FEI Technical Appendix C: Collision Risk Modelling

South Kyle II Wind Farm

04 June 2026

1412177

Vattenfall

Contents

1. Methods

Following submission of the Environmental Impact Assessment (EIA) for the proposed South Kyle II wind farm development (Proposed Development Area), avian collision risk modelling (CRM) carried out according to the Band Report (2024) Collision Risk Model, has been re-run for an updated turbine layout ('Amended Proposed Development'). In addition, it was noted that the NatureScot guidance accompanying the model has been updated since submission of the assessment and now specifies use of a collision risk zone (CRZ) which represents the rotor diameter plus 500 m, whereas the original assessment was carried out using a CRZ definition of rotor diameter plus 200 m. The modelling has also been re-run using this updated buffer specification to indicate whether and how this affects the outcomes. Based on a rotor radius of 85 m (see Table 1.1), the respective CRZs of 285 m buffer of the proposed turbines on the original CRZ and a 585 m CRZ buffer of the proposed turbines based upon current guidance.

As previously, the analysis was carried out using the spreadsheet provided alongside the most recent NatureScot CRM guidance (NatureScot, 2024). Inputs for the spreadsheet were derived from raw survey data using R version 4.3.0 (R Core Team, 2023).

1.1. Turbine and wind farm parameters

Turbine and wind farm parameters did not change since the number and type of turbine proposed remain the same. However, the relocation of three of the turbines, and also the transition to the 585 m CRZ buffer did result in slightly different collision risk zones so the latitude used in the modelling, representing the latitude at the centre point of the collision risk zone polygon, differs slightly for each analysis. All wind farm and wind turbines parameters used in the CRM are presented in Table 1.1 and Table 1.2.

As for the original assessment, no large array correction was applied due to the relatively small number of turbines.

Table 1.1: Wind farm attributes used in collision risk analysis

Attribute	Original 285 m collision risk zone	Updated 285 m collision risk zone	Updated 585 m collision risk zone	Source
Latitude (degrees)	55.32954	55.32966	55.32940	Latitudinal coordinate of the centroid of the CRZ
Number of turbines	11	11	11	Provided by Developer
Hub height (metres)	115	115	115	Provided by Developer
Rotor radius (metres)	85	85	85	Provided by Developer
Number of blades	3	3	3	Provided by Developer
Rotation speed (rpm)	7.03	7.03	7.03	See Appendix A
Maximum blade width (metres)	4.5	4.5	4.5	Provided by Developer
Pitch (degrees)	15	15	15	Not available so tool default applied

1.2. Flight activity surveys

As in the original assessment, all modelling was based on data from VP surveys conducted between April 2021 and February 2023 from six vantage point (VP) locations, designed such that the 2 km semi-circular viewsheds would cover as much of the Proposed Development Area as possible. The viewshed from VP6 did not overlap with any of the collision risk zones considered.

Table 1.2: Proportion of time turbines were assumed to be operational by month of the year

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Proportion of time available (i.e. not shut down for maintenance/repair)*	0.94	0.94	0.92	0.94	0.85	0.85	0.85	0.92	0.92	0.94	0.94	0.94
Proportion of time above cut-in and below cut-out (i.e. at operational wind speeds)**	0.96	0.97	0.93	0.92	0.92	0.86	0.87	0.90	0.92	0.96	0.95	0.96
Total proportion of time operational	0.91	0.91	0.86	0.86	0.78	0.73	0.74	0.82	0.85	0.90	0.90	0.90

*Source: *Indicative values taken from worked example in NatureScot, 2024, **Provided by the Developer*

1.2.1. Height bands

Bird activity was recorded relative to three height bands, presented in Table 1.3.

Table 1.3: Height bands used to record bird flight activity at the Site

Height band	Height range (m)
HB1	<10
HB2	10 – 210
HB3	> 210

As in the original assessment, since the height within which the proposed turbine blades will rotate (potential collision height or PCH; 30 – 200m, see Table 1.1) falls within height band 2, only flight activity within this height band was considered to be at potential collision risk.

1.3. Analysis using standard VP survey data only

1.3.1. Bird data and species included

The number of flights and individuals of target bird species recorded during surveys, within or passing through the CRZ and within or passing through the CRZ at PCH are presented in Table 1.4. There were no differences in the numbers or individuals in any of these categories for the old and new layout applying the 285 m CRZ buffer, but there were additional flights associated with use of the 585 m CRZ buffer. These are provided in additional columns in Table 1.4.

CRM was only run for birds for which at least three flights or 10 individuals were recorded within the CRZ at PCH during the course of the surveys. Two target species fulfilled this criterion for the 285 m CRZ: barnacle goose and lesser black-backed gull (Table 1.4). Goshawk also met this requirement for the 585 m CRZ buffer.

