sited wind farms can be risky;
- Identifying and mitigating turbines through Collision-Risk Modelling (Percival 2013) reduces that risk;
- Landscape features such as ridges for soaring, or valleys for commuting, are high-risk areas for raptors or migrants;
- Poor weather and high winds induce birds to fly lower and increases the chance of collision;
- Illuminating towers or buildings increases avian mortality, but gaps left in corridors of turbines may reduce overall mortality risk. Intermittent flashing lights (red or green) have been found to attract fewer birds;
- High risk species include those with low manoeuvrability (cranes, vultures); high air speed (raptors, wetland birds); distracted fliers (raptors chasing prey, courting birds displaying); and soaring species that seek lift off slopes (pelicans, storks);
- The most recent research shows exciting possibilities of reducing eagle mortalities by 100% by painting half of one blade black (Stokke et al. 2017);
- A sensitivity map for South Africa's most collision-prone species has been produced for bird-wind farm interactions and can be downloaded from: http://www.birdlife.org.za/conservation/terrestrial-bird-conservation/birds-and-renewable-energy/wind-farm-map/item/298-avian-wind-farm-sensitivity-map-documentation

Mitigating the risks is compromised by fast-moving objects being difficult to detect – even for raptors, due to retinal blur (i.e. turbine blades moving at 300-km/h). Raptors also have a low ability to see contrast – poorer than human abilities (Potier et al. 2018). However, exciting work has been done in Smøla, Norway, where a 2-year experiment with a black-painted turbine blade at four turbines showed a 100% reduction in fatalities of White-tailed Eagles *Haliaeetus albicilla* (Stokke et al. 2017). http://cww2017.pt/images/Congresso/presentations/oral/CWW17_talk_S07_5_Stokke%20et%20al.pdf

Other mitigations include:

- ❖ Site wind farms away from: (i) large concentrations of birds (e.g. roosts, wetlands or breeding colonies); (ii) migration corridors; (iii) slopes used by soaring birds; and (iv) breeding collision-prone birds,

- ❖ Monitor deaths per turbine and be prepared to shut down high-mortality turbines at times of high risk (i.e. migration or breeding seasons). Those individual turbines that kill more than one Red Data birds per year should be given particular attention. The likely position of these turbines can be identified pre-construction from the number of flights (Passage Rates) near them, and the proportion of flights at blade-swept height (BSH).
- ❖ The use of intense, flashing, short wavelength LED (light emitting diode) lights to deter raptors from close approaches to turbines in risky positions (Foss et al. 2017).

Here we review just the collisions with turbines, and particularly the effect of changing the number of turbines, hub height, and blade length.

4.2 Collision rates at wind farms in South Africa

Approximately 25 wind farms are currently operational in South Africa including facilities at Klipheuwel and Darling in the Western Cape (van Rooyen 2001, Jenkins 2001, 2003, Simmons et al. 2011), in the Karoo and several in the Eastern Cape (Doty and Martin 2011, Ralston-Paton et al. 2017). In a review of data from eight operational farms in South Africa monitored for over a year, Ralston-Paton et al. (2017) found that raptorial birds are the most impacted group, with 36% of all 271 known fatalities in 285 turbine-years to be small to large birds of prey. This gives a relatively median rate of mortality (adjusted for observer error and carcass removal) at 4.1 birds/turbine/year (Ralston-Paton et al. 2017). This ranges from 2.1 to 8.6 birds/turbine/year. This is similar to that reported elsewhere in the world at 5.2 birds/turbine/year (Loss et al. 2013).

4.3 Avian effects of changing hub heights and blade-swept area

Probably the two most important papers on mortality and the effect of increased hub height and blade length is that of Barclay et al. (2007) and Loss et al. (2013). They assessed collision rates of birds and bats at 33 and 53 sites (respectively) in North America, with a range of turbines from 3 to 454, and assessed the effect of variation in turbine height and blade-swept area on the mortality rates of birds and bats.

Barclay et al. (2007) found:

- no significant effect of increased height or blade length on the number of birds killed;
- However, he included lattice towers which are now known to bias mortality results upwards for shorter towers.

Loss et al (2013), re-analysing all data from Barclay et al and new studies, (minus the lattice towers that are no longer used) found:

- A significant effect of hub height on the number of avian mortalities at 53 wind farm sites in the USA. (Blade length could not be assessed because of statistical collinearity with hub height);
- In a model that included region and hub height, avian fatalities increased from about 2 birds/turbine/year at hub heights of 40-m to 6.2 birds/turbine/year at 80-m hub height;
- This represents a ~3-fold increase in mortalities between 40-m and 80-m hub height.

In their review of facilities in Europe and the USA combined, Drewitt and Langston (2008) found that taller communication towers were more likely to kill birds, than shorter ones. Similarly, taller transmission lines (i.e. 400 kV vs 220 kV lines) are more likely to kill collision-prone birds than shorter ones (J Pallett unpubl. data).

4.4 Collision-prone birds

Collision-prone birds (CPBs) are generally either:

- large species and/or species with high ratios of body weight to wing surface area, and low manoeuvrability (cranes, bustards, vultures, gamebirds, waterfowl, falcons);
- species that fly at high speeds (gamebirds, pigeons and sandgrouse, waterfowl, swifts, falcons);
- species that are distracted in flight – predators or species with aerial displays (many raptors, aerial insectivores, some open-country passerines);
- species that habitually fly in low light conditions (owls, dikkops, flamingos); and
- species with narrow fields of forward binocular vision (Drewitt & Langston 2006, 2008, Jenkins et al. 2010, Martin & Shaw 2010, Ralston-Paton et al. 2017).

Our own research data from a wind farm in the Eastern Cape indicates that fatalities of four Black Harriers *Circus maurus* were associated with the months when they spent more time at blade-swept height. No fatalities occurred when the harriers were flying at low levels (Simmons and Martins 2017).

These traits confer high levels of susceptibility, which may be compounded by high levels of exposure to man-made obstacles, such as overhead power lines and other wind farm infrastructure (Jenkins et al. 2010). Exposure is greatest in (i) highly aerial species; (ii) species that make regular and/or long distance movements (migrants and species with widely separated resources food, water, roost and nest sites); and (iii) species that fly in flocks such as vultures (increasing the chances of incurring multiple fatalities in single collision incidents). Soaring species may be particularly prone to colliding with wind turbines or power lines where these are placed along ridges – where turbines would exploit the same updrafts favoured by birds such as vultures, storks, cranes, and most raptors (Erickson et al.

2001, Drewitt & Langston 2006, 2008, Jenkins et al. 2010). In Europe, most mortalities recorded are large vultures and eagles (e.g. de Lucas et al. 2008).

5 IMPLICATIONS TO BIRDS FROM THE PROPOSED AMENDMENTS

5.1 General considerations: hub height and blade length

The question arises: do taller turbines (from 80-m or 92-m hub height to a range between 92m and up to 120-m) with longer blades (ranging from 58-m to 78-m), increase the risk of mortality of birds through direct impact?

The Loss et al. study, using a large data set (from 53 wind farms in the USA), showed that there was a *significant* effect of increasing height on bird fatalities. With an increase in hub height from 40-m to 80-m, avian fatalities increased from about 2 to 6.2 birds per turbine per year.

Therefore, the increase in hub height from 92-m to 120-m is predicted to have some influence on the background mortality rates for birds such as eagles in the Witberg setting. By exactly how much is the question we attempt to answer below.

5.2 Modelling fatalities for increased hub heights beyond 80-m

There are two methods to predict bird fatalities with increases in hub height

- (1) Modelling real fatality data at wind farms with different hub heights to determine if a relationship occurs between fatalities and hub height (Appendix 1) (note this does not use Witberg Wind Farm data because it is not operational);
- (2) Determine through collision-risk modelling (Band et al. 2007) the effect of taller turbines on the risk to eagles flying over the Witberg ridges. This was undertaken by Percival (2018, 2019) – based on site specific data;

(1) Fatality data and hub height ("Loss model")

We took the fatality-hub height data of Loss et al. (2013) and asked statisticians (Dr Birgit Erni and Francisco Cervantes) from UCT's Department of Statistics, Ecology and the Environment, to model the American data beyond 80-m hub heights. To strengthen the forecast for fatalities at 120-m hub heights, and to make them applicable to South Africa, we included the South African data (seven data points available from Ralston et al. 2017). These included two wind farms with 90-m and 95-m hub heights. The results (Appendix 1) indicate that fatalities are expected to increase exponentially 2.6-fold from

6.2 to 22.0 (95% CI = 12, 65) birds/turbine/year as turbines are increased from 80-m to 120-m. Fatalities are expected to increase two-fold for turbines increasing from 92-m to 120-m (Appendix 1).

This increased risk is supported by records of the flight heights of two main collision-prone eagles on a wind farm site at Springbok in similar montane terrain, where we recorded flight heights in 10-m bands over six site visits. (This was not done so accurately at the Witberg where flights were recorded in much larger bands). For both Verreaux's (n = 418 records) and Booted Eagles (n = 160 records), the proportion of flight heights at the higher blade-swept heights (BSH) there of 60-m to 220-m increased from about 35% to 69% for both species as hub heights increased from 80-m to 140-m.

We conclude, that given our statistical "Loss" model (Appendix 1) and the fact that twice as many eagle flights occur at these heights, for both small and large eagles, between 2.0- and 2.6-fold more avian fatalities are forecast by increasing turbines from 80-m or 92-m to 120-m.

(2) Collision-risk modelling (CRM)

Using data collected on eagle flights in the original site visits (Turpie at al. 2012), Percival (2018, 2019) found that the number of collisions likely by adult eagles with the turbines was lower at greater hub heights. The CRM model (Band et al. 2007) predicted that for 25 turbines in the August 2018 layout (Figure 2) the number of adult and juvenile eagles likely to be killed by the 120m turbines is 0.26 eagles per year (based on 98% avoidance rates, worst case). These are much lower rates than 0.86 eagles predicted for the previously authorised 27 turbines of 92 m hub height/ 116m rotor diameter per year (based on 98% avoidance rates) (Percival 2013). Thus, the new layout of 25 turbines is better than the previous layout for 27 turbines, based on 98% avoidance rates.

Thus, these two models (CRM and Loss model) give opposite predictions: the Loss model predicts increased fatalities, the CRM reduced fatalities. Both have their positives and downfalls.

- The CRM model uses eagle data collected on the Witberg site, while the Loss model uses all bird data from elsewhere;
- The CRM model gives no confidence limits, while the Loss model gives 95% confidence limits indicating how well the model predicts future outcomes;
- The Loss model forecasts beyond the present height of South African turbines (95 m) and requires verification for 120-m turbines;
- The Loss model is based on empirical data from 60 wind farms in the USA and South Africa, the CRM is based on the 1 wind farm in South Africa under assessment.

