Appendix C9A.05

Deer Collision Risk Assessment

DEER MANAGEMENT SOLUTIONS

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REPORT SUBMITTED TO RPS CONSULTING ENGINEERS, WEST PEIR BUSINESS CAMPUS, DUN LAOGHAIRE, CO. DUBLIN A96,N6T7

DEER COLLISION RISK ASSESSMENT ON THE TEN-T PRIORITY ROUTE IMPROVEMENT PROJECT, DONEGAL

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SEPTEMBER 2023

PROJECT NO: TEN-T

DEER MANAGEMENT SOLUTIONS

REPORT SUMMARY

1. *Between September 4th and 8th 2023, Deer Management Solutions carried out a Deer Collision Risk Assessment on the TEN-T Priority Route Improvement Project on the N15, N13 and N14 National routes in Co. Donegal.*

2. *The project site was divided into four sections, Section 1 west of Ballybofey / Stranorlar, Section 2 on the main route (N13) into Letterkenny and Section 3 subdivided into Section 3A (N14) southeast of Letterkenny, and 3B (N14) northwest of Lifford. (For further details see* ***4.0****, p.6).*

3. *Ground survey work was carried out on each of the four road Sections to identify Potential Deer Collision Zones (PDCZ) and involved surveying each road section by vehicle. Once PDCZs had been identified, a more detailed assessment of identified PDCZs was undertaken on foot to check for evidence of deer presence (tracks, dung, damage etc) and to assess habitat characteristics (woodland, agriculture, urban and sub-urban) and the overall context within the general landscape (For details see* **6.0***, Results).*

4. *Once PDCZs had been identified and assigned a Risk Assessment Score they were then allocated a Mitigation Level (s) appropriate to the potential risk of deer collisions occurring (For details see* **6.0***, Results).*

5. *A total of seven PDCZs were identified on all four road sections, four on Section 1, and one each on Sections 2, 3A and 3B. Of these, one PDCZ was identified as No Risk, three were identified as Low Risk, two as Moderate Risk and one as High Risk (For details see* **6.0***, Results).*

6. *Whilst the historical number of reported collisions involving deer on both the N15, N13 and N14 are relatively low (2 reported), and the distribution and density of deer species present in the area is not well known, it was clear that on all identified PDCZs, there was likely to be an increasing risk of collisions occurring in future, due to increasing distribution and density of deer, improved road surfaces and higher overall traffic volume and speed.*

7. *A multi-faceted approach to mitigation is required, which deals with each of the factors in a systematic and targeted manner that is appropriate to the overall scale of the problem. Furthermore, it is recommended that long-term monitoring and recording of Mitigation effectiveness is undertaken.*

8. *Mitigation measures have been recommended at all Low, Moderate and High Risk sites as described in Section 7 and summarised below.*

9. *For the three Low Risk sites (1.1, 2.1 and 3B.1), the following mitigation measures are recommended: cutting of roadside vegetation up to 15m from road edge; and fixed warning signage on the approaches to the locations.*

10. *For the two Moderate Risk sites (1.3 and 1.4), the same mitigation as the Low Risk sites is proposed. Where it is considered necessary, the fixed warning signage can be supplemented with Vehicle Activated Signage (VAS) particularly during the key times of year for deer activity in the autumn and spring.*

11. *For the High Risk site (3A.1), the same mitigation as the Low Risk sites is proposed supplemented by the inclusion of deer fencing and a deer underpass.*

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1. BACKGROUND

Deer Vehicle Collisions (hereafter DVCs), involving deer have presented a major problem in the UK, the United States and many other European countries for decades. However, accidents involving deer (and other wildlife) have only recently become a serious problem in many parts of Ireland, mainly as a result of greatly improved road infrastructure and consequent increases in traffic volumes. A review by various authors of figures for European countries, where regular records of DVCs are kept, illustrates the scale of the problem. For example, the Deer Initiative in their National Deer-Vehicle Collisions project in the UK (2003-2005), showed that rates of DVCs in the UK in the late 1990s were estimated at around 30,000 but were more likely to be around 50,000. In Europe, collision rates were higher and have increased significantly with over 140,000 accidents involving deer in Germany, 55,000 in Sweden, 35,000 in Austria, 10,000 in Denmark and 9,000 in Switzerland. The authors estimated that in total, the number of deer killed on roads each year in Europe is in excess of 500,000 (Groot Bruinderink and Hazebroek, 1996). A similar picture is presented of the number of collisions occurring in the United States where the number of accidents involving deer also appears to be increasing (Romin and Bissonette 1996; Putman 1997; Staines *et al*. 2001; Hedlund 2004; State Farm Insurance 2009).

The economic costs associated with DVCs can be significant - serious human injury or fatality, damage to vehicles and costs to the insurance industry and additional burdens on health systems. Langbein (2007) estimated that the 'value of prevention' of human injury in the UK was likely to be in the region of £30 Million and that insurance claims arising from DVCs in England alone were estimated to be £13.5 Million (Langbein 2007). In Ireland, figures relating to vehicle damage and insurance claims are most likely logged by insurance companies, although they may not record these as specifically involving deer.

In most of Europe, the United States and the UK, DVC data are collected and maintained in a centralised system. In Ireland, data on the number, location, frequency and severity of deer vehicle collisions DVCs have only recently been recorded by Transport Infrastructure Ireland (TII), but this data may not be widely available. Data from An Garda Siochana in 2018, shows that just over 100 accidents involving deer have been recorded countrywide with some injuries but no identifiable fatalities.

The lack of systematic quantitative data collection on DVCs clearly presents a significant problem for local authorities and road infrastructure planners and makes planning and mitigation for both existing and new road projects extremely challenging. Furthermore, the lack of sufficient detailed information (i.e. time of year, time of day, species) on DVCs and a limited understanding of the factors which influence their frequency or risk, will likely pose a major handicap in the development of effective management in future.

2. INTRODUCTION

There has been relatively little recent research into the scale and cause of Deer Vehicle Collisions both internationally and nationally and because official records are only maintained in relatively few countries (Langbein *et. al*. 2011), the scale of the problem is likely to be greatly underestimated. What is evident, is that as road infrastructures improves and proliferates, traffic volumes and speed increase. At the same time, ungulate (hoofed animal) densities throughout Europe are also increasing, (Gill, 1990; Appolonio *et al*. 2010), and as a consequence the frequency of road traffic accidents involving ungulates is likely to escalate.

In Ireland, as in most of northern and central Europe, the UK and the United States, the abundance and distribution of the three main species of deer (red, sika and fallow) has increased significantly over the last two decades and is showing little sign of decline. For example, compound annual rates of expansion of 7% for red deer, 3% for fallow and 5% for sika deer were found by Carden *et al.* (2011) while the total range increases were 565% for red deer, 174% for fallow and 353% for sika deer (Carden *et al.* 2011). However, to date there has never been any systematic attempts to quantify either deer density or distribution with the exception of some limited regional and local efforts. In general, these local and regional census efforts are almost always reactive, in response to either real or perceived levels of damage, an increase in the frequency of DVCs or other negative effects of deer over-abundance. TII have since (2015) maintained a centralised database for all recorded DVCs that are reported to have occurred in the country (TII 2021). However, it is widely accepted that the majority of DVCs that do occur, are never reported for a variety of reasons. Also, An Garda Siochana generally do not systematically record instances of collisions involving deer unless the accident serious injury or fatality. Actual real-time data on the number or frequency of these collisions is limited.

This project was commissioned due to concerns over the potential for DVCs to occur on the Priority Route Improvement on National routes (N13 and N14) in Co. Donegal. Transport Infrastructure Ireland (TII) have (since 2015) maintained a centralised data base for all recorded DVCs that are reported to have occurred in the country (TII 2021). However, it is widely accepted that the majority of DVCs that do occur, are never reported for a variety of reasons. Also, An Garda Siochana generally do not systematically record instances of collisions involving deer unless the accident involves serious injury or fatality.

Data from TII on DVCs that have occurred on the N13 and N14 between 2015 and 2020 show that two collisions involving deer occurred on the N14 in the same general location (one in 2015 and a second in 2017) whereas none have been reported thus far on the N13 (TII 2021).

There is also some limited, but useful historical data on red deer densities (km^{-2}) held by Coillte that relate to some of their properties in the general vicinity of both the N13 and N14 that were surveyed in 2014.

