2025

Beinn Ghlas Repowering

Appendix 7.3: Collision Risk Modelling

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Introduction

1. Birds that are not displaced by the Proposed Development would be potentially vulnerable to collision with the turbines. The level of collision with wind turbines is presumed to be dependent on the level of flight activity over the Proposed Development and the ability of birds to detect and manoeuvre around rotating turbine blades. Birds that collide with a turbine are likely to be killed or fatally injured. This may in turn affect the maintenance of bird populations.

2. Further studies in the field of bird-wind farm research are required to establish with certainty the extent to which birds can avoid collision with wind turbines, although an increasing body of evidence suggests that avoidance capacity is very high (Whitfield & Madders, 2006[1]; Urquhart & Whitfield, 2016[2]; SNH, 2018[3]). The indications from studies are that collisions are rare events (e.g., Fielding *et al*., 2021)[4] and occur mainly at sites where there are unusual concentrations of birds and turbines, or where the behaviour of the birds' concerned leads to high-risk situations (e.g., Gill *et al*., 1996[5]; Percival, 1998[6]; de Lucas *et al.,* 2007[7]). Examples include migration flyways, and where the food resource, and therefore level of bird activity, is exceptional.

Collision Risk Modelling

3. The Band collision risk model (CRM) (Band *et al*., 2007)[8] was used to estimate the potential number of bird collisions likely to occur at the Proposed Development. The model requires input data based on species biometrics and flight characteristics, turbine specification and data on flights observed at the site.

4. NatureScot guidance on collision risk modelling was used (SNH, 2000[9]; Band *et al*., 2007[8]). This is a three-stage process, which involves:

   a) An assessment of the probability of a collision, based on a bird flying through an operational turbine; and
   b) An estimation of the number of birds passing through the swept zone of the turbine blades.

   Multiplying stages a) and b) provides an estimate of collision risk with the turbines, assuming no avoidance action. After, the third stage is applied:

[1] Madders, M. & Whitfield, D.P. (2006). Upland raptors and the assessment of wind farm impacts. Ibis, 148, pp 43-56.
[2] Urquhart, B. & Whitfield, D.P. (2016). Derivation of an avoidance rate for red kite *Milvus milvus* suitable for onshore wind farm collision risk modelling Natural Research Information Note 7. Available at https://www.natural-research.org/ecological-research-charity/our-publications
[3] Scottish Natural Heritage (SNH). (2018). Avoidance Rates for the onshore SNH Wind Farm Collision Risk Model. SNH Information and Guidance Note. Scottish Natural Heritage, Battleby.
[4] Fielding, A.H., Anderson, D., Benn, S., Dennis, R., Geary, M., Weston, E. & Whitfield, D.P. (2021). Non-territorial GPS-tagged golden eagles *Aquila chrysaetos* a two Scottish wind farms: Avoidance influenced by preferred habitat distribution, wind speed and blade motion status. PLoS ONE 16(8): e0254159. https://doi.org/10.1371/journal.pone.0254159
[5] Gill, J.P., Townsley, M. & Mudge, G.P. (1996). Review of the impacts of wind farms and other aerial structures upon birds. SNH Review 21: 68pp.
[6] Percival, S.M. (1998). Birds and Turbines: managing potential planning issues. Proc. of the 20th BWEA Conference 1998: pp 345-350.
[7] de Lucas, M., Janss, G.F.E. & Ferrer, M. (eds). (2007). Birds and Wind Power: Risk Assessment and Mitigation. Quercus, Madrid.
[8] Band, W., Madders, M., & Whitfield, D.P. (2007). Developing field and analytical methods to assess avian collision risk at wind farms. In: de Lucas, M., Janss, G.F.E. & Ferrer, M. (Eds.) Birds and Wind Farms: Risk Assessment and Mitigation, pp. 259- 275. Quercus, Madrid.
[9] SNH. (2000). Windfarms and Birds: Calculating a theoretical collision risk assuming no avoiding action. SNH Information and Guidance Note. Scottish Natural Heritage, Battleby.

c) An avoidance rate is applied (where known) to account for the fact that many species will take avoidance action.

5. The result of the model provides an estimate of the number of collisions that can be expected over a year or for the lifetime of the wind farm.

6. For the turbines proposed, the probability of a bird being struck by a turbine blade when passing through the rotor swept volume has been estimated, assuming no avoidance (see **Appendix 1**). However, it is widely accepted that birds are able to avoid turbine blades in a number of ways. Birds may exercise avoidance by detecting the wind farm or turbine and modifying their flight lines to avoid the structures (Macro avoidance). At close proximity, birds may see an oncoming blade and emergency avoidance action can be taken (Micro avoidance) (SNH, 2000)[9]. As such, an avoidance rate (SNH, 2018)[3] was applied to each model to estimate the collision risk for each species respectively.

Wind farm characteristics

7. The scheme has seven turbines and the flight risk volume (Vw), in these analyses, is based on a buffer constructed with a radius of 500 m (area = 353.6 ha), centred on the turbine locations with a height that was equal to the diameter of the turbine blades (133.2 m). The turbines used for the collision risk modelling were based on a hub height of 83 m, giving an overall tip height of 149.9 m. Turbine specifications were obtained from the manufacturer[10] and are shown where relevant.

Viewsheds

8. Flight data were obtained from a total of six Vantage Points (VPs) that overlooked the seven-turbine layout. Viewsheds were estimated using a Digital Elevation Model (DEM) and a 20 m vertical offset above the ground surface (lowest point of rotor sweep at 16.5 m) (**Figure 1**). Other details of the viewshed calculation are given in **Table 1**.

Table 1. Vantage point survey effort and visible areas within the 500 m buffer drawn around the turbines.