Bird parameters used for the modelling of species using standard VP survey effort are presented in Table 1.5.

Table 1.4: Number of flights and individuals of target bird species recorded during surveys (including VP6), within or passing through the collision risk zone (CRZ) and within or passing through the CRZ at PCH.

Species - Scenario	Dataset	Year 1 (2021 - 2022)				Year 2 (2022 - 2023)				Total	
		Breeding		Non-breeding		Breeding		Non-breeding			
		Flights	Individuals	Flights	Individuals	Flights	Individuals	Flights	Individuals	Flights	Individuals
Barnacle goose – 285 m CRZ	Full	0	0	2	250	0	0	0	0	2	250
	CRZ	0	0	2	250	0	0	0	0	2	250
	CRZ at PCH	0	0	2	250	0	0	0	0	2	250
Barnacle goose – 585 m CRZ	Full	0	0	2	250	0	0	0	0	2	250
	CRZ	0	0	2	250	0	0	0	0	2	250
	CRZ at PCH	0	0	2	250	0	0	0	0	2	250
Canada goose – 285 m CRZ	Full	2	4	0	0	0	0	0	0	2	4
	CRZ	1	2	0	0	0	0	0	0	1	2
	CRZ at PCH	1	2	0	0	0	0	0	0	1	2
Canada goose – 585 m CRZ	Full	2	4	0	0	0	0	0	0	2	4
	CRZ	1	2	0	0	0	0	0	0	1	2
	CRZ at PCH	1	2	0	0	0	0	0	0	1	2
Goshawk – 285 m CRZ	Full	1	1	1	1	2	2	1	1	5	5
	CRZ	0	0	1	1	0	0	1	1	2	2
	CRZ at PCH	0	0	1	1	0	0	1	1	2	2
	Full	1	1	1	1	2	2	1	1	5	5

Species - Scenario	Dataset	Year 1 (2021 - 2022)				Year 2 (2022 - 2023)				Total	
		Breeding		Non-breeding		Breeding		Non-breeding			
		Flights	Individuals	Flights	Individuals	Flights	Individuals	Flights	Individuals	Flights	Individuals
Goshawk – 585 m CRZ	CRZ	1	1	1	1	0	0	1	1	3	3
	CRZ at PCH	1	1	1	1	0	0	1	1	3	3
Greylag goose – 285 m CRZ	Full	0	0	0	0	1	2	0	0	1	2
	CRZ	0	0	0	0	1	2	0	0	1	2
	CRZ at PCH	0	0	0	0	1	2	0	0	1	2
Greylag goose – 585 m CRZ	Full	0	0	0	0	1	2	0	0	1	2
	CRZ	0	0	0	0	1	2	0	0	1	2
	CRZ at PCH	0	0	0	0	1	2	0	0	1	2
Golden plover – 285 m CRZ	Full	0	0	4	61	0	0	0	0	4	61
	CRZ	0	0	0	0	0	0	0	0	0	0
	CRZ at PCH	0	0	0	0	0	0	0	0	0	0
Golden plover – 585 m CRZ	Full	0	0	4	61	0	0	0	0	4	61
	CRZ	0	0	0	0	0	0	0	0	0	0
	CRZ at PCH	0	0	0	0	0	0	0	0	0	0
Herring gull – 285 m CRZ	Full	0	0	0	0	3	18	0	0	3	18
	CRZ	0	0	0	0	0	0	0	0	0	0
	CRZ at PCH	0	0	0	0	0	0	0	0	0	0
	Full	0	0	0	0	3	18	0	0	3	18

Species - Scenario	Dataset	Year 1 (2021 - 2022)				Year 2 (2022 - 2023)				Total	
		Breeding		Non-breeding		Breeding		Non-breeding			
		Flights	Individuals	Flights	Individuals	Flights	Individuals	Flights	Individuals	Flights	Individuals
Herring gull – 585 m CRZ	CRZ	0	0	0	0	0	0	0	0	0	0
	CRZ at PCH	0	0	0	0	0	0	0	0	0	0
Hen harrier – 285 m CRZ	Full	1	1	3	3	1	1	0	0	5	5
	CRZ	0	0	0	0	1	1	0	0	1	1
	CRZ at PCH	0	0	0	0	1	1	0	0	1	1
Hen harrier – 585 m CRZ	Full	1	1	3	3	1	1	0	0	5	5
	CRZ	1	1	1	1	1	1	0	0	3	3
	CRZ at PCH	1	1	0	0	1	1	0	0	2	2
Kestrel – 285 m CRZ	Full	14	15	0	0	0	0	0	0	14	15
	CRZ	1	1	0	0	0	0	0	0	1	1
	CRZ at PCH	1	1	0	0	0	0	0	0	1	1
Kestrel – 585 m CRZ	Full	14	15	0	0	0	0	0	0	14	15
	CRZ	2	2	0	0	0	0	0	0	2	2
	CRZ at PCH	2	2	0	0	0	0	0	0	2	2
Red kite – 285 m CRZ	Full	0	0	0	0	1	1	0	0	1	1
	CRZ	0	0	0	0	0	0	0	0	0	0
	CRZ at PCH	0	0	0	0	0	0	0	0	0	0
Red kite – 585 m CRZ	Full	0	0	0	0	1	1	0	0	1	1
	CRZ	0	0	0	0	0	0	0	0	0	0
	CRZ at PCH	0	0	0	0	0	0	0	0	0	0