We are unable to determine why the two models give opposite results, but perhaps it is due to the data sets differing i.e. the Loss model is based on fatality data not collected on-site, and the CRM is based on site-specific data on flights. The proportion of eagles in the Loss model is also unknown, as it is based on all birds killed.

Why did the Loss model forecast that taller turbines would lead to high fatalities? There are two possible reasons, one ecological, one statistical:

(i) Ecologically, taller turbines and their greater blade-swept height are more likely to intersect migrating eagles. For example, Golden Eagles *Aquila chrysateos* studied in North America, tended to fly two- to four-fold higher (average 135-m to 341-m) than resident eagles (63-m to 83-m: Katzner et al. 2012). In Witberg this is corroborated by the higher proportion of flights at the Blade Swept Height (BSH) for two species of eagle (Percival 2013) outside the area proposed for turbine placement;

(ii) Statistically, longer blades are often (but not always) associated with taller turbines. For example, if blade length is doubled from 40-m to 80-m then the blade-swept area quadruples from 5,027-m^2 to 20,108-m^2. Thus, by chance, a passing bird has a four-fold higher probability of intersecting a blade from a taller turbine. With avoidance behaviour this may well be decreased, but data are lacking for South African species.

Thus, the *location* of turbines becomes increasingly important if increased heights increase the chances of fatalities. In this sense, choosing the best 25 sites from the 27 turbine that have already been authorised, will go a long way in reducing the higher number of fatalities expected for the 120-m turbines. This was one goal of the CRM modelling (Percival 2018, 2019) and is reflected in Figure 2.

To overcome the difficulties associated with the opposite results of the two models, we propose:

- that the two model results are combined. That is:
- Loss model (based on international fatality data and some South African data; not considering Witberg Wind Farm data), shows that collision fatality risk increases two-fold as turbine hub height increases.
- The CRM modelling shows that the collision risk decreased from 0.86 Verreaux's Eagles adults (27 turbines with 92-m hub height) to 0.26 adults (for 25 turbines) per year as Hub Height (HH) increased to 120-m.
- The proposed way forward is for the results of the CRM modelling (Table 2) to be combined with the predictions of the Loss model (Appendix 1). This allows us to take the results of both approaches into account without favouring one over the other. See 5.4 below. i.e. (0.26 adult Verreaux's Eagle collision risk) x2 = 0.52, below the level of 0.86 in the authorised layout.

5.3 Siting of turbines in relation to eagle activity and buffers

Rather than the eagles using all parts of their territory equally, most activity is aligned linearly east-west along the valley – along the rock faces where their nests and their prey (Rock Hyrax *Procavia capensis*) typically occur (Gargett 1990, Davies 1994, Simmons 2005). At Witberg this was true and, in addition, both eagle pairs on north-facing cliffs headed in a northerly direction when hunting. Using the data collected in 2012 and 2014 (Turpie et al. 2012, Simmons and Martins 2015) we showed that in a combined 333 hours of observation of eagles, the birds flew within the proposed wind farm boundary on only seven occasions. A very low Passage Rate of 0.021 eagles per hour. This included the juvenile eagle at Nest 1 (Bantam nest) in 2014/2015. Because of the unexpectedly low passage rate we recommend that some turbine positions fall within the 3-km, now promulgated as the preferred buffer around active eagle nests (Ralston-Paton 2017).

The low passage rates were confirmed in our follow-up assessment in 2019: in 28 hours observation overlooking the eagle nests no eagles were observed flying over the proposed turbines. The Passage Rate for the (6) eagle flights that were observed was low at 0.21 birds per hour.

To satisfy BLSA guidelines that (i) no turbines are allowed within 1.5-km of nests; and (ii) mitigations may be required as the turbines are erected, we suggest that mitigations may be required if eagles change their flight patterns.

Three systems are suggested:

- The DT bird system http://www.detect-inc.com/avian.html has been independently tested once on eagles in Norway (May et al. 2012). It correctly identified more than 80% of the eagle flights and took corrective action. However, the number of false positives (detecting birds that were not eagles) was also above 50%. This means that the system was successful in reducing mortality but was inefficient in that it stopped turbines when no risk to eagles was apparent. The system costs approximately ~ZAR500,000 per turbine (2017). Other, newer, systems may be required and available by the time the Witberg WEF becomes operational. Such a "multi-sensor" system is being tested now in South Africa (J Avni pers comm) and works on video surveillance in preference to radar-detection which has reliability issues.

- The use of black-blade mitigation (Stokke et al. 2017). Marking turbine rotors in this way has been tested recently with a clever experiment in Norway where turbines were killing large numbers of White-tailed Eagles *Haliaetus albicilla* and other ground-dwelling species. By painting one turbine blade black, researchers at the Norwegian Institute of Nature Research reduced the incidence of overall bird fatalities by 71% relative to unpainted controls (Stokke et al. 2017). More impressive was the fact that no further eagle mortalities were recorded over 2-years, relative to unpainted controls (R May in litt).

- The use of intense short wavelength LED lights. These were recently investigated on Red-tailed Hawks *Buteo jamaicensis* in the USA – one of the most collision-prone species there (Foss et al. 2017). The lights produced >5-fold more aborted approaches at hawk lures at a banding station than those at a control without the LED lights (Foss et al. 2017). This should be investigated in South Africa where hawks and other raptors feature prominently in all fatality reports (Ralston-Paton et al. 2017).

5.4 Numbers of turbines vs increased hub height

Will a decrease from 27 turbines, 92m hub height and 116m rotor diameter (authorised), to 25 turbines at 120-m hub height decrease the probability of avian fatalities? By quantifying the increased number of fatalities with a 120-m hub height (Loss model) we can determine if the reduced number of turbines can, indeed, compensate for this.

From the model forecasting the number of fatalities at the new hub heights of 120-m (Appendix 1) the predicted total number of fatalities for 25 turbines is 400 birds (with 95% confidence limits of 225 to 700). This is higher than the number predicted for 60 turbines at 80-m hub heights of 347 birds.

For eagles alone, the model (Appendix 1) suggests a 2.0-fold increase in fatalities when hub heights are increased from 92-m to 120-m.

This is supported by independent data from a montane wind farm in Springbok where we recorded the proportion of eagle flights in the blade swept area (35% of flights) doubled (to 70% of all flights) from 80-m hub height turbines (with 44-m blades) to 120-m turbines with 66-m blades (Appendix 1).

By employing these increased fatality rates to the Collision-Risk model results given in Percival (2018, 2019) we can gauge how many eagles may be affected at different avoidance rates. Avoidance Rates are a theoretical probability that a bird will see – and physically avoid – spinning turbine blades (Band et al. 2007).

The proportion of fatalities is forecast to decrease for the 120-m hub height turbines over 92-m turbines (Appendix 1). The 2019 Collision-Risk Modelling (Table 3) estimates that the total number of Verreaux's Eagles killed per year will decline as follows for adults and juveniles:

- (2 x 0.26=) **0.52 adults** for 120 m turbines from (2 x 0.33=) **0.66 adults** for 92m turbines, and
- (2 x 0.02=) **0.04 juveniles** for 120-m turbines from (2 x 0.03=) **0.06 juveniles** for 92-m turbines (Table 4);
- Giving a total of 0.56 Verreaux's Eagles killed / year for 25 turbines at 120-m hub height
- For Booted Eagles the estimates remain very low at 0.04 collisions/year (120-m turbines) and
- for Martial Eagles it remains at no fatalities.

These are relatively median levels of fatality at below one eagle per year.

Table 3. Collision risk modelling predictions for all eagles on site at the proposed Witberg wind farm (Percival 2013, 2018, 2019). The results are compared for 92 m (27 authorized in green) and 120m high turbines (25 proposed in pink). A range of avoidance rates for adults and juveniles are given (combining Table 5c and Table 6 in Percival 2013, 2018, 2019). This incorporates all **25 turbines** being moved to the least risk configuration. Predictions in bold represent the results thought to most likely represent reality.

Species	**Precautionary predicted number of collisions per year**											
	East zone			**Mid zone**			**West zone**			**TOTAL**		
Avoidance rate	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**
Verreaux's Eagle (adults) **92 m** (27 Authorised)	0.1	0.04	0.02	1.06	0.42	0.21	0.99	0.39	0.20	2.14	**0.86**	0.43
Verreaux's Eagle (adults) **92m** (Proposed)	0	0	0	0.55	0.22	0.11	0.27	0.11	0.05	0.83	**0.33**	0.17
Verreaux's Eagle (adults) **105 m** (Proposed)	0	0	0	0.49	0.20	0.10	0.24	0.10	0.05	0.73	**0.29**	0.15
Verreaux's Eagle (adults) **120 m** (Proposed)	0	0	0	0.43	0.17	0.09	0.21	0.09	0.04	0.65	**0.26**	0.13
Verreaux's Eagle (juveniles) **92 m** (27 Authorised)	-	-	-	-	-	-	-	-	-	0.21	**0.08**	0.04
Verreaux's Eagle **(juv) 92 m** (Proposed)										0.08	**0.03**	0.02
Verreaux's Eagle **(juv) 105 m** (Proposed)										0.07	**0.03**	0.01
Verreaux's Eagle **(juv) 120 m** (Proposed)	-	-	-	-	-	-	-	-	-	0.06	**0.02**	0.01
Booted Eagle **92m** (Authorised)	0.0	0.0	0.0	0.08	0.03	0.02	0	0	0	0.08	**0.03**	0.02
Booted Eagle **92m** (Proposed)	0	0	0	0.1	0.04	0.02	0	0	0	0.1	**0.04**	0.02
Booted Eagle **105m** (Proposed)	0	0	0	0.1	0.04	0.02	0	0	0	0.1	**0.04**	0.02
Booted Eagle **120m** (Proposed)	0	0	0	0.09	0.04	0.02	0	0	0	0.09	**0.04**	0.02
Martial Eagle (both)	0	0	0	0	0	0	0	0	0	0	**0**	0

Table 4. Predictions for the number of eagle fatalities per year on the proposed Witberg wind farm combining the CRM model of Percival (2019) and taking account of the two-fold increased likelihood of fatalities due to increased hub height to 120m (Appendix 1). The results for 98% avoidance are the most likely to reflect reality. These estimates incorporate all 25 turbines being moved to the best locations to give the lowest risk configuration.