3. OBJECTIVES

1. To assess the potential risk of Deer Vehicle Collisions (DVC) on four specific sections of proposed new road corridors (Refer to Section 4 for the sections).
2. To survey contiguous habitats on the above sections from the public road, to determine potential DVC hotspot areas.
3. To make recommendations with regard to mitigation measures designed to minimise the risk of DVC occurring.
4. To provide a Deer Collision Risk Assessment for each of the four road sections.

4. STUDY AREAS

This Deer Collision Risk Assessment of the TEN-T PRIPD has considered the following four sections of the proposed development:

- Section 1 - N15 and N13 west of Ballybofey / Stranorlar
- Section 2 - N13 north to Letterkenny and N14 east of Letterkenny
- Section 3A - N14 southeast of Letterkenny
- Section 3B - N14 northwest of Lifford

5. METHODOLOGY

Using the maps supplied (Figs. 2-5) each proposed road section (including spurs off the main route) were, where possible, surveyed from the public road in the early morning (06:30hrs) and late evening (19:30hrs) with each section taking approximately six hours to complete. A vehicle mounted thermal imaging camera was also used to detect any possible deer presence close to the proposed routes.

In addition to using prior knowledge of known local deer populations, potential areas that were likely deer collision flashpoints were identified from aerial maps and these were assessed in more detail during survey work. At these locations, detailed searches for evidence of deer presence and activity (footprints, tracks, dung, damage etc.) were undertaken on both sides of the road and within woodland blocks where this was deemed necessary.

Once potential flashpoints had been identified, a Deer Collision Risk Assessment was undertaken for that specific site using the form below (see Table 1 below).

Table 1. Deer Collision Risk Assessment Form

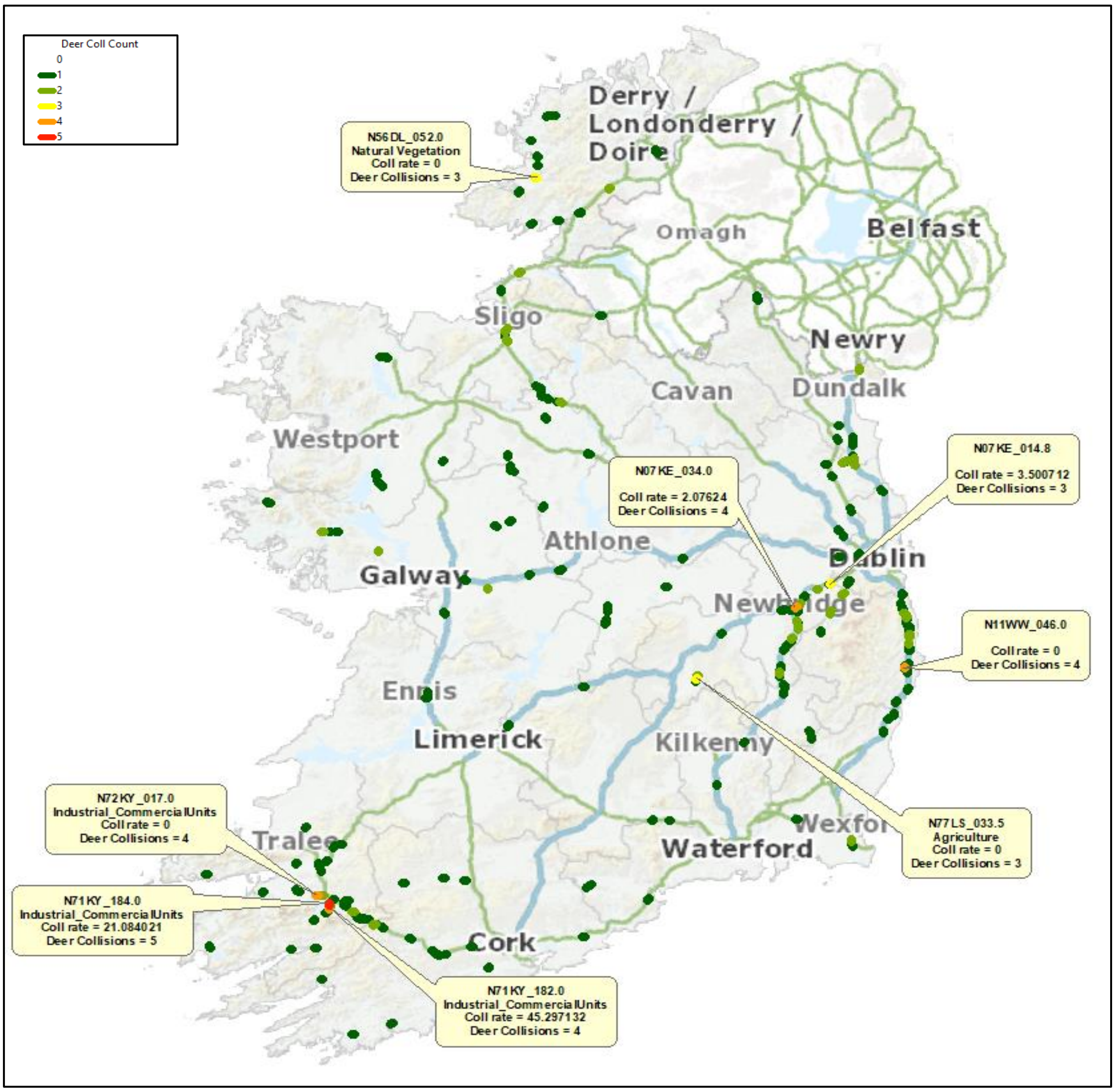
ROAD DESIGNATION	ROAD SECTION Length (km)	CONTIGUOUS HABITATS PRESENT	COLLISION RISK	PROPOSED MITIGATION LEVEL
N13 - WEST OF BALLYBOFEY	SECTION 1 12.09km		1 - NO RISK	
			2 - LOW RISK	
			3 - MODERATE RISK	
			4 - HIGH RISK	

RISK DESCRIPTORS
1 - (NO RISK) = Little or no risk of deer collisions occurring
2 - (LOW RISK) = Possibility of collisions occurring - occasional
3 - (MODERATE RISK) = Probability of collisions occurring - infrequent
4 - (HIGH RISK) = High probability of collisions occurring - frequent

HABITATS
OPEN AGRICULTURE
FOREST / WOODLAND
RIPARIAN WOODLAND
SUB-URBAN
URBAN

MITIGATION
VEHICLE ACTIVATED SIGNAGE - VAS
VEGETATION CLEARANCE - VC
FENCING - F
OVER / UNDERPASS

Figure 1: TII map showing numbers and locations of Deer Vehicle Collisions - image courtesy of Transport Infrastructure Ireland 2021



6. RESULTS

6.1 SUMMARY RESULTS: DEER COLLISION RISK ASSESEMENT

REF: TEN-T PRIPD PRIORITY ROUTE IMPROVEMENT PROJECT, DONEGAL.
DATE: September 2023.
COUNTY: DONEGAL.
ROAD DESIGNATIONS: N15, N13 and N14

Table 2. Summary of results

ROAD	ROAD SECTION	POTENTIAL COLLISION ZONE	AFFECTED ROAD LENGTH	GRID REF.	CONTIGUOUS HABITATS	DEER SPECIES	COLLISION RISK	MITIGATION LEVEL
N13	1 (12.09km)	1.1	±1,000m	H105929	Agriculture / Forestry	RED	2 LOW RISK	1
		1.2	±500m	H129955	Forestry / Urban / Sub-urban Agriculture		1 NO RISK	None
		1.3	±800m	H156983	Agriculture / Forestry		3 MODERATE	1
		1.4	±650m	H163991	Agriculture / Forestry		3 MODERATE	1

ROAD	ROAD SECTION	POTENTIAL COLLISION ZONE	AFFECTED ROAD LENGTH	GRID REF.	CONTIGUOUS HABITATS	DEER SPECIES	COLLISION RISK	MITIGATION LEVEL
N13	2 (7.80km)	2.1	±400m	C199088	Agriculture / Forestry	SIKA	2 LOW RISK	1

ROAD	ROAD SECTION	POTENTIAL COLLISION ZONE	AFFECTED ROAD LENGTH	GRID REF.	CONTIGUOUS HABITATS	DEER SPECIES	COLLISION RISK	MITIGATION LEVEL
N14	3A (8.82km)	3A.1	±750m	H269070	Agriculture / Forestry	RED	4 HIGH	1 & 2

ROAD	ROAD SECTION	POTENTIAL COLLISION ZONE	AFFECTED ROAD LENGTH	GRID REF.	CONTIGUOUS HABITATS	DEER SPECIES	COLLISION RISK	MITIGATION LEVEL
N14	3B (10.6km)	3B.1	±400m	H295015	Agriculture / Forestry	RED	2 LOW RISK	1