Species - Scenario	Dataset	Year 1 (2021 - 2022)				Year 2 (2022 - 2023)				Total	
		Breeding		Non-breeding		Breeding		Non-breeding			
		Flights	Individuals	Flights	Individuals	Flights	Individuals	Flights	Individuals	Flights	Individuals
Lesser black-backed gull – 285 m CRZ	Full	18	37	0	0	15	18	0	0	33	55
	CRZ	7	10	0	0	0	0	0	0	7	10
	CRZ at PCH	6	9	0	0	0	0	0	0	6	9
Lesser black-backed gull – 585 m CRZ	Full	18	37	0	0	15	18	0	0	33	55
	CRZ	12	16	0	0	3	4	0	0	15	20
	CRZ at PCH	8	11	0	0	3	4	0	0	11	15
Peregrine – 285 m CRZ	Full	0	0	2	2	1	1	0	0	3	3
	CRZ	0	0	0	0	0	0	0	0	0	0
	CRZ at PCH	0	0	0	0	0	0	0	0	0	0
Peregrine – 585 m CRZ	Full	0	0	2	2	1	1	0	0	3	3
	CRZ	0	0	0	0	0	0	0	0	0	0
	CRZ at PCH	0	0	0	0	0	0	0	0	0	0
Pink-footed goose – 285 m CRZ	Full	0	0	0	0	0	0	2	125	2	125
	CRZ	0	0	0	0	0	0	1	60	1	60
	CRZ at PCH	0	0	0	0	0	0	0	0	0	0
	Full	0	0	0	0	0	0	2	125	2	125

Species - Scenario	Dataset	Year 1 (2021 - 2022)				Year 2 (2022 - 2023)				Total	
		Breeding		Non-breeding		Breeding		Non-breeding			
		Flights	Individuals	Flights	Individuals	Flights	Individuals	Flights	Individuals	Flights	Individuals
Pink-footed goose – 585 m CRZ	CRZ	0	0	0	0	0	0	2	125	2	125
	CRZ at PCH	0	0	0	0	0	0	0	0	0	0
Snipe – 285 m CRZ	Full	6	7	0	0	0	0	3	3	9	10
	CRZ	0	0	0	0	0	0	0	0	0	0
	CRZ at PCH	0	0	0	0	0	0	0	0	0	0
Snipe – 585 m CRZ	Full	6	7	0	0	0	0	3	3	9	10
	CRZ	0	0	0	0	0	0	0	0	0	0
	CRZ at PCH	0	0	0	0	0	0	0	0	0	0
Woodcock – 285 m CRZ	Full	0	0	0	0	0	0	1	1	1	1
	CRZ	0	0	0	0	0	0	1	1	1	1
	CRZ at PCH	0	0	0	0	0	0	0	0	0	0
Woodcock – 585 m CRZ	Full	0	0	0	0	0	0	1	1	1	1
	CRZ	0	0	0	0	0	0	1	1	1	1
	CRZ at PCH	0	0	0	0	0	0	0	0	0	0
Whooper swan – 285 m CRZ	Full	0	0	1	22	0	0	1	5	2	27
	CRZ	0	0	0	0	0	0	1	5	1	5
	CRZ at PCH	0	0	0	0	0	0	1	5	1	5

Species - Scenario	Dataset	Year 1 (2021 - 2022)				Year 2 (2022 - 2023)				Total	
		Breeding		Non-breeding		Breeding		Non-breeding			
		Flights	Individuals	Flights	Individuals	Flights	Individuals	Flights	Individuals	Flights	Individuals
Whooper swan – 585 m CRZ	Full	0	0	1	22	0	0	1	5	2	27
	CRZ	0	0	1	22	0	0	1	5	2	27
	CRZ at PCH	0	0	0	0	0	0	1	5	1	5

Table 1.5: Bird attributes used in CRM.

