Credit Valley Conservation

Fish and Wildlife Crossing Guidelines

CREDIT VALLEY CONSERVATION

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Comments and Suggestions:
This document and the recommendations provided herein was developed based on the most recent scientific research available to Credit Valley Conservation (CVC) as well as professional opinion and experience. CVC recognizes that road ecology is an evolving science with new information becoming available regularly. As a result, CVC will review any new information or technologies that support wildlife crossing provided by the proponent or their consultants in support of their specific project.

If you have any questions regarding the guidelines contact a CVC Planning Ecologist.

1 Executive Summary

Credit Valley Conservation's (CVC) Fish and Wildlife Crossing Guideline provides guidance on reducing impacts to wildlife and incorporating best management practices (BMP) within transportation planning and development projects. The document summarizes the current state of scientific knowledge on road ecology, crossing system design and best management practices in order to:

- Improve the function of natural heritage systems (including municipal, regional and the Credit Valley watershed natural heritage systems)
- Promote land conservation by protecting wildlife species, habitat and movement corridors required for lifecycle processes
- Encourage collaboration and proper consultation with all relevant agencies in order to promote effective and timely project planning, development and review
- Allow proponents to incorporate BMPs, mitigation measures and crossing systems from project initiation
- Improve human and wildlife safety within CVC's jurisdiction and reduce costs associated with vehicular-wildlife collisions

Proponents are responsible for familiarizing themselves with all relevant information and ensuring compliance with the legislation and policies of all applicable agencies. The information provided within this guideline is not authoritative, but recommended in order to minimize application review time and ensure the protection of significant ecological features and their associated functions within CVC jurisdiction.

Part of CVC's mandate is to conserve, restore and manage the natural resources in the Credit River watershed. CVC has Memorandums of Understanding (MOUs) with many of our member municipalities to identify significant natural features and functions, and to review environmental studies for any development that may impact natural features and functions. Under Ontario Regulation 160/06 (Development, Interference with Wetlands and Alteration to Watercourses and Shorelines Regulation), CVC reviews development proposals to ensure any interference with wetlands or alterations to a watercourse is acceptable and that any development within a regulated area meets all CVC requirements under the Regulation including conservation of land.

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2 Overview

Road ecology studies the impacts of roads and traffic on fish and wildlife, and their habitat. It is an important discipline that informs conservation efforts in light of the negative impacts roads can have on fish and wildlife populations. The impacts of roads can be direct or indirect. Direct impacts include habitat loss, road mortality and injury. Indirect impacts include habitat fragmentation, wildlife population decline, habitat degradation, barriers to fish passage and road avoidance behaviour by wildlife.

Fish, mammals, birds, reptiles and amphibians are all vulnerable to the impacts of roads, which includes effects to species abundance and diversity. These impacts have been particularly detrimental to reptiles and amphibians due to their biology and behaviour (e.g. thermoregulation on warm asphalt, nesting on gravel roads and shoulders, slow moving, low fecundity and late age of maturity). Poorly designed crossings impact fish by limiting access spawning, feeding, nursery or refuge areas. It is important to consider that the roads do not impact all species similarly and it may take several generations for impacts to be realized. Long and short term effects of transportation design on wildlife must be considered in order to minimize future impacts.

Wildlife-vehicular collisions cause substantial damage to motor vehicles and have an impact on human safety and the economy. Each year, an estimated six per cent of motor vehicle collisions involve wildlife, sometimes resulting in human fatalities and injuries. There can be substantial costs associated with repairing damaged property (MTO, 2016). More vehicle-wildlife interactions can be expected due to future population growth and increased development. This makes appropriate road design increasingly necessary.

When properly designed, culverts and bridges can function as crossing structures to safely and effectively allow fish and wildlife to cross beneath a road. This reduces the number of wildlife-vehicle interactions and enables fish and wildlife to access habitat that may otherwise be inaccessible. Crossing structures tied in with fencing to funnel wildlife to the structure are even more effective since they prevent wildlife from crossing a road overland. Studies indicate that fencing that extends beyond the natural area can further reduce wildlife-vehicle collisions. For the purpose of this document a fish and/or wildlife crossing structure coupled with fencing is considered a *crossing system.*

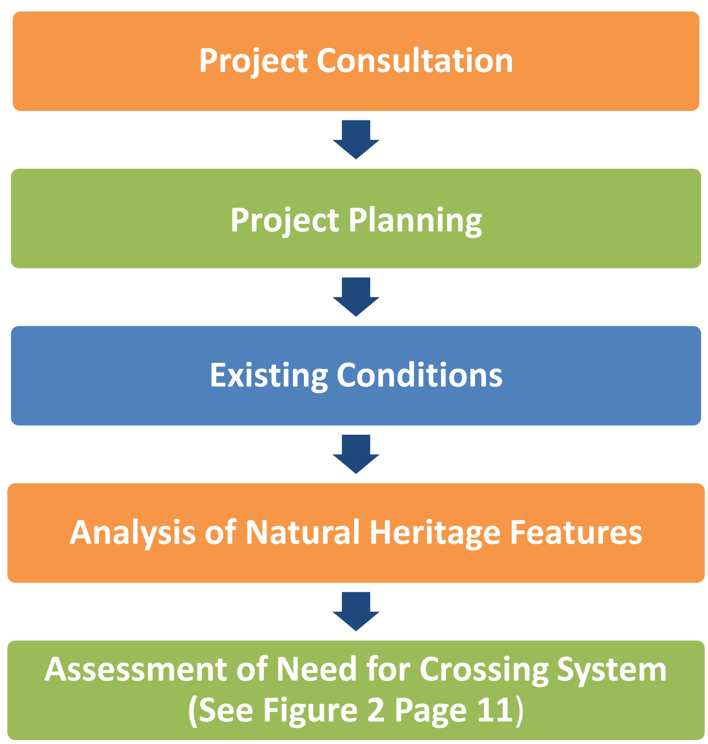
Assessing the natural heritage features of a site can inform when and what type of crossing system is recommended. These guidelines apply to terrestrial and aquatic species and help proponents determine what surveys are required, when and what types of design features and/or mitigation measures are warranted and for what particular group of species or habitat type. While this document describes best management practices for crossing system design, CVC prefers options that avoid natural heritage features altogether. Where this is not possible, best management practices and mitigation measures should be considered.

Part of CVC's mandate is to conserve, restore and manage the natural resources in the Credit River watershed. CVC has memorandums of understanding (MOUs) with many member municipalities to identify significant natural features and functions and to review environmental studies for any development that may impact them. Under Ontario Regulation 160/06 (Development, Interference with Wetlands and Alteration to Watercourses and Shorelines

Regulation), CVC reviews development proposals to ensure any interference with wetlands or alterations to a watercourse is acceptable and that any development within a regulated area meets all CVC requirements under the Regulation including conservation of land.

Figure 1 can be used by the proponent to determine when a crossing system is necessary, and how to design for target species or habitat type. CVC recommends using the Fish and Wildlife Crossing Guidelines for all private and public linear infrastructure and crossing proposals within CVC's jurisdiction that go through the *Environmental Assessment Act, Planning Act* or CVC Regulations process. This includes new roads, road widenings, culvert and bridge replacements, and fish and wildlife impact mitigation retrofits. Given the dynamic nature of transportation projects and their approvals process, the following recommendations do not act as a blueprint approach for all projects. Proper consultation with all involved stakeholders is still required. Although most of CVC's review of crossings is for roadworks, these crossing guidelines can be applied to projects involving railroads, trails and laneways.