<u>RISK DESCRIPTORS</u>
1 - (NO RISK) = Little or no risk of deer collisions occurring
2 - (LOW RISK) = Possibility of collisions occurring - occasional
3 - (MODERATE RISK) = Probability of collisions occurring - infrequent
4 - (HIGH RISK) = High probability of collisions occurring - frequent

Figure 2: Potential Deer Collision Zones - Section 1 (1.1, 1.2, 1.3, 1.4) - image courtesy of google maps (Map data © 2023 Google)

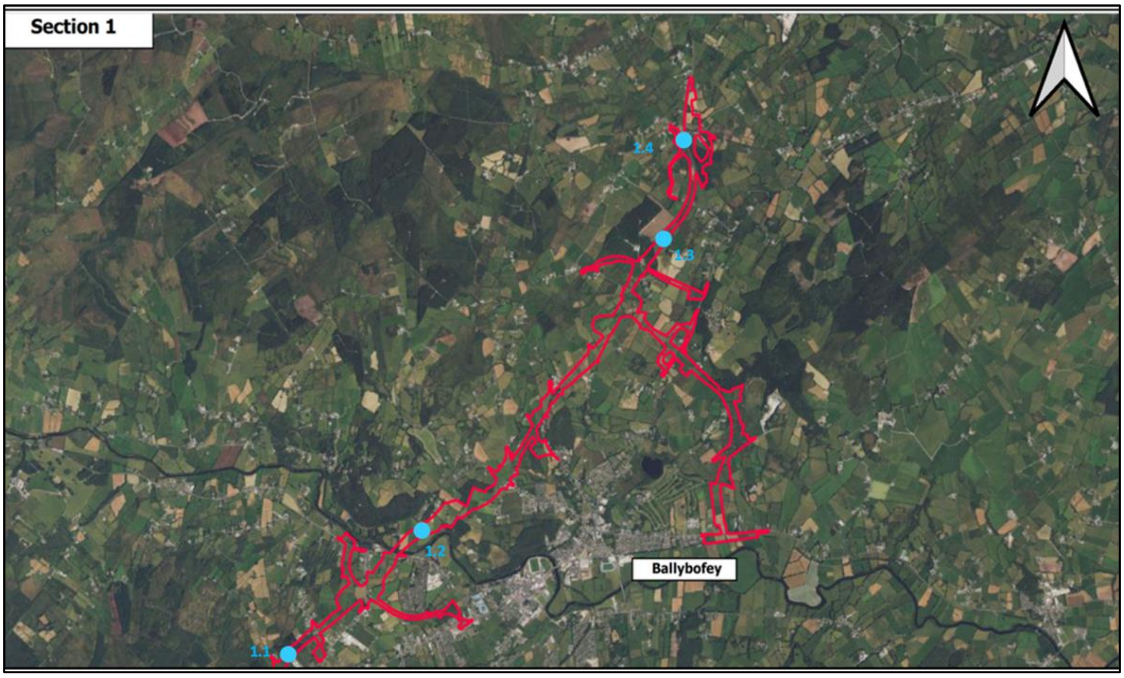


Figure 3: Potential Deer Collision Zone - Section 2 (2.1) - image courtesy of google maps (Map data © 2023 Google)

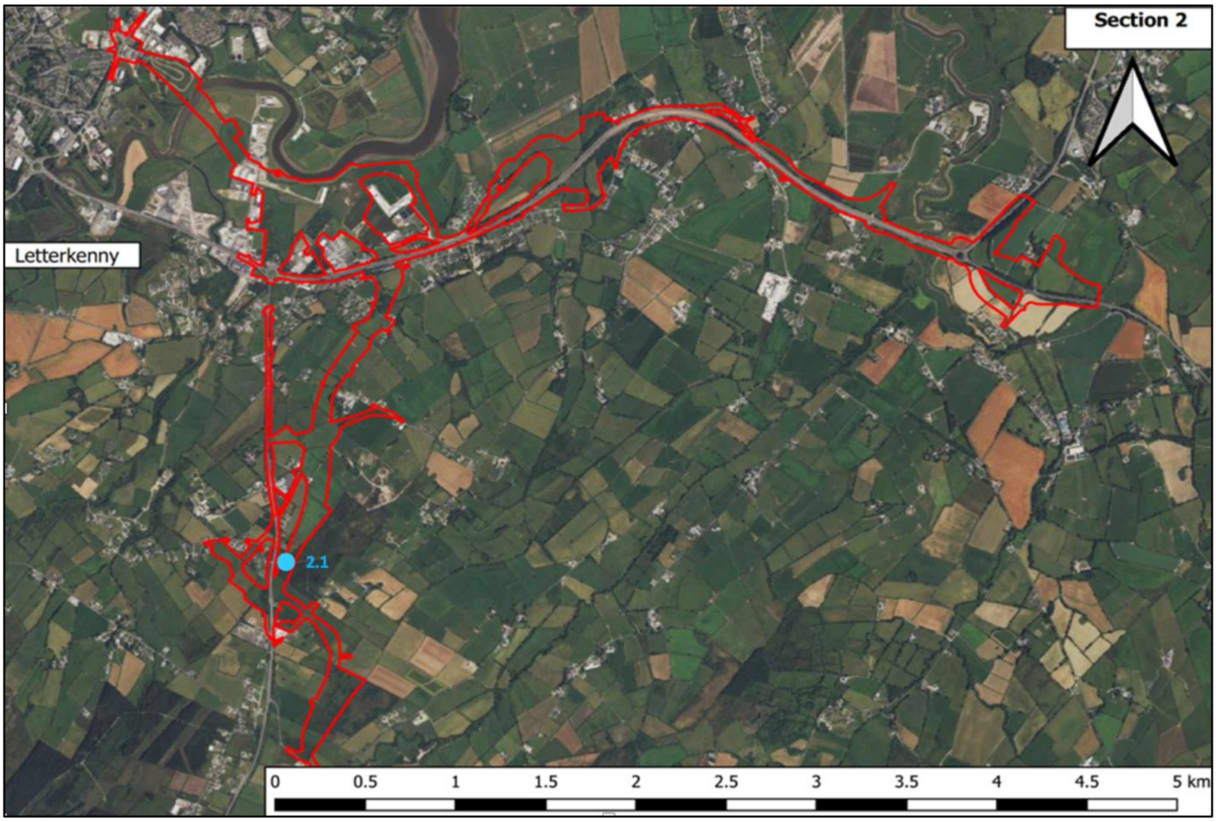


Figure 4: Potential Deer Collision Zone - 3A.1 (showing deer migration routes) - image courtesy of google maps (Map data © 2023 Google)