Species	Bird length (metres)*	Wingspan (metres)*	Bird speed (metres/second) **	Flapping or gliding	Percent of flights upwind (%)	Nocturnal activity ranking	Recommended avoidance rate***	Seasonal definitions used
Barnacle goose	0.70	1.45	17.0	Flapping	50%	2	0.998	Breeding: March to August Non-breeding: September to February
Lesser black-backed gull	0.58	1.43	13.1	Flapping	50%	1	0.995	Breeding: March to August Non-breeding: September to February
Goshawk	0.55	1.5	11.3	Flapping	50%	1	0.980	Breeding: March to August Non-breeding: September to February

*Sources: *Snow and Perrins, 1998; **Alerstam et al., 2007; ***NatureScot, 2018 (barnacle goose and goshawk) and Furness, 2019 (lesser black-backed gull)*

1.3.2. Temporal effort

Temporal survey effort is summarised by month in Table 1.6 below. Temporal effort is used in a calculation of density of seconds of bird flight activity per km^2 per second of survey effort. The Band Report (2024) CRM can incorporate density inputs at a monthly resolution, however here, densities were calculated on a seasonal basis due to relatively low sampling effort per VP per month (following NatureScot, 2024) (see Section 1.3.4). Seasonal effort used for CRM is presented in

Table 1.7.

Table 1.6: Temporal survey effort used in CRM.

Month-Year	Year	Season	Hours survey effort					
			VP1	VP2	VP3	VP4	VP5	VP6*
Apr-21	Year 1	Breeding	9	9	9	9	6	6
May-21	Year 1	Breeding	9	6	12	9	12	12
Jun-21	Year 1	Breeding	9	9	6	9	9	9
Jul-21	Year 1	Breeding	6	9	6	6	6	6
Aug-21	Year 1	Breeding	3	3	3	3	3	3
Oct-21	Year 1	Non-breeding	12	12	12	12	12	12
Nov-21	Year 1	Non-breeding	6	6	6	6	6	6
Dec-21	Year 1	Non-breeding	3	6	6	6	6	6
Jan-22	Year 1	Non-breeding	9	6	6	6	6	6
Feb-22	Year 1	Non-breeding	6	6	6	6	6	6
Mar-22	Year 2	Breeding	6	6	6	6	6	6
Apr-22	Year 2	Breeding	6	6	6	6	6	6
May-22	Year 2	Breeding	6	6	6	6	6	6
Jun-22	Year 2	Breeding	6	6	6	6	6	6
Jul-22	Year 2	Breeding	6	6	6	6	6	6
Aug-22	Year 2	Breeding	6	6	6	6	6	6
Sep-22	Year 2	Non-breeding	6	6	6	6	6	6
Oct-22	Year 2	Non-breeding	6	6	6	6	6	6
Nov-22	Year 2	Non-breeding	6	6	6	6	6	6
Dec-22	Year 2	Non-breeding	6	6	6	6	6	6
Jan-23	Year 2	Non-breeding	6	6	6	6	6	6
Feb-23	Year 2	Non-breeding	6	6	6	6	6	6

VP 6 did not overlap with the CRZ.

Table 1.7: Temporal effort used for CRM of data from standard VP surveys.

Year	VP	Survey effort (seconds)	
		Breeding season	Non-breeding season
Year 1	VP1	129600	129600
	VP2	129600	129600
	VP3	129600	129600
	VP4	129600	129600
	VP5	129600	129600
	VP6*	129600	129600
Year 2	VP1	129600	129600
	VP2	129600	129600
	VP3	129600	129600
	VP4	129600	129600
	VP5	129600	129600
	VP6*	129600	129600

VP 6 did not overlap with the CRZ.

1.3.3. Spatial effort

Spatial effort is also used in the calculation of density of seconds of bird flight activity per km^2 per second of survey effort. The areas used in the CRM are presented in Table 1.8.

Table 1.8: Spatial effort used in CRM (in km^2).

VP	Area of the CRZ covered (km^2) – original assessment	Proportion of CRZ covered (%) – updated 285 m buffer	Area of the CRZ covered (km2) – updated 585 m buffer
1	0.83	0.82	1.87
2	0.46	0.46	1.14
3	2.37	2.40	4.90
4	0.11	0.11	0.37
5	0.25	0.25	0.85
6	0	0	0
Total area of CRZ	2.78	2.78	7.08

1.3.4. Analysis

1.3.4.1. Commuting (directional) species

Barnacle goose and lesser black-backed gull are typically considered as commuting species which will likely pass directly through a site. For such species, the number of observed passages through the viewsheds are used to derive a flux rate (also referred to as mean traffic rate or MTR) which can then be converted into a bird density (referred to as D_A) for use within the Band (2024) model. Bird density was calculated separately for each viewshed, season and year. As described above, whilst density inputs for the Band model can be provided per month, monthly survey effort was not considered sufficient to enable robust monthly density estimates to be generated, therefore average seasonal estimates were calculated and used as the input for the months covering that season.