VP No.	Visible area with 500m turbine buffer (ha)	Hours of observation between September and March (hrs)	Hours of observation between April and August (hrs)	Total hours of observation (hrs)
1	147.6	18.00	0	18.00
2	79.8	71.00	75.00	146.00
3	142.7	75.00	75.00	150.00
4	35.6	68.00	78.00	146.00

[10] https://www.nordex-online.com/en/product/n133-4-8/

Table 1. Vantage point survey effort and visible areas within the 500 m buffer drawn around the turbines.

VP No.	Visible area with 500m turbine buffer (ha)	Hours of observation between September and March (hrs)	Hours of observation between April and August (hrs)	Total hours of observation (hrs)
5	1.7	69.00	69.00	138.00
7	206.2	66.00	81.00	147.00

Flight activity within 500 m of turbines

9. A summary of flight activity recorded within VP viewsheds, and 500 m of the proposed turbines is given in **Table 2**. All flights that passed within VP viewsheds and 500 m of the proposed turbines are shown in **Figures 2** – **4**.

Table 2. Summary of flight activity recorded within VP viewsheds and 500 m of the proposed turbines.

Species	Total flights	'At-risk' flights	No. individuals 'at-risk'	CRM undertaken
Golden eagle	18	15	16	**Yes**
Golden plover	5	5	44	No
Hen harrier	2	2	2	No
Merlin	3	3	3	No
Peregrine	2	2	2	No
Pink-footed goose	5	2	41	No
Red kite	4	4	4	No
White-tailed eagle	21	19	19	**Yes**
Whooper swan	2	2	37	No

10. An 'at–risk' flight is one which passes into the 500 m turbine buffer with at least part of its flight at an altitude between 0 m and 150 m. Professional judgement was used as to whether a CRM was undertaken for each species, based on the Nature Conservation Importance of the species and the number of 'at-risk' flights or the number of individuals potentially 'at-risk'.

11. Details of 'at-risk' flights for consideration under a CRM are shown in **Table 3** and **Table 4**. The total flight duration recorded during the vantage point watches was adjusted to give an estimate for the total expected over the period of occupancy by each species. The total potential flying time for each species was estimated from the sum of the day lengths of each day. Day length was estimated, for each day, using the method of Forsythe *et al*. (1995)[11] at latitude 56.42875° N.

[11] Forsythe, W.C., Rykiel, E.J., Stahl, R.S., Wu, H. & Schoolfield, R.M. (1995). A model comparison for day length as a function of latitude and day of year. Ecological Modelling. 80: 87 –95

Table 3. Golden eagle flight durations recorded within VP viewsheds and clipped to 500 m survey buffer. Part, or all, of these flights at a height of 0 – 150 m agl places them at risk of a collision with the turbine blades (shaded columns).

Species	Season	VP No.	Bout ID	No. of birds	Total fly time (s)	Time in height category (s)					
						<20m	20-50m	50-100m	100-150m	150-200m	>200m
Golden eagle	Apr-Aug	2	BGR_210422_001_B001	1	196					61	135
			BGR_210804_001_B001	1	43						43
		3	BGR_220606_001_B001	1	153	139	14				
		4	BGR_210419_002_B001	1	54				54		
			BGR_220629_003_B004	1	43			31	12		
		7	BGR_210407_001_B001	1	71					25	46
			BGR_220608_001_B001	1	31	31					
			BGR_220608_001_B002	1	1	1					
	Sep-Mar	4	BGR_200929_002_B002	1	5			5			
			BGR_200929_002_B005	1	4	4					
			BGR_210318_001_B001	1	23		23				
			BGR_210318_001_B002	1	11		11				
			BGR_210927_001_B001	1	40			40			
			BGR_210927_001_B002	1	16			16			
			BGR_220323_001_B009	1	67				24	43	
		7	BGR_210310_002_B001	1	16			5		11	
			BGR_210310_002_B002	1	52			52			
			BGR_220214_001_B005	2	11		11				
Golden eagle Total				**19**	**837**	**175**	**59**	**149**	**90**	**140**	**224**

Table 4. White-tailed eagle flight durations recorded within VP viewsheds and clipped to 500 m survey buffer. Part, or all, of these flights at a height of 0 – 150 m agl places them at risk of a collision with the turbine blades (shaded columns).

Species	Season	VP No.	Bout ID	No. of birds	Age	Total fly time (s)	Time in height category (s)					
							<20m	20-50m	50-100m	100-150m	150-200m	>200m
White-tailed eagle	Apr-Aug	3	BGR_220629_001_B001	1	IMM	89		43	46			
		4	BGR_210422_002_B002	1	A	88			17	41	30	
			BGR_220629_002_B008	1	IMM	125	15	30		80		
			BGR_220705_001_B001	1	IMM	79		79				
			BGR_220705_001_B002	1	IMM	26	26					
			BGR_220712_001_B001	1	IMM	75		16	59			
			BGR_220810_002_B002	1	IMM	268	15	30	77	146		
		7	BGR_210427_002_B002	1	A	32		8	24			
			BGR_210427_002_B004	1	A	281		127			154	
			BGR_220506_001_B001	1	IMM	64		64				

Table 4. White-tailed eagle flight durations recorded within VP viewsheds and clipped to 500 m survey buffer. Part, or all, of these flights at a height of 0 – 150 m agl places them at risk of a collision with the turbine blades (shaded columns).

