Mitigating multi-species mortality and fragmentation on the Trans-Canada Highway, Mount Revelstoke and Glacier National Parks, British Columbia

Final Report

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Executive Summary

Highways and roads within Mount Revelstoke and Glacier National Parks (MRG) contribute to habitat fragmentation and direct wildlife mortality from vehicle collisions. Anticipated highway expansion will likely increase wildlife mortalities and further contribute to demographic and genetic isolation of certain wildlife species. Site-specific mitigations have reduced wildlife road mortality and increased connectivity across highways. However, traditional highway mitigations in MRG will be challenging due to excessive snow loads and numerous avalanche and avalanche debris events. There are 144 avalanche paths that directly impact the highway in Glacier National Park (S. Boyle, MRG Field Unit, personal communication, 2014).

MRG have a large amount of pre-existing data on highway-related mortality, observations and radiotelemetry-based movements for many species. The data has never undergone a formal review or comprehensive analysis to address highway mitigation needs in the event of a future Trans-Canada Highway (TCH) twinning project. The purpose of this research was to compile MRG wildlife data, review the data for select species and use the most statistically robust information to analyse conflicts between wildlife and the TCH, and from analyses of highway-related mortality and regional-scale connectivity, identify key areas for implementing mitigation measures on the TCH. We limited our study to terrestrial wildlife species.

Wildlife-vehicle collision (WVC) data can be used to identify locations where animals are killed and public safety is at risk, so it is often the primary driver of highway mitigation strategies; therefore, we examined spatial and temporal patterns of road mortality. We compiled WVC data for MRG from all available sources provided by Parks Canada Agency. We found a total of 691 useable records for WVCs in Cansis. Mortalities occurred between 21 December 1961 and 18 October 2010. The locations of WVCs were evenly distributed throughout the national parks. A total of 50 wildlife species were recorded as killed on the highway, including small and large mammals, birds, and reptiles. We summarized collision data numerically, monthly and spatially for black bears, caribou, deer (white-tailed and mule), elk, grizzly bears, moose, mountain goats, and wolverines.

We used a landscape resistance (i.e. connectivity) model first developed for black bears and generalized here to help identify key areas for highway mitigation. We used the generalized forest connectivity model to identify and prioritize important habitat linkages for carnivores and ungulates by examining where least cost paths cross the TCH. We identified important cross-highway linkages and corridors. As expected, many linkages follow low-mid elevation gradients and contour with major watersheds. There was little difference between the least cost paths under different hypotheses so we used the basic model with no road resistance to identify habitat linkages. Three key areas of cross-highway movement emerged: the area along the eastern edge of Mount Revelstoke National Park, the provincial lands between the national parks, and the Beaver Valley. Our analysis also highlighted Rogers Pass as an important corridor for east-west movement with few options for cross-highway movement.

We compared landscape resistance-based least cost paths to habitat-based least costs paths developed for grizzly bears, and to WVC data, to help identify and prioritize the locations of potential highway mitigation. We found a high degree of congruence between the three methods.

In September 2014, we visited the MRG study area and assessed the on-the-ground feasibility of mitigating the TCH.

Our comparison of least cost paths and mortality sites identified 24 TCH sites deemed suitable for mitigation measures (hereafter, mitigation emphasis sites); 14 sites in Glacier, 5 sites in Mount Revelstoke and 5 sites on provincial lands between the two parks. . For each site, we ranked the importance to regional and local connectivity, the threat posed from road-caused mortality based on road-kill records, and the feasibility of implementing mitigation measures at the site. We ranked each of these four categories, giving higher scores for areas with higher degrees of overlap with WVCs or least cost paths. We developed recommendations for mitigation opportunities at each mitigation emphasis site. The relative importance of each site varies by species and local landscape attributes across the >100 km highway corridor. Each site and conservation ranking was informed by field data on wildlife movement, wildlife mortality and expert opinion based on site visits. A variety of mitigation measures are recommended, from simple to complex, some requiring work off-site (e.g., salt diversion), while others necessitating structural work on the highway (e.g., wildlife underpass construction).

We averaged the values for the 19 sites within MRG (5 from Province were excluded). Eight of the 19 sites had scores equal to or above the average score. We discussed each of these sites and their mitigation recommendations in light of their respective attributes associated with local and regional conservation values and the safety of motorists traveling the TCH.

Due to the unique landscape and climatic attributes of MRG, measures designed for the TCH will need to be adapted to these biogeographic features and conditions. We identified three main issues that will influence landscape-specific guidelines for highway mitigation: 1) Deep snowpack, 2) snow sheds as wildlife overpasses, and 3) mountain goats and highway salt. We address the technical aspects of mitigation design and implementation to address these areas.

The cost of mitigation measures is an important factor in planning and decision-making. Often the more costly but proven measures are passed over in favour of less costly measures that are less likely to meet performance goals. We reviewed the factors affecting costs of mitigation, the current costs of wildlife crossing structures, and cost-benefits of reducing WVC.

Monitoring is an integral part of a highway mitigation project, even long after the measures have been in place. We discuss methods of assessing mitigation measure performance in light of management objectives and goals. Study designs that provide the most inferential strength will be of greatest value for effectiveness assessment of crossing structures. Monitoring performance is an adaptive process that will inform decision-making with regard to planning and design of subsequent phases of this project.

Last, we identified future research and monitoring needs in MRG. These consisted of activities that can be initiated immediately with low cost investment, while other activities require more capital fund investments from the Field Unit. Not listed in order of priority or management importance, these needs include: 1) camera monitoring at existing below-grade passages, 2) mortality data collection in Provincial sections of TCH, 3) wolverine resource selection function mapping and genetic sampling, and 4) mountain goat salt dispersion mitigation trials.

Table of Contents

List of Tables

List of Figures

1. Introduction

Highways and roads within Mount Revelstoke and Glacier National Parks (MRG) contribute to habitat fragmentation and direct wildlife mortality from vehicle collisions (Woods and Harris 1989, Reid Crowther 1995). Anticipated highway expansion will exacerbate wildlife mortality numbers and likely further contribute to demographic and genetic isolation of certain wildlife species. Throughout North America, the application of site-specific mitigations has reduced wildlife road mortality and improved means of habitat connectivity across highways (Forman et al. 2003, Beckmann et al. 2010). However, traditional highway mitigations in MRG will be challenging due to the unique seasonal issues related to excessive snow loads and numerous avalanche and avalanche debris events.

A conceptual study of TCH twinning through MRG was prepared over two decades ago (Reid Crowther 1995). Data were compiled within a comprehensive framework on a range of environmental resources and was presented in a database format that could be used in subsequent cumulative assessments of impacts. The intent was to provide a database that could complement existing and future information sources specific to MRG

Over the past decade, highway widening has been proposed for the MRG. It is anticipated that highway expansion will increase wildlife mortality on the Trans-Canada Highway (TCH) unless wildlife-highway interactions are understood at a species-specific level and appropriate mitigations are enacted. Highway mitigation measures have been shown to reduce the amount of wildlife-vehicle collisions and improve motorist safety (Clevenger et al. 2001, Huijser et al. 2007). Further, recent research along the TCH in Banff National Park has provided compelling evidence how a system of wildlife crossings can promote genetic diversity and connectivity among populations (Sawaya et al. 2013, 2014).

MRG currently possesses a large amount of pre-existing data on highway-related mortality, observations, radio telemetry-based movements and population genetics for a variety of species. The data exists in multiple formats and states, is of varying quality, and has never undergone a formal review or comprehensive analysis to address highway mitigation needs in the event of a future TCH twinning project.

The purpose of this research was to compile MRG wildlife data, review the data for select species and use the most statistically robust information to analyse conflicts between wildlife and the TCH, and from analyses of highway-related mortality and regional-scale connectivity, identify key areas for implementing mitigation measures on the TCH. The study was limited to terrestrial wildlife species and does not address aquatic organisms and barriers to hydrological connectivity.

This project will help MRG with the following:

- Identify areas of greatest concern for motorists and wildlife based on wildlife mortality data.
- Conduct landscape resistance analysis using least-cost modeling to identify key cross-highway corridors on the TCH.
- Prioritize highway mitigation options based on a comparison of the similarity of landscape resistance models to observational data, i.e. sightings and road-kill data.
- Recommend measures to mitigate wildlife mortality and habitat fragmentation on the TCH at key cross-highway corridors.
- Propose new techniques for mitigating highway impacts on wildlife in high snow load areas.
- Make recommendations for monitoring mitigation measures to assess performance.
- Provide costs (and benefits if possible) associated with recommended measures.
- Identify potential gaps in MRG data and recommend means of addressing future data needs.

This work will ensure that through a rigorous analysis of multi-species mortality and fragmentation on the TCH appropriate mitigation recommendations will be identified for MRG decision makers in advance of highway twinning and reconstruction. Information from this project will be incorporated into future TCH Environmental Impact Assessments, project planning, engineering and budgeting. This project directly supports Park Management Planning requirements related to terrestrial connectivity, and supports efforts to stabilize Forest Health Ecological Integrity measures related to reducing human caused wildlife mortality.

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2. Study Area

MRG are located in the Columbia Mountains of southern British Columbia, Canada, and encompass 260 km^2 and 1350 km^2, respectively (Figure 2.1). Glacier National Park was designated in 1886, along with Yoho National Park, as a 76 km^2 reserve around Mount Macdonald and Roger's Pass. By 1930 the area had grown to a 1350 km^2 national park. Approximately 600,000 visitors enter Mount Revelstoke National Park and nearby Glacier National Park each year.

The climate is characterized by high annual precipitation, heavy snowfall, and relatively moderate winter temperatures. The study area is ~7000 km^2 with elevations ranging from 438 m to 3377 m. This range of elevation gives rise to three distinct biogeoclimatic zones: Interior Cedar-Hemlock, Engelmann Spruce-Subalpine Fir, and Alpine Tundra (Krajina, 1959). Dense stands of western hemlock (*Tsuga heterophylla*) and western red cedar (*Thuja plicata*) dominate the valley bottoms and Engelmann spruce (*Picea engelmanii*) and subalpine fir (*Abies lasiocarpa*) cover mid to upper elevations. Elevations above 2000 m are dominated by alpine environments which include herbaceous meadows, low shrubs, alpine tundra, non-vegetated habitats and glaciers. Rugged mountainous terrain with steep v-shaped valleys creates avalanche paths that comprise over 17% of the land cover. In snow free months, avalanche paths produce several food sources important to foraging bears including, glacier lilies (*Erythronium grandiflorum*), spring beauties (*Claytonia lanceolata*), and cow parsnip (*Heracleum lanatum).* There are 201 glacier masses, covering over 12% of the total park area with ice (S. Boyle, MRG Field Unit, personal communication, 2014). MRG have an extensive backcountry trail network and are a popular destination for both winter and summer recreationalists. Together, these national parks protect high-quality montane wildlife habitat from surrounding activities such as widespread timber harvesting, mining and helicopter skiing (Krebs et al. 2007).

The study was focused on the 56.3 km TCH transportation corridor that bisects MRG. Revelstoke National Park has 12.5 km of TCH, while Glacier National Park has 43.8 km within its boundaries. The ecological integrity of both national parks is undermined by this major transportation corridor (Parks Canada 2010). The TCH runs through the study area, and directly through Glacier National Park, with summer traffic volumes exceeding an average of 20,000 vehicles per day year-round (Parks Canada, Highway Service Centre, unpublished data). Additionally, a two-track transcontinental railway runs parallel to the TCH throughout the extent of the study area. Both the TCH and railway are a source of wildlife mortality (Hurley et al. 2009) and habitat fragmentation. Proctor et al. (2012) found that genetic fragmentation exists among grizzly bear populations within the study area.

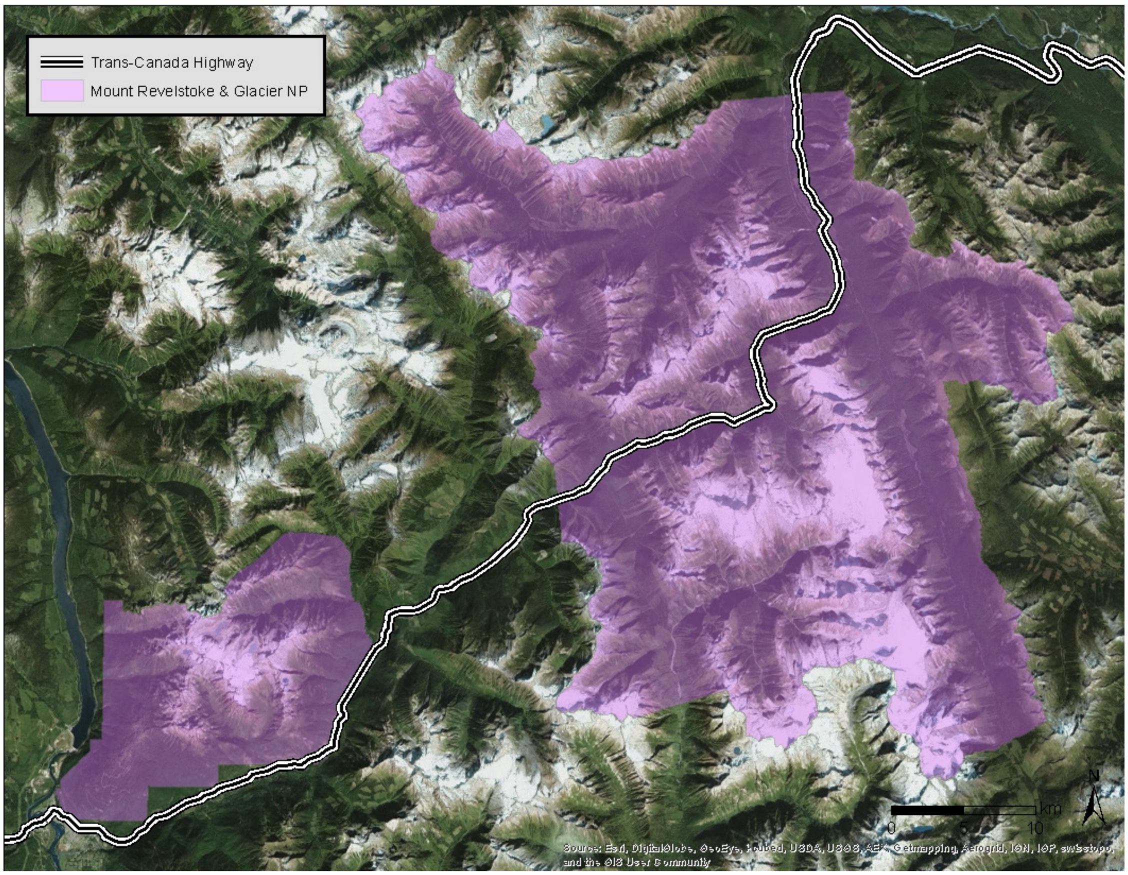

Figure 2.1: Map of Mount Revelstoke National Park (left) and Glacier National Park (right), the Trans-Canada Highway, and the focal study area in the Columbia Mountains of southeastern British Columbia.

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3. Occurrence of Wildlife-Vehicle Collisions

3.1 Introduction

The TCH through MRG takes a toll on animals crossing the road in the Columbia Mountains, British Columbia. Wildlife-vehicle collision (WVC) data can be used to identify locations where animals are killed and public safety is at risk, so it is often the primary driver of highway mitigation strategies; therefore, we examined spatial and temporal patterns of road mortality. Most wildlife agencies collect WVC data as part of their routine objectives to monitor wildlife, but often data are patchy, inconsistent, and unreliable. Fortunately, Parks Canada Agency has been collecting WVC data consistently in MRG for over 40 years.

3.2 Methods

We compiled WVC data for Mount Revelstoke and Glacier National Parks from all available sources provided by Parks Canada Agency; a few records were also recorded for the provincial lands between parks. We primarily used roadkill data from querying Parks Canada's Cansis database for mortality types that were recorded as "h" for highway. Records with erroneous spatial information (i.e. located >50 m from TCH) were removed from analysis. We used the remaining records to examine spatial and temporal patterns of road-caused mortality. We plotted locations of mortalities in NAD 83 UTM Datum using ArcGIS 10 (ESRI, Redlands, California, USA). We used all records in the database collected between 1961 and 2010; although data were collected after 2010, they were not compiled or error checked by park staff so we excluded them from our analysis to maintain consistent data quality across years.

3.3 Results

We found a total of 691 useable records for wildlife-vehicle collisions in Cansis, including a few mortality records for provincial lands outside the national parks. Mortalities occurred between 21 December 1961 and 18 October 2010; one male grizzly bear mortality was also included from 10 May 2011. The locations of vehicle collisions with all animals were evenly distributed throughout the national parks (Figure 3.2). A total of 50 wildlife species were recorded as killed by the highway, including small and large mammals, birds, and reptiles (Table 3.1).

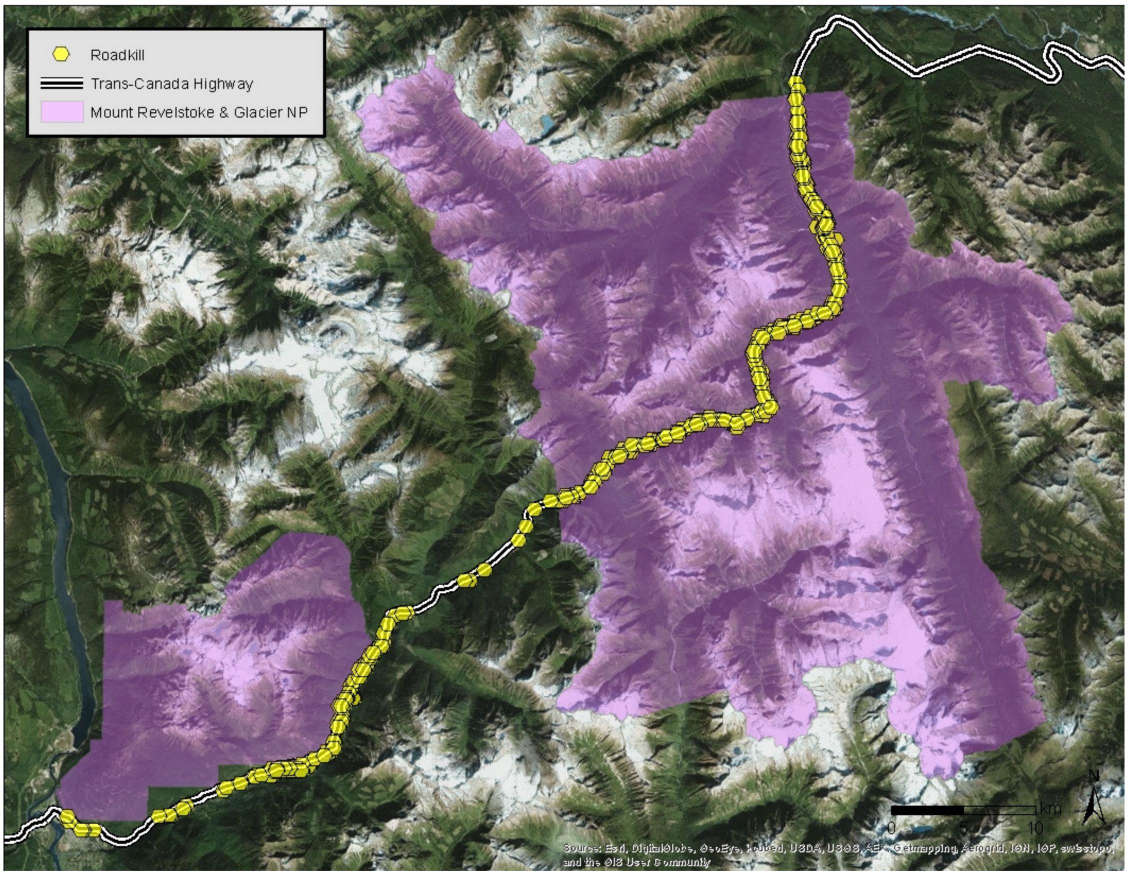

Figure 3.1: Wildlife-vehicle collisions on the Trans-Canada Highway in Mount Revelstoke and Glacier National Parks, British Columbia.