Bird density was calculated as follows:

1. The average flight direction of each commuting species was calculated using all data available (i.e. including flights recorded outside of the CRZ) for that species to maximise the sample size used.
2. Each viewshed surveyed was clipped by a polygon representing the CRZ as defined previously (i.e. a 285 m buffer around the proposed turbine locations).
3. The maximum width of each clipped viewshed perpendicular to the average flight direction for each species was measured using QGIS. These values are presented in Table 1.9.
4. The number flights of each species within each viewshed and season, excluding those only occurring in the uppermost unbounded height band (to allow inclusion of a height parameter for the bird density calculation - see below), was calculated.
5. Flux rate in metres per second for each year, season and VP was calculated as:

$$Flux\ rate_{sp} = N\ flights_{sp} \,/\, Seconds\ surveyed \,/\, Maximum\ viewshed\ width$$

   Where *sp* is species, *Maximum viewshed width* is measured in metres and N flights excludes flights only passing through the unbounded upper height band (to allow inclusion of a height parameter for the bird density calculation - see below).
6. Bird density was then calculated as:

$$Bird\ density_{sp} = Flux\ rate_{sp} \times (\pi/2) \,/\, (bird\ speed_{sp} \times height\ of\ bounded\ survey\ area)$$

   Where the height of the bounded survey area corresponds to the highest height of the topmost height band, in this case 210 m.

Table 1.9: Maximum length of the baseline perpendicular to flight direction covered by each viewshed. VP6 is not included since this the viewshed did not overlap with the CRZ.

VP	Length of the baseline covered by the viewshed (m)					
	Barnacle goose			Lesser black-backed gull		
	Original	Updated 285 m CRZ*	Updated 585 m CRZ	Original	Updated 285 m CRZ*	Updated 585 m CRZ
1	2707	2973	3424	2940	2370	2570
2	1935	1924	2101	1924	1445	1880
3	3336	2869	3337	3095	2724	3117
4	306	347	651	309	325	644
5	570	570	1978	570	570	1312

*Note that these distances were calculated manually in the original assessment but are now calculated using an algorithm for greater accuracy and repeatability

Seasonal averages were then constructed by averaging across VPs and years for each season, weighted by effort in km^2 seconds.

Final densities used are presented in Table 1.10.

Table 1.10: Densities used for CRM of directional flights

Scenario	Species	Breeding		Non-breeding	
		Mean	Standard deviation	Mean	Standard deviation
Original assessment	Barnacle goose	0	0	0.0000479	0.0001128
	Lesser black-backed gull	0.0000025	0.0000035	0	0
Updated 285 m buffer	Barnacle goose	0	0	0.0000489	0.0001075
	Lesser black-backed gull	0.0000030	0.0000041	0	0
Updated 585 m buffer	Barnacle goose	0	0	0.0000369	0.0000883
	Lesser black-backed gull	0.0000046	0.0000048	0	0

Proportion of birds at risk height

The Band Report (2024) model also requires an input representing the proportion of birds at risk height. This was calculated based on only those birds passing through the CRZ. All flights passing through the collision risk height range at any time were considered to be at risk height. Any birds that passed only through the unbounded upper height band would have been excluded in order for the proportion of birds at risk height to reflect the subset of flights applied for the density estimation. However, in this case, no such flights were observed. Proportions used in the modelling are presented in Table 1.11.

Table 1.11: Proportion of directional flights at risk height within the CRZ

Scenario	Species	Total birds flying within the CRZ	Birds ever flying at risk height	Percentage birds ever at risk height
Original assessment	Barnacle goose	250	250	100%
	Lesser black-backed gull	10	9	90%
Updated 285 m buffer	Barnacle goose	250	250	100%
	Lesser black-backed gull	10	9	90%
Updated 585 m buffer	Barnacle goose	250	250	100%
	Lesser black-backed gull	20	15	75%

1.3.4.2. Non-directional species

Goshawk is expected to spend time travelling within the CRZ ('non-directional flight') rather than passing directly through ('commuting flight'). For such species, bird density for use within the Band (2024) model can be calculated directly from seconds of flight activity (see below). As above, average seasonal estimates were calculated and used as the input for the months covering that season.

The number of seconds of activity of each species occurring within each viewshed per season per year was calculated as:

$$Seconds\ of\ activity = \sum_{fl=1}^{n\ flights} Duration_{fl} * Number\ of\ birds_{fl} * Proportion\ length\ in\ viewshed_{fl}$$

These values are presented in Table 1.12.