Species	Estimated Number of eagle collisions per year assuming the (25) turbine heights increase from 92m to 120 m (combining Percival 2019 and the Loss model – Appendix 1) TOTAL				
Avoidance rate	95%	98%	99%	Proposed precautionary combination of models (CRM x Loss) at 98% avoidance	Conclusion
Verreaux's Eagle (adults) Authorised (27)	2.14	**0.86**	0.43		
92m HH (25)	0.83	0.33	0.17	**0.66**	**Acceptable as it lies below 0.86 (the authorised level fatality rate)**
105m HH (25)	0.73	0.29	0.15	**0.58**	
120m HH (25)	0.65	0.26	0.13	**0.52**	
Verreaux's Eagle (juveniles) Authorised (27)	0.21	**0.08**	0.04		
92m HH (25)	0.08	0.03	0.02	**0.06**	**Acceptable as it is the same or below 0.08 (the authorised level fatality rate)**
105m HH (25)	0.07	0.03	0.02	**0.06**	
120m HH (25)	0.06	0.02	0.01	**0.04**	
Booted Eagle (120 m HH) (25)	0.09	**0.04**	0.02	**0.08**	
Martial Eagle (25)	0	**0**	0	**0.0**	

Updated CRM

These annual fatality rates for Verreaux's Eagles are, relatively low for healthy populations of Verreaux's Eagle but to reduce impacts to a minimum they require **mitigation as suggested below**. We note also that the Minister of Water and Environment Affairs in her judgement of the appealed conditions dated 13 August 2013, required the following conditions to be met:

> "(Condition 40) Should any unanticipated negative impacts be recorded, G7 commits to reducing these impacts. Mitigation measures to achieve this includes shutting down problematic turbines, if this is deemed necessary."

Following further appeals by I&APs the Minister also required (20 February 2016) that:

"(Condition 37) Pre-construction monitoring must be extended to record the flight paths of the juvenile Verreaux's Eagle and the monitoring of breeding sites must be implemented both during and after the construction phase."

"(Condition 41) After discussions with the Department and prior to the commencement of construction, the applicant must develop and implement a monitoring programme for the Verreaux's Eagles, to the satisfaction of the Department. A copy of the monitoring programme must be provided to the Department and to Birdlife South Africa by the applicant within 30-days of being developed."

In light of this, and based on our expert opinion of the threatened eagles at Witberg, the following mitigations are suggested:

(i) the turbines closest to the known eagle nests are moved to at least 1.5-km (the distance at which significant Verreaux's Eagle flight activity falls away: [Percival 2013] and because this is the non-negotiable buffer recommended by BLSA [Ralston-Paton 2017]);

(ii) Birdlife South Africa Verreaux's Eagle guidelines recommend a 3-km buffer around all active nest (Ralston-Paton 2017), but reduced that recommendation to 1.5-km where survey data show few flights occur. Our data now covering 401 hours, do show a very low Passage Rate of 0.021 eagles/hour;

(iii) Post-construction, all turbines killing one or more Red Data bird per year will need to be fitted either with (a) the highly effective black-blade mitigation; or its equivalent; or (b) automated deterrent or curtailment.

It is our understanding, following a meeting with Witberg Wind Power (Pty) Ltd (July 2018), that all of the requirements, which could have been met at this stage, have been met. That is:

- (condition 37) the behaviour, flight paths and high-risk areas of the juvenile eagle were mapped in 2014 (Simmons and Martins 2015). No flights of either the young bird or adult were observed within the 1.5-km buffer now complied with (this remained unchanged in the Feb 2019 site visit);
- (condition 37) Witberg Wind Power (Pty) Ltd agree to undertake eagle monitoring during and after construction;
- (condition 40) Witberg Wind Power (Pty) Ltd agree to following either shut down of problem turbines or implement other mitigation measures deemed appropriate;
- Witberg Wind Power (Pty) Ltd will develop and implement a monitoring programme for the Verreaux's Eagles, to the satisfaction of the Department of Environment (DEA). A copy of the monitoring programme will be provided to the Department and to Birdlife South Africa by the applicant within 30-days of being developed.

5.5 Quantifying the impacts

Several raptors were previously identified (Avisense 2010, Turpie et al. 2012, Simmons and Martins 2015) as likely to be negatively affected by displacement, loss of habitat or direct mortality. These are all in the top 100 collision-prone species: Verreaux's Eagle (*Vulnerable*, 2nd), Martial Eagle (*Endangered*, 5th), Black Harrier (*Endangered*, 6th), Lanner Falcon (*Vulnerable*, 22nd), and Booted Eagle (55th). Given their abundance and susceptibility to collision (Ralston-Paton et al. 2017) Jackal Buzzards (42nd) may also be impacted. The following tables quantify the impacts for these raptors, particularly South African Red Data birds (Taylor et al. 2015). This incorporates the data from 2010, 2015 and 2019, reflects the amended layout, includes all the CRM modelling (Percival 2018, 2019) and accounts for the estimated two-fold increase in fatality due to increased hub heights (92-m to 120-m).

The first table indicates the Construction Phase impacts; the second, Operational Phase impacts.

The **Significance** of the impact (S) is given by the equation (NEMA 2010):

S = (E+D+M)P

Where
E = Extent (local or wide-scale, ranked from 1 to 5)
D= Duration (length of time of the effect, ranked from 1 to 5)
M= Magnitude (the size of the negative effect, ranked from 1 to 10)
P=Probability (the likelihood of the event happening, ranked from 1 to 5)

The Nature of the impact will be negative in that birds will either be: (i) displaced by habitat alteration; (ii) displaced by disturbance during or after construction; (iii) impacted by turbine blades directly; (iv) impacted by the existing and proposed 132 kV lines.

The Extent of the impact will be local **(1)** reducing foraging habitat in the immediate wind farm area for the raptors, but may be higher if the space created by the death of territorial individuals brings in other birds to be killed (the sink effect), or they are displaced from breeding through disturbance.

The Duration will be short-term (**2)** for the duration of the construction (18 months) but **(5)** for the operational lifetime of the wind farm for all species.

The Magnitude is ranked as a medium-high impact **(6)** for the raptors, particularly those frequently flying at 92 m rotor height (Verreaux's Eagles, Booted Eagles and Jackal Buzzards). However, this will increase to **(8)** as hub height increases to 120 m according to fatalities forecast by Loss et al. (2013) and statistical inference in Appendix 1.

The Probability of occurrence of the raptors flying into the rotor blades is ranked as probable **(4)** given their aerial nature and the high proportion of time that both Verreaux's and Booted Eagles spend at these blade-swept heights (see Appendix 1).

The Significance [S = (E+D+M)P] is as follows for the species identified as at risk:

All raptors S = (1 + 5 + 8)4 = 56

These ratings indicate that, for all raptorial species, the resultant significance weightings (56) has a direct influence on the decision to develop and, therefore, must be mitigated.

Table 5. Significance table explaining the relevance of the scores used.

Parameter	Scores	Interpretation
Extent (Area) **E**	1-5	1-2 (Local), 3-4 (regional) 5 (national)
Duration (period of impact) **D**	1-5	1 (v short term, 0-5 yr) 2 (short term, 2-5 yr) 3 (Medium term of 5-15 yr) 4 (long term > 15 yr) 5 (life time of the development)
Magnitude (size of impact) **M**	1-10	1 (negligible) 2 (minor) 4 (low, and cause an impact on the process) 6 (moderate, process continue but modified) 8 (high) 10 (v high, destruction of patterns and cessation of processes)
Probability (likelihood the impact will occur) **P**	1-5	1 (improbable) 2 (improbable, but still low likelihood) 3 (distinct probability) 4 (highly probably, most likely to occur) 5 (definite, will occur regardless of any prevention)
Significance **S** = (E+D+M)P	3-100	3-30 (low, impact will not have a direct influence on decision to develop) 30-60 (Medium, impact could influence the decision to develop unless effectively mitigated) 60-100 (High, impact must have an influence on the decision to develop the area).
Confidence		Sureness that the input variables are sound and well researched in determining the final significance level.

Table 6a. A summary of the quantified impacts during construction to the raptors likely to be impacted by the wind farm for the amended layout and turbine dimensions. We compare the impacts with those estimated for the pre-construction report.

Construction Phase

Nature: Direct mortality, disturbance or avoidance of area around the wind farm for the raptors identified as "at risk" above due to human disturbance, heavy machinery, or overhead lines, during construction.		
	Without mitigation	**With mitigation**
Extent	1 (local)	1 (local)
Duration	2 (short-term)	2 (short-term)
Magnitude	6 (moderate)	4 (low)
Probability	4 (highly probable)	3 (distinct probability)

Significance (E+D+M)P	**36** (Moderate= could influence the decision to develop unless effectively mitigated)	**21** (Low significance = impact will not have direct influence on decision to develop)
Status (+ve or –ve)	Negative	Negative to neutral
Confidence	High (Pearce-Higgins et al. 2012)	High
Reversibility	High	High
Irreplaceable loss of species?	No (Both Verreaux's and Booted Eagles may suffer short term disturbance, displacement, and loss of breeding but return after construction)	Reduced
Can impacts be mitigated?		Partially, yes

	Authorised Project*		**Proposed Amendment****	
	Pre-mitigation impact rating	**Post-mitigation impact rating**	**Pre-mitigation impact rating**	**Post-mitigation impact rating**
Extent	**1**	**1**	**1**	**1**
Duration	**2**	**2**	**2**	**2**
Magnitude	**6**	**4**	**6**	**4**
Probability	**4**	**3**	**4**	**3**
Reversibility	High	High	High	high
Irreplaceable loss of species?	No (Both eagle species may suffer short term disturbance, displacement, and loss of breeding but return after construction)		No (Both eagle species may suffer short term disturbance, displacement, and loss of breeding but return after construction)	
Significance rating	**36 (medium)**	**21 (low)**	**36 (medium)**	**21 (low)**

*** 27 turbines at 92 m height**

**** 25 turbines at 120 m height**

Mitigation: Disturbance during wind farm construction was found to have greater impacts on birds in the UK than post-construction impacts (Pearce-Higgins et al. 2012). There are generally two classes of mitigation to avoid disturbing Red Data birds around wind farms during construction: (i) limit construction activities (building, blasting etc) to seasons when birds are not breeding – to reduce disturbance causing nest failure; (ii) limit construction activities (building, worker-presence, power-line-stringing) from areas within 1000-m of known Red Data species' nests at times when eagles or other Red Data species are incubating/feeding small nestlings. Verreaux's Eagles start breeding in April-July and have a small nestling on the nest from June – August (Simmons 2005).

We therefore, recommend as mitigations: (i) not constructing within 1000-m of Verreaux's Eagle nests or Booted Eagle nest during their early breeding season (May – June) or small-chick rearing season (June – July). For breeding Booted Eagles, the seasons to avoid are August – September; (ii) avoid blasting or causing noise disturbance in the same seasons anywhere within 3-km of active nests for all Red Data species.

Table 6b. A summary of the quantified impacts during operations to the raptors likely to be impacted by the wind farm for the amended layout and turbine dimensions. We compare the impacts with those estimated for the pre-construction report. Note, no quantified assessment was given in Turpie et al. (2012) so we have applied numbers to the qualitative assessments.

