MINISTRY OF TRANSPORTATION

Environmental Guide for Mitigating Road Impacts to Wildlife

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MINISTRY OF TRANSPORTATION

Environmental Guide for Mitigating Road Impacts to Wildlife

Part of the Environmental Standards and Practices

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Comments and Suggestions

The Ministry of Transportation welcomes comments and suggestions on ways to improve the document with the objective of providing a practical and pragmatic approach to environmental management in the Province of Ontario. MTO anticipates that changes will be warranted to clarify, improve and incorporate new information. The format of the document is designed to accommodate such changes. Such revisions and amendments will be incorporated in later editions of this document. MTO will not formally respond to unsolicited comments submitted in response to the document.

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VERSION HISTORY

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1 INTRODUCTION AND PURPOSE

Roads function to meet society's social and economic needs for safe and efficient transportation, travel opportunities, and the movement of goods and services. In doing so, roads exert various effects on the surrounding landscape, some of which may be positive, or at least neutral, but many of which can be negative.

The purpose of this document (the Guide) is to provide practical advice and guidance to proponents of roads on potential strategies that may be used to mitigate the impacts of roads to terrestrial and semi-aquatic wildlife species once a transportation facility has been identified as required or has been constructed, and the facility has already been routed or constructed to avoid, or minimize impact on, sensitive habitat areas.

Road undertakings may consist of new construction as well as twinning, widening or rehabilitation of existing roads and bridges. All projects are undertaken through an Environmental Assessment (EA) Process. In planning, wildlife habitat avoidance should be considered to the extent possible in association with other environmental factors and competing resource trade-offs. In design, further refinements (e.g., horizontal and vertical alignment shifts) may be made along the alignment to avoid identified impacts to wildlife.

Guidance in this document is based on an extensive literature review of the current scientific knowledge supplemented by professional experience. The increased recognition that road design and landscape ecology are intertwined, has led to the heightened consideration of road effects on wildlife and corresponding wildlife mitigation strategies.

In addition to consideration of the wildlife species being impacted by a road, it is also important to consider the road type and setting within the context of mitigation strategy planning, selection and design, e.g. northern vs. southern landscapes and geography, adjacent Crownland vs. private property, urban vs. rural, provincial vs. municipal, controlled access vs. non-controlled access, etc.

Furthermore, while aesthetics are considered throughout the Guide, along with such strategies as encouraging natural vegetation, including trees adjacent to the roadway as a means to mitigate, for example, noise and edge canopy removal, etc., these may be challenging to integrate in some settings, may attract wildlife to the roadside, or may be in conflict with other road design and safety requirements. In some instances it may be more beneficial to make the road right-of-way as inhospitable to wildlife as possible to avoid implementing measures that inadvertently promote inhabitation, e.g. in the north where traffic impacts and collisions with large mammals is the primary concern for wildlife and the travelling public.

Monitoring of the effectiveness of implemented strategies is also very important, but to date has been variable in extent and design. While the monitoring database is rapidly growing, there are still large gaps in knowledge especially for smaller animals such as amphibians and reptiles. As new information becomes available it will help guide planners and designers in road design.

The Guide contains the following sections:

Section2 – Road Ecology Concepts
Section3 – Identifying Wildlife Conflict Zones
Section4 – Wildlife Mitigation Measures for Road Design
Section5 – Quality Assurance and Monitoring
Section6 – References

The Guide begins with a detailed discussion of road and landscape ecology concepts and literature in Section 2. The process of identifying wildlife conflict zones is then discussed in Section 3. Section 4 provides a general overview of mitigation measures and where they are used, as well as how effective they are. More details are provided in Fact Sheets that are grouped into structural and animal categories, and referenced throughout the overview. The overview text has many cross-references that can be quickly accessed with a 'Ctrl Click'. Pictures, references, and case studies are used to illustrate the text (photo credits are noted for each picture).

Section 5 provides advice on the design and implementation of mitigation measure monitoring and the references in Section 6 provide a snapshot of the current information, which is continually being collected in this dynamic field. Active links to internet sites have been provided. These change frequently and may become out of date.

1.1 The Role of Other Documents

This Guide is one of MTO's Environmental Standards and Practices documents. Below are documents that relate to or are referenced within this Guide.

1.1.1 Environmental Protection Requirements for Transportation Planning and Highway Design, Construction, Operation and Maintenance

Environmental Protection Requirements (EPRs) comprise a series of statements organized by environmental factors. The EPRs are a synthesis and interpretation of the requirements in over sixty statutes, supporting regulations and formal government policies applicable to environmental aspects of transportation planning and highway design, construction, operation and maintenance activities. Direct reference is made to EPR's throughout the Guide.

1.1.2 Class Environmental Assessment for Provincial Transportation Facilities (Class EA)

The Environmental Assessment Act provides for the preparation of Class Environmental Assessments (Class EA). MTO's Class EA is an approved planning document that defines groups of projects and activities and the EA processes, which MTO commits to following for each of these undertakings.

1.1.3 Environmental Reference for Highway Design (ERD)

The ERD addresses the technical requirements for environmental impact assessment and environmental protection/mitigation relating to preliminary and detail design of transportation projects. It outlines the scope of work, staff qualifications, and specific timing and documentation requirements for each environmental specialty area.

Section 3 of the ERD provides the processes and procedures relevant to Terrestrial Ecosystems and highway design.

1.1.4 Engineering Standards and Manuals

The engineering design of transportation projects within the jurisdiction of the Ministry of Transportation of Ontario (MTO) is based on and reflects the principles and procedures identified in MTO engineering standards and manuals. The development of environmental management options must be consistent with the approach outlined in these documents.

1.1.5 MTO Wildlife Mitigation Program Analysis and Tools Report (MTO 2015)

Beginning in 2013, MTO began a program analysis of its efforts to mitigate the impacts of provincial roads on large and small animals (mainly endangered and threatened birds, small mammals, snakes, turtles and amphibians) as well as the development of tools to assist MTO staff with mitigation planning, design and placement of both temporary and permanent mitigation measures along provincial roads. Other objectives include recommendations for devising a public awareness strategy and tools for better Wildlife-Vehicle Collision data collection, monitoring and management to facilitate road ecology strategies province-wide.

1.1.6 Ministry of Natural Resources and Forestry Best Management Practices for Mitigating the Effects of Roads on Amphibian and Reptile Species at Risk in Ontario (MNRF 2016)

The role of this document is to provide guidance for devising a mitigation plan for at risk amphibians and reptiles in Ontario in order to meet the requirements of the Endangered Species Act, 2007 (ESA) or its associated regulations. The intended audience includes planning authorities (local or provincial government), individuals applying for ESA requirements, consultants working on their behalf and conservation organizations involved in the planning and design of road mitigation for all new roads and road rehabilitation and improvement projects. The focus is on the use of crossing structures and fencing, however other supplementary mitigation measures are also discussed.

2 ROAD ECOLOGY CONCEPTS

Road Ecology, as defined by Forman et al. (2003) is the interaction of roads and vehicles with the environment. This approach goes beyond the more traditional view of habitat loss associated with a new road as it embodies the broader consideration of the interaction between road and ecological networks. Furthermore, because roads are associated with other anthropogenic developments, road ecology also considers the entire human footprint.

Environmental impacts can be separated into the following components: air quality, noise, wildlife, water and vegetation. Impacts can be separated into direct impacts such as those that are visible, e.g. road-kill, or flooding due to a road impacting water flow, and those that are not visible such as effects on ecosystem processes including wildlife and hydraulic connectivity.

Road ecology is a relatively new consideration in the management and design of roads that requires a multi-disciplinary and multi-partnered effort. Integration requires transportation planners, ecologists and engineers to prepare the designs, while policy and decision-makers facilitate implementation of an emerging discipline into an ongoing road improvement process (planning, design, construction, and operation/maintenance).

Road ecology may be implemented along a ***road*** defined as an open passage for vehicles to use or a ***road corridor*** that considers the full right-of-way (ROW) that includes the road, medians, ditches, and verges that may be periodically maintained (Forman et al. 2003). Road impacts and solutions may also extend away from roads into the ***road effect zone*** (Section 2.2). Table 2.1 highlights some actions and their environmental benefits that may be implemented during all aspects of road planning and design, adapted and expanded from Forman et al. (2003).

Table 2.1 Actions and environmental benefits for integrating road ecology into the road building process

Action	Environmental Benefit
Use cleaner fuels (underway with ongoing research)	Reduces greenhouse gas emissions as well as release of harmful contaminants to aquatic and terrestrial systems
Increase re-cycling of vehicle parts beyond current levels	Reduces stockpiling and release of contaminants
Close or rehabilitate remote roads that are no longer needed.	Reduces human access and disturbance
Concentrate higher speed traffic and truck traffic on primary roads	Reduces the dispersion of noise and road barrier effects across variety of road types
Improve design of road surface, tires, engines, vehicles (ongoing research and development)	Reduces noise generation and contaminant release
Depress road profile (where feasible), provide vegetation and/or soil berms in design	Reduces traffic disturbance and noise spread (for people and wildlife), promotes snow drift control and driver safety
Perforate road corridors with wildlife crossing structures and fencing where roads bisect natural areas	Reduces road barrier effect and effects of habitat fragmentation
Improve road salt management (underway)	More efficient use of road salt, less wastage, reduced salt contamination of aquatic areas, vegetation, and wells
Avoid intrusive road lighting into wildlife habitat	Reduces risk of lowering habitat quality or changing wildlife life cycle activities

2.1 Landscape Impacts

Terms such as ***landscape ecology, landscape connectivity, landscape matrix and habitat patches*** have often been used when discussing the landscape impacts of roads (Forman and Alexander, 1998; Forman et al. 2003, Smith et al. 2011). These terms are described below in context of their application to road ecology in Ontario.

Landscape ecology in the context of roads, is the study of how landscape structure affects the processes that determine the abundance and distribution of organisms (Fahrig, unpublished essay). Roads are ubiquitous features in the landscape that play a large role in landscape structure and impact the processes, such as movement of animals and water, that determine where animals live in relation to roads. Landscape ecology often entails illustrating, and assessing these patterns in a Geographic Information System.

Landscape connectivity may be defined as the degree to which the landscape facilitates the movements of ecological flows (Forman et al. 2003). From a wildlife perspective, landscape connectivity may be defined as the degree to which the landscape impedes or facilitates wildlife movement.

In Southern Ontario, landscape connectivity is assessed and evaluated by first mapping natural features and then connecting these features into a system, commonly termed Natural Heritage System (NHS). In Northern Ontario there is currently no system that has evaluated landscape connectivity.

2.2 Landscape Road Evaluations

Road density, road effect zone, and connectivity and fragmentation indices are often used to measure and evaluate roads and their impacts on the landscape (Forman 1999, 2000; Jaeger 2000; Eigenbrod et al. 2009). These terms are described below in context of their application to road ecology in Ontario.

Road Density is the average total road length per unit of landscape area (such as kilometres per square kilometre). Generally as road density increases impacts on biodiversity are more severe (Findlay et al. 2000). Some of these impacts are as follows:

- As road density increases, natural habitat is fragmented into smaller patches, wildlife road avoidance and/or mortality may increase, human access is enhanced, and water flow regimes may be altered;
- Some animals that are more vulnerable to road density are:
  - Wolves (*Canis lupus*) and Mountain lions (*Puma concolor*): less than 0.6 km / km^2 (summarized in Forman and Hersperger 1996);
  - Timber Rattlesnakes (*Crotalus horridus*), East Texas: associated with areas of lowest road density, and therefore less habitat disturbance, fragmentation, and road mortality effects (Rudolph et al., 1998);
  - Moose (*Alces alces*) crossing rates decrease at higher road densities that reach approximate thresholds of 0.2 and 0.4 km / km^2 in summer and winter respectively (Beyer 2013);
  - Woodland Caribou (*Rangifer tarandus caribou*) populations are positively related to mature coniferous forests, and negatively related to wolves and road density in the Canadian Boreal forest (Bowman et al. 2010);
  - A negative correlation has also been identified between the density of paved roads within 1-2 km of wetlands and the diversity of wildlife and plant species in those wetlands (Findlay et al. 2000), and
  - Amphibian abundance was positively correlated with forest cover, distance to wetlands >20 ha, and amount of marsh habitat and negatively correlated with road density in a study that looked at adjacent land use in 74 Ontario wetlands (Houlahan and Findlay 2003).

Road Effect Zone is an area where the ecological effects or impacts extend outward from the road for varying distances from the actual road footprint (Forman 2000). These effects may relate to invasive plant spread, wildlife movement and heavy deer- use areas, salt spray/drift, stream channelization, changes in wetland drainage, noise effects (people and wildlife), and stream salt intrusion (among others). The road effect zone may be asymmetric. For example, road effects related to wind such as the spread of dried salt may be more severe on one side of the road than the other (Forman and Deblinger, 1998).***Connectivity and Fragmentation Indices*** There are many indices that can measure connectivity or fragmentation in the landscape. One example is effective mesh size (m_{eff}) that measures the probability that two points chosen randomly in a region are connected (Jaeger 2000). Roads fragment habitat and impede movement between two points and m_{eff} can be applied to evaluate fragmentation caused by a road or a road network within a known study area (Girvetz et al. 2008).

A highly connected landscape might be one where natural habitat patches (such as forests, old fields, thickets, and wetlands) are surrounded by other lands (the landscape matrix) that facilitate wildlife movements between habitat patches. However, in most cases in Southern Ontario wildlife will encounter roads because there is no point more than 1.5 km from a road (Ontario Road Ecology Group 2010). Therefore transportation planners and ecologists are trying to find ways to alleviate the fragmentation and barrier effect of roads by integrating crossing structures and fencing where animals most need them.

2.3 Overview of Road Effects on Wildlife

Road effects on wildlife have been reviewed in a number of documents (see for example: Forman and Alexander, 1998; Fahrig and Rytwinski 2009; Bishop and Brogan 2013; MNRF 2016). A review of 79 studies found that roads and/or traffic had negative impacts on 114 wildlife species or groups, while road effects were positive for 22 wildlife groups that were mainly small mammals (Fahrig and Rytwinski 2009). Road effects vary among species groups because some are vulnerable to traffic disturbances, e.g. noise, light, pollution, traffic motion, while other species such as amphibians and reptiles are vulnerable to being killed on roads (Fahrig and Rytwinski 2009).

In Ontario the species that are most subject to negative effects of roads are amphibians and reptiles. Presently, seven of eight turtle species are at risk and road mortality is a number one threat for five of these species. Snake species are following the same trend. A synthesis of road impacts on these species may be found in the MNRF Best Management Practices for Mitigating the Effects of Roads on Amphibian and Reptile Species at Risk in Ontario (MNRF 2016).

The four main ecological effects of roads are summarized in the literature as follows:

1) Habitat fragmentation;
2) Barrier effects;
3) Habitat loss and degradation, and;
4) Wildlife road-kill.

Habitat Fragmentation

Habitat fragmentation leads to habitat degradation by creating smaller natural habitat patches and often results in decreased population abundance and species diversity. Smaller habitat patches means less resources are available to meet wildlife needs and animals then perish or recolonize new habitat. Roads may then act as barriers to movement as well as mortality sinks (see descriptions below). Habitat fragmentation effects are most pronounced for:

- Wildlife species such as large mammals, e.g. Grizzly Bears (*Ursus arctos*), that use large habitat areas for feeding, breeding, shelter and migration movements;
- For area sensitive bird species, such as Scarlet Tanager (*Piranga olivacea*), that require large interior woodlands to support a viable breeding population;
- Species that require both terrestrial and aquatic habitat to complete their life cycles, e.g. amphibians, because roads often bisect these essential elements, and;
- Conversely, species with high intrinsic mobility, habitat generalists, and species that utilize and benefit from roadside habitat are less affected by habitat fragmentation, e.g. small mammals such as Meadow Voles (*Microtus pennsylvanicus)* or birds of prey such as Red-tailed Hawk (*Buteo jamaicensis*).

Barrier Effects

Roads may behave as partial wildlife filters, in that they may be crossed by some wildlife species, and they may be avoided by other wildlife species. When wildlife need to access resources such as breeding or feeding areas the road may impede access, affecting abilities to recolonize areas, and in the long-term restricting gene flow. For those animals, e.g. some amphibians where roads do not impose a barrier, many individuals will cross roads to access breeding wetlands and are subject to high rates of road mortality. Some examples where road barrier effects have been documented are:

- Garter Snakes (*Thamnophis sirtalis parietalis*) have been shown to avoid gravel roads (Shine et al. 2004);
- Snow tracking studies along Highway 69 in Ontario have shown that large animal activity (mainly ungulates), e.g. crossing rates and presence along ROW, are less on roads with high traffic volumes than on those with lower traffic volumes (MTO 2014), and;
- On roads with traffic volumes greater than 10,000 vehicles per day such as State Route 260 in Arizona, elk (*Cervus elaphus*) do not cross the road and this was mitigated with the use of wildlife underpasses (Dodd et al. 2009).

Habitat Loss and Degradation

Reduced habitat quality and degradation may occur in habitats bordering the highway from a number of indirect factors from roads including:

- Invasive plants do well in habitats disturbed by road construction and habitat intrusion can spread into adjacent natural areas changing vegetation composition, reducing biodiversity, and impacting wildlife species. The effects are often localized within 10 to 100 m and are often site-specific (Forman et al. 2003);

- Habitat damage occurs from migrating chemicals, salt spray and other contaminants generated from passing vehicles and run-off. The zones of influence are site-specific, with elevated concentrations typically near the road and concentration gradients declining progressively with distance (Transportation Association of Canada 1999; Forman et al. 2003), and;
- There is evidence of lowered habitat quality associated with road traffic noise for birds. McClure et al. (2013) found over a 25% decline in bird abundance and almost complete avoidance by some species when comparing a transect with simulated traffic noise to a control transect without simulated traffic noise.

Wildlife Road-kill

Road mortality is a leading cause of decline for many reptile species (Gibbons et al. 2000) and is a well-documented threat for amphibians and reptiles in Southern Ontario (Fahrig et al., 1995; Ashley & Robinson 1996; Haxton 2000; MacKinnon et al. 2005; Seburn 2007). Historical records of turtle mortality along the Long Point Causeway (3.3 km) show up to 202 road-killed turtles annually and this road-kill is still occurring today (Ashley and Robinson 1996). Mackinnon et al. (2005) found 71 road-killed turtles along a 12.2 km stretch of a county road in the District Municipality of Muskoka in 2003 and 2004. Gunson et al. (2014) found over 700 dead turtles along 100 km of Highways 7 and 41 in three years of monitoring. These studies demonstrate that when an active road with no mitigation measures bisects high quality reptile habitat there are corresponding high levels of road mortality.