Table 1.12: Seconds of flight activity for goshawk

Year	VP	Non-breeding
Year 1	1	0
Year 1	2	139.05
Year 1	3	0
Year 1	4	0
Year 1	5	0
Year 2	1	0
Year 2	2	0
Year 2	3	0
Year 2	4	0
Year 2	5	187.36

Bird density was then calculated by dividing seconds of activity in each season, year and VP by the product of the spatial effort (area in km^2 of each viewshed falling within the CRZ – presented in section 1.3.3) and the temporal effort (presented in section 1.3.2). This is represented in the equation below.

$$Bird\ density_{sp} = Seconds\ of\ activity_{sp} \ / \ (Seconds\ surveyed\ \times Area\ surveyed)$$

Final densities used were calculated as an average across VPs and years, weighted by survey effort. A weighted standard deviation was also calculated. Final densities used are presented in Table 1.13.

Table 1.13: Densities used for CRM of non-directional flights

Species	Breeding		Non-breeding	
	Mean	Standard deviation	Mean	Standard deviation
Goshawk	0.0001052	0.0001736	0.0001380	0.0004134

Proportion of birds at risk height

The proportion of birds at risk height was calculated based on 15 second snapshot height band data collected by surveyors. This was calculated as:

$$Proportion\ at\ risk\ height = \frac{\sum_{fl=\ 1}^{n\ flights} \sum_{HB}^{n\ height\ bands} N\ birds_{fl} \times\ Prop\ height\ band\ at\ risk\ height_{HB}\ \times Prop\ snapshots\ \ in\ height\ band_{HB}}{Total\ N\ birds}$$

Resulting proportions of birds at risk height are presented in Table 1.14.

Table 1.14: Proportion of non-directional flight activity at risk height

Species	Total birds	Total "birds" at risk	Percentage at risk height
Goshawk	3	2.73	91.00

1.4. Uncertainty in outputs

There is a high degree of uncertainty in outputs of the collision risk model due to variance and uncertainty in:

1. The input parameters used. This includes input parameters relating to the birds including the biometric and behavioural parameters applied and in the estimation of flight activity arising from sampling error and inaccuracy of flight mapping and/or estimation of flight height, and uncertainty in turbine and wind farm input parameter values used, which may be indicative or average values.
2. Simplifications made within the collision model itself.
3. Uncertainty in the final design option applied.

The latter doesn't apply in this case since the turbine and wind farm parameters are known. Uncertainty for each of the components are guesstimated in Table 1.15 and an overall estimate was calculated as the square root of the sum of the squares of these guesstimates. This uncertainty was then applied to calculate limits around collision estimates in section 2.

Table 1.15: Approximation of uncertainty

Source of uncertainty	Range of uncertainty
Variance and uncertainty in flight activity/migration passages and other input parameters	± 70.0%
Simplifications in the collision model	± 20.0%
Design options yet to be finalised	N/A
Overall	± 72.8%

2. Results

2.1. Barnacle goose

Estimated annual barnacle goose collision rates are presented in Table 2.1. Predictions using the recommended avoidance rate for barnacle goose are highlighted in bold.

Table 2.1: Predicted number of barnacle goose collisions per year and indicative confidence limits (see Section 1.4)

Assessment	Avoidance rate	Breeding	Non-breeding	Annual
Original	95%	0	0.0231 (0.0063 - 0.0399)	0.0231 (0.0063 - 0.0399)
	98%	0	0.0092 (0.0025 - 0.0160)	0.0092 (0.0025 - 0.0160)
	99%	0	0.0046 (0.0013 - 0.0080)	0.0046 (0.0013 - 0.0080)
	99.5%	0	0.0023 (0.0006 - 0.004)	0.0023 (0.0006 - 0.004)
	99.8%	**0**	**0.0009 (0.0003 - 0.0016)**	**0.0009 (0.0003 - 0.0016)**
Updated – 285 m CRZ buffer	95%	0	0.0231 (0.0063 - 0.0400)	0.0231 (0.0063 - 0.0400)
	98%	0	0.0093 (0.0025 - 0.0160)	0.0093 (0.0025 - 0.0160)
	99%	0	0.0046 (0.0013 - 0.0080)	0.0046 (0.0013 - 0.0080)
	99.5%	0	0.0023 (0.0006 - 0.0040)	0.0023 (0.0006 - 0.0040)
	99.8%	**0**	**0.0009 (0.0003 - 0.0016)**	**0.0009 (0.0003 - 0.0016)**
Updated - 585 m CRZ buffer	95%	0	0.0175 (0.0048 - 0.0302)	0.0175 (0.0048 - 0.0302)
	98%	0	0.0070 (0.0019 - 0.0121)	0.0070 (0.0019 - 0.0121)
	99%	0	0.0035 (0.0010 - 0.0060)	0.0035 (0.0010 - 0.0060)
	99.5%	0	0.0017 (0.0005 - 0.0030)	0.0017 (0.0005 - 0.0030)
	99.8%	**0**	**0.0007 (0.0002 - 0.0012)**	**0.0007 (0.0002 - 0.0012)**

2.2. Lesser black-backed gull

Estimated annual lesser black-backed gull collision rates are presented in Table 2.2. Predictions using the recommended avoidance rate for lesser black-backed gull are highlighted in bold.