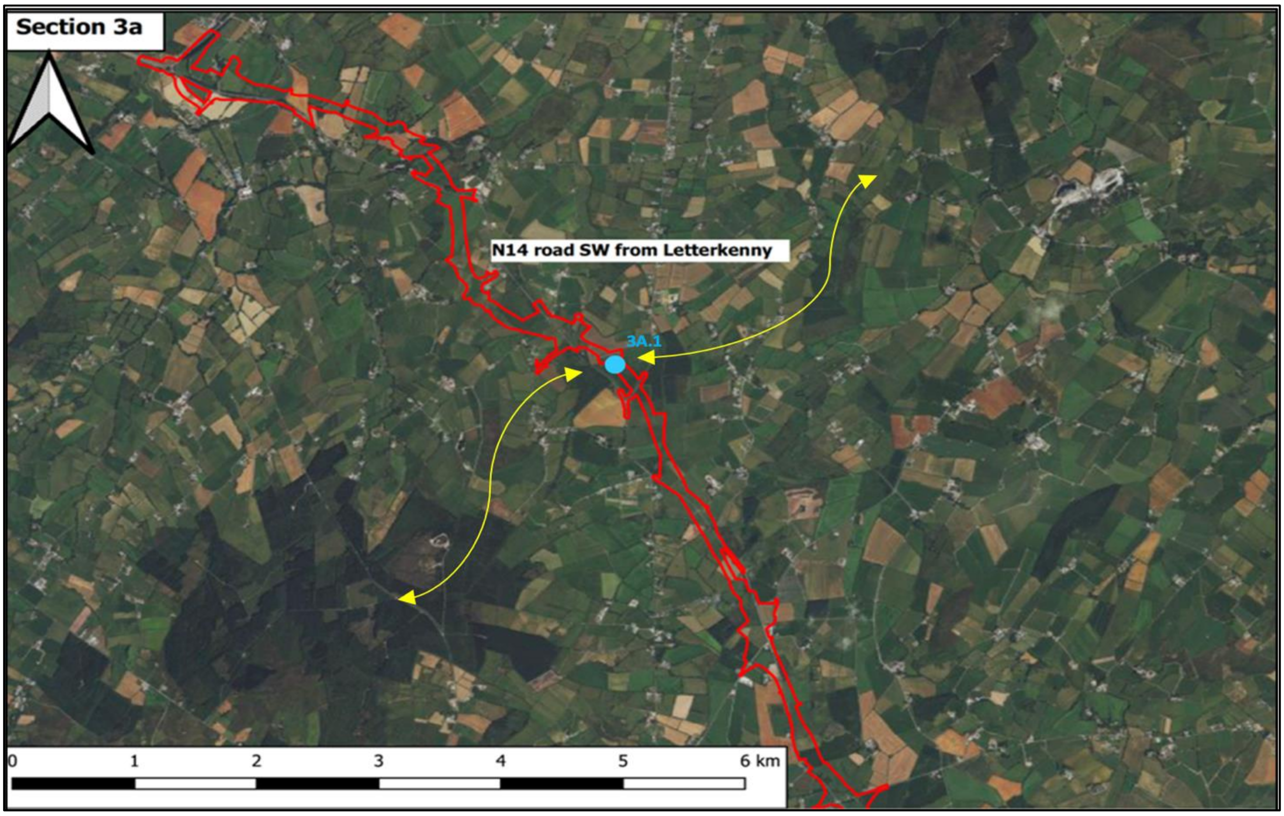


Figure 5: Potential Deer Collision Zone - 3B - image courtesy of google maps (Map data © 2023 Google

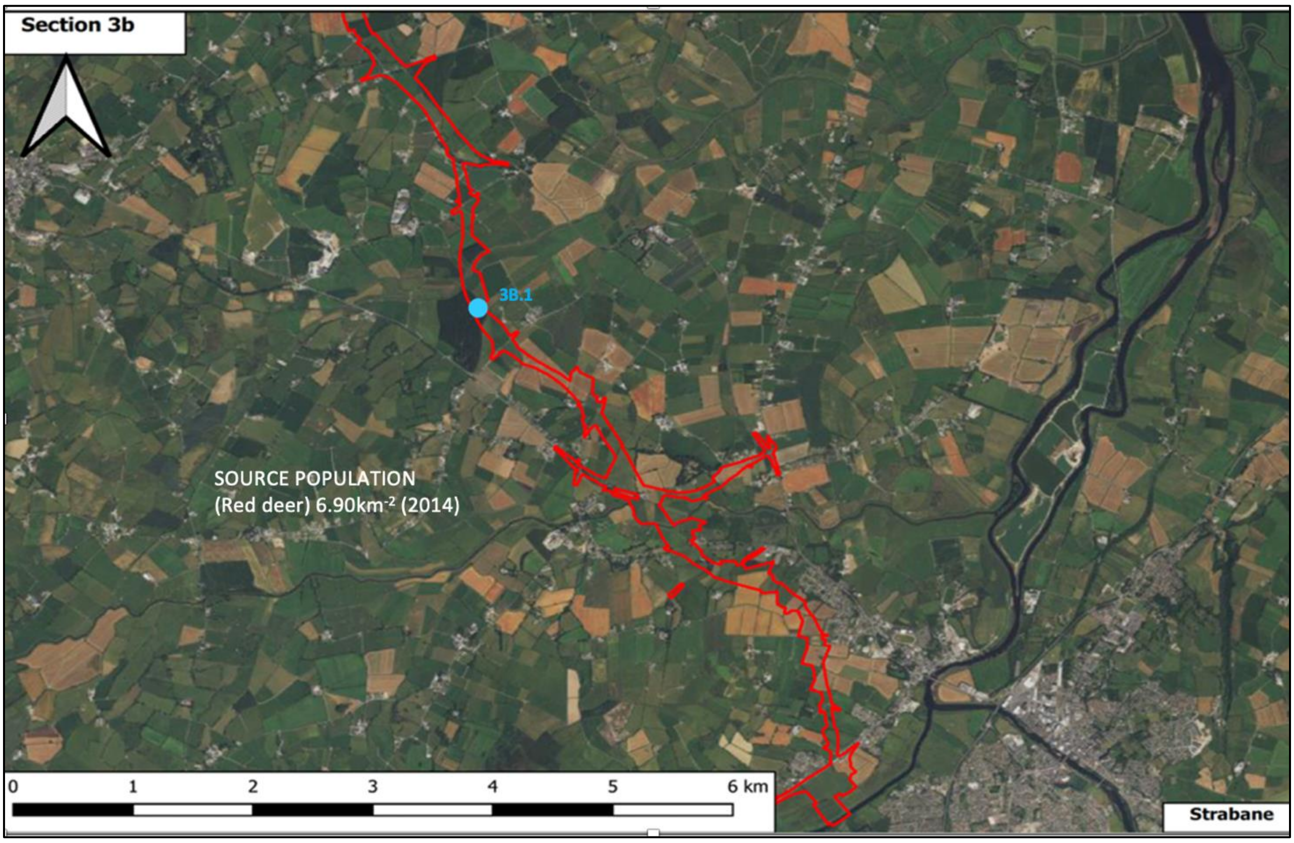


Figure 6: Details of Deer Collision Zones on Section 1 (1.1 and 1.2) - image courtesy of google maps (Map data © 2023 Google)

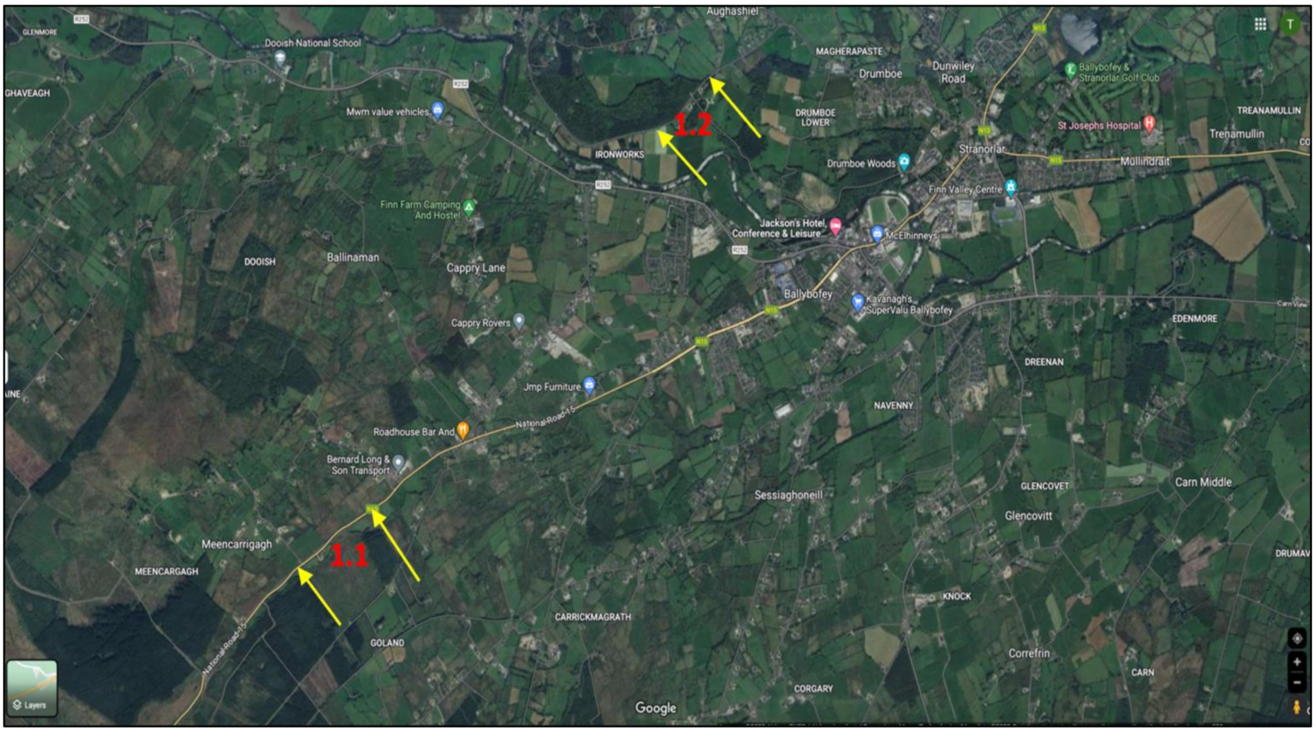


Figure 7: Details of Deer Collision Zones on Section 1 (1.3 and 1.4) - image courtesy of google maps (Map data © 2023 Google)

