Carn Fearna Wind Farm Technical Appendix 9.3: Collision Risk Model Analysis





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1 INTRODUCTION

- 1.1.1 This Technical Appendix has been prepared to accompany **Chapter 9: Ornithology**, in **Volume 2**, of the Environmental Impact Assessment (EIA) Report for Carn Fearna Wind Farm (the Proposed Development).
- 1.1.2 It presents the details and results of collision mortality risk calculations, completed to inform the assessment for the Proposed Development upon ornithological interests.
- 1.1.3 This Technical Appendix is supplementary to **Technical Appendix 9.1**, in **Volume 4**, of the EIA Report, which provides full details of baseline ornithological studies. Figures referenced within this Technical Appendix are presented in **Volume 3a** of the EIA Report.

2 METHODOLOGY

- 2.1.1 The NatureScot (previously Scottish Natural Heritage, SNH) or 'Band' collision risk model (Collision Risk Model, CRM) (Band *et al.*, 2007) has been used to estimate the collision mortality risk to target species from the Proposed Development¹.
- 2.1.2 The NatureScot CRM calculates collision mortality risks in three stages:
 - Stage 1: the estimation of the number of birds passing through the rotor swept volume of the wind farm, based on baseline Vantage Point (VP) flight activity data;
 - Stage 2: the estimation of collision likelihood i.e. the probability of a bird flying through a rotor being hit, based on bird and wind farm parameters and whereby all collisions are assumed to be fatal. This provides an estimate of how many fatal collisions could occur, in theory, should birds take no avoiding action; and
 - After multiplying Stage 1 and Stage 2 an avoidance factor is then applied i.e. whereby it is assumed birds take action to avoid collision.

2.2 Wind Farm Parameters

- 2.2.1 The Proposed Development comprises nine turbines, with four turbines of 180 m maximum tip height, 99 m hub height, and five turbines of 200 m maximum tip height, 119 m hub height. For both turbine tip heights, maximum rotor diameter is 162 m.
- 2.2.2 For the purposes of analysis, the flight risk volume (Vw) is based on a buffer constructed around the turbine envelope with a radius of 300 m (area = 305.36 ha) and a height at least equal to the rotor diameter (162 m). This adopts a precautionary approach based on the candidate turbine rotor radius of 81 m.
- 2.2.3 Turbine parameters are summarised in **Table 2.1.** The final turbine model will be dependent on a procurement process and has not yet been confirmed. For the purposes of this assessment, the candidate turbine is the 'V162 Vestas' but given the lack of available specification for all parameters for the turbine type, specification for a comparable candidate turbine (the 'Vestas V164-8.0') is used

¹ Note, the CRM analysis was undertaken prior to the updated guidance from December 2024 (Band, 2024) and thus adheres to the previous guidance as referenced. The results presented within this TA are considered robust, given as stated in the new guidance (Band, 2024) that collision risk estimates resulting from application of the new approach is not expected to differ substantively from those derived from the application of the earlier SNH guidance (Band *et al.*, 2007).

where parameters for the V162 are not available. Rotation period and downtime are representative values.

Parameter	Value	Unit
Wind farm survey area (300 m turbine buffer)	305.36	ha
No. of rotors	9	-
No. of blades	3	-
Height to tip	180 - 200	metres
Hub height	99 - 119	metres
Rotor diameter	162	metres
Rotor radius	81	metres
Max chord	5.4	metres
Pitch	15	degrees
Rotation period	5.7	seconds
Downtime	15	%

Table 2.1: Turbine parameters.

2.3 Viewsheds

- 2.3.1 Target species flight activity data for use in CRM calculations has been obtained from three Vantage Points (VPs) during VP flight activity surveys between September 2019 and August 2021 (VPs 1 3). Note, a fourth VP was used during the two years of survey, but given design evolution, the viewshed of VP 4 is entirely outside the wind farm survey area, so for the purpose of the CRM analysis is not considered further.
- 2.3.2 Visible areas for each VP location have been calculated using an observer height of 1.5 m and a 20 m vertical offset above the ground. The extent of the visible area that could be seen from each VP location was confirmed during a reconnaissance visit.
- 2.3.3 **Table 2.2** presents the visible areas of each viewshed and that which falls within the wind farm survey area constructed using a 300 m buffer around the turbines for the purpose of analysis.
- 2.3.4 Note, overlaps between VPs was minimal and thus overlaps were included in each VP viewshed, and VP viewsheds are provided in **Figure 9.2** in **Volume 3a** of the EIA Report.

VP	Grid Reference	Orientation	Visible Area (ha)
			Within 300 m turbine buffer
1	NH 43987 61589	West	144.15
2	NH 42982 62942	West	196.92
3	NH 41163 61165	North north-east	13.73

Table 2.2: VP locations and viewshed visible areas.