Figure 1: *Steps to determine when to incorporate fish and wildlife crossing systems and best management practices in new roads and upgrades to existing roads. Please refer to sections 4-9 of this document for more information on assessing the need for a crossing system, determining target wildlife species, analyzing the natural heritage features, best management practices and design considerations.*



3 Project Consultation

Consulting with CVC, municipalities and other regulatory agencies throughout all phases of a project can ensure the preservation and enhancement of habitat connectivity and safe and effective fish and wildlife passage. It will also encourage a timely review of the submissions.

CVC recommends the proponent consult with CVC, municipalities and other regulatory agencies in order to:

- review current legislative and policy requirements
- co-ordinate and integrate the Fish and Wildlife Crossing Guidelines with other local and/or regional municipal environmental report requirements
- scope any environmental study requirements based on the scale of the project and the significance and sensitivity of natural heritage features
- identify the required practitioners who should undertake the appropriate environmental studies

4 Project Planning

It is important to consider fish and wildlife at each stage in a road project, starting with the planning phase. When assessing preferred alternatives, new roads should avoid the Credit River Watershed Natural Heritage System (CRWNHS), municipal natural heritage systems (NHS) and significant habitats (e.g. wetlands, woodlands, watercourses, valleylands, habitat for species at risk (SAR) and known migration routes/wildlife movement corridors). Collecting field data and reviewing existing background data can provide the proponent with information to create a constraints map.

Where roads cannot avoid significant habitats, they must be designed to minimize potential impacts to fish and wildlife, incorporating crossing and mitigation measures as appropriate. Crossing systems can help maintain and support local and regional biodiversity.

Best management practices that minimize wildlife-vehicular interactions and promote fish and wildlife passage should also be considered at the planning stage. This includes traffic calming measures, downcast lighting, and timing road construction and maintenance activities to avoid sensitive timing windows for wildlife.

The majority of road-related projects CVC reviews are for existing roads that require modification or upgrading (e.g. widening, culvert replacement, changes from rural to urban cross section). These projects should be viewed as opportunities to enhance existing crossing structures or apply new mitigation measures in cases where they were previously absent. Installing crossing structures and wildlife fencing during the construction phase of a new road or upgrade of an existing road is more cost effective than retro-fitting the road with these design features post-construction.

The cost of mitigation measures must be considered when evaluating alternatives during the route planning stage. Taking the precautionary approach and incorporating crossing systems at the planning stage can limit the need for detailed fish and wildlife, or road mortality surveys.

Taking the **precautionary approach** and incorporating crossing systems and/or best management practices designed to safely pass the anticipated or target wildlife at the planning stage can save the client the expense and effort of completing detailed fish and wildlife, or road mortality surveys.

5 Existing Conditions

Identifying fish and wildlife passage needs for both existing and new roads may involve a combination of desktop analysis and fieldwork. Detailed surveys may not be required if the precautionary approach is taken and crossing systems are installed when a road crosses the CRWNHS, Municipal NHS, a known or potential significant habitat (e.g. wetlands, Significant Woodlands, aquatic or terrestrial habitat for SAR), or in known hot spots of wildlife road mortality. In order to minimize the time and costs associated with completing surveys, field data collection and reporting, CVC recommends that proponents assume the presence of wildlife species in areas with identified significant habitat features. Please note that some projects may require the completion of these surveys for purposes other than fish and wildlife crossing considerations as a result of the regulatory/ legislative process (i.e. as defined in Environmental Impact Study (EIS) Terms of Reference (TOR) or Environmental Assessment (EA) process). If a proponent wishes to implement the precautionary approach within their project, appropriate consultation with CVC and all applicable agencies is still necessary to identify site features and target wildlife, as well as to scope project requirements in order to support successful wildlife passage.

5.1 Background Assessment/Desktop Analysis

Background data is to be collected and analysed before the start of field surveys. This information can be used to identify and map features that are likely to provide habitat connectivity or wildlife movement opportunities, including watercourses and natural areas bisected by roads.

- Natural Heritage: Contact CVC and Ministry of Natural Resources and Forestry (MNRF) for existing natural heritage data, including CRWNHS and features mapping and fish community mapping.

- Species at Risk (SAR): Contact the MNRF to request a SAR screening. If SAR are identified in the area, provide a statement about each SAR, as it relates to habitat suitability on the site and potential impacts on the species and/or habitat as related to roads (e.g. direct road mortality, habitat fragmentation, etc.).

- Road Mortality/Wildlife-Vehicle Collision Records: For existing roads, Municipal (Road Departments) and Provincial (MTO) data can be used to identify potential road mortality hot spots (for one possible method, see Gunson et al. 2012 - https://www.rom.on.ca/sites/default/files/publication/pdf/nwjz.121401.Gunson.pdf

- Traffic Volume – Information Request: Contact the MTO, local municipality or region to request traffic volume data (existing and forecast). Traffic volume can have a significant impact on the ability of wildlife to successfully cross a road. Roads with an average annual daily traffic (AADT) of >300 cars have been shown to have a substantial impact on wildlife. Aquatic species will not be affected by traffic volume; successful passage is dependent upon the proper design of a bridge or culvert.

- Land Use: Consider existing and future land uses. Wildlife crossing systems may not be appropriate in locations where natural heritage features have been permitted for removal on one or both sides of the road or where future development will negate the benefits of their construction.

Table 1 provides a summary of data type and sources that can be consulted in the completion of background assessments.

Table 1: *Type, source, and spatial extent of data for background assessments*

DATA TYPE	DATA SOURCES	SPATIAL EXTENT OF DATA
Ecological Land Classification (ELC)	CVC	CVC Jurisdiction
Corridor mapping	CVC	CVC Jurisdiction
Waterbodies and watercourses (including related hazard considerations such as floodplain etc)	CVC	CVC Jurisdiction
Natural features and systems (e.g. woodlands, wetlands, CRWNHS, Municipal NHS etc.)	CVC	CVC Jurisdiction
	MNRF	Ontario
	Municipal NHS	Municipal Jurisdiction
Fish communities	CVC	CVC Jurisdiction
	MNRF	Ontario
Fish spawning records	CVC	CVC Jurisdiction
Species at Risk records	MNRF	Ontario
Road kill observations	Regional and local municipalities (Roads Department)	Municipal Jurisdiction
	MTO (Annual Road Safety Reports)	Ontario
	Ontario Reptile and Amphibian Atlas	Ontario
Wildlife-vehicle collisions	Police	Police Jurisdiction
Culvert data (may also include species usage, incidental wildlife observations and flows).	CVC	CVC Jurisdiction
	Local municipalities	Municipal Jurisdiction

5.2 Supporting Field Surveys

If the proponent chooses not to take the precautionary approach, ecological surveys and field studies must be conducted prior to the design and evaluation of alternative solutions. Some or all of the following surveys may be necessary depending on the scale of the project and the natural heritage features present. The scope will be determined during pre-consultation. These surveys must be done by qualified individuals who carry out the approved protocols at an appropriate scale, in the appropriate season and at the appropriate time. This document provides recommendations for wildlife crossing systemBMP's, but certain projects may require some or all of the aforementioned surveys for purposes other than wildlife crossing system assessments (i.e. as defined in the EIS TOR/ EA Planning Phase). Where it is not possible to carry out the recommended survey procedures (i.e. in cases where access to private lands is not granted) the precautionary approach should be taken and habitat should be assumed to continue into adjacent areas. The following surveys and methods are adapted from various provincially recognized protocols and/or current scientific information as prescribed by regulatory agencies (i.e. MNRF, CAs, MOE, MTO).