Table 3.1: Wildlife-vehicle collisions by decade for all species along the Trans-Canada Highway in Mount Revelstoke and Glacier National Parks, British Columbia.

Species	TOTAL	1960s	1970s	1980s	1990s	2000s	2010
American Crow	2	0	0	1	1	0	
Barred Owl	6	0	1	4	0	1	
Beaver	32	0	6	18	5	3	
Black Bear	116	3	23	46	35	9	
Boreal Owl	1	0	0	1	0	0	
Canada Goose	1	0	0	0	0	1	
Caribou	3	1	0	0	1	1	
Columbian Ground Squirrel	6	0	0	4	0	2	
Common Raven	3	0	1	0	2	0	

Coyote	46	5	4	16	11	10	
Elk	10	0	0	2	7	1	
Ermine	1	0	0	1	0	0	
Great Blue Heron	1	0	0	0	0	1	
Great Horned Owl	4	0	0	4	0	0	
Grizzly Bear	7	0	4	0	2	1	
Hoary Marmot	4	0	3	1	0	0	
Least Weasel	1	0	0	1	0	0	
Long-eared Owl	2	0	1	1	0	0	
Lynx	3	1	2	0	0	0	
Marten	26	0	5	15	6	0	
Masked Shrew	1	0	0	1	0	0	
Merlin	1	0	0	0	1	0	
Moose	71	0	5	24	26	16	
Mountain Goat	82	2	4	28	21	26	1
Mule Deer	57	2	4	22	23	5	1
Northern Saw-whet Owl	1	0	0	1	0	0	
Pileated Woodpecker	1	0	0	1	0	0	
Pine Grosbeak	2	0	0	1	1	0	
Pine Siskin	18	0	0	11	7	0	
Porcupine	105	1	24	60	13	5	2
Red Crossbill	3	0	3	0	0	0	
Red Sided Garter Snake	2	0	0	2	0	0	
Red Squirrel	2	0	0	2	0	0	
Red-tailed Hawk	2	0	1	0	0	1	
Ruffed Grouse	5	0	0	3	2	0	
Rufous Hummingbird	1	0	0	0	0	1	
Snowshoe Hare	12	0	1	9	1	1	
Steller's Jay	1	0	0	1	0	0	
Unidentified Bear	1	0	1	0	0	0	
Unidentified Deer	5	0	0	0	2	3	
Unidentified Grouse	1	0	0	0	0	1	
Unidentified Otter	1	0	0	0	1	0	
Varied Thrush	1	0	0	1	0	0	
Western Jumping Mouse	1	0	0	1	0	0	
White-tailed Deer	26	1	1	5	11	7	1
White-winged Crossbill	2	0	1	0	1	0	
Wilson's Warbler	1	0	0	1	0	0	
Wolf	4	0	0	0	0	4	
Wolverine	1	0	0	0	1	0	
Woodchuck	3	0	0	2	0	1	

Black Bears

In Parks Canada's Cansis database, we found 116 black bear-vehicle collisions. Black bear mortalities occurred between 23 July 1964 and 1 July 2008 and were concentrated during summer months (Figure 3.2.1). The locations of vehicle collisions with bears were not clustered and were almost uniformly distributed along the entire length of the TCH in our study area (Figure 3.2.2).

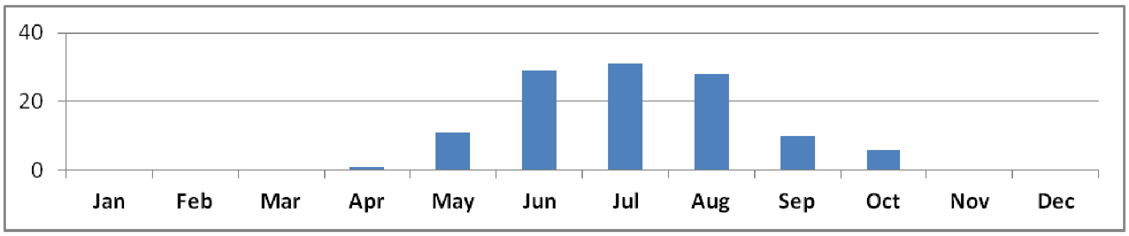

Figure 3.2.1: Road-caused black bear mortalities by month along the Trans-Canada Highway.

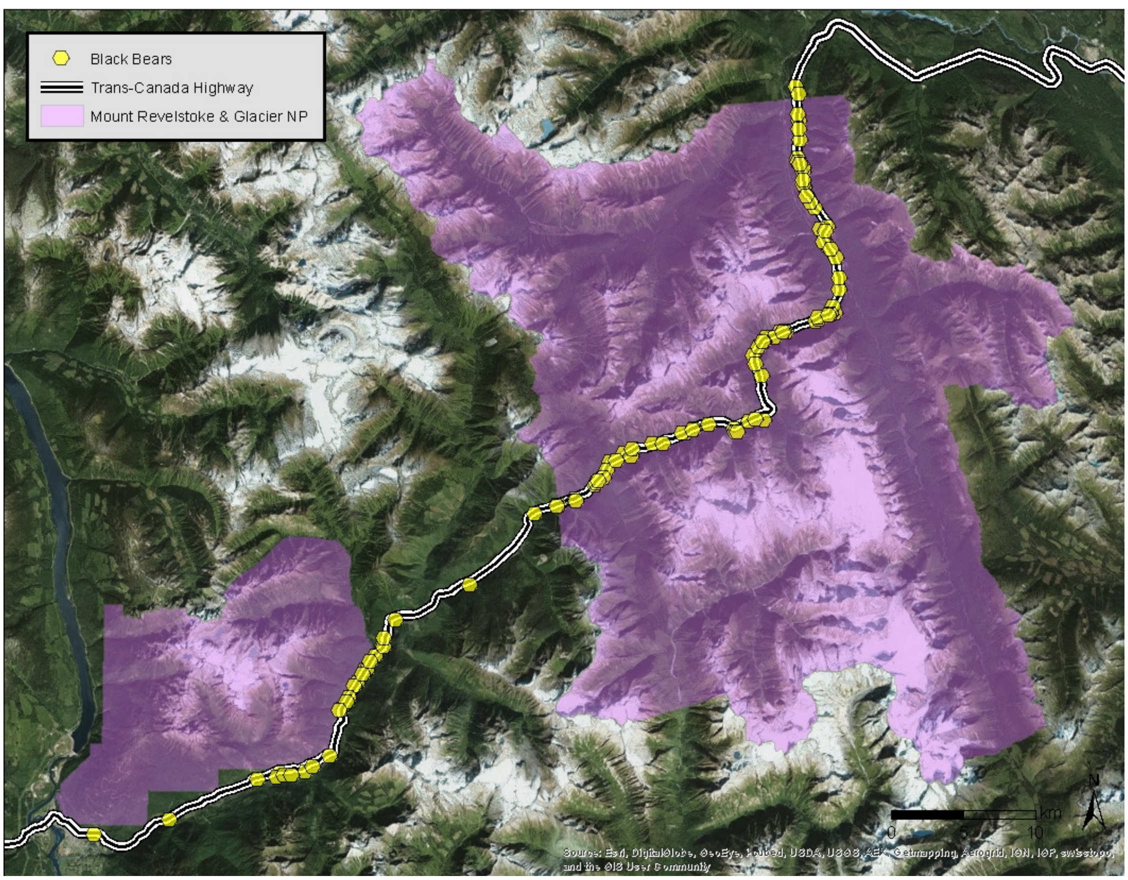

Figure 3.2.2: Black bear-vehicle collisions on the Trans-Canada Highway in British Columbia.

Caribou

In Parks Canada's Cansis database, we found 3 caribou-vehicle collisions. Caribou mortalities occurred on 14 December 1961, 29 February1992, and 18 November 2008. Caribou mortalities were concentrated during winter months (Figure 3.3.1). The locations of vehicle collisions with caribou were not clustered and were almost uniformly distributed along the entire length of the TCH in our study area (Figure 3.3.2).

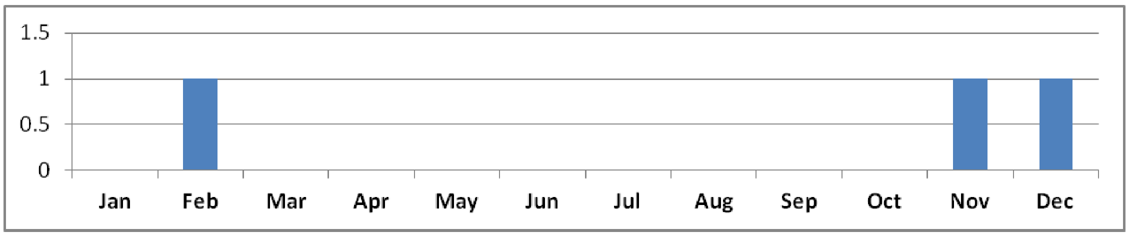

Figure 3.3.1: Road-caused caribou mortalities by month along the Trans-Canada Highway.

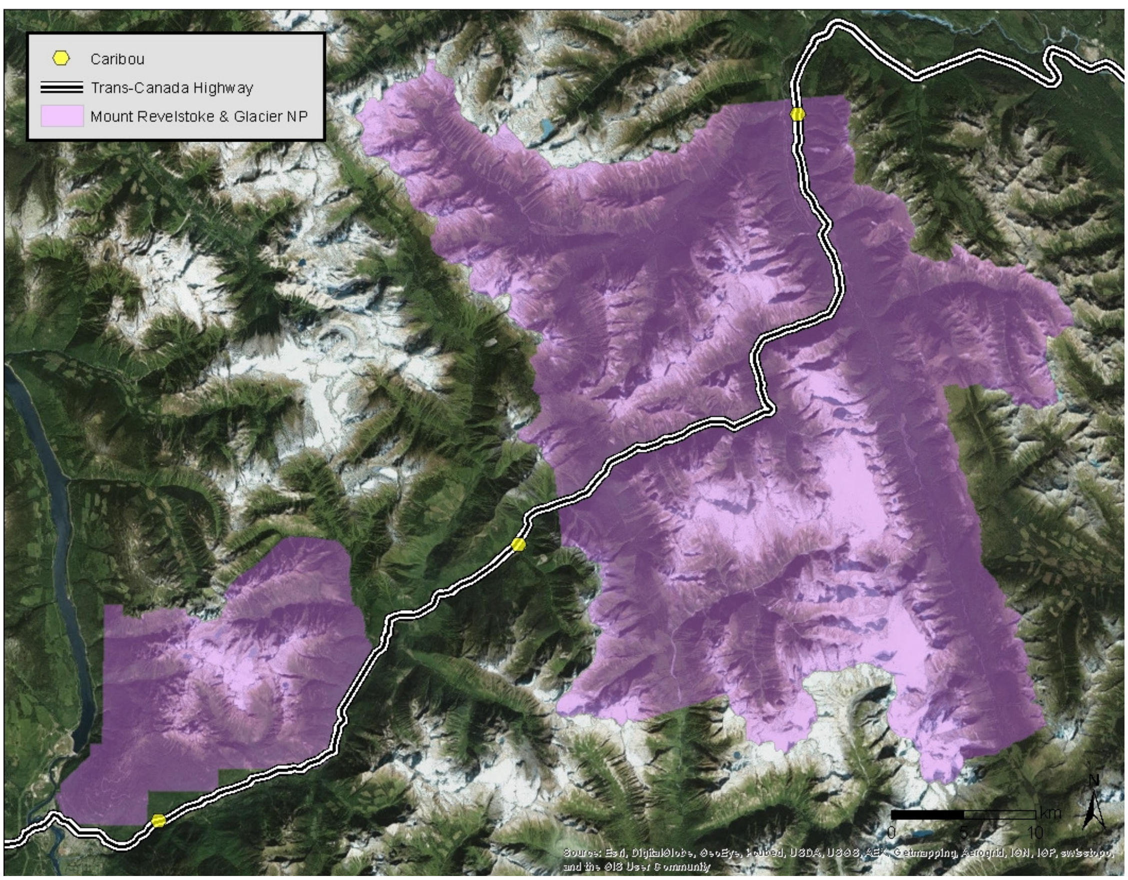

Figure 3.3.2: Caribou-vehicle collisions on the Trans-Canada Highway in British Columbia.

Deer Species *(mule deer and white-tailed deer)*

In Parks Canada's Cansis database, we found 88 deer-vehicle collisions, including 57 mule deer, 26 white-tailed deer, and 5 unknown deer species. Deer mortalities occurred between 29 August 1962 and 18 October 2010. Deer mortalities were concentrated during early summer and late fall (Figure 3.4.1). The locations of vehicle collisions with deer were clustered along the east boundary of Revelstoke and the Beaver Valley on the TCH (Figure 3.4.2).

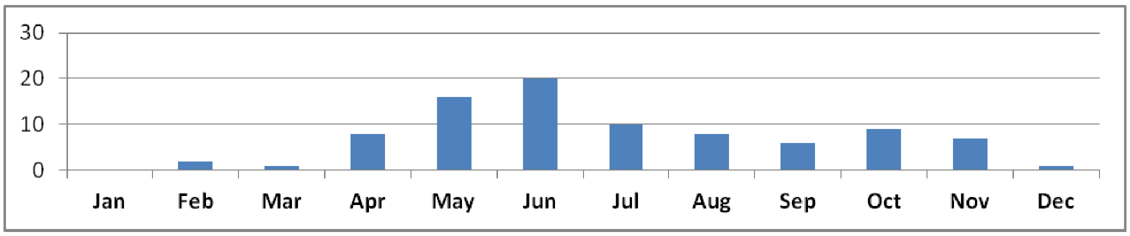

Figure 3.4.1: Road-caused deer mortalities by month along the Trans-Canada Highway.

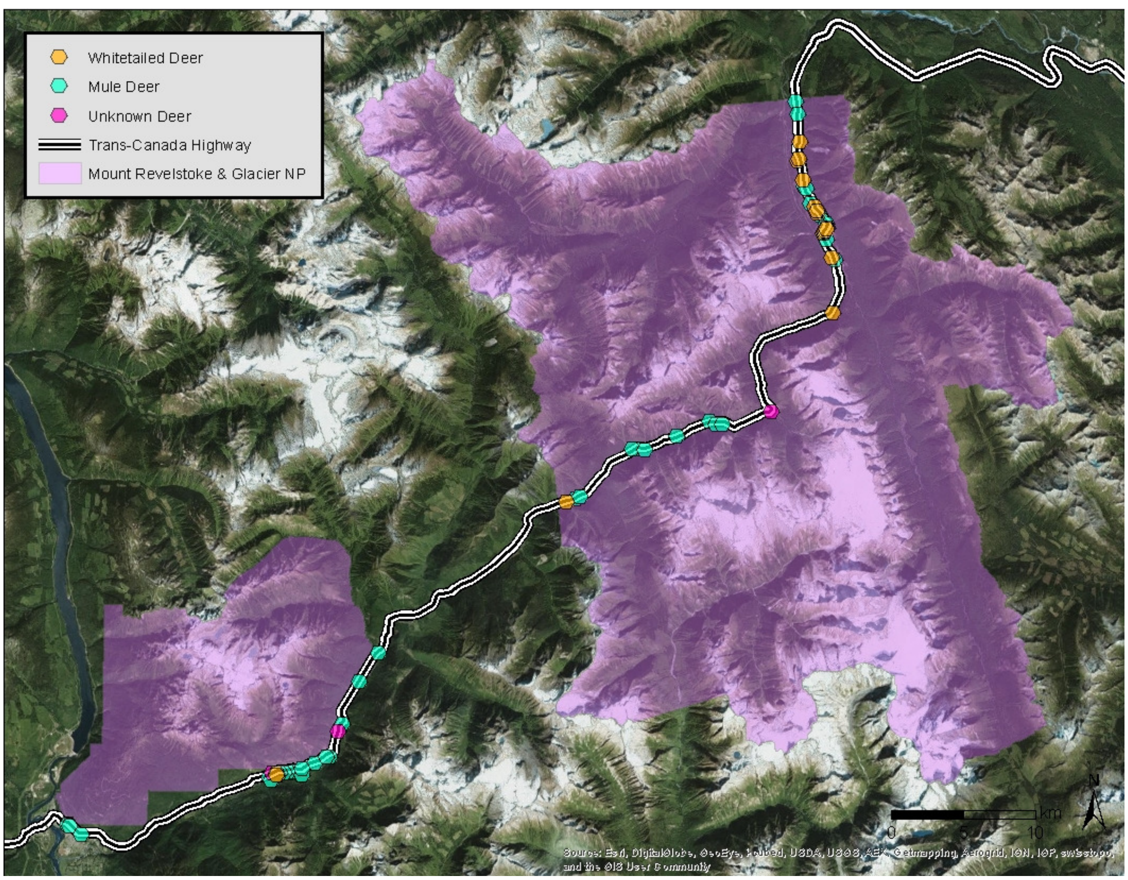

Figure 3.4.2: Deer-vehicle collisions on the Trans-Canada Highway in British Columbia.

Elk

In Parks Canada's Cansis database, we found 10 elk-vehicle collisions. Elk mortalities occurred between 13 November 1987 and 26 March 2002. Elk mortalities were concentrated during late winter and early spring (Figure 3.5.1).The locations of vehicle collisions with elk were primarily clustered in the Beaver Valley on the TCH in our study area (Figure 3.5.2).

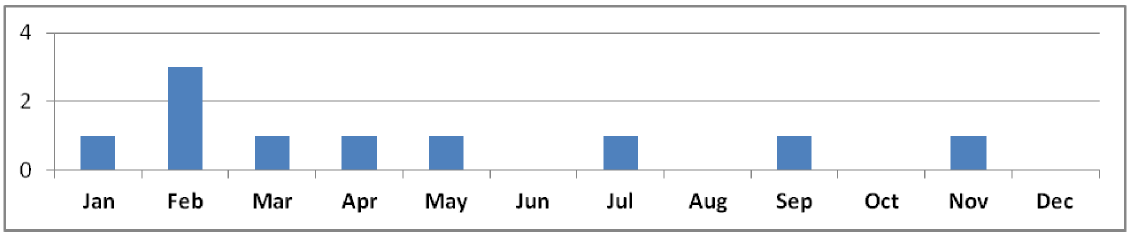

Figure 3.5.1: Road-caused elk mortalities by month along the Trans-Canada Highway.