Species	Season	VP No.	Bout ID	No. of birds	Age	Total fly time (s)	Time in height category (s)					
							<20m	20-50m	50-100m	100-150m	150-200m	>200 m
White-tailed eagle	Apr-Aug	7	BGR_210415_003_B001	1	IMM	326			38	127	101	60
			BGR_210415_003_B002	1	IMM	518				121	30	367
			BGR_210427_002_B006	1	IMM	162				162		
			BGR_210427_002_B007	1	A	24				24		
			BGR_210519_002_B002	1	A	128		15	30	15		68
			BGR_210804_002_B002	1	A	33	16	17				
			BGR_210804_002_B003	2	A + JUV	67					48	19
			BGR_220825_001_B001	1	A	66					10	56
	Sep-Mar	2	BGR_210203_001_B001	1		32	5	16	11			
		3	BGR_201214_001_B001	1	IMM	58		31	27			
			BGR_220307_001_B001	1	IMM	55			24	31		
White-tailed eagle Total				**22**		**2596**	**77**	**476**	**353**	**747**	**373**	**570**

12. Full details of all other flights that passed within 500 m of the proposed turbines are shown in **Appendix 2**.

Species-specific information

13. **Table 5** summarises the species-specific information used in the collision risk calculations. Collision probability was obtained using the SNH (2000)[9] model and details, for each species, are available in **Appendix 1**. Species length and wingspan have been derived using a mean of the figures presented within Snow & Perrins (1998)[12] and flight speeds were derived using Alerstam *et al.* (2007)[13] or Provan & Whitfield (2006)[14] as suggested by NatureScot (SNH, 2014)[15].

Table 5. Species-specific information used in the collision risk calculations.

Species	Bird length			Wingspan			Flight speed (ms^{-1})	Collision probability (%)	Total potential flying time (hrs)
	Min (cm)	Max (cm)	Average (m)	Min (cm)	Max (cm)	Average (m)			
Golden eagle	75	88	**0.82**	204	220	**2.12**	14.1	6.7	4,500
White-tailed eagle	70	90	**0.80**	200	240	**2.20**	13.4	6.8	4,500

[12] Snow, D. W. & Perrins, C. M. (1998). The Birds of the Western Palearctic. Concise Edition. Oxford University Press.
[13] Alerstam T., Rosén M., Bäckman J., Ericson P.G.P. & Hellgren O. (2007). Flight speeds among bird species: allometric and phylogenetic effects. PLoS Biol, **5**, 1656-1662
[14] Provan, S. & Whitfield, D.P. (2006). Avian flight speeds and biometrics for use in collision risk modelling. Report to Scottish Natural Heritage from Natural Research (Projects) Ltd
[15] SNH. (2014). Bird Speeds and Biometrics for Collision Risk Modelling. Scottish Natural Heritage, Inverness.

Results

14. For the purpose of these analyses an unaged white-tailed eagle was taken to be an adult, providing a worst-case. **Table 6** summarises the results of collision risk modelling for each of the species.

Table 6. Collision risk modelling results

Species		Occupancy	Avoidance Rate (%)	Birds colliding per year	Number of years per collision
Golden eagle		All year	99.0	0.010	104.1
White-tailed eagle	Adult	All year	95.0	0.054	18.6
	Sub-adult	All year	95.0	0.192	5.2

15. The annual collision risk for golden eagle is predicted to be 0.01 birds or one bird every 104.1 years.

16. The annual collision risk for adult white-tailed eagle is predicted to be 0.054 birds or one bird every 18.6 years.

17. The annual collision risk for sub-adult white-tailed eagle is predicted to be 0.192 birds or one bird every 5.2 years.

Detailed calculations

Golden eagle

WIND FARM PARAMETERS		
Size of windfarm envelope	353.6	ha
Number of turbines	7	
Rotor diameter	133.2	m
Hub height	83.0	m
Max. chord	4.10	m
Pitch	15.0	degrees
Rotation period	6.12	s
Turbine operation time	85	%

BIRD PARAMETERS		
Length	0.82	m
Wingspan	2.12	m
Flapping (0) or gliding (+1)	1	
Assumed flight speed	14.1	ms^-1
Number of hours birds potentially present	4500	hrs
Assumed avoidance rate	99	%

BAND USED TO DEFINE 'RISK HEIGHT'		
Max height	150	m
Min height	0	m

VP	Watch Data		Bird Flight Data	
	Area (ha)	Time (hrs)	Total (s)	'Risk height' (s)
1	147.6	18.00	0	0
2	79.8	146.00	239	0
3	142.7	150.00	153	14
4	35.6	146.00	263	216
5	1.7	138.00	0	0
7	213.1	147.00	182	68
Totals	620.5	745.0	837	298

Flight Activity Per Unit Time & Area			Weighted By Observation Effort	
VP	Observation effort (HaHr)	Flying time at 'risk height' (Hahr^-1)	Weighting	Adjusted time at 'risk height' (Hahr^-1)
1	2656.80	0.0000000	0.037	0.0000000
2	11650.80	0.0000000	0.161	0.0000000
3	21405.00	0.0000002	0.295	0.0000001
4	5197.60	0.0000115	0.072	0.0000008
5	234.60	0.0000000	0.003	0.0000000
7	31325.70	0.0000006	0.432	0.0000003
Totals	72470.50	0.000002055	1.000	0.0000011

Mean activity hr^-1 in wind farm	
Risk height	0.04038%
Rotor height	0.03586%

MORTALITY ESTIMATE		
Flight risk volume (Vw)	470937445.8	m^3
Rotor radius^2	4435.56	m
Combined rotor swept area (Va)	97543	m^2
Vr = Va * (d + l)	479424	m^3
Bird occupancy (n)	1.61	hrs / yr
Bird occupancy of rotor swept vol (b)	5.91	bird-secs
Bird transit time (t)	0.35	secs
No. of transits through rotors	16.97	per year
Estimated no. of collisions	0.96	per year
After allowing for avoidance	0.010	per year
i.e. equivalent to one bird every	**104.1**	**years**

White-tailed eagle – adult only

WIND FARM PARAMETERS		
Size of windfarm envelope	353.6	ha
Number of turbines	7	
Rotor diameter	133.2	m
Hub height	83.0	m
Max. chord	4.10	m
Pitch	15.0	degrees
Rotation period	6.12	s
Turbine operation time	85	%