Operational phase

Nature: Direct mortality, disturbance or avoidance of area around the wind farm for the raptors identified as at risk above, due to disturbance, or impacts with turbine blades and overhead lines during operations.		
	Without mitigation	**With mitigation**

Extent	1 (local)	1 (local)
Duration	5 (long-term)	5 (long-term)
Magnitude	8 (high)	6 (moderate)
Probability	4 (highly probable)	3 (distinct probability)
Significance (E+D+M)P	56 (Medium significance = impact should influence decision to develop unless mitigated)	36 (Medium significance impact could influence the decision to develop unless effectively mitigated)
Status (+ve or –ve)	Negative	Negative to neutral
Confidence	High	High
Reversibility	Low	High
Irreplaceable loss of species?	No (Verreaux's Eagles are not uncommon, and the rarer Booted Eagles may be less susceptible to collision and displacement)	Reduced
Can impacts be mitigated?	Yes	Partially, yes

	Authorised Project*		**Proposed Amendment****	
	Pre-mitigation impact rating	**Post-mitigation impact rating**	**Pre-mitigation impact rating**	**Post-mitigation impact rating**
Extent	**1**	**1**	**1**	**1**
Duration	**5**	**5**	**5**	**5**
Magnitude	**8**	**6**	**8**	**6**
Probability	**4**	**3**	**4**	**3**
Reversibility	Low	Medium	Low	Medium
Irreplaceable loss of species?	No (Verreaux's Eagles are not uncommon and rarer Booted Eagles may be less susceptible to collision and displacement)		No (Verreaux's Eagles are not uncommon and rarer Booted Eagles may be less susceptible to collision and displacement)	
Significance rating	**56 (medium-high)**	**36 (medium)**	**56 (medium-high)**	**36 (medium)**

*** 27 turbines at 92 m height**

**** 25 turbines at 120 m height**

Mitigation: There are generally five classes of mitigation for birds around wind farms: (i) re-position the turbines to avoid impacts or disturbance for the birds; (ii) redesign the turbines to alter the present pattern/shape/size of the turbines so birds see them more readily and avoid contact; (iii) curtail or shut-down-on-demand the turbines when collision-prone birds approach; (iv) manipulate the habitat to reduce the attractiveness of the site to collision-prone raptors; (v) reduce the overall number/height of turbines.

Because the combination of the CRM (Percival 2019) and the Loss model (Appendix 1) forecasts that the taller turbines are predicted to increase fatalities to 0.56 adult and juvenile Verreaux's Eagles per year (at 98% avoidance rates: Table 4) this is judged to be an acceptable level of mortality because it reduces the number well below one eagle per year, and it reduces the fatalities to below that for the already authorized turbine layout (0.94 adult + juvenile Verreaux's Eagles). If the fatality rate is higher than these two models predict (i.e. >1.0 eagle per year) then mitigations will be required.

We recommend as mitigations:

(i) the turbines closest to the known eagle nests are moved to at least 1.5-km (the distance at which significant Verreaux's Eagle flight activity falls away: Percival 2013);

(ii) Birdlife South Africa Verreaux's Eagle guidelines recommend a 3-km buffer around all active nest and a 1.5-km no-go buffer (Ralston-Paton 2017). Since only seven eagle flights in 333 hours (a Passage Rate of 0.021 eagles/hour) were recorded we feel the 3-km buffer is not necessary and 1.5-km is recommended.

(iii) Post-construction, all turbines killing one or more Red Data bird per year will need to be fitted either with (a) the highly effective black-blade mitigation, or (b) automated deterrent or shut-down-on-demand; (this follows the Minister's recommendation too).

Operational phase monitoring is essential to determine the actual impacts on birds and therefore, the required mitigation measures and thresholds. This was also a stipulation of the EA. Such an approach requires a flexible Adaptive Management Plan to be implemented during operation. Such an Adaptive Management Plan must allow for changes to be implemented within a maximum time-frame of 3-4 weeks.

The Wind Farm must agree to follow the mitigation measures that may result from the operational monitoring and Adaptive Management Plan.

(i) In accordance with the Adaptive Management Plan, appropriate mitigation measures, such as curtailment at specific environmental conditions or during high-risk periods (i.e. post construction monitoring shows 1 Red Data species killed at these turbines per year, then the use of appropriate automatic shut down or deterrent technology will have to be implemented in the case of mortality of Red Data species [defined as: 1 Red Data species killed per year]).

The operational monitoring study design must determine the turbines that require appropriate mitigation measures. Through such monitoring, we have found at other operational wind farms that 25% of the turbines are responsible for 75% of the fatalities, allowing specific risky turbines to be targeted (Simmons and Martins 2019).

Two adaptive management mitigations are recommended if Red Data species are found to be killed:

(i) investigate painting half a blade black to deter raptors, as undertaken by Norwegian wind farms to reduce white-tailed Eagle deaths with great success (Stokke et al. 2017).

(ii) Implement the automated "Multi-sensor" video system, presently under test by J Avni, which deters incoming birds or feathers the blades, or turns off turbines as collision-prone species approach within 500-m of these turbines;

For **all** new overhead power lines to be fitted with diurnal and nocturnal bird diverters to reduce collisions and burying all internal power lines in the WEF, wherever that is possible. The shortest possible route from the wind farm to the existing power line be taken to reduce fatalities.

Cumulative impacts:

Cumulative impacts (Masden et al. 2010) are those that may affect a species in a small area (e.g. a wind farm) yet have a wide-scale influence. If resident territorial birds are killed by turbines for example, then other individuals will be pulled in to take up the vacant territory. A wide-spread population reduction may occur as a result of the WEF acting as a sink. This is less likely for the Verreaux's Eagles given that they are a relatively common (but iconic) montane species. For breeding Booted Eagles, however, this may have a greater impact on their population because there are an estimated 700 breeding pairs in South Africa (Martin 2005).

All renewable energy applications within 30-km of Witberg are assessed below (Table 8).

Residual impacts:
After mitigation, direct mortality or area avoidance by the species identified above may still occur and further mitigation (e.g. turbine shut-down) will be needed.

Below we compare the impacts of the two turbine proposals to determine if the new Amendment of 25 turbines with higher hub heights and longer blades is better than the previous (Authorised) layout of 27 turbines of 92 m hub heights (Table 7). The table indicates that the 25 turbines of 120-m hub heights reduces the modelled impacts from medium-high (score 56) to medium (score 36). Indicating a nett reduction in risk for the Witberg Eagles for the Amended layout.

Table 7: A comparative assessment of the impacts of the Authorised Project (27 turbines at 92-m hub height) and the Proposed Amendment (25 turbines at between 92m and 120-m hub height) with mitigations.

	Authorised Project (27 turbines 92-m HH)	**Proposed Amendment (25 turbines 92 -120-m HH)**
Nature	**Negative:** Fatality of Red Data birds on site. Possible displacement of same species	**Negative:** Fatality of Red Data birds on site. Possible displacement of same species
Extent	**1** (local)	**1** (local)
Duration	**5** (lifetime of wind farm)	**5** (lifetime of wind farm)
Magnitude	**8** (high)	**6** (moderate)
Probability	**4** (highly probable)	**3** (distinct probability)
Reversibility	Low	Medium
Irreplaceable loss of species?	No (Verreaux's Eagles are not uncommon and rarer Booted Eagles may be less susceptible to collision and displacement) Combination	No (Verreaux's Eagles are not uncommon and rarer Booted Eagles may be less susceptible to collision and displacement)
Quantified loss of eagles per year (CRM x Loss model)	**0.94** Verreaux's Eagles **0.06** Booted Eagles	**0.56** Verreaux's Eagles **0.08** Booted Eagles
Significance rating	**56 (medium-high)**	**36 (medium)**

Mitigation: There are generally five classes of mitigation for birds around wind farms: (i) re-position the turbines to reduce impacts or disturbance for the birds; (ii) redesign the turbines to alter the present colour/shape/size of the turbines so birds see them more readily and avoid contact; (iii) curtail or shut-down-on-demand the turbines when collision-prone birds approach; (iv) manipulate the habitat to reduce the attractiveness of the site to collision-prone raptors; (v) reduce the overall number/height of turbines.

Because the combination of the CRM (Percival 2019) and the Loss model (Appendix 1) forecasts that the taller turbines are predicted to increase fatalities to 0.56 adult and juvenile Verreaux's Eagles per year (at 98% avoidance rates: Table 4) this is judged to be an acceptable level of mortality because it reduces the number well below one eagle per year, and it reduces the fatalities to below that for the already authorized turbine layout (0.94 adult + juvenile Verreaux's

Eagles). If the fatality rate is higher than these two models predict (i.e. >1.0 eagle per year) then mitigations will be required.

We recommend as mitigations:

(iv) the turbines closest to the known eagle nests are moved to at least 1.5-km (the distance at which significant Verreaux's Eagle flight activity falls away: Percival 2013);

(v) Birdlife South Africa Verreaux's Eagle guidelines recommend a 3-km buffer around all active nest and a 1.5-km no-go buffer (Ralston-Paton 2017). Since only seven eagle flights in 333 hours (a Passage Rate of 0.021 eagles/hour) were recorded we feel the 3-km buffer is not necessary and 1.5-km is recommended.

(vi) Post-construction, all turbines killing one or more Red Data bird per year will need to be fitted either with (a) the highly effective black-blade mitigation, or (b) automated deterrent or shut-down-on-demand; (this follows the Minister's recommendation too)