Table 2.2: Predicted number of lesser black-backed gull collisions per year and indicative confidence limits (see Section 1.4)

Assessment	Avoidance rate	Breeding	Non-breeding	Annual
Original	95%	0.0009 (0.0002 - 0.0016)	0	0.0009 (0.0002 - 0.0016)
	98%	0.0004 (0.0001 - 0.0006)	0	0.0004 (0.0001 - 0.0006)
	99%	0.0002 (<0.0001 - 0.0003)	0	0.0002 (<0.0001 - 0.0003)
	99.5%	**0.0001 (<0.0001 - 0.0002)**	**0**	**0.0001 (<0.0001 - 0.0002)**
	99.8%	<0.0001 (<0.0001 - 0.0001)	0	<0.0001 (<0.0001 - 0.0001)
Updated – 285 m CRZ buffer	95%	0.0010 (0.0003 - 0.0018)	0	0.0010 (0.0003 - 0.0018)
	98%	0.0004 (0.0001 - 0.0007)	0	0.0004 (0.0001 - 0.0007)
	99%	0.0002 (0.0001 - 0.0004)	0	0.0002 (0.0001 - 0.0004)
	99.5%	**0.0001 (<0.0001 - 0.0002)**	**0**	**0.0001 (<0.0001 - 0.0002)**
	99.8%	<0.0001 (<0.0001 - 0.0001)	0	<0.0001 (<0.0001 - 0.0001)
Updated 585 m CRZ buffer	95%	0.0014 (0.0004 - 0.0024)	0 (0 - 0)	0.0014 (0.0004 - 0.0024)
	98%	0.0005 (0.0001 - 0.0009)	0 (0 - 0)	0.0005 (0.0001 - 0.0009)
	99%	0.0003 (0.0001 - 0.0005)	0 (0 - 0)	0.0003 (0.0001 - 0.0005)
	99.5%	**0.0001 (<0.0001 - 0.0002)**	**0 (0 - 0)**	**0.0001 (<0.0001 - 0.0002)**
	99.8%	<0.0001 (<0.0001 - 0.0001)	0 (0 - 0)	<0.0001 (<0.0001 - 0.0001)

2.3. Goshawk

Estimated annual goshawk collision rates are presented in Table 2.3. Predictions using the recommended avoidance rate for goshawk are highlighted in bold.

Table 2.3: Predicted number of goshawk collisions per year and indicative confidence limits (see Section 1.4)

Assessment	Avoidance rate	Breeding	Non-breeding	Annual
Original	-	-	-	-
Updated – 285 m CRZ buffer	-	-	-	-
Updated 585 m CRZ buffer	95%	0.0339 (0.0092 - 0.0586)	0.0302 (0.0082 - 0.0522)	0.0641 (0.0174 - 0.1108)
	98%	**0.0136 (0.0037 - 0.0234)**	**0.0121 (0.0033 - 0.0209)**	**0.0257 (0.0070 - 0.0443)**
	99%	0.0068 (0.0018 - 0.0117)	0.006 (0.0016 - 0.0104)	0.0128 (0.0035 - 0.0222)
	99.5%	0.0034 (0.0009 - 0.0059)	0.003 (0.0008 - 0.0052)	0.0064 (0.0017 - 0.0111)
	99.8%	0.0014 (0.0004 - 0.0023)	0.0012 (0.0003 - 0.0021)	0.0026 (0.0007 - 0.0044)

3. References

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A. Calculation of mean rotor speed

Mean rotor speed was calculated based on wind speed frequency distribution data for the Site and the cut-in, cut-out and rated speeds of the turbine model indicated for the Project (SG6.6-155), as well as the minimum and maximum operational rotor speeds. These values are presented in Table 3.1. The calculation was based on an assumption of the following relationship between wind speed and rotor speed: Rotor speed is assumed to be 0 until the wind speed reaches cut-in speed, at which point the rotor will start rotating at the minimum rotation speed. The rotation speed is then assumed to increase linearly until the rated wind speed at which it will be rotating at the maximum operational rotor speed. The turbine is assumed to continue to rotate at this speed until the cut-out wind speed is reached at which point rotor speed returns to 0. This relationship is visualised, in Figure 3.1.

Table 3.1: Manufacturers data used as input parameters to calculate mean rotor speed for the Project

Parameter	Units	Value
Cut-in wind speed	m/sec	3
Rated wind speed	m/sec	11.5
Cut-out wind speed	m/sec	25
Minimum operational rotor speed	RPM	5.1
Maximum operational rotor speed	RPM	8.8

Wind speed distribution data for the Site was provided by the Developer. The distribution is visualised in Figure 3.1.