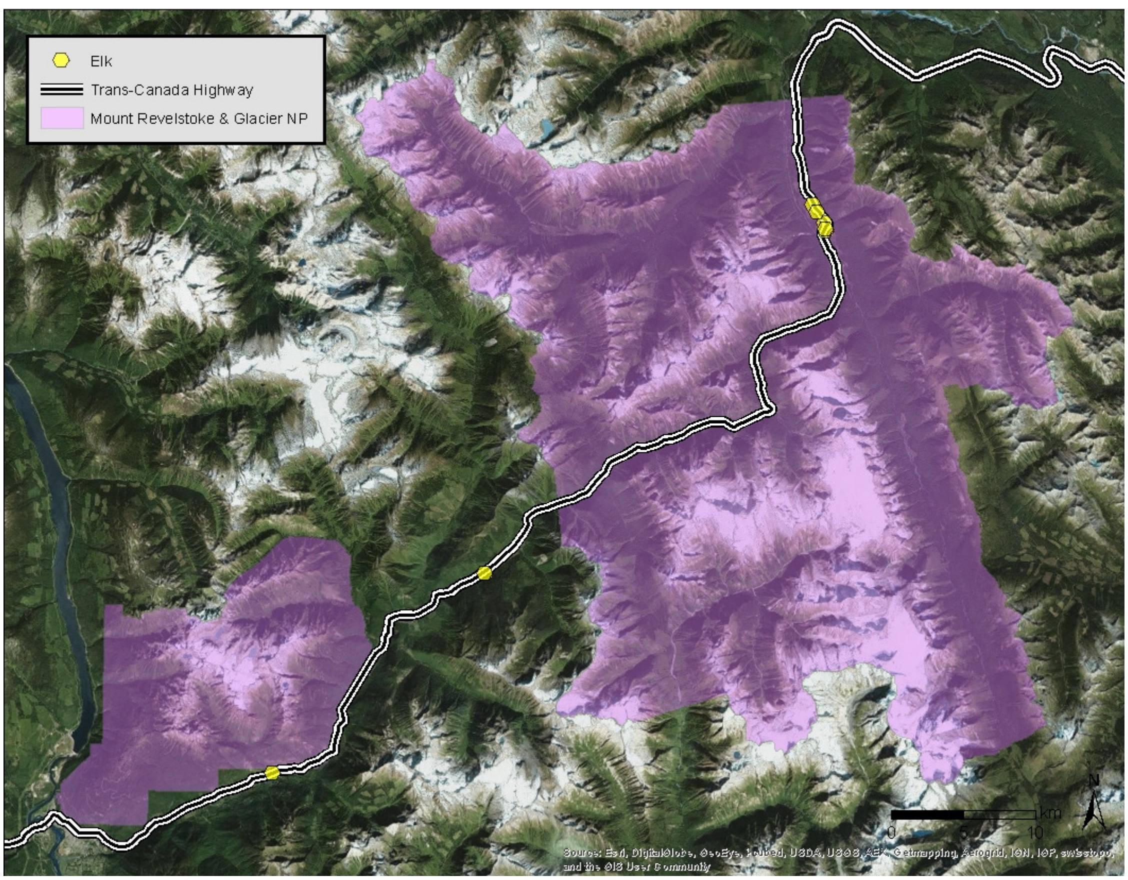

Figure 3.5.2: Elk-vehicle collisions on the Trans-Canada Highway in British Columbia.

Grizzly Bears

In Parks Canada's Cansis database, we found 10 grizzly bear-vehicle collisions. Grizzly bear mortalities occurred between 15 May 1971 and 10 May 2011. Grizzly bear mortalities were concentrated during early summer and fall (Figure 3.6.1). The locations of vehicle collisions with grizzly bears were clustered near Rogers Pass on the TCH (Figure 3.6.2).

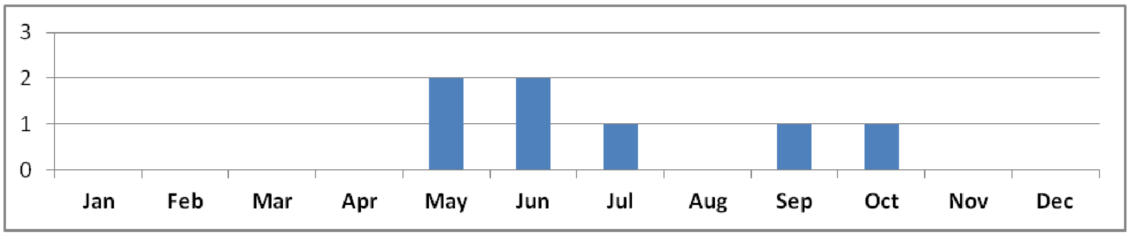

Figure 3.6.1: Road-caused grizzly bear mortalities by month along the Trans-Canada Highway.

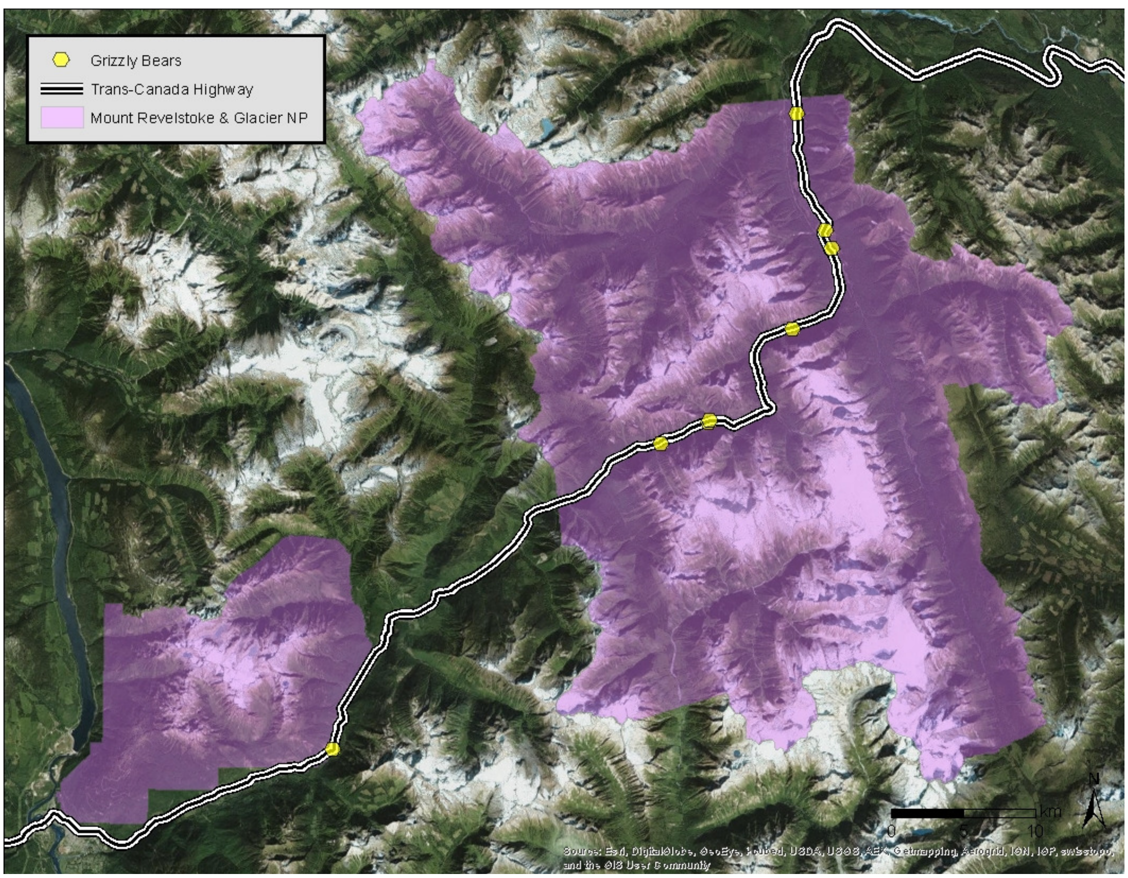

Figure 3.6.2: Grizzly bear-vehicle collisions on the Trans-Canada Highway in British Columbia.

Moose

In Parks Canada's Cansis database, we found 71 moose-vehicle collisions. Moose mortalities occurred between 1 October 1970 and 8 October 2009. Moose mortalities were concentrated during early late fall and winter, but occurred during every month (Figure 3.7.1). The locations of vehicle collisions with moose were clustered on the east boundary of Revelstoke and the Beaver Valley on the TCH (Figure 3.7.2).

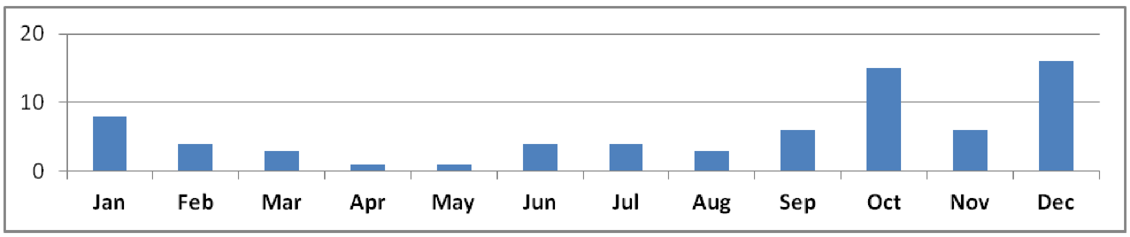

Figure 3.7.1: Road-caused moose mortalities by month along the Trans-Canada Highway.

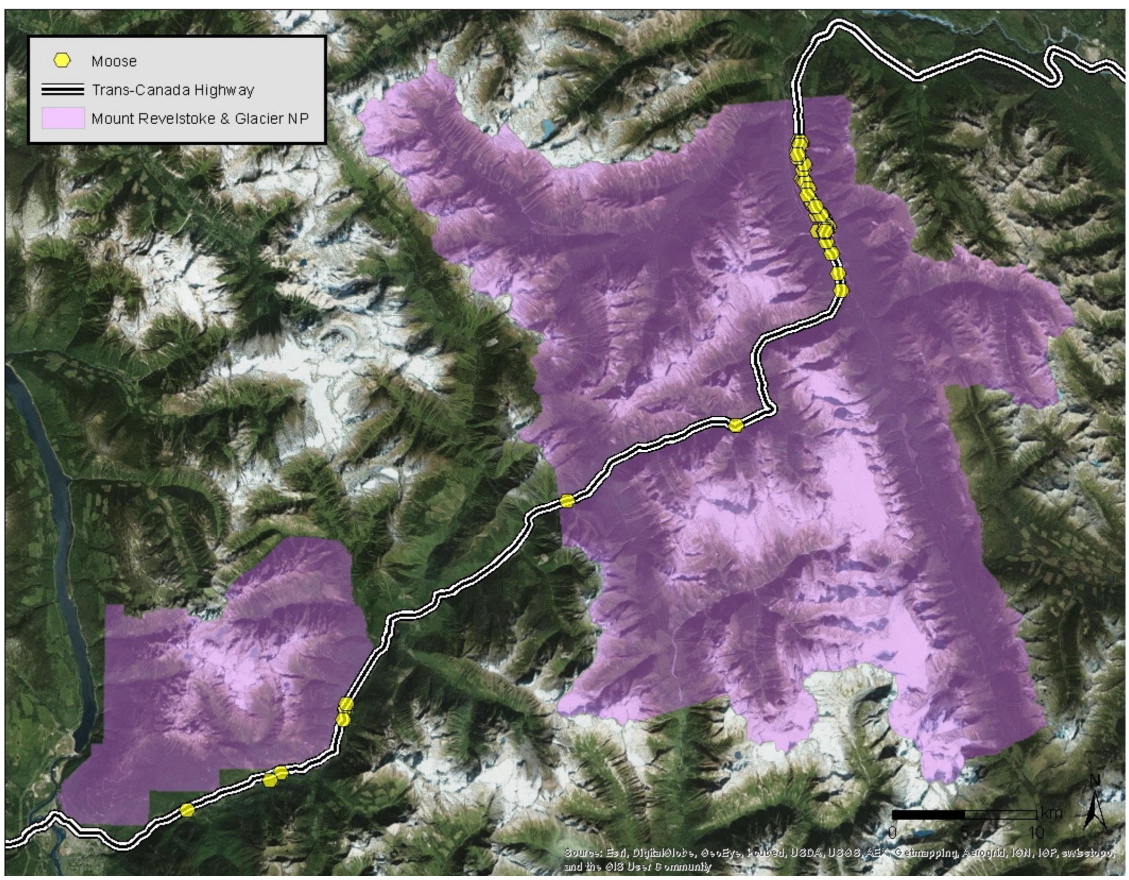

Figure 3.7.2: Moose-vehicle collisions on the Trans-Canada Highway in British Columbia.

Mountain Goats

In Parks Canada's Cansis database, we found 82 mountain goat vehicle collisions. Mountain goat mortalities occurred between 16 September 1964 and 11 July 2010. Mountain goat mortalities were highly concentrated during June and July (Figure 3.8.1). The locations of vehicle collisions with mountain goats were clustered around the eastern snow sheds on the TCH in Glacier National Park (Figure 3.8.2).

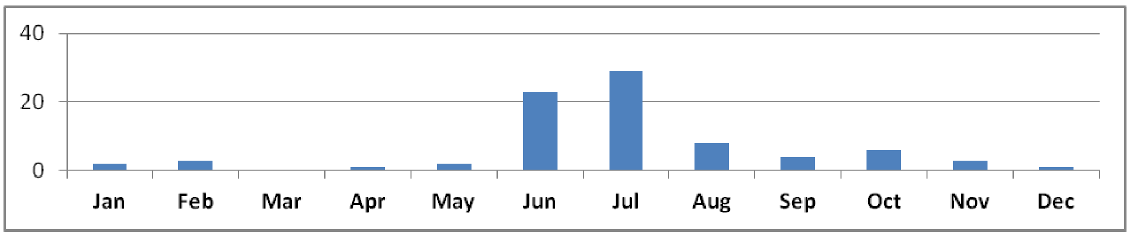

Figure 3.8.1: Road-caused goat mortalities by month along the Trans-Canada Highway.

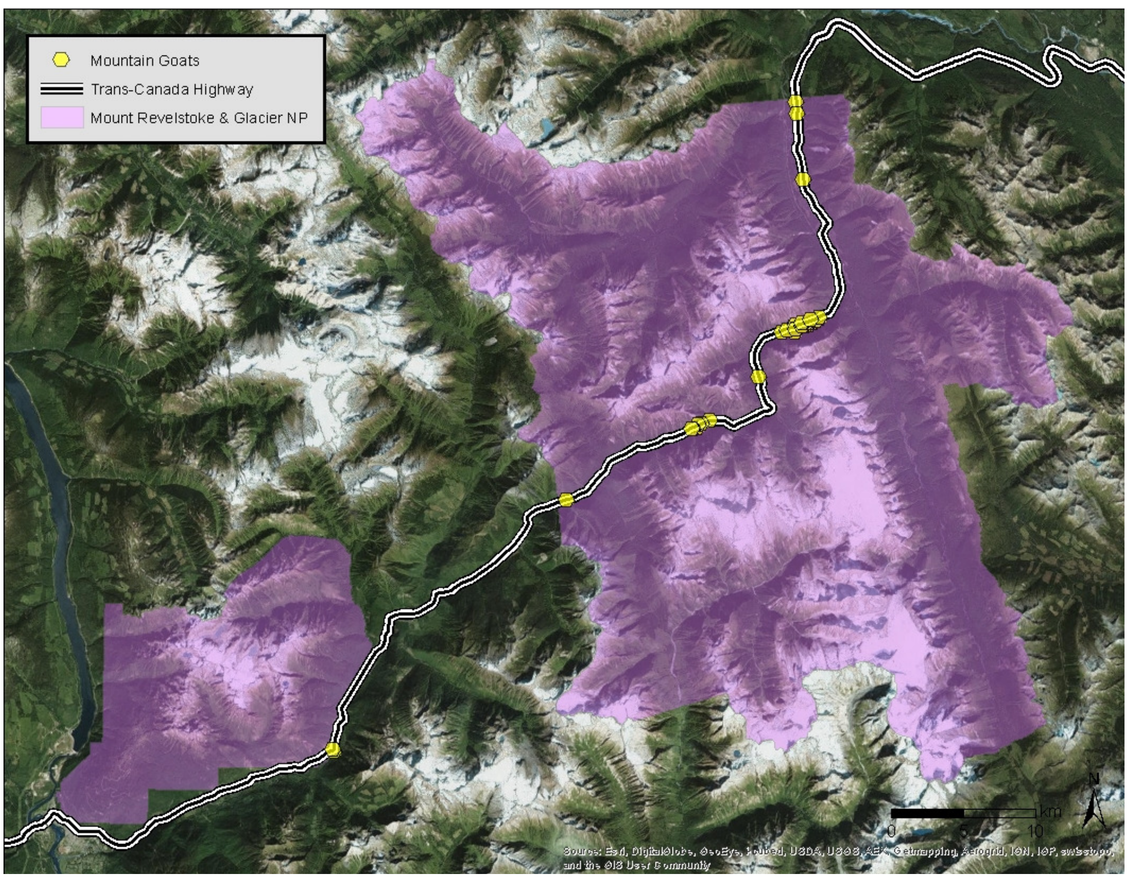

Figure 3.8.2: Mountain goat-vehicle collisions on the Trans-Canada Highway in British Columbia.

Wolverines

In Parks Canada's Cansis database, we found 1 wolverine-vehicle collisions. The wolverine mortality occurred on 12 December 1995 (Figure 3.9.1). The locations of vehicle collisions with wolverines were sparse and not clustered on the TCH (Figure 3.9.2).

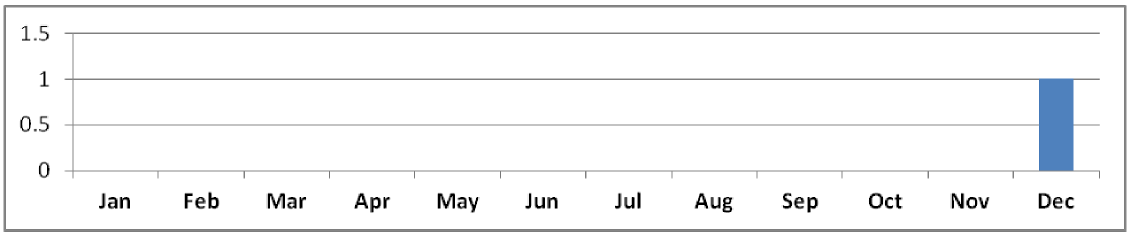

Figure 3.9.1: Road-caused wolverine mortalities by month along the Trans-Canada Highway.

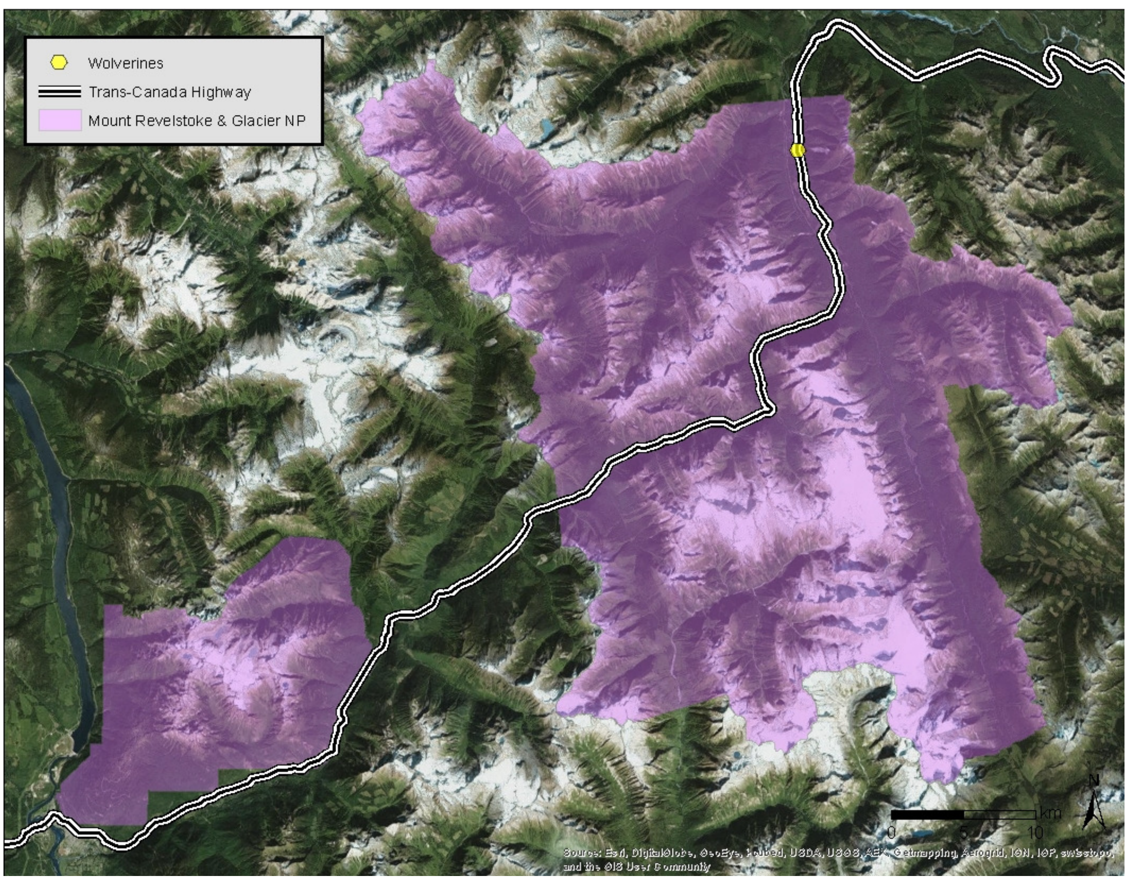

Figure 3.9.2: Wolverine-vehicle collisions on the Trans-Canada Highway in British Columbia.