- Vegetation community assessment:
    - To be completed based on the protocol of the Ecological Land Classification System for Southern Ontario, first approximation (Lee *et al*. 1998).

- Assessment of existing crossing for fish and wildlife passage:
    - Assessment of structure permeability and use by fish and wildlife (e.g. existing dimensions and openness ratio, evidence of existing passage, limitations to terrestrial passage, presence and suitability of substrate within culvert, etc.).
    - To be completed for all existing crossings.
    - Map wetlands, watercourses, areas of groundwater upwelling *etc*..
    - Identification of substrate and water depth inside structure
    - Confirmation of bankfull channel under the crossing
    - Identification of barriers (e.g. perched culvert, woody debris *etc*.).
    - Assessment to be carried out in the spring during periods of high flow and in August under low flow conditions. High/ low flow data to be utilized to assess fish passage within the structure. See Appendix 2 for swimming speed of various species.

- Fish community:
    - Surveys to be completed if no existing or insufficient information on fish community is available
    - Electrofishing
        - Intermittent watercourses - April to June
        - Permanent watercourses - June to September
    - Spawning surveys – contact CVC for spawning protocol
        - Brook trout – October to November
        - Pike – March to April

- Amphibian call surveys:
    - To be completed where wetlands are within 200m of the road.
    - To be completed according to the protocol outlined in the Marsh Monitoring Program (Bird Studies Canada, 2009) with respect to timing and weather conditions.
    - CVC recommends extending the duration of each point count from the standard 3 minute length to 6 minutes to help ensure the data collected is representative

of the habitat conditions and function. CVC suggests the increased survey length recognizing that the existing protocol was designed for monitoring and not habitat function assessment.
    - If chorus frog (*Pseudacris triseriata*) is believed to be in the area and appropriate habitat conditions are present, day time surveys are required.

- Vernal pool surveys:
    - To be completed where vernal pools are present within 300m of the road.
    - Complete egg mass surveys and/or minnow trap surveys for the detection of woodland breeding amphibians.
    - Surveys are to be completed between March and May, depending on local weather and site conditions.
    - MNRF to be contacted for necessary permitting.

- Turtle nesting surveys:
    - To be completed where wetlands or open aquatic habitats are within 200m of the road.
    - Identify and map areas of sand and gravel substrates in open, sunny locations.
    - Nesting surveys are to be completed between late May and early July to observe actively nesting turtles.
    - Surveys to detect predated nests should be completed in June/July to increase chance of species identification based on egg size and count.

- Turtle basking surveys
    - To be completed where wetlands or open aquatic habitats are within 200m of the road.
    - Basking surveys to be completed in the morning/early afternoon between late April to July using binoculars on sunny days with temperatures between 50 °F (10 °C) and 80 °F (27 °C).
    - If basking traps are proposed, MNRF to be contacted for necessary permitting.

- Wildlife movement corridors (potential and existing):
    - To be identified and mapped, based on presence of valleyland features, critical habitat (e.g. overwintering, breeding, nesting etc.), and/or evidence of established crossings (e.g. defined paths, road mortality "hot spot" *etc.*).
    - Unconfined or confined valleylands should be considered as potential movement corridors in areas where there is an absence or scarcity of larger valley systems (e.g. in urban areas).

- Significant wildlife habitat (potential and confirmed):
    - To be identified and mapped, both onsite and on adjacent lands.
    - Refer to *MNRF Significant Wildlife Habitat Technical Guide* (2000), *MNRF Significant Wildlife Habitat Mitigation Support Tool* (2015), *MNRF Eco-Regional Criteria Schedule for 6E and 7E* (2015), and *Peel Caledon Significant Woodlands and Significant Wildlife Habitat Study* (North- South Environmental Inc., Dougan & Associates and Sorensen Gravely Lowes, 2009) for guidance on thresholds and habitat mapping.

- Road mortality surveys:
    - CVC recognizes that road mortality surveys are labour intensive and typically not required.
    - May be required when a road bisects a sensitive natural area, or when there is existing evidence of heavy road mortality.
    - Can be completed for the length of the study area, or in targeted areas depending on adjacent natural heritage features (scope to be determined during pre-consultation).
    - Surveys should be completed by walking or biking, as surveys by car can underestimate road mortalities for small bodied animals.
    - Multiple years of data should be collected to determine hot spot locations
    - Sample data sheet provided in Appendix 1.