Figure 8: Details of Deer Collision Zones on Section 2 (2.1) - image courtesy of google maps (Map data © 2023 Google

Figure 9: Details of Deer Collision Zones on Section 3A (3A.1) - image courtesy of google maps (Map data © 2023 Google)

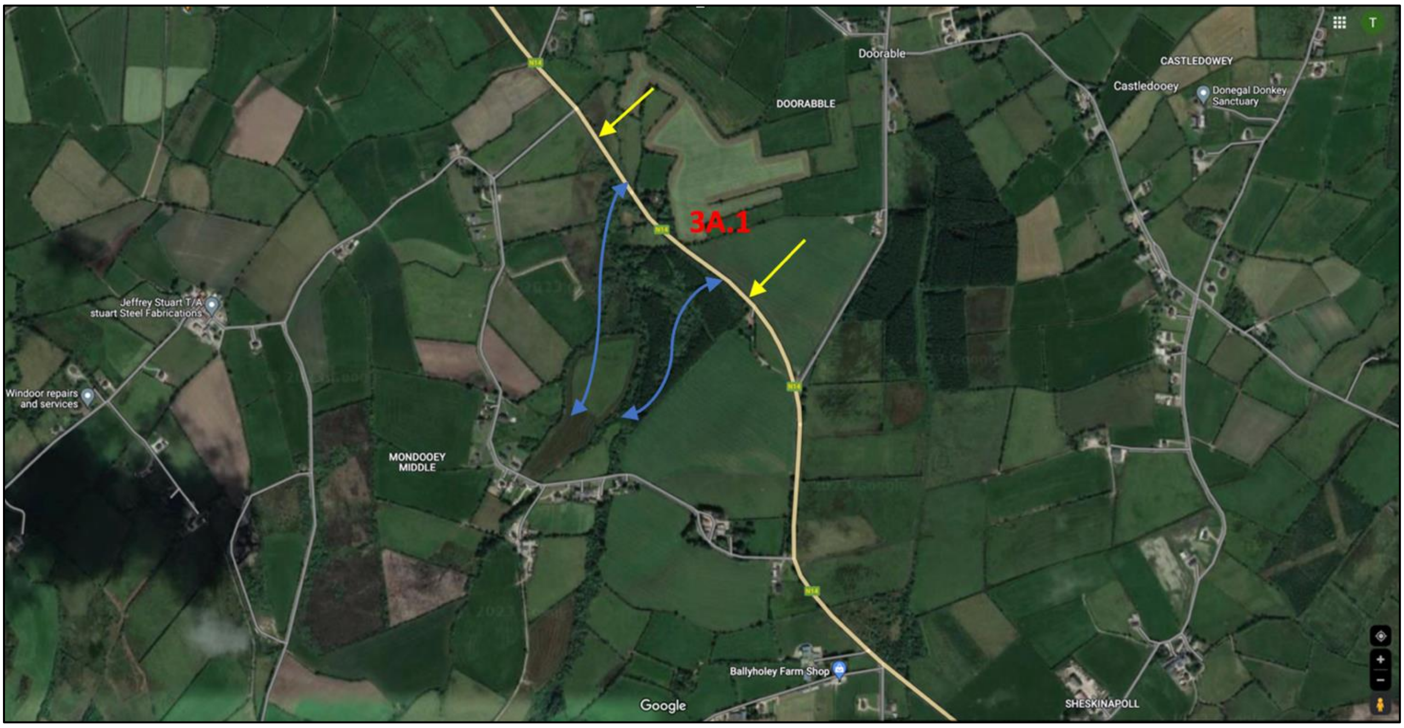


Figure 10: Details of Deer Collision Zones on Section 3B (3B.1) - image courtesy of google maps (Map data © 2023 Google)

Figure 11: PDCZ 3A.1 looking north (above) and below looking south on N14

6.2 SECTION 1 POTENTIAL DEER COLLISION ZONES

There were four Potential Deer Collision Zones (PDCZ) identified on this section. Section 1.1 (GR H105929) is located just south of the town of Ballybofey on the existing N15. Section 1.4 (GR H163991) is located on the existing N13 at Teevickmoy. Both these locations are at the interface between the existing national roads and the new TEN-T PRIPD route. The other two PDCZs were identified on the proposed new TEN-T PRIPD route, Section 1.2 (GR H129955) and Section 1.3 (GR H156983).

1.1(GR H105929) - This section was considered to be an area of low risk of deer collisions although deer were present in the Coillte property adjacent to the N15. There was no visible evidence deer crossing at this point, but in view of the location and proximity to other forestry blocks, measures from Mitigation level 1 are recommended on this section.

1.2(GR H129955) - This section was a mix of agriculture and urban / sub-urban landscape with a small woodland (Creggan wood) adjacent to the proposed new route. There was no evidence of deer in this woodland and it was considered to be an area of no risk of collisions occurring. No Mitigation is recommended on this section.

1.3(GR H156983) - This section was agriculture / forestry mixed landscape with a significant forestry plantation just north of the proposed new route. There was evidence of red deer in this plantation and given its position in relation to other woodland (1.3km to the east) in the overall landscape, it was considered to be an area of moderate risk of deer collisions occurring. Mitigation level 1 is recommended on this section.

1.4(GR H163991) - This section was also within an agricultural / forestry landscape and red deer were found to be present in the plantation to the north of the N13. As with the 1.3 above given the position of this plantation within the overall landscape and its proximity to other woodland (within 1.0 - 2.0km) and forestry it was considered to be an area of moderate risk of deer collisions occurring. Mitigation level 1 is recommended on this section.

6.3 SECTION 2 POTENTIAL DEER COLLISION ZONE

There was only one PDCZ identified on this section of the proposed new route at Section 2.1 (GR C199088) between the townlands of Listillon, Drumany and Lurgybrack.

2.1(GR C199088) - This section was close to an urban / sub-urban landscape with a small amount of woodland present. However, sika deer were found to be present in the woodland block adjacent to the proposed new route and it was considered to be an area of low risk of deer collisions occurring. Measures from Mitigation level 1 are recommended on this section.

6.4 SECTION 3A POTENTIAL DEER COLLISION ZONE

There was only one PDCZ identified on this section of the proposed new route at Section 3A.1(GR H269070) in the townlands of Doorabble and Ballyholey Far.

3A.1 (GR H269070) - This section of road was in a predominantly agricultural landscape but with scattered patches of woodland. Red deer were present in the woodland adjacent to the N14 and there was a significant amount of deer activity noted in the woodland itself (tracks, droppings, bark-stripping) - more than at any other location. Also, this woodland block is close (within 3.0km) to an identified source population of red deer at Mongorry and it is likely that red deer have migrated from Mongorry northwards via this point to the Inishowen Peninsula. Given the location of the plantation and its proximity to the N14, its position within the overall landscape it was considered an area of high risk of deer collisions occurring. As a minimum, measures from Mitigation level 1 are recommended on this section. However taking into consideration the layout of the proposed new N14 and the potential for increasing deer activity, it is recommended that consideration be given for enhanced mitigation. Measures at this location, e.g. deer fencing, and if appropriate, a deer underpass to reduce the risk of DVCs
It is recommended that Mitigation level 1 is undertaken in the first instance, but due consideration should be given to also undertake Mitigation level 2, provided that sufficient monitoring of mitigation effect is undertaken.

6.5 SECTION 3B POTENTIAL DEER COLLISION ZONE

There was only one PDCZ identified on this section of the proposed new route at Section 3B.1 (GR H295015) in the townland of Mulnaveigh.

3B.1 (GR H295015) - This section was in a predominantly agricultural landscape with occasional scattered woodland. Red deer were found in the plantation adjacent to the proposed new route but a very low density. Given that this plantation is relatively isolated it was considered to be an area of low risk of deer collisions occurring. Measures from Mitigation level 1 are recommended on this section.

7. RECOMMENDED MITIGATION MEASURES

7.1 HIERARCHY OF MITIGATION

Where (economic) resources have been, or are likely to be allocated to DVC mitigation, it is critical that they are directed to actions and measures that have the potential to produce tangible results. Furthermore, actions need to be appropriate to the scale of the problem, rather than spending limited resources on large-scale, but largely unnecessary mitigation measures. In particular, efforts should concentrate on specific sections of road or identified flash points or Potential Deer Collision Zones (PDCZ) on which there is a high likelihood or incidence of DVCs occurring or having occurred in the past.