BIRD PARAMETERS		
Length	0.80	m
Wingspan	2.20	m
Flapping (0) or gliding (+1)	1	
Assumed flight speed	13.4	ms^-1
Number of hours birds potentially present	4500	hrs
Assumed avoidance rate	95	%

BAND USED TO DEFINE 'RISK HEIGHT'		
Max height	150	m
Min height	0	m

VP	Watch Data		Bird Flight Data	
	Area (ha)	Time (hrs)	Total (s)	'Risk height' (s)
1	147.6	18.00	0	0
2	79.8	146.00	32	27
3	142.7	150.00	0	0
4	35.6	146.00	88	58
5	1.7	138.00	0	0
7	213.1	147.00	598	260
Totals	620.5	745.0	718	345

Flight Activity Per Unit Time & Area			Weighted By Observation Effort	
VP	Observation effort (HaHr)	Flying time at 'risk height' (Hahr^-1)	Weighting	Adjusted time at 'risk height' (Hahr^-1)
1	2656.80	0.0000000	0.037	0.0000000
2	11650.80	0.0000006	0.161	0.0000001
3	21405.00	0.0000000	0.295	0.0000000
4	5197.60	0.0000031	0.072	0.0000002
5	234.60	0.0000000	0.003	0.0000000
7	31325.70	0.0000023	0.432	0.0000010
Totals	72470.50	0.000001008	1.000	0.0000013

Mean activity hr^-1 in wind farm

Risk height	0.04675%
Rotor height	0.04152%

MORTALITY ESTIMATE		
Flight risk volume (Vw)	470937445.8	m^3
Rotor radius^2	4435.56	m
Combined rotor swept area (Va)	97543	m^2
Vr = Va * (d + l)	477961	m^3
Bird occupancy (n)	1.87	hrs / yr
Bird occupancy of rotor swept vol (b)	6.83	bird-secs
Bird transit time (t)	0.37	secs
No. of transits through rotors	18.60	per year
Estimated no. of collisions	1.08	per year
After allowing for avoidance	0.054	per year
i.e. equivalent to one bird every	**18.6**	**years**

White-tailed eagle – sub-adult only

WIND FARM PARAMETERS		
Size of windfarm envelope	353.6	ha
Number of turbines	7	
Rotor diameter	133.2	m
Hub height	83.0	m
Max. chord	4.10	m
Pitch	15.0	degrees
Rotation period	6.12	s
Turbine operation time	85	%

BIRD PARAMETERS		
Length	0.80	m
Wingspan	2.20	m
Flapping (0) or gliding (+1)	1	
Assumed flight speed	13.4	ms^-1
Number of hours birds potentially present	4500	hrs
Assumed avoidance rate	95	%

BAND USED TO DEFINE 'RISK HEIGHT'		
Max height	150	m
Min height	0	m

VP	Watch Data		Bird Flight Data	
	Area (ha)	Time (hrs)	Total (s)	'Risk height' (s)
1	147.6	18.00	0	0
2	79.8	146.00	0	0
3	142.7	150.00	202	202
4	35.6	146.00	573	517
5	1.7	138.00	0	0
7	213.1	147.00	1104	512
Totals	620.5	745.0	1879	1231

Flight Activity Per Unit Time & Area			Weighted By Observation Effort	
VP	Observation effort (HaHr)	Flying time at 'risk height' (Hahr^-1)	Weighting	Adjusted time at 'risk height' (Hahr^-1)
1	2656.80	0.0000000	0.037	0.0000000
2	11650.80	0.0000000	0.161	0.0000000
3	21405.00	0.0000026	0.295	0.0000008
4	5197.60	0.0000276	0.072	0.0000020
5	234.60	0.0000000	0.003	0.0000000
7	31325.70	0.0000045	0.432	0.0000020
Totals	72470.50	0.000005799	1.000	0.0000047

Mean activity hr^-1 in wind farm

Risk height	0.16682%
Rotor height	0.14814%

MORTALITY ESTIMATE		
Flight risk volume (Vw)	470937445.8	m^3
Rotor radius^2	4435.56	m
Combined rotor swept area (Va)	97543	m^2
Vr = Va * (d + l)	477961	m^3
Bird occupancy (n)	6.67	hrs / yr
Bird occupancy of rotor swept vol (b)	24.36	bird-secs
Bird transit time (t)	0.37	secs
No. of transits through rotors	66.36	per year
Estimated no. of collisions	3.84	per year
After allowing for avoidance	0.192	per year
i.e. equivalent to one bird every	**5.2**	**years**

Appendix 1

Probability of collision - golden eagle

						Upwind:			Downwind:		
K: [1D or [3D] (0 or 1)	1		r/R	c/C	α	collide			collide		
NoBlades	3		radius	chord	alpha	length	p(collision)	y(x)	length	p(collision)	y(x)
MaxChord	4.10 m		0				1.00	0.000		1.00	0.000
Pitch (degrees)	15.0		0.05	0.575	4.13	15.57	0.54	0.054	14.35	0.50	0.050
			0.1	0.622	2.06	8.53	0.30	0.059	7.21	0.25	0.050
BirdLength	0.82 m		0.15	0.781	1.38	6.94	0.24	0.072	5.28	0.18	0.055
Wingspan	2.12 m		0.2	0.939	1.03	6.23	0.22	0.087	4.23	0.15	0.059
F: Flapping (0) or gliding (+1)	1		0.25	0.971	0.83	5.32	0.18	0.092	3.26	0.11	0.057
			0.3	0.923	0.69	4.42	0.15	0.092	2.46	0.09	0.051
Bird speed	14.1 m/sec		0.35	0.875	0.59	3.77	0.13	0.092	1.91	0.07	0.046
RotorDiam	133.2 m		0.4	0.827	0.52	3.26	0.11	0.091	1.51	0.05	0.042
RotationPeriod	6.12 sec		0.45	0.780	0.46	2.86	0.10	0.090	1.21	0.04	0.038
			0.5	0.732	0.41	2.53	0.09	0.088	0.98	0.03	0.034
integration interval	0.05		0.55	0.684	0.38	2.56	0.09	0.098	1.11	0.04	0.042
			0.6	0.637	0.34	2.36	0.08	0.098	1.01	0.03	0.042
Bird aspect ratioo: β	0.38		0.65	0.589	0.32	2.18	0.08	0.098	0.93	0.03	0.042
			0.7	0.541	0.29	2.02	0.07	0.098	0.87	0.03	0.042
			0.75	0.494	0.28	1.88	0.07	0.098	0.83	0.03	0.043
			0.8	0.446	0.26	1.74	0.06	0.097	0.83	0.03	0.046
			0.85	0.398	0.24	1.62	0.06	0.096	0.85	0.03	0.051
			0.9	0.350	0.23	1.50	0.05	0.094	0.87	0.03	0.054
			0.95	0.303	0.22	1.40	0.05	0.092	0.88	0.03	0.058
			1	0.255	0.21	1.29	0.04	0.090	0.88	0.03	0.061