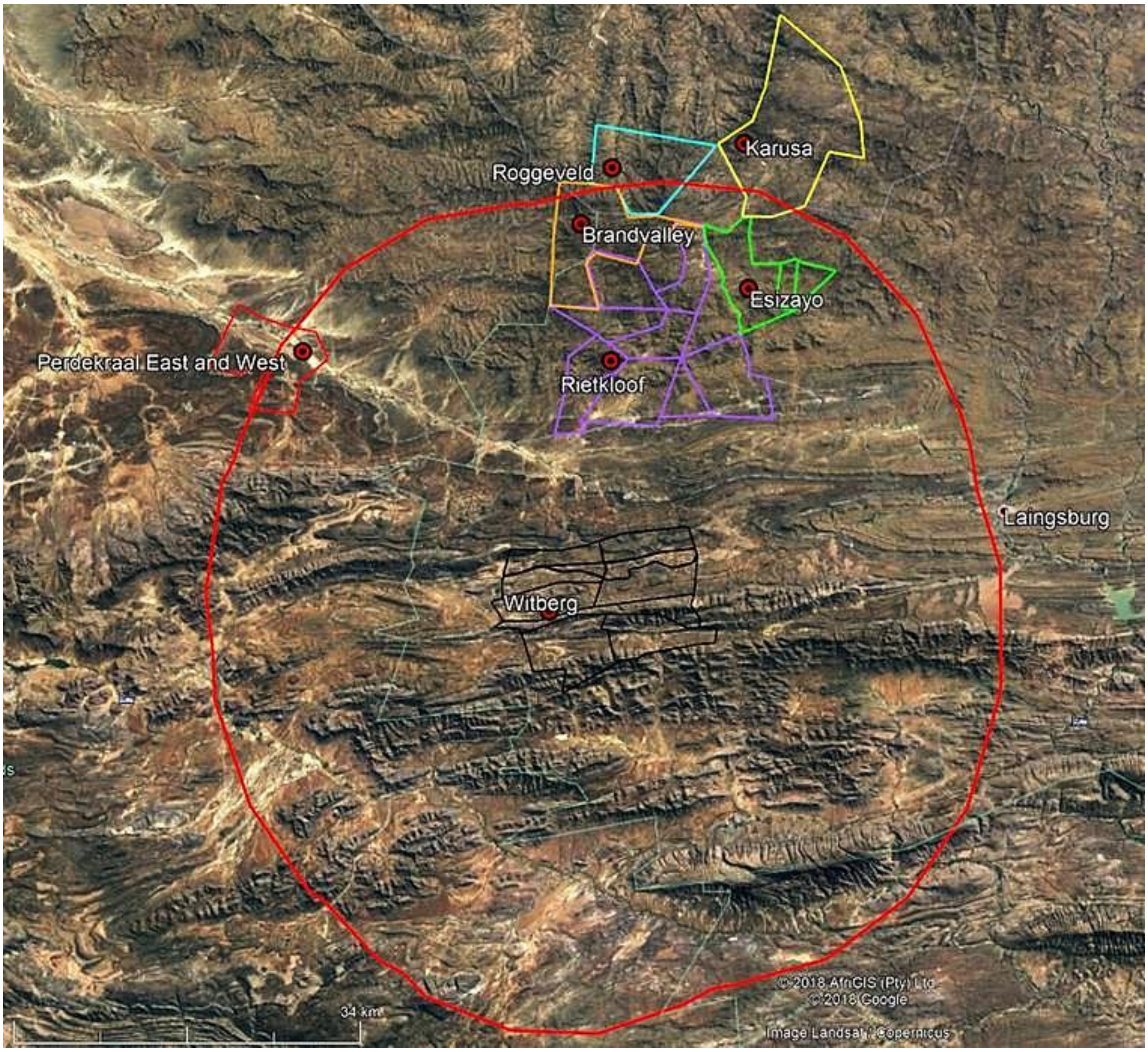

Figure 4: All renewable energy applications lodged with the DEA within a 30-km radius of the Witberg WEF site. All are wind farm sites.

5.6 Cumulative impacts

Cumulative impacts are defined as "impacts that result from incremental changes caused by either past, present or reasonably foreseeable actions together with the project" (Hyder 1999, in Masden et al. 2010).

In this context, cumulative impacts are those that will impact the avian communities in and around the Witberg development, mainly by other renewable energy facilities (wind and solar farms) and associated infrastructure in the Nama Karoo biome. This will happen via the same factors identified here viz: collision, avoidance and displacement.

As a starting point, we determined the number and nature of the renewable energy farms around the regions within a 30-km radius (Figure 4) and secondly, calculated their impact on avifauna.

Table 8: All renewable energy projects within a 30-km radius of the Witberg WEF, and their approval status with the DEA. Source: https://www.environment.gov.za/mapsgraphics DEA second quarter 2018 updated by Building Energy.

	Project Title (Applicant)	Distance from Witberg WEF (km)	Technology	Megawatts	Current Status
1	Rietkloof (Rietkloof wind farm)	21.0-km	Wind Power	140	Approved
2	Esizayo	~25-km	Wind Power	140	Approved
3	Brand Valley	30-km	Wind Power	140	Approved
4	Perdekraal East and West	30-km	Wind Power	140	Approved
5	Roggeveld	30 km	Wind Power	140	Approved
Totals:	**5 wind farms (= 700 MW)**				

Given the general assumption that footprint size and bird impacts are probably linearly-related for wind farms, a starting point in determining cumulative impacts is to calculate:

- the number of birds displaced per unit area, by habitat destruction, or disturbed or displaced by human activity;
- the number of birds killed by collision with the turbines on site; and
- the number of birds killed by collision with infrastructure leading away from the site.

Five renewable energy developments within 30 km are currently on record with the DEA (Table 7) and all are approved. Most are north or west of the Witberg study site (Figure 4). The total output from the five approved sites is 700 MW (Table 7).

We searched for data to populate the Cumulative Impacts table from data from Birdlife South Africa on 1-2-years' post-construction monitoring of avian fatalities at wind farms (Ralston-Paton et al. 2017).

The national review of post-construction **avian fatalities at wind farms** (Table 7), including data from the Karoo and Eastern and Western Cape wind farms, indicate that

- South African wind farms kill about 4.1 birds/turbine/year (range 2.1 – 8.6 fatalities/turbine/year). This is similar to the international-derived mean of about 5.25 birds/turbine/year (Loss et al. 2013).
- In terms of avian fatalities per megawatts, an average of 2.43 birds/MW/year (range 0.95 – 5.9 fatalities/MW/year) occur in South Africa (Ralston-Paton et al. 2017).
- The majority of the fatalities recorded (36%) in South Africa are raptors (Table 7).

Using the median value of **2.43 bird fatalities/MW/year** we can calculate the average (and range) of fatalities expected for all wind farms:

1. the median number of (all) birds estimated to be killed by the five wind farms (totalling 700 MW) is 1700 birds/year (range 665 – 4130 birds/y).

Note that this may be a slightly inflated figure given that many early wind farms in South Africa did not have stringent mitigation measures to reduce impacts to birds, especially appropriate buffers and siting of turbines, potentially inflating fatality rates. Thus, the lower range (665 fatalities/year) is more likely. This includes all birds not just eagles or raptors.

Table 9: Summary of all birds and Red Data raptors killed at eight wind farms in South Africa from 2014–2016. From Birdlife South Africa (Ralston-Paton et al. 2017).

Wind farms	Turbines	Months monitored	Avian fatalities	Adjusted mortality rate*
6	46, 9, 41, 40, 60, 32	69	309	4.1 birds/turbine/year
Main groups		Proportion of all avian fatalities		Ranking
Raptors (small-medium)		33%		1
Raptors (eagles)		3%		6
Others/unknown		16%		2
Swifts, swallow and martins		14%		3
Passerine (small perching birds)		14%		3
Waders and wetland birds		10%		5
Red Data raptors as a proportion of all birds killed		12/309 = 3.9%		

How many threatened (red data) species does this represent ?

- About 12 of 309 fatalities (4%) were Red Data species of raptors from the review of the seven wind farm sites (Table 9).
- Thus, from a wind farm output of 700MW and ~1700 fatalities, approximately (4% x 1700 =) 68 Red Data raptors are predicted to be killed per year. The range is 27 – 165 red data raptors.
- **Thus, a total of about 68 (range 27-165) Red Data raptors is estimated for the cumulative impacts for the five wind farms per year.**

Table 10: Cumulative impacts of the Witberg wind farm in the Western Cape, relative to five other renewable energy facilities within 30-km of the site.

Nature*:* The impact of the wind energy facilities proposed in the Western Cape is expected to be negative and arise from disturbance, displacement and collision for birds around the wind turbines. The associated infrastructure will also impact species in the form of impacts with un-marked power lines.

The direct impact of the wind farms (Table 8) was gauged using data released by Birdlife South Africa for fatalities at seven wind farms in South Africa (Ralston-Paton et al. 2017). About 4.1 birds/turbine/year, or ~2.43 birds/MW/year are killed annually. If a total of 700 MW is generated per year from these renewable energy farms, then we estimate <1700 (all) birds killed per year there (includes larks, swifts etc).

About 4% of the total of the wind farm fatalities are expected to be threatened Red Data raptors (Ralston-Paton et al. 2017). Thus, we can predict a maximum of 68 threatened raptors may be included in this total per year without mitigation. Thus, the likely impact varies from medium to high without mitigation. Careful mitigation can reduce this to acceptable levels.

	Cumulative Impact with Authorised project*	**Cumulative Impact with Proposed Amended Project****
Extent	Regional (3)	Regional (3)
Duration	Long-term (5)	Long-term (5)
Magnitude	Moderate (5)	Moderate (4)
Probability	Probable (3)	Probable (3)
Significance	**Medium (39)**	**Medium (36)**
Status (positive/negative)	Negative	Negative
Reversibility	Medium	Medium
Loss of resources/species?	Possible	Possible
Can impacts be mitigated?	Probably, Yes	Yes

Confidence in findings:

Medium: the mortality data released by Birdlife South Africa for wind farms allows us to estimate the probable mortality, but the mitigation measures suggested to avoid major raptor fatalities are unknown for the other wind farms. Without mitigation measures (i.e. the avoidance of high-use and high-risk avian areas by turbines, or black-blade or curtailment mitigations) chances of mortality increase greatly. The rate of avian fatalities is likely to vary across years with different rainfall events.

Because individual wind farms in South Africa rarely release data, it is difficult to gain accurate data without specific studies in these areas. Thus, these cumulative impact assessments will remain of low confidence until all specialist studies are made public.

Mitigation:

Reducing avian impacts at wind energy facilities is in its infancy in South Africa. Recommended measures specifically for the proposed Witberg facility include:

- Avoiding all nest areas and foraging/roosting areas of Red Data species in the siting of said facilities, guided by the CRM and known flight paths. Given the increased likelihood of eagle fatalities due to the taller turbines (Appendix 1) buffers around nests must be maintained at the 1.5-km no-go buffer recommended in the Verreaux's Eagles guidelines (Ralston-Paton 2017); this means no wind farm-related development can take place within this no-go buffer with the exception of access roads;
- If operational-phase monitoring indicates that one or more Red Data bird is killed at any turbine per year, then we recommend that black-blade mitigation as the first method used to reduce eagle mortalities;
- Multi-sensor deterrent/shut down systems can be tried as a second-tier mitigation;
- Intense short-wave radiation (Foss et al. 2017) should also be tested as a deterrent;
- If audible or visual deterrence is ineffective then selective stopping of turbines should be tried;
- Marking all new overhead power lines with bird diverters and staggering pylons of adjacent lines to reduce large birds colliding with them;

6 CONCLUSIONS AND RECOMMENDATIONS

The presence of breeding collision-prone and Red Data bird species in the Witberg Wind Farm area (in the form of Verreaux's and Booted Eagles) and the presence of other collision-prone species requires careful siting of the proposed turbines. This was undertaken by Witberg Wind Power (Pty) Ltd for the authorised project, based on the original avian impact assessment (Avisense 2010, Turpie et al. 2012, Simmons and Martins 2015), and in discussions with the specialists and following Collision-Risk Modelling (Percival 2013, 2018 , 2019). The suggested amendments of increasing the hub height (and power output) and reducing the number of turbines and relocation of turbines (including associated infrastructure) is considered here, as an addendum, for the effect it may have on the large collision-prone eagles.