Traffic collisions with large animals are increasing in Ontario but are not, typically, a conservation threat for some large ungulates such as deer (Munro 2012). In Ontario, mitigation for large animals is warranted from a road safety and a socio-economic perspective (Vanlaar et al. 2012), while mitigation for reptiles is warranted from a conservation and legislative need (MTO 2012). Common factors contributing to wildlife road mortality are summarized below:

- Vehicle speeds and traffic volumes play a large role in the risk of wildlife collisions, however the risk is further influenced by wildlife behaviour while crossing roads, e.g. speed and reaction;
- When wildlife cross roads will influence the risk of collisions. Animals that cross during high traffic volumes, e.g. turtle nesting season in June, will experience higher collisions rates. In addition, wildlife such as ungulates that cross during dawn and dusk periods when visibility is poor for motorists may experience higher rates of wildlife-vehicle collisions (WVCs; Hubbard et al. 2000; Finder et al. 1999; Gunson et al. 2003), and
- Favourable habitat adjacent to and bisected by a road will also contribute to high mortality rates.

These four main ecological effects of roads on wildlife may have time lag effects as illustrated in Figure 2.1 and explained below:

- Habitat loss occurs initially with road construction/upgrading;
- Reduction in adjacent habitat quality may then occur within a few seasons because of more proximate traffic and noise, and increased light/wind penetration (for wooded areas);
- In time, wildlife road mortality will become evident at a new facility, or perhaps more evident at an upgraded facility;
- The road barrier effects may take several generations to be observed, if population monitoring were being undertaken.

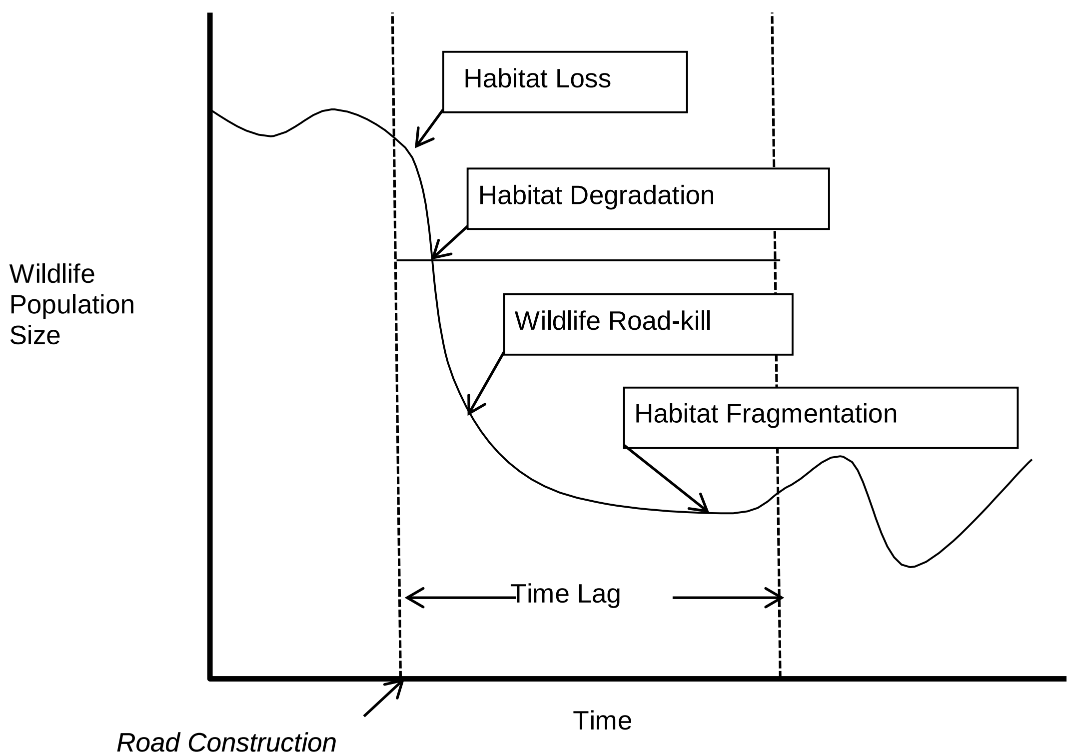


Figure 2.1 Time lag for road effects **(adapted from Forman et al. 2003)**

3 IDENTIFYING WILDLIFE CONFLICT ZONES

Mitigation dollars are limited, and should be employed responsibly for maximum benefit. Two key questions face the road designer, engineer and environmental specialist when considering roads and wildlife resources:

Is wildlife mitigation required?

For minor road rehabilitation or pavement re-surfacing, where adjacent wildlife habitat is limited or non-existent (as in an urban setting), the answer may be “NO”. However, professional judgment should be applied on a case by case basis, particularly where it is evident that wildlife movement opportunities are present and will be maintained in an urban setting (such as an existing habitat linkage feature).

Where there is evidence of existing or potential wildlife conflict based on site-specific conditions and information, whether the project entails major road rehabilitation, extension, widening or twinning, the answer may be “YES”.

Where the undertaking is new road construction on a new alignment through varying habitats, the potential for future wildlife conflict and impact is increased. In such cases, some level of wildlife mitigation to increase road permeability should be considered. Again, it is assumed that previous planning leading to the approved alignment has attempted to site the road so that impacts on wildlife habitat are minimized. Furthermore, information collected during the planning study should be used in the development of mitigation strategies during preliminary design and detail design.

If wildlife mitigation is required, where should it be located?

Suggested approaches to answering the question of where wildlife mitigation is most required are identified in Sections 3.1 and 3.2 below. Section 3.1 shows how to identify and prioritize wildlife conflict zones using a landscape-based approach, while Section 3.2 explains how to identify more localized locations for mitigation using field-based methods.

Wildlife conflict zones are identified as road segments where animals are most likely to interact with the road, and where mitigation efforts should be considered. These segments vary in length and scale, depending on the site, species and objectives for wildlife mitigation. For example, conflict zones for turtles may be identified along large stretches of road when they bisect extensive wetlands, such as on Highway 7 between Madoc and Kaladar in Ontario (Gunson et al. 2014). Conflict zones may be more easily identified for habitat specialists such as turtles, because specific wetland habitats can be located. It is more difficult for habitat generalists such as deer, because habitat use is more generalized to widespread, open forest habitat near roads (Finder et al. 1999; Malo et al. 2004; Gunson et al. 2009).

The approach used to identify where wildlife conflict zones, or hotspots, will likely occur depends on the available data sources, the planning scale used, and target species. A general approach is outlined in Figure 3.1. Assessments need to consider both adjacent habitat and land-use surrounding a road (Section 3.1), as well as the features on the road itself (Section 3.2). Both sections are followed by a list of data sources that can be used to undertake landscape and road conflict assessments.

3.1 Road Impacts on Landscape Structure

- Assess where Natural Heritage Systems (NHS) and other landscape connectivity information intersect with roads;
- Assess where riparian areas and valleys intersect with roads, and where existing bridges occur as these intersections are often correlated with animal road crossings (Gunson et al. 2011, TRCA Crossing Guidelines);
- Assess where ridge lines, fencerow vegetation, hedge or tree rows intersect roads;
- Assess where habitat used by the target species occurs in relation to the road, for example where wetlands (including vernal pools) and forest complexes occur adjacent to the road as these features are associated with amphibian and reptile road crossings (see Gunson et al. 2012). Wetland on one side and upland forest on the other side are likely areas for amphibian spring migrations;
- Assess where roads intersect with low-lying adjacent valleys and low- elevation zones using digital elevation models and contour maps; e.g. wildlife species such as ungulates will cross roads where they bisect level terrain, typically less than 5% slope (Dussault et al. 2006), and
- Assess where roads bisect transition areas between habitat types (such as forest/field edges).

3.2 Road Feature Assessment

Wildlife conflict zones are also associated with features of the road itself, and the following assessments should be completed:

- Assess where linear road features such as guard-rails, Jersey barrier, fencing, and medians have been installed for driver safety as these may funnel animals to specific locations along roads (Gunson et al. 2009);
- Assess where sideroads (such as gravel roads, logging roads), and even rail lines intersect the road as their intersections with roads are often wildlife conflict zones;
- Assess where culverts and bridges occur along roads because they are associated with drainage corridors that animals use;
- Assess traffic volume, speed, road width, and number of lanes to gauge the risk of collisions between motorists and wildlife on roads, and

- Assess where roads have sandy verges that are near wetlands and lakes because these areas are often used by turtles for nesting.

3.3 Field-based Assessment

Field-based assessments can help verify and refine where wildlife mitigation is required from landscape and road feature assessments. Field-based assessments are typically conducted during the environmental assessment (EA) for a rehabilitation project or a proposed new facility, at the preliminary design stage. The recommended strategy for conducting field-based assessments includes:

- Review relevant biophysical information within the study area, e.g. information collected during the route planning EA study such as Ecological Land Classifications (ELC) in the ROW;
- Contact and integrate information from local naturalists, government agencies, conservation authorities and non-government agencies in the region;
- Employ road ecologists and species experts familiar with the landscape and target wildlife species to evaluate wildlife conflict zones and devise site-specific road mitigation strategies;
- Locate and map features likely to be associated with conflict zones (Section 3.1and 3.2), such as drainage areas, culverts, Jersey barriers, special habitat features (such as feed or foraging areas), and the distance to cover (for species that use cover);
- Collect systematic on-road observations, as applicable (Section 3.4), and
- Conduct additional field sampling including but not limited to video surveillance, live trapping, pit-fall traps, and sand pad tracking (Section 5.1; MNRF 2016).

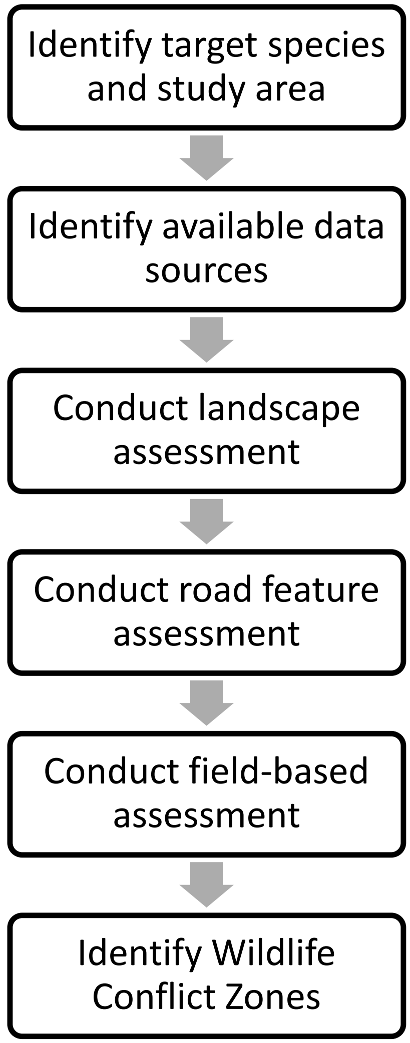


Figure 3.1 Approach for identifying wildlife conflict zones

3.4 Data Sources

The following data sources are required to assess where wildlife conflict zones or hotspots will occur for a species or species group. On-road data collection is specific to conducting road surveys in the field. Additional information to define the occurrence of the hotspot can be assessed with landscape and road-related information collected in the field or at a desktop.

3.4.1 On-Road Data Collection

Species-specific observations on and adjacent to a road are crucial to assessing where wildlife conflict zones have occurred and may occur. It is important to note that low-levels of wildlife road observations does not necessarily mean that wildlife road mortality is not a concern. This is because wildlife may be avoiding the road or populations may have been depleted due to previous WVC rates. Therefore it is crucial to obtain historical records if available, in addition to collecting new information.

All compiled data can be used for developing WVC models. In this case, models or tools are a mathematical organization of empirical data (wildlife observations) to describe patterns of road-kill and WVC occurrence. These patterns can be described on the road where the data was collected or may be used to predict where road-kills and WVCs may occur on un-sampled roads (Gunson and Teixeira 2015, MTO 2015). The former is typically referred to as a hotspot analysis and looks at where WVCs are concentrated and at what scale they occur. These patterns inform where road mitigation is needed for the species or species group that they are developed for.

Examples of such studies completed on Ontario highways are Highway 7 (Gunson et al. 2014; MTO 2015), and Highway 401 (LGL Limited 2007). The objectives of each study are similar and aim to:

- Determine what and how many animal species are killed on the road;
- Determine where each species is killed along the road;
- Evaluate higher than expected wildlife conflict zones;
- Evaluate higher than expected occurrence of WVCs, road-kill, or alive on road sightings in time, e.g. seasonal or time of day; and
- Associate hotspots with landscape and road features that exist along the road ROW.

Other data sets for both large and small animal observations on-road can be sourced for each region by contacting the district MNRF office, MTO regional office and MTO Road User Safety Division. Refer to MTO 2015 for a complete listing of province-wide WVC, road-kill, and on-road observations.

3.4.2 Landscape Assessment

- Aerial images;
- Cultural and historic features;
- Oak Ridges Moraine (ORM), Greenbelt, Natural Core Areas, Natural Linkage Areas, Countryside Areas, Settlement Areas and NHS;
- Drainage features, wetlands, and open water;
- Terrestrial land use such as natural and cultural vegetation and agricultural areas;
- Valleylands and floodplains;
- Topography measured by digital elevation models (DEM) and contour mapping;
- Wildlife trails identified through background sources, field surveys or aerial photos;
- Integrated hydrology network that measures hydrology flow and groundwater discharge and recharge areas;
- Areas of identified significant wildlife habitat (as defined in the MNR Significant Wildlife Habitat Technical Guide 2000);
- Municipal, provincial, or federal designated natural or earth science areas, policy

areas, environmentally significant areas, conservation areas, areas of natural or scientific interest;

- Whenever possible all landscape-based information can be used to develop spatially explicit connectivity models using desktop tools such as Circuitscape; and
- Information from supporting documents such as consultant, academic, and government reports.

3.4.3 Road-Related

- Culvert and bridge inventory data, e.g. Ontario Bridge Management System (OBMS);
- Culvert inventories < 3 m inventoried by each MTO region;
- Jersey barrier, guard rail, sign and median inventories;
- Ontario Road Network road layer;
- Railway and trail layers;
- MTO highway routes layer;
- Linear Highway Referencing System (LHRS), and
- Annual Average Daily Traffic Volume (AADTV) count data.

4 WILDLIFE MITIGATION MEASURES FOR ROAD DESIGN

Road improvements and rehabilitation may strive to reduce habitat loss for some species. When this is not possible, a mitigation strategy that strives to reduce road impacts and facilitate safe movement of wildlife across the road is an important objective of the road design process.

Four stages to designing and monitoring mitigation strategies for roads are presented below:

1) Avoidance – plan for a route that avoids and/or minimizes impacts on wildlife and ecosystems; avoidance measures include avoiding and buffering road alignments from natural habitat during the EA/preliminary design stage;
2) Mitigation - identify and implement a suite of mitigation approaches in the road design for habitat protection and facilitating wildlife movement. These measures should be cost-effective, properly located, and sensitive to anticipated future land use changes bordering the road;
3) Habitat creation and management – strategies such as wetland substrate salvage, topsoil salvage, habitat creation or improvements (on and off the ROW), and more ecologically based road vegetation management are being advanced and implemented in various jurisdictions to benefit wildlife and soften habitat impact, and
4) Monitoring – evaluate whether a mitigation strategy for wildlife is effective and strive to determine if wildlife population abundance is improved due to mitigation and what types of mitigation designs work best (MNRF 2016). Monitoring needs to build on what is already known in order to fill knowledge gaps, and the results applied to mitigation design and the road building process in an adaptive manner.

After evaluating where mitigation is required, the next step is to decide what type of mitigation may be used at each location. Although research is rapidly progressing in the field of road ecology, there are still many unknowns about road mitigation design and effectiveness. What is known is that some measures are more effective than others. Therefore the description of mitigation measures is divided into two sections:

Section 4.1– measures that are meant to influence motorist behaviour, are somewhat temporary in their installation, and whose overall effectiveness is difficult to measure and/or is not known, and

Section 4.2– measures that have known effectiveness in reducing WVCs and are more permanently embedded into the road network (Huijser et al. 2008a)

Further information about the use of specific mitigation strategies from both a structural and animal perspective can be found in Fact Sheets in Section 4.3.

4.1 Modifying Motorist Behaviour

Mitigation measures that influence motorist behaviour are discussed below in sub-sections under the following headings:

- Traffic volume and speed;
- Right-of-way vegetation management;
- Road lighting;
- Public education and awareness;
- Wildlife habitat awareness (WHA) signs, and
- Roadside wildlife detection systems (WDS).

This list is not exhaustive and is only meant to capture the most common measures that are used to reduce WVCs by modifying motorist behaviour.

4.1.1 Traffic Volume and Speed

Traffic volume and speed are contributing factors to wildlife road mortality although this relationship is not necessarily linear and its impacts vary by species (Jones 2000; Charry and Jones 2009). If it is known when traffic and wildlife will interact over a specific period of time, temporary mitigation measures that reduce traffic or slow vehicles may be possible. Such traffic reduction measures include detours and road closures to divert traffic away from the high risk mortality zones. Traffic calming measures include enforced speed reduction zones, use of speed bumps, ROW vegetation management and road design measures. Enforced speed zones and road closures have been implemented on primary and secondary highways in Banff National Park, Alberta. Mandatory night-time closures and lowered speed limits are implemented on the Bow Valley Parkway in spring when Grizzly Bears are active in the Trans- Canada Highway transportation corridor.

4.1.2 Right-of-Way Vegetation Management

When motorists can see and react to animals approaching the road (or vice versa) it may reduce the likelihood of a WVC. Improved visibility can be accomplished by clearing vegetation and maintaining grass-herb vegetation with roadside mowing. However, there are other implications with this technique because grass and herbaceous vegetation are an attractive food source for ungulates in a forested environment (Rea 2003; Gunson et al. 2009). Furthermore, the creation of open habitat may be a deterrent to smaller animals such as birds and butterflies, increasing the barrier effect of roads for these animals. A roadside vegetation management plan that provides aesthetics, habitat for smaller animals, motorist visibility, and a reduction of WVCs requires careful thought and research, and will vary on a site-specific basis.