Overall p(collision) = Upwind 8.7% Downwind 4.7%

Average 6.7%

Probability of collision – white-tailed eagle

					Upwind:			Downwind:		
K: [1D or [3D] (0 or 1)	1		r/R	c/C	α	collide			collide		
NoBlades	3		radius	chord	alpha	length	p(collision)	y(x)	length	p(collision)	y(x)
MaxChord	4.10 m		0				1.00	0.000		1.00	0.000
Pitch (degrees)	15.0		0.05	0.575	3.91	14.98	0.55	0.055	13.76	0.50	0.050
			0.1	0.622	1.95	8.21	0.30	0.060	6.89	0.25	0.051
BirdLength	0.80 m		0.15	0.781	1.30	6.68	0.25	0.074	5.02	0.18	0.055
Wingspan	2.20 m		0.2	0.939	0.98	6.00	0.22	0.088	4.00	0.15	0.059
F: Flapping (0) or gliding (+1)	1		0.25	0.971	0.78	5.13	0.19	0.094	3.07	0.11	0.056
			0.3	0.923	0.65	4.27	0.16	0.094	2.31	0.08	0.051
Bird speed	13.4 m/sec		0.35	0.875	0.56	3.64	0.13	0.094	1.79	0.07	0.046
RotorDiam	133.2 m		0.4	0.827	0.49	3.16	0.12	0.093	1.41	0.05	0.041
RotationPeriod	6.12 sec		0.45	0.780	0.43	2.78	0.10	0.092	1.12	0.04	0.037
			0.5	0.732	0.39	2.46	0.09	0.090	0.90	0.03	0.033
integration interval	0.05		0.55	0.684	0.36	2.49	0.09	0.100	1.04	0.04	0.042
			0.6	0.637	0.33	2.30	0.08	0.101	0.95	0.03	0.042
Bird aspect ratioo: β	0.36		0.65	0.589	0.30	2.13	0.08	0.101	0.88	0.03	0.042
			0.7	0.541	0.28	1.97	0.07	0.101	0.82	0.03	0.042
			0.75	0.494	0.26	1.83	0.07	0.101	0.81	0.03	0.045
			0.8	0.446	0.24	1.70	0.06	0.100	0.84	0.03	0.049
			0.85	0.398	0.23	1.58	0.06	0.099	0.86	0.03	0.054
			0.9	0.350	0.22	1.47	0.05	0.097	0.87	0.03	0.058
			0.95	0.303	0.21	1.37	0.05	0.095	0.87	0.03	0.061
			1	0.255	0.20	1.27	0.05	0.093	0.87	0.03	0.064

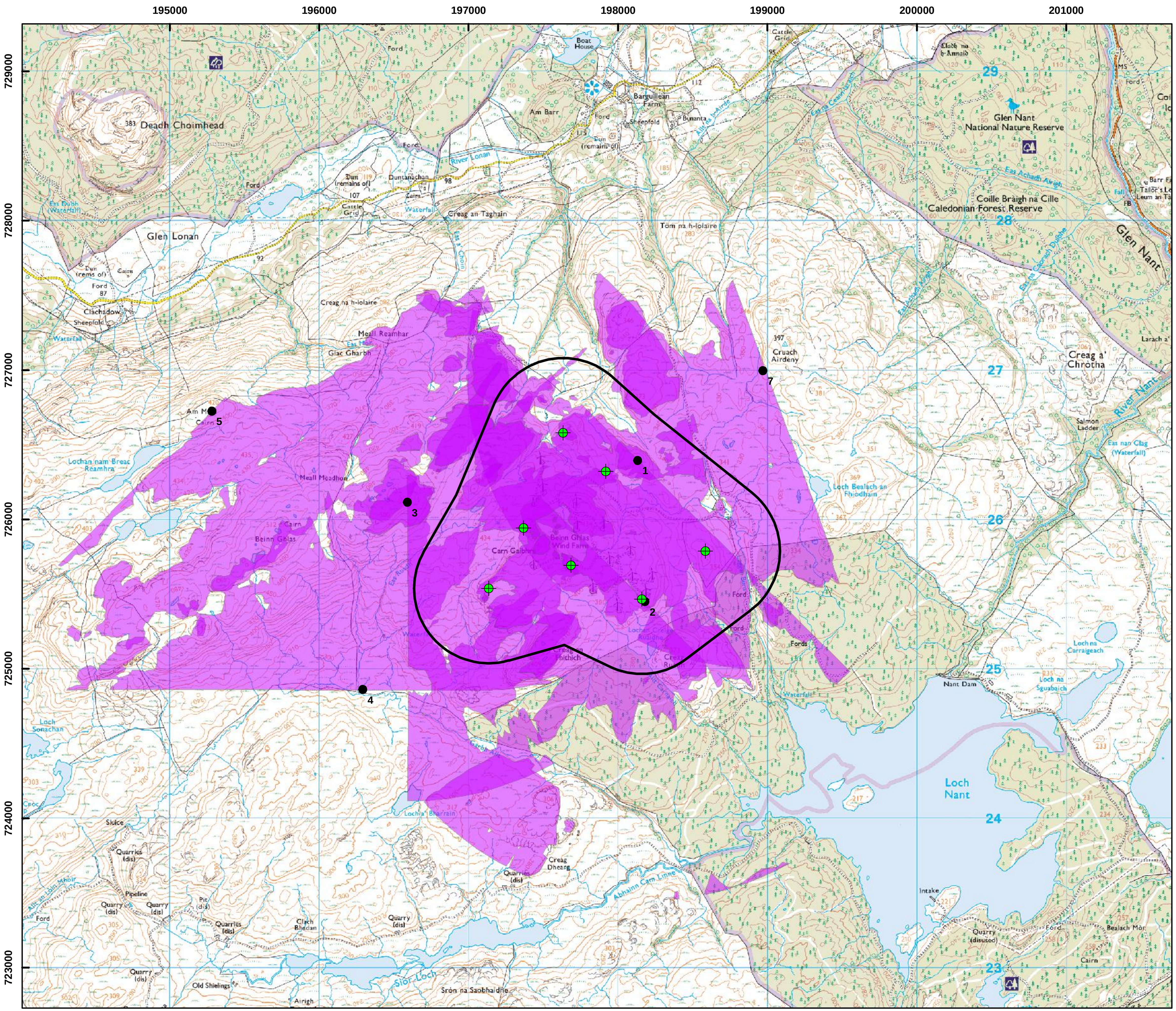
Overall p(collision) = Upwind 8.9% Downwind 4.7%