4. Connectivity Modeling

4.1 Introduction

Connectivity models can be useful for identifying important habitat linkages and areas for highway mitigation. Previously, Geographic Information System (GIS)-generated habitat models based on expert opinion have been used to determine the regionally important locations for wildlife crossing structures (Clevenger et al. 2002). Recent attention has focused on the use of landscape resistance models to guide highway mitigation efforts (Landguth et al. 2012). These types of connectivity models that test the landscape by resistance hypothesis to gene flow (McRae 2006) may be particularly well-suited for identifying important crossing locations as they model large, landscape scale processes (i.e dispersal patterns). We used a landscape resistance (i.e. connectivity) model, previously developed for black bears (Cushman et al. 2006) and generalized here, to help identify key areas for highway mitigation. We did not specifically model ungulate movements, because we had insufficient location data to create reliable ungulate landscape resistance surfaces. Instead of modeling ungulate connectivity directly, we used black bears as surrogates to represent general forest connectivity across the highway (Landguth et al. 2011) and used wildlife observational data to identify important areas for grizzly bear and mountain goat movements (see Section 6.1 and Section 6.2). Our specific objective for least cost path analysis was to use the generalized forest connectivity model for black bears to identify and prioritize important habitat linkages for carnivores and ungulates by examining where least cost paths cross the TCH in MRG.

4.2 Methods

For our connectivity models, we focused on black bears because they get hit frequently on the Trans-Canada Highway, they have huge home ranges so they need to cross roads frequently to access habitat patches, they disperse long distances so they are good species for landscape resistance models (Cushman et al. 2006), and they are suitable surrogates for other forest dwelling species (e.g., ungulates, cougars, wolves). We gathered *landscape data* to hypothesize resistance to movement for black bears: a hypothesized approach allows us to test the interactions and relative strengths of each additional environmental variable on the effects on connectivity in this area – How influential are the roads, how strong are the pathways under different model scenarios? We tested the following hypotheses to movement for black bears: 1) Null model of isolation-by-distance (i.e. resistance to movement only through Euclidean distance), 2) Isolation-by-distance + Roads layer, 3) Elevation, Roads, and Landcover from Cushman et al. (2006), ShortBull et al. (2011). We created *landscape resistance models* hypothesizing resistance to movement for black bears (Figure 4.1). We converted each of the landscape data to a landscape resistance model following Cushman et al. (2006). We placed 100 points in the middle of our study area and 100 points on the edge of our study area in areas with low resistance values. Preliminary runs explored number of points and point placement with relatively little change in path convergence. Least cost path models identify the shortest path of least resistance from point A to point B. We used UNICOR (Landguth et al. 2012) to run least cost paths between the 200 starting points and examined areas where the paths crossed the TCH.

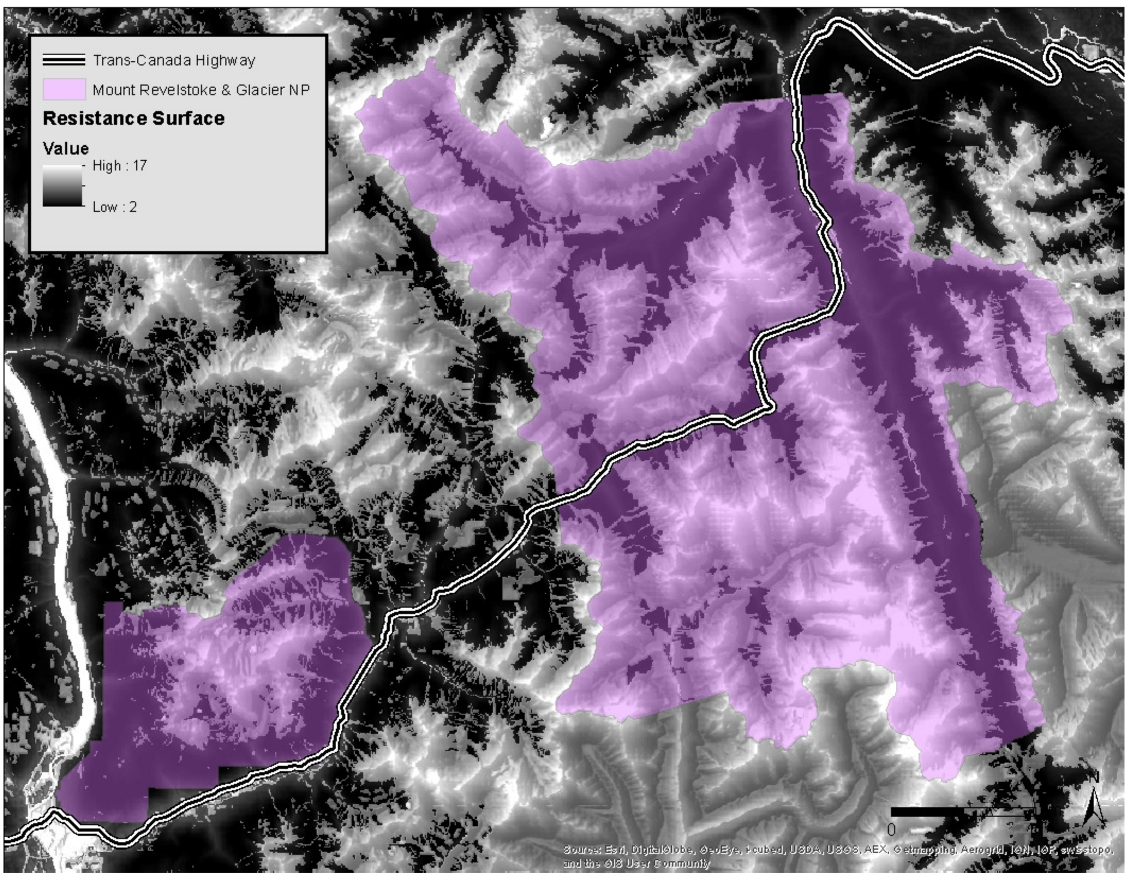

Figure 4.1: Our landscape resistance surface for black bears in Mount Revelstoke and Glacier National Parks, British Columbia.

4.3 Results

We identified a number of important cross-highway linkages and corridors using least cost paths from UNICOR (Figure 4.2). As expected, many of the least cost paths follow low-mid elevation gradients and contour with major watersheds. There was little difference between the least cost paths under different hypotheses so we used the elevation and forest cover resistance removing road resistance in order to identify habitat linkages. Three areas of particular importance to cross-highway movement emerged from this analysis, the area along the eastern edge of Mount Revelstoke, the provincial lands between the national parks, and the Beaver Valley (dark brown lines in Figure 4.2). Our analysis also highlighted Rogers Pass as an important corridor for east-west movement with few options for cross-highway movement.

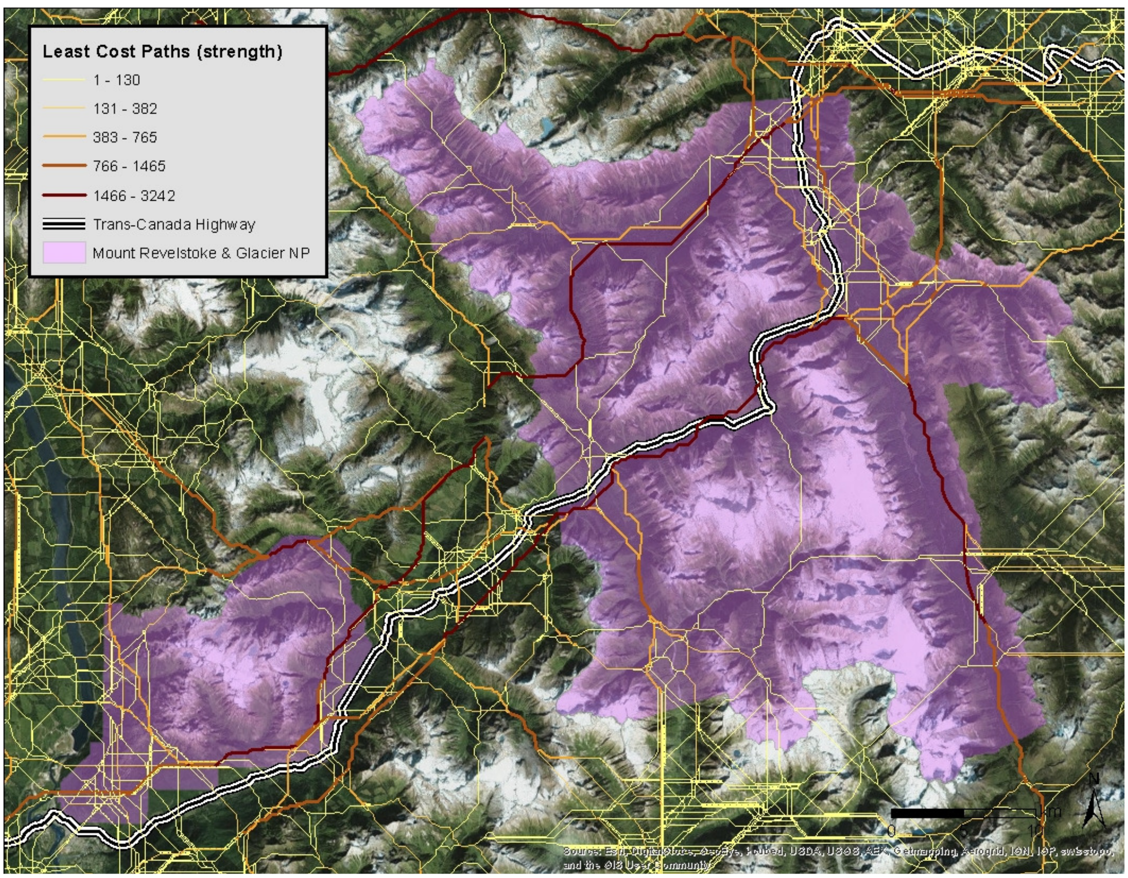

Figure 4.2: UNICOR's least cost paths for black bears in Mount Revelstoke and Glacier National Parks, British Columbia.

References

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Short Bull, R.A., S.A. Cushman, R. Mace, T. Chilton, K.C. Kendall, E.L. Landguth, M.K. Schwartz, K. McKelvey, F.A. Allendorf. 2011. Why replication is important in landscape genetics: American black bear in the Rocky Mountains. Molecular Ecology 20:1092-1107.

5. Synthesis of Wildlife-Vehicle Collisions (WVC) and Connectivity Models

5.1 Introduction

Connectivity models can be useful for identifying important wildlife corridors; however, like all models, they are gross oversimplifications of biological reality. Assigning values to landscape variables and ranking their relative importance to landscape scale movement is a somewhat subjective process. Thus, the most powerful inference from connectivity models based on expert opinion can be drawn when the results are congruent with different model types and with disparate data sources. Our objective was to compare landscape resistance-based least cost paths to habitat-based least costs paths and to wildlife-vehicle collision data to help identify and prioritize the locations of wildlife crossing structures.

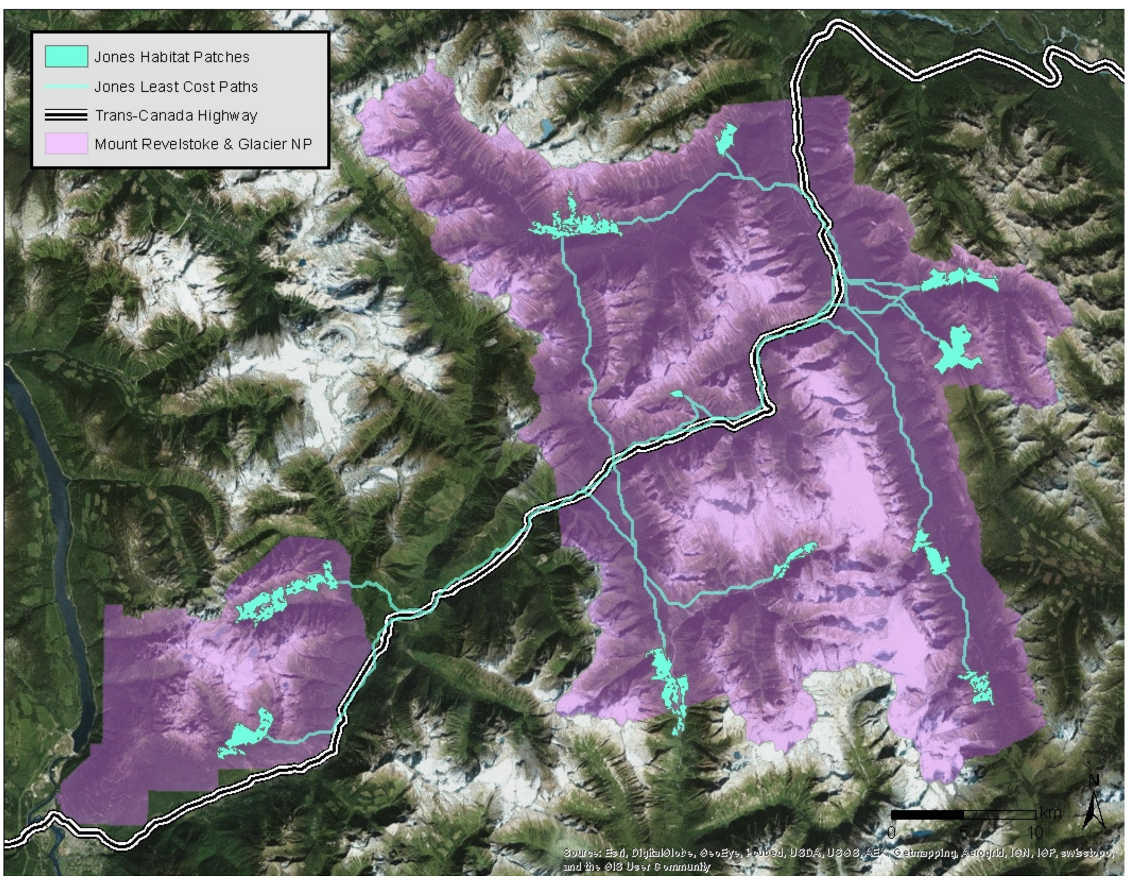

Figure 5.1: Habitat patches and least cost paths for grizzly bears in Mount Revelstoke and Glacier National Parks, British Columbia (Jones 2012).

5.2 Methods

We compared least cost paths from UNICOR, WVC locations, and habitat-based least cost paths from Jones (2012) to determine areas of congruence for identifying areas for highway mitigation emphasis along the TCH in MRG. Least cost path analysis with UNICOR (Landguth et al. 2012) and WVC data collection and results were described previously (Sections 3 and 4 respectively). Habitat-based least cost paths were created by Andrew Jones as part of his Master of Science thesis at Royal Roads University (Jones 2012). Jones created a resource selection function (RSF) for grizzly bears using GPS (Global Positioning System) collar data and then used this habitat layer to run least cost paths between 12 high quality habitat patches (Figure 5.1) in Circuitscape (McRae 2006), which uses circuit theory to predict movement patterns and identify important wildlife corridors (McRae et al. 2008). Lastly, we compared the overlap between our least cost paths, Jones's least cost paths and WVC data.

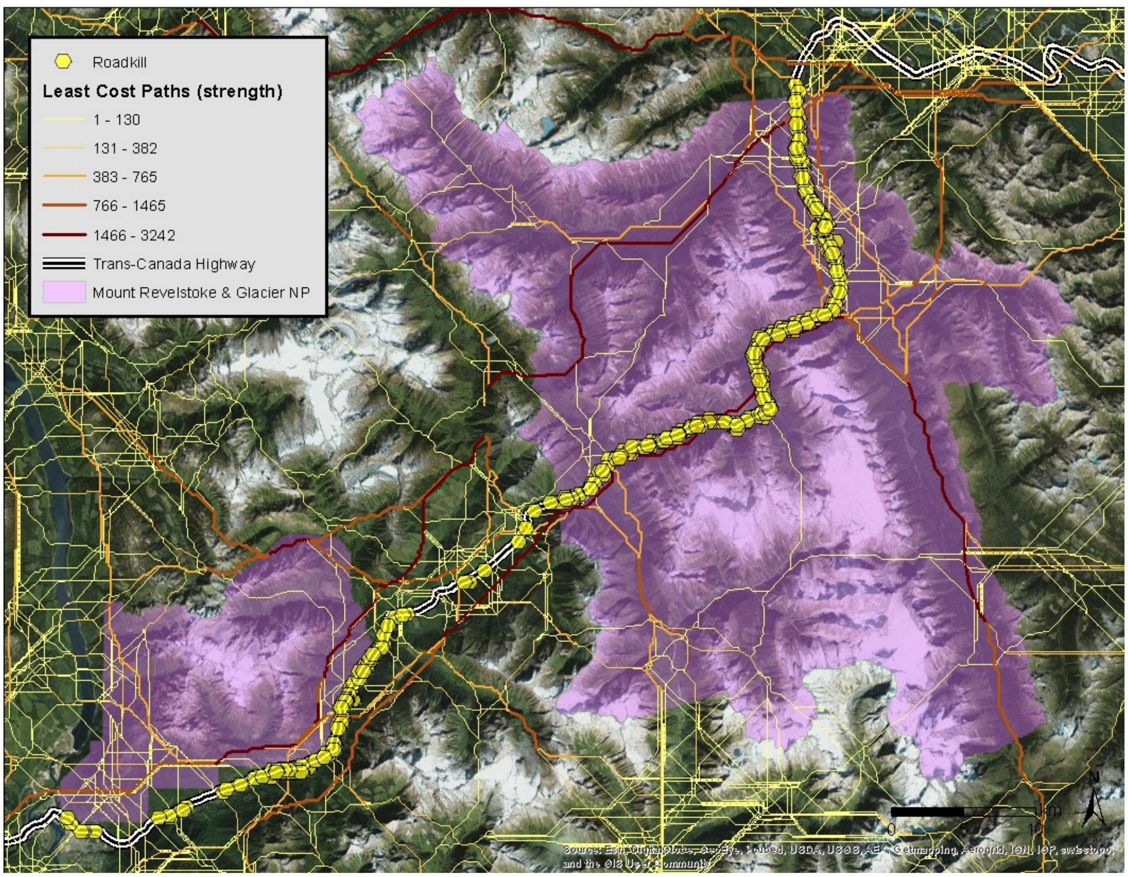

Figure 5.2: Comparison of UNICOR's least cost paths and wildlife-vehicle collision data in Mount Revelstoke and Glacier National Parks, British Columbia.

5.3 Results

We found a high degree of congruence between our three methods to determine crossing structure placement: landscape resistance-based least cost paths, WVC data, and habitat-based least cost paths from Jones (2012). As expected, our least cost paths overlapped with mortality hotspots, particularly in the Beaver Valley, which had a high density of cross-highway linkages and a high concentration of road-kill (Figure 5.2). Although we used very different techniques (UNICOR versus CIRCUITSCAPE) on different species (black bears, grizzly bears), our least cost paths with relatively high corridor strength were congruent with habitat linkages identified by the least cost paths of Jones (2012). Perhaps this is not so striking when the amount of rock and ice in the study area are considered as these areas are generally avoided by least cost paths, because they have little habitat value (i.e., high resistance) and connectivity models generally perform better when excluding habitat rather than predicting high quality habitat.

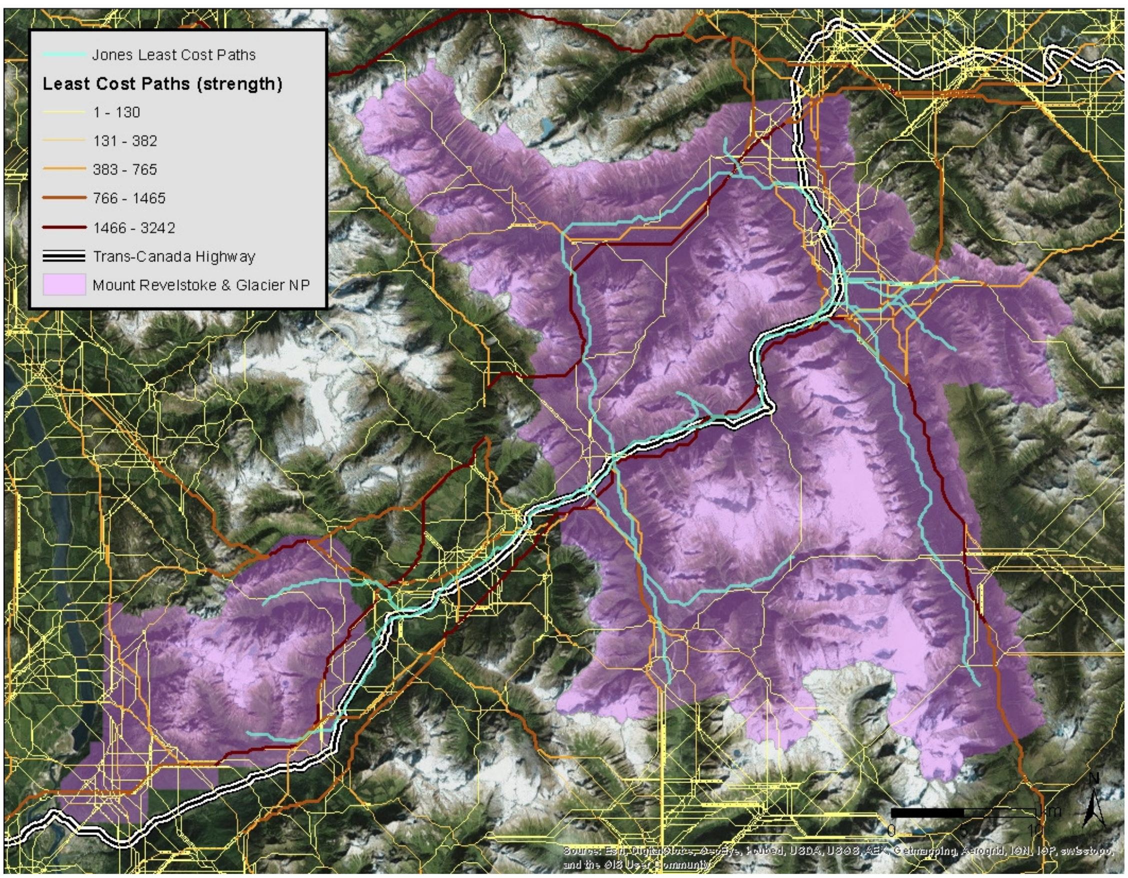

Figure 5.3: Comparison of UNICOR's least cost paths for black bears and least cost paths for grizzly bears in Mount Revelstoke and Glacier National Parks, British Columbia (Jones 2012).

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6. Recommendations

6.1. Highway Mitigation Design and Prioritization

Identification of Mitigation Emphasis Sites

Our comparison of least cost paths and mortality sites identified 24 TCH sites deemed suitable for mitigation measures (hereafter, mitigation emphasis sites); 14 sites in Glacier, 5 sites in Mount Revelstoke and 5 sites on provincial lands between the two parks. For each site, we ranked the importance to regional and local connectivity, the threat posed from road-caused mortality based on road-kill records, and the feasibility of implementing mitigation measures at the site. We ranked each of these four categories from 1 to 5, giving higher scores for areas with higher degrees of overlap with WVCs or least cost paths. We recorded scores and comments

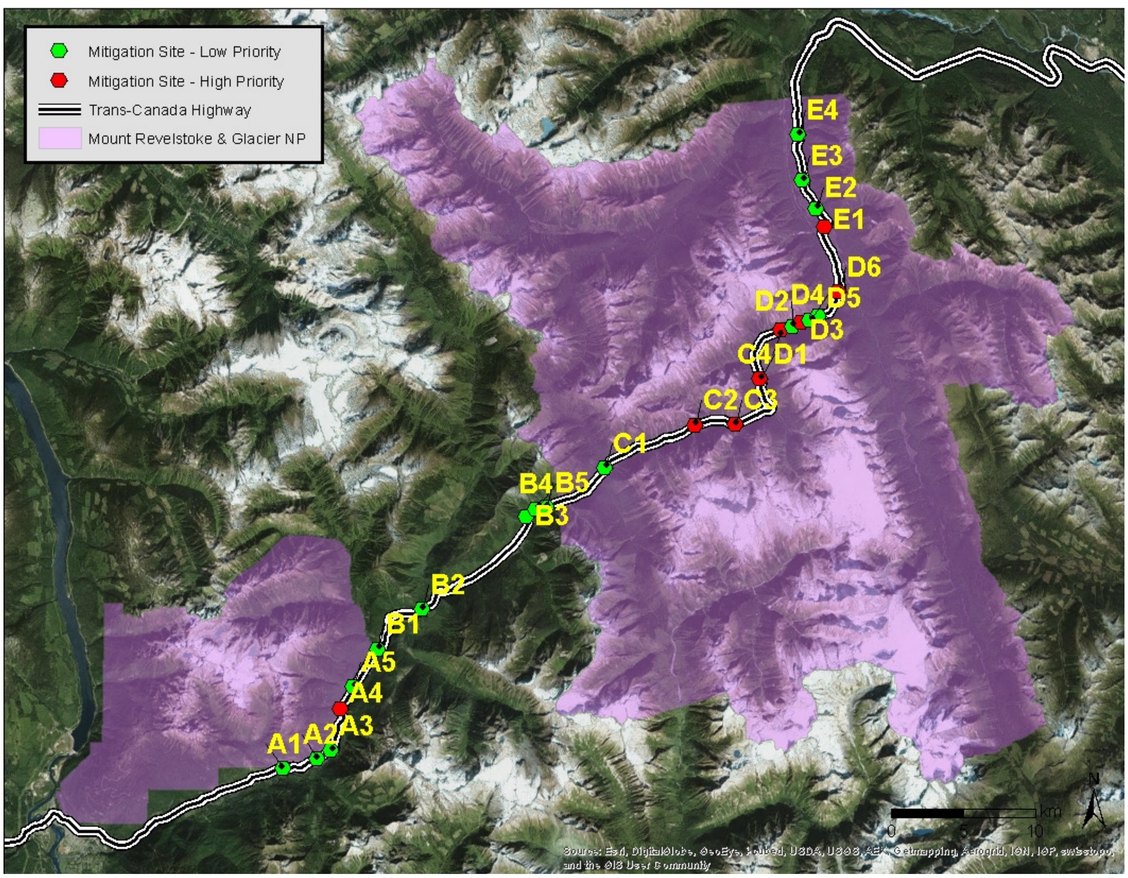

Figure 6.1: Recommended emphasis sites for mitigation of the Trans-Canada Highway through Mount Revelstoke and Glacier National Parks in British Columbia.

on Hot Sheets (**Appendix A**) and averaged scores to prioritize the mitigation emphasis sites as high and low priority (Figure 6.1). What we term “low priority” sites are those that have scores less than or equal to the average of the 24 sites; however, we recommend that mitigation measures be implemented at all 24 sites, not just the high priority sites.

Mitigation Emphasis Sites

As described above, *mitigation emphasis sites* are specific locations within the MRG study area where opportunities for reducing wildlife–vehicle collisions and improving connectivity for all wildlife are highest, including fragmentation-sensitive species (Figure 6.1.). Focusing highway mitigation efforts in these 24 areas should improve motorist safety, reduce wildlife mortalities and improve habitat linkages and animal movement through transitional habitat along these highway segments.

We spent two days visiting each of the mitigation emphasis sites in the field during September 2014. From the field evaluation of the 24 mitigation emphasis sites, recommendations were described as actions that can be carried out in the short-term and long-term. *Short-term* mitigation consists of relatively simple, low-cost actions to reduce wildlife–vehicle collisions and improve the local and regional conservation values of the area. This type of mitigation may be combined with other highway construction or upgrade projects in the area (e.g., bridge reconstruction, culvert replacement, passing lanes). Recommendations for *long-term* mitigation would typically occur during major reconstruction and lane expansion of the Trans-Canada Highway in the study area.

We developed recommendations for mitigation opportunities at each mitigation emphasis site along the Trans-Canada Highway in MRG. The relative importance of each site varies by species and local landscape attributes across the >100-kilometer highway corridor. Each site and conservation ranking was informed by field data on wildlife movement, wildlife mortality and expert opinion. A variety of mitigation measures are recommended, from simple to complex, some requiring work off-site (e.g., salt diversion), while others necessitating structural work on the highway (e.g., wildlife underpass construction).

Mitigation Measures

In a recent report to the U.S. Congress, commissioned by the Federal Highway Administration, Huijser et al. (2007) summarized 36 different animal–vehicle collision mitigation measures currently in use throughout the world. The mitigation measures were grouped into four types:

- Measures that attempt to influence driver behaviour (18).
- Measures that attempt to influence animal behaviour (10).
- Measures that seek to reduce wildlife population size (4).
- Measures that seek to physically separate animals from the roadway (4).

As part of the 2007 report, a Technical Working Group was convened that included seven national experts in the area of animal–vehicle collisions. One of their tasks was to rank the current animal–vehicle collision mitigation measures into three categories:

1. Measures that should be implemented (where appropriate).
2. Measures that appear promising but require further investigation.
3. Measures or practices that are proven ineffective.

Selected Trans-Canada Highway mitigation measures

The recommendations for improving motorist safety and wildlife connectivity for the TCH include a total of six different proven or promising mitigation measures.

Table 6.1 includes a list of the measures, their effectiveness in reducing WVCs (if data are available), the target of the measure (type) and the ranking category as presented in the Huijser et al. (2007) report.

Table 6.1: Wildlife mitigation measures, their focus and effectiveness.

Mitigation measure	Effectiveness	Type[1]	Category[2]
Salt diversion (Intercept feeding/salt licks)	N/A[3]	Animal	Promising
Animal detection system	87%	Driver	Promising
Fencing	86%	Separate	Proven
Underpass with waterflow	86%	Animal	Proven
Underpass – wildlife	86%	Animal	Proven
Overpass – wildlife	86%	Animal	Proven

[1] *Driver*: Measures that attempt to influence driver behaviour; *Animal*: Measures that attempt to influence animal behaviour; *Size*: Measures that seek to reduce wildlife population size; *Separate*: Measures that physically separate animals from the roadway. From Huijser et al. 2007.
[2] *Proven*: Measures that should be implemented (where appropriate); *Promising*: Measures that appear promising, but require further investigation. From Huijser et al. 2007.
[3] Not Available: data or studies on effectiveness

Mitigation Recommendations

A large amount of information has been amassed specific to each mitigation emphasis site. Information Sheets (**Appendix A**) were prepared for each site and describe all site-specific information with regard to mitigation importance, target species, wildlife objectives, and mitigation measures recommendations. The Information Sheets are a quick and easy reference that summarizes mitigation opportunities at each site. There are many mitigation emphasis sites throughout the TCH corridor and multiple recommendations for each site. Instead of reviewing each site, we highlight the most relevant sites with regard to a) regional conservation and connectivity, b) wildlife–vehicle collision reduction and c) immediate mitigation action that Parks Canada can undertake.

Matrix Valuation

We averaged the values for the 19 sites within MRG, excluding the Provincial sites because they lacked reliable road-kill data and therefore were not comparable. The average score for the matrix valuation of the 19 sites was 3.13. Eight of the 19 sites had scores equal to or above the average score and are listed below from west to east.

- Revelstoke: Site 4 (3.50)
- Rogers Pass: Site 2 (3.75)
- Rogers Pass: Site 3 (3.25)
- Rogers Pass: Site 4 (3.75)
- Glacier Snow Sheds: Site 1 (3.50)
- Glacier Snow Sheds Site 6 (3.50)
- Beaver River: Site 1 (3.75)
- Beaver River: Site 3 (3.25)

We discuss each of these sites and their mitigation recommendations in light of their respective attributes associated with local and regional conservation values and the safety of motorists traveling the Trans-Canada Highway. Specific mitigation techniques are italicized; general descriptions and technical guidelines of each mitigation emphasis site are found in **Appendix B**.

Revelstoke - Site 4

This site had the second highest matrix score among all the TCH sites in the study area (3.50; tied with Glacier Snow Sheds, Site 1 and 6). It is particularly important in terms of regional connectivity conservation and transportation mitigation opportunities, with valuation scores 5 and 4, respectively. In the long-term, a *wildlife underpass* and *fencing* are recommended should the highway be upgraded or expanded to four lanes. A wildlife underpass structure is the most suitable design given the type of terrain at the site. The recommended dimension for the underpass is minimum 11 m wide and ≥3m high (see *wildlife underpass,* **Appendix B, Sheet D**) and is based on the high probability of grizzly bear movement in this area and it being a key linkage zone across the TCH.

In the long-term, if the highway is reconstructed, there is a relatively easy opportunity to mitigate the highway with a *wildlife underpass* in this area as slopes are gentle, the highway is raised on fill and there is ample space below grade to fit a wildlife underpass of the recommended dimensions.

Wing fencing (minimum 200-500 m) should be used to guide wildlife to the underpass. There are rock-cuts and steep terrain in the area that would facilitate fence termination points. Snow levels at this location may cause problems with wing fencing, primarily snow creep, however it would be advisable to test the integrity of the fence in an adaptive management process. The technical specifications for wildlife fencing in high snow areas are provided in **Appendix C** and should be used for fence design at this site.

Rogers Pass – Site 2

This site had the highest matrix score among all the TCH sites in the study area (3.75; tied with Rogers Pass Site 4 and Beaver River Site 1). It is particularly important in terms of regional connectivity conservation and transportation mitigation opportunities, with equal valuation scores of 5. In the long-term, a *wildlife underpass* and *fencing* are recommended should the highway be upgraded or expanded to four lanes. At this site a wildlife underpass structure is the most suitable design given the type of terrain at the site. In this area the slopes are gentle, the highway is raised on fill and there is sufficient space below grade to construct a wildlife underpass of the recommended dimensions. The recommended dimension for the underpass is minimum 11 m wide and ≥3m high (see *wildlife underpass,* **Appendix B, Sheet D**) and is based on the high probability of grizzly bear movement through this area and it being a key linkage zone across the TCH.

Wing fencing (minimum 200-500 m) should be used to guide wildlife to the underpass. There are rock-cuts and steep terrain in the area that would facilitate fence termination points. Snow levels are a concern at this site and may cause problems with wing fencing, primarily snow creep and possibly snow throw from snowplowing. However it would be advisable to test the integrity of the fence at this site in an adaptive management process. The technical specifications for wildlife fencing in high snow areas are provided in **Appendix C** and should be used for fence design at this site.

This is the only site that is in relatively close proximity to the Canadian Pacific Railway mainline as the highway and railway are bundled close together. Preliminary research and analysis of rail mortality locations in Banff National Park indicated that wildlife crossing structures in close proximity to the railway were not more likely to be areas of high railway-related mortality of wildlife.

Rogers Pass - Site 3

This site had the third highest matrix score among all the TCH sites in the study area (3.25; tied with Beaver River Site 3). The location is recognized as a site with high regional conservation value (= 4). It is not an area of high road-related mortality of wildlife (score = 1). It has high opportunities for highway mitigation (score = 5) given the existing open span bridge at Loop Brook Creek. It is an important site from a conservation and management standpoint, to preserve for local and regional scale movements of wildlife, particularly fragmentation-sensitive species such as grizzly bears, wolverines and lynx.

Potential opportunities in the <u>long-term</u> consist of highway twinning (bridge construction) project. All bridge construction must be designed with wildlife movement (and hydrologic flow) in mind. A new bridge at this site should be designed with a wide span, allowing dry travel sections (7–10 m wide) above high-water mark and more than 4 m vertical clearance. Wing *fencing* (200–500 m depending on terrain) should be used to guide wildlife to the underpass (see *Wildlife underpass with waterflow*, **Appendix E**, Sheet I).

Rogers Pass – Site 4

This site had the highest score (along with two other sites) and is one of the most critical habitat linkages in the entire TCH corridor in MRG. It is particularly important in terms of regional and local conservation (both = 5) for grizzly bears and other wide-ranging carnivores (wolverines, lynx). Empirical data from the movements of a GPS-collared female grizzly bear indicated that this area was used extensively

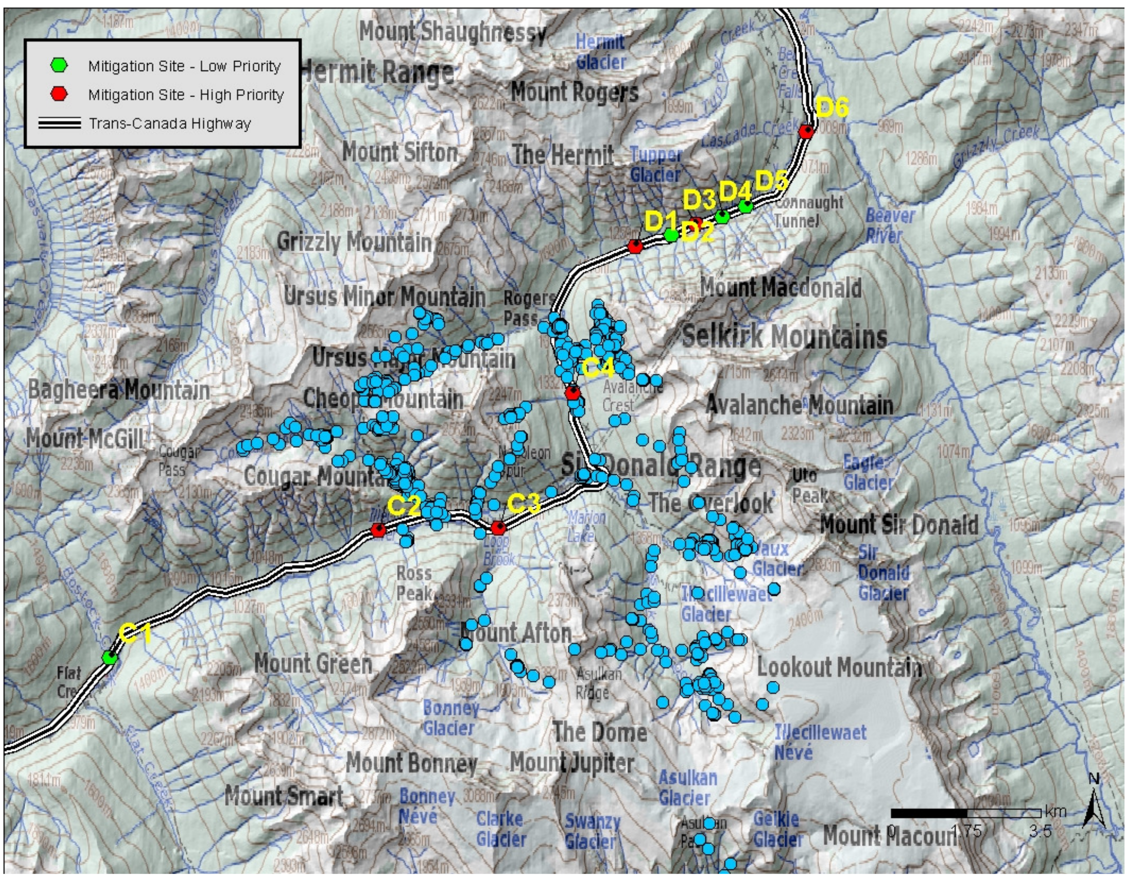

Figure 6.2: Female grizzly bear Global Positioning System (GPS) collar locations from 2012 near Rogers Pass, British Columbia.

and numerous crossings of the TCH occurred at this location and within the vicinity (**Figure 6.2.**). The site is also characterized by the relative ease of mitigating the site for connectivity (= 4). Like Rogers Pass Site 3, highway-related mortality is not an issue at this location.

In the long-term, a *wildlife overpass* and *fencing* are recommended should the highway be upgraded or expanded to four lanes (see *wildlife overpass,* **Appendix B, Sheet F**).
A wildlife overpass structure is the most suitable design given the highway passes through a ridge cut resulting in raised embankments (elevated terrain) on both sides of the highway. This highway-terrain configuration facilitates the construction of an overpass structure. A similar situation can be seen at the “Lake Louise wildlife overpass” in Banff National Park. The recommended minimum dimension is >40 m wide (see Clevenger and Huijser 2011). Selection of design type (arched, span) and materials (concrete, steel) will be dependent on terrain, engineering constraints and pricing of materials.

Snow is a concern at this location due to high avalanche activity in the area and annual snowfall. It is not recommended to install fencing at this location due the frequent over-road avalanche activity. Getting wildlife in the area to find, start using, and learn to adapt to this structure can be facilitated by cutting trails to the overpass approach ramps. Although the site is not in an area of frequent human use it will be important to close this area to the public in order to allow wildlife to use the structure. Similar restricted activity closures (year-round) have been put in place at the wildlife overpasses in Banff National Park.

Glacier Snow Sheds - Site 1

This site had the second highest matrix score among all the TCH sites in the study area (3.50; tied with two other sites). It is particularly important in terms of mortality (primarily goats) and transportation mitigation opportunities, with valuation scores 4 and 5, respectively. Like all five snow shed sites in Glacier National Park, there are excellent short-term mitigation measures that can be implemented without waiting for the highway to be twinned. There multiple mitigation strategies that can be used at snow sheds that primarily consist of keeping mountain goats off the highway and outside tunnels. These measures are listed below without priority or ranking:

1. *Salt diversion*. This method has been shown to be effective in a pilot project at a hot spot for mountain goat road-kills on Highway 3A near Keremeos in the Okanagan Valley. As pilot project should take place implementing salt diversion at areas away from snow sheds. The method consists of diverting goats from highway salt to areas where salt are manually dispersed in areas adjacent to escape terrain and habitats they occupy.
2. *Animal-detection system*. A radar-based animal detection system placed at tunnel entrances to warn motorists when goats and other wildlife are on the highway near tunnel entrances. The same radar-based animal detection systems placed inside tunnel will detect wildlife inside tunnel and warn motorists approaching tunnel.
3. *Create barrier*. Block off exterior wall of snow shed where there are existing gaps in wall that allow wildlife, primarily goats, to access tunnel interior. Make the outside wall as impermeable as possible.
4. *Block step walkway*. Build 1-2 structures along length of tunnel outside wall, consisting of interlocking precast concrete 'lego' blocks, that allow for wildlife (goats and bears primarily) to ascend and descend from snow shed roofs.

Fencing notes: High snow levels and frequent avalanche activity is a concern at this location, therefore fencing is not recommended for any mitigation.

Glacier Snow Sheds – Site 6

This site had the second highest matrix score among all the TCH sites in the study area (3.50; tied with two other sites). It is particularly important in terms of regional scale connectivity and transportation mitigation opportunities, with valuation scores 5 and 4, respectively. Like all the snow shed sites (n=5) there are excellent <u>short-term</u> mitigation measures that can be implemented without waiting for the highway to be twinned. There multiple mitigation strategies that can be used at snow sheds that primarily consist of keeping mountain goats off the highway and outside tunnels. These measures are listed below without priority or ranking:

1. *Salt diversion*. This method has been shown to be effective in a pilot project at a hot spot for mountain goat road-kills on Highway 3A near Keremeos in the Okanagan Valley. As pilot project should take place implementing salt diversion at areas away from snow

sheds. The method consists of diverting goats from highway salt to areas where salt are manually dispersed in areas adjacent to escape terrain and habitats they occupy.

2. *Animal-detection system*. A radar-based animal detection system placed at tunnel entrances to warn motorists when goats and other wildlife are on the highway near tunnel entrances. The same radar-based animal detection systems placed inside tunnel will detect wildlife inside tunnel and warn motorists approaching tunnel.
3. *Create barrier*. Block off exterior wall of snow shed where there are existing gaps in wall that allow wildlife, primarily goats, to access tunnel interior. Make the outside wall as impermeable as possible.
4. *Block step walkway*. Build 1-2 structures along length of tunnel outside wall, consisting of interlocking precast concrete 'lego' blocks, that allow for wildlife (goats and bears primarily) to ascend and descend from snow shed roofs.

Fencing notes: High snow levels and frequent avalanche activity is a concern at this location, therefore fencing is not recommended for any mitigation.

Beaver River - Site 1

This site had the highest matrix score among all the TCH sites in the study area (3.75; tied with two other sites). It is particularly important in terms of regional connectivity conservation (score = 4), mortality (score = 4) and transportation mitigation opportunities (score = 4). The site has good opportunities for highway mitigation given the existing open span bridge at the Beaver River crossing and sufficient space for wildlife passage. It is an important site from a conservation and management standpoint, to preserve for local and regional scale movements of wildlife, particularly fragmentation-sensitive species such as grizzly bears, wolverines and lynx along with ungulates in the area including moose.

Potential opportunities in the long-term consist of highway twinning (bridge construction) project. All bridge construction must be designed with wildlife movement (and hydrologic flow) in mind. A new bridge at this site should be designed with a wide span, allowing on the west (north) side a dry travel section (>5 m wide) above high-water mark and more than 4 m vertical clearance. Wing *fencing* (200–500 m depending on terrain) should be used to guide wildlife to the underpass (see *Wildlife underpass with waterflow*, **Appendix B, Sheet E**).

Fencing notes: Snow not likely a concern at this location due to lower elevation compared to other parts of Glacier National Park.

Beaver River - Site 3

This site shared the third highest matrix score among all the TCH sites in the study area (3.25; tied with two other sites). It is particularly important in terms of ease of transportation mitigation opportunities (score = 5). In the long-term, a *wildlife underpass* and *fencing* are recommended at this site should the highway be upgraded or expanded to four lanes. A wildlife underpass structure is the most suitable design given the type of terrain at the site. In this area the slopes are gentle, the highway is raised on fill and there is sufficient space below grade to construct a wildlife underpass of the recommended dimensions. The recommended dimension for the underpass is minimum 11 m wide and ≥3m high (see *wildlife underpass,* **Appendix B, Sheet D**) and is based on the high probability of grizzly bears and other carnivores moving through this area that is adjacent to a carcass disposal site.

Wing fencing (minimum 200-500 m) should be used to guide wildlife to the underpass. There are suitable locations for fence terminations at roadside rock cuts. Snow is not an issue due to the lower elevation compared to other parts of Glacier National Park.

6.2. Mountain goat occurrence, mortality risk and mitigation measures

Although not pertaining to wildlife mortality or regional-scale connectivity, we felt that the occurrence and mortality risk of mountain goats in MRG merited special attention in this report. Mountain goats are an iconic species in MRG. There is little information regarding population demographics, genetics and connectivity requirements. However residual impacts and regional stressors have been identified as a management concern (Parks Canada 2010). The number of mountain goat mortalities on the TCH has remained steady during the last three decades, roughly 25 mortalities per decade (Table 3.1.). However, nine mountain goats were killed on the TCH in the last two years of which seven of those occurred in 2014. The high number of road-related mortalities is a cause of concern for Resource Conservation and conservation of mountain goats in MRG (D. Backman, MRG Field Unit, personal communication, 2014).

We plotted the observations of mountain goats on or near the TCH between 1961 and 2014, along with mountain goat road-kills, i.e., same mortality data used in Section 3 and Figure 3.8.2. Mortality locations and observations were then compared to mitigation emphasis sites for each zone, except Zone B due to a lack of mortality data in the Provincial section between the two national parks. We found the mountain goat observation data aligned with mitigation emphasis sites and the areas with the highest frequency of observations corresponded with high priority mitigation emphasis sites (Zone C, Site 2, Zone D, Site 3). One location that had high number of observations but was not a high priority mitigation, emphasis site was Zone A, Site 3 (Laing's Corner). Although this location is not designated as high priority we have made recommendations to target mitigation measures at this site (see Section 6.2. and 10).

6.3. Landscape-specific guidelines for Highway Mitigation in Mount Revelstoke-Glacier National Parks

The application of site-specific mitigations has significantly reduced road-related mortality of wildlife and improved means of habitat connectivity across highways (Dodd et al. 2007, Huijser et al. 2007, Sawaya et al. 2013). However, traditional highway mitigations are confounded in Mount Revelstoke and Glacier National Parks due to the unique landscape they are found. Some of the unique landscape and climatic attributes of MRG consist of extremely high snowfall, high prevalence of avalanche activity, and highly dissected and steep terrain, i.e., limited areas for wildlife movement thus highly defined movement corridors. There are 144 avalanche paths that directly impact the highway in Glacier National Park (S. Boyle, MRG Field Unit, personal communication, 2014). Standard or traditional mitigation measures up until now used elsewhere may not apply or be as effective in MRG. Mitigation measures designed for the TCH in MRG will need to be adapted to these climatic and landscape conditions. There are three main issues we have identified during the project that will influence landscape-specific guidelines for highway mitigation:

- o High snowfall and resulting deep snowpack in the highway corridor
  - ▪ Dissected landscape and steep terrain, which leads to:
  - ▪ Numerous avalanche paths with frequent avalanche activity
- o Prevalence of snow sheds to mitigate avalanche activity
- o High frequency of vehicle collisions with mountain goats

We address the technical aspects of mitigation design and implementation to address high snowfall and mountain goat-vehicle collisions below.

1. Deep snowpack

There are few places in the world where highway mitigation for wildlife is centered in areas of high snowfall (northern Norway, Washington State Cascades, MRG). High snowfall can wreak havoc on fencing and affect usage of underpasses and culverts that might become blocked or partially blocked by snow.

The number of suitable locations for mitigating highways maybe limited in highly dissected and mountainous areas due to terrain, MRG is a good example. *Continuous fencing* is not recommended as an option in this type of landscape as steep and rugged terrain limit or prevent animal movement across the highway. However, *partial or segmented fencing* will be the most effective in terms of reducing wildlife-vehicle collisions (because they are targeted at specific locations of frequent collision occurrence) and cost-benefits (excluding fencing in areas where wildlife are not likely crossing the highway). The disadvantage of partial fencing is that the fence terminations need to be adequately addressed to avoid displacing the collision hot spot being mitigated to the fence ends.

Several methods are used to reduce accidents with wildlife at fence ends or inside the fenced area.

Jump-outs or escape ramps (see **Appendix B, Sheet C**): Jump-outs placed near the fence ends allow animals that gain access inside the fenced area to exit quickly, thus minimizing the amount of time in the fenced area and movements across the highway. Jump-outs should be placed on each side of the highway in close proximity to fence ends. If warranted additional jump-outs can be placed as a back-up measure in case animals do not find the first jump-out. Jump-outs are relatively cheap measures (approximately $5000-10,000; T. McGuire, Highway Service Ctre, Parks Canada, personal communication, 2010) being built of interlocking precast concrete blocks.

Animal-detection systems (see **Appendix B, Sheet A**): Detection systems have been successfully used to reduce wildlife-vehicle collisions at fence terminations. Radar-based detection systems have proven far more effective and reliable compared to earlier radar-based models and break-the-beam systems (Huijser et al. 2007). Detection systems should be placed at mitigation emphasis sites with greatest likelihood of animals reaching the end of the fence and crossing the highway. This may occur at one fence termination or both. An adaptive management approach could be taken with regard to mitigating fence terminations by monitoring wildlife activity and mortality at fence terminations. If rates of wildlife-vehicle collisions become problematic then detection systems can be installed. Monitoring of animal-detection systems will be important to evaluate their effectiveness at reducing accidents. Current costs for radar-based animal-detection systems are roughly $200,000/km (Blake Dickson, Rotalec, personal communication, 2013). This cost covers the animal-detection system; all its components required for operation and full installation costs.

Trail cutting to wildlife crossing structures: This is a simple but untested method intended to get wildlife to use crossing structures in the shortest amount of time possible. By creating trails in the area outside of crossing structures wildlife should find the safe passages quickly, learn to use them, and begin using them on a regular basis. The faster wildlife are able to find crossing structures and begin using them, the less likely they will be crossing the highway in high mortality risk areas without mitigation fencing.

Fence damage

Fences may be damaged in areas of high snowfall. First, deep snowpacks shift over the course of winter (snow creep) and severely damage fence material and posts. There are few places where fencing has been used in high snowfall areas. In **Appendix C** we provide technical specifications for fencing that has been used in high snowfall areas of Norway. Research has taken place in Washington State's Cascade Mountains to devise the best fence materials to minimize snow creep damage. The Washington State Department of Transportation office in Yakima, Washington conducted that research and will be a valuable contact for designing fencing in MRG where snow creep may be a problem. The Highway Service Centre in Banff National Park may be experimenting with a "knock-down" or removable wildlife fence at the Bosworth Slide Path in Yoho National Park (P. Chambefort, Highway Service Centre, Banff National Park, personal communication, 2014). If the fence is installed it will serve as a good trial project for future deployment in areas prone to avalanche activity.

Avalanches can obliterate fences and other infrastructure in their path. We have recommended that crossing structures be built without fencing in areas most prone to avalanche activity. In these particular locations it will be critical to cut trails to crossing structures so wildlife find them and quickly learn that they are safe passages.

Wildlife underpass obstruction by snow

Finally, deep snow packs are capable of blocking partially or entirely culverts and wildlife underpasses. For the most part, we have recommended large span crossing structures at sites that may receive high snowfall. Animal movements and activity generally slows down and movements are restricted during winter, particularly in areas of high snowfall. Therefore we don't expect this to be a significant problem or management concern.

2. Snow sheds as wildlife overpasses

There are five snow sheds that have been built on the TCH to mitigate avalanche activity across the highway. Because of their overpass-type design snow sheds have the potential to function as overpasses for wildlife movement. Wildlife such as grizzly bears and mountain goats have been observed on snow shed roofs. Grizzly bears, mountain goats, wolverine and lynx are associated with avalanche paths and can be frequently found in their vicinity (Krebs et al. 2007; J Woods, MRG Field Unit, personal communication 1999).

The main obstacle to snow sheds functioning, as a wildlife overpass is the inability of wildlife to be able to access or travel off the snow shed roof on the downslope side. Snow sheds have an exterior wall on the downslope side that is an approximately 7-8 m drop, making it impossible for wildlife to ascend or descend from the roof. Snow sheds could be adapted to function as a wildlife overpass if a ramp-like structure could be built to allow wildlife to ascend and descend from their roof.

<u>Block step walkway (ramp)</u>

We recommend that at each snow shed, access up and down from the snow shed roof is made possible by constructing a simple walkway built of interlocking precast concrete blocks ("block step walkway"). For each snow shed only one or two structures would need to be built along the length of tunnel. From our field site visits we discovered that there is ample room at all snow sheds to construct these block structures. Having the block step walkway in place would allow for wildlife (goats and bears primarily) to ascend and descend from show shed roofs. Block step walkway ramps are relatively cheap measures (ca. $10,000-$15,000 each) depending on the number of interlocking precast concrete blocks required at a snowshed. Variations on this walkway such as an earthen ramp reinforced around the perimeter by lock blocks, would be fully explored within an engineering design phase.

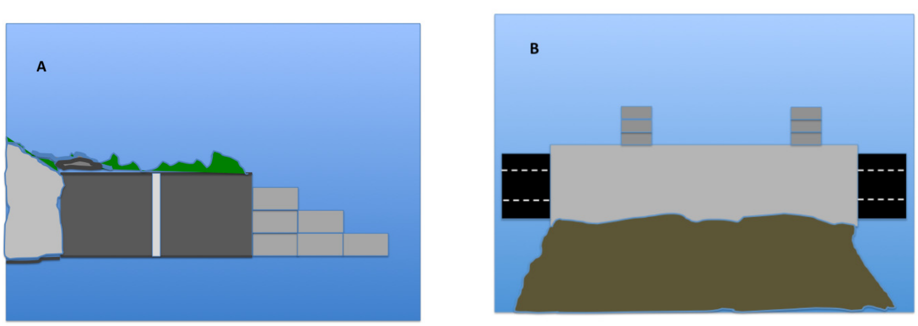

Figure 6.3: Block step walkway adaptation at snow sheds. A: Side view facing lanes of traffic and tunnel entrance, B: top view with block step walkways on exterior wall of snow shed.

3. Mountain goats and highway salt

The main reason mountain goats are on the highway is to lick road salt. This is a common occurrence in areas where mountain goats and bighorn sheep are in close proximity to roads and highways that use salt in winter as a deicing agent (Singer 1978, Clevenger et al. 2010). Most accidents with mountain goats in MRG occur in late spring and early summer after snowmelt, but generally occur year-round (MRG, unpublished data). The same seasonal pattern of accidents occurs elsewhere (Singer and Doherty 1985, Huijser and Paul 2008, Hengeveld and Cubberley 2012).

Salt diversion methods have been piloted to keep mountain goats off Highway 3A (near Keremeos) in the Okanagan, by attracting them to areas where salt is dispersed over an area roughly 300 m above the road (A. Walker, BC Ministry of Forests, Lands, Natural Resource Operations, Penticton, BC, personal communication, 2014). Three different forms of salt are used: cobalt blocks, trace mineral blocks and granulated coarse salt. The sites receiving salt are within a 50-100 m radius in order to limit more dominant goats from capitalizing all the salt. The sites are approximately 300 m directly above where goats are observed congregating on the highway. The predictable travel route and large quantities of salt dispersed (ca. 300 kg per year) is believed to be the reason why goats have not come down to the highway. The goats at this location do not migrate across this stretch of highway to access a seasonal range. To date there has not been a single report of a goat on Highway 3A since they discovered the sites. Cameras are also placed at the salted sites and travel routes to highway to evaluate this method of keeping goats off the highway.

We highly recommend that this relatively simple, cost-effective method be trialed in MRG immediately. In MRG trials could be targeted at snow sheds and areas that mountain goats congregate that are not associated with snow sheds. Ideal locations away from snow sheds would include Revelstoke Site 3 (Laing's Corner) and Lauretta's Corner south of Revelstoke Site 4. We recommend that salt diversion efforts like the one on Highway 3A be part of a larger meta-study which MRG would be a part of, utilizing the same techniques and objectives. These trials could be conducted with mountain goats or bighorn sheep and situated in national parks, e.g., MRG, Yoho, Jasper, Kootenay and problematic areas outside national parks, e.g., Highway 3 Crowsnest Pass and Highway 95 Radium, B.C. By working together as a meta-study, all utilizing same methods and techniques, data can be merged and stronger inferences will be made regarding the feasibility and reliability of this innovative method of keeping goats and sheep off roadways.

Animal-detection systems

Radar-based animal detection systems are gaining popularity among transportation agencies in North America due to relatively low cost and increasing reliability at reducing collisions with elk, deer and moose (M. Huijser, Western Transportation Institute, personal communication, 2014). The radar-based system "tracks" animals while they are inside the road corridor and continues to activate warning road signage until animals are well outside the predetermined area of concern. Detection systems are most effective in areas that have very localized, site-specific problems with ungulate-vehicle collisions (defined hot spots), commonly occurring ungulate aggregations due to road salt or other attractants, or movement across roads (fence terminations or defined movement corridors). We are not aware of other examples where detection systems have been used at localized congregations of mountain goats or bighorn sheep. However, we believe that implementation of this method at these sites has a high likelihood of being effective at reducing road-related mortalities of mountain goats in MRG and elsewhere. Further, should the focal area of mountain goat congregations shift along the road in the future, it is relatively easy to move detection systems from one location to another (Blake Dickson, Rotalec, personal communication, 2014).

We recommend implementation of radar-based animal-detection systems on the TCH in MRG in the short-term to reduce collisions with mountain goats at congregations sites associated with snow sheds and their entrances in addition to areas away from show sheds (e.g., Revelstoke Zone A, Site 3).

Sealing of snow shed walls

This is a mitigation measure that can be implemented immediately. At nearly all of the snow sheds we visited the exterior wall had sections (ranging from for 25-100 m) that that were open and exposed to eastbound traffic, either due to boards being damaged (possibly from vehicle accidents) or intentional design of the shed wall (Figure 6.4.). Regardless, these openings allow mountain goats to access the tunnel interior and lick road salt, thereby becoming more vulnerable to collisions with vehicles. Prior to any mitigation efforts being implemented to reduce goat-vehicle collisions at snow sheds, the point of access to tunnels needs to be sealed off completely. Once this is achieved, the only way that mountain goats would be able to access the tunnel interior is from their entrances. The recommended animal-detection systems will cover the area at snow shed entrances and their interior, thus alerting motorists when mountain goats are near the entrances or gain access to the tunnel interior from the entrance area.

Figure 6.4: Example of opening in show shed exterior wall that allows mountain goats access the tunnel interior and road surface (photo credit: T Clevenger).

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7. Costs associated with recommended mitigation measures

Just as there are a variety of measures designed to mitigate the impacts of roads on wildlife populations, there are a range of costs for these measures. Typically large crossing structures (wildlife overpasses) are more costly than smaller, below-grade passages (wildlife underpasses). The cost of the respective measures is an important factor in planning and decision-making. Often the more costly but proven measures are passed over in favour of less costly measures that are less likely to meet performance goals. There is no clear formula for cost estimating standard bridge and culvert work, and estimates for wildlife crossing structures can be even more obscure. There are many factors that can influence the estimated cost of wildlife crossing structures and discussed briefly below.

7.1. Factors affecting costs

There are a number of factors that can affect the cost of wildlife crossing structures (or bridges) in transportation projects. The driving factors can be divided into three areas: Engineering, Labor and Construction Management and Market.

Engineering considerations include topography, soils, and materials. The type of terrain (topography) and soils can greatly affect construction costs. As a general rule, the more level the terrain the lower the costs, although taking advantage of variable terrain can reduce the size of the structure. Less rocky soil also results in lower costs. High costs are generally incurred when building in rugged and rocky terrain and when blasting is required to remove rock. The type of construction materials will affect costs and will vary as prices change over time for steel, concrete and other construction materials. The accessibility of the materials used in construction will impact costs. Generally, the more abundant and the closer materials are to the site, the less cost in using them for construction. Design options such as pre-cast concrete or cast-in-place will affect costs, as pre-cast concrete beams and arches may be less expensive than cast-in-place. Overall costs will be lower if pre-casting is done for many beams or arches rather than just a few. Lastly, simple designs will be less costly than complex designs that might require greater construction time and more and/or different materials than those commonly used elsewhere.

Depending on the location and current state of economy, construction labor prices may vary widely. The same is true for construction labor wages in developed vs. developing countries. Market conditions and state of economy can have profound influences on the cost of infrastructure projects. Budgets for projects will be high during "boom" times or active economic growth and can be a fraction of the cost during stagnant economic periods. As an example, when project budgets were created for upgrading the Trans-Canada in Banff National Park, the province of Alberta was in a boom phase. However, by the time bids were accepted and work tendered, Alberta's economy had stagnated and contract bids were significantly lower than original engineers' estimates. On the paving contact alone, bids came in at CD$ 40 million less than budgeted.

Construction management and market can have an impact on costs. Whether construction firms have experience building crossing structures may have some effect on costing. Inexperienced firms may have higher construction bids and longer schedules to account for delays in construction and risk.

7.2. Current costs of wildlife crossing structures

Costs for construction of wildlife crossing mitigation on the TCH in MRG are difficult to estimate for this report. The costs presented in Table 7.1. may be used as a guide; however, more accurate estimates can be obtained from the Highway Service Centre in the Banff Field Unit, which has recently completed highway twinning with mitigation for wildlife on Phase 3B of the TCH. It is important to keep in mind that costs can vary considerably from province to province and are influenced by the economic conditions at the time of construction.

The costs presented in Table 7.1 were obtained from engineering consultation by Banff National Park's Highway Service Centre in 2001 (Parks Canada, unpublished data), and they can be expected to have doubled since that time. The approximate cost of a 50-m wide wildlife overpass in Banff National Park was $2 Million in 1997. The most recently built 60-m wide wildlife overpasses were constructed on Phase 3B at a cost of approximately $5-6 Million each (D.

Graham, Highway Service Centre, Banff National Park, personal communication; Table 7.1.). All cost estimates are in Canadian dollars. Unless specified otherwise. In summary, the current cost of wildlife overpasses and underpasses are quite variable and the current trend is decreasing costs due to use of new materials (geo-synthetic reinforced soil) and designs (low load structures).

1. *Banff National Park, Alberta, Canada – Trans-Canada Highway twinning (2 to 4 lanes) with crossing structures.*

All three crossing structures listed below were built on a 4-lane highway (thus "2" structures) with a 15-20 m wide median.

a) 2 - 12 m wide wildlife underpasses (Figure 7.1) two separate structures for each two lane with shoulder carriageway with 15-20 m median) in 2013 dollars: **CD$ 1.8 to 2 million.** This results in an average cost per structure of $950,000 and a cost of $80,000 per meter width of structure.

Figure 7.1: Open span wildlife underpass on Trans-Canada Highway near Dead Man's Flats, Alberta (photo credit: T Clevenger).

b) 2 -22 m wide wildlife underpasses (Figure 7.2) two separate structures for each two lane with shoulder carriageway with 15-20 m median): **CD$ 3.8 to 4 million.** This results in an average cost per structure of CD$ 2 million and a cost of CD$ 90,000 per meter width of structure.

Figure 7.2: Example of 22 m wide wildlife underpass, Trans-Canada Highway, Banff National Park, Alberta (photo credit: T Clevenger).

c) 2- 60 m wide wildlife overpasses (structure plus landscaping only (excluding roadway) over two separate two lane with shoulder carriageways with 15-20 m median): **CD$ 4.8 to 5 million.**

This results in an average cost per structure of $2.5 million and a cost of $40,000 per meter width of structure.

2. *Pinedale, Wyoming, USA* – 2-lane Highway 191.

Two 50 m wide wildlife overpasses (Figure 7.3) each constructed at **$ 5 million** in 2010. This results in an average cost per overpass structure of $2.5 million and a cost of $50,000 per meter width of structure.

Figure 7.3: Fifty metre wide wildlife overpass at Pinedale, Wyoming USA (photo credit: H. Sawyer).

These underpass and overpass cost estimates are in agreement with costs of crossing structures in the following locations:

- Highway US 93 Montana (42 wildlife underpasses)
- Trans-Canada Highway, Dead Man's Flats and Canmore, Alberta (2 wildlife underpasses)
- Interstate 90, Washington State, Snoqualmie Pass East Project (4 wildlife underpasses)

3. Silver Zone Pass, Nevada, USA – 4 lane Interstate-80.

A 65 m x 65 m (200 ft x 200 ft) wildlife overpass was built in 2012 and cost **$US 2.5 Million**.

Table 7.1: Examples of commonly used wildlife crossing structure types, dimensions, materials and costs in Canadian dollars (Highway Service Centre, Parks Canada, Banff, Alberta, unpublished data, 2001). Cost indications for crossing structures relate to the structures only and do not include fencing and/or visual barriers.

Crossing structure type	Dimensions (width (road length) x height)	Materials	$Cost/m	Unit cost $	Comments
Structures					
Box culvert underpass	3.0 x 2.5 m	Concrete	2,800	180,000	Less cover required compared to metal culverts (= less cost)
Elliptical culvert underpass	7 m x 4 m	Corrugated steel	5,400	225-250,000	Greater time to install due to bolting together pieces
Open-span bridge underpass	~12 m x ~5 m	Concrete	50,000-60,000	700,000 to 1 million	Based on 12 m wide structure. Greater than 15 m width requires centre pier and expansion joints (>cost)
Overpass	52 m (w) x 70 m (l)	Concrete	33,650	1.75 million	Prefabricated concrete arches. 1-2 days to install arches. Ease of re-routing traffic.
Viaduct (underpass)	200 m section	Concrete spans	62,500	12.5 million	
Overpass tunnel (cut & cover)	27 m (w) x 200 m (l)		119,300	24 million	
Fencing					
Wood post - no apron	2.4 m high	Page wire	35		
Wood post - w/apron	2.4 m high	Page wire	50		
Steel post/ - w/apron	2.4 m high	Page wire	90		

7.3. Benefits of reducing wildlife-vehicle collisions (WVCs)

The costs associated with wildlife crossing structures are always an important consideration in highway mitigation projects. However, there are many benefits provided by mitigation measures aimed at reducing WVCs, such as fewer motorist accidents that may cause human injuries, deaths, and property damage.

Benefits to wildlife include protecting individual wildlife from death or injury, keeping populations intact, and allowing individuals free movement to access important habitats and resources, thus enhancing long-term survival and population viability.

A review of thirteen different mitigation measures used by transportation agencies - such as warning signs, vegetation removal, fencing, wildlife crossing structures - to reduce WVCs (Huijser et al. 2007) indicated estimated effectiveness can vary from as low as a 26% reduction in WVCs (seasonal wildlife warning signs) to a 100% reduction in WVCs (elevated roadway).

Each mitigation measure has a different cost to implement and maintain and thus the selection of the appropriate mitigation measure should take into account the different safety and conservation goals as well as its effectiveness in reducing WVCs.

7.4. Direct monetary costs of ungulate-vehicle collisions

Huijser et al. (2009) summarized the costs of the most prevalent group of ungulates - deer, elk, and moose - that are the source of over 90 percent of wildlife-vehicle collisions in North America (Table 6.3.).

Cost-effectiveness thresholds

For mitigation that is aimed at reducing ungulate-vehicle collisions to be cost-effective, there needs to be a break-even point or a dollar value threshold. Huijser et al. (2009) thoroughly detailed these values for deer, elk and moose in North America (Table 7.2.).

The number of deer-, elk-, and moose-vehicle collisions per kilometer per year were compared to the actual cost of different mitigation measures and the realized effectiveness of each technique. For example, if a road section averages 4.4 deer-vehicle collisions per kilometer per year, a combination of wildlife fencing, under- and overpasses, and jump-outs would be economically feasible, because the threshold value of 4.3 is exceeded (Table 7.3.).

The threshold value for less costly mitigation of fencing, jump-outs and one wildlife underpass, however, is 3.2 deer-vehicle collisions per kilometer per year.

Because we know the cost of different mitigation measures per year (Table 7.3.) and their effectiveness at reducing WVCs (see Huijser et al. 2007), we can calculate the break-even point for sections of highway with high WVC rates.

Table 7.2: Summary of the monetary costs (2007 US Dollar costs) of the average wildlife vehicle collision in North America for three common ungulates.

Description	Deer	Elk	Moose
	Dollars	Dollars	Dollars
Vehicle repair costs per collision	$2622	$4550	$5600
Human injuries per collision	$2702	$5403	$10,807
Human fatalities per collision	$1002	$6683	$13,366
Towing, accident attendance, and investigation	$125	$375	$500
Hunting value animal per collision	$116	$397	$387
Carcass removal and disposal per collision	$50	$75	$100
Total	$6617	$17,483	$30,760

Table 7.3: Threshold values for different mitigation measures used to reduce deer-vehicle collisions by >80%. Adapted from Huijser et al. 2009.

Mitigation Measure	$CD Cost (2007)/yr	Deer/km/yr
Rate[1]	3%	3%
Fence	$6304	1.1
Fence, underpass & jump-outs	$18,123	3.2
Fence, under & overpass, jump-outs	$24,230	4.3
ADS[2]	$37,014	6.4
gap, ADS & jump-outs	$28,150	4.9
Elevated roadway	$3,109,422	470
Road tunnel	$4,981,333	752.8

1: For explanation of discount rate, see Huijser et al. 2009.
2: ADS: Animal detection system

These values exclude values not easily monetized, such as the existence value of wildlife, peace of mind for motorists, reduced staff time responding to wildlife collisions, impeded traffic flow due to vehicles stopping to watch wildlife near roads, etc. Considering these factors would tip the threshold values lower. Also, these threshold values are specific to the study area for Huijser et al. (2009).

Application of cost-effectiveness model

Because the cost of different mitigation measures per year is known, as is their effectiveness at reducing collisions with wildlife, it is possible to calculate the break-even point for sections of highway with high ungulate-vehicle collision rates. However, this is not the case in MRG where rates of ungulate-vehicle collisions are lower than the threshold values from the Huijser et al. (2009) publication. Huijser's cost-effectiveness model was primarily intended for highways where high road-kill rates and motorist safety is the main impetus for mitigation. Often on these highways there are few if any regulatory requirements for mitigating highway impacts on wildlife mortality and reduced connectivity. In MRG, however, the type and extent of highway mitigation is determined through the federal environmental impact assessment process. This process evaluates the TCH impacts based on the requirements of the *Canadian Environmental Assessment Act* and is guided by the *Canada National Parks Act*. Although there were no sites that were above the cost-benefit threshold in MRG this does not imply that mitigation measures are not required. Mitigating TCH effects on wildlife mortality, connectivity and ultimately the ecological integrity of MRG is of paramount importance in this ecosystem.

The cost-benefit model does have application for roads with high road-kill rates. For example it was recently applied to Highway 3 in the Crowsnest Pass of Alberta and British Columbia (Clevenger et al. 2010). Highway 3 has rates of wildlife-vehicle collision that are as high as an average of nine WVC per kilometre per year. The mitigation assessment using the cost-benefit model found that half of the high collision sites along Highway 3 in the Crowsnest Pass, Alberta were found to have estimated annual costs in excess of the threshold cost.

A similar highway mitigation assessment using the cost-benefit model was conducted on the TCH east of Canmore, Alberta (Lee et al. 2012). The cost-benefit model is also being used to guide local mitigation recommendations for three highway segments in Jackson Hole, Wyoming and a highway segment in northern Idaho.

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8. Assessing mitigation measure performance

Some basic rules about monitoring the function of wildlife crossings and assessing their conservation value were provided in Forman et al. (2003). The criteria used to measure their function or conservation value, however, will depend on the intended purpose of the wildlife crossings, the taxa of interest and the biological level of organization most relevant to monitoring and research goals.

Monitoring needs to be an integral part of a highway mitigation project, even long after the measures have been in place. Monitoring and research can range from a simple, single-species population within the highway corridor to more complex ecological processes and functions within regional landscapes of conservation importance.
Wildlife crossing structures are, in essence, site-specific movement corridors strategically placed over highways that bisect important wildlife habitat. Like wildlife corridors, crossing structures should allow for the following five biological functions:

1. Reduced mortality and increased movement (genetic interchange) within populations;
2. Meeting biological requirements such as finding food, cover and mates;
3. Dispersal from maternal or natal ranges and recolonization after long absences;
4. Redistribution of populations in response to environmental changes and natural disturbances (e.g., fire, drought); movement or migration during stressful years of low reproduction or survival; and
5. Long term maintenance of metapopulations, community stability, and ecosystem processes.

These functions encompass three levels of biological organization—genes, species/population, community/ecosystem—which form the basis for developing natural resource management and conservation plans.

From these five functions it is possible to set performance objectives, determine best methods to monitor, develop study designs, and resolve the management questions associated with the project objectives.

Note that these functions increase both in complexity and in the cost and time required to properly monitor whether they are being facilitated (Table 6.5.). Not all ecological functions may be of management concern for transportation agencies, particularly those at the more complex end of the scale; however, they will be of concern for land and natural resource management agencies.

Table 8.1: Levels of conservation value for wildlife crossing systems as measured by ecosystem function achieved, level of biological organization targeted, type of connectivity potential, and cost and duration of research required to evaluate status.

Level	Ecosystem Function (simple to complex)	Level of Biological Organization[a]	Level of Connectivity[b]	Cost and Duration of Research[c]
1a	Movement within populations and genetic interchange	Genetic	Genetic	Low cost – Short term
1b	Reduced mortality due to roads	Genetic & Species/population	Genetic & Species/population	Low cost – Short term
2	Ensure that the biological requirements of finding food, cover and mates	Species/population	Demographic	Moderate-to-High cost – Long term
3	Dispersal from maternal ranges and recolonization after long absences	Species/population	Functional	Moderate-to-High cost – Long term
4	Populations to move in response to environmental changes and natural disasters;	Ecosystem/community	Functional	High cost – Long term
5	Long term maintenance of metapopulations, community stability, and ecosystem processes	Ecosystem/community	Functional	High cost – Long term

[a] See Noss 1990, Redford and Richter 1999.
[b] Genetic: Predominantly adult male movement across road barriers; Demographic: Genetic connectivity with confirmed adult female movement across road barriers; Functional: Genetic and demographic connectivity with confirmed dispersal of young females that survive and reproduce.

[c] Based on studies of large mammals. Cost and duration will largely be dependent upon area requirements, population densities, and demographics.

Simple and low-cost techniques using remote cameras can be used to detect animals using wildlife crossing structures, i.e., level 1 - *genes*. However, information about numbers of distinct individuals, their gender and genetic relationships cannot be reliably obtained using remote cameras.

A non-invasive genetic sampling method was used to assess population-level benefits (level 2 – *species/populations*, Table 6.5.) of wildlife crossings on the Trans-Canada Highway in Banff National Park, Alberta (Clevenger and Sawaya 2009; Sawaya et al. 2013, 2014).

8.1. Study Designs to Measure Performance

Inferential Strength

Inferential strength in the context of mitigation monitoring is the ability to accurately evaluate whether mitigation efforts have achieved their desired effect. Maximizing inferential strength depends both on the ability to minimize confounding effects and to maximize statistical power.

Monitoring designs with low inferential strength lead to situations where researchers either detect an effect that is not actually there (a Type I error) or fail to detect an effect that is actually present (a Type II error). Minimizing the likelihood of making either type of error is of critical importance to transportation managers and researchers if they are to reliably demonstrate that mitigation measures are effective.

Roedenbeck et al. (2007) addressed this subject by identifying relevant research questions in road ecology today, recommending experimental designs that maximize inferential strength, and giving examples of such experiments for each of five research questions.

Types of Study Design and Resulting Inferential Strength

There are several types of study designs for evaluating how well mitigation measures perform.

BACI Design: One design consists of measuring and comparing impacted areas (I) with non-impacted areas or control sites (C) and assessing how some variable of interest behaves before (B) and after (A) a management intervention such as highway construction or mitigation. In this "BACI" design, if the difference between the control and impact (often referred to as "treatment") site is greater after intervention than before, then there is strong evidence that intervention has had a causal effect.

To increase inferential strength BACI designs should sample at more than one paired treatment + control site. Locating suitable control sites unaffected by roads can be a challenge, particularly when studying impacts on wide-ranging large mammals.

BA Design: Of lower inferential strength than BACI is the before and after impact (BA) design. This requires sampling one site and evaluating how some environmental variable behaves before and after the impact. The impact could also be some form of management intervention, such as the implementation of mitigation measures. The BA design at one site can demonstrate that the environmental variable changed over time, but it cannot exclude the possibility that change was caused by some reason other than the observed impact.

CI Design: A third approach compares impacted (I) sites with control (C) sites (those that are non-impacted) using a CI design. Data are only collected or made available for the period after intervention or mitigation. The inference is that if the control and impact sites differ in some environmental variable of concern, this difference is, at least in part, due to the intervention. This inference is valid only if control and impact sites would be identical in the absence of intervention.

The study design options described run from high to low inferential strength: BACI, BA, and CI. The key monitoring and research questions identified earlier are found in

Appendix 4. The table provides a suggested framework for designing studies to evaluate whether the general objectives of highway mitigation are being met.

8.2. Adaptive Management

Adaptive management consists of deriving benefits from measured observations from monitoring to inform decision-making with regard to planning and design of subsequent phases of a project. An example of adaptive management would be changing the design of wildlife crossing structures on subsequent phases of highway reconstruction after obtaining empirical data from the use of structures from earlier phases. Some examples are shown below.

- Microhabitat elements within wildlife crossings may require changes if monitoring shows they do not facilitate movement of smaller wildlife.
- Monitoring of fencing may identify deficiencies that lead to revised design or materials used for construction in future phases.
- Pre-construction data on local species occurrence and wildlife movements may lead to changes in the locations and types of wildlife crossing structures (e.g., from small-sized to medium-sized culverts) should monitoring reveal previously undocumented unique populations or important habitat linkages.

Whatever the case may be, monitoring ultimately provides management with sound data for mitigation planning, helps to streamline project planning and saves on project costs.
Regular communication and close coordination between research and management is necessary for adaptive management to be effective. This will allow for timely changes to project design plans that reflect the most current results from monitoring activities.

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9. An Approach for Monitoring Impacts

Roads and traffic affect wildlife at multiple levels of biological organization: therefore different management questions require different types of research and mitigation measures. Certain questions can be "big" or general and may require answers from multiple scales and perspectives. However, big picture research is not necessarily general in nature. General principles have to be well founded, and they are often based on thorough studies of the life histories of wildlife species.

This hierarchical approach covers the entire biological spectrum from genes on up to higher levels of communities and ecosystems. It is well suited to answering most transportation and natural resource agency management needs of reducing road impacts on wildlife populations. It can provide guidelines and decision support regarding the monitoring and evaluation of wildlife crossings.

Another value of the hierarchy approach is the recognition that effects of roads and traffic can reverberate through other levels, often in unpredictable ways, as secondary and cumulative effects. Specific indicators can be identified at multiple levels of organization to monitor and assess the performance of mitigation designed to reduce road-related mortality, and restore movements and interchange within populations.

9.1. Monitoring and Assessment Guidelines

The guidelines below are designed for monitoring plans evaluating the conservation value and efficacy of wildlife crossings. This framework can be used to formulate management questions, select methodologies, and design studies to measure performance of wildlife crossings in mitigating road impacts.

1. *Establish goals and objectives.* What are the mitigation goals? Generally the goals are to reduce wildlife–vehicle collisions and/or reduce barrier effects to movement and maintain genetic interchange.

2. *Establish baseline conditions.* Determine the extent, distribution and intensity of road and traffic impacts to wildlife in the area of concern. The impacts may consist of mortality, habitat fragmentation (reduced movements) or some combination thereof. In most cases, the conditions occurring pre-mitigation will comprise the baseline or control.
3. *Identify specific management questions to be answered by monitoring.* These questions will be formulated from the goals and objectives identified in Step 1 and conditions identified in Step 2. Some questions might include:

    - Is road-related mortality increasing or decreasing as a result of the mitigation measures?
    - Is animal movement across the road increasing or decreasing?
    - Are animals able to disperse and are populations able to carry out migratory movements?

Before starting a monitoring program, specific benchmarks and thresholds should be agreed upon that trigger management actions. For example, >50% reduction in road-kill would be acceptable, but <50% reduction would trigger additional management actions to improve mitigation performance. Normally a power analysis is also performed to determine if these reductions can actually be detected (see below).

4. *Select indicators.* Identify indicators at the appropriate level(s) of biological organization (i.e., genes, species/population, and community/ecosystem) that correspond to the specific goals and objectives identified in Step 1 and the questions developed in Step 3. For example:

- Gene flow and genetic structure may indicate whether exchange of genes (i.e., breeding or movement of individuals) occurs across the highway;
- Population distribution, abundance and within-population movement data, as well as demographic processes such as dispersal, fecundity, survivorship, and mortality rates, may permit the assessment of species or population-level connectivity; and

- Herbivory and predation rates may indicate whether exchange across highways contributes to more stable ecosystem processes and community dynamics.

5. *Identify control and treatment areas.* If pre-mitigation data are available, then indicator response in adjacent "control" areas may be compared with treatment areas—i.e., road sections with wildlife crossings. It will be important to control for differences in habitat type and population abundance between treatment and control areas. Therefore controls and treatments should comprise similar habitats, and some means of obtaining population abundance indices to control for confounding effects should be used.
6. *Design and implement a monitoring plan.* Apply principles of experimental design to select sites for monitoring the identified goals and objectives from Step 1 and questions in Step 3. Although treatments and controls should ideally be replicated, this may not always be possible.
7. *Validate relationships between indicators and benchmarks.* Research carried out over the short and long term will be needed to determine whether the selected indicators are meeting the management goals and objectives.

9.2. Setting Monitoring and Performance Targets

Developing Performance Targets

Few studies have rigorously monitored and researched the performance of highway mitigation measures using study designs with high inferential strength. For some agencies, monitoring has not been a priority, much less research—if circumstantial evidence suggested that animals appeared to use wildlife crossings, then they were deemed effective.

One of the difficulties in developing performance targets is agreeing on what defines a "reduction" in wildlife–vehicle collisions and an "increase" in landscape connectivity or animal movements across a highway. Transportation agencies tend to have relatively relaxed targets or expectations for how well crossing structures perform. In contrast, resource and land management agencies generally require more science-based evidence that wildlife crossings or other measures result in positive changes to wildlife movements and regional population connectivity.

Reliably Detecting Change in Target Parameters

A decrease in road-related mortality and an increase in the frequency of highway crossings by focal species may generally be considered performance targets for mitigation efforts. Broad definitions such as these can be used to measure the effectiveness of mitigation measures and whether targets are being met.

However, properly designed monitoring programs with research-specific study designs and predefined performance targets will have the greatest ability to evaluate whether mitigation efforts are meeting their targets.

Developing Consensus-Based Performance Targets

The lead agency and other stakeholders need to know how their mitigation investment dollars are being spent and how the technology can be transferred to future projects. Taxpayers will also want to know whether the measures are effective. Targets designed to evaluate whether the amount of observed change is acceptable should be determined *a priori* by the transportation agency responsible for the project with the concerns of the natural resource management agency and other project stakeholders in mind.

The agreed-upon targets need to be scientifically defensible. Without specific targets and a means to track performance, transportation and resource management agencies can come under scrutiny for not having objectively defined targets or performance standards.

Because landscape conditions and population dynamics vary over time, short- and long-term monitoring and performance targets should be assessed periodically and readjusted accordingly.

Focal Species

All species from a project area cannot be monitored. The selection of focal species should result in monitoring data that will be most relevant to either the greatest number of species in the area, or to those species that are the most sensitive to the process being monitored, e.g., ability to cross highways. Table 9.1. provides some criteria to help guide the selection of focal species.

Table 9.1: Guide to selecting focal species based on monitoring criteria and ecosystem context**.**

	1. Monitoring	
Primary Criteria		
	Ecological Attributes	Which focal species will serve as the best indicators of change and maintenance of ecological processes?
	Sample Size Requirements	Which focal species will provide large enough datasets to permit sufficiently accurate and precise analyses for the monitoring needs?
Secondary Criteria		
	Benefits to Management	Will the information acquired from monitoring the selected focal species provide benefits to (a) local management (e.g., transportation agency, land management agency) and/or (b) management elsewhere, such that it will have broader research application (e.g., significant contribution to knowledge base and science of road ecology)?
	Public Profile and Support	Is at least a subset of the selected focal species high-profile and charismatic such that they resonate with the general public and help to gain public and private support for the project (e.g., cougar, wolverine)?
	2. Ecosystem Context	
	Taxonomic Diversity	Do the selected focal species represent a diversity of taxonomic groups?
	Levels of Biological Organization (see Noss 1990)	Do the selected focal species provide information suitable

		for addressing questions aimed at the first two levels of biological organization (genes/individuals, species/populations)?

Selected focal species are indicators of changes—positive or negative—that result from efforts to mitigate road impacts in the project corridor.

The selected survey methods should permit the collection of data from a large number of species—e.g., most medium and large mammals. Rigorous evaluation of these data will, however, be limited to those species that generate sufficient amounts of data for statistical analyses and inference (see below). In these cases, focal species will not be identified until pre-mitigation population surveys have begun or pilot data is collected in the project area.

Another consideration is how monitoring focal species can translate into direct management benefits and support from outside the project (Table 9.1.). Some wildlife species may resonate with the public and information about them may help generate support for the project. While this is a secondary criterion, it is important to consider in the selection process.

Monitoring information must be of value at the project level, as managers are interested in project-specific applications. However, some results will have management benefits beyond the project area boundaries and have national or international significance in advancing knowledge of wildlife crossing mitigation. Attempts should be made to choose focal species and management questions that have impacts at the project and national or international scale.

After identifying suitable focal species, a second consideration relates to how well the focal species fit within an ecosystem context. For each of the management questions it will be important to maximize the taxonomic diversity represented in the suite of focal species, e.g., amphibians, reptiles, small to large mammals. Road effects on wildlife populations are scale-specific, and such an approach will, therefore, help to ensure that some of the more important scale-related issues (spatial and temporal) of the investigation are adequately addressed.

9.3. Monitoring Methods

There are a variety of wildlife survey methods available today. These methods range from the relatively simple (reporting of wildlife–vehicle collisions by transportation agency personnel) to the complex (capture and global positioning system [GPS] collaring of individual animals). Whatever the monitoring objective and focal species, the selection of appropriate survey methods is critically important (Table 9.2.).

In some cases multiple methods exist for a given objective–species combination and researchers will have the luxury of balancing cost with specific data requirements and available funding or personnel.

For some methods, most costs occur at the onset of monitoring efforts (e.g., purchase of remote cameras), whereas for others the costs are largely distributed throughout the monitoring period (e.g., snow tracking).

Table 9.2: Summary of available monitoring methods, the appropriate time to employ them (pre- or post-construction), potential target species, and cost estimates for conducting wildlife monitoring (from Clevenger et al. 2008).

Monitoring purpose	Available monitoring methods	Timing	Target species	Check frequency	Area of use	Estimated cost	Cost loading
Assess wildlife–vehicle collision rate							
	Carcass removal by maintenance crews, Parks Canada and/or natural resource agency staff	Pre; post	Elk, deer, black bear and other large species when possible	As occurs	Median/right-of-way	Low	Continuous
	Wildlife–vehicle collision reports by RCMP	Pre; post	Elk, deer, black bear and other large species when possible	As occurs	Median/right-of-way	Low	Continuous
	Systematic driving surveys	Pre; post	Medium to large mammals	1–7 days	Median/right-of-way	High	Continuous
Assess use/effectiveness of wildlife crossing structures (existing and proposed)							
	Remote cameras or video	Pre; post	Medium to large mammals	Weekly	Wildlife crossings/Culverts	Medium	Front-loaded
	Track beds	Pre; post	Medium to large mammals	1–3 days	Wildlife crossings/Dry culverts	Medium	Continuous
	Unenclosed track plates	Pre; post	Medium to large mammals	1–3 days	Wildlife crossings/Dry culverts	Medium	Continuous
	Enclosed track plates	Pre; post	Small to medium mammals	1–3 days	Small dry culverts	Medium	Continuous

Monitoring purpose	Available monitoring methods	Timing	Target species	Check frequency	Area of use	Estimated cost	Cost loading
	Hair collection devices with DNA analysis	Pre; post	Select medium to large mammals	3–5 days	Wildlife crossings/Culverts	Medium to high*	Continuous and end-loaded
	Trap, tag, and recapture/ resight	Pre; post	Amphibians, reptiles, small mammals	Select times	Ponds and water bodies within or adjacent to highway	Low	Continuous
	GPS collaring	Pre; post	medium to large mammals	Select times	Within animal home range	High	Front-loaded
Assess rate of at-grade highway crossings by wildlife							
	Remote still cameras or video (deployed randomly)	Pre**	Medium to large mammals	Weekly	Right-of-way	Medium to high	Front-loaded
	Remote still cameras or video (deployed at targeted locations)	Pre**	Medium to large mammals	Weekly	Right-of-way	Medium to high	Front-loaded
	Track beds (deployed randomly)	Pre**	Medium to large mammals	1–3 days	Right-of-way	Medium to high	Continuous
	Track beds (deployed at targeted locations)	Pre**	Medium to large mammals	1–3 days	Right-of-way	Medium to high	Continuous
	Snow track transects	Pre**	Medium to large mammals active in winter	3–5 times per winter***	Right-of-way	Medium	Continuous
	GPS collaring	Pre; post	medium to large mammals	Select times	Within animal home range	High	Front-loaded

Monitoring purpose	Available monitoring methods	Timing	Target species	Check frequency	Area of use	Estimated cost	Cost loading
Monitor wildlife use of locations throughout and adjacent to the project area							
	Remote still cameras or video at scent stations	Pre; post	Medium to large mammals	Weekly	Within 1 mile of highway	Medium	Front-loaded
	Track plots or track plates at scent stations	Pre; post	Small to large mammals	1–3 days	Within 1 mile of highway	Medium	Continuous
	Hair collection devices with DNA methods	Pre; post	Small group of targeted species	3 days	Within 1 mile of highway	Low to high*	Continuous and end-loaded
	Snow tracking	Pre; post	Medium and large mammals active in winter	3–5 times/winter	Within 1 mile of highway	Medium	Continuous
	Scat detection dogs with DNA methods	Pre; post	3-4 targeted mammals	1 full season	Within 1 mile of highway	Medium to high*	Front-loaded
	Trap, tag, and recapture/ resight	Pre; post	Amphibians, reptiles, small mammals	Select times	Ponds and water bodies within or adjacent to highway	Low	Continuous
	GPS collaring	Pre; post	medium to large mammals	Select times	Within animal home range	High	Front-loaded
Evaluate effectiveness of wildlife fencing							
	Highway maintenance crews report animals inside fencing	Post	Medium to large mammals	As occurs	Median/right-of-way	Medium	Continuous

Monitoring purpose	Available monitoring methods	Timing	Target species	Check frequency	Area of use	Estimated cost	Cost loading
	Systematic checks of fence integrity	Post	Medium to large mammals	Monthly	Fenceline	Medium	Continuous
	GPS collaring	Pre; post	medium to large mammals	Select times	Within animal home range	High	Front-loaded
Evaluate effectiveness of jump-outs							
	Remote cameras or video	Post	Medium to large mammals	Weekly	Jump-outs	Medium	Front-loaded
	Track beds on top of jump-outs	Post	Medium to large mammals	1–3 days	Jump-outs	Medium	Continuous

* Cost depends largely on objectives—species-specific identification via DNA methods costs less than individual identification. Both can be cost effective when compared with more labor-intensive methods.
** Although these methods can be used to monitor post-construction, it is assumed that wildlife fencing will so dramatically reduce at-grade highway crossing attempts as to make monitoring unnecessary and extremely cost-ineffective.
*** Will depend on statistical power considerations, number and timing of snow events, and time constraints.

10. Future research to address gaps in Parks Canada data

As part of this report we identify future research and monitoring needs in MRG. These consist of activities that can be initiated immediately with low cost investment, while other activities require more capital fund investments from the Field Unit. They are not listed in order of priority or management importance.

Camera monitoring at existing below-grade passages

Any information that can be obtained on safe movement of wildlife across the TCH is valuable for park management and future transportation planning and design in MRG. Given the steep and rugged terrain in the study area, wildlife movement is limited and localized to areas where travel provides the least energetic costs and critical habitats are accessed. These localized areas essentially consist of pinch-points along the TCH; many are associated with major drainages (creeks and rivers) and what we have identified as primary mitigation emphasis sites. These are sites where our Least Cost Path models were in agreement with grizzly bear movement models developed by Jones (2012).

Cameras have proven to be a low-cost effective tool for monitoring wildlife movement on the landscape and at human-made pinch points such as wildlife crossing structures (Ford et al. 2009, O'Connell et al. 2011). Cameras should be placed at major creek/river crossings on the TCH in MRG to collect information on whether the existing bridge structures are used by wildlife for safe passage, what species travel through them and during what seasons of the year. This information will be valuable for assessing the importance of these existing crossing structures for safe passage prior to highway twinning and construction of mitigation measures on the TCH. Remote cameras can be set up to detect animal movement. If Lithium batteries are used the cameras can be set out and checked for operation and battery life every 2-3 months or even longer intervals.

Mortality data collection in Provincial section of Trans-Canada Highway

Mount Revelstoke and Glacier National Parks are essentially relatively small isolated federally protected areas separated by BC Crown Land. Because the two parks are relatively small in size it is unlikely that most large mammals, particularly wide-ranging carnivores and ungulates, live year-round within the park boundaries. For that reason the fate of wildlife outside the park on provincial section of the TCH has implications for wildlife demographics in the two parks.

We discovered that there is an obvious lack of information on wildlife mortality on the BC section of the TCH between the two parks. We recommend that efforts be made to 1) coordinate with BC Ministry of Transportation to improve data collection on road-killed wildlife; 2) initiate means within Parks Canada MRG to have staff record wildlife mortality information while traveling between the two parks; and 3) initiate a citizen science-based program in Revelstoke to enlist the support of driving public to record wildlife road-kill. Citizen science based reporting of road-kills has been highly successful in areas with chronic road-kill (Tracy et al. 2006, Paul et al. 2014). Smartphone apps have been developed and are increasingly becoming important tools for the public to report wildlife road-kills.

The Miistakis Institute created the citizen science-based road-kill reporting program, *RoadWatch in the Pass* that uses an on-line mapping tool to enable volunteer data collection and improve data accuracy. Recently they developed a smartphone app for Cenovus staff to record wildlife road-kills while driving roads in the areas where they work. The Highway 3 Partnership (WTI-MSU, Miistakis, Yellowtone to Yukon Conservation Initiative, Wildsight) is currently developing a smartphone app for the British Columbia section of Highway 3, to complement the on-line mapping tool developed for *RoadWatch in the Pass*. Two approaches will be developed; a simple interface for passengers in vehicles where a participant selects a species button for observed road-kills and a more sophisticated model for government staff and highway maintenance contractors who can stop at a road kill location and enter additional information. The app will be developed for Android and iPhