Guideline for planning wildlife crossing structures

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Acknowledgments

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Animal-Vehicle Collision Mitigation Guidelines

The following guidelines are available to mitigate animal-vehicle collisions in Alberta:

1. Guideline for Planning Animal-Vehicle Collision Mitigations

2. Guideline for Planning Wildlife Crossing Structures (this guideline)

3. Guideline for Planning Wildlife Exclusion Fencing

1.0 Preface

The purpose of this guideline is to promote the effective design of animal-vehicle collision (AVC) mitigation on provincial highways. Consultants (engineering and environmental; the Consultant) shall follow this guideline when preparing an AVC Mitigation Plan with wildlife crossing structures for Alberta Transportation and Economic Corridors (the Department).

This guideline emphasizes specifications to mitigate for AVCs and shall inform the planning and design of wildlife crossing structures. This guideline is supplemental to the Department's *Bridge Conceptual Design Guidelines*. If discrepancies exist between this document and the *Bridge Conceptual Design Guidelines*, the *Bridge Conceptual Design Guidelines* shall take precedence. Guidance provided herein is based on collaboration among Alberta Transportation and Economic Corridors' Technical Standards Branch, Alberta Environment and Protected Areas, and Parks Canada, input from other provincial jurisdictions, and a thorough review of prevailing AVC mitigations and best practices at the time of preparation. Updates are expected occasionally as new information becomes available and more AVC mitigations are constructed in Alberta.

The below guidelines are not a substitute for professional engineering and biological advice that may be necessary for site-specific conditions. Close collaboration is expected, and should begin in the early design stages, among consulting biologists, ecologists/landscape architects, bridge engineers, traffic safety engineers, and the Department's Regions and Technical Standards Branch (Bridges and Environmental Regulation sections).

2.0 Introduction to Wildlife Crossing Structures

Wildlife crossing structures physically separate wildlife from traffic and allow safe wildlife passage across roadways. Underpasses (below-grade crossings) and overpasses (above-grade crossings) are the typical crossing structures used to mitigate for AVCs when paired with a wildlife exclusion fence[1].

The Department recommends that all wildlife crossing structures are paired with an exclusion fence to keep wildlife off the roadway and to guide wildlife towards the crossing structure when mitigating for AVCs. Wildlife crossing structures alone, without fencing, do not reduce AVCs (Clevenger and Huijser 2011; Dodd et al. 2007; Rytwinski et al. 2016).

2.1 Typical Use Scenario

Wildlife crossing structures, in combination with exclusion fences, are an effective mitigation to improve motorist safety as they physically separate wildlife from traffic. Typically, a wildlife crossing structure is suitable:

- When the objective is to improve or maintain wildlife connectivity across a fenced roadway.
- Where suitable wildlife habitat will continue to exist, on either side of the road, within the service life of the structure.
- On high and low volume roads with high design speeds (≥80 km/hr).
- Where quality habitat exists, and wildlife selectively travel.

[1] Refer to the Guideline for Planning Wildlife Exclusion Fencing.

2.2 Effectiveness

Collision Reduction

Wildlife crossing structures paired with a wildlife exclusion fence are effective at reducing AVCs and providing connectivity for wildlife across the roadway. An exclusion fence that extends along the roadway for at least 5 km consistently reduces AVCs with large-bodied animals by 80-100% (Huijser et al. 2016a). Shorter fences have a more variable effectiveness (0 - 94%) and are less overall effective in reducing collisions (Huijser et al. 2016a).

Wildlife Connectivity

Many species will use a well-designed and well-situated crossing structure (Clevenger and Huijser 2011; Huijser et al. 2016b). When combined with an exclusion fence, crossing structures maintain wildlife connectivity similar to, or as an improvement of, unmitigated highway sections (Huijser et al. 2016b). Together the crossing structure and exclusion fencing may also increase the population size, improve gene flow, allow for seasonal migration, and improve population viability or population persistence of target species by reducing unnatural mortality and reducing the barrier effect of the transportation corridor (van der Ree et al. 2009; Sawyer et al. 2012; Sawaya et al. 2014).

3.0 Typical Design

Many factors contribute to the success of a wildlife crossing structure project and influence wildlife usage, including the exclusion fence design. This guideline describes the crossing structure type, the structure's placement and dimensions, wildlife sightlines and cover, target wildlife species, and human use as key factors to consider when designing a wildlife crossing structure. Factors to consider when designing a wildlife exclusion fence are available in the *Guideline for Planning Wildlife Exclusion Fencing*.

3.1 Structure Types

Purpose-built underpasses and overpasses are suitable to mitigate for AVCs when combined with an exclusion fence. Although designed for purposes other than for wildlife, multi-span watercourse bridges, viaducts, livestock passes, and other highway structures (i.e., bridge files[2], culverts[3]) may also be used to mitigate for AVCs, if the design criteria outlined in this guideline are met. Retrofit these existing structures to incorporate AVC design criteria or improve the design during a replacement/new bridge construction.

The Department's *Bridge Conceptual Design Guidelines* (version 3.0) apply to all bridge planning in Alberta. These bridge design guidelines cover structure types (i.e., all bridge size structures), sizing, geometrics, hydrotechnical design, and more. The Consultant shall follow the *Bridge Conceptual Design Guidelines* when selecting a structure type and incorporate AVC design criteria outlined in the wildlife crossing structure guideline when planning AVC mitigation.

Table 1 lists example structure types and dimensions used in Canada and the United States to mitigate for AVCs. The dimensions describe the width, height, and length of the structure from the perspective of the animal and are shown in Appendix A.

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[2] Bridge files are structures greater than (>) 1.5 metres (m) diameter. These can include bridge-sized culverts, standard bridges, and major bridges.

[3] Culverts are buried structures that are less than or equal to (≤) 1.5 m diameter.

TABLE 1: EXAMPLE WILDLIFE CROSSING STRUCTURE TYPES IN CANADA AND ELSEWHERE

Wildlife Crossing Structure Type[1]	Example Structures[2]		Typical Dimensions	Example Photo
Wildlife Overpass	▪ Alberta: – 50 m wide, Highway 1 Banff National Park (Wakeling et al. 2015) – 60 m wide, Highway 1 Bow Valley Gap (due to open in 2023) ▪ British Columbia: – 60 m wide, Highway 1 Yoho National Park – 7 m wide, Highway 1 Golden – 7 m wide, Highway 1 near Yoho National Park	▪ Ontario: – 30 m wide, Highway 69 – 120 m wide, Herb Gray Parkway Ecopassage ▪ Wyoming: – 46 m wide, Highway 191 (Western EcoSystems Technology Inc. 2015)	40-60 m wide	 Redearth Overpass, Alberta Highway 1 (photo credit: Parks Canada)
Open/Single Span Bridge Underpass	▪ Alberta: – 13 m wide x 5 m high x 13 m long (plus twinned structure) Stewart Creek (Three Sisters) underpass, Highway 1 – 15 m wide x 5.3 m high x 13 m long (plus twinned structure) Wind Valley (Dead Man's Pass) underpass, Highway 1 – Banff National Park, Highway 1, has open span bridges of many sizes. Some examples are (Clevenger and Waltho 2000; Clevenger and Barrueto 2014): • 9 m wide x 2.9 m high x 40.1 m long • 9.8 m wide x 2.7 m high x 27.2 m long • 13.4 m wide x 2.5 m high x 83.2 m long • 14.9 m wide x 3.2 m high x 38 m long • 19.0 m wide x 5 m high x 46 m long • 24 m wide x 4 m high x 47 m long	▪ British Columbia: – 7 m wide x 5.5 m high x 23 m long underpass (plus adjacent single span bridge), Mount Hunter Creek underpass, Highway 1 ▪ Ontario: – 8.5 m wide x 3.25 m high (twinned structure), Highway 26 ▪ Quebec: – 27 m wide x 7.5 m high x 50 m long (twinned structure), Route 175 – 35.5 m wide x 9.5 m high x 45 m long (twinned structure), Route 175 – 120 m wide x 10.9 m high x 14.3 m long, Rivière Calway, Autoroute 73 – 177 m wide x 14 m high x 12.6 m long, Rivière des Plante, Autoroute 73 ▪ Arizona State Route 260 (Dodd et al. 2012): – 9.0 m wide x 6.7 m high x 33.5 m long – 9.8 m wide x 5 m high x 38 m long	12-30 m wide, ≥5 m high	 Deadman's Pass, Alberta Highway 1 (photo credit: Alberta Transportation and Economic Corridors)
Large Mammal Underpass	▪ Alberta: – 4.2 m wide x 3.5 m high x 96.1 m long steel culvert, Highway 1 Banff National Park (Clevenger and Waltho 2000) – 7.3 m wide x 3.4 m high x 62.5 m culvert, Highway 1 Banff National Park – 11 m wide x 7 m high x 60 m long precast concrete arch on the North Highway Connector Project, City of Red Deer ▪ Ontario: – 4 m wide x 4 m high x 16 long concrete box culvert (plus twinned structure), Highway 11 – 5 m wide x 5 m high x 24.1 m length concrete box culvert (plus twinned structure), Highway 69	▪ Quebec: – 6 m wide x 3.8 m high x 26.7 m long prefabricated concrete arch culvert, Route 138 – 10 m wide x 5 m high x 13.4 m long concrete box culvert, Autoroute 73 ▪ New Brunswick: – 4.3 m wide x 4.1 m high x 16.5 m long precast reinforced concrete box culvert, Route 7 – 6 m wide x 4.2 m high x 38.33 m long precast reinforced concrete box culvert, Finnegans Hill Structure, Route 7 – 10.95 m wide x 4.19 m high x 41.42 m long structural plate corrugated steel pipe arch, Hunter Brook (west), Route 2 – 13.46 m wide x 7.32 m high x 81.61 m long structural plate corrugated steel pipe arch, Kerrs Ridge Crossing, Route 1	≥7 m wide, ≥4 m high	 North Highway Connector Underpass, City of Red Deer (photo credit: City of Red Deer)
Medium Mammal Underpass	▪ Alberta: – 3 m wide x 2.4 m high x ~65 m long concrete box underpasses, Highway 1 Banff National Park. ▪ Ontario: – Multiple underpasses (concrete round and box culverts) ranging in size from 0.6 - 2 m diameter, Highway 175.	▪ New Brunswick: – 4.26 m wide x 2.44 m high x 27.43 m long concrete box culvert, Route 114 ▪ Nova Scotia: – 3.1 m wide x 3.7 m high x 50 m long concrete underpass, Highway 101 – 1.86 m wide x 2.43 m high x 58 m long concrete underpass (with an 9.8 m long atrium in median and a greenhouse roof on top to prevent snow accumulating in underpass), Highway 104 (White 2017)	0.8-3 m wide, 0.5-2.5 m high	 Kootenay National Park (photo credit: Parks Canada)

1. Although not listed, dry pipe culverts (typical dimensions 0.3 - 0.6 m diameter) are used by small-medium mammals.
2. Several wildlife crossing structures exist across Alberta including on and off the provincial highway network as well as across Canada and elsewhere. These example crossing structures were designed for specific project objectives and site conditions and should not be viewed as a design recommendation by the Department.

3.2 Structure Placement

The best location for the wildlife crossing structure may not be directly at the AVC-prone location. Instead, consider placing the crossing structure:

1. along the highway with wildlife exclusion fencing,
2. where site-conditions are suitable for construction, and
3. where wildlife naturally travel (e.g., area of quality habitat) and may continue to travel over the life of the crossing structure (~75 years).

The Consultant must consider the following criteria when placing a wildlife crossing structure:

Fences	Pair crossing structures with an exclusion fence because fencing acts to funnel wildlife to the crossing structure and improves the use of the structure (refer to the *Guideline for Planning Wildlife Exclusion Fencing*). The fence should extend at least 1 km beyond the crossing structure.
Site-Conditions	Underpasses are typically in road fills and overpasses in road cuts. While it may be more expensive to construct crossing structures in flat terrain, it is possible by lowering or raising the roadbed for the crossing structure or lengthening the approaches to an overpass.
Site-Conditions	Geotechnical, environmental, and engineering site conditions must be appropriate to maintain the overall integrity and function of the structure. Refer to the *Department's Bridge Conceptual Design Guidelines* and ensure that technical considerations, such as soil stability, snow loads and drifting, and local groundwater levels at candidate wildlife crossing sites, are addressed before construction.
Wildlife Movement	Place the crossing structures where wildlife can easily find them. This includes placing the structures where high-quality habitat for the target species exists on both sides of the highway and or where wildlife are known to cross the highway. River valleys and riparian areas are movement zones for moose, deer, and other species, especially in Alberta's White Area (settled area). In Utah, Cramer (2012) suggested watercourse crossings are an excellent opportunity to improve wildlife passage for most wildlife species. Bridges, designed for purposes other than for wildlife, may be retrofitted and or constructed to mitigate for AVCs and allow wildlife passage.
Wildlife Movement	Place the crossing structures where wildlife are likely to continue crossing for the structure's full service life (~75 years). This may require protecting adjacent lands from development. Key Wildlife and Biodiversity Zones, parks and protected areas, and large riverine valleys have some level of protection from land use development and are good examples of a suitable crossing structure location.
Wildlife Movement	Position the structure opening as to allow the approaching wildlife to see through the structure or to see protected cover on the other side (Bissonette and Cramer 2008; White 2017). For overpasses, make use of existing ridgelines and road cuts. For underpasses, position the crossing structure at the level of the watercourse or bottom of the road fill. Wildlife prefer this position of the structure opening rather than being above or below the approach levels (Bissonette and Cramer 2008; White 2017).
Wildlife Movement	Maximize the distance between the crossing structure and human developments. Nearby townsites and human activity can significantly influence wildlife use of the crossing structure (Clevenger and Waltho 2000), especially for wildlife unaccustomed to human disturbances. It is also important to consider the encroachment of developments (e.g., towns) over the life of the crossing structure (~75 years).
Wildlife Movement	Locate crossing structures away from (to the extent feasible) a parallel rail line, road, and other developments that are unsafe for, or could entrap, wildlife. Rail lines (and their legal boundaries) sometime run parallel to provincial highways (in places separated only by tens of meters) and must be considered when selecting the placement of a crossing structure across a highway. Although Gilhooly et al. (2019) found no evidence of highway fencing and crossing structures changing the distribution of animal-train collisions (TransCanada Highway in Banff National Park), highway AVC mitigation planning should evaluate parallel transportation developments at each site. Passing trains could repel wildlife from using a highway crossing structure and or the crossing structure could funnel wildlife to the rail line and result in animal-train mortality at specific sites. Another parallel road can have similar effects on the crossing structure as a rail line. Avoidance of, and or integration with, parallel transportation developments should be considered.

3.3 Structure Dimensions, General Openness, and Spacing

The best dimensions for a wildlife crossing structure continue to be researched. Although it seems many of Alberta's large mammals seem to prefer larger structures that appear open (Wakeling et al. 2015; Cramer 2013; Clevenger and Waltho 2005). Parks Canada has also seen the best overall results with the larger wildlife crossing structures (T. Kinley pers. comm 2020).

Early wildlife crossing structure literature refers to an openness ratio (structure's height x width / length). A minimum openness ratio >0.6 (based on measurements in meters) for mule deer passage was once suggested, but this has not been well tested and more recently determined that mule deer use underpasses with a smaller openness ratio (Krawchuck et al. 2005). Clevenger and Huijser (2011) discuss the limitations when relying on an openness ratio. It is for these reasons that the Department's design guideline do not specify openness ratios. Instead, this guideline refers to the feeling of openness or confinement as a concept when considering the tradeoffs in underpass width, height, and length design.

Structure dimensions (as seen by wildlife), general openness considerations, and spacing between wildlife crossing structures are described below.

Dimensions	Maximize the width and height and minimize the length of underpasses while also optimizing construction costs. Longer underpass structures should have larger openings to improve the overall openness. For overpasses, maximize the width. Refer to Section 3.5 for species' preferred structure types and dimensions.
Dimensions	Include the terrestrial bank(s) of a watercourse within the underpass to allow year-round dry passage for wildlife. For large mammals, the dry pathways should be ≥2.0 m wide (Clevenger and Huijser 2011) and have a clearance (height) suitable for the target species passage. Refer to Section 3.4 for additional pathway specifications. Erosion, fish and aquatic organisms, and downstream flooding must not be adversely affected by enlarging the structure.
Dimensions	Follow special overhead conditions for overpasses on designated high load corridors.
General Openness	Twin the underpass structures on divided highways, with one structure under each travel direction. Leave the median open and enclose with a fence. Alternatively, incorporate a skylight/atrium at narrow medians but caution that open skylights risk water ponding in the underpass and may require measures to mitigate.
General Openness	Consider additional design features that can contribute to the feeling of openness: ▪ Open span bridges (without structural pillars) feel more open than multi-span bridges. Bridge pillars and support walls contribute to the feeling of confinement. ▪ Narrow pillars, spaced far apart and away from the wildlife pathway, are less confining than support walls. ▪ Earthen slopes at bridge abutments (e.g., 2:1 slope) feel more open than vertical wall abutments.
Spacing	Where feasible, provide multiple wildlife crossing opportunities along the fenced zone. A mix of crossing structure types (e.g., underpasses, overpasses, modified bridges) and size classes are preferred (Clevenger and Waltho 2005). For large mammals, the optimal spacing between wildlife crossing structures is 1.5-2.0 km apart (Huijser unpublished data; T. Kinley pers. comm 2019). However, the spacing between structures is dependent upon the landscape and target species (Clevenger and Huijser 2011). Wildlife crossing structures are spaced on average approximately 2 km apart (ranging from 1.5-6.0 km) in seven North American projects (Huijser et al. 2008).

3.4 Wildlife Sight Lines, Protective Cover, Pathways, and Other Treatments

Factors such as sight lines, nearby protective cover, noise and light from passing vehicles, and other factors influence wildlife use of a crossing structure. Design and retrofit crossing structures with the following in mind:

Sight Lines	Design structures for wildlife to have a clear line of sight to the other side of the highway. This requires twinned structures, those separated by a median, to have similar horizontal and vertical alignments. Also applicable to the apex of an overpass; a flatter apex allows better sight lines across the structure.
Sight Lines	Slope the underpass and overpass approach ramps similar to those found in the surrounding landscape. In flat and open terrain, the approaches to an overpass should be as gradual as possible to a maximum grade of 6H:1V, or even less for target species that depend on flat landscapes (e.g., pronghorn). In mountainous terrain, one or both approach ramps may have steeper slopes (Clevenger and Huijser 2011). However, gentle slopes, maximum 3H:1V is a preferred design (T. McQuire pers. comm. 2019). Clevenger and Huijser (2011) caution that there is a trade-off between designing gentle approach slopes and retaining existing surrounding vegetation cover. Note that the slope may also have consequences for the design and load bearing capacity of an overpass.
Cover	Restrain from clearing a construction footprint larger than necessary. It is important to minimize the extent of clearing during construction and to maintain existing habitat in proximity to the wildlife crossing structure and approaches.
Cover	Replant vegetation post-construction or after a retrofit. On overpasses, plant more densely at the overpass approaches and limited planting at the apex. Consider the following characteristics of the vegetation planting on top of the overpass and at the crossing structure's openings and approach zones (Huijser et al. 2008): ▪ Choose native and palatable species; ▪ Choose a diversity of plant species to form a complex vertical structure comprising native trees, shrubs, and herbaceous in forested landscapes. A mix of slow and fast-growing native plant species is suitable. In grasslands, native graminoids and other natural materials (e.g., logs, rocks) are suitable; ▪ Plan for multiple cover types, such as open and densely vegetated areas that are integrated with, or a continuity of, the surrounding landscape. Refer to the habitat types that are preferred by the target specie(s); ▪ Replicate the surrounding habitat types. In forested areas, the approaches to a crossing structure should have similar vegetation species. Caution using tall trees with deep root systems on top of an overpass that could pose a risk to the integrity of the structure; ▪ Include other natural materials such as rocks and logs (e.g., rock piles, false dry creek bed, large woody debris, tree stumps, root wads); and ▪ Attract wildlife to the structure by using ponds or water holes on either side of a crossing structure, berry-producing plants, and other palatable vegetation.
Human Use	Limit human use and other human disturbances at the wildlife crossing structures and approach zones to the extent possible. Human use at the crossing structure can significantly reduce wildlife use. Large boulders or tree trunks at structure entrances can be used to discourage motorized use. In multi-functional landscapes with species that are accustomed to a certain level of human disturbance (e.g., urban environment), the Consultant may consider combining non-motorized human use (e.g., pedestrians, bicyclists, equestrian use) and wildlife use in the same structure however it is discouraged. If human-wildlife co-use is needed, physically separate the pathway for humans away from the wildlife path, as much as possible. Berms, tree stumps, and other natural materials can also minimize visual disturbances between the wildlife and human paths.
Noise and Light	Design the wildlife crossing structures to limit traffic noise and light inside the underpass, on top of the overpass, and near the approaches. For example, expansion joints on bridge decks may create a "clacking" noise when driven over and may disturb wildlife in and around the underpass. Additionally, light from headlights may be stochastic in nature and/or exceed the levels that a full moon would produce at the structure approaches. Use soil berms, solid fences (e.g., planks), and dense vegetation plantings (or a combination of) to reduce or eliminate noise and light at the wildlife crossing structure.

Noise and Light Screens	Model noise and light levels at the candidate wildlife crossing structure location(s) and approaches to identify if mitigation is required during the detailed design.
Noise and Light Screens & Reflective Surfaces	Minimize use of reflective materials, such as polished concrete, on crossing structures. Sunlight reflecting off the polished concrete side-walls of an underpass on Autoroute 73, Quebec was determined to adversely affect deer use of the structure (D. Boudreault pers. comm 2021).
Pathway & Substrates	Create and maintain a wildlife pathway to allow wildlife movement under/through an underpass. The wildlife pathways should have the following characteristics: ▪ At least 2 m wide path with a clearance height appropriate for the target species; ▪ Walkable substrate of gravel and or native soil; not rip-rap. Typical rip-rap is a barrier to ungulate movement during snow-free periods. Should rip-rap already exist, overlay gravel, sand, and or native soils on top of the rip-rap to create and maintain a walkable pathway; ▪ Above the elevation of the ordinary high-water mark to allow dry passage year-round; ▪ Along both banks of a watercourse; ▪ Above any stormwater outfalls to minimize the risk of washing out the pathway; and ▪ Revegetated at each end of the pathways to connect to the neighbouring habitat on either side of the highway.
Pathway & Substrates	Deposit native soils inside the underpass to cover the structures floors. The soil should not erode over time and allow drainage to minimize water pooling inside the structure. Alternatively, use open bottom underpass structures, wherever site conditions are suitable, as determined through the Conceptual Design Process.
Pathway & Substrates	Allow for proper drainage on overpasses and inside underpasses.
Pathway & Substrates	Consider the following substrate characteristics on top of the entire overpass, inside underpasses, and at the crossing structure's openings and approach zones: ▪ Native soil to maximize the seed bank and minimize the introduction of weed species; ▪ On overpasses, maximize soil depths for sufficient plant growth. Choose soil depth and associated water retention carefully. Note that the soil depth may have consequences for the design and load bearing capacity of an overpass. The Department recommends engaging with the Consultant to determine the appropriate soil depths required to support the planned revegetation on the overpasses; and ▪ In underpasses, consider adding a natural substrate layer at least 15 cm thick (Huijser et al. 2008).
Pathway & Substrates	Avoid excessive use of rip-rap in/on and near the wildlife crossing structure. When rip-rap is used to stabilize shorelines and prevent erosion, the wildlife crossing structure must be designed with a wildlife pathway (of suitable width and clearance for the target species) that is clear of any barriers. Retrofit existing watercourse bridges to create a barrier-free wildlife pathway by removing existing rip-rap or covering the rip-rap with local gravels/sands (Clevenger and Huijser 2011) through the entire crossing structure.
Existing Fences	No right-of-way or livestock fences should remain at the approaches of a wildlife crossing structure. Consider options to remove, modify, and or replace existing livestock/property fencing. If a landowner requires a livestock fence, consider moving the fence farther away from the crossing structure (per site-specific requirements) and or modifying the fence to be wildlife friendly. The Department is developing wildlife friendly fence *Best Practice Drawings*.

3.5 Wildlife Species Suitability

The wildlife crossing structure needs to function for the target species. As important, the design should aim for multi-species functionality, including for species at risk and small-bodied species. Incorporating suitable habitat, rocks and woody debris, widening structures to preserve natural watercourses and banks, and careful selection of substrate materials are some examples of a multi-species design.

Each target species may have different passage requirements based on their ecology. Typically, species that prefer small structures will also use larger structures when cover and other design features are provided, but large-bodied species generally do not use smaller structures. Table 2 can assist when planning the type and size of the wildlife crossing structure to suit the target species. Overall, most ungulates prefer overpasses and open span bridges. However, a diversity of species, including ungulates, are known to also use well-designed underpasses (Sielecki 2007; Clevenger and Waltho 2000).

Clevenger et al. (2009) found that small and medium-sized mammals use drainage culverts to cross the TransCanada Highway. Although not provided in Table 2, small-bodied wildlife (e.g., badger) use small diameter structures when the passage is dry.

TABLE 2: SUITABILITY OF DIFFERENT WILDLIFE CROSSING STRUCTURES FOR SELECT WILDLIFE SPECIES

	Wildlife Overpass	Open/Single Span Bridge Underpass	Large Mammal Underpass	Medium Mammal Underpass	Additional Comment
Ungulates					
Deer (white-tailed, mule)	✔	✔	✔	×	▪ Uses multiple types and sizes of crossing structures. ▪ Tend to prefer crossing structures that feel open (higher, wider, and shorter). ▪ Kintsch et al. (2021) determined that the overpasses (30 m wide) and underpasses (12.8 m wide x 4.3 m high x 20 m long) along Colorado's Highway 9 were both adequately sized and functioned equally well for mule deer (no discernable preference for the structure type). ▪ Known use of medium mammal underpasses, but these smaller-sized underpasses are not a typical design for deer. ▪ Minimum underpass dimensions suggested at 6 m wide x 2.4-3.0 m high (Wakeling et al. 2015; Cramer 2017). Length seems to be the most important dimension associated with successful mule deer passage of underpasses; the shorter the better (Cramer 2013). Underpass length should be ≤37 m and preferably less (Wakeling et al. 2015; Cramer 2017; Cramer 2013). Underpass width is the second most important factor; wider is more important than higher (Cramer 2013). ▪ Noise levels and distance from forest cover also influenced deer use of underpasses in Banff National Park (Clevenger and Waltho 2005).
Elk	✔	✔	○	×	▪ Uses multiple types of crossing structures but seem to prefer overpasses and large underpasses (Clevenger and Waltho 2000; Clevenger et al. 2009; Clevenger and Barrueto 2014). ▪ Tend to use crossing structures that feel open (higher, wider, and shorter), proximal to water, distant from forest cover, and have low noise levels (Clevenger and Waltho 2005; Clevenger and Barrueto 2014). ▪ Uses open span bridges 9.0-9.8 m wide (dimension excludes 2:1 fill slopes) x 6.7 m high x 34-41 m long in Arizona (Dodd et al. 2012). ▪ In the first few years post-construction, preferred overpasses (30 m wide) to large mammal underpasses (12.8 m wide x 4.3 m high x 20 m long) along Highway 9 in Colorado (Kintsch et al. 2021); however, initial preferences can change over time with habituation (Kintsch et al. 2021; Clevenger and Barrueto 2014). ▪ Infrequently use all available crossing structure types (overpasses, bridge underpasses, and underpass culverts) in Utah (Cramer 2017).
Moose	✔	✔	○	×	▪ Uses multiple types of crossing structures including overpasses, open span bridges, and large mammal underpasses (Clevenger and Waltho 2000; Cramer 2017; Clevenger et al. 2009; Kintsch et al. 2021). ▪ Tend to prefer crossing structures that feel open (higher, wider, and shorter); however, show high fidelity to many structure types when in proximity to preferred habitat (Clevenger and Barrueto 2014) ▪ Minimum underpass dimensions suggested at 12 m wide x 4.5 m high (Clevenger and Huijser 2011). ▪ In Colorado, moose passage rate* was 90% at underpasses (12.8 m wide x 4.3 m high x 20 m long) and 87% at overpasses (30 m wide; Kintsch et al. 2021). ▪ In Ontario, moose passage rate* was highest at the 30 m wide Highway 69 overpass (passage rate of 0.97, based on 251 documented crossings) then compared to the Highway 69 large mammal underpass (closed concrete box culverts, twinned structures, each 5 m wide x 5 m high x 24.1 m long with open median; passage rate of 0.73, based on 71 documented crossings) (C. Giesbrecht pers. comm. 2021). Vibrations from traffic, noise, and low vegetation cover at the closed box culvert underpasses are believed to adversely affect wildlife use (C. Giesbrecht pers. comm. 2021). ▪ In Quebec, moose documented to use culvert underpass 6 m wide x 3.8 m high x 26.7 m long (Route 138), and bridges designed for small and medium-sized mammals (e.g., 9.1 m wide x 2.5 m high x 13 m long and another 9.3 m wide x 1.8 m high x 13 m long (Route 175). Although not a typical design for moose, these structures are in areas of higher moose densities (estimated at 14.8 and over 4.5 moose/10 km^2 along Routes 138 and 175, respectively) and moderately light traffic volumes (D. Boudreault pers. comm. 2021).
Woodland Caribou	?	?	?	×	No additional comments
Pronghorn	✔	✔	○	×	▪ Preference for structure types may differ by individual and populations in Colorado (Kintsch et al. 2021). ▪ Strongly prefers overpasses (e.g., 46 m wide x 24 m long) to open span bridges (e.g., 20 m wide x 4 m high x 13 m long) on Highway 191, Wyoming (Western EcoSystems Technology Inc. 2015). ▪ Overpasses (30 m wide) and underpasses (12.8 m wide x 4.3 m high x 20 m long) along Colorado's Highway 9 both function well for pronghorn (99% passage rate of all structures); but pronghorn are 1.75 times more likely to use an underpass than an overpass when standardized for the structure's availability on the landscape (Kintsch et al. 2021).
Bison	✔	✔	?	×	No additional comments

TABLE 2: SUITABILITY OF DIFFERENT WILDLIFE CROSSING STRUCTURES FOR SELECT WILDLIFE SPECIES

	Wildlife Overpass	Open/Single Span Bridge Underpass	Large Mammal Underpass	Medium Mammal Underpass	Additional Comment
Bighorn Sheep	✔	✔	○	×	▪ Tend to prefer crossing structures that feel open (higher, wider, and shorter). ▪ Strongly prefers overpasses to large mammal underpasses along Colorado’s Highway 9 (Kintsch et al. 2021). ▪ Uses the Highway 1 overpass (7 m wide) near Yoho National Park and the Mount Hunter Creek Bridge large mammal underpass in British Columbia (Czernick pers. comm 2021). ▪ Minimum underpass dimensions suggested at 12 m wide x 4.5 m high (Clevenger and Huijser 2011).
Mountain Goat	✔	✔	○	×	▪ Tend to prefer crossing structures that feel open (higher, wider, and shorter). ▪ Minimum underpass dimensions suggested at 12 m wide x 4.5 m high (Clevenger and Huijser 2011).
Carnivores					
Bobcat	✔	✔	✔	✔	▪ Uses a variety of structure types but prefers crossing structures that feel confined. ▪ Twice as likely to use medium mammal underpasses than larger structures (Kintsch et al. 2021). ▪ Uses watercourse bridges (Cramer 2017; Kintsch et al. 2021).
Canada Lynx	✔	✔	?	?	▪ Documented use of overpass and open span bridge (Clevenger and Huijser 2011).
Cougar	✔	✔	✔	○	▪ Prefers underpasses especially those that feel confined (i.e., long and narrow; Clevenger et al. 2005), but will use all types of crossing structures (Cramer 2017). ▪ Preference for confined underpasses may change over time. Results from Banff National Park indicate that the initial preference for underpasses changed to overpasses possibly as the tree cover matured on the overpasses (Clevenger and Barrueto 2014). ▪ Tend to prefer structures near forest cover (Clevenger and Waltho 2005; Clevenger and Barrueto 2014).
Coyote	✔	✔	✔	✔	▪ No documented preference to crossing structure types (Clevenger and Barrueto 2014).
Red Fox	✔	✔	✔	✔	No additional comments
Wolf	✔	✔	○	×	▪ Prefers overpasses and large underpass structures but will use other types of crossings. ▪ Tend to prefer structures that feel open (higher, wider, and shorter) (Clevenger and Waltho 2005; Clevenger and Barrueto 2014).
Wolverine	✔	✔	?	?	▪ Use of open span bridges and a large mammal underpass (Clevenger and Huijser 2011).
Black Bear	✔	✔	✔	○	▪ Tend to prefer underpasses that feel confined (long and narrow; Clevenger et al. 2005; Clevenger and Barrueto 2014) but will use all types and sizes of crossing structures including overpasses. ▪ Preference for confined underpasses may change over time (Clevenger and Barrueto 2014). ▪ Prefers crossing structures distant to watercourses (Clevenger and Waltho 2005; Clevenger and Barrueto 2014).
Grizzly Bear	✔	○	○	×	▪ Prefers overpass structures but will use open span bridges and large underpasses (Clevenger et al. 2009; Clevenger and Waltho 2000; 2005). Use of underpasses increase over time, but smaller structures (i.e., those 7 m wide x 4 m high and smaller) continue to be under-utilized over time (Clevenger and Barrueto 2014). ▪ Clevenger and Barrueto (2014) recommend overpasses and large open span bridges in Banff National Park. ▪ Minimum underpass dimensions suggested at 12 m wide x 4.5 m high (Clevenger and Huijser 2011). ▪ Prefers crossing structures distant from towns and areas of human-activities.

Adapted from Clevenger and Huijser 2011.

* Passage Rate is a ratio of the number of documented confirmed crossings in comparison to the number of total approaches (i.e., accounts for the number of times an animal approaches the structure but does not cross).

✔ Optimal solution

○ Possible depending on each site and design

× Not typically suitable

? Unknown, more data are required

4.0 Maintenance Considerations

Highway maintenance contractors are responsible for regularly maintaining the wildlife crossing structures and associated exclusion fences. Although maintenance is not the responsibility of the Consultant, the Consultant shall design the wildlife crossing structures and associated mitigations to facilitate long-term maintenance and inspection.

Designs must allow Highway Maintenance Contractors (and their equipment/vehicles) easy access to the wildlife crossing structures and exclusion fences for regular inspection and maintenance. Consider installing swing gates (locking, self-closing), on each side of the wildlife crossing structure to ease maintenance work. Refer to the Guideline for Planning Wildlife Exclusion Fencing for the maximum clearance at the gate pad and gate posts. Gates must maintain a functional height (i.e., 2.5 m) to exclude wildlife.

5.0 Related Publications

All AVC mitigation work is to be done in accordance with the most recent version of the Department's publications and federal and provincial environmental legislation. Where conflict exists between design bulletins and other Department publications, the design bulletins shall govern. Government of Alberta publications are provided on the Government of Alberta's website.

Primary publications that should be considered for wildlife crossing structure design include but are not limited to:

- *Alberta Wildlife Watch Program Documents*
  - Describes the Alberta Wildlife Watch (AWW) program. which works to reduce animal-vehicle collisions on provincial highways, improve driver safety, and minimize the impacts of highways on wildlife populations. The AWW Program allows the Department to cost-effectively collect and analyze high-quality data for effective decision making across the provincial highway network.
- *Bridge Aesthetics Study*
  - This resource provides an overview on the aesthetics of bridges constructed in Alberta. Bridge aesthetics may need to be considered for AVC mitigation projects.
- *Bridge Assessment Guidelines*
  - Outlines how structures managed by the Department are to be assessed. Wildlife crossing structures may be visually or functionally separate from the typical bridge structure; however, these structures should be managed under the same guidelines.
- B*ridge Conceptual Design Guidelines*
  - These guidelines apply to all Department projects involving bridge size structures (i.e., wildlife crossings), including anything identified as Bridge Planning under the current version of the *Engineering Consultant Guidelines*.
- *Bridge Load Evaluation Manual*
  - Details the Department's bridge load evaluation guidelines, practices, and policies and is intended to supplement the requirements of Canadian Standards Association S6-14. Wildlife crossing structures fall under the category of bridge structures which will need to conform to the Department's bridge guidelines, practices, and policies.
- *Bridge Management Strategy Guideline/Manual*
  - This manual provides guidelines and best practices for the planning and scheduling of bridge maintenance, rehabilitation, and replacement activities. The manual aims to maximize the return on the investment, and deviation from these guidelines may be necessary to accommodate certain projects. While the document is primarily meant for the Department's use, projects should be designed for the typical management/maintenance strategies.
- *Bridge Structures Design Criteria*
  - The Bridge Structures Design Criteria documents bridge design practices and policies for the Department and is intended to supplement the requirements of the Canadian Highway Bridge Design Code CSA S6-14. Where AVC mitigation projects are considered to be bridge structures, these design criteria apply.
- *Design Exceptions Guideline*
  - A project requires a Design Exception (DE) when it does not follow the Department's published standards. DEs allow for innovation and optimization of projects (including AVC mitigation projects) by allowing flexibility in the design where warranted.