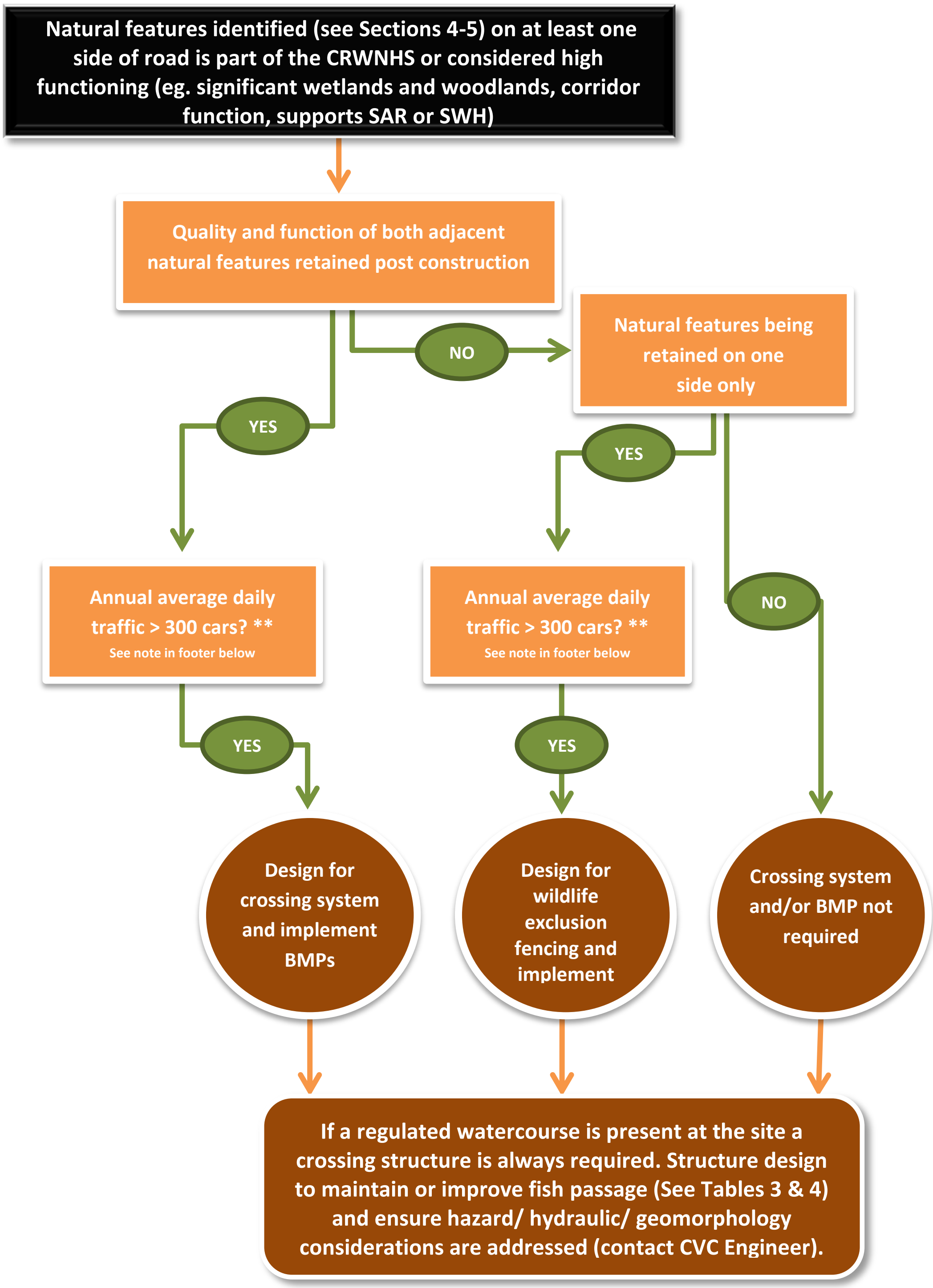
6 Analysis of Natural Heritage Features

Background and site level field assessment data should be analyzed and used to create a map that identifies where crossing systems are necessary to limit road impacts. Crossing systems must be considered when adjacent habitat on at least one side is part of the CRWNHS, a Municipal NHS or considered sensitive or significant (e.g. wetlands, watercourses, valleylands, woodlands, habitat that provides important corridor function, or supports significant wildlife habitat or habitat for species at risk). They must also be considered when there is evidence of existing road mortality or collision hot spots. Fish passage must be considered for all watercourse crossings. It is important to consider that thresholds for determining significance tend to be lower in urban areas compared to rural areas due to a more fragmented landscape, smaller size and lower quality of available habitat, lower species diversity as well as higher human populations and the corresponding number of vehicles.

7 Assessment of Need for Crossing Systems

Figure 2 can be used as an assessment tool to help determine when roads should be designed with wildlife crossing systems and when mitigation measures and/or aquatic passage should be considered. As defined previously, a crossing system refers to a crossing structure that is tied in with fencing. Best management practices refer to all other design or behaviour modification approaches to minimize impacts, including exclusion fencing without the use of crossing structures. Please note that a CVC Planning and Development Services review team, along with external agencies (i.e. MNRF) will assess each project individually. Using field data, experience and expertise, it will be determined when and where wildlife crossing systems and/or BMPs are necessary to limit potential impacts. This chart does not presuppose the degradation or removal of natural heritage features within a project site. Additional consultation and review is required in order to reach an agreement that is acceptable for the proponents, CVC, municipalities and all applicable agencies.

Figure 2: *Assessment tool to determine when roads should be designed with crossing systems, and when mitigation measures and/or fish passage should be considered*



*Crossing system design/ BMPs dependent on the target wildlife species/ group. Refer to Sections 7-9.

**** If annual average traffic volume is less than 300 cars a crossing system/ BMPs are typically not required. Considerations for fish passage is still required if a watercourse is present at the site.**

***Refer to Tables 3 & 4 for crossing system design considerations and BMPs by wildlife group.

If a fish or wildlife crossing structure and/or fencing is warranted based on the ecological assessments described in previous sections, the target fish or wildlife group(s) may be identified (see **Table 2** for the preferred habitat of different groups of wildlife common to the CVC watershed). The recommended design for crossing structures and fencing is dependent on the species or groups of species being targeted. Size, shape and material of the crossing can have an impact on crossing success for different species. Height, length, material and depth of fencing can affect a crossing system's success in funneling target species away from the road and through the crossing structure. There may be limited data available on certain wildlife in the watershed and wildlife surveys can be labour intensive and not always accurate in the depiction of species present Due to this, assumptions can be made on the likelihood of different groups of wildlife present based on habitat type as classified through preliminary ecological assessments.

Table 2 identifies preferred habitat movement corridors for different groups of wildlife. Habitat quality also affects species presence. While there are many ways for evaluating and ranking habitat type and quality within literature (i.e. Gunderson); professional experience, individual site evaluations and background data collection are most effective for determining the need for crossing systems.

Table 2: *Preferred habitat interactions of different groups of wildlife common to the CVC watershed.*

Preferred Habitat Movement Corridors	Wildlife Group
Valley > 3m deep	• Large mammals (e.g deer, coyote)
Forest to Forest	• Large mammals (e.g deer, coyote) • Small mammals (e.g. mouse, vole, squirrel) • Mid-sized mammals (e.g. fox, raccoon, skunk) • Amphibians and reptiles (e.g. frog, salamander, turtle, snake)
Forest to Meadow	• Large mammals (e.g deer, coyote) • Small mammals (e.g. mouse, vole, squirrel) • Mid-sized mammals (e.g. fox, raccoon, skunk) • Reptiles (e.g. snakes)
Forest to Wetland	• Amphibians and reptiles (e.g. frog, salamander, turtle, snake) • Small mammals (e.g. mouse, vole, squirrel) • Mid-sized mammals (e.g. fox, raccoon, skunk)
Wetland to Wetland	• Amphibians and reptiles (e.g. frog, salamander, turtle, snake)
Meadow to Meadow	• Small mammals (e.g. mouse, vole, squirrel) • Mid-sized mammals (e.g. fox, raccoon, skunk) • Reptiles (e.g. snakes)
All watercourses	• Fish and other aquatic species • Amphibians and reptiles (e.g. frog, salamander, turtle, snake) • Small mammals (e.g. mouse, vole, squirrel) • Mid-sized mammals (e.g. fox, raccoon, skunk)

***Note:** It is assumed that birds, bats, butterflies, odonates and other insects will travel between all habitats. Crossing systems are not designed specifically for these species, however, BMPs may be used to provide impact mitigation.

9 Fish and Wildlife Crossing and Fencing Design

A crossing system should be designed to allow for passage of all anticipated or target species identified by assessing the natural heritage features of an area. This could include the design of a multifaceted crossing system that accommodates passage for multiple species along the project span. For instance a road widening and culvert replacement project could incorporate components of large mammal passage (i.e. fencing) as well as amphibian and fish passage (i.e. bridge or BMP culvert installation). For further information on crossing system BMPs for various species please refer to Table 3.

New and the retrofitted crossing structures and fencing should integrate engineering and ecological requirements. This minimizes the risk of natural hazards, reduces road mortality and maintains or improves habitat connectivity. Ecological considerations for crossing structures and fencing are addressed in the proceeding sections. Design should be collaborative and should involve engineers and/or geomorphologists to ensure all engineering and natural hazard mitigation requirements are met (i.e. flooding, erosion, geomorphology). Refer to relevant CVC guidelines for other technical requirements.