2.4 VP Flight Activity Data

2.4.1 Survey effort (hours) completed at each VP location between September 2019 and August 2021 is summarised in **Table 2.3**. Full details of all target species flights during the VP flight activity surveys are presented in **Technical Appendix 9.1** and are shown in **Figures 9.5a-c** in **Volume 3a** of the EIA Report.

VP	2019				2020						Year 1		
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
1	12	12	6	6	6	3	12	12	6	9	9	6	99
2	12	12	6	6	6	12	12	12	6	9	9	6	108
3	12	12	6	6	6	3	12	12	6	9	9	6	99
VP	2020	I	I	1	2021	1	1	1	1	1	1	1	Year 2
VP	2020 Sep	Oct	Nov	Dec	2021 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Year 2 Total
VP 1	2020 Sep 12	Oct 12	Nov 6	Dec	2021 Jan 3	Feb	Mar 15	Apr 12	May 6	Jun 6	Jul 12	Aug 6	Year 2 Total
VP 1 2	2020 Sep 12 12	Oct 12 12	Nov 6 6	Dec 6 6	2021 Jan 3 6	Feb 12 12	Mar 15 12	Apr 12 12	May 6 6	Jun 6 6	Jul 12 12	Aug 6 6	Year 2 Total 108 108

 Table 2.3: VP flight activity survey effort summary – 2019-21.

2.5 'At Collision Risk' Flights

- 2.5.1 The flights of golden eagle, white-tailed eagle, hen harrier, red kite, peregrine, merlin, osprey, greylag goose, pink-footed goose, whooper swan, teal, grey heron, red-throated diver, golden plover and greenshank were recorded as 'at risk', identified as those flights recorded within 300 m of the turbines and flying at collision risk height (e.g. between 18 -200 m). Given the two different sizes of turbines used (180 m and 200 m tip height), the highest tip height (200 m) is used as the upper limit of the collision risk height, while the lower limit of the collision risk (height 18 m) is derived from the lower rotor sweep of the shortest turbine height (180 m). As a precaution, bird flights at height bands 2 (10-25 m), 3 (25-150 m), 4 (150-180 m) and 5 (180+ m), as utilised during survey recording, are regarded as 'at collision risk'. This is precautionary as some flights regarded as being at risk will actually have been below or above collision risk height, with height band 2 being below the minimum rotor sweep of the largest turbines (200 m tip height) and height band 5 being above the maximum rotor sweep of the smallest turbines (180 m tip height).
- 2.5.2 CRM calculations have only been undertaken for those target species with three, or more, "at collision risk" flights, or greater than 20 birds if less than three flights, within any one survey year, and this comprised golden eagle and red kite.
- 2.5.3 CRM calculations have not been undertaken for pink-footed goose, because although there were three "at collision risk" flights in Year 2 (but not in Year 1), NatureScot guidance states that CRM for pink-footed goose is only required where a site has potential connectivity with a designated area with this species as a qualifying feature; due to the species robust population and high avoidance rate (99.8 %, SNH, 2018). In the case of the Proposed Development, pink-footed goose is not identified as a qualifying interest of any statutory designated site for nature conservation within 20 km of the site, and as such potential connectivity between the site and such designations is not established in accordance with NatureScot guidance (SNH, 2016).

- 2.5.4 Similarly, whooper swan was not subjected to CRM calculation. Only two flights (total of 27 birds) were recorded entirely within height band 5 (180+ m) during the same survey in October 2019² in Year 1 (with no such flights in Year 2). The flights are representative of transient activity, and given they were in height band 5 are likely to have been, in reality, above risk height. The documented 'core' foraging range for the species is less than 5 km (SNH, 2016). The Cromarty Fifth Special Protection Area (SPA) is located 11.6 km east of the site at its nearest point, and whooper swan is a qualifying species. Given the distance of the SPA from the site (11.6 km) well exceeds the core foraging range of whooper swan (<5 km), connectivity with the SPA is discounted. Furthermore, like pink-footed goose, whooper swan has high avoidance rates (99.5 %, SNH, 2018).
- 2.5.5 Details of "at collision risk" flight activity of all target species is provided in **Annex 1**.
- 2.5.6 "At collision risk" flight activity recorded during the survey period (two years) for golden eagle and red kite, and which has been used in CRM calculations is summarised in **Table 2.4**. As a precaution all "at collision risk" flights were considered in the CRM calculations even where these were clearly identified as juvenile birds (two such golden eagle flights in Year 2).

Species	Total No. of Flights	Total No. of Birds	Total Time at Collision Risk Height (secs) ³			
Golden eagle	23	24	5,197			
Red kite	23	23	4,587			

Table 2.4: "At collision risk" flight activity.

2.6 Target Species Parameters

2.6.1 Target species parameters used to calculate collision probabilities using the NatureScot (SNH, 2000) are presented in **Tables 2.5** and **2.6** together with calculated collision probabilities, recommended avoidance rates and seasons for both target species in accordance with NatureScot guidance (SNH, 2014, 2017 & 2018). The results of the collision probability calculations are given in **Annex 2**.

Species	Length (m)	Wingspan (m)	Flight Speed (m/s)	Collision Probability (%)	Avoidance Rate (%)	'Gliding' or 'flapping' flight
Golden eagle	0.82	2.12	11.9	8.2	99.0	Gliding
Red kite	0.63	1.85	12	7.3	99.0	Gliding

Table 2.5: Target species parameters.

Table 2.6: Se	easons considered	l in CRM analys	sis.
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	Seasons Considered				
Species	Breeding Season	Non-breeding Season			
Golden eagle	February to August	September to January			
Red kite	March to July	August to February			

² Flock of 21 swans followed by 6 swans within 15 minutes of each other, all within height band 5 (180+ m) on 24/10/2019 (see **Table A1-1** for further details).

³ Total time at collision risk multiplied by the number of birds.

- 2.6.2 For each target species, the potential number of active hours within each season have been calculated following Forsythe *et al.* (1995) and using a latitude of 57.62011 (that of the site). Active hours relate to daylight hours for both the target species which were subject to CRM calculation.
- 2.6.3 For both target species, estimates have been calculated for both the breeding season and the nonbreeding season rather than one estimate for the full year, to take into account differing flight activity through the survey year.
- 2.6.4 Both target species identified for analysis were classed as having 'non-directional' flights (random in nature) for the purposes of the CRM analysis.

3 COLLISION RISK ANALYSIS

3.1.1 Table 3.1 presents a summary of the annual collision mortality estimates calculated for the two target species for which CRM analysis was undertaken. Mortality risks were calculated for breeding and non-breeding seasons in each survey year for both target species. These are all based on a downtime of 15 %. Collision mortality risk calculations are provided in Annex 3.

Species	Avoidance	Occupancy	Collisio	Collision Mortality Estimate			
species	Rate	Occupancy	Year 1	Year 2	Average		
Golden eagle	99.0 %	Non-breeding season	0.062	0.089	0.076		
		Breeding season	0.060	0.141	0.101		
Red kite	99.0 %	Non-breeding season	0.066	0.078	0.072		
		Breeding season	0.067	0.054	0.061		

Table 3.1:	Collision	mortality	estimates.
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ANNEX 1 – "AT COLLISION RISK" FLIGHT ACTIVITY

Table A1-1 present "at collision risk" flight activity for target species recorded during the two-year survey period (September 2019 to August 2021) at all three VPs; the number of birds, total flight duration and time spent below (HT1) and at (HT2 – HT5, regarded as a precaution) collision risk height is presented. Note, of these, golden eagle and red kite were subject to CRM analysis. Year 1 is September 2019 to August 2020, and Year 2 is September 2020 to August 2021. British Trust for Ornithology (BTO) codes⁴ used in **Table A1-1** are EA: Golden eagle, KT: Red kite, WS: Whooper swan, PG: Pink-footed goose, GJ: Greylag goose, WE: White-tailed eagle, T.: Teal, RH: Red-throated diver, GP: Golden plover, H.: Grey heron, OP: Osprey, ML: Merlin, PE: Peregrine, HH: Hen harrier and GK: Greenshank.

Date	VP	Species	No. of Birds	Start Time (24hrs)	Total Flight Duration (secs) ⁵	Total Time Spent (secs) ⁵			Notes		
						HT1	HT2	HT3	HT4	HT5	
20/09/2019	2	EA	1	09:30	185	0	20	15	15	135	Adult, female hunting.
20/09/2019	2	EA	1	10:56	176	0	26	0	15	135	Same adult, hunting.
20/09/2019	2	EA	1	12:20	140	0	30	20	45	45	Same adult, hunting.
24/10/2019	1	КТ	1	13:51	45	0	0	45	0	0	-
24/10/2019	2	WS	21	16:22	1,260	0	0	0	0	1,260	-
24/10/2019	2	WS	6	16:36	450	0	0	0	0	450	-
28/10/2019	1	КТ	1	13:29	48	0	0	48	0	0	-
28/11/2019	3	GJ	15	11:31	1,410	0	0	0	0	1,410	-
10/01/2020	2	WE	1	13:12	198	0	120	60	18	0	1st winter bird.
18/03/2020	1	КТ	1	13:55	71	0	71	0	0	0	Direct flight.
24/04/2020	1	Т.	2	20:43	42	0	30	12	0	0	-
25/04/2020	1	EA	2	09:53	640	0	0	640	0	0	Pair.
25/04/2020	1	GJ	2	13:16	196	0	0	0	196	0	-

Table A1-1: Target species "at collision risk" flight activity (Wind Farm Area: 300 m).

⁴ Available at <u>https://www.bto.org/sites/default/files/u16/downloads/forms_instructions/bto_bird_species_codes.pdf</u> (Accessed 09/01/2025).

⁵ Total time multiplied by the number of birds.

Date	VP	Species	No. of Birds	Start Time (24hrs)	Total Flight Duration (secs) ⁵	Total Time Spent (secs) ⁵					Notes
						HT1	HT2	HT3	HT4	HT5	
25/04/2020	1	EA	1	13:56	267	0	240	27	0	0	Female
30/04/2020	1	КТ	1	13:11	72	0	27	45	0	0	-
05/05/2020	2	EA	1	14:07	78	0	0	0	33	45	Adult female.
11/06/2020	2	RH	1	21:39	247	15	15	217	0	0	Flew from loch.
07/07/2020	2	КТ	1	11:47	154	15	15	124	0	0	Hunting.
07/07/2020	2	КТ	1	12:15	372	72	225	75	0	0	Hunting.
07/07/2020	2	КТ	1	13:59	475	0	0	195	210	70	-
22/07/2020	1	КТ	1	11:48	58	0	0	58	0	0	-
19/08/2020	1	КТ	1	14:54	312	0	105	207	0	0	Hunting.
21/08/2020	2	GP	11	10:42	5,687	0	0	572	3,135	1,980	-
01/09/2020	2	PE	1	13:24	145	30	85	30	0	0	Juvenile hunting.
01/09/2020	2	EA	1	18:03	193	0	43	105	45	0	Adult, female hunting.
03/09/2020	1	EA	1	12:02	264	0	0	129	90	45	Hunting.
03/09/2020	1	EA	1	15:03	184	0	0	94	45	45	Hunting.
03/09/2020	1	EA	1	15:18	332	0	0	285	47	0	Adult hunting.
10/09/2020	2	PG	79	07:18	20,856	0	0	0	15,405	5,451	-
10/09/2020	2	PG	11	08:24	2,288	0	0	0	0	2,288	-
10/09/2020	2	КТ	1	10:16	205	0	25	180	0	0	-
10/09/2020	2	КТ	1	10:47	431	0	75	120	236	0	Hunting
10/09/2020	2	КТ	1	11:01	236	0	131	105	0	0	Hunting
28/10/2020	1	GJ	2	14:21	70	0	0	70	0	0	-
28/10/2020	1	КТ	1	14:27	780	405	375	0	0	0	Hunting and soaring.

Date	VP	Species	No. of Birds	Start Time (24hrs)	Total Flight Duration (secs) ⁵	Total Time Spent (secs) ⁵					Notes
						HT1	HT2	HT3	HT4	HT5	•
03/11/2020	2	EA	1	14:27	20	0	20	0	0	0	Hunting, unaged.
03/11/2020	2	EA	1	14:21	158	0	45	113	0	0	Juvenile.
11/12/2020	2	PE	1	12:39	125	0	20	105	0	0	Adult male.
28/01/2021	1	EA	1	10:11	221	0	71	150	0	0	Juvenile, steady.
24/02/2021	2	КТ	1	10:29	225	0	0	0	225	0	Long (gliding) flight.
24/02/2021	2	КТ	1	13:49	60	0	0	60	0	0	Adult.
08/03/2021	1	EA	1	13:12	466	0	0	466	0	0	Adult.
08/03/2021	1	EA	1	13:19	193	0	0	30	133	30	Adult, display.
08/03/2021	1	EA	1	13:36	378	0	30	105	60	183	Same adult as above.
08/03/2021	1	КТ	1	14:33	142	0	60	82	0	0	Hunting.
08/03/2021	1	EA	1	14:40	84	0	54	15	15	0	Adult hunting.
17/03/2021	2	EA	1	16:31	163	0	0	0	60	103	-
17/03/2021	2	КТ	1	17:20	205	0	0	15	15	175	-
18/03/2021	3	кт	1	09:59	186	15	45	126	0	0	-
29/03/2021	2	кт	1	12:32	267	60	207	0	0	0	-
02/04/2021	3	нн	1	13:22	366	0	0	180	105	81	Circled up, not sexed.
02/04/2021	3	EA	1	15:25	208	0	0	208	0	0	Adult.
14/04/2021	2	ML	2	09:06	140	0	0	90	0	50	Adult pair calling.
14/04/2021	2	КТ	1	10:39	122	0	30	92	0	0	-
14/04/2021	2	КТ	1	13:14	78	0	78	0	0	0	-
16/04/2021	1	EA	1	10:16	273	0	0	135	45	93	Adult male.