Various examples, adapted from Forman et al. (2003) are provided below in Figures 4.1 to 4.5:

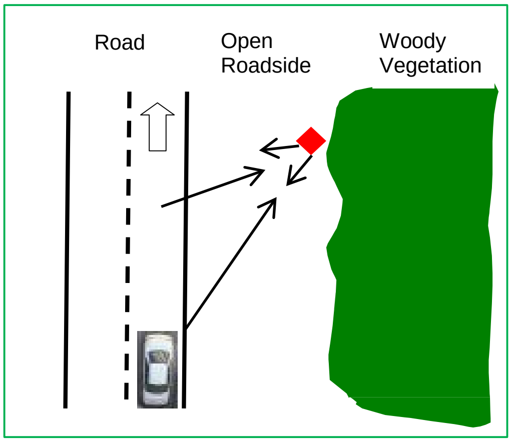
<table>
<tr><td>Wildlife =</td><td>Open View =</td><td>Blocked View =</td></tr>
<tr><td>

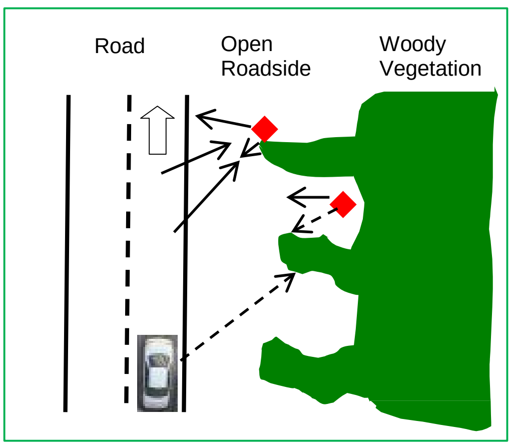
Figure 4.1 Driver-wildlife visibility – Open field of view</td><td colspan="2">A completely open roadside bordering wooded areas does not obstruct views between motorists and wildlife. Variability in roadside structure (and perhaps viewing aesthetics) is limited but safety in terms of vehicle/wildlife awareness is enhanced.</td></tr>
<tr><td>

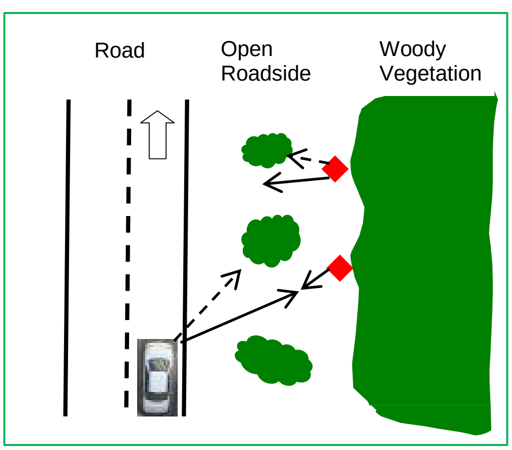
Figure 4.2 Driver-wildlife visibility – Scalloped edges</td><td colspan="2">A scalloped roadside vegetation scenario occurs where “tongues” of vegetation are retained in the design. Variability in the roadside habitat structure (and perhaps viewing aesthetics) increases. Visibility of wildlife depends on wildlife and vehicle locations relative to the “tongues” of vegetation. Some views are open, and some are blocked. Scalloped edges may act to guide wildlife towards the road, which is problematic unless intended in association with a crossing structure.</td></tr>
<tr><td>

Figure 4.3 Driver-wildlife visibility - Single row plantings</td><td colspan="2">Roadside vegetation may consist of evenly spaced linear clumps of shrubs/trees. Again, visibility of wildlife varies depending on wildlife and vehicle locations relative to the roadside vegetation. Motorist views ahead may be blocked. Viewing experience for motorists might be monotonous with long lines of planted roadside vegetation.</td></tr>
</table>

Wildlife = ◆	Open View = ——→	Blocked View = - - - - - ->

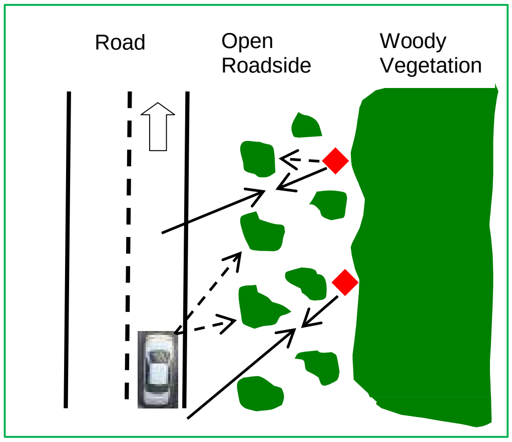


Figure 4.4 Driver-wildlife visibility - Staggered double row plantings

Staggered double plantings of roadside vegetation can provide some variability in structure and viewsheds. Diagonal views between motorists and wildlife may be unimpeded depending on vehicle/wildlife locations, but views may be blocked from other vantage points.

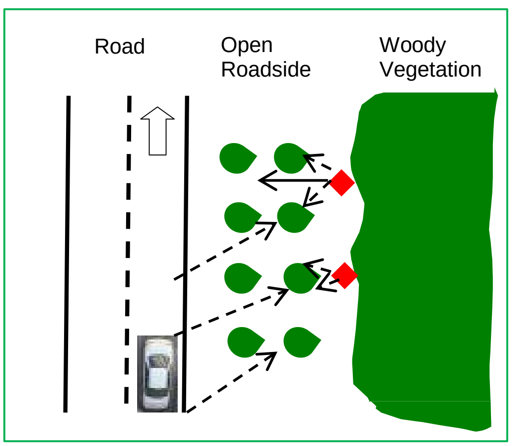


Figure 4.5 Driver-wildlife visibility - Linear double row plantings

Non-staggered double plantings of roadside vegetation provide a different viewing experience. Diagonal views between motorists and wildlife are largely blocked when wildlife are at the forest edge. Views are only apparent when wildlife is closer to the road, which may make collision avoidance very difficult.

4.1.3 Road Lighting

There is limited research on the effectiveness of road lighting for increasing motorist visibility and reducing the risk of deer-vehicle collisions (Forman et al. 2003; Knapp 2004). However, there is one study in Alaska that showed that a lighted area of road with fences reduced moose-vehicle collisions by 95% and a lighted area without fences by 65%. It was not determined if this decrease was attributed to less moose crossing the road or whether the motorists could see the animals at greater distances and take evasive action to avoid a collision (http://www.fs.fed.us/wildlifecrossings/case-histories/other/GlennHighway.php). Another study by Reed (1981) showed that road lighting did not reduce the number of WVCs. In fact, some experimental studies and anecdotal evidence suggest that artificial lighting may have unintended effects on different wildlife species, including nocturnal foraging and migration movements, predator-prey interactions, light attraction or repulsion, possible influence on social interactions, collisions with lighted structures (towers and bridges), and reduction of habitat quality (see for example English Nature 1996; Buchanan 1993, 2002; Wise and Buchanan 2002; Gauthreaux and Belser 2002; de Molenaar et al. 2000).

Where road lighting intrudes into natural areas, possible wildlife influences (adapted from de Molenaar et al. 2000) might include:

- Prey species and ultimately their predators may be attracted to the lighted ROW increasing collision risk for these animals; for example insects would be attracted to lights increasing the presence of birds and collision risk for these animals;
- Lighting may lengthen effective “daylight”, thereby increasing foraging time for some species and the likelihood of being involved in a collision, and
- Light may attract species such as bats and seabirds to roadsides.

The extent of knowledge concerning the effects of artificial road lighting is limited, and further research is required before species-specific mitigation measures can be developed. For example, migrating birds are attracted to artificial light (Kociolek et al. 2011), but blue and green light causes less disorientation to the same migrating species (Poot et al. 2008). Frogs and toads have been shown to be attracted to artificial light, while newt migrations to and from breeding ponds are impaired when light is constant (Perry et al. 2008). Timing of some avian breeding and singing is affected by artificial light (Longcore and Rich 2004; Kociolek et al. 2011), and even small mammals will reduce their activity under artificial light (Beier 2006).

Lighting considerations for insect populations (English Nature 1996) and other animals include:

- Avoid installing lighting near potentially vulnerable sites or when human activity is low, e.g. rest areas at night, unless required for human safety or to meet other road safety requirements;
- Avoid installing lighting adjacent to wildlife habitat areas (such as forest) unless unavoidable for reasons above;

- If required adjacent to wildlife habitat areas, design lighting or install shades to emit down and away from the natural area;
- Use low-pressure sodium lamps or UV filters and employ whatever other measures are feasible to reduce the intensity and amount of light reaching natural areas;
- Track and implement new technologies that address light pollution mitigation as they become available and tested, and
- Use different coloured lights for different species, e.g. migrating birds are not as attracted to green or blue light (Poot et al. 2008).

4.1.4 Public Education and Awareness

An education and awareness campaign that includes tools such as public service announcements, web-based resources and news bulletins, is intended to inform motorists about ways to avoid WVCs. Increased education and awareness may result in increased community support for monetary investment in more costly measures that are effective at reducing WVCs. Well planned and targeted campaigns can show reduced numbers in WVCs. For example, the 'Speeding Costs You Deerly' campaign in Ottawa showed a collision reduction with deer of approximately 38%. This campaign used direct messaging through mass media, speed enforcement, and roadside messaging (Thomas 2007). It is recommended to combine awareness campaigns with other mitigation strategies, specifically roadside awareness signs (section 4.1.5; Biota Research and Consulting 2003; Knapp 2004; Gunson and Schuler 2012; MNRF 2016).

4.1.5 Wildlife Habitat Awareness Signs

Road awareness signs have historically been used for large animals such as moose and deer but have more recently been used for smaller animals such as snakes and turtles (Kintsch et al. 2015). The MTO has recently developed a policy for taxon-specific Wildlife Habitat Awareness (WHA) signs for snakes, turtles, amphibians, birds and small mammals (MTO 2012). The policy qualifies the placement of a sign with the following criteria:

1) The road must bisect habitat for an Endangered or Threatened Species At Risk (SAR) for which road mortality is a threat, and
2) The target species must habitually cross the road, or have been documented as occupying habitat next to the ROW as identified with monitoring surveys and field investigations.

A strategy and recommendations for implementation have also been developed in several documents for MTO (Gunson et al. 2012; MTO 2015). In order to maximize effectiveness, signs need to be selectively placed at verified hotspots where SAR are most likely to be found on or near a road.

Evaluation of effectiveness is currently underway and preliminary findings have shown that up to 70% of motorists do notice signs and traffic speed assessments have shown a reduction in speed at WHA sign locations. Whether this equates to a reduction in road mortality for the target species needs to be measured with longer-term studies. Other short- term studies have shown that signs reduce collisions for large animals, e.g. deer in Found and Boyce (2011), and camels in Al-Ghamdi and AlGadhi (2004).

4.1.6 Wildlife Detection Systems

Roadside wildlife detection systems (WDS) are designed to modify motorist behaviour by using digital warning signs to alert motorists when an animal has been detected in a defined crossing zone. The use of WDS is still considered experimental, although these systems have been tested and have variable success at reducing WVCs from 58% to 100% (Ward et al. 1980; Huijser and McGowen 2003; Gordon et al. 2004; Huijser et al. 2006*,* 2009 *a,b*). The above authors recommend implementation of WDS only if some WVCs are tolerated and wildlife fencing and crossing structures are not feasible or possible (Section 4.2). The use of WDS should be evaluated to expand selection of technologies and uses to increase the reliability and confidence in effectiveness of the systems.

4.2 Modifying Animal Behaviour

4.2.1 Overview

This section provides an overview of mitigation measures, e.g. crossing structures and/ or fencing systems that aim to modify animal behaviour, and that have been shown to be effective:

- Wildlife overpass;
- Wildlife underpass, e.g. viaduct, bridge;
- Large tunnel (>3 m span), and small tunnel (<3 m span) (span refers to the maximum clear width of the tunnel), and
- Fencing and escape measures.

It is important to note that correctly designed and installed fencing <u>without</u> safe crossing opportunities results in an increase in the barrier effect of roads and traffic for the target species. Fencing should only be considered alone when motorist safety is the primary concern, crossing structures are not possible and the fence will not block animals from accessing necessary resources. Building dedicated wildlife crossing structures should also not be considered alone because effectiveness and use will be compromised. Fencing should be considered a retrofit option when road infrastructure, such as culverts and bridges are evaluated or modified to allow wildlife passage and the structures are situated at wildlife crossing locations.

A combination of fencing that is at least 5 km in length, along with wildlife crossing structures, is the only approach that has been shown to substantially reduce (>80%) vehicle collisions with large ungulates (Clevenger et al. 2001, Clevenger et al. 2009; Clevenger and Barrueto 2014). These systems are less effective for carnivores. For example, over a 24 year period on the fenced section of the Trans-Canada Highway in Banff National Park there was only an 18% reduction in carnivore mortality (not including coyote; Clevenger and Barrueto 2014). This is because carnivores such as Black Bears (*Ursus americanus*) and Canada Lynx (*Lynx Canadensis* are more adept at breaching the fencing system (see Section 4.3.2; MTO 2015).

Fencing in combination with crossing structures is also the most effective system for terrestrial and aquatic smaller animals such as amphibians and reptiles (MNRF 2016). Dodd et al. (2004) showed that effectiveness varied by species and fence type, but a fencing and tunnel system reduced collisions with small animals from 65% to 93%. Gunson et al. (2014) showed that a temporary fence along 1 km of Highway 7 in Ontario reduced collisions with turtles up to 50%, and the documented road mortality was attributed to fence ends. Smaller animals will use a variety of small crossing structures (see for example Yanes et al., 1995; Brudin 2003; Clevenger et al. 2001).

While landscape bridges (very wide overpasses) or viaducts are the most permeable crossing structures for most species, budgets may restrict their implementation. In some cases, bridges and viaducts are already present in the road network for infrastructure purposes, and additional design elements such as wildlife terrestrial pathways can enhance use by wildlife (Lesbarrères and Fahrig 2012). Due to uncertainty of use of structures by some species, a range of crossing structure types and dimensions (width, height, and length) and riparian bridge pathways is desirable when considering multi-species designs (Carsignol 2005). Structures should be placed in wet, dry, upland and low-lying habitats that provide optimal connectivity for both home range and dispersal movements of the target species.

Although site-specific, Bissonette and Adair (2008) provide a metric option to guide spacing of crossings that uses home range areas and average daily movement distance to inform distance between structures. For example, using this metric it is recommended to place structures 1.4 km apart for White-tailed Deer and 5.0 km for Black Bear. For a multi-species strategy it is recommended to use the minimum spacing distance to ensure permeability that meets both home range and dispersal movements. It is also important to recognize that home range size varies over time for individuals and for populations and is correlated with resource availability and distribution (Bissonette and Adair 2008). The average spacing for large mammal crossing structures along US Highway 93 in Montana, I-75 in Florida, SR 260 in Arizona, Banff National Park in Canada, and ongoing reconstruction on I-90 in Washington State is 1.9 km (range for the average spacing of structures in these individual areas is 0.8-2.9 km).

For smaller animals, it has been recommended to space crossing structures 300 m apart (Carsignol 2005). However, this distance must be further refined based upon the target species, budget, and site-specific engineering and ecological considerations. For example, when designing structures for salamanders it is recommended to space structures closer together along known migratory routes (e.g. no more than 50 m apart) to accommodate shorter home range movements (MNRF 2016).

Other general considerations when siting and spacing crossing structures include:

- Allowing permeability under or over the road for ecosystem processes, as well as physical processes (e.g. water flow);
- Changing weather conditions that may change habitat requirements;
- Providing permeability for site-specific movements, e.g. within a species' home range, but also for landscape movements, e.g. dispersal between home ranges;
- Providing permeability for individuals (and populations) to continue seasonal migration movements (e.g. elk), and
- Clearing and development near and adjacent to mitigation measures that may compromise effectiveness.

4.2.2 Design Considerations by Structure

This section provides a general overview of road and wildlife design considerations for various components of a crossing structure and fencing system. The focus is on larger structures that may be used for all species but with special attention to larger carnivores and ungulates as the target species. This is because this is where the majority of research has been conducted, and concurrent to this document a BMP manual has been prepared with a focus on road mitigation design considerations for amphibians and reptiles (MNRF 2016). This general overview is followed by a series of Fact Sheets for specific taxa and mitigation measures for both large and small animals.

A key design consideration for all structures is the degree of openness. Openness has previously been calculated as the ratio between the cross-sectional area of the structure opening and the length of the structure that must be traversed by wildlife (expressed typically as a fraction). The underlying concept is that greater openness may facilitate use by wildlife species that are not tolerant (or less tolerant) of confined areas for movement (the tunnel effect). Early research in the field identified minimum suggested openings for ungulates such as Mule Deer (*Odocoileus hemionus*) (Reed et al. 1975), and later studies and anecdotal observations have suggested openness ratios ranging from 0.6 or greater for species such as White-tailed Deer. However, deer will use structures with lower openness ratios, and more current research is indicating that a variety of small to mid-size wildlife species will utilize smaller culverts.

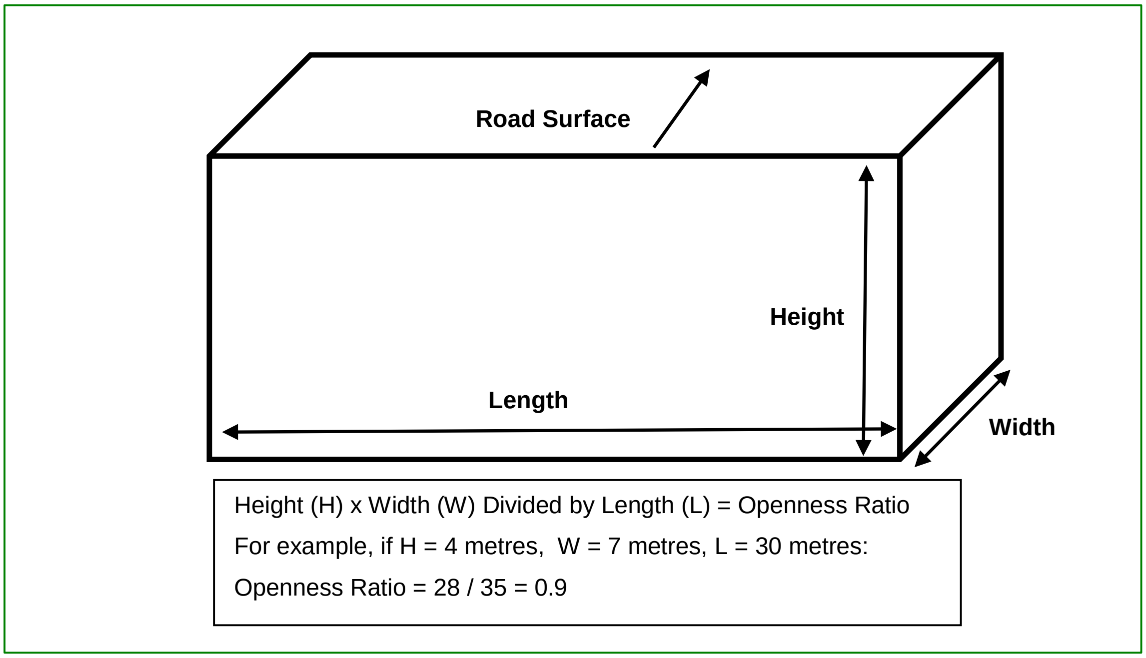


Figure 4.6 Openness Ratio Calculation for Culvert / Underpass

The current literature has not adequately tested the optimal openness ratio for all taxa (Clevenger and Huijser 2011) and it is recommended to use this measure as one of many factors to guide crossing structure design. Examples of other design factors to consider for increased openness include:

- Maximize cross-sectional areas at the tunnel entrances;
- Increase openness by using two structures when an open median is present; and
- Create openness at the tunnel top with slotted openings.