9.1 New Crossing Structures

Crossing structures are presumed necessary for all watercourse crossings and for roads that bisect the CRWNHS, municipal NHS or habitat that is considered high functioning. This is true for new roads or for upgrades where culvert replacement is required. The significance of natural features is determined on an individual project basis in consultation with CVC and external regulatory agencies (i.e. municipalities, MNRF, NEC, etc.). Crossing structures can be dedicated terrestrial (i.e. dry) wildlife passages. They can also be required for hydraulics, geomorphology and fish passage, and have design elements to ensure dry passage for all or part of the year (e.g. over-sized banks, terrestrial shelves etc.). Crossing structures will ideally be designed to maximize species usage and maintain or improve connectivity at an ecosystem level. While some larger crossing structures (i.e. bridges, viaducts, culverts) may integrate human access, these structures should be designed to prevent human-wildlife impacts.

General recommendations for all wildlife crossing structures include ensuring that structure openness ratio (OR) and dimensions are adequate for the target species or habitat, and structure length is minimized to the extent possible. OR refers to the amount of light visible at the end of a structure and in road ecology is used as a measure of the permeability of the crossing structure to wildlife. It is calculated as the cross sectional area of the structure entrance divided by its length (all measurements in meters):

OR for:

Box Culvert = [Height X Width]/ Length

Corrugated Steel Pipe (CSP) = $[\pi r^2]$/Length
*where π= 3.14 and r= radius of the CSP opening

Studies have been completed on minimum recommended OR for different groups of wildlife. Achieving these sizes should be the target where possible. Minimizing culvert length, maximizing culvert height and width, and designing culverts with slotted openings on top to allow light to penetrate are design features that can increase OR. Hydraulics, geomorphology, cost, the footprint of the road and sensitivity of adjacent natural areas are factors that must also be considered in the sizing and design of the structure.

In addition to OR, it is important to consider placement of and spacing between structures, the shape of the structure, substrate and vegetation present, embeddedness, approaches and fencing. Clear line of sight from one end of the structure to the other is also important for some species. If crossing structures are designed to accommodate the target species with more restrictive passage preferences (e.g. largest openness ratio, tightest spacing etc.), the expectation is that they will often be suitable for other species whose preferences are not as limiting. In most cases design elements for different wildlife and habitat groups can be incorporated into a single design to increase likelihood of multi-species usage.

9.2 Retrofitting an Existing Structure

When there is a pre-existing road and it is not possible to replace an existing crossing structure, there are several mitigation measures that can be implemented to improve wildlife crossing. The extent of mitigation is determined through the same assessment process outlined in Figure 1. **The design engineer should be consulted prior to altering design features for any existing structure designed to pass flow.** Mitigation measures include but are not limited to the following:

- Removing barriers at structure entrances that could impede fish and wildlife passage (e.g. grates, fencing).
- Clearing debris/obstructions within the structure that impede passage.
- Improving the natural substrate or cover within the structure.
- Installing fencing to guide wildlife towards crossing structure entrances.
- For a structure with no dry passage for terrestrial species, installing ledges along the structure length on both sides, with ramps at structure entrances.
- Planting native vegetation around structure entrances to provide cover to wildlife, while maintaining clear line-of-sight through the culvert.
- Installing baffles in the structure to provide/enhance fish passage.
- If culvert is perched, applying mitigation measures to provide/enhance fish passage.

Additional measures that can be implemented while retrofitting an existing structure are identified in **Section 9: Best Management Practices**.

9.3 Fencing

Crossing structures alone may not effectively mitigate the impacts of roads. Conditions within structures can vary drastically from conditions on the surface of the road, which may deter wildlife from using them. Fencing enhances the effectiveness of crossing structures by funneling wildlife to these openings and creating a barrier to prevent them from crossing overland, reducing rates of road mortality. Alternatively, wildlife fencing may be used as a standalone management practice for scenarios in which the goal is to deter or exclude wildlife from crossing the road (i.e. a full crossing system with structures and fencing is not required). For instance, an area in which suitable habitat is only present on one side of the road.

Fencing, as interpreted in this document, is considered to be any type of barrier, including retaining walls and vertical trenching. A variety of different fencing material can be effective depending on the target species, including concrete, recycled plastic material, sheet piling, page wire fencing, and silt fencing. In addition, temporary and permanent one way movement and exclusion systems have been design specifically to keep wildlife off roads and funnel them to crossing structures (http://animexfencing.com/, http://www.aco.co.uk/index.php).

The target species should be a consideration when selecting fencing materials in order to reduce the risk of entanglement, and the opportunity for wildlife to climb the fence, pass underneath or through openings.

Fencing should be continuous on both sides of the road with no gap between the fence and the crossing structure entrance. The terminus of the fence should curve away from the road and be located beyond the target natural area, in a location where wildlife is less likely to cross the road. It is important that there be no vegetation or debris adjacent to the fence for wildlife to use as a ladder. Fencing should be located a sufficient distance from the road to minimize vehicular encroachment, and damage from snow removal and road maintenance.

Table 3 provides recommendations for the design of crossing structures and barrier fencing for different groups of wildlife and habitat types. The information in this table was compiled from several sources, including: Biolinx Environmental Research Ltd and E. Wind Consulting 2004, Cavallaro *et al*. 2005, Arizona Fish and Game Department 2006, Ecoplans Limited 2006, Beier *et al*. 2008, Ontario Ministry of Transportation 2008, Ontario Ministry of Natural Resources and Forestry 2016, Stantec Consulting 2010, Clevenger and Huijser 2011, Kintsch and Cramer 2011, OMNR 2013, Gunson *et al*. 2014, Eco-Kare International and the Town of Oakville 2015, Toronto and Region Conservation Authority 2015.

Table 3: *Wildlife crossing and fencing recommendations for species and habitats commonly found within the Credit River watershed*

WILDLIFE GROUP	OPENNESS RATIO (m)	CROSSING STRUCTURE DIMENSIONS	PLACEMENT / SPACING OF CROSSING STRUCTURES	SUBSTRATE WITHIN CROSSING STRUCTURE[1]	APPROACH TO CROSSING STRUCTURE	FENCING *where fencing is to be used as standalone/ exclusion strategy, eliminate ramps/ gates/ fence openings from design	OTHER CONSIDERATIONS
Large mammals ***e.g. deer, coyote***	• 0.6-1.0 for ungulates • 0.2 for other large mammals	• Recommend width and height both ≥3 m, but no less than 2 m tall • For ungulates, length should not be > 90 m without an open median	• Dependent on topography (i.e. valley over 3 m), habitat and target species • Ideally spaced every 1.5 km	• Natural, dry substrate that is vegetated where possible • Avoid use of rip-rap • If medium-large sized stone is required, fill interstitial spaces with material appropriate for wildlife footing	• Natural vegetative cover adjacent to entrances, while maintaining clear line-of-sight	• Galvanized steel chain-link fencing, retaining wall or similar, 2.8 m tall with posts every 4-5 m • Bottom of fence buried 20-40 cm underground to prevent animals from digging under • Angling fence away from road may prevent animals from climbing over • Fence should extend a min. 500 m on either side of crossing and incorporate earthen ramps or one-way gates every 0.5-1 km	• Minimal or no human use of structure • On highways, an open median can increase light levels and reduce tunnel effect, encouraging use of structure by deer
Mid-sized mammals ***e.g. fox, raccoon, skunk***	• Recommend ≥0.4, but no less than 0.1	• Width and height each ≥1 m	• Ideally spaced every 150-300 m • Multiple crossings are typically not required for this wildlife group. Incorporate dry passage for mid-sized mammals into crossing structures for other wildlife where possible.	• For dry culverts, install natural substrate with some cover (e.g. branches, debris) to provide refuge from predators • If medium-large sized stone is required, fill interstitial spaces with material appropriate for wildlife footing	• Natural cover (e.g. woody debris, flat rocks), and native vegetation near to entrances and leading to adjacent habitat	• Galvanized steel chain-link fence, retaining wall or similar, 1-2 m high • Bottom of fence buried 20-40 cm underground to prevent animals from digging under • Fence should extend a minimum 500 m on either side of the crossing and incorporate escape routes (earthen ramps or one-way gates) every 0.5-1 km	• Incorporate dry terrestrial passage zone at least 0.5-0.7 m in width (preferably 1 m) on either side of a watercourse • Incorporate elevated ledges in structures with no terrestrial passage zone • Cutback adjacent vegetation from fencing structures to prevent arboreal species from climbing over the fencing and into the ROW
Small mammals ***e.g. mouse, vole, squirrel***	• 0.05	• Width and height each 0.3-1.0 m	• Ideally spaced every 50m • Multiple crossings are typically not required for this wildlife group. Incorporate dry passage for small mammals into crossing structures for other wildlife where possible.	• Dry culverts - install natural substrate with some cover (e.g. branches, debris) to provide refuge from predators • Avoid rip-rap as this can impede animal movement • If medium-large sized stone is required, fill interstitial spaces with material appropriate for wildlife footing	• Natural cover and native vegetation near to entrances and leading to adjacent habitat	• Solid permanent material (e.g. concrete, aluminum), Animex, ACO or equivalent fencing, or hardware cloth with ¼ inch mesh or less • 1-1.8 m tall, depending on the jumping/climbing ability of the target species, and with a 15 cm wide lip along the top edge angled away from the road at 45° to prevent animals from climbing over • Bottom of fence buried 10-20 cm • Cloth fencing can be attached to the bottom of fencing for larger wildlife • Consider backfilling with natural soil and plant materials on side of fence adjacent to road. This may decrease impacts from snow collection, allow animals that become trapped in the ROW to climb over and decrease any visual/ aesthetic concerns	• Many species prefer dark lighting conditions • Incorporate dry terrestrial passage zone at least 0.5-0.7 m in width (preferably 1 m) on either side of a watercourse • Incorporate elevated ledges in structures with no terrestrial passage zone • Cutback adjacent vegetation from fencing structures to prevent arboreal species from climbing over the fencing and into the ROW • Incorporate cover structures within dry passage area of crossing (i.e. brush piles, roots, rock, grass)
Amphibians and Reptiles ***e.g. frog, salamander, turtle, snake***	• Turtles recommend ≥0.25, but no less than 0.1 • Amphibians and snakes recommend ≥0.1, but no less than 0.07	• Recommend width and height both ≥1 m, but no less than 0.5 m • Length ideally less than 25 m	• Ideally aligned with predictable movement paths (e.g. annual migration routes) • Structures should be no more than 50-100 m apart for amphibians (depending on migration radius of species) and 150-300 m apart for reptiles	• For dry culverts, install natural substrate with some cover (e.g. native soil, leaf litter, branches, debris, sod) to provide refuge from predators • Many species prefer/require moist substrate • Avoid large rocks and rip-rap • If medium-large sized stone is required, fill interstitial spaces with material appropriate for wildlife footing	• Natural cover but not obstructing entrance • Minimal/low growing vegetation to maintain clear path and line-of-sight	• Solid permanent material (e.g. concrete, aluminum), Animex, ACO or equivalent fencing, or hardware cloth with ¼ inch mesh or less • Height 0.4-1.2 m, depending on jumping/climbing ability of the target species. MNRF recommends a minimum height of 30 cm for salamanders, 60cm for turtles and 100 cm for snakes and anurans • Include a curved design or a 15 cm wide lip along the top edge angled away from the road at 45° to prevent animals from climbing over • Bottom of fence buried 10-20 cm • Fence should extend 100 m on each side of crossing structure • Cloth can be attached to the bottom of tall fencing	• Ambient light, temperature and moisture conditions maintained where possible; can be facilitated through the addition of slots/grates • Utilize cover structure (i.e. brush piles) at entry and exit of structure while ensuring clear line of site through the structure is maintained. • Steel is not a desirable material for structures due to its conductivity, which makes it cold during the spring migratory period • Polymer concrete maintains temperature and moisture conditions • Turtles prefer crossings with standing water or moderate flow

[1] Any engineered substrate of culverts/bridges must meet hydraulic/geomorphological requirements

						• Consider backfilling with natural soil and plant materials on side of fence adjacent to road. This may decrease impacts from snow collection, allow animals that become trapped in the ROW to climb over and decrease any visual/ aesthetic concerns	• Incorporate 0.5-1.0 m of terrestrial/ riparian passage zone on either side of a watercourse • Incorporate ledges in structures with no terrestrial passage
Fish	• N/A	• Preferred hierarchy of crossing structure: bridge> open box> closed box > CSP • Minimum bankfull span • Culvert not perched	• All watercourses	• Open bottom is required to maintain natural stream substrate and processes • Native substrate if closed bottom • Backfill with native substrate consistent with the existing upstream substrate size and texture • If stone is part of the design rounded or sub-angular is required.	• 10-20% embedded • Vegetation to provide stream shading • Pools U/S & D/S of culvert • Natural stream gradient should be maintained U/S, D/S and through the watercourse crossing. • Ensure low flow channel provided within structure. Minimum depth of water in low flow 15-20cm.	• N/A	• Match habitat conditions (e.g. stone sizing) inside the structure to natural conditions. If not possible, ensure conditions (e.g. water velocity and depth) allow passage. • Consider baffles as part of design for retrofits • Design for 0% slope in culvert where feasible • For slopes > 5% contact CVC planning ecology • Consider fish passage capabilities in relation to flows through the structure and swimming speeds of target fish species/ groups.. Refer to table in Appendix 2 for swimming speeds of various species/groups of fish.

10 Best Management Practices

In addition to installing fish and wildlife crossing systems, municipalities can incorporate BMPs into the design of a road, through the construction, operation and maintenance stages. BMPs can mitigate the impacts of roads on fish, wildlife and human safety, and can be applied to new and existing roads. **Table 4** identifies best management practices for the different target groups of wildlife species. These measures are most effective when implemented in conjunction with properly designed crossing structures and fencing. They can also be effective on their own when other opportunities are limited. Each of the measures in the proceeding table should be reviewed in conjunction with crossing and fencing design. Justification should be provided if implementation is not feasible.

Table 4: *Best management practices for road design and construction, operation and maintenance phases for target groups of wildlife*

Wildlife	Road Design	Construction, Operation and Maintenance
All fish and wildlife	• Minimize footprint of road and length of culvert where feasible. • Whenever possible, design new roads near edges of habitat (as opposed to directly through) to reduce fragmentation and potential need for crossings. • Install traffic calming measures (e.g. speed bumps, rumble strips, roundabouts), wildlife crossing signs, and/or animal-vehicle detection systems. • Install noise barriers (e.g. soil berms or solid walls) to minimize disturbance to adjacent natural areas. • Avoid or minimize artificial lighting adjacent to natural areas and wildlife corridors, unless required for human safety. If lighting is required, use downcast and directional options that avoid unnecessarily broadcasting light to the natural area. • Modify infrastructure (i.e. curbs, drainage grates, Jersey barriers) to facilitate wildlife movement.	• Reduce speed limits on roads with known high wildlife mortality or that bisect natural areas. • Implement seasonal road closures during times of wildlife migration. • Create public awareness and education campaigns. • Wildlife-habitat awareness signage may be placed in areas adjacent to SAR habitat. • Manage roadside vegetation to ensure that drivers and wildlife have a clear field of view. • In the event that a fish and/or wildlife rescue is needed, MNRF should be contacted to obtain a Wildlife Scientific Collector's permit. • Protect the existing habitat during the construction of the road and crossing structure through adequate erosion and sediment control and stormwater management; any measures implemented should be regularly monitored to ensure continued satisfactory performance. • Inspect fences periodically for damage that could affect the integrity of the fence or allow passage of wildlife. Inspections should occur following spring melt and heavy rain events; this is especially important when using temporary geotextile fencing. • Ongoing monitoring and maintenance of crossing structures and fencing post-construction, with adaptive management implemented as needed • Avoid use of salt for winter road maintenance near Natural Heritage System features, especially those adjacent to watercourse crossing structures (i.e. bridges, culverts) • Provide habitat creation/ offsetting at nearby location where impacts cannot be avoided
Reptiles and Amphibians	• During design, light sensitive areas (e.g. wetlands with breeding amphibians) should be mapped in order to inform the appropriate placement (or avoidance) of lighting fixtures. • Consider constructing habitat features for reptiles and amphibians beyond the footprint of the road, including turtle nesting habitat and snake hibernacula. Incorporating these habitat features may reduce the number of individuals attempting to cross the road if all critical habitat features of the species are located on one side of a road. Guidance on the creation of snake hibernacula and turtle nesting areas can be found on the Toronto Zoo website (http://www.torontozoo.com/AdoptAPond/resources.asp). • Incorporate sloped and roughened curbs along roadsides in areas with salamanders and turtles to prevent animals from being trapped in the ROW.	• Temporary fencing should be installed along road embankments/shoulders where work is proposed and around stockpiles of gravelly and sandy substrate to prevent turtles from nesting from late May to early July. • Avoid grading road shoulders during the following turtle nesting and incubation periods: ▪ Turtle nesting: late May to early July. ▪ Nest incubation: June to September. • Do not use fine wire or plastic mesh netting where snakes are present because they are easily entangled and killed in the material.
Mammals	• For bats, install taller streetlights (since bats forage on the insects that congregate near them). Diversionary methods (e.g. vegetation and berms adjacent to the road) can also be used to "lift" bats and encourage them to fly higher over a road. • Avoid constructing roads near or adjacent to known migration or hot spot routes. • Provide sloped and roughened curbs to allow small mammals (e.g.; moles) to get off the road surface.	• Avoid construction near sensitive habitat features and at sensitive times of year (i.e. during deer migration and overwintering yards) • Consider planting species that are less attractive to ungulates for food adjacent to ROW • Install roadside wildlife detection systems for larger mammals where installation of crossing system is limited by topography etc.
Birds	• Installation of diversionary methods (e.g. diversion poles, vegetation, berms, fencing) to encourage birds to fly higher over the road, out of the path of traffic. Diversion poles are used on crossing structures (usually bridges over water), whereas the other methods could be used on any roadway. • Reduced speed limits recommended for some types of birds (birds of prey, scavenger birds, geese, turkeys, grouse, ducks). • Install sound barriers (vegetated or constructed) to reduce potential disturbance in areas providing breeding bird habitat. • Studies indicate that terrestrial passage structures will be utilized by avifauna (specifically geese and ducks) if they are adequately sized (minimum 1.5m width and height, dry or wet passage). Signage and traffic calming measures may also be utilized in areas known for high	• Bridge maintenance activities should be timed to not interfere with bridge-nesting birds (e.g. cliff swallow), if present. • Please be aware of updates to and requirements of the Migratory Birds Convention Act which governs the protection and conservation of migratory birds within Canada. Any potentially destructive or disruptive activity such as vegetation clearing should be avoided between April and August. It is the proponent's responsibility to adhere to all pertinent laws, regulations and permit requirements including but not restricted to the Migratory Birds Convention Act and the Migratory Birds Regulations. Further information on the general nesting periods of migratory birds in Canada can be found at: http://www.ec.gc.ca/paom-itmb/default.asp?lang=En&n=4F39A78F-1.

	concentrations of geese and/or nesting sites.	

Fisheries	• Avoid building on meander bends, braided streams or other unstable areas
	• Fish passage is most easily maintained when the water crossing design maintains natural stream processes within or under the crossing.
	• Avoid use of gravel/unfixed material for road constructions near watercourses. Utilize hard surfaces (such as concrete or asphalt) when possible to limit disturbance impacts such as dust and excess sedimentation.
	• Use natural substrates in the crossing.
	• Avoid areas containing confirmed or potential breeding habitat.
	• Remove barriers and improve fish passage where barrier exists
		• Construction should be completed in the dry, when there is no flow in the channel, or by use of a by-pass channel, dam and pump or other construction techniques..
		• Work during low flow conditions and avoid work during large precipitation/runoff events
		• In-water works to be completed between
		  ▪ July 1st and March 31st for warmwater communities;
		  ▪ June 15th and September 15th for coldwater communities; and
		  ▪ July 1st and September 15th for Redside Dace habitat.
		• Maintain fish passage during construction where feasible
		• Minimize the extent and duration of dewatering
		• Stabilize and re-vegetate any disturbed areas as soon as possible

11 Monitoring

Post-construction monitoring will be determined during the consultation process with CVC and other regulatory agencies through the planning process. Monitoring fish and wildlife crossing systems is not a typical requirement of linear infrastructure projects, however, it may be required under certain circumstances (e.g. in areas of high significance, as defined in the EIS TOR or EA process, or as a requirement of other regulatory agencies). Monitoring requirements typically relate to multiple aspects of a project (i.e. site stabilization, restoration success) however, incidental field observations may be used to determine a relative level of success for crossing system implementation. Monitoring guidelines are available by contacting CVC. For further information on appropriate strategies for monitoring wildlife crossing systems please refer to the *CVC Guidelines for Monitoring Fish and Wildlife Crossings*.

12 Glossary

Best Management Practices (BMP) - approaches based on current knowledge/ understanding that when utilized, seek to limit the potential negative impacts and achieve objectives. For instance, the use of wildlife crossing systems is a BMP of road ecology in limiting negative human-wildlife interactions on roadways.