In general, the change in hub height of the proposed turbines is expected to have a negative influence on the mortality experienced by sensitive birds in the study area. This arises from an analysis of 53 wind farms in the USA by Loss et al. (2013). That indicates a significant effect of hub height on avian fatalities (the higher the turbine the greater the chance of avian fatality). To forecast how many fatalities 120-m high turbines may incur, we modelled the USA data, and incorporated South African data (Appendix 1). This does not include Witberg site-specific data because these data are for operational wind farms only. Fatalities of 6.2 birds/turbine/year for 80-m turbines were predicted to increase 2.6-fold to 16 fatalities/turbine/year (95% confidence limits 9-28) at 120-m hub heights. For 92-m (authorised) turbines the fatalities of 8.0 birds/turbine/year is forecast to rise 2.0-fold to 16.0 birds/turbine/year.

An independent specialist also undertook a Collision-Risk Model (Percival 2013, 2018, 2019) using site specific eagle data to determine mortality rates of between 0.26 and 0.13 adults and between 0.02 and 0.01 juvenile Verreaux's Eagles for 98% and 99% avoidance rates respectively, for the proposed 25 turbine layout and 120-m turbines.

By combining these different modelling approaches, we calculate the following is likely in terms of potential eagle fatalities:

- Authorised 27 turbines of 92-m hub height (0.92 adult + juvenile Verreaux's Eagles/year) will have higher avian (eagle) costs, than;
- 25 turbines of between 105-m and 120-m hub height between 0.62 and 0.56 adult + juvenile Verreaux's Eagle fatalities/year, respectively (Table 4).

Therefore, the proposed amendments (increased hub height and fewer turbines) will result in a change to the significance of the impact(s) assessed for birds in the original EIA (compared in Table 7). The expected decrease in eagle fatalities arises because (i) the CRM predicted fewer eagle fatalities at higher hub heights (Percival 2018, 2019), but (ii) the area swept by the blades increases exponentially (blade-length^2) with an increase in blade length, increasing the likelihood that birds will impact the blades (Appendix 1). The rotational speed of larger turbine blades is slower and this may assist in reducing fatalities for the larger turbines.

The significance will change in a positive manner (lower impact) if the turbine height is increased (to between 105m and 120-m). However, if the models incorrectly forecast the predicted fatalities, the significance of the impact can be reduced to acceptable levels (<1 eagle per year) through the mitigation suggested. On present evidence, few flights (7 in 333 hours) took place through the 3-km buffers on the wind farm; thus, the impact of turbines within 1.5-km will be of low significance.

If there are fatalities, we recommend: (i) black-blade painting, which was found to be highly effective for White-tailed Eagles in Norway (Stokke et al. 2017), subject to obtaining approval from the South African Civil Aviation Authority. Curtailment, as previously proposed (Simmons and Martins 2015) which includes shut-down-on-demand by automatic systems such as the Multi-sensor systems can also be used. New deterrent systems such as intense shortwave LED lighting (Foss et al. 2017) should also be considered if turbines are found to kill one or more Red Data birds per year from the post-construction monitoring. Mitigations during construction should include: (i) avoiding construction within 1000-m of active nests of Red Data species during the early breeding season and chick-rearing times (May-July).

We previously recommended that a written-agreement must be included in the Environmental Authorization with the land owners that they not persecute the *Vulnerable* red data eagles breeding on their property (Simmons and Martins 2015). This recommendation arose out of the finding that an active Verreaux's Eagle nest was removed from the Elandsfontein property and burned at the base of the cliff. Similarly, 2 of the 3 nests at VE nest area 2 (Figure 2) had been removed in February 2019. This rate of nest removal at the Witberg site (3 nests in 24 nest-years) is 15-fold higher than the nest removal rate (1 nest in 112 nest-years) from two other study sites in the Western Cape (M. Murgatroyd Unpubl. Data). We recommend that the eagle-persecution agreement must state that:

- Verreaux's Eagles, (or Martial Eagles) as threatened Red data species, cannot be persecuted on the Witberg wind farm, because it is illegal to do so anywhere in South Africa (http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S1727-37812013000400006.);
- This means that eagles (adults, juveniles, chicks or eggs) on the wind farm cannot be shot, poisoned, trapped, their nests removed or the nest contents taken or in any way interfered with.

It appears that this was not included in the Environmental Authorisation. This recommendation must be re-instituted, and the written agreement appended to the authorisation.

We argue that the farmer is ultimately responsible for everything that happens on his property and he must take responsibility for any illegal activity. This can be enforced by having trail cameras overlooking the nest cliff. The careful planning and risk modelling that has gone into this report by both the developer and the specialists is under-mined if this loophole to persecuting the eagles is not closed.

All overhead power lines should be marked with bird diverters. Where possible, on-site power lines should be buried, as typical within wind farms. Where that's not possible new lines should be aligned with existing lines where possible and the pylons staggered to reduce bustard deaths (Simmons, Pallett and Brown in prep). With all these mitigations considered, and the marking of the overhead lines, the risks to collision-prone birds on the WEF site can be reduced to minimal acceptable levels.

The cumulative impacts for the five renewable energy facilities within 30-km of the Witberg site are expected to be medium as gauged by an estimated 1700 birds (including species such as larks and swifts) and 68 (range 27-165) Red Data raptors per year. The lower end of the range (27 red data raptors per year) is expected given that many early wind farms did not have stringent mitigation measures. If all wind and solar farms enact suitable mitigation measures, these impacts, too, can be reduced to acceptable levels.

In conclusion, the currently proposed amendments (i.e. 25 turbines with hub heights of 92m up to 120-m) is likely to incur fewer eagle fatalities than the authorised 27 turbines of 92-m HH, with all turbines outside the 1.5 km buffer for all eagle nests. This is calculated to be 0.52 eagles per year (worst case). If this rate is exceeded suitable mitigations, including (i) all turbines killing one or more Red Data bird per year must be black-blade painted; or (ii) fitted with automated deterrent or shut-down-on-demand, then Witberg Wind Power (Pty) Ltd can reduce their environmental/avian footprint to acceptable levels.

Birdlife South Africa (Ralston 2017) recommend during-construction monitoring and a minimum of 24 months post-construction monitoring at wind farms where impacts to Verreaux's Eagles are expected. This will determine the effects of the wind farm on the Red Data species identified as at risk. With these mitigations, we can recommend that the Witberg wind farm, as amended, can be allowed to proceed.

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9 July 2018
Revised 24 July 2018
Revised 21 August 2018
Re-revised 3 September 2018
Re-revised 28 February 2019

8 Appendix 1: The use of statistical inference to forecast possible bird fatalities when turbine heights are increased

Please note: the turbine numbers and avian fatalities used here are for indicative purposes only. The statistical model uses empirically-derived real data from wind farm studies in North America and South Africa and is used to forecast what avian fatalities may occur for different hub heights in real-life situations in South Africa.

The use of statistical inference to forecast possible bird fatalities when turbine heights are increased

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Some South African wind farms are contemplating increasing hub height of the wind turbines from 80-m to 120-m or 140-m. Environmental Consultants, Birds & Bats Unlimited, were requested to assess the possible impact to birds of this increased height. This is a report of our findings based on the international published literature, and statistical interpolation by two specialists.

We have used the data and trends from the meta-analysis of Loss et al (2013) who analysed results from 53 studies of avian fatalities and hub height in the USA, once carcass-finding biases and scavenger removals were accounted for. They found a significant positive relationship between avian fatalities and hub height for turbines from 36-m to 80-m. Avian fatalities increased 10-fold over this size range (0.6 to 6.2 birds/turbine/year).

Note that Smallwood (2013) found the opposite trend (decreasing fatalities per turbine with increased height). However, his data were skewed by a plethora of older small turbines with lattice towers – that attract perching birds – with very high fatality rates. Since lattice towers are no longer employed, this bias no longer exists, and his results are not a true reflection of avian fatalities into the future. Loss et al. (2013) accounted for this bias in their re-assessment. Their results are shown below (Figure A1).

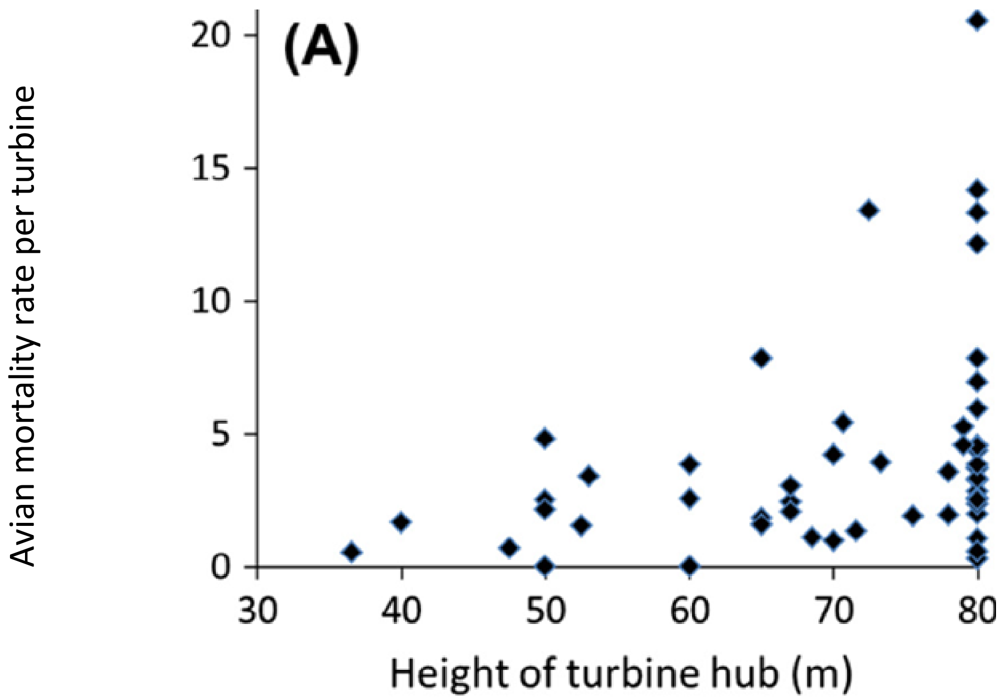

Figure A1: Results from Loss et al. (2013) indicating the significant relationship between hub height and avian mortality for 53 studies from the USA.

Modelling fatality/hub height estimates

To determine what the avian fatalities might be for taller turbines we asked two statisticians to help forecast what these rates might be, using statistical modelling. Dr Birgit Erni of the Department of Statistical Sciences at UCT and her PhD student Francisco Cervantes modelled the results provided by

Figure A2: Modelled results of avian fatalities in relation to hub height for turbines above 80-m . Data taken from Loss et al. (2013) and modelled with 95% confidence limits. Circled on the graph are the projected average number of fatalities for 120-m (22 fatalities/turbine/year).

Loss et al. (2013) to determine what the effects may be. The data for this analysis were available in the supplementary material provided in Loss et al.'s (2013) paper.

Their results are shown in Figure A2 using only the results from the USA.

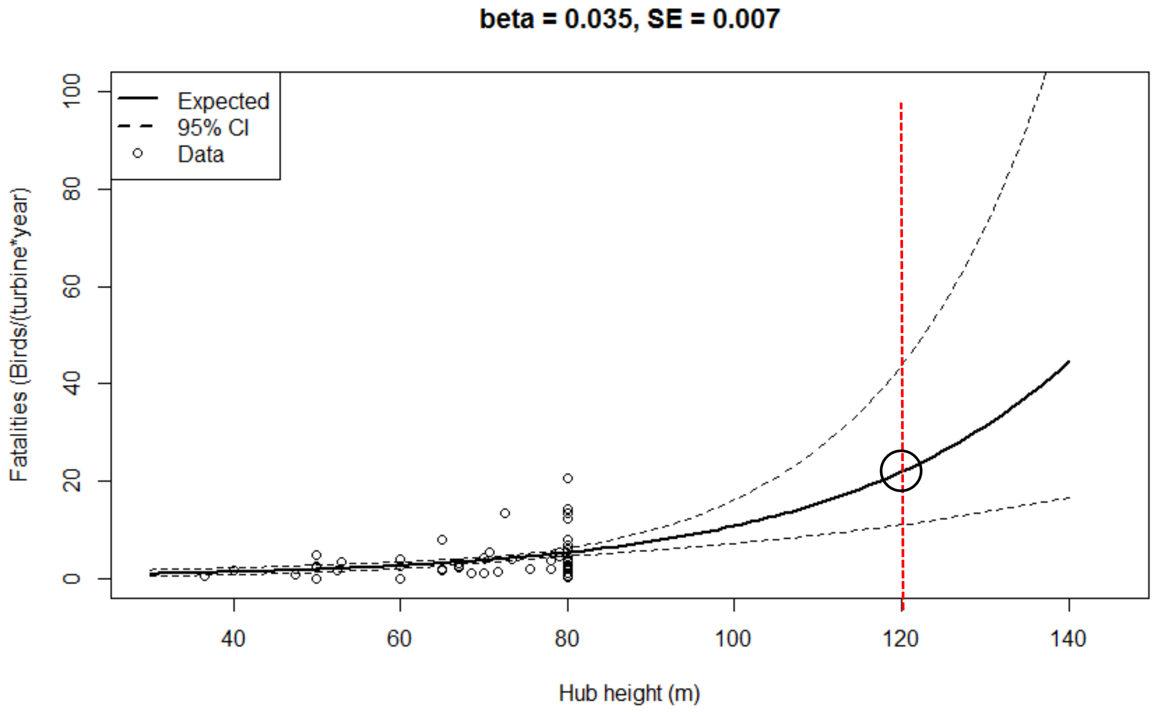

Figure A2: Modelled results of avian fatalities in relation to hub height for turbines above 80-m . Data taken from Loss et al. (2013) and modelled with 95% confidence limits. Circled on the graph are the projected average number of fatalities for 120-m (22 fatalities/turbine/year).

Their modelling indicates that the relationship between turbine height and fatalities was exponential and a predicted 22 birds (95% CI = 11, 44) may be killed on average per turbine per annum by 120-m turbines and 44 birds (95% CI = 17, 119) per annum by 140-m turbines (Figure A2) in the USA.

Such models are only statistical constructs of what may happen in reality, and it is dangerous to extrapolate too far beyond real data. This is reflected in the wide confidence intervals for the predicted average (dashed lines in the graph above).

To **test for robustness,** we went a step further and added empirically-derived South African data to the models from that reported by Ralston-Paton et al. (2017). These data, like those extracted from Loss et al. (2013), were corrected for observer biases and scavenger-removal of carcasses below turbines. They are useful because, of the eight South African wind farms with post-construction fatality data, two farms had (32) turbines of 90-m and (37) turbines of 95-m (Ralston-Paton 2017).

The results indicate (Figure A3) that the model predicts slightly lower average fatalities and decreases the uncertainty around the estimates of avian fatalities for turbines of 120-m (16 birds, 95% CI = 9, 28) and 140-m turbines (28 birds, 95% CI = 12, 65).

Thus fatalities

- increased by 2.6-fold (6.2 to 16 fatalities) from 80-m to 120-m hub heights
- increased by 2.0-fold (8.0 to 16 fatalities) from 92-m (authorised) to 120-m hub height

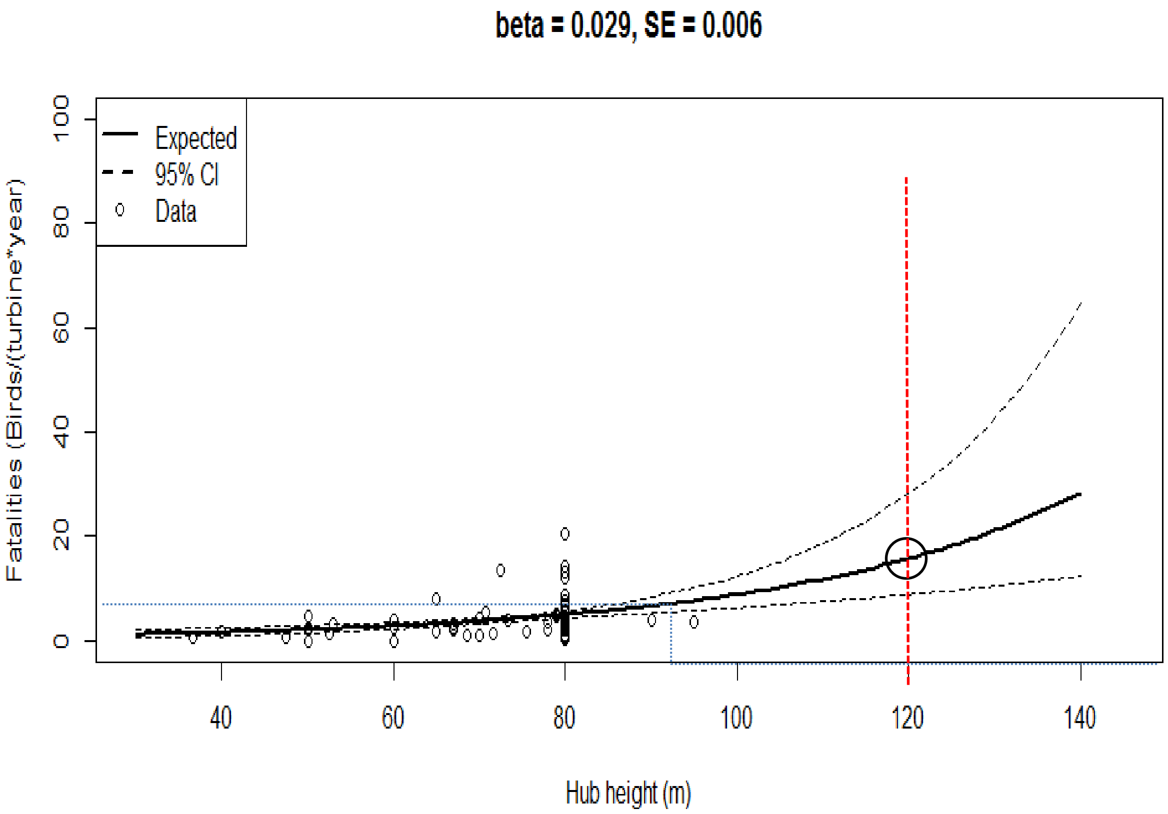

Figure A3: Modelled data combining avian fatalities **from the USA** (Loss et al. 2013) **and from South Africa** (Ralston-Paton et al. 2017) and their relation to hub height. The South African data (n = 7 farms) include two with hub heights of 90-m and 95-m. The combined data and 95% confidence limits predict 6.2 fatalities at 80-m, 16 birds (95% CI = 9, 28) will be killed on average per year for 120-m-high turbines and 28 (95% CI = 12, 65) birds on average for 140-m-high turbines.

We can also determine the confidence intervals around the extrapolated fatalities beyond 80-m hub height using a boot-strapping method. These are 95% bootstrap prediction intervals. These intervals predict the actual observations, rather than the average.

These confidence intervals are based on the original data of Loss et al (2013), and we used them to determine if the South African data points fall within the 95% confidence limits derived from the North American data (Figure 4). One would expect to see ~ 5% of actual observations to fall outside these limits.

The results indicate that the South African data all lie within the 95% confidence intervals. This means that the inference on fatalities at hub heights beyond 80-m, derived from the data of Loss et al. (2013) and applied to South African data (red points in Figure A4) is relatively robust, and we can draw some conclusions on South African wind farms where taller turbines may be used.

Again, these are only valid if the same relationship between fatalities and height holds beyond 90-95-m. Further data for taller turbines are, thus, required to validate these models.

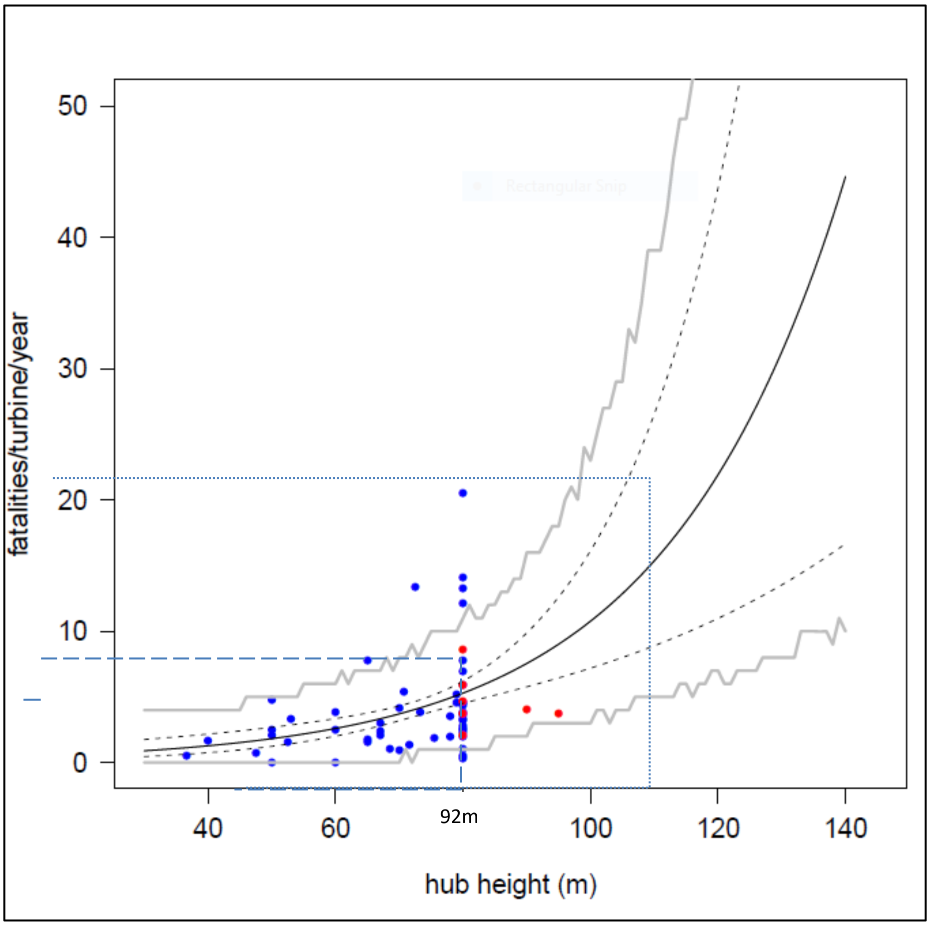

Figure A4: Prediction intervals from bootstrapping analyses based on North American hub height/fatality data (Loss et al. 2013 = blue data points) to determine if South African data (= Red Data points) fall within 95% confidence intervals.