Average 6.8%

Appendix 2

Table 7. Flight durations of all other species recorded within VP viewsheds and clipped to 500 m survey buffer. Part, or all, of these flights at a height of 0 – 150 m agl places them at risk of a collision with the turbine blades (shaded columns).

Species	Season	VP No.	Bout ID	Number of birds	Total flight time (s)	Flight Height					
						<20m	20-50m	50-100m	100-150m	150-200m	>200m
Hen harrier	Apr-Aug	2	BGR_210601_001_B002	1	16	16					
	Sep-Mar	3	BGR_211209_001_B001	1	7	7					
Hen harrier Total				**2**	**23**	**23**					
Merlin	Apr-Aug	4	BGR_220629_002_B012	1	20			20			
	Sep-Mar	2	BGR_200930_001_B001	1	7	7					
		3	BGR_200924_003_B001	1	52			15	37		
Merlin Total				**3**	**79**	**7**		**35**	**37**		
Peregrine	Sep-Mar	1	BGR_200924_001_B001	1	42		16		26		
			BGR_200924_001_B003	1	12	12					
Peregrine Total				**2**	**54**	**12**	**16**		**26**		
Red kite	Apr-Aug	2	BGR_220422_001_B001	1	45	45					
		7	BGR_210427_002_B003	1	15			15			
			BGR_210427_002_B001	1	207	127	80				
			BGR_210427_002_B005	1	83		83				
Red kite Total				**4**	**350**	**172**	**163**	**15**			
Whooper swan	Sep-Mar	3	BGR_211015_002_B002	7	600			41	559		
			BGR_211021_001_B003	30	1361				1361		
Whooper swan Total				**37**	**1861**			**41**	**1920**		
Golden plover	Apr-Aug	3	BGR_220420_001_B001	5				*			
			BGR_220421_001_B001	2		*					
		7	BGR_210427_002_B008	3		*	*				
	Sep-Mar	3	BGR_211015_002_B001	10			*	*	*		
			BGR_211021_001_B002	24		*	*	*			
Golden plover Total				**44**		*****	*****	*****	*****		
Pink-footed goose	Apr-Aug	3	BGR_210419_001_B001	60						*	*
	Sep-Mar	1	BGR_200924_001_B002	40					*	*	
			BGR_200924_001_B004	1		*	*	*	*	*	*
		2	BGR_200924_002_B001	68							*
			BGR_200924_002_B002	76							*
Pink-footed goose Total				**245**		*****	*****	*****	*****	*****	*****