Confined Valley Systems - means where the watercourse is located within a valley corridor, either with or without a floodplain, and is confined by valley walls. The watercourse may be located at the toe of the valley slope, in close proximity to the toe of the valley slope or removed from the toe of the valley slope. The watercourse can contain perennial, intermittent or ephemeral flows and may range in channel configuration, from seepage and natural springs to detectable channels.

Constraints Map - a map that documents and visually communicates all of the environmental concerns and restrictions that apply to an area, which can thereby be used to predict the best (if any) location at a site that is suitable for development.

Credit River Watershed Natural Heritage System (CRWNHS) - a system of natural heritage features, buffers on these features, and natural heritage areas in the Credit River watershed, intended to strategically protect and connect natural habitat, including both terrestrial and aquatic ecosystems. The natural heritage features of the system include valleylands, woodlands, wetlands, aquatic habitat, Lake Ontario shoreline, significant wildlife habitat and habitat of endangered and threatened species. For more information, please see the Credit River Watershed Natural Heritage System Final Technical Report (http://www.creditvalleyca.ca/wp-content/uploads/2015/12/CRWNHS-Phase-3-Natural-Heritage-System-methodology_2015-10-02-FINAL.pdf).

Crossing system - a fish and wildlife crossing structure coupled with fencing

Hydraulic assessment - Assessment of water flow, substrate and water depth inside structure

Hydrologic system - Wetlands, watercourses and areas of groundwater upwelling

Openness Ratio (OR) **-** cross sectional area of the structure entrance divided by its length (all measurements in meters)

Road Mortality Hot Spots - Areas exhibiting high rates of wildlife mortality due to vehicle collision

Sensitive and Significant Habitats - all watercourses and wetlands, significant woodlands, significant wildlife habitat (SWH), habitat for Species at Risk (SAR)], and known migration routes/wildlife movement corridors and linkage features.

Traffic Calming Measures - the utilization of physical design and other measures (such as behaviour modification) to improve safety for motorists, pedestrians and cyclists. It aims to encourage safer, more responsible driving and potentially reduce **traffic** flow.

Unconfined Valley Systems - means those systems where the watercourse is not located within a valley corridor with discernable slopes, but relatively flat to gently rolling plains and is not confined by valley walls. The watercourse can contain perennial, intermittent or ephemeral flows and may range in channel configuration, from seepage and natural springs to detectable channels.

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Appendix 1 - Road Mortality Surveys

Road mortality surveys can be labour intensive and may or may not be required by CVC depending on the scale of the project, the sensitivity of adjacent features, and whether or not appropriate design and mitigation is proposed. A sample data sheet has been provided below in the event that road mortality surveys are required.

Different groups of species exhibit patterns of road mortality that are often seasonal and coincide with the species' life history. When road mortality surveys are required they should be completed at different times of the year in order to fully assess the impacts of the road on wildlife populations. General patterns in Ontario include the following:

- Turtles exhibit high rates of mortality in late May to June, which coincides with breeding and nesting.
- Snakes exhibit bimodal peaks in road mortality in early spring and late autumn, coincident with emergence from and migration to hibernacula.
- Frogs and toads exhibit a bimodal peak in road mortality associated with adults moving to wetlands to breed in the spring, and juveniles moving from wetlands to upland habitats following metamorphosis in the summer. Surveys should be completed on warm rainy nights to yield the most accurate results.
- Generally mammals have not been shown to exhibit a seasonal pattern in road mortality, likely due to the fact that in Ontario many are active year round.

Hot spot locations can vary year-to-year. Multiple years of data should be collected prior to identifying hot spots.

Road Mortality Study Field Sheet

Observers:

Date: ______________________ **Air Temp:** _______°C
Start Time: _____________ **End Time:** _____________
Survey Method: Driving Biking Walking
Precipitation: None Light Heavy

Status
AOR – Alive On Road
ABR – Alive Beside Road
DOR – Dead On Road
DBR – Dead Beside Road

Survey Comments:

Wildlife Observations

#	Species	Status	Position & proximity on road	UTM		GPS Acc. (+/- m)	Comments (e.g. behaviour, size, etc.)
	EXAMPLE Snapping Turtle	AOR	Centre of northbound lane, facing W – 1m from edge of road	**E**	0597560	4	Turtle crossing from E to W side of rd – size of carapace 28cm from back of neck to tail – leeches on R rear leg
				N	4843928		
				E			
				N			
				E			
				N			
				E			
				N			
				E			
				N			
				E			
				N			
				E			
				N			

Continued From: Date:_______________ Observers: ___________________________________ Page ____ of ____							
#	Species	Status	Position & proximity on road	UTM		GPS Acc. (+/- m)	Comments
				E			
				N			
				E			
				N			
				E			
				N			
				E			
				N			
				E			
				N			
				E			
				N			
				E			
				N			
				E			
				N			
				E			
				N			
				E			
				N			
				E			
				N			

Appendix 2 – Fish Swimming Speeds

Adapted from *MTO Environmental Guide for Fish and Fish Habitat* (2006). The following chart can be used in conjunction with flow data and fish collection records to determine if a structure is passible by the target species or species groups. If it is not passable, improvements and BMPs should be adopted to ensure passibility.

Species end Life Stage (size – mm)		Sustained* Speed (m/s)	Prolonged* Speed (m/s)	Burst * Speed (m/s)
Coho	Adults Juveniles (120mm) Juveniles (90mm) Juveniles (50mm)	0.0 – 2.7	2.7 – 3.2 0.4 – 0.6 0.3 – 0.5 0.2 – 0.4	3.2 – 6.6
Chinook	Adults	0.0 – 2.7	2.7 – 3.3	3.3 – 6.8
Rainbow Trout	Adults Juveniles (125mm) Juveniles (50mm)	0.0 – 0.9 0.0 - 0.38 0.0 – 0.15	0.9 – 1.8 0.38 – 0.75 0.15 – 0.3	1.8 – 4.3 0.75 – 1.13 0.3 – 0.45
Brown Trout	Adults Juveniles (>75mm)	0.0 – 0.7 0.0 – 0.6	0.7 – 1.9	1.9 – 3.9
Arctic Char	Adults		0.6 – 1.1	
Arctic Grayling	Adults	0 – 0.8	0.8 - 2.1	2.1 – 4.3
Whitefish	Adults	0 – 0.4	0.4 – 1.3	1.3 – 2.7
Walleye	Adults (230 – 410mm) Adults		0.0 – 1.1	
Carp	Adults	0 – 0.4	0.4 – 1.2	1.2 – 2.6
Suckers	Adults	0 – 0.4	0.4 – 1.5	1.6 – 3.1
Small forage fish	(50 – 65mm) **	0 – 0.22	0.22 – 0.29	0.29 – 0.40
Medium forage fish	(90 – 110mm) **	0 – 0.31	0.31 – 0.68	0.68 – 0.76
Large forage fish	(180 – 230mm) **	0 – 0.42	0.42 – 0.95	0.95 – 1.11
Game fish	(450 – 750mm) **	0 – 0.8	0.08 – 1.63	1.63 – 2.16

* Sustained speed can be maintained indefinitely.
Prolonged speed can be maintained for up to 200 minutes.
Burst speed can be maintained for up to 15 seconds.
(Chillbeck 1992)

** Calculations based on a generalized relationship between fish length and swimming speed for species using the same swimming form (Katopodis and Gervais 1991).