Date	VP	Species	No. of Birds	Start Time (24hrs)	Total Flight Duration (secs) ⁵	Total Time Spent (secs) ⁵					Notes
						HT1	HT2	HT3	HT4	HT5	
20/04/2021	2	GK	1	11:40	30	15	15	0	0	0	Flew over loch.
20/04/2021	2	GK	2	13:02	60	0	30	30	0	0	Flew over loch.
22/04/2021	3	PG	70	12:03	10,500	0	0	0	0	10,500	Flew very high.
31/05/2021	3	кт	1	18:07	305	0	15	15	45	230	Hunting.
19/07/2021	2	EA	1	17:14	173	0	0	0	120	53	Adult male.
27/07/2021	1	RH	2	11:19	178	0	58	120	0	0	Landed on loch, calling.
27/07/2021	1	EA	1	11:22	176	0	26	105	45	0	Female, with below.
27/07/2021	1	EA	1	11:22	260	35	75	120	30	0	Male, with above.
27/07/2021	1	OP	1	13:27	184	0	19	105	45	15	Calling.
27/07/2021	1	GP	11	15:13	1,023	198	495	330	0	0	Flying across moor.
29/07/2021	1	Н.	1	10:07	401	206	195	0	0	0	-
29/07/2021	1	ML	1	14:54	49	19	15	15	0	0	Hunting.
25/08/2021	2	кт	1	11:12	350	45	165	140	0	0	-

ANNEX 2 – COLLISION PROBABILITY CALCULATIONS

Golden eagle

K: [1D or [3D] (0 or 1)	1	1 Calculation of alpha and p(collision) as a function of radius									
No. Blades	3					1	Upwind:		I	Downwind:	
Max Chord	5.4	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	15		radius	chord	alpha	length	p (collision)	from radius r	length	p (collision)	from radius r
Bird Length	0.82	m	0.025	0.575	5.33	23.99	1.00	0.00125	22.38	0.99	0.00124
Wingspan F: Flapping (0) or gliding	2.12	m	0.075	0.575	1.78	8.53	0.38	0.00283	6.92	0.31	0.00230
(+1)	1		0.125	0.702	1.07	6.32	0.28	0.00349	4.36	0.19	0.00241
			0.175	0.860	0.76	5.65	0.25	0.00437	3.24	0.14	0.00251
Bird speed	11.9	m/sec	0.225	0.994	0.59	5.26	0.23	0.00524	2.48	0.11	0.00247
Rotor Diam	162	m	0.275	0.947	0.48	4.37	0.19	0.00532	1.72	0.08	0.00210
Rotation Period	5.70	sec	0.325	0.899	0.41	3.73	0.17	0.00537	1.22	0.05	0.00175
			0.375	0.851	0.36	3.59	0.16	0.00595	1.21	0.05	0.00200
			0.425	0.804	0.31	3.26	0.14	0.00612	1.01	0.04	0.00190
			0.475	0.756	0.28	2.98	0.13	0.00627	0.87	0.04	0.00183
Bird aspect ratio: β	0.39		0.525	0.708	0.25	2.75	0.12	0.00638	0.87	0.04	0.00202
			0.575	0.660	0.23	2.54	0.11	0.00646	0.94	0.04	0.00240
			0.625	0.613	0.21	2.36	0.10	0.00652	0.99	0.04	0.00275
			0.675	0.565	0.20	2.19	0.10	0.00654	1.03	0.05	0.00307
			0.725	0.517	0.18	2.04	0.09	0.00654	1.05	0.05	0.00336
			0.775	0.470	0.17	1.90	0.08	0.00650	1.06	0.05	0.00362
			0.825	0.422	0.16	1.77	0.08	0.00644	1.05	0.05	0.00385
			0.875	0.374	0.15	1.64	0.07	0.00635	1.05	0.05	0.00405
			0.925	0.327	0.14	1.52	0.07	0.00623	1.03	0.05	0.00422
			0.975	0.279	0.14	1.41	0.06	0.00607	1.01	0.04	0.00436
				Overall p(co	llision) =		Upwind	11.0%		Downwind	5.4%
								Average	8.2%		