nrp NATURAL RESEARCH PROJECTS LIMITED

Key

- Turbine locations
- Flight activity survey area
- Vantage Points
- Viewsheds

Date produced: 07/02/2025
Source: NRP LTD

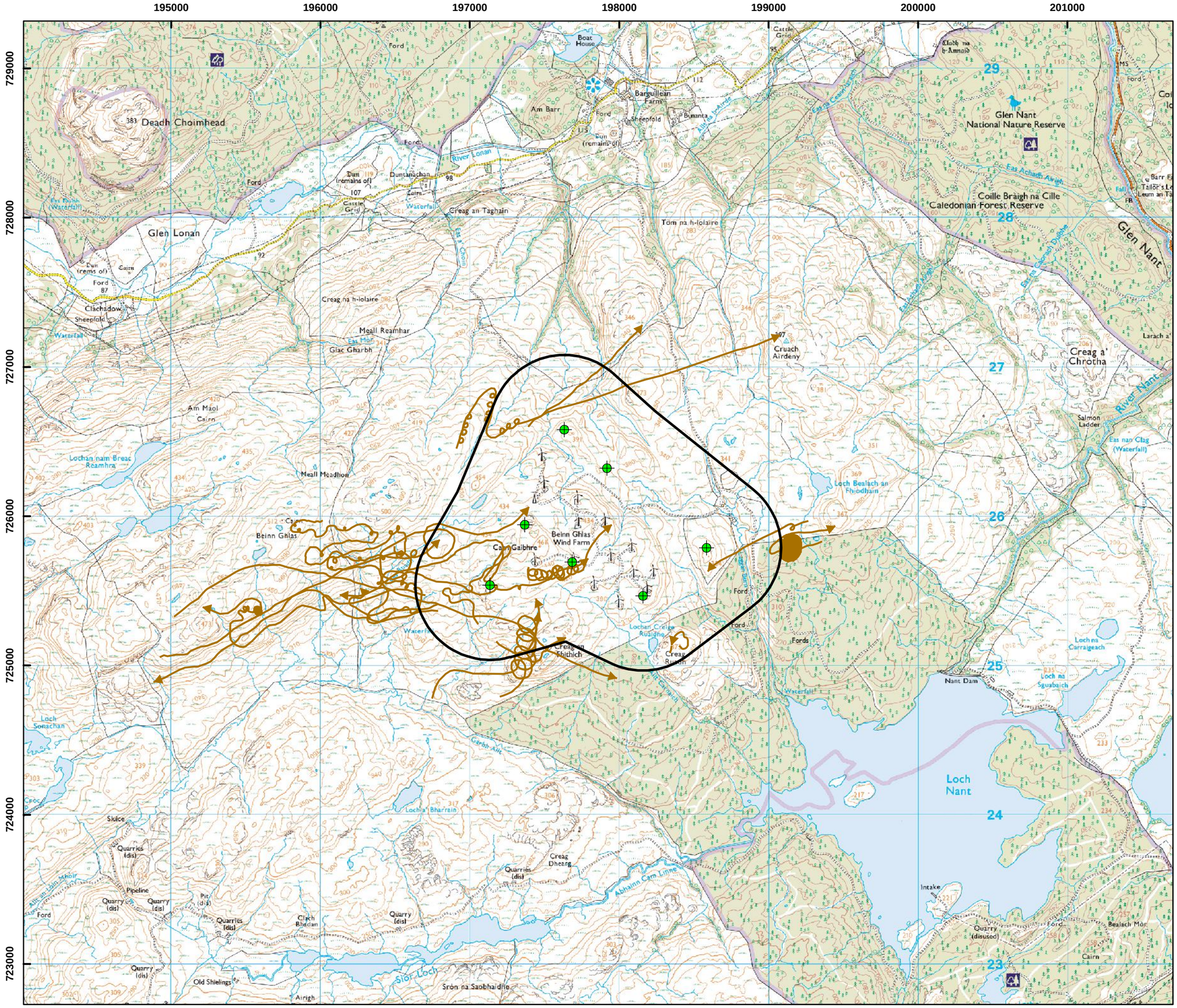
N

0 0.25 0.5 1 km

Figure 1.