- *Design Guidelines for Bridge Size Culverts*
    - Provides guidance to design and construct culvert-based projects.

- *Engineering Consultant Guidelines for Highway, Bridge and Water Projects (ECG) - Volume 1 - Design and Tender and Volume 2 - Construction Contract Administration*
    - The Department's *Engineering Consultant Guidelines for Highway, Bridge and Water Projects* (ECG) should be followed for all wildlife crossing structure projects. The ECG provides guidelines, requirements, and references for the Department's projects. Although the ECG is tailored for highway, bridge, and water projects, a great deal of the information can be applied to wildlife crossing structure mitigation projects. Consultants should adhere to the information in the ECG for their AVC mitigation projects as they would with any provincial highway, bridge, and water management project.

    - Consultants should confirm that additional design bulletins regarding the ECG that may be applicable to their project are considered. A list of the Department's design bulletins can be found on the Government of Alberta's website.

- *Engineering Drafting Guidelines for Highway and Bridge Projects*
    - All wildlife crossing structure mitigation drawings should adhere to the guidelines and standards established in the Department's *Engineering Drafting Guidelines for Highway and Bridge Projects*.

- *Environmental Construction Operations (ECO) Plan Framework*
    - Each wildlife crossing structure project requires an ECO Plan that demonstrates how the project's environmental impacts will be identified and mitigated. Wildlife crossing structures should be designed and constructed to adhere to environmental regulations, bylaws, guidelines, and any environmental commitments.

- *Erosion and Sediment Control Manual*
    - Wildlife crossing structures should be designed in a manner that does not impact the effectiveness and or implementation of erosion and sediment control measures (temporary and or permanent) on provincial highways. All mitigation projects should implement appropriate erosion and sediment control measures during their construction to prevent impacts to the environmental and or mitigation effectiveness through erosion or sediment runoff. Mitigation projects should use best management practices that factor in the potential for wildlife movement and or access to the erosion and sediment control measures implemented.

- *General Specifications and Specification Amendments for Highway and Bridge Construction*
    - This document is supplemental to the *Standard Specifications for Highway Construction* and the *Standard Specifications for Bridge Construction* manuals. Details of which are provided below.

- *Geotechnical and Erosion Control Best Management Practices*
    - Geotechnical and Erosion Control Best Management Practices (BMPs) are provided by the Department to help design and construct roads and bridges. These BMPs are applicable to all Highway Infrastructure where geohazards are present (i.e., landslides, rock falls, and erosion).

- *Guide to Bridge Planning Tools*
    - This document provides links to several of the Department's GIS datasets, maps, and hydrotechnical analysis tools (e.g., excel spreadsheets, calculators) for bridge planning. These datasets and tools may be a valuable resource for wildlife crossing structure projects.

- *Highway Geometric Design Guide*
    - The guide is to promote uniformity for highway design in Alberta and to encourage safe and efficient roads for the well-being of Alberta's public. Although it is aimed at highway construction, some portions of the document may assist when planning wildlife crossing structures, such as section C.4.6 Culvert Installation.

- *Roadside Design Guide*
    - The Department developed this guide to assist in the development of cost-effective, safe, roadside environments. Although most of the document focuses on standard highway and bridge construction, there may be information applicable to some wildlife structure mitigation projects.

- *Standard Specifications for Bridge Construction*
    - As titled, the *Standard Specifications for Bridge Construction* provides high-level detail for a multitude of bridge construction aspects. Many of these aspects and specifications are likely applicable, if not required, for the construction of most wildlife crossing structure projects.

- *Standard Specifications for Highway Construction*
    - Although not as directly applicable to crossing structures as the *Standard Specifications for Bridge Construction*, the *Standard Specifications for Highway Construction* provides high-level detail for a multitude of highway construction aspects which may be applicable to some wildlife crossing structure projects.

- *Terms of Reference for Environmental Evaluation of Highway Infrastructure Projects*
    - This Terms of Reference outlines the requirements for completing an Environmental Evaluation (EE) and is applicable for functional planning studies and preliminary design work. Where required, an EE may be required to proceed with a highway infrastructure project, including AVC mitigation projects. The EE must identify environmentally sensitive features, including but not limited to, fish bearing watercourses, wetlands, and federally/provincially protected species.

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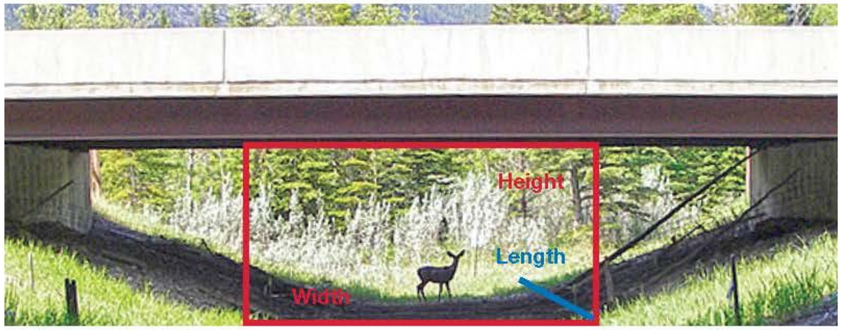
APPENDIX A

Measuring Crossing Structure Dimensions

Appendix A:
Measuring Crossing Structure Dimensions



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