The seven sections of the N15, N13 and N14 that have been identified as PDCZ are on both the existing national roads and on the proposed new sections of the TEN-T PRIPD. The existing roads are currently high traffic volume, high speed, and sometimes winding well-surfaced sections of carriageway. The proposed TEN-T road infrastructure is likely result in increased traffic speed and traffic volume. At the same time, deer density and distribution is expected to increase in the region. Of all the sites surveyed only 3A.1 is regarded as a High Collision Risk site and is identified as perhaps the only north to south crossing point for deer along the entire length of the N14 between Letterkenny and Lifford. It therefore requires consideration of specific increased mitigation measures.

Thus, the consideration of any mitigation measures, needs to take account of all the factors involved, so that a multi-faceted, step-wise approach to reducing DVC occurrence can be successfully implemented.
Table 3. below shows a hierarchy of proposed mitigation measures that can be considered, with the most appropriate mitigation measures for this project ranked 1 to 2 in order of priority. Those ranked levels 3 to 4 are measures that may need to be considered in the longer term, in the event that there are any increases in DVCs as a result of increases in deer populations and hence interactions with the national road network. All Potential Deer Collision Zones should be designated as Deer Collision Zones with selected mitigation measures applied as required.

Table 3. Hierarchy of proposed mitigation

LEVEL	MITIGATION MEASURES IN ORDER OF PREFERENCE	ADVANTAGES	DISADVANTAGES
1	CUTTING OF ROADSIDE VEGETATION UP TO 15M FROM ROAD EDGE.	• ENHANCES DRIVER VISABILITY AS WELL AS ANIMAL VISIBILITY AT ROAD VERGES. • EASY IMPLEMENTED AND MAINTAINED. • COST EFFECTIVE.	• INCREASES OPERTIONAL COST. • ANIMALS MAY STILL NOT BE VISIBLE DURING LOW LIGHT CONDITIONS OF DURING HOURS OF DARKNESS.
	FIXED WARNING SIGNAGE.	• VISIBLE TO DRIVERS. • EASILY IMPLEMENTED AND MAINTAINED. • COST EFFECTIVE.	• EFFICACY MAY DIMINISH OVER TIME DUE TO DRIVER FAMILIARITY WITH WARNING SIGNS.
	VEHICLE ACTIVATED SIGNAGE (VAS).	• HIGHLY VISIBLE TO DRIVERS. • EASILY IMPLEMENTED AND MAINTAINED. • COST EFECTIVE.	• INCREASED OPERATIONAL COSTS. • REQUIRES POWER SUPPLY.
	RUMBLE STRIPS / SPEED RAMPS.	• NOISE INCREASE INCRREASES DRIVER ATTENTION. • SLOWS TRAFFIC.	• NOT ACCEPTABLE TO PLACE RUMBLE STRIPS AND / OR SPEED R AMPS ON NATIONAL ROADS WITH 100KM/HR NATIONAL ROADS. • POTENTIAL SAFETY ISSUES WITH VEHICLES TRAVELLING OVER RUMBLE STRIPS / SPEED RAMPS AT EXCESSIVE SPEED. • DISRUPTS FREE-FLOWING TRAFFIC.
	REDUCTION IN SPEED LIMIT ON SPECIFIC SECTIONS.	• SLOWS TRAFFIC.	• NOT ACCEPTABLE TO REDUCE SPEED LIMIT ON NEW SECTION OF NATIONAL PRIMARY ROUTE. • REQUIRES HEIGHTENED ENFORCEMENT TO ENSURE REDUCTIONS IN SPEED ARE BEING ENFORCED. • DISRUPTS FREE FLOWING-TRAFFIC.
2	DEER FENCING.	• PREVENTS DEER FROM CROSSING AT UNSAFE LOCATIONS. • CAN BE INSTALLED AT SPECIFIC SECTIONS IF REQUIRED	• CAN LEAD TO HIGH COSTS IF EXCESSIVE LENGTHS OF FENCING ARE REQUIRED. • INCREASED OPERATIONAL COSTS. • DEER MAY BECOME TRAPPED INSIDE THE CARRIAGEWAY CORRIDOR IF NOT

LEVEL	MITIGATION MEASURES IN ORDER OF PREFERENCE	ADVANTAGES	DISADVANTAGES
			DIRECTED TO A SAFE CROSSING POINT. • MAY DIRECT DEER TO PROVATE PROPERTY CAUSING UNFORSEEN DAMAGE.
3	FENCING WITH AT-GRADE DEER CROSSINGS	• DIRECTS DEER TO SAFER CROSSING POINTS. • CAN BE INSTALLED ALONGSIDE LIGHTING, SPEED REDUCTIONS.	• HIGH COST. • INCREASES OPERATIONAL COSTS. • DISRUPTS FREE-FLOWING TRAFFIC.
4	ANIMAL OVER / UNDER PASS	• REMOVES THE POTENTIAL FOR DEER AND VEHICLE INTERACTIONS AT HIGH RISK SITES WITH LARGE NUMBERS OF DEER CROSSINGS. • CAN BE HIGHLY EFFECTIVE WITH FENCING TO DIRECT DEER TO SAFE CROSSING POINTS.	• VERY HIGH CONSTRUCTION COSTS. • INCREASES OPERATIONAL COSTS.

Further discussion on the above mitigation measures is provided below

7.2 MITIGATION LEVEL 1

7.2.1 CUTTING / MANAGEMENT OF ROADSIDE VEGETATION

The management, or removal and maintenance of roadside vegetation is a relatively straightforward mitigation measure that can be implemented quickly and relatively cost-effectively. The benefits include increased driver awareness and visibility of animals along each side of the road, while at the same time increasing visibility to deer themselves of on-coming traffic (Waring et al. 1991). According to Lavsund & Sandergren (1991), clearance of a 20 metre strip either side of the highway decreased moose collisions by almost 20% (Lavsund & Sandergren 1991). However, where vegetation removal is proposed, it is important to consider the timing, as the cutting of low growing vegetation (grasses / herbs etc) and their subsequent re-growth, may prove attractive to grazing deer, which may also increase the number of animals using the road verge.

Cutting roadside vegetation, particularly in locations where vegetation is close to the road verge, should be carried in the autumn or winter and all necessary legislative requirements should be adhered to (e.g. Wildlife Acts, Habitats Regulations, Forestry Act etc.) prior to works beginning. Trees and heavy vegetative cover (bushes, bracken etc.) should be cut back to a distance of up to 15 metres from the road verge where possible and practicable and should include vegetation and low branches up to a height of at least 2.0 metres above ground. Low lying vegetation such as grasses should be maintained by cutting throughout the year to avoid increased usage of deer at road verges.

7.2.2 FIXED WARNING SIGNAGE

Fixed deer warning signs are perhaps the most frequently used mitigation to reduce DVCs and these can be seen with increasing frequency on many roads (minor and major) throughout the country. These signs warn drivers that there is an increased risk of deer crossing the road along particular segments of roadway, but tend to be unspecific in relation to the actual location of the danger zone. Also, because these signs are permanent structures, drivers can become habituated to their presence particularly if not reinforced by an actual experience of seeing deer crossing the road, resulting in diminished effectiveness (see Putman 1997; Hedlund *et al.* 2004; Stanley *et al.* 2006).

7.2.3 VEHICLE ACTIVATED SIGNAGE (VAS)

Various types of more advanced signs such as dynamic digital message boards and animal / vehicle activated warning systems, have been developed, with the specific purpose of increasing driver awareness of the potential danger (Huijuser *et al*. 2006, Mastro *et al.* 2008). However, for these signs to be most effective, they should be erected at known regular deer crossing points and activated only at specific times of the year (e.g. autumn and spring) where accidents are known to be more frequent. For example, Sullivan *et al*. (2004) reported some success with temporary enhanced signage erected only during the autumn and spring migration of mule deer (*Odocoilus hemionus*) which resulted in a fall in the percentage of speeding vehicles from 19% to 8% and a reduction in DVCs estimated at 50% (Sullivan *et al*. 2004).