4.2.2.1 Overpass

There are numerous types of crossing structures, but to date the most effective structures for multiple species are wildlife overpasses. Wildlife overpasses provide structures for animals to cross the road above grade and have 100% openness. In addition, overpass structures provide opportunities to implement different types of micro-habitat conditions for small and large animals. Trees and brush provide cover for species but also mimic the surrounding habitat in forest ecosystems. Pools of water have also been used on top of overpasses in a stepping stone approach to provide hydration for semi-aquatic animals (van der Grift 2009).

Previous research has shown that Grizzly Bear, moose, deer, and elk prefer to use a 50 m wide overpass than nearby box tunnels in Banff National Park (7.2 m^2 cross sectional area; Clevenger et al. 2009) and similar results were found for moose and deer in Ontario (25 m^2 cross sectional area; MTO 2014). Black Bear tend to use both underpasses and overpasses with similar frequency (Clevenger et al. 2009; MTO 2014).

Wolves and lynx are more reluctant to use crossing structures at first, but over time prefer to use structures with more openness (Clevenger and Barrueto 2014).

Typically, for large and small mammals in Europe, it has been recommended to build overpasses between 40-50 m wide (Van Wieran and Worm 2001; Renard 2008). Canada's first two overpasses were built 50 m wide in Banff National Park in the 1980's and several new overpasses have recently been added, deck width 60 m (Clevenger and Barrueto 2014). Ontario's first wildlife overpass was completed in 2010; it has a deck width of 30 m and has a straight deck so that animals can view from one side of the structure to the other.

4.2.2.2 Underpass

Generally speaking, wildlife underpasses are below grade and allow animals to travel under the road. In this document, wildlife underpasses are defined as viaducts, bridges, and large (> 3 m span) and small (< 3 m span) tunnels (see Fact Sheets in Section 4.3). Tunnels are used to describe crossing structures for wildlife as opposed to standard drainage culverts for water.

Although past research shows that wildlife use crossing structures, it is not always known what design type works best for each species in different landscapes (van der Grift et al. 2013). In general, larger wildlife species are more comfortable using larger, more open structures. A study by Cramer (2012) that monitored dedicated and existing underpass structures in Utah showed that Mule Deer were more likely to use shorter, wider, and higher box culverts. However, the culverts were dispersed across different roads and the study did not take into account varying Mule Deer abundance within the vicinity of each culvert. The study recommends that culverts should be less than37 m in length, and that twinned tunnels separated by a median are a good option on divided roads.

Clevenger and Waltho (2005) showed that underpasses that are high and wide but short in length promote use by Grizzly Bear, Gray Wolves (*Canis lupus*), elk, and deer (*Odocoileus* spp.), whereas Black Bear and cougars (*Panthera concolor*) favoured less open structures. Moose and deer are hesitant, however will use smaller box tunnels (5 m x 5 m x 24 m long) that each pass under two lanes of road, based on 3 years of monitoring (MTO 2014). Cramer (2012) found both moose and elk were hesitant to use box tunnels that varied in size and design on several highways in Utah, but moose did use some bridges and one metal elliptical tunnel.

Smaller tunnels designed for amphibians and reptiles follow the general rules outlined above. Structurally, tunnels that provide more openness will facilitate passage by most species of amphibians and reptiles, however there have been few rigorous research studies that have compared crossing designs in real-life settings (MNRF 2016). In general, for amphibians and reptiles, tunnels should not be more than 25 m long, and several variations in design exist to allow more openness such as an open top design

(MNRF 2016). Other design modifications may create more natural crossings, including using the natural substrate floor. This can be achieved by burying a tunnel, adding natural substrate, or using an arch design that extends along the natural aquatic or terrestrial habitat. Arch tunnels used in aquatic habitat areas should extend along both aquatic habitat as well as adjacent terrestrial pathways (Lesbarrères and Fahrig 2012).

General rules are much more difficult to discern for smaller mammal species because they will use a variety of crossing types. A study by Mata et al. (2008) showed that width is important, while a study by Clevenger and Barrueto (2014) showed moles and mice prefer longer, closed drainage culverts. These studies show that it is important to have a good understanding of the ecology and behaviour of the target species in order to design effective crossing structures.

Drainage culverts that are designed to convey water may be used by terrestrial species when they are dry, aquatic species when they are wet, and by semi-aquatic species in wet and dry conditions. Small mammals such as Red squirrels (*Tamiasciurus hudsonicus*), Short-tailed weasels (*Mustela ermine*), Long-tailed weasels (*Mustela frenata)*, Deer mice (*Peromyscus maniculatus*), and Snowshoe hares (*Lepus americanus*) will use drainage culverts in the Rocky Mountains (Clevenger et al. 2001; Clevenger and Barrueto 2014). Gunson et al. (2014) showed that Painted Turtle (*Chrysemys picta*) and Snapping Turtles (*Chelydra serpentine*), Northern Watersnake (*Nerodia sipedon*) and Garter Snakes used small drainage culverts in Ontario. Furthermore, Caverhill et al. (2011) showed that nineteen individual male and female Blanding's Turtles (*Emydoidea blandingii*) used a larger 1.8 m drainage culvert under Highway 24 in Ontario.

4.2.2.3 Fencing and Escape Measures

Historically, fencing has been used to define boundaries and exclude domestic animals from roads. In the past 30 years, fencing has been more commonly used to exclude small and large animals from ROWs. Various types of fencing designs exist and are continually evolving that are more suitable for some species than others. Fencing is commonly used in Canada, Europe, and the United States because large ungulates pose a serious traffic safety hazard for motorists (Clevenger and Barrueto 2014; Gagnon et al. 2010; Mountrakis and Gunson 2009). Fencing is also being used for smaller animals, especially when roads and associated road mortality pose a conservation concern, e.g. turtles in Southern Ontario (MNRF 2016).

Large animal exclusion fencing is a vital component when implementing crossing structures because fencing funnels animals to associated underpasses and overpasses, as well as excludes wildlife from entering the ROW. Exclusion fencing does not usually extend along the entire road length because it is site-specific, it poses a barrier to wildlife movement, and there are budgetary constraints. Therefore fencing is sited and prioritized at known or predicted conflict zones, and may range from several kilometres to tens of kilometres for large animals.

The fence end effect may be magnified with shorter lengths of fencing. Huijser et al. (unpublished data 2013) showed that multiple crossing structures tied together by 1.6 to km of wildlife fencing has only shown a 50-60% reduction in WVC's. Fairbanks (2013) undertook a literature review of data for short lengths of fence from 3 m to 256 m and suggests that short sections of fencing may be far less effective in reducing WVCs than longer sections of fencing (covering several miles), as deer will frequently enter the ROW at the fence ends.

The fence end phenomenon has been documented for turtles (Gunson et al. 2014) and for large animals (Clevenger et al. 2001; Cserkész et al. 2013). Animals often follow the fence line to the nearest fence end, especially when animals are attracted to the road ROW, e.g. turtles for nesting, or large animals for grazing and feeding. To alleviate this concern there are several structural or placement considerations for fence ends; use of one strategy over another is primarily dependent on site- and species- specific characteristics and desired effectiveness:

- Extending the fence end past the defined wildlife conflict zone up to a distance equivalent to the mean daily home range distance;
- Siting the fence end at inhospitable habitat for the target species, for example forested, brushy habitat alongside wetlands for snakes and amphibians;
- Siting the fence end where structural features, such as rock cliffs pose a barrier to animal movement;
- Constructing the fence end to angle away from the road at a specific distance, e.g. up to 100 m for larger animals;
- Placing obstructions at the fence end such as rock pits or rock piles to deter wildlife from going around the fence;
- Placing Texas gates, electro-mats or electric fencing at fence ends to deter animals from entering the road, and
- Integrating steep road slopes (raised roads) at fence ends so animals such as moose are not able to navigate the steep gradient to the road.

Electric fences have the potential to offer a less expensive alternative to a deer-exclusion barrier. An example of this type of fence is produced by ElectroBraid Fence Ltd., in Dartmouth, Nova Scotia and is comprised of a 0.6 cm polyester rope with copper wire woven into it that is carried on fiberglass posts set at 15 m intervals. This fencing proved effective at excluding deer from feeding sites at a study in Ohio, i.e. mean deer intrusions at feeding sites with fencing were < 1/day while at feeding sites with no fencing, intrusions were 84 – 86/day (Seamans and VerCauteren 2006).

Three years of monitoring on Highway 69 in Ontario has shown varying effectiveness of steep rocky road inclines and rock piles. Moose do not navigate these rock piles however deer will navigate them and enter the ROW, although it is unclear if only a few deer breach the system or many individuals.

Electro-mats, e.g. ElectroMat™ are electrically charged mats embedded in the roadway or pathway where wildlife cross or enter roads and have shown some success. Along State Route 260 in Arizona an electro-mat was installed at a fence end. Prior to installation there were 89 elk and 14 deer (Dec 2006-June 2010) on the highway and after installation there were 21 elk and 0 deer (July 2010-October 2013). 7 of those 21 animals accessed the road at one specific time when the power went down (Gagnon, unpublished data).

Varying designs of cattle guards, ungulate guards, or Texas gates have also been used where the fence ends at road interchanges, with some success for deer (Allen et al. 2013). Ungulate guards on Highway 69 (9 m wide and 4.5 m long) have been shown to be effective for moose and possibly deer. However Black Bear and Eastern Wolves (*Canis lupus lycaon*) will climb over the guards, and one White-tailed Deer has been documented jumping over the guard (MTO 2014). Expanding the width of these guards or increasing the spacing between metal bars are possible design solutions, however there is a safety concern for animals that do attempt to navigate these gates.

Roadside escape measures such as one-way gates and jump-outs (sloped run-offs) are located along exclusion fencing to allow animals that have breached the system to gain access back to the safe side of the fence. Design and success vary by species and site. Jump-outs have been 8-11 times more effective than one-way gates for Mule Deer in Utah, and have lower maintenance requirements than one-way gates (Bissonette and Hammer 2000). Black Bear and White-tailed Deer (*Odocoileus virginianus*) have used the one-way gates along Highway 69, however monitoring is difficult because sample size is dependent on animals breaching the system and only 6-8 of the 26 one-way gates are monitored with cameras (MTO 2014).

One-way gate designs require special considerations because the curved tongs must be adjusted so they swing back into place when moved but must also allow animals to easily push through. Jump-outs require maintenance to remove vegetation from the sloped ramp as well as on the jump-out floor as any obstructions would pose a safety hazard for the animals (http://environment.fhwa.dot.gov/WVCtraining/mod4/module_4_12.asp).

4.3 Fact Sheets

Links to Wildlife Mitigation Strategies Fact Sheets		
Wildlife Crossing Structure Systems	**Wildlife Crossing Warnings**	**Animal Groups**
Wildlife Overpass	Wildlife Detection System	Ungulates: White-tailed Deer and Moose
Wildlife Underpass: Viaduct	Wildlife Habitat Awareness Signs	Large to Mid-Size Carnivores: Black Bear, Wolf and Coyote
Wildlife Underpass: Bridge		Small and Medium-Sized Mammals: Rodents up to the size of medium Carnivores
Wildlife Underpass: Large Tunnel		Amphibians: Salamanders, Frogs and Toads
Wildlife Underpass: Small Terrestrial Tunnel		Reptiles: Snakes and Turtles
Wildlife Underpass: Small Drainage Culvert		
Wildlife Fencing and Escape Measures		

Below are 15 detailed Fact Sheets for selected wildlife mitigation measures that modify both motorist (Section 4.1) and animal (Section 4.2) behaviour. In general it is recommended to have funnel fencing and escape measures (Fact Sheet 7a) implemented with all crossing structures (Fact Sheets 1a-6a). Generally, less human use at and surrounding the crossing structures will increase use of structures by wildlife (Clevenger and Waltho 2000; Ford et al. 2009).

Note that bats have not been included as a specific Animal Group in this version of the Guide, although road effects, namely road-effect zone have been documented for this group of animals (see Berthinussen and Altringham 2012), and road mortality is a concern for Ontario's Species at Risk bat species. Research for effective road mitigation measures that are suitable for this species group is needed.

Fact Sheet 1a. Wildlife Overpass

Wildlife Overpass	
DESCRIPTION	• Structural deck or bridge that is built over the road, animals therefore cross the road above grade (Figure 4.7); • A wildlife overpass may also be constructed by tunnelling the road, e.g. Herb Grey Parkway, Windsor, Ontario.
 Figure 4.7 Overpass on Highway 69, Ontario (K. Gunson).	 Figure 4.8 Top of 30 m wide overpass before vegetation plantings (MTO, Northeastern Region).
 Figure 4.9 Top of 50 m wide overpass in BNP, Alberta (Eco-Kare International).	 Figure 4.10 60 m wide overpass under construction in BNP, Alberta (Eco-Kare International).
TARGET WILDLIFE GROUPS	• Multi-species structure that may facilitate species use with habitat modifications on the deck structure, e.g. vegetation plantings and pools for amphibians.
APPLICATION SUITABILITY	• Used on large highways where underpasses are not feasible or may be too long, e.g. greater than 25 m;

Wildlife Overpass	
	• Potential to improve barrier effect caused by high traffic volumes; • Suitable for connecting large expanses of natural habitat and at migration corridors that will capture a diversity of wildlife species movements across the road.
ADVANTAGES	• Structures allow 100% openness; • Have been successful as a multi-species strategy (large mammals, birds, amphibians, and reptiles); • Have been shown to maintain genetic interchange for grizzly bears (Sawaya et al. 2014); • Allow brush, shrub and grass plantings along entire length of structure.
DISADVANTAGES	• Relatively expensive, however integrating innovative solutions and materials may reduce cost (see ARC design competition Link to ARC Design Competition (http://competition.arc-solutions.org/finalists.php).
IMPLEMENTATION CONSIDERATIONS	• Can utilize rocky outcrops in the ROW as footing for deck placement (Figure 4.12); • Build in locations where human use is minimized to maximize effectiveness for wary wildlife such as carnivore species; • Requires natural planting strategy to improve effectiveness; • Width varies however 50 m wide has been recommended in the literature (Figure 4.8 - Figure 4.10); • Allow drainage from the top deck; • Requires funnel fencing to be effective (Fact Sheet 7a. Wildlife Fencing and Escape Measures).
CONSTRUCTION COSTS	• Relatively high, e.g. $3-5 million depending on site, structural materials, road closures required, etc.; • Can reduce costs by implementing when road upgrades occur.
MAINTENANCE IMPLICATIONS	• Requires maintenance of micro habitat features for small animals such as brush piles or vernal pool creation; • Requires human use management to avoid impacts on wildlife use.

Fact Sheet 2a. Wildlife Underpass: Viaduct

Wildlife Underpass: Viaduct	
DESCRIPTION	• Elevated, long multiple-span bridge (150 to 600 m) used to span entire valleys, rivers, provincially significant wetland complexes, or floodplains (Figure 4.11).
 Figure 4.11 Viaduct on Highway 416, Ottawa (Ecoplans / McCormick).	 Figure 4.12 Viaduct spanning 5 Mile Creek in BNP, Alberta (K. Gunson).
TARGET WILDLIFE GROUPS	• Multi-species structure, that also allows for physical processes (hydraulic and geomorphological) to continue (Figure 4.12); • Allows passage for terrestrial and aquatic species when structure spans rivers, creeks and wetlands.
APPLICATION SUITABILITY	• Structures typically located across incised valleys, areas with undulating terrain, and over water bodies, however can be constructed at wildlife corridor crossings; • Often installed to maintain other transportation needs such as road and railway passage, as well as natural ecosystem functions.
ADVANTAGES	• Broad range of wildlife species (aquatic and terrestrial) can be accommodated; • Maintains natural habitat and terrain or can be restored to these conditions.
DISADVANTAGES	• High construction cost; • If required to span riverine valley, then there may be additional costs to facilitate terrestrial use by wildlife along adequate adjacent pathways.
IMPLEMENTATION CONSIDERATIONS	• Improve passage by small animals by adding necessary microhabitat features, such as small stumps and vernal pools; • Span the entire width of natural habitat by adding more spans, ensure adequate terrestrial passage if crossing riparian system (Figure 4.12);

Wildlife Underpass: Viaduct	
	• Maintain soil and vegetation conditions during construction, additional land restoration and creation of microhabitat can be integrated after construction; • Large rip rap material can impede movement for some animals and use should be avoided where animals will cross.
CONSTRUCTION COSTS	• Relatively high (could be several million dollars depending on design and materials); • If required to span riverine valleys, additional cost for wildlife would only be additional spans for terrestrial passage.
MAINTENANCE IMPLICATIONS	• Slope stabilization maintenance may be minimized with vegetation, buried rip rap, etc.; • Microhabitat conditions and materials for habitat creation such as log piles for target species should be maintained and not removed and strategically placed in or on a structure so that it does not impede movement for animals. • Maintenance activities must consider protection of bird nests of migratory species and at risk bird species (See Fact Sheet 6b. Bird Mitigation Measures).

Fact Sheet 3a. Wildlife Underpass: Bridge

Wildlife Underpass: Bridge	
DESCRIPTION	• Single or multiple span bridge over a watercourse or dry valley (Figure 4.13); • Single span bridge rests on abutments with no intermediate support columns (also called open span bridge); • Multi-span bridge has one or more intermediate support columns between abutments.

Figure 4.13 Single span bridge, Conestogo River (Ecoplans / McCormick).

Figure 4.14 Single-span bridge for deer passage on Highway 26 (MTO Central Region).

Figure 4.15 Multi-span bridge with separated traffic directions and wildlife pathway, Lovering Creek Bridge (K.Gunson).

Figure 4.16 Open single span bridge in Banff National Park (K. Gunson).

Wildlife Underpass: Bridge

Figure 4.17 Open/single span wildlife overpass bridge in Banff National Park (Eco-Kare International).

Figure 4.18 Open/single span bridge with creek bridge pathway for terrestrial wildlife crossings (Eco-Kare International).

TARGET WILDLIFE GROUPS	• Will typically enable movement by a wide variety of wildlife, including ungulates, large carnivores, mid-size and small mammals, amphibians and reptiles; • Amphibian and reptile movement can be facilitated if favourable habitat conditions exist or are integrated into the overall design (such as cover, damp conditions); • Avoid creating movement barriers, such as rocky steep rip rap inclines adjacent to creeks and rivers.
APPLICATION SUITABILITY	• Typically installed at larger watercourses and valleys to address hydrology, navigable waters, floodplain, and/or other landscape connectivity requirements; • In Banff National Park installed as dedicated wildlife underpasses (Figure 4.16 and Figure 4.17); • Should span a terrestrial crossing zone as well as a riparian zone (Figure 4.18).
ADVANTAGES	• Broad range of wildlife species can be accommodated; • Good opportunity for both aquatic and terrestrial passage when spanning waterways.
DISADVANTAGES	• Relatively high construction costs per span used.