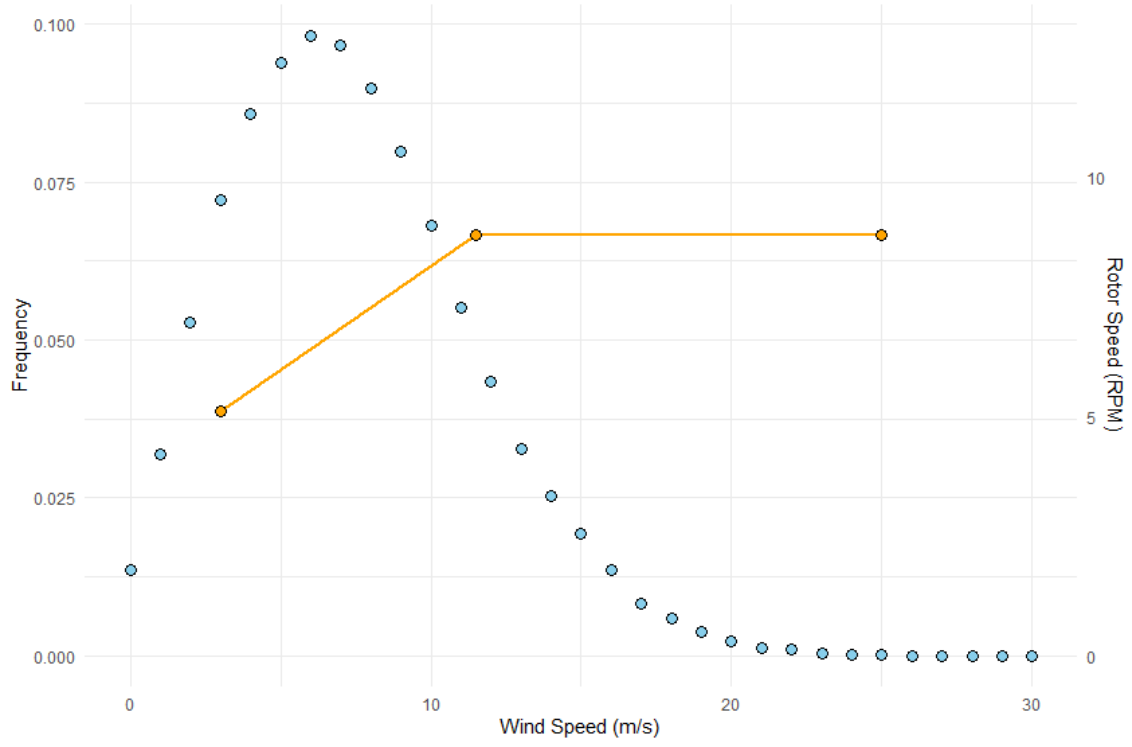

Figure 3.1: Wind speed distribution calculated and assumed relationship of wind speed and rotor speed based on manufacturers wind speed cut-in, operational range and cut-out and minimum and maximum operational rotor speeds.

The average rotor speed parameter required for the CRM was calculated as an average of rotor speeds at a 1 m/s, weighted by the frequency at which each wind speed increment is expected to occur on site. This calculation is presented in Table 3.2.

Table 3.2: Calculation of mean rotor speed

Wind speed (m/s)	Wind speed frequency	Turbine rotor speed (RPM)	Product of wind speed frequency and turbine rotor speed
0	(0.014)	0.000	-
1	(0.032)	0.000	-
2	(0.053)	0.000	-
3 (Cut-in)	0.072	5.100	0.367584862
4	0.086	5.511	0.473025722
5	0.094	5.922	0.555258996
6	0.098	6.333	0.621616175
7	0.097	6.744	0.652273753
8	0.090	7.156	0.643226268
9	0.080	7.567	0.603455303
10	0.068	7.978	0.542880535
11	0.055	8.389	0.462253881
12 (Operational range)	0.043	8.800	0.381722785
13	0.033	8.800	0.288675974
14	0.025	8.800	0.222629802
15	0.019	8.800	0.170636007
16	0.014	8.800	0.118943334
17	0.008	8.800	0.073373483
18	0.006	8.800	0.051793047
19	0.004	8.800	0.033324208
20	0.002	8.800	0.021078566
21	0.001	8.800	0.011844146
22	0.001	8.800	0.009134045
23	0.000	8.800	0.004316087
24	0.000	8.800	0.002007482
25 (Cut-out)	0.000	8.800	0.001304864
26	(0.000)	0.000	-
27	(0.000)	0.000	-
28	(0.000)	0.000	-
29	(0.000)	0.000	-
30+	(0.000)	0.000	-
Sum of operational frequencies:	**0.897**	**Sum of operational products:**	**6.312**
Weighted average turbine operational rotor speed (Sum of product / Sum of frequencies)			**7.034 RPM**

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