Red kite

K: [1D or [3D] (0 or 1)	1		Calculation of	of alpha and	p(collision) a	as a function	of radius				
No. Blades	3					1	Upwind:		L	Downwind:	
Max Chord Pitch (degrees)	5.4 15	m	r/R radius	c/C chord	α alpha	collide length	p (collision)	contribution from radius r	collide length	p (collision)	contribution from radius r
Bird Length	0.63	m	0.025	0.575	5.38	23.26	1.00	0.00125	21.65	0.95	0.00119
Wingspan	1.85	m	0.075	0.575	1.79	8.29	0.36	0.00273	6.68	0.29	0.00220
F: Flapping (0) or gliding (+1)	1		0.125	0.702	1.08	6.18	0.27	0.00339	4.22	0.19	0.00231
			0.175	0.860	0.77	5.55	0.24	0.00426	3.15	0.14	0.00242
Bird speed	12	m/sec	0.225	0.994	0.60	5.19	0.23	0.00512	2.41	0.11	0.00238
Rotor Diam	162	m	0.275	0.947	0.49	4.31	0.19	0.00520	1.67	0.07	0.00201
Rotation Period	5.70	sec	0.325	0.899	0.41	3.68	0.16	0.00525	1.17	0.05	0.00167
			0.375	0.851	0.36	3.20	0.14	0.00527	0.82	0.04	0.00135
			0.425	0.804	0.32	3.08	0.14	0.00574	0.83	0.04	0.00155
			0.475	0.756	0.28	2.80	0.12	0.00584	0.69	0.03	0.00144
Bird aspect ratio: β	0.34		0.525	0.708	0.26	2.57	0.11	0.00591	0.67	0.03	0.00155
			0.575	0.660	0.23	2.36	0.10	0.00595	0.75	0.03	0.00189
			0.625	0.613	0.22	2.17	0.10	0.00596	0.80	0.04	0.00219
			0.675	0.565	0.20	2.01	0.09	0.00594	0.83	0.04	0.00247
			0.725	0.517	0.19	1.85	0.08	0.00589	0.85	0.04	0.00271
			0.775	0.470	0.17	1.71	0.08	0.00582	0.86	0.04	0.00293
			0.825	0.422	0.16	1.58	0.07	0.00571	0.86	0.04	0.00312
			0.875	0.374	0.15	1.45	0.06	0.00558	0.85	0.04	0.00327
			0.925	0.327	0.15	1.33	0.06	0.00541	0.84	0.04	0.00340
			0.975	0.279	0.14	1.22	0.05	0.00522	0.82	0.04	0.00350
				Overall p(co	llision) =		Upwind	10.1%		Downwind	4.6%
								Average	7.3%		

ANNEX 3 – COLLISION RISK MODEL CALCULATIONS

Golden Eagle (Year 1; Non-breeding season)

		Watch data		Flying time (s)	Flying time hahr-1	v	Veighted flyiı	ng time ha hr^-1
VP	Area (ha)	Time (hrs)	HaHr	Risk height	Risk height		Weightin	ng Risk height
1	144.2	42.0	6054.3	0	0.0000000000		0.40628523	0.00000000
2	196.9	42.0	8270.6	669	0.0000224550		0.55501691	.1 0.000012463
3	13.7	42.0	576.7	0	0.0000000000		0.03869785	58 0.00000000
Totals	354.8	126.0	14901.6	669	0.0000074850		1.00000000	00 0.000012463
Mean activity hr	^-1 in wind farm			WIND FARM DATA	I			
Risk height	0.00381	0.3806%		Wind farm area (ha)	305.36			
Daylight hours			1,463.6					
Downtime			15	0.85		D	162.0	
Vw =			494683200			L+d	6.22	
Vr =			1153859	No. of turbines	9	R	81	
Vr/Vw =			0.0023325					
Speed			11.9					
Vw Occupancy =			5.5700	20051.9				
Vr Occupancy =			0.0130	46.8				
Transit time =			0.5227					
Transits =			89.483					
Collision probab	ility from Annex 2		0.082					
Collisions with n	o avoidance		7.338	Collisions with 99% avoid	dance & downtime		0.062	
Collisions with 9	9% avoidance		0.073	Years for 1 death	16.03			

Golden Eagle (Year 1; Breeding season)

		Watch data		Flying time (s)	Flying time hahr-1	Weighted fly		ng time ha hr^-1
VP	Area (ha)	Time (hrs)	HaHr	Risk height	Risk height		Weightin	g Risk height
1	144.2	57.0	8216.6	323	0.0000109129		0.37354950	0.000004077
2	196.9	66.0	12996.7	133	0.0000028503		0.59087065	4 0.000001684
3	13.7	57.0	782.6	0	0.0000000000		0.03557984	5 0.00000000
Totals	354.8	180.0	21995.9	456	0.0000045877		1.00000000	0 0.000005761
Mean activity hr	^-1 in wind farm			WIND FARM DATA				
Risk height	0.00176	0.1759%		Wind farm area (ha)	305.36			
Daylight hours			3,025.9					
Downtime			15	0.85		D	162.0	
Vw =			494683200			L+d	6.22	
Vr =			1153859	No. of turbines	9	R	81	
Vr/Vw =			0.0023325					
Speed			11.9					
Vw Occupancy =			5.3228	19162.0				
Vr Occupancy =			0.0124	44.7				
Transit time =			0.5227					
Transits =			85.511					
Collision probab	ility from Annex 2		0.082					
Collisions with n	o avoidance		7.012	Collisions with 99% avoid	dance & downtime	owntime 0.060		
Collisions with 9	9% avoidance		0.070	Years for 1 death	16.78			

Golden Eagle (Year 2; Non-breeding season)

		Watch data		Flying time (s)	Flying time hahr-1	v	Weighted flying time ha hr^-1		a hr^-1
VP	Area (ha)	Time (hrs)	HaHr	Risk height	Risk height		Weightin	g	Risk height
1	144.2	39.0	5621.9	584	0.0000288508		0.38854044	6 (0.000011210
2	196.9	42.0	8270.6	341	0.0000114368		0.57160510	5 (0.000006537
3	13.7	42.0	576.7	0	0.0000000000		0.03985444	9 (0.000000000
Totals	354.8	123.0	14469.2	924	0.0000134292		1.00000000	0 (0.000017747
Mean activity hr	^-1 in wind farm			WIND FARM DATA					
Risk height	0.00542	0.5419%		Wind farm area (ha)	305.36				
Daylight hours			1,463.6						
Downtime			15	0.85		D 162.0			
Vw =			494683200			L+d	6.22		
Vr =			1153859	No. of turbines	9	R	81		
Vr/Vw =			0.0023325						
Speed			11.9						
Vw Occupancy =			7.9316	28553.7					
Vr Occupancy =			0.0185	66.6					
Transit time =			0.5227						
Transits =			127.422						
Collision probab	ility from Annex 2		0.082						
Collisions with n	o avoidance		10.449	Collisions with 99% avoid	dance & downtime		0.089		
Collisions with 9	9% avoidance		0.104	Years for 1 death		11.26			

Golden Eagle (Year 2; Breeding season)

		Watch data		Flying time (s)	Flying time hahr-1	v	Veighted flyir	ng time ha hr^-1
VP	Area (ha)	Time (hrs)	HaHr	Risk height	Risk height		Weightin	g Risk height
1	144.2	69.0	9946.4	925	0.0000258401		0.41705085	1 0.000010777
2	196.9	66.0	12996.7	213	0.0000045538		0.54495298	6 0.000002482
3	13.7	66.0	906.2	34	0.0000105315		0.03799616	3 0.000000400
Totals	354.8	201.0	23849.3	1173	0.0000136418		1.00000000	0 0.000013658
Mean activity hr	^-1 in wind farm			WIND FARM DATA				I
Risk height	0.00417	0.4171%		Wind farm area (ha)	305.36			
Daylight hours			3,015.2					
Downtime			15	0.85		D	162.0	
Vw =			494683200			L+d	6.22	
Vr =			1153859	No. of turbines	9	R	81	
Vr/Vw =			0.0023325					
Speed			11.9					
Vw Occupancy =	:		12.5756	45272.0				
Vr Occupancy =			0.0293	105.6				
Transit time =			0.5227					
Transits =			202.028					
Collision probab	ility from Annex 2		0.082					
Collisions with n	o avoidance		16.566	Collisions with 99% avoid	dance & downtime	1	0.141	
Collisions with 9	9% avoidance		0.166	Years for 1 death	7.10			

Red kite (Year 1; Non-breeding season)

	Watch data			Flying time (s)	Flying time hahr-1	v	Veighted flyir	ng time ha hr^-1	
VP	Area (ha)	Time (hrs)	HaHr	Risk height	Risk height		Weightin	g Risk h	eight
1	144.2	51.0	7351.7	700	0.0000264636		0.37004179	8 0.00000	9793
2	196.9	60.0	11815.2	0	0.0000000000		0.59471245	9 0.00000	0000
3	13.7	51.0	700.2	0	0.0000000000		0.03524574	3 0.00000	0000
Totals	354.8	162.0	19867.1	700	0.0000088212		1.00000000	0 0.00000	9793
Mean activity hr	^-1 in wind farm			WIND FARM DATA	I				
Risk height	0.00299	0.2990%		Wind farm area (ha)	305.36				
Daylight hours			2,204.5						
Downtime			15	0.85		D	162.0		
Vw =			494683200			L+d	6.03		
Vr =			1118613	No. of turbines	9	R	81		
Vr/Vw =			0.0022613						
Speed			12						
Vw Occupancy =	:		6.5921	23731.4					
Vr Occupancy =			0.0149	53.7					
Transit time =			0.5025						
Transits =			106.792						
Collision probab	ility from Annex 2		0.073						
Collisions with n	o avoidance		7.796	Collisions with 99% avoid	dance & downtime	1	0.066		
Collisions with 9	9% avoidance		0.078	Years for 1 death	15.09				

Red kite (Year 1; Breeding season)

		Watch data		Flying time (s)	Flying time hahr-1	v	Veighted flyir	ng time ha hr^-1
VP	Area (ha)	Time (hrs)	HaHr	Risk height	Risk height		Weightin	g Risk height
1	144.2	48.0	6919.2	227	0.0000091272		0.40628523	1 0.000003708
2	196.9	48.0	9452.2	355	0.0000104240		0.55501691	1 0.000005785
3	13.7	48.0	659.0	0	0.0000000000		0.03869785	8 0.00000000
Totals	354.8	144.0	17030.4	582	0.0000065171		1.00000000	0 0.000009494
Mean activity hr	^-1 in wind farm			WIND FARM DATA	I			
Risk height	0.00290	0.2899%		Wind farm area (ha)	305.36			
Daylight hours			2,285					
Downtime			15	0.85		D	162.0	
Vw =			494683200			L+d	6.03	
Vr =			1118613	No. of turbines	9	R	81	
Vr/Vw =			0.0022613					
Speed			12					
Vw Occupancy =			6.6242	23847.2				
Vr Occupancy =			0.0150	53.9				
Transit time =			0.5025					
Transits =			107.313					
Collision probab	ility from Annex 2		0.073					
Collisions with n	o avoidance		7.834	Collisions with 99% avoid	dance & downtime	1	0.067	
Collisions with 9	9% avoidance		0.078	Years for 1 death	15.02			

Red kite (Year 2; Non-breeding season)

		Watch data		Flying time (s)	Flying time hahr-1	v	Weighted flying time ha hr^-1	
9	Area (ha)	Time (hrs)	HaHr	Risk height	Risk height		Weightin	g Risk height
1	144.2	57.0	8216.6	94	0.0000031633		0.39397426	6 0.000001246
2	196.9	60.0	11815.2	781	0.0000183541		0.56652545	7 0.000010398
3	13.7	60.0	823.8	0	0.0000000000		0.03950027	7 0.00000000
Totals	354.8	177.0	20855.6	874	0.0000071724		1.00000000	0 0.000011644
Mean activity hr	^-1 in wind farm			WIND FARM DATA	I			I
Risk height	0.00356	0.3556%		Wind farm area (ha)	305.36			
Daylight hours			2,193.8					
Downtime			15	0.85		D	162.0	
Vw =			494683200			L+d	6.03	
Vr =			1118613	No. of turbines	9	R	81	
Vr/Vw =			0.0022613					
Speed			12					
Vw Occupancy =			7.8005	28081.8				
Vr Occupancy =			0.0176	63.5				
Transit time =			0.5025					
Transits =			126.369					
Collision probab	ility from Annex 2		0.073					
Collisions with n	o avoidance		9.225	Collisions with 99% avoid	dance & downtime	e 0.078		
Collisions with 9	9% avoidance		0.092	Years for 1 death	h 12.75			

Red kite (Year 2; Breeding season)

	Watch data			Flying time (s)	Flying time hahr-1	Weighted flying time ha hr^-1		
VP	Area (ha)	Time (hrs)	HaHr	Risk height	Risk height		Weightin	ng Risk height
1	144.2	51.0	7351.7	0	0.000000000	0.420987983		33 0.00000000
2	196.9	48.0	9452.2	482	0.0000141725	0.541272473		73 0.000007671
3	13.7	48.0	659.0	1	0.0000006274	0.037739544		0.00000024
Totals	354.8	147.0	17462.9	484	0.0000049333		1.00000000	00 0.000007695
Mean activity hr^-1 in wind farm				WIND FARM DATA				
Risk height	0.00235	0.2350%		Wind farm area (ha)	305.36			
Daylight hours		2,285						
Downtime			15	0.85		D	162.0	
Vw =			494683200			L+d	6.03	
Vr =			1118613	No. of turbines	9	R	81	
Vr/Vw =			0.0022613					
Speed			12					
Vw Occupancy =			5.3691	19328.7				
Vr Occupancy =			0.0121	43.7				
Transit time =			0.5025					
Transits =			86.980					
Collision probability from Annex 2			0.073					
Collisions with no avoidance			6.350	Collisions with 99% avoidance & downtime			0.054	
Collisions with 99% avoidance			0.063	Years for 1 death			18.53	