Wildlife Underpass: Bridge	
IMPLEMENTATION CONSIDERATIONS	• Typically provides good light and views of adjacent habitat from either direction which is favoured by many species; • Structures that provide creek bridge pathways at waterway crossings facilitate movement for both aquatic and terrestrial species; • Bridges may integrate pedestrian trails if desired (van der Grift et al. 2013). However, encouraging human activity in more remote settings with large carnivores may result in avoidance by wary species, and/or risk of animal/human interaction (safety concern, Section 5). • Limited vegetation growth due to low light and moisture conditions, therefore use supplementary material such as stumps and logs for cover and shelter to facilitate movement by smaller wildlife species.
ESTIMATED CONSTRUCTION COST	• Construction costs are high and can range from $0.5 million to several million depending on dimensions, materials, and method of construction; • However, if required for other reasons, limited additional cost to facilitate wildlife use.
MAINTENANCE IMPLICATIONS	• Slope stabilization maintenance may be minimized with vegetation, buried rip rap, etc.; • Microhabitat conditions and materials for habitat creation such as log piles for target species should be maintained and not removed and strategically placed in or on a structure so that it does not impede movement for animals. • Maintenance activities must consider protection of bird nests of migratory species and at risk bird species (See Fact Sheet 6b. Bird Mitigation Measures); • Slope stabilization maintenance may be minimized with vegetation and more conducive to wildlife movement than rocks and rip rap.

Fact Sheet 4a. Wildlife Underpass: Large Tunnel

Wildlife Underpass: Large Tunnel >3.0 m	
DESCRIPTION	• Defined as structures (structural culverts) at least 3.0 m in height and / or width; • Tunnels may be box shaped with or without bottoms; • Tunnels may be arch shaped with or without footings; • Tunnel design specifically for wildlife. Retrofits to existing tunnels vary and are still emerging world-wide.

Figure 4.19 Box tunnel (5.0 m x 5.0 m) with open bottom on Highway 69 (K. Gunson).

Figure 4.20 Box tunnel (4.0 m x 4.0 m) with open bottom on Highway 11 (K. Gunson).

Figure 4.21 Open arch-style culvert – double cell (Ecoplans / McCormick).

Figure 4.22 Multi-cell pre-cast open bottom culvert, Markham (Ecoplans / McCormick).

TARGET WILDLIFE GROUPS	• Smaller animals, coyote-sized and smaller; • Wildlife monitoring work in BNP has documented Black Bear use of tunnels ranging from 2.5 to 4 m high, 7 to 13 m wide, and 25 to 68 m long, with Openness Ratios ranging from 0.2 to 1.2 (Clevenger et al. 2009); • Tunnels greater than 4 m will be used by ungulates but deer, moose and wolves prefer a wider span and larger overpasses;

Wildlife Underpass: Large Tunnel >3.0 m	
APPLICATION SUITABILITY	• More frequently being installed solely for wildlife use, e.g. Highway 69 and Highway 11 (Figure 4.19 and Figure 4.20); • Can be arranged in a series of multiple chambers (Figure 4.22); • Tunnels at water crossings can employ open bottom design with footings (Figure 4.21); • Open bottom structures require special design considerations to maintain low flow channel integrity and terrestrial passage; • Tunnels at water crossings must ensure that fish passage requirements are met. The MTO Drainage Design Standards and the MTO Environmental Guide for Fish and Fish Habitat provide guidance on design considerations.
ADVANTAGES	• Variations in design and structural materials allow flexibility for implementation to accommodate target species needs; • Tunnels implemented for snowmobiles, pedestrian and vehicle access may also be used for wildlife.
DISADVANTAGES	• Closed conditions do not allow the same air flow, moisture, and light conditions as larger more open structures; • Flooding and winter ice formation in closed bottom tunnels with water pools may discourage use by certain animals.
IMPLEMENTATION CONSIDERATIONS	• Plan for multi-species use by including wider tunnels with terrestrial creek pathways; • Terrestrial pathways should be 0.5 m for small and medium animals, and 2-3 m for large mammals (Clevenger and Huijser 2011); • Integrate a drainage design that may include smaller equalization culverts at wetland locations to avoid flooding; • Allowing continuous sight-lines through tunnels.
CONSTRUCTION COSTS	• Costs are moderate, depending on size, materials and design modifications; • Concrete box culvert 3 x 2.1 m is approximately 3,500 per metre; and 3.3 m x 2.8 m is 7,800 per metre (MNRF 2016). Corrugated metal arch culvert w metal footings 2.99 m x 1.45 m rise is approximately $1,500 per metre.
MAINTENANCE IMPLICATIONS	• Culverts and bridges are typically inspected for safety and maintenance measures. Standard inspection criteria could be expanded for wildlife use to include vegetation control and woody debris blockages in and around culvert entrances to allow for openness and accessibility; • Maintenance is required for damage due to erosion and deposition of sediments often resulting from poor construction; • Maintenance activities must consider protection of nesting migratory birds (See Fact Sheet 6b. Bird Mitigation Measures) and other wildlife species.

Fact Sheet 5a. Wildlife Underpass: Small Terrestrial Tunnel

Wildlife Underpass: Small Terrestrial Tunnel < 3 m	
DESCRIPTION	• Known as wildlife tunnels, amphibian tunnels, wildlife pipes, ecopipes, ecoculverts and ecopassages; • Box culvert is 4-sided, typically with a concrete bottom, rectangular or square-shaped – can also have an open bottom and/or open top configuration (Figure 4.24); • Metal tunnels (round, oval, elliptical) or Acrylonitrile Butadiene Styrene (ABS) plastic tunnels; • Dedicated for wildlife use, typically smaller mammals, amphibians and/or reptiles in upland setting, i.e. away from wetland habitat.

Figure 4.23 Tunnel for amphibians with native substrate, York Region (Ecoplans / McCormick).

Figure 4.24 Open bottom and open top tunnel for Massasauga Rattlesnakes (K. Gunson).

Figure 4.25 Reptile tunnel (2.3 m x 3.0 m) on Highway 69 (Eco-Kare International).

Figure 4.26 ACO surface tunnel (0.5 m x) in Waterton National Park (Parks Canada).

Wildlife Underpass: Small Terrestrial Tunnel < 3 m	
TARGET WILDLIFE GROUPS	• Small to mid-size mammals (van der Ree 2009), reptiles, and amphibians (MNRF 2016).
APPLICATION SUITABILITY	• Upland tunnels facilitate overland movement of wildlife between two upland areas or between uplands and wetlands; • Tunnels for amphibians were first used in Europe, and are being used more in North America (Pagnucco et al. 2012), and Australia (Hamer et al. 2014); • Wildlife pipes or ecopipes are small, dry tunnels primarily designed for passage by small and medium-sized mammals and snakes; • More than 300 wildlife pipes have been installed in the Netherlands along Dutch motorways to assist in the recovery of badgers (Veenbaas and Brandjes 1999); • Pipes have been installed for Red-Sided Garter Snakes on a road in Manitoba (Roberts 2010).
ADVANTAGES	• Low cost allow several tunnels to be implemented to accommodate a broad range of terrestrial wildlife species (small to mid-sized); • Implementation of several tunnels varying in design allow effective and rigorous monitoring; • Opportunity to retro-fit and modify existing tunnels in the road network to facilitate passage for smaller animals; • Can be installed independently of major road construction upgrades.
DISADVANTAGES	• Require periodic maintenance to clear culvert of debris.
IMPLEMENTATION CONSIDERATIONS	• Tunnels that use the counter sunk approach (partially buried) can provide both low flow conditions and terrestrial movement opportunities with proper installation; • Install between overwintering and breeding habitat for amphibians; • Open top tunnels need to be flush with road surface (see ACO tunnels installed by the Quebec Ministry of Transportation 2001 used by salamanders and frogs); • Tunnel bottoms need to be flush with adjacent terrain at entrances; • In some cases, provision of a number of regularly spaced smaller culverts (150-300 m spacing) may be more cost-effective than placement of a few larger structures (Carsignol 2005); • Ledges constructed of wood, concrete or earth have been added to existing Dutch waterway culverts to facilitate terrestrial wildlife passage (see Veenbaas and Brandjes 1999); • Considerations in retrofitting or designing wildlife ledges made from wood planks, concrete and earth berm ledges for tunnels of varying size have been monitored and successfully used by mid-size mammals and amphibians in the Netherlands (Veenbaas and Brandjes, 1999): • Extended earth banks within the culvert were 1.5 to 3.5 m wide; wood planks fixed to culvert walls were 0.25 to 0.6 m wide; floating wood

Wildlife Underpass: Small Terrestrial Tunnel < 3 m	
IMPLEMENTATION CONSIDERATION (cont'd)	planks 0.3 m wide (adjust to water level changes); concrete ledges 0.4 to 1.3 m wide; plastic gutters 0.25 m wide and covered with sand; • Widening the ledge increases multi-species use and effectiveness; • Bayview Avenue, York Region installed series of round and oval tunnels, concrete and CSP, ranging in size from 1.2 to 1.7 (Figure 4.23), have been used by small mammals, toads and frogs (Ecoplans Limited and McCormick Rankin Corporation 2002); Norfolk County installed two terrestrial ACO open-top box tunnels (0.5 m) and one hydraulic tunnel for amphibian and reptile passage between an open bay and wetland habitat on the Long Point causeway. Snapping and Painted Turtles, and Garter Snakes have been documented using all structures (Whitelock 2013 unpublished data).
CONSTRUCTION COSTS	• Costs for tunnels (materials, installation and funnel fencing) could range from $15,000 to $80,000 depending on length, materials, availability of precast materials, road conditions, and whether a retrofit or new construction is involved; • The average cost of materials and installation of ACO 0.5 m wide polymer concrete tunnels with open tops is $13,000; • Cost for larger box culverts vary up to $25,000 for 1.8 m concrete box culverts.
MAINTENANCE IMPLICATIONS	• Periodic maintenance required to address culvert blockage from debris and vegetation and any erosion; • Tunnels may be flushed with a high power fire hose in accordance with MTO Best Management Practices for fisheries protection; • For non-amphibian tunnels, some vegetation leading to and around the entrance is desirable to both guide approaching wildlife and provide cover (Clevenger et al. 2001); • Maintenance activities must consider protection of nesting migratory birds (See Fact Sheet 6b. Bird Mitigation Measures) and other wildlife species.

Fact Sheet 6a. Wildlife Underpass: Small Drainage Culvert

Wildlife Underpass: Small Drainage Culvert	
DESCRIPTION	• Typically installed along roads for cross-drainage purposes (Figures 4.27 to 4.30); • Culverts may be box type or rounded (circular, elliptical, pipe arch) and may or may not be buried in the ground when implemented; • Culvert materials may be corrugated steel pipe, metal plate, cast-in-place concrete, or pre-cast concrete; • These culverts may be seasonally dry, damp, or permanently full of water for extended periods (Figures 4.28 to 4.30).

Figure 4.27 Circular CSP drainage culvert, Kitchener (Ecoplans / McCormick).

Figure 4.28 Round drainage culvert that needs smaller mesh fencing and rocky substrate removed (K. Gunson).

Figure 4.29 Amphibian / drainage culverts, York Region (Ecoplans / McCormick).

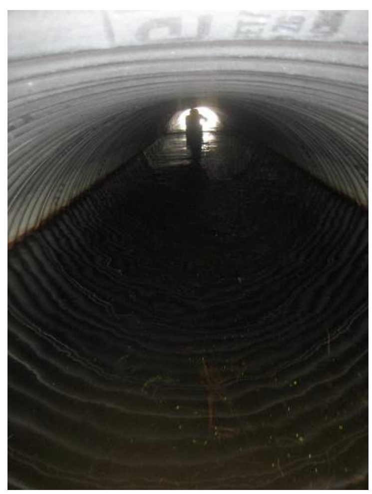


Figure 4.30 Drainage culvert (1.8 m) with standing water used by Blanding's Turtles (K. Gunson).

Wildlife Underpass: Small Drainage Culvert	
TARGET WILDLIFE GROUPS	• Drainage culverts are not necessarily designed for wildlife movement; • Monitoring work in Ontario, Alberta, the U.S. and Europe have shown that small animals such as rabbits, mice, lizards, snakes, turtles, frogs, foxes, weasels, badgers, coyotes, snowshoe hares and red squirrels will use drainage culverts when dry and for aquatic species when wet (Clevenger et al. 2001; Brudin 2003; Foresman 2004; Mata et al. 2008; Caverhill et al. 2011; Gunson et al. 2014).
APPLICATION SUITABILITY	• Drainage culverts are routinely installed on highways, low volume roads, driveways, and railways, to handle either permanent or seasonal cross-drainage flow, or to act as water level equalizers in areas of poor drainage.
ADVANTAGES	• Small size, routine maintenance, and upgrades in the road network allow for design modifications to accommodate wildlife species, e.g. buried bottom, installation of terrestrial ledge, wing walls, new materials, upsizing, etc; • Use of specialized wildlife fencing can be used with drainage culverts to increase use.
DISADVANTAGES	• Culvert may become blocked with woody debris or beaver dams; • Beaver baffles at culvert ends do not allow passage by some wildlife such as turtles.
IMPLEMENTATION CONSIDERATIONS	• Use stream simulation guidelines (USFS SSWG 2008) to create conditions inside a structure that simulate conditions found in the natural stream such as water depth, flow, water velocity, and substrate and channel characteristics; • Use baffles to reduce water velocity in culverts and to reduce scouring and perched culverts at entrances; • Culverts with standing water will be used by semi-aquatic and aquatic species, for example a 1.8 m drainage culvert with installation of fencing was shown to be used by Blanding's Turtles on Highway 24 in Ontario (Figure 4.3; Caverhill et al. 2011); • Culverts designed to convey water can also allow terrestrial wildlife movements by adding substrate material, installing them so the tunnel is periodically dry, adding ledges, or using vole tunnels (Foresman 2003); • Metal mesh ledges for small mammal use have been retrofitted in 1.2 m steel drainage culverts in Montana (Foresman 2004); • More frequently placed culverts (150 to 300 m intervals) using a range of sizes (1 to 1.5 m for mid-size animals; 0.5 to 1 m size for small mammals) can improve connectivity across roads for small animals; • Need to consider equal elevation grades inside culvert and at entrances so water does not pool or flood culvert in low water seasons; • Rip-rap should not be used inside, or at the entrances of the tunnels; use natural substrate when possible.
ESTIMATED CONSTRUCTION COST	• Costs for standard drainage culverts are nominal relative to road construction costs.

Wildlife Underpass: Small Drainage Culvert	
MAINTENANCE IMPLICATIONS	• Maintenance of wildlife tunnels may include clean out, removal of debris, addressing drainage problems affecting structures; • Maintenance of vegetation plantings at entrances;

Fact Sheet 7a. Wildlife Fencing and Escape Measures

Wildlife Fencing and Escape Measures	
DESCRIPTION	• Wildlife fencing is installed for two purposes: to exclude animals from the road, and to funnel wildlife to crossing structures (Figure 4.31); • Wildlife exclusion fences vary in height, length, design and materials, depending on site-specific application and target species (Figure 4.35, to Figure 4.38); • One-way gates are specialized gates and designs vary; generally consist of two sets of curved tines mounted vertically on spring closed hinges; tines should be equipped with ball ends to avoid harm to animals (Figure 4.33); • Allow large animals (typically ungulates) to pass from the road ROW to the safe side of the fence; • The gates are installed at intervals along wildlife fencing and should be sited near fence ends and other likely breach points; • Gates should be positioned in from the fence line in a v-pattern to funnel animals to the gate; • Jump-outs are alternatives to one-way gates. The ramps are sloped earthen ramps or concrete blocks that allow animals in the road ROW to reach the top of the wildlife fence and jump down to the safe side of the fence (Figure 4.34).

Figure 4.31 Wildlife fencing in median with arch culvert, New Brunswick (Ecoplan/McCormick).

Figure 4.32 Wildlife fencing with top wires on Highway 11 (K. Gunson).

Wildlife Fencing and Escape Measures	
 Figure 4.33 One-way gate positioned inwards from fence line, Highway 69 (K. Gunson).	 Figure 4.34 Newly installed Jump-out on Highway 11 (1.8 m high) (K. Gunson).
 Figure 4.35 Large animal fencing and fence end at rock cliff on Highway 69 (K. Gunson).	 Figure 4.36 One-way gate with fence extension to funnel animals to gate, Nova Scotia (K. Gunson).