Vantage Points and viewsheds used in collision risk modelling

Beinn Ghlas Repowering



nrp NATURAL RESEARCH PROJECTS LIMITED

Key

- Turbine locations
- Flight activity survey area

Flight lines

- Golden eagle

Date produced: 06/02/2025

Source: NRP LTD

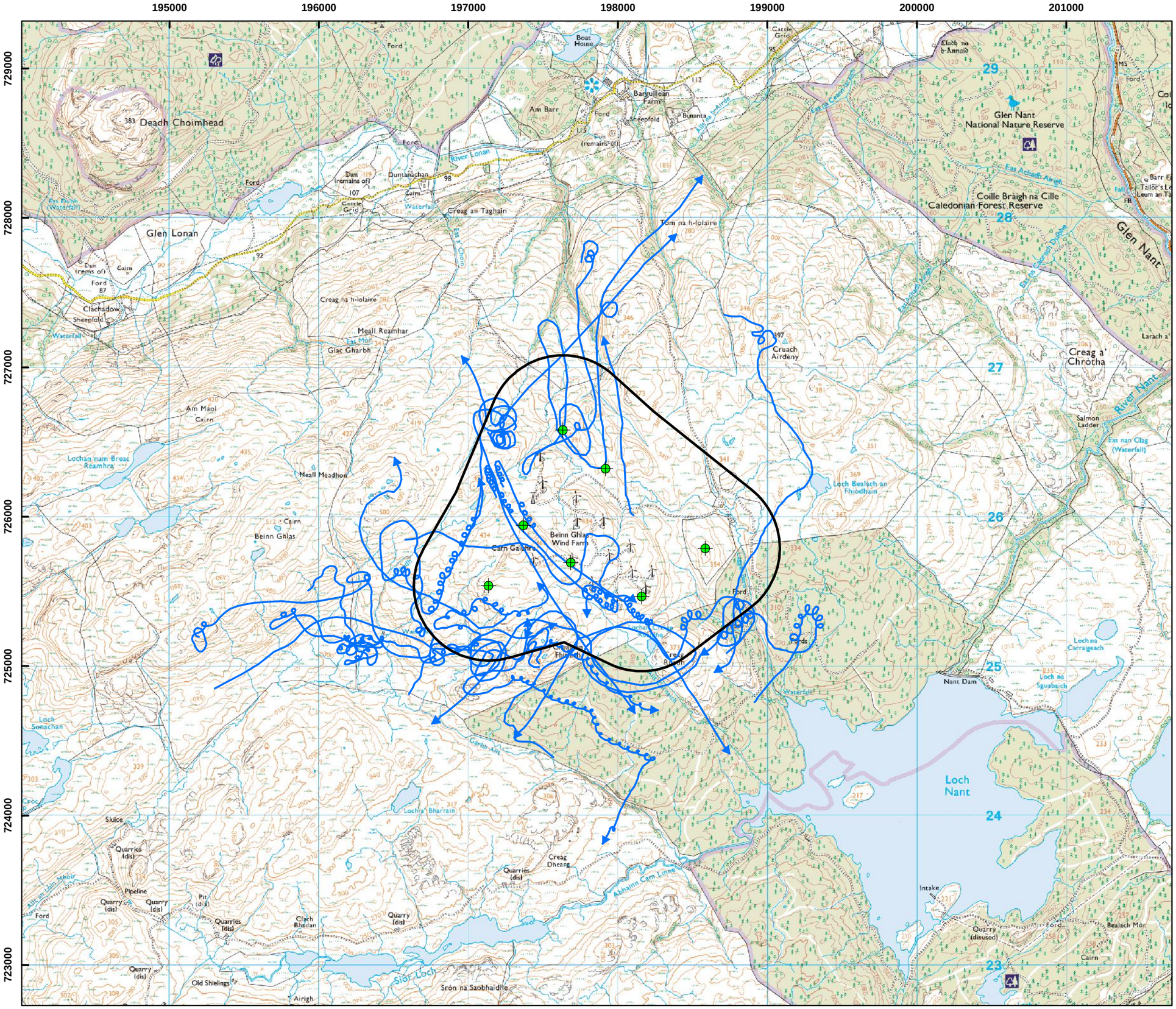
N

0 0.25 0.5 1 km

Figure 2.

All golden eagle flights that passed through the 500m turbine buffer

Beinn Ghlas Repowering



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NATURAL RESEARCH PROJECTS LIMITED

Key

Turbine locations

Flight activity survey area

Flight lines

White-tailed eagle

Date produced: 06/02/2025

Source: NRP LTD

N

0 0.25 0.5 1 km

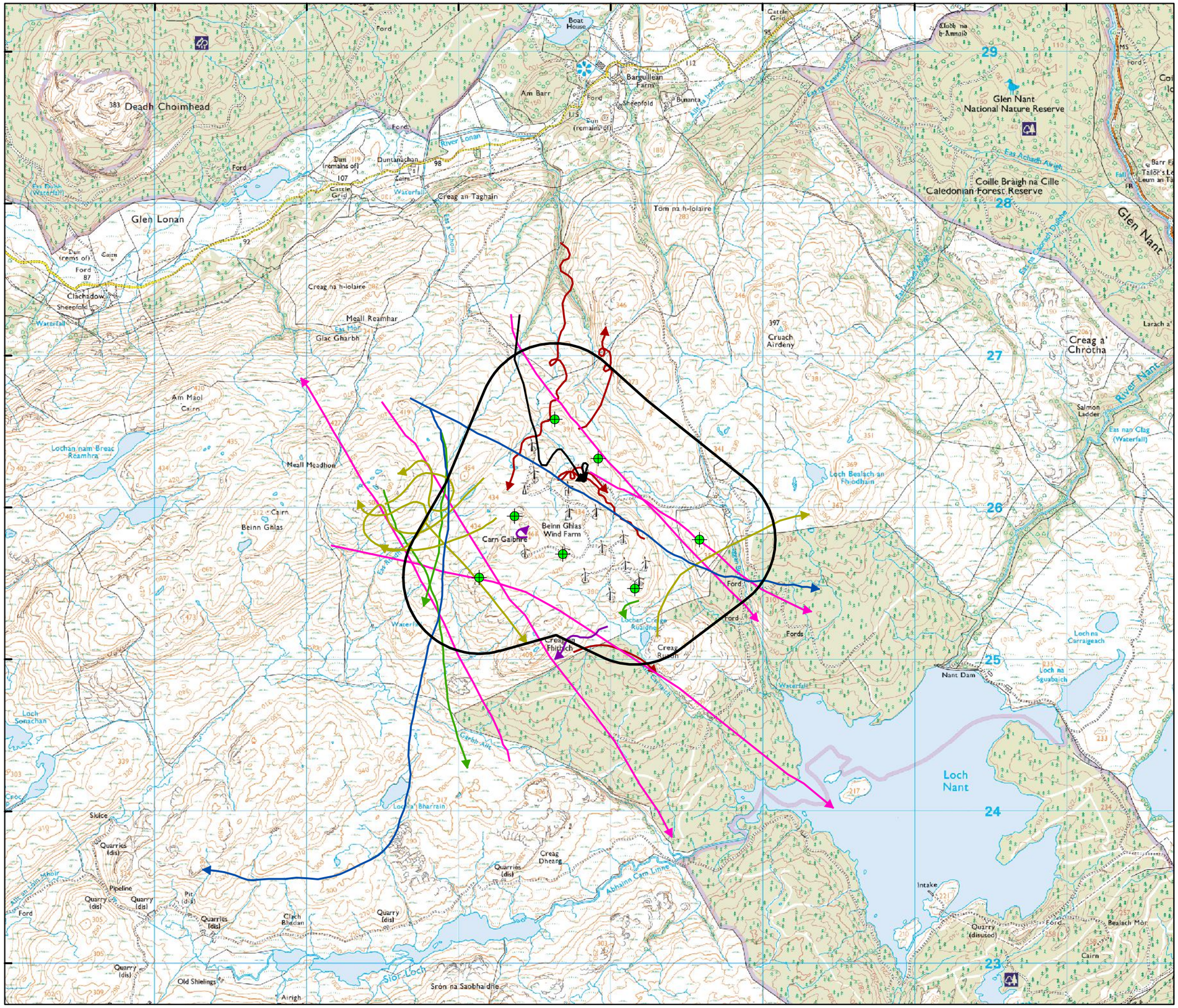
Figure 3.

All white-tailed eagle flights that passed through the 500m turbine buffer

Beinn Ghlas Repowering

195000 196000 197000 198000 199000 200000 201000

729000 728000 727000 726000 725000 724000 723000



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NATURAL RESEARCH PROJECTS LIMITED

Key

- Turbine locations
- Flight activity survey area

Flight lines

- Golden plover
- Hen harrier
- Merlin
- Peregrine
- Pink-footed goose
- Red kite
- Whooper swan

Date produced: 06/02/2025

Source: NRP LTD

N

0 0.25 0.5 1 km

Figure 4.

All flights by other species that passed through the 500m turbine buffer

Beinn Ghlas Repowering