Validating predictions with eagle flight height data

We can only apply these fatality estimates as rough estimates to how many birds may be impacted, because:

- different wind farms will have a different suite of at-risk collision-prone species, and
- those species may also fly at different heights depending on topography, behaviour (hunting, displaying or commuting), or weather.

For one proposed wind farm site, we collected flying heights of the Collision-Prone raptors by estimating flight heights in each of six visits equally spaced throughout the year. We recorded heights in bands (1-20-m, 20-40-m, 40-120-m, 120-160-m, 160+m) at first sighting for one large, highly-collision-prone species, the **Verreaux's Eagle** *Aquila verreauxii,* and a smaller, less collision-prone eagle, the **Booted Eagle** *Aquila pennatus*. These two species are ranked 2nd and 55th respectively in the top 100 collision-prone species (Birdlife South Africa).

We calculated the proportion of flights for the following combination of hub-heights corresponding to the highest and lowest blade-swept heights (BSH) for the different turbines:

- 80-m turbines – BSH: 36 – 124-m
- 120-m turbines – BSH: 54 – 186-m
- 140-m turbines – BSH: 60 – 220-m

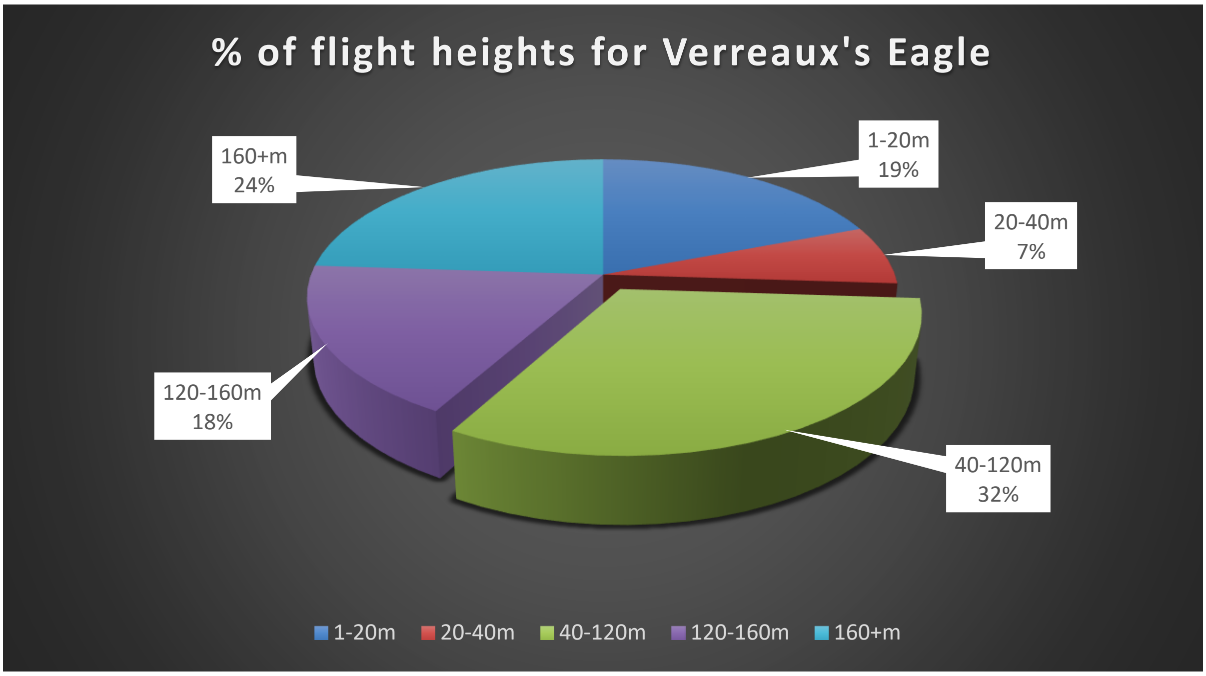

Figure A5: Flight heights recorded for Verreaux's Eagles at a proposed WEF in Springbok in montane habitat. Data collected January, April, June, August 2012; November 2014 and February 2015, covering all seasons, and based on 418 records of flying eagles.

The results (Figure A5) indicated that:

- most flights of Verreaux's Eagles were recorded in the height band 40-120-m (32%),
- fewest flights, of the 418 recorded across all seasons, were recorded in the band 20-40-m (7%). This is not necessarily surprising for large resident eagles.

What proportion of flights occur in the "risky" blade-swept zone for different height turbines?

Because we recorded in height bands (0-20-m, 20-40-m, 40–120-m, 120-160-m and 160$^+$ m) we had to estimate the proportions of flights in the important BSH category of 36-124-m for the 80-m turbines. We did so in the following way:

We started with the proportion of flights in the band 40-120-m (= **32%**). We then calculated the proportion of flights that occurred down to 36-m in the 20-40-m band as a fifth of the flights occurring there (4/20 of 7% = **1.4%**). At the upper end, for the proportion of flights from 120-130-m, we took the "first 4-m" of all flights in 120-160-m band, or 4-m/40-m = 10%. Thus 10% of 18% = **1.8%**.

Similar procedures were followed to estimate the proportion of risky flights for the 120-m and 140-m turbines (Table A1).

Table A1. The estimated proportion of risky flights by **Verreaux's Eagles** for different-sized turbines, based on 418 recorded flights, 2012-2105.

Turbine Hub Height (blade length)	Blade-swept height (m) Lowest	: Highest	Proportion of flights in these risky zones
80-m (44-m)	36	124	35.2%
120-m (66-m)	54	186	60.4%
140-m (80-m)	60	220	68.7%

The estimates of the proportion of risky flight at blade-swept heights (BSH) doubled from 35% for the 80-m turbines to almost 70% for the 140-m turbines (Table A1). The 120-m high turbines were intermediate at 60%.

Thus, for **Verreaux's Eagles**, the likelihood that more deaths might occur with taller turbines (from statistical models: Figure 4) is corroborated by the behaviour of the birds in their natural environments: the proportion of risky flights almost doubled from 35% for the 80-m turbines to 69% for the 140-m turbines.

For **Booted Eagles** the proportion of risky flight at BSH was similar to that for their larger-bodied cousins (Table A2). Based on 160 flights recorded from 2012 to 2015 across all seasons, the proportion of flights in the BSH rose from ~35% to ~70 % with an increase in hub height from 80-m to 140-m. For this species, equal numbers of risky flights were calculated for 120-m hub heights.

Table A2. The estimated proportion of risky flights by **Booted Eagles** for different-sized turbines, based on 160 recorded flights, 2012-2105.

Turbine Hub Height (blade length)	Blade-swept height (m) Lowest	: Highest	Proportion of flights in these risky zones
80-m (44-m)	36	124	34.5%
120-m (66-m)	54	186	70.6%
140-m (80-m)	60	220	69.2%

Thus, for both large and small eagle species recorded on the South African wind farm site, we can conclude that the proportion of risky flights in the BSA increase two-fold when turbines are increased from 80-m to 120-m. This concurs with the statistical inference based on North American and South African data that fatalities increase about 2.6 -fold when turbines are increased from 80-m to 120-m.

Reasons for higher fatalities

Why would higher turbines be predicted to kill more birds than smaller turbines? There are two possibilities, one ecological, one statistical:

(iii) Ecologically, taller turbines and their greater blade-swept height are more likely to intersect migrating eagles studied in North America which tend to fly 2- to 4-fold higher (average 135-341-m) than resident birds (63-83-m: Katzner et al. 2012);

(iv) Statistically, longer blades are associated with taller turbines. For example, 120-m high turbines have 68-m blades at Witberg (while 80-m turbines had 44-m blades). This 1.55-fold increase in blade-length more than doubles the blade-swept area from 6,083-m^2 to

14,530 m^2. Thus, by chance, a passing bird has a 2.4-fold higher probability of intersecting a blade from a taller turbine.

These possibilities can, therefore, explain why fatalities are predicted to increase from an average of 6 to 16 (95% CI = 9, 28) birds per turbine per year when hub height is increased from 80-m to 120-m.

What combination of turbine numbers and height will minimise avian fatalities?

In Table A3 below we use the statistically inferred fatality estimates for different numbers and heights of turbines to determine which combination gives the lowest number of fatalities.

Table A3 Re-assessing the potential average number of avian fatalities per year with increases or decreases in turbine heights and turbine numbers. The number of turbines is based on the premise that turbine number x power/turbine output = 140MW. Hence (i) **56** turbines of 80-m turbines x 2.5MW = 140MW, or (ii) **31** turbines of 120-m x 4.5MW = 140MW; or (iii) **28** turbines of 120-m x 5.0MW = 140MW. Based on fatality estimates modelled by Erni and Cervantes (see Figures 3 and 4). This increases the average fatality estimates (for 80-m turbines) from 6.2 birds.turbine.year^{-1} to 16 birds.turbine.year^{-1} for 120-m turbines, a 2.58-fold increase.

		Turbine number		
Turbine height	Ave No. fatalities/ turbines/yr[a] (95% CI)[b]	**56 turbines** (of 2.5 MW) Total fatalities (95% CI)	**31 turbines** (of 4.5 MW) Total fatalities (95% CI)	**28 turbines** (of 5.0 MW) Total fatalities (95% CI)
80-m	6.2	**347 birds**	**-**	**-**
120-m	16 (9-28)	896 (504-1568) birds	496 (279-868) birds	**448** (252-784) birds

[a] extrapolated from trends in Figure 3. [b] CI= Confidence limits, derived from Figure 3

We conclude from these new fatality estimates that 28 turbines of 120-m hub-height will kill about 100 more birds per year than 56 turbines of 80-m. If fatalities due to taller turbines occur at the lower end of the 95% confidence limits modelled, then 28 turbines of 120-m hub height are the best option with 252 fatalities (Table 3, last column, bottom row).

Acknowledgements: We thank Dr Scott Loss and his team for answering our questions and allowing us access to their data, and for the wind farm manager for prompting us to look at our flight-height data to link the statistics to real-life situations.

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1 May 2017