Wildlife Fencing and Escape Measures	
 Figure 4.37 Reptile fence along Highway 69 (K. Gunson).	 Figure 4.38 Chain link fence with Animex fence attached at bottom for small animals (Animex Fencing).
TARGET WILDLIFE GROUPS	• Can be designed for all wildlife groups.
APPLICATION SUITABILITY	• Fencing is commonly used to both funnel and exclude wildlife from roads; • When used without crossing structures may cause an increased fence-end effect in addition to a barrier effect; • Electric fencing may be a cost-effective exclusion design that has been shown to be effective for deer and elk in Arizona; • Fencing up to 2.4 m high is recommended for large animals and is typically wire fence mesh with wood or steel posts; additional top wires or t-post extension arms can be used to extend the height of the fence up to 2.8 m high (Figure 4.32); • The bottom end of the fencing may be lined with a smaller mesh apron or covered with another type of barrier to prevent entry by small animals (Figure 4.38); especially where the underlying terrain is uneven; apron should be buried to prevent animals from going under fence; • Continuous fencing that is buried into the ground is more effective at excluding both large and small animals from the road; • Stand-alone small animal fence materials should include permanent materials such as aluminum sheeting, armour stone or stone wall, heavy duty hardwire cloth (with specs that are effective to the site conditions and species), and specialized heavy-duty plastic materials (MNRF 2016; • Hard wire cloth for smaller animals such as amphibians and reptiles requires a tight mesh to minimize animals getting through or climbing the fence (less than ½ inch for small snakes; MNRF 2016); • Additional top wires, and/or an angled top is required for fences that

Wildlife Fencing and Escape Measures	
	animals will attempt to climb (MNRF 2016); • Funnel fencing should connect all tunnels and culverts; when there is only one crossing, extend the fencing just beyond the habitat or crossing zone used by the species (Caverhill et al. 2011; MNRF 2016); • For small animals, it is extremely important to build a durable solid fence to ensure that no gaps or holes exist under, and along the fencing material and where the material abuts road features such as culverts, and wildlife passages (MNRF 2016).
ADVANTAGES	• Effective at excluding wildlife from roads and reducing WVCs when properly designed and maintained; • Increase effectiveness of wildlife crossing structures by funneling wildlife towards crossing structures; In Pennsylvania 65% of structures used by deer had ROW fencing funnelling them to the structure (Brudin 2003); • Once fencing was installed on Highway 69 in Ontario, crossing structure use at an underpass and overpass increased dramatically (MTO 2014); • Fencing has been shown to reduce WVC mortality by 80-100% for large ungulates (Clevenger and Barrueto 2014).
DISADVANTAGES	• All fences require maintenance to remain effective; the more durable the fence design and materials used, the less maintenance required; • Multiple species considerations may be required at each site and increases complexity of design; • May also trap animals that breeched the fence system to be trapped in the ROW; one-way escape measures may help reduce this issue.
IMPLEMENTATION CONSIDERATIONS	Fence: • Fencing must be coupled with crossing structures to retain landscape connectivity and avoid fence-end effect; • The decision to install funnel fencing suitable for ungulates and large carnivores should consider factors such as site conditions including terrain, motorist safety, feasibility of installing crossing structures, adjacent land use such as driveways and other road interchanges, crossing corridors for wildlife, and costs to install and maintain; • Extending the fencing 800 m on either side of an underpass structure has shown a significant reduction in deer-vehicle collisions and consistent use of structures (McCollister and Van Manen 2009); • Shorter fencing lengths will most likely work better when sited in known travel corridors – fencing will likely need to extend further where travel corridors are not well defined and when crossing structures are not present; • Wildlife fencing for large animals should be at least 2.4 m high and buried into the ground (to reduce likelihood of wildlife entry under the fence); • Set fence back a few feet from ROW boundary to facilitate fence maintenance (repair); although fences should be placed outside the roadway clear zone as much as possible; • Designers should try to locate wildlife fencing as close to the Right-of-Way limits as is practical. Protection of wildlife fencing with roadside barriers in accordance with the MTO Roadside Safety Manual should be considered as a last resort when the fencing is located within the clear

<table>
<tr><th colspan="2">Wildlife Fencing and Escape Measures</th></tr>
<tr><td rowspan="2">IMPLEMENTATION CONSIDERATIONS (cont’d)</td><td>zone or adjacent to the toe of a sideslope (or frontslope) steeper than 4H:1V or where there is a high potential for impact;
• Place fencing at a safe distance from trees that may uproot or fall on fence;
• Top wire on fence can help limit damage of falling trees;
• The TransCanada Highway Three Sisters Interchange in Canmore, Alberta has 2.5 m high wildlife fencing consisting of round pine logs and page wire configuration with design variations to accommodate installation in stable ground, soft ground and rock (Bell and Carter 2000).</td></tr>
<tr><td>Escape Measures:
• Fence-end effect can be reduced/overcome by solutions such as using rock piles, placing fence end extensions away from the road, or tying fence ends in with inhospitable habitat and steep slopes and rocky cliffs (see Section 4.2.2);
• Additional “fence-end” solutions that have been employed at the TransCanada Highway in Canmore, Alberta include (Bell and Carter 2000):
– Wildlife fencing has been tied in to the ends of the Bow River bridges at the west end of the project area. At the east end, the wildlife fencing was angled and tied in to the highway (guiderail) edge;
– Potential crossing habitat beyond the fence end was rendered inhospitable for ungulates by stripping the topsoil and installing landscape fabric covered with rock or pit run gravel (creating an unstable walking surface);
• Mitigation at Highway 11 in Ontario has rock piles and steep highway slopes at fence ends to deter ungulates from approaching the highway;
• Mitigation at Highway 69 in Ontario is tied into Canadian Shield rock cliffs;
• One-way gates may be installed where animals are likely to breach the fence system, e.g. at fence ends or approximately 0.5 to 1.0 km apart;
• Effectiveness of one-way gates is still very experimental and limited use has been documented for Black Bears and White-tailed Deer on Highway 69 (MTO 2014);
• Gates may be more effective if they are offset from the fence line in a ‘V’ pattern (Figure 4.33);
• Gates may be more effective if a fence extension is included to funnel animals to gate (Figure 4.36);
• Jump-outs are considered 10-12 times more effective than one-way gates for Mule Deer, and have lower maintenance requirements (see Forman et al. 2003; Bissonette and Hammer 2000);
• At the Three Sisters Interchange in Canmore Alberta, jump-outs have been installed as escape areas for wildlife that become trapped in the highway ROW. These ramps are placed in a corner of the fence line near existing natural cover. The side walls are constructed of interlocking concrete blocks, and sub-drainage is provided using perforated pipe and filter gravel. Native backfill is used behind the wall (Bell and Carter 2000);</td></tr>
</table>

Wildlife Fencing and Escape Measures	
	• Typically jump-out heights range from 1.5 to 2.2 m (Bissonette and Hammer 2000, Huijser et al. 2008a); • The taller fence is lowered at the ramp site and forms an integral part of the drop-off that allows animals to jump to the safe side of the fence (Bissonette and Hammer 2000); • Jump-outs must be kept clear of vegetation that would impede animals moving on, jumping off and landing safely on the other side; • Jump-outs may not work as well in snowy or icy conditions; The fence line should be tight with the jump-out ramp otherwise deer may get caught between the ramp and fence; • The use of both escape measures may be an effective multi-species strategy as implemented on Highway 11 where there are 26 paired one-way gates and jump-outs on the new mitigated section near Sundridge, Ontario (Healy and Gunson 2014); • Spacing of approximately 0.5 km throughout the length of the fence is recommended, and frequency should be increased to approximately every 0.25 km for the first kilometre at fence-ends (Golder 2013).
CONSTRUCTION COSTS	• Costs for ungulate fencing can range from $30,000 to $50,000 per km based on costs incurred for the Fredericton to Moncton Highway (Ecoplans 1998); • In British Columbia, 2.4 m high ungulate fencing costs between $40,000 and $80,000 (Seilecki 2004) per km to fence both sides of a road; • Maintenance costs for fencing may be 1% of fencing construction costs per year (Reed 1982).
MAINTENANCE IMPLICATIONS	• Life span of wooden posts and wire mesh fencing is about 20-25 yrs.; • Checking for damage and quickly repairing gaps in fence is essential to avoid fence breaches by wildlife; • Fencing in association with wildlife structures is effective, but it does require a long-term maintenance commitment that must be considered in maintenance budgets; • Fences can be damaged by falling trees, vehicle accidents, and unauthorized cutting by ATV and snowmobile operators; • Fence posts can shift due to frost heave; • Hinges of one-way gates tend to stick under winter conditions due to freezing and should be checked and maintained routinely; • Vegetation growth needs to be regularly controlled; • Regular maintenance of jump-outs is required to clear vegetation and woody debris from the jump-out and landing locations; • The landing spot around the outside wall should have loose soil or another soft material to prevent animals from seriously injuring themselves (http://environment.fhwa.dot.gov/WVCtraining/mod4/module_4_12.asp)

Fact Sheet 8a. Wildlife Detection System (WDS)

Wildlife Mitigation Approaches Wildlife Crossing: Warning	
Wildlife Detection System	
DESCRIPTION	• Series of solar powered or battery operated heat sensors/infra-red cameras/motion detectors used to detect animals near the road (Figures 4.39 and 4.40); • Drivers are alerted to approaching animals via a digital message board and/or flashing signs/lights; • Cameras are installed at each end of the wildlife crossing zone.

Figure 4.39 Wildlife detection system, Highway 17, Ontario (MTO Northeastern Region).

Figure 4.40 Wildlife detection system, Highway 6, Ontario (MTO Northeastern Region).

TARGET WILDLIFE GROUPS	• Developed for ungulates but will detect some other larger animals such as Mountain Lions, wolves, Black Bears.
APPLICATION SUITABILITY	• Currently experimental; research and development continue and will likely result in technologically advanced and low-maintenance systems in the future; • Typically placed in a high collision zone or high crossing zone; • Can be used at or near established wildlife structures to alert drivers to animal presence at those specific sites; • Can also be used on a temporary basis when seasonal wildlife-vehicle conflicts are apparent; Recent research has shown WDS have had variable success in detecting large mammals, but they can be effective in reducing collisions with large mammals by 58-99% (Huijser et al. 2006; Huijser et al. 2009a, b; Sharasfsaleh 2010; Huijser 2010);

Wildlife Mitigation Approaches Wildlife Crossing: Warning	
Wildlife Detection System	
	• Many WDS projects fail, due to technical problems, others because of management issues or lack of ongoing commitment by managing agencies; • Difficult to engage public support because often motorists don't see animals at crossing locations and confidence in system functionality is therefore reduced.
ADVANTAGES	• Systems may be programmed to alert drivers only when an animal is approaching so there is less of a chance of desensitization as with static signs; • Somewhat portable system.
DISADVANTAGES	• Life-span costs are more expensive than crossing structures and fencing because WDS only last up to 10 years (Huijser 2009a, 2009b); • Many factors can impair alerting system, such as snow, heat and exhaust from truck stacks; • Reducing vehicle speed may be dangerous (e.g. rear-end collisions) on higher volume roads (e.g. >15,000 vehicles/day) and therefore it is preferred to physically separate animals and traffic on high volume roads; • Most tested systems identified in the literature have had malfunctions and technical difficulties to varying degrees.
IMPLEMENTATION CONSIDERATIONS	• Can be relocated to high risk areas in response to changing land use or traffic patterns; • Effectiveness is variable and currently requires ongoing specialized maintenance, therefore consider more effective measures such as crossing structures and fencing for long-term cost effectiveness.
CONSTRUCTION COSTS	• Moderate first-time installation costs; • Relatively moderate to high on-going costs due to technical issues and continual maintenance.
MAINTENANCE IMPLICATIONS	• Equipment must be checked and maintained frequently.

Fact Sheet 9a. Wildlife Habitat Awareness (WHA) and Other Signs

<table>
<tr><th colspan="2">Wildlife Habitat Awareness (WHA) and Other Signs</th></tr>
<tr><td>DESCRIPTION</td><td>

Widely used to alert drivers of potential wildlife crossings (e.g. Figure 4.41, Figure 4.42 and Figure 4.44);
Traditional warning signs are diamond shaped with a yellow background and black silhouettes of animals or potential dangers illustrated in the foreground, e.g. leaping deer sign;
Many types of turtle warning signs have been placed on Ontario’s municipal roads (Gunson and Schueler 2012);
Other diverse signs have also been used and the MTO has developed and is testing a new policy to install WHA signs at selected locations on the road network (MTO 2012; MTO 2015). These signs feature a brown square background with a yellow image to avoid using the yellow diamond which indicates a hazard to drivers Figure 4.43).

</td></tr>
</table>

Figure 4.41 Digital wildlife warning sign (K. Gunson).

Figure 4.42 Snake-crossing sign, Manitoba (Manitoba Department of Conservation).

Wildlife Habitat Awareness (WHA) and Other Signs

Figure 4.43 WHA sign for turtles, Highway 7, Ontario (K. Boadway).

Figure 4.44 Moose Alert enhanced warning sign in Newfoundland (K. Gunson).

TARGET WILDLIFE GROUPS	Used for all wildlife groups; most common for deer and moose, however more recently used for smaller animals such as turtles, snakes, and small mammals world-wide (Kintsch et al. 2015; Jackson et al. 2015).
APPLICATION SUITABILITY	• Easy to install and maintain; • Should be installed in selected locations where higher than expected animals will cross roads; • Can be used as temporary measures to mark where more permanent mitigation is required; • Should be accompanied with a public awareness and education campaign.
ADVANTAGES	• May accommodate a broad range of wildlife species; • Low one-time costs facilitate widespread use; • Flexibility in use, such as enhance visibility with flashing lights or used seasonally during highest wildlife crossing times.
DISADVANTAGES	• Effectiveness of measures is only known short-term, i.e. within one month or year of placement; • Most drivers initially respond to signs by reducing traffic speeds, however longer-term response (greater than one year) is unknown (Pojar 1975; Al-Ghamdi, and AlGadhi 2004; MTO 2015); • Drivers become habituated to static signs; • There is some evidence that drivers will deliberately try to run over snakes, especially if signs alert drivers that they may be present (Ashley et al. 2007); • Novel signs are prone to theft (Gunson and Schueler 2012).
IMPLEMENTATION CONSIDERATIONS	• Sign placement for MTO WHA signs focuses on endangered or threatened SAR turtles and snakes; unsure of utility for small mammals and birds; • WHA sign placement is based on where SAR will be present next to roads and presence of suitable habitat;

Wildlife Habitat Awareness (WHA) and Other Signs	
	• Input may also be received from other data sources to verify locations for placement such as the public, academic sources, and MNRF; • Improvements to static signs include use of overhead digital warning signs, e.g. in British Columbia and Ontario, to indicate when a wildlife hazard is imminent or when the historic wildlife collision rate is extreme (Healy and Gunson 2014); these signs are considered useful for short-term and seasonal wildlife movement events, and even salt-lick sites (Sielecki 2004); • Signs should be placed as ‘temporary markers’ for more permanent mitigation measures (MTO 2012; MTO 2015).
CONSTRUCTION COSTS	• Production and installation costs are relatively low (in the range of $150 to $600 in 2014).
MAINTENANCE IMPLICATIONS	• Require inventory to record location, design, year of placement, theft protection measures; • Easily installed; • Newer, more novel signs require anti-theft devices such as greased or bolts that require a special wrench; • May need to be replaced due to deterioration, vandalism or theft.

4.3.1 Species Group Fact Sheets

Animal Groups
Ungulates: White-tailed Deer and Moose
Large and mid-sized carnivores: Black Bear, Wolf and Coyote
Small and Medium-Sized Mammals: Rodents up to the size of medium Carnivores
Amphibians: Salamanders, Frogs and Toads
Reptiles: Snakes and Turtles
Birds: All species impacted by roads

More general uses of crossing structures as multi-species measures are found in Section 4.3.1. This section focuses on details of crossing structures and/or fencing and other measures that are most effective (from the current literature) for the species group specified.

Fact Sheet 1b. Ungulates: White-tailed Deer and Moose

<table>
<tr><th colspan="3">Road Design Mitigation Measures</th></tr>
<tr><th colspan="2">Ungulates</th><th>Moose and Deer</th></tr>
<tr><th>Mitigation Measure</th><th>Type</th><th>Species-Specific Implementation Considerations</th></tr>
<tr><td rowspan="3">FENCING AND ESCAPE MEASURES</td><td>Fencing</td><td>• Used to improve effectiveness of ungulates using crossing structures (McGuire and Morrall 2000; Dodd et al. 2009; MTO 2014);
• Most effective for ungulates with no gaps greater than 23 cm to avoid deer crawling under or squeezing through;
• Minimum 2.4 m tall galvanized, steel chain-link or high-tensile, fixed-knot, galvanized steel, mesh fence is recommended;
• The length of fence required is determined by number of structures, species, site conditions, and extent of travel or migration corridor perpendicular to the road;
• Possibly shorter sections of fence may be used to funnel wildlife to crossing structures if located in well-defined travel corridors – fencing will need to extend further, i.e. up to 5 km to minimize fence end effect where travel corridors are not well defined (McCollister and Manen 2010; Fairbank 2013).</td></tr>
<tr><td>One-Way Gates</td><td>• One-way gates are used with fencing and wildlife crossings to allow ungulates that breeched the fence system to escape the ROW;
• Deer have been shown to use one-way gates but moose have not in Ontario (Healy and Gunson 2014), however Link to US Federal Wildlife Crossing Toolkit</td></tr>
<tr><td>Jump-out</td><td>• Preliminary data show reasonable use by Mule Deer, but jump-outs may need to be lower for White-tailed Deer (Huijser et al. 2013; http://www.mdt.mt.gov/other/research/external/docs/research_proj/wildlife_crossing/phaseii/progress_nov13.pdf)
• White-tailed Deer have successfully used jump-outs at 6 feet high, however have also been documented using jump-outs the ‘wrong way’ (MTO unpublished data);
• The optimum height for White-tailed Deer is experimental and research has shown that earthen ramps between 1.5 - 1.8 m ramps are adequate for Mule Deer;
• Jump-outs have been shown to be 8-11 times more effective than gates for Mule Deer in Utah, and have lower maintenance requirements (Bissonette and Hammer 2000);
• Jump-outs have not been shown to be effective for moose for a variety of reasons; moose are not as agile as deer and will show hesitancy to jump onto a vegetated or icy landing surface; therefore it is important to keep moose out of ROW fenced areas by taking careful consideration for fence end treatments at steep slopes and rock piles;
• Research in Arizona is finding that jump-outs that are 1.5 m high are too low to prevent elk from entering the road ROW.</td></tr>
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<table>
<tr><td colspan="3">Road Design Mitigation Measures</td></tr>
<tr><td colspan="2">Ungulates</td><td>Moose and Deer</td></tr>
<tr><th>Mitigation Measure</th><th>Type</th><th>Species-Specific Implementation Considerations</th></tr>
<tr><td rowspan="3">WILDLIFE CROSSING STRUCTURES</td><td>General</td><td>• Minimizing human activity near the structure is considered important for wildlife use;
• Less time for habituation (up to 1-3 year) to structure is less than for carnivores (Clevenger et al. 2009);
• Use fencing to funnel animals to crossing structures.</td></tr>
<tr><td>Wildlife Overpass</td><td>• Deer, elk, and moose prefer to use a wildlife overpass as opposed to an underpass (Figure 4.46; Clevenger and Barrueto 2014; MTO 2014).</td></tr>
<tr><td>Underpass</td><td>• In Pennsylvania, 65% of structures used by deer had fencing in the ROW to funnel ungulates to structure (Brudin 2003);
• As structure length increases, the size of the opening should increase to obtain a desired openness ratio;
• To reduce the tunnel effect and increase openness use an open road median;
• Provide open, level approaches to structures;
• Guide animals to structures with terrain, berms or vegetation;
• Preliminary data have shown White-tailed Deer sometimes repel, and also cross a 4 m x 4 m box culvert open at median on 4–laned highway (MTO unpublished data);
• Crossing structures for Mule Deer should be less than 36 m in length, and wider rather than higher (Cramer 2012);
• Deer use structures ranging in openness ratios from 0.6 to 1.0;
• Deer will use structures containing some water (up to 0.6 m depth; Brudin 2003), but will avoid structures in spring if ice is present inside;
• Deer will use structures with a concrete bottom, although ideally some substrate is desirable;
• Elk prefer larger, open-span bridges (Clevenger and Barrueto 2014);
• Moose tend to use a wide range of wildlife crossing types along Highway 175 in Quebec, including underpasses with small openness ratios (Bouffard et al. 2010) but show preferences for more open structures when available (Figure 4.45).</td></tr>
</table>

Road Design Mitigation Measures	
Ungulates	Moose and Deer
 Figure 4.45 A moose enters a 5m x 5m underpass (MTO, Northeastern Region).	 Figure 4.46 A deer crosses a dedicated wildlife overpass (MTO, Northeastern Region).

Fact Sheet 2b. Large to Mid-Size Carnivores: Black Bear, Wolf, Lynx, and Coyote

Road Design Mitigation Measures		
Large to Mid-sized Carnivores		Black Bear, Wolf and Coyote
Mitigation Measure	**Type**	**Species-Specific Implementation Considerations**
FENCING AND ESCAPE MEASURES	Fencing	• Should be a minimum of 2.4 m tall, ideally with the bottom buried in ground to prevent animals from moving under the fence (MTO 2014); • Use 4 inch mesh size that decreases closer to bottom to avoid breaches by young animals and smaller species such as coyote, wolves and lynx; • Use steel posts to prevent animals from climbing, e.g. Black Bears; • Use extension arms and top wires to increase height and prevent animals from climbing over fence.
	One-Way Gates	• Black Bears will use one ways gates (MTO 2014).
	Jump-out	• N/A (unknown whether research has shown that carnivores will use jump-outs).
WILDLIFE CROSSING STRUCTURES	General	• Minimizing human activity near the structure is considered important for wildlife use; • Time for habituation (up to 5 years) to structure is often required (Clevenger et al. 2009); • Use fencing to funnel animals to crossing structures.
	Wildlife Overpass	• Carnivores will use overpasses; lynx used the overpasses in Banff National Park 56% of the time (total 18 passages (1996-2004; Clevenger and Barrueto 2014).
	Underpass	• Black Bears, coyotes and cougars will use underpasses as well as overpasses, i.e. these species do not appear to be affected by the ‘tunnel effect’; • Figure 4.47; Clevenger and Barrueto 2014; MTO 2014); • Wolves prefer larger underpasses (Clevenger and Barrueto 2014) and overpasses (Figure 4.48).

Road Design Mitigation Measures

Large to Mid-sized Carnivores | Black Bear, Wolf and Coyote

Figure 4.47 A Black Bear travelling through twinned 5m x 5m underpass (MTO Northeastern Region).

Figure 4.48 A wolf on a wildlife overpass, Highway 69, Ontario culvert (MTO Northeastern Region).

Fact Sheet 3b. Small and Medium-Sized Mammals: Rodents up to the size of medium Carnivores

Road Design Mitigation Measures		
Small and Medium-Sized Mammals		Rodents, Rabbits, Weasels, Badger, Red Fox, Lynx up to the size of medium-sized carnivores
Mitigation Measure	**Type**	**Species-Specific Implementation Considerations**
FENCING	Fencing	• Use of smaller mesh fencing along the bottom of large animal fencing can direct small mammals to wildlife structures; • The bottom end of the fencing must be buried well to prevent digging and entry into the ROW; • For wide ranging mammals, fencing is difficult to implement in short sections because these animals may move around fence ends, fencing in a 'V' pattern may guide animals to crossing structures; • Fence and One-way gates designed for large mammals will allow easy access for these animals onto the ROW (Figure 4.50).
CROSSING STRUCTURES	General	• All wildlife structures should provide cover such as roots, tree branches, rock, wood debris, and grass wads that for prey species; • Vegetative cover at tunnel entrances will help to funnel and direct animals to tunnels (Yanes et al. 1995; Clevenger et al. 2001); • Specialized bat boxes may be installed on crossing structures. An example is the development of a bat culvert made out of a modified drainage culvert in Texas (Texas Department of Transportation 1999); • Structures in aquatic conditions need to implement dry passage modifications such as a bench above high water-levels where the entrance extends into dry habitat.
	Small Terrestrial Tunnel	• Small mammals will tend to use smaller cross-sections (equal or less than 2 m wide), because their lifecycle frequently involves moving along confined spaces, e.g. tunnel-boring mammals such as voles; • Adding ledges (the wider the better), and/or vole tubes to existing culverts that lack a terrestrial wildlife pathway can provide movement opportunities for a diversity of small mammal species (see for example Foresman 2004); • Badgers have been known to travel through drainage culverts as small as 0.25 m in diameter (Figure 4.49; Rodriguez et. al., 1996).
GENERAL	General	• Crossing structures, fencing and signage may be difficult to site at specific road crossings for wide-ranging small animals such as American Badger, therefore a public education and awareness campaign is currently being used in Ontario Link to Ontario Badgers (http://www.ontariobadgers.org/); • If awareness signage is used for badgers then require specific illustration or text to demonstrate sign specificity for this species where it occurs (J. Sayers, pers. comm.); • Multi-species considerations include providing cover (e.g. rocks, root wads) inside larger underpass tunnels and on overpasses for invertebrates, reptiles, amphibians, and small mammals (Connolly-Newman 2013).

Road Design Mitigation Measures	
Small and Medium-Sized Mammals	Rodents, Rabbits, Weasels, Badger, Red Fox, Lynx up to the size of medium-sized carnivores
 Figure 4.49 A badger exits a small drainage culvert (R. Klafki).	 Figure 4.50 Lynx are able to reverse-traverse one-way gates designed for large ungulates (MTO, Northeastern Region).

Fact Sheet 4b. Amphibians: Salamanders, Frogs, and Toads

Road Design Mitigation Measures		
Amphibians		Salamanders, Frogs and Toads
Mitigation Measure	**Type**	**Species-Specific Implementation Considerations**
FENCING	Fencing	• Fencing at least 40 cm high arranged in a 'V' pattern to guide amphibians to crossing structures; • Use fencing that allows drainage; however mesh size needs to be small enough to prevent amphibians from climbing fence (MNRF 2015); • Fencing height should be from 30 to 60 cm depending on species (MNRF 2016); • Top may be angled away from the roadway to prevent climbing species from going over the fence; • Integrate natural features to funnel amphibians (e.g. wood, stone, earth); • Exclusion fencing should be durable, relatively maintenance free, and smooth enough that salamanders and turtles cannot climb over.
CROSSING STRUCTURES	General	• Site crossings near or along known migration corridors (MNRF 2016); • When using multiple structures with fencing, structures should not be separated more than 50 m (Ryser and Grossenbacher 1989); • Use of amphibian/reptile tunnels is dependent on size and openness, placement, substrate, funnelling to the structure, vegetation cover, moisture, hydrology, temperature and light (MNRF 2016). • Integrate ledges (Veenbaas and Brandjes 1999) or earthen ramps when water flow may impede species use; • With respect to species such as Spotted Salamander, a key factor facilitating amphibian use of a tunnel is the presence of adequate light, which can be influenced by the orientation of the tunnel entrance (Jackson 2002 pers. comm.); • Amphibian use may be enhanced by integrating suitable substrate conditions, cover features, light, and damp conditions; • Open grates or slots along the top of the structure allow moisture into the tunnel important during salamander movements; • Sandy soil should be used to cover the bottom of the tunnel.
	Small Terrestrial Tunnel and Small Drainage Culvert	• Several species of toads and salamanders used drainage culverts with ACO funnel fencing (Great Basin Spadefoot (*Spea intermontana*), Western Toad (*Anaxyrus boreas*), Long-toed Salamanders (*Ambystoma macrodactylum*); Jonquil Crosby, unpublished data); • As road width increases, i.e. greater than 25 m more open tunnels are recommend that are greater than 1.5 m in width (MNRF 2016); Puky et al. (2007) showed newt, toads and frogs used 1 m existing tunnels in a motorway in Hungary. • High water flow during spring melt may need to be channeled or modified to facilitate amphibian passage in smaller drainage culverts;

Road Design Mitigation Measures		
Amphibians		Salamanders, Frogs and Toads
Mitigation Measure	**Type**	**Species-Specific Implementation Considerations**
		• Amphibians have been shown to use smaller open-top tunnels (Long-toed Salamanders; Pagnucco 2011; and open-top tunnels may compensate for openness from larger structures (Jackson et al. 2015); • Arch tunnels that provide the natural bottom substrate are optimal and substrate and microhabitat conditions may be modified to optimize use.

Road Design Mitigation Measures

Amphibians — Salamanders, Frogs and Toads

Figure 4.51. A Green Frog entering a drainage culvert along Highway 7 (MTO East Region).

Figure 4.52 Open-top ACO tunnel on the Long Point Causeway installed for turtle, snake and amphibians passage (K. Gunson).

Fact Sheet 5b. Reptiles: Snakes and Turtles

Road Design Mitigation Measures		
Reptiles		Snakes and Turtles
Mitigation Measure	**Type**	**Species-Specific Implementation Considerations**
FENCING	[Fencing]()	• Fencing needs to use permanent materials, e.g. wood, stone, tight wire mesh, earth, sheet piles, plastic or concrete fencing with a minimum height between 0.6 to 1.0 m depending on the climbing ability of the target species (Figure 4.55; OMNR 2013; MNRF 2016); • Length of funnel fencing is determined by target species and site conditions ((Figure 4.55;MNRF 2016); • Top may be angled away from the roadway to prevent species from climbing and getting over fence Heavy duty temporary silt fencing and wire mesh products used in construction projects and not properly installed may cause mortality for large-bodied snake species (and Figure 4.56).
CROSSING STRUCTURES	General	• Arch tunnels that provide natural bottom substrate are optimal for snakes; • Cover objects at larger crossing structures are ideal for snakes seeking shelter; • Tunnels with water (standing or low flow) will be used by turtles but not by some species of snakes; • Site crossings near or along known migration corridors where turtles or snakes will likely cross roads to access necessary habitat (MNRF 2016); • When using multiple structures with fencing, structures should not be separated more than several hundreds of metres (Carsignol et al. 2005).
	Small Terrestrial Tunnel	• Similar to amphibians, use of small tunnels has been shown to be influenced by size, openness, substrate, vegetation cover, moisture, hydrology, temperature and light (MNRF 2016); • Tunnels should be greater than 1.5 m in width for roads that are 15-25 m wide (MNRF 2016); • Using two structures that open in the median may reduce length and increase openness; • Riparian pathways at least 0.5 to 1.0 m wide on both sides of a spanned waterway can provide movement opportunities for reptiles, amphibians and mammals.
	Small Drainage Culvert	• Turtles and snakes have used smaller drainage culverts, however more open culverts with light and greater width will most likely increase use (Figure 4.54; Caverhill et al. 2011); • A study by Kingsbury et al. (2015) showed that Garter Snakes (*Thamnophis sirtalis*), Eastern Ribbonsnake (*Thamnophis sauritus*), and Copperbelly Watersnakes (*Nerodia erythrogaster neglecta*)used 1.0 m and 0.33 m culverts; • Gunson et al. (2014) documented one Garter Snake enter a 0.5 m drainage culvert and one Northern Watersnake repel from a tunnel (Figure 4.53).

Road Design Mitigation Measures	
Reptiles	Snakes and Turtles
	
Figure 4.53 A Northern Watersnake enters a culvert, but was later seen exiting without crossing (MTO East Region).	Figure 4.54 A Snapping Turtle exits a drainage culvert (MTO East Region).

Road Design Mitigation Measures	
Reptiles	Snakes and Turtles
 Figure 4.55 Small animal permanent plastic fencing (Animex Ltd.) that can be made to specifications to meet target and site specific needs (Animex Fencing).	 Figure 4.56 Snake trapped and killed in reinforced silt fence mesh (OMNR 2003).

Fact Sheet 6b. Bird Mitigation Measures

Road Design Mitigation Measures		
Birds		All species impacted by roads
Mitigation Measure	**Type**	**Species-Specific Implementation Considerations**
	Road Threats	• Bird species are known to fly low over roads while travelling between areas within their breeding grounds or migrating (e.g. King Rails (*Rallus elegans*) and Least Bitterns (*Ixobrychus exilis*; COSEWIC 2009, 2011); • For some bird species, e.g. Barn Owl (*Tyto alba*), Loggerhead Shrike (*Lanius ludovicianus migrans*), Barn Swallow (*Hirundo rustica*), Whip-poor-will (*Caprimulgus vociferous*) and other birds of prey road mortality risk is directly related to hunting and feeding behaviour at roadsides (Figure 4.58; MTO 2015); • Barn Swallows nest on bridges and in culverts, and forage between 1 and 10 m above roads and roadsides (Table 5 of MTO 2015; COSEWIC 2011), making them vulnerable to collisions with vehicles.
MITIGATION MEASURES	General	• Birds will fly over wildlife overpasses (Figure 4.57) and research in Australia has shown that overpasses are used by forest birds to cross roads (Jones, and Pickvance. 2013); • WHA signs may be a plausible and an effective strategy for Least Bitterns, where roads bisect marsh habitat (Jon McCraken, Bird Studies Canada pers. comm.); • Should be accompanied with a public awareness campaign because the bird sign does not depict the specific species; • Embankments along roads (3 m high) located where breeding birds nest would create noise barriers and may force birds to fly above vehicle height (Pons 2000); • Alternatively trees, posts or fences may be used to encourage higher flight; • Forested roadsides and medians can also force birds to fly higher and also lessen the barrier gap caused by roads for forest interior species (St. Clair et al. 1998); • Use less roadside lighting; • In Barn Owl (*Tyto alba*) habitat, plant shrubs, trees and fences along the roadside to decrease habitat openness and discourage hunting (Gomes et al 2009);
	Maintenance	• Removal and destruction of active nests of migratory birds is prohibited during road and construction maintenance activities (see Environmental Protection Requirement WLD-3); • Schedule structure maintenance and construction activities to avoid the nesting period of migratory species (consult with Environment Canada and MNRF to verify the breeding period based on geographic location); • Alternatively, implement measures to discourage nesting prior to maintenance and construction such as deterrent netting/tarps.

Road Design Mitigation Measures	
Birds	All species impacted by roads
 Figure 4.57 A corvid (crow or raven) flying over wildlife overpass, Highway 69.	 Figure 4.58 Red-tailed Hawk perched on side of road possibly to hunt.

4.4 Other Mitigation Measures

4.4.1 Habitat Creation

Habitat creation opportunities can occur in situations where road undertakings unavoidably cross or affect public lands (for example, conservation authority lands, Crown lands). In most of Southern Ontario, opportunities are limited because of the relatively small extent of public land and the predominance of land under private ownership. Habitat creation outside the ROW may require a combination of a special land purchase, a willing and able habitat management steward, and agency negotiation.

The use of habitat creation as an effective measure is largely unknown and monitoring is essential as effectiveness will likely vary on a site-specific basis. Some habitat creation examples are provided below that are intended to provide alternative habitats for amphibians and reptiles (also See OMNR 2015). Other examples of providing habitat to keep animals away from roads and associated infrastructure are nest boxes used to keep Barn Swallows from nesting on bridges that are being upgraded.

Wildlife Habitat Creation

DESCRIPTION

- This may occur where there is a loss of important wildlife habitat or function (vernal pools/wetland for amphibians) caused by roads (Figure 4.59); in this example habitat creation was on Conservation Authority lands;
- Rationale for habitat creation may be when a new road will bisect specialized habitat sites that animals move to seasonally (often across roads), such as nesting, hibernation, or breeding sites.

Figure 4.59 Wetland habitat creation pilot project, York Region

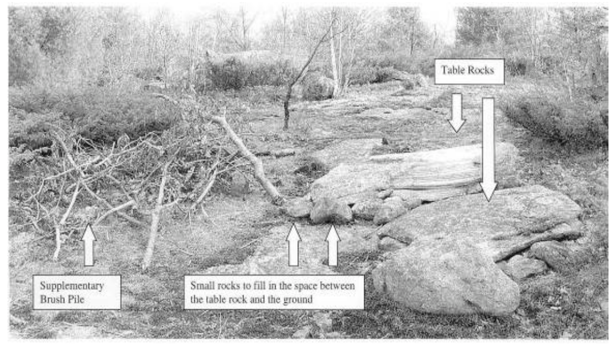

Figure 4.60 Pilot snake gestation site near Highway 69, Ontario

TARGET WILDLIFE GROUPS

Turtles

- Many Ontario turtles move from wetland sites to upland sites such as road embankments for nesting. Turtle mortality occurs either as turtles attempt to nest on the road edge, or attempt to cross the road to reach a suitable nesting site. Providing alternative nesting habitat through creation of sand deposits near the wetland source area or in the movement path, may be a means of obviating the need for turtles to cross the road, or the need of providing a dedicated crossing structure (Beaudry et al. 2010). However, it is possible that turtles may ignore new nesting areas due to nest site fidelity. Further, created nesting sites require maintenance to keep them clear of vegetation. Alternate habitat sites should be used in association with funnel fencing and crossing structures.

Snakes

- Hibernacula sites provide over winter cover for a variety of Ontario snakes (Willson 2005 describes construction of these sites);
- Gestation sites are used by gravid snakes during the period of egg/young development (Parent and Black describes construction of these sites).
- Rock or brush piles away from ROW may be able to substitute for destroyed habitat from new roads, these habitat should be created during construction when suitable equipment and manpower is available;
- For a threatened species such as the Eastern Massasauga Rattlesnake, preferred sites encompass flat table rocks for sunning, smaller rocks for additional cover, and nearby vegetation cover or brush piles for shelter and protection from the sun, as required (Figure 4.60; MNRF 2016).

Amphibians

- Strategic habitat creation, such as vernal pools, on the same side of the road as upland hibernation may prevent animals from crossing roads

Wildlife Habitat Creation	
	(MNRF 2016); • ROW hydrology, e.g. ditching, and drainage should be managed to control runoff flow, and filter contaminants for creation of clean vernal pool habitat for amphibians adjacent to or near roads.
APPLICATION SUITABILITY	• In Ontario, resource agencies at the local/municipal, provincial and federal level are emphasizing habitat creation/restoration work that recognizes and addresses habitat removals and residual effects associated with road construction. Restoration work associated with Highway 407 has entailed both areas within the ROW and additional areas beyond the ROW (including landlocked parcels); • The Bayview Extension on the Oak Ridges Moraine in Richmond Hill, in addition to providing dedicated amphibian tunnels at strategic locations, also provided strategic contour landscaping and buffering along the ROW, as well as a wetland/upland habitat creation area located away from the ROW on Conservation Authority lands (Figure 4.59; Ecoplans and MRC 1997).
ADVANTAGES	• Wildlife use new habitat away from roads, lessening road mortality threat.
DISADVANTAGES	• May require a long time before intended wildlife begins to use the habitat site, due to specific site fidelity; • Effectiveness of measures largely unknown and require maintenance; • Habitat creation initiatives outside the MTO ROW create challenges because of different ownership – see comments above.
IMPLEMENTATION CONSIDERATIONS	• Land-locked parcels provide opportunities for habitat creation/restoration work. However, if these parcels are located off the ROW and under different ownership, then mechanisms will be required to initiate and manage the selected parcel, whether with the current owner, or through acquisition and involvement of other parties; • Unless managed, habitat quality adjacent to busy roads is degraded and projects away from road ROWs are recommended; • Contribution to a habitat banking fund under the jurisdiction of a Conservation Authority or other agency (such as the Nature Conservancy) may be another approach to obtaining land for habitat creation/restoration work; • Proposed habitat creation/restoration plans should be reviewed by species experts in the study area; • Habitat creation/restoration work should utilize compatible, indigenous native vegetation wherever possible, particularly adjacent to significant resource areas.
CONSTRUCTION COSTS	• Vary depending on site size, level of planting effort, and maintenance required.
MAINTENANCE IMPLICATIONS	• Will almost always be necessary to maintain habitat properties for target species, can be integrated into a monitoring plan.