More advanced dynamic signs have also been recently developed (e.g. Flashing Light Animal Sensing Host or FLASH systems) that are activated when animals approach or are close to the roadway. These signs operate on the basis of either thermal detection, seismic ground vibrations or breaking laser or infrared beams located along the edge of the road. Also, these signs may be triggered by the speed of on-coming traffic which display intermittent messages either on portable trailers at the road side, or message boards mounted above the carriageway. According to Langbein *et al*. (2011) numerous different versions of these systems have been operational in Europe and North America although definitive data on their effectiveness is limited at present. Nevertheless, several studies have demonstrated that drivers do pay attention and slow-down in response to activated systems (Gordon *et al.* 2001; Hammond & Wade 2004; Hardy *et al*. 2006; Huijser *et al.* 2006; Langbein *et al*. 2011).

7.2.4 RUMBLE STRIPS / SPEED RAMPS

Rumble strips or speed ramps can be installed in addition to other measures at PDCZs where the risk of collision is high. They are relatively easy to install and require minimal maintenance. However, these measures will cause temporary disruption to traffic flow and may, on higher-speed roads, cause a safety issue if drivers do not adjust their speed accordingly in anticipation of the speed ramp.

For a new national primary road with a speed limit of 100km/hr, the reduction of the overall speed limit over certain sections of the road is not considered a practical solution.

7.2.5 REDUCTION IN SPEED LIMITS

Reducing overall vehicle speed can help reduce both the likelihood and severity of DVCs occurring. However, in order to play a major role in significantly reducing overall vehicle speeds and have a substantial effect on modifying driver behaviour on this section of road, increased levels of enforcement are necessary.
For a new national primary road with a speed limit of 100km/hr, the reduction of the overall speed limit over certain sections of the road is not considered a practical solution.

7.3 MITIGATON LEVEL 2

7.3.1 DEER FENCING

There is a strong consensus amongst the research community, which concludes that high-tensile fencing is likely to remain the primary method used to try and reduce DVCs at identified sites of high risk. However, many authors have emphasised that where fencing has failed to prove effective, that it is related to poor construction, specification, poor materials, inadequate planning, lack of maintenance or lack of appropriate deer-fencing expertise. Also, fencing to eliminate deer crossing entirely, is both site and species specific and often has limited success, unless sufficient prior scoping and planning is carried out in advance. Furthermore, where fences are of insufficient overall length, this can frequently result in animals moving along the inside of the fence until they reach the end of the fence-line (end-runs) and onto the road with no clear pathways of escape (Reed *et al*. 1979; Ward 1982; Clevenger *et al*. 2001, 2002; Staines *et al*. 2001). Most importantly, if a decision has been made to install fencing, then fence lines must be designed in such a way that animals are specifically channelled towards dedicated crossing points (see below) whilst at the same time effectively discouraging crossings at points on the carriageway that pose the greatest risk of a collision

7.4 MITIGATION LEVEL 3

7.4.1 FENCING WITH AT-GRADE DEER CROSSINGS

The most effective application of barrier fencing, is to erect it in short lengths, combined with alternative safer means of crossing that are specifically designed and planned so that animals can be deflected towards actual designated crossing points.

Dedicated cross walks (where deer are directed by funnel fencing to specified crossing points) are often used as DVC mitigation measures. However, in order for these structures to be effective, additional important infrastructure is required, such as funnel fencing and the use of animal-activated detection systems.

In central Arizona, Gagnon *et al*. (2018) aimed to achieve modified motorist behaviour without long-term habituation while allowing wildlife (elk and white-tailed deer) to cross the highway via a dedicated crosswalk. In conjunction with a designated at-grade crosswalk, they installed an animal-activated detection system (AADS) and motorist alert signage to prevent collisions when animals crossed. They documented wildlife use of the crosswalk zone between 2007 and 2014 using video cameras and over that time, recorded 1,719 individuals crossing at the cross walk. They found however, that increasing traffic volumes reduced the frequency of successful crossings and that almost three-quarters of elk crossings occurred between 23.00 and 03.00hours when traffic volume averaged just 0.6 vehicles/min (Gagnon *et al*. 2018).

7.5 MITIGATION LEVEL 4

7.5.1 DEER OVER/UNDERPASS

In continental Europe the concept of underpasses or overpasses is becoming more acceptable and they are becoming widely used, mainly to improve road safety but with the added benefit of reducing the potential for fragmentation of wildlife populations and their associated habitats. However, there are relatively few examples of how wildlife underpasses or overpasses can be modified from existing structures and most of these are likely to be built as part of new road infrastructure schemes rather than retro-fitted to existing roads. In Germany, Giorgii *et al*. (2007) investigated the use a range of different structures by animals, built specifically for wildlife during over the last 20 years. He used mapping of tracks and other signs including filming by infra-red cameras either on or below the structures themselves. He found that green. Bridges and viaducts were the most widely used (85% of all records) and using multiple regression analysis, that the older and wider the structure the more intensive the use (Giorgii *et al*. 2007).

From the many extensive reviews (Reed *at al.* 1975; Hedlund *et al*. 2003; Iuell *et al.* 2003; Giorgii *et al*. 2007; Ollson *et al.* 2008) both on specification of underpasses and overpasses and their effectiveness, it is clear that a number of factors are important, for example, it takes time for wildlife and deer in particular to acclimatise to new structures but over time as vegetation grows and the structures become part of the overall landscape they begin to use then more frequently. Also, to be most effective underpasses and overpasses need to be located in relation to natural deer paths or migration routes and factors such as size (wide openings and short lengths), design (earth floors), visual appearance (exit clearly visible from entrance) and woody vegetation cover at the entrance should be considered (Danielson & Hubbard 1998). Fencing to be most effective, should be used to channel deer to overpasses and underpasses. For example, Ward (1982) describes how a system of fencing and six underpasses were used along a 7.8 mile section of interstate highway that crossed a mule deer migration route. The system did not disrupt deer movement and virtually eliminated DVCs (Ward 1982; Hedlund *et al.* 2003).

7.6 RECOMMENDATIONS FOR EACH SECTION

7.6.1 SECTION 1

ROAD	ROAD SECTION	POTENTIAL COLLISION ZONE	COLLISION RISK	MITIGATION LEVEL	RECOMMENDED MITIGATION MEASURES
N15 and N13	1 (12.1 km)	1.1	2 LOW	1	• Cutting of roadside vegetation up to 15m from road edge. • Fixed warning signage.
		1.2	1 NONE	None	None.
		1.3	3 MODERATE	1	• Cutting of roadside vegetation up to 15m from road edge. • Fixed warning signage or Vehicle Activated Signage (VAS).
		1.4	3 MODERATE	1	• Cutting of roadside vegetation up to 15m from road edge. • Fixed warning signage or Vehicle Activated Signage (VAS).

In Section 1, it is recommended that the cutting of roadside vegetation be undertaken as the primary mitigation measure at the three locations 1.1, 1.3 and 1.4. In addition, fixed warning signage should be erected on the approaches to those locations to warn drivers of the potential for deer to be active in the area of the road at these locations. At both 1.3 and 1.4 consideration can be given to enhancing the signage with Vehicle Activated Signage (VAS), particularly during the key times of year for deer activity in the autumn and spring.

7.6.2 SECTION 2

ROAD	ROAD SECTION	POTENTIAL COLLISION ZONE	COLLISION RISK	MITIGATION LEVEL	RECOMMENDED MITIGATION MEASURES
N13	2 (7.8 km)	2.1	2 LOW	1	• Cutting of roadside vegetation up to 15m from road edge. • Fixed warning signage.

In Section 2, it is recommended that the cutting of roadside vegetation be undertaken as the primary mitigation measure at location 2.1 with fixed warning signage also erected on the approaches to this location. It should be noted that it is proposed as part of the TEN-T PRIPD, that the area of forestry to the east of the road project will be felled which may further reduce the likelihood of deer crossing the road at this location.

7.6.3 SECTION 3A

ROAD	ROAD SECTION	POTENTIAL COLLISION ZONE	COLLISION RISK	MITIGATION LEVEL	RECOMMENDED MITIGATION MEASURES
N14	3A.1 (12.1 km)	3A.1	4 HIGH	1 & 2	• Cutting of roadside vegetation up to 15m from road edge. • Fixed warning signage or Vehicle Activated Signage (VAS). • Deer fencing. • Deer underpass.

In Section 3, the area around location 3A.1 is the only High Risk area identified for the TEN-T PRIPD in this deer collision risk assessment. Give the interactions between the existing N14 and the proposed new N14, along with attenuation ponds, and the likelihood of deer activity north and south of both roads, it is considered appropriate for mitigation measures at this location to include a deer underpass to be constructed at approximate chainage 4+500. This will be further enhanced with deer fencing north and south of the new N14 road, vegetation maintenance (including additional landscape planting where necessary), and fixed warning signage.

7.6.4 SECTION 3B

ROAD	ROAD SECTION	POTENTIAL COLLISION ZONE	COLLISION RISK	MITIGATION LEVEL	RECOMMENDED MITIGATION MEASURES
N14	3B (10.6 km)	3B.1	2 LOW	1	• Cutting of roadside vegetation up to 15m from road edge. • Fixed warning signage. • Deer fencing if considered necessary.

In Section 3, it is recommended that the cutting of roadside vegetation be undertaken as the primary mitigation measure at location 3B.1 with fixed warning signage also erected on the approaches to this location. Should deer activity increase in this area, consideration should be given to providing deer fencing between approximate chainages 11+500 and 12+200 both north and south of the proposed new N14.

Provision is also to be made for deer passage on the southern bank of the Swilly Burn river under the proposed N14 river bridge at approximate chainage 11+500.

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APPENDIX

Overview of approaches to deer collision mitigation and their advantages and disadvantages in different contexts (after Langbein *et al.* 2011).

MITIGATION MEASURES	SUITABLE SITUATIONS AND SUPPORTING MEASURES	POTENTIAL EFFECTIVENESS / ADVANTAGES	DISADVANTAGES
FENCING	Major high risk roads of high traffic flow; most effective when leads to safer crossing points and contains escape ramps / leaps	Well proven effectiveness where of appropriate mesh size and height and sufficient length to prevent 'end runs' [1,2,3,4,5]	High erection and maintenance costs; barrier effect also to other wildlife [6]
OVERPASSES / GREEN BRIDGES	Major high risk roads; most effective with lead-in fencing and natural ground cover	Well proven effectiveness; ungulate usage increases with width; smaller structures can also help alleviate wildlife collisions [7,8,9]	High cost; feasibility dependent on landscape. More readily installed on new-build than for existing roads. [8]
UNDERPASSES / VIADUCTS	Major high risk roads; most effective with lead-in fencing and natural ground cover	Good – where of adequate specification. Mostly lower costs than overpasses of similar size. [7,9,10]	High cost; feasibility dependent on landscape. Often longer delay before used by ungulates than in case of overpasses. [7,9]
HIGHWAY CROSSWALKS	Low to medium speed routes; needs to be supported by fencing, signage, speed restriction and ideally deer-grids.	Good – if well signed. [11]	Not likely to be acceptable on major routes where traffic must be kept flowing
OPTICAL WILDLIFE WARNINGS	Roads of low traffic volume providing some traffic free periods. Vegetation around reflectors needs to be kept clear	Limited convincing evidence of success. Relatively low cost; do not prevent normal range use. [12,13]	Rapid habituation where lit up by frequent traffic. Can at best only function during night. Many trials indicate ineffective. [14,15,16,17,18]
ACOUSTIC WILDLIFE WARNING	Roads of low traffic volume, where habituation least likely & providing safe crossing periods	Variable evidence. Lasting effects likely to depend on type and variability of signals. [19,20]	General effectiveness remains unproven. Limited potential on roads of higher traffic volume. Much higher (x10) cost than optical reflectors. [17,21]
CHEMICAL OLFACTORY DETERRENTS	Roads of moderate to low traffic flow	Limited convincing evidence of success. Most intent to raise level of alertness, rather than prevent animals crossing. [22]	Limited independent evidence of effectiveness. Requires renewal at regular intervals. Likely habituation. [17,19,23,24]
VEHICLE MOUNTED ULTRASOUND WHISTLES / ELECTRONIC HORNS		Limited effectiveness. Some types very cheap to install. [25]	No convincing evidence of effectiveness. Requires renewal at regular intervals. Likely habituation [17,19,23,24]
STANDARD WILDLIFE WARNING SIGNS	Any road type, but should be targeted to forewarn of short, well-defined sections of risk	Can help to absolve legal responsibility of road authorities or population managers. Moderate cost	Over-abundance of wildlife and other signage leading to reduced effect on driver behaviour. Low effectiveness (if any) at reducing collisions. [29,30,31]
INTERACTIVE SPEED-ACTIVATED SIGNAGE	Any road type, but should be targeted to forewarn of short, well-defined sections of risk	Some potential, but yet unproven for DVC reduction. Increased driver perception. [32,33]	Driver habituation over time, if not reinforced by seeing animals near crossing the point and as digital signage becomes more common [34,35]
INTERACTIVE WILDLIFE	Major well-defined animal crossing points on roads of moderate traffic flow	Promising effects on driver awareness and	High cost compared to standard or speed activated signage.

MITIGATION MEASURES	SUITABLE SITUATIONS AND SUPPORTING MEASURES	POTENTIAL EFFECTIVENESS / ADVANTAGES	DISADVANTAGES
ACTIVATED SIGNAGE		local speed reduction. [36,37,38]	Variable reliability of differing sensor types [35]
SPEED LIMITS	Low to moderate traffic flow routes. Speed sign at same site as wildlife sign preferable	Good – provided well enforced. Reduces severity of accidents if not necessarily frequency	Feasibility / acceptability for major roads limited.
REDUCTION OF LOCAL DEER DENSITY	Prevention of increases, if not reduction of deer numbers required in order for most other measures (including fencing) to be effective	Good, provided undertaken over a wide area and as one part of overall DVC reduction strategy. [39,40,41,42]	Localised culling may shift rather than reduce collisions and destabilise populations. Public understanding of need to control wildlife is limited. [14,43]
IMMUNO-CONTRACEPTION	Isolated self-contained populations	Non-lethal; higher public acceptability in some countries / situations than culling. Limited short-term effectiveness	Requires a high proportion of population inoculated. Ethically questionable. Very high cost [5]
REDUCING ANIMALS' DISTURBANCE	Forests or areas with high human / dog disturbance	High potential where dog walking and human activity often panics deer to cross roads. Low cost if achieved through restrictions on activity in specific high-risk areas.	Difficult to achieve compliance. E.g. keeping dogs on leads. May be contrary to other policies to increase public use of forests and the countryside.
VERGE CLEARANCE	All roads. Ideally verges re-sown with grass mixtures of low digestibility. Clear verges also a pre-requisite if reflectors in use	Promising – improved forward visibility for drivers and animals; dependent on width possible to clear. [45,46,47]	Effect on collision reduction not fully proven. Increased forage production on verge may attract animals if not timed carefully.
PUBLIC AWARENESS RAISING AND DRIVER EDUCATION	Increasing importance as traffic and collision risk escalates. Animal hazard awareness should be built into national driver syllabuses	High potential – relatively low cost if based on leaflets and printed media; can be integrated with other road safety campaigns.	Effects unclear; may be short-lived unless replicated. Responsiveness of driving public questionable

1 – Reed *et al*. (1982); 2 – Ward (1982); 3 – Ballon (1985); 4 – Putman *et al*. (204); Mastro *et al*. (2008); 6 – Feldhammer *et al*. (1986); 7 - Ohlbrich (1984); 8 – Iuell *et al*. (2003); 9 – Georgii *et al*. (2007); 10 - ECONAT (1992); 11 – Lehnert & Bissonette (1997); 12 – Schaffer and Penland (1985); 13 – Gladfelter (1982); 14 – Waring *et al*. (1991); 15 – Reeve & Anderson (1993); 16 – Woodward *et al*. (1973); 17 – Voss (2007); 18 – D'angelo (2006); 19 – Pokorny *et al*. (2008); 20 – Pokorny & Policnic (2008); 21 – Langbein (2007b); 22 – Kerzel & Kirchberger (1993); 23 – Lebensorger (1993); 24 – Lutz (1994); 25 – Tracy (2003, in DVCIC 2003); 26 – Romin & Dalton (1992); 27 – Schober & Sommer (1984); 28 – Scheifele *et al*. (2003); 29 – Putman (1997); 30 – Hedlund *et al*. (2004); 31 – Stanley *et al*. (2006), 32 – Sullivan *et al.* (2004); 33 – Hardy *et al*. (2006); 34 – Pojar *et al*. (1975); 35 – Hujser *et al*. (2006); 36 – Gordon *et al*. (2003); 37 – Hammond & Wade (2004); 38 – Mosler-Berger & Romer (2003); 39 – McCaffery (1973); 40 – Schwabe *et al*. (2002); 41 – Rondeau & Conrad (2003); 42 – Sudharsen *et al*. (2006); 43 – Doerr *et al*. (2001); 44 – Rutberg & Naugle (2008); 45 – Jaren (1991); 46 – Staines *et al*. (2001); 47 – Lavasund & Sandgren (1992); 48 – Rea (2003).