4.4.2 Noise Abatement

Policies for noise abatement for human receptors are in place in Ontario and are applied where criteria are met. Little is known about noise mitigation on roads for wildlife and few guidelines have been developed in Ontario and other jurisdictions.

The limited amount of work specifically looking at noise effects on wildlife (primarily birds) is based on European research. Research in the Netherlands has concluded that a reduced bird density in grassland and forest adjacent to Dutch roads is best explained by noise from roads. Effects were influenced by traffic volume (10,000 or 50,000 vehicles per day) and habitat type (grassland or woodland) and ranged from 125m to 560m away from roads for all bird species combined (Reijnen et al. 1996, 1997). A recent study by McClure et al. (2013) documented a one-quarter decline in bird abundance and almost complete avoidance by some species when a road was mimicked in natural habitat as compared to control site suggesting that traffic noise is a major driver of road effects on birds.

It is not clear from existing research how noise pollution may affect wildlife. It is conjectured that road noise may hinder vocal communication ability amongst birds. However, some species with song frequencies above those of traffic noise may be more abundant near roads, suggesting that they are less susceptible to noise pollution (Rheindt 2003).

It is not clear to what extent other wildlife species are affected by road noise in Ontario or elsewhere. The ability to differentiate road proximity effects and roadway noise in apparently diminished habitat quality adjacent to road continues to be a research challenge and objective. Carefully designed research in the Ontario setting is needed.

Avoiding habitat areas and providing some separation (buffering) between new road facilities and natural core areas are good ways to reduce or eliminate the possible effects on wildlife associated with road noise. Some additional mitigation considerations in the context of road design are as follows:

- Depressing the road grade for new roads adjacent to habitat areas may reduce noise effects due to the berm effect of the adjacent embankments. This design measure should be carefully considered in terms of increased potential for snow drifting, and effects on groundwater interception, which might create more tangible negative effects relative to the noise reduction benefits. Snow drift control can be provided with careful design of plantings, and groundwater interception may not always be a concern;
- Contour grading and landscape planting may also play a role in visual screening and some noise reduction for specific road sections, particularly if such measures are associated with salt spray control. An example of this approach is shown in Figure 4.61.

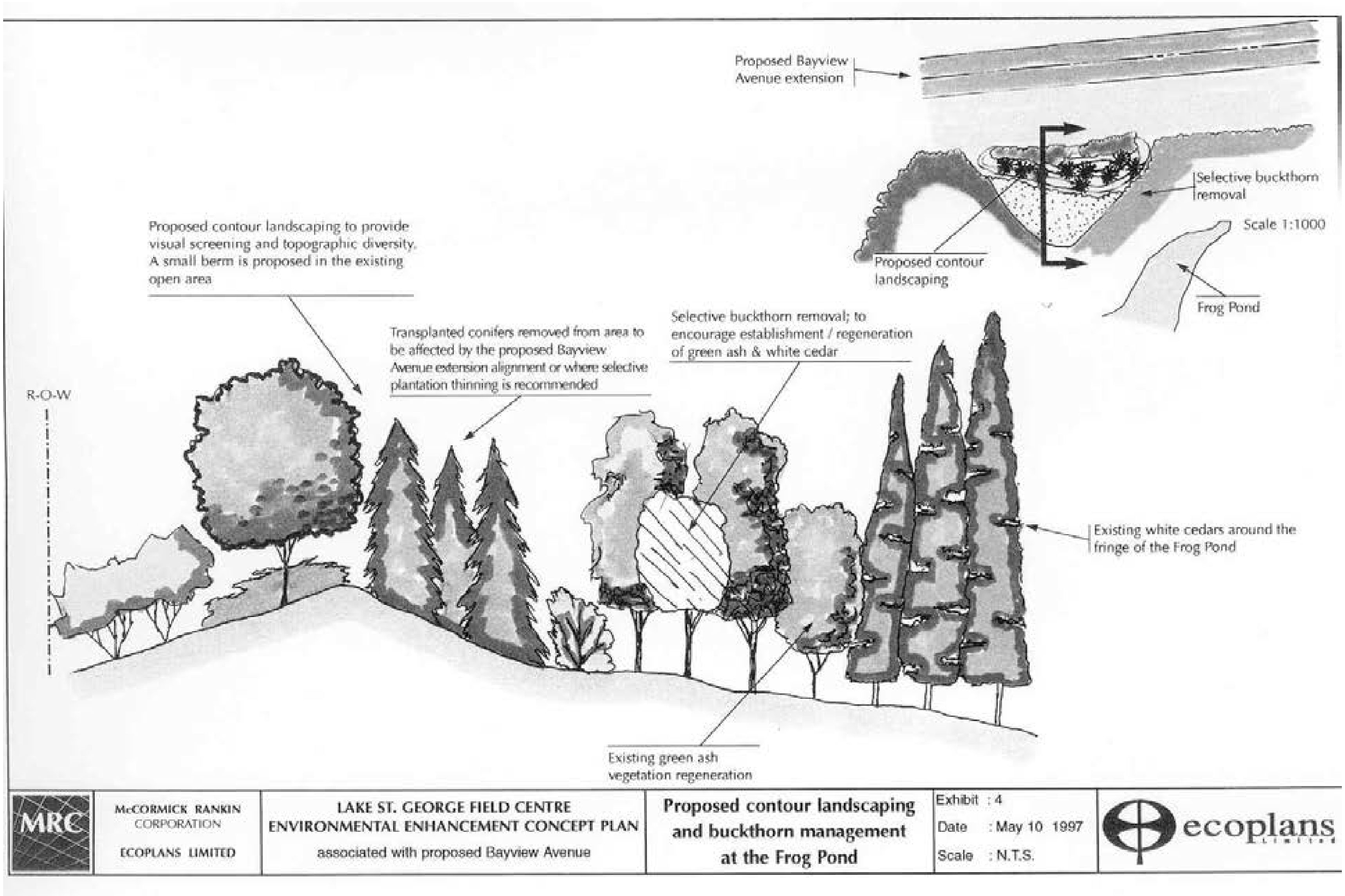

Figure 4.61 Berm and Landscape Buffer, York Region

4.4.3 Woodland Edge Pre-Stressing

Woodland edge removal from road rehabilitation or upgrading typically leads to secondary effects associated with edge canopy removal. Increased wind and light penetration facilitates tree damage (such as sun-scald), blow down (of shallow-rooted or hazard trees), spread of light-tolerant invasive plants (to the detriment of native ground flora), and increased susceptibility to salt spray and other contaminants. These effects can combine to reduce wildlife habitat quality.

Woodland edge management and pre-stressing can soften these effects and facilitate development of a new edge, particularly if pre-stressing can be initiated in advance (1 or 2 years) of actual clearing and road construction.

Figure 4.62 is an example of a pre-stressing and woodland edge management concept for a major Regional Road in York Region, Ontario that illustrates this type of approach and that was implemented in advance of construction.

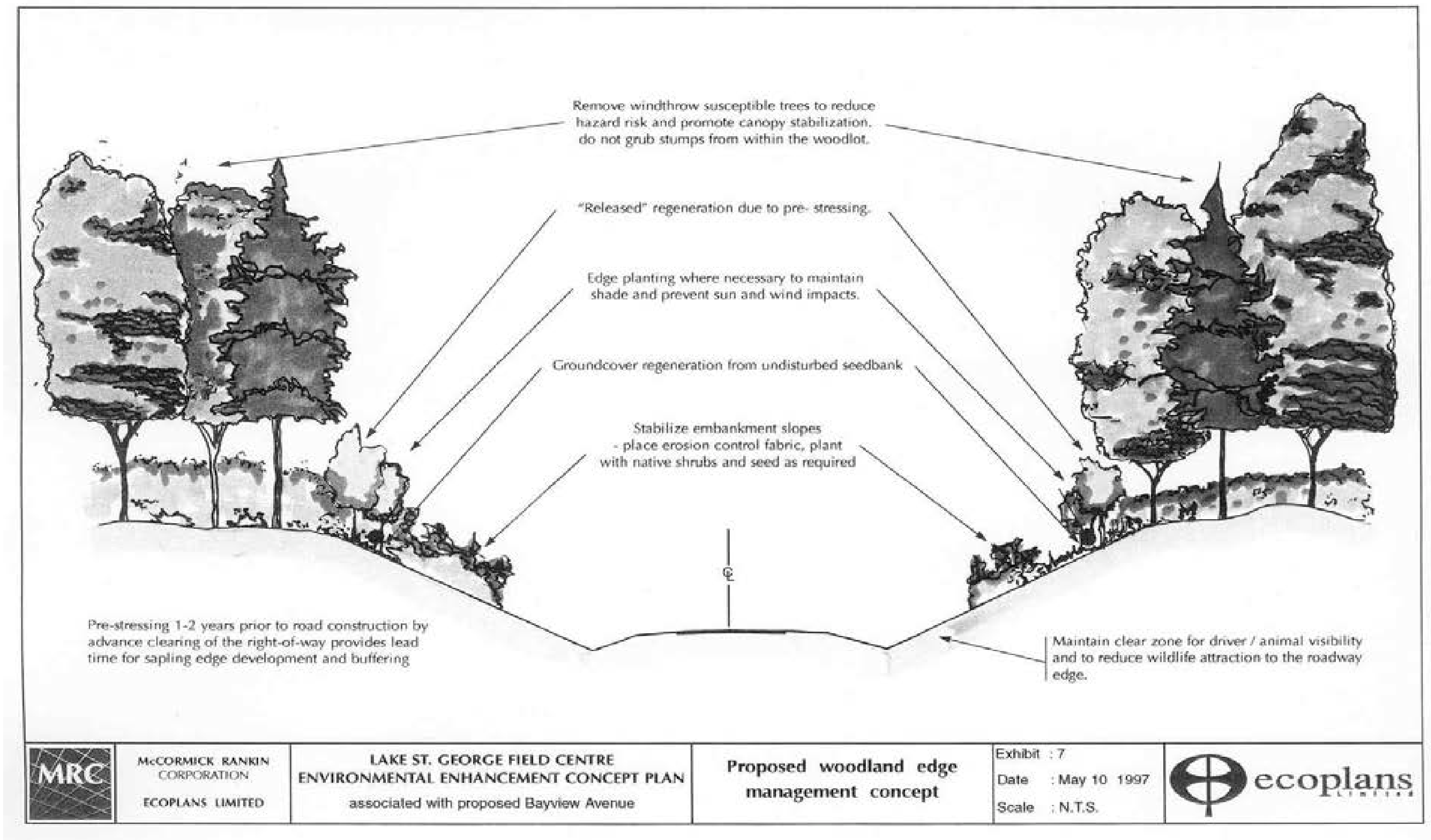

Figure 4.62 Woodland Edge Management Concept, York Region

5 QUALITY ASSURANCE AND MONITORING

Quality Assurance and Quality Control is normally undertaken to ensure that: 1) mitigation design specifications are complete and accurately translated into contract drawings and documents; 2) mitigation measures and structures are properly implemented in the field; and 3) mitigation structures (such as wildlife crossing facilities) are working after the construction project is completed.

An environmental specialist with road assessment experience should be part of any design review to ensure that terrestrial and aquatic environmental objectives are considered throughout the design process and in any proposed design revisions. The environmental specialist must be fully aware of the environmental setting of the project and the rationale for the environmental protection measures proposed in the original design.

5.1 Monitoring – Are Wildlife Crossing Structures Working?

Research is lacking that informs the best design for wildlife road mitigation measures as well as whether mitigation improves population abundance of target species near roads. Some studies have looked at comparisons of crossing structure design types for large animals and have measured effectiveness by comparing relative abundance information surrounding structures with information on wildlife using the structures (Clevenger et al. 2001; Clevenger and Barrueto 2014; MTO 2014). This information is needed to adequately measure design preferences of crossing structures by specific species.

The largest research gap for wildlife mitigation effectiveness is whether mitigation systems have an overall benefit for wildlife populations (Lesbarrères & Fahrig 2012; van der Grift et al. 2013). Recently work by Sawaya et al. (2013 and 2014) have shown that crossing structures are effective at providing genetic and demographic connectivity for bear populations in Banff National Park. More rigorous monitoring that measures population level effectiveness such as before-after-control-impact (BACI) studies (Roedenbeck et al. 2007) are required to lessen uncertainty and to evaluate and optimize mitigation dollars for wildlife conservation.

Several guideline compilations for monitoring mitigation measures have been compiled (see Clevenger and Huijser 2011, OMNR 2013; Andrews et al. 2015). Another recent document provides guidelines for both mitigation design and monitoring techniques for amphibians and reptiles (MNRF 2016). Table 6.1 below summarizes the pros and cons of wildlife structure monitoring techniques for all animals based on a literature review and Table 6.2 summarizes the research questions and monitoring approach that needs to be undertaken to adequately inform mitigation effectiveness.

Table 5.1 Monitoring Wildlife Mitigation Measures: Crossing Structures

Technique	Application	Advantages	Disadvantages	Sample References
Tracks and track beds	ID wildlife tracks in mud bottom of structure or in installed track beds (mud, marble dust or fine white sand) at both ends of structure. Rake beds clean after each check; suitable for underpasses where pads are sheltered from weather events; suitable for terrestrial mammals	Relatively easy to install and check. Have been used in passages ranging from 0.25 to 13 m in width. Varieties of wildlife species are detectable.	Cost-benefit analyses have shown that camera monitoring is more successful than track pads; difficult to determine number or direction of animals if many tracks.	Clevenger and Waltho 2003; Ford et al. 2009; Mata et al. 2008.
Snow tracking	Assess winter wildlife tracks entering and exiting underpasses and travelling on overpasses.	Relatively cost-effective because do not have any set-up costs, i.e. mother nature provides medium.	Completely weather dependent for sample size and quality of tracks; specialized skills required for tracking and identifying to species with gait, shape, and size of tracks.	Singleton and Lehmkuhl 1999; Barnhum 2003; Alexander and Waters 2000; MTO 2014.
Ink and soot panels	Ink beds or soot panels with paper placed on either	Effective for small mammals and possibly amphibian tracks. Can	Will not ID to species for some groups (such as amphibians). Prone	Jackson and Tynin 1989; Veenbaas and Brandjes

Technique	Application	Advantages	Disadvantages	Sample References
	side of structure to record tracks of small animals passing through.	distinguish between amphibian groups (not species) if good print available.	to wash out if structure flooded. Species moving through drainage course will not be recorded. Requires weekly checks and periodic replacement of panels. Some species may jump over panels.	1999; Federal Highway Administration 2002; Clevenger et al. 2001.
Infrared or motion activated cameras	Camera installed in structure and triggered by either motion detector or infrared beam; cost increases with settings available; able to determine species, and in most cases behaviour, records date, time and temperature.	Good for recording medium and large size animal passage – photo ID is usually possible. Range of wildlife species can be recorded with proper placement/design. Motion detectors may be more effective for larger mammals. Can collect information on movement direction, frequency, time and date. Digital camera units are now widely used and only need to be checked one time a month; some cameras are able to take video footage however others have rapid-fire which enables 10-15 pictures to	Can be prone to theft. Motion activated cameras not as reliable with cold blooded animals because require a differential in temperature between object and ambient temperature. Motion activated cameras are better for smaller animals, however require animal to break a beam so need to be strategically placed for where animal is moving.	Woodhouse et al. 2002; Brown et al. 2004; Dodd et al. 2007a; MTO 2014; Gunson et al. 2014.

Technique	Application	Advantages	Disadvantages	Sample References
		be taken 0.2 seconds apart when triggered.		
Pitfall traps	Collection pails combined with temporary drift fencing.	With proper design, can confirm species ID/sex and use of structure by frogs and salamanders, some reptiles.	Can be labour intensive for set up and sampling, depending on number of structures and traps. Requires Scientific Collector Permit from Ontario MNRF for animal handling, marking and release (lead time of 2- 3 months for application).	Abson and Lawrence 2003; Ecoplans Limited 2003; Pagnucco et al. 2011.
Direct observations and tagging	Monitoring of tunnel use by amphibians during spring night movements. May include marking or tissue samples; often volunteers used.	Provides direct evidence of tunnel use, opportunity to observe animal behaviour approaching and within tunnels.	Requires several field personnel and/or frequent checks of tunnels, usually over a number of nights; need to be available when amphibians are moving. Scientific Collector Permit required from Ontario MNRF for handling and tissue taking (lead-time of 2-3 months for application).	Jackson and Tyning 1989
Radio-telemetry	Has been used primarily with	Can provide information on crossing rates for	Considerable investment in start-up effort and	Jackson 1999; Woods

Technique	Application	Advantages	Disadvantages	Sample References
tracking	ungulates, large carnivores in US, Europe and Canada.	individual animals. Captures entire animal movement in relation to a study area; best used in a before and after study design. New GPS transmitters can be programmed to monitor animal locations at desired intervals and to fall off the animal at a pre-selected time (used in Elk monitoring in Arizona – 2005).	costs; need to capture, handle and monitor animals. Only obtain data from the animals that have collars, so need to collar an adequate number of individuals from a population.	1990; Land and Lotz 1996; Dodd et al. 2007b

Table 5.2 Monitoring Wildlife Mitigation Measures: Fencing & Crossing Structures

Goal	Monitoring Approach	Methodology
Road-kill Reduction	Pre and Post	• Measured by comparing road kill frequencies pre and post-mitigation.
	Long-term	• For new road construction, road-kill records need to be collected for at least 3 years prior to and 3 year post implementation of wildlife mitigation measures to account for changing conditions that influence wildlife movements, this should be compared to control sites to control for environmental stochasticity.
Barrier Effect Reduction	Habitat Connectivity	• Measured by ensuring passage monitoring, and use of habitat on both sides of structure using techniques from Table 5.1.; Also can measure change in population abundance to assess whether mitigation measures improved negative impacts of the road or wildlife abundance is the same before and after the road extension.
	Genetic Connectivity	• Measure gene flow across roads by obtaining genetic information from wildlife crossings with data collected from surrounding populations; • Document gene flow by showing migration, reproduction and genetic admixture (Sawaya et al. 2014); • Requires longer term monitoring and financial commitments.
	Demographic Connectivity	• Sex and age of individuals using crossing structure (Sawaya et al. 2013); • Estimate the proportions of wildlife populations that use crossing structures; • Can assess sex and age with cameras for ungulate species (MTO 2014), however require genetics data to assess second bullet above; • Can use telemetry data to assess sex and age of individuals using crossing structures (Olsson et al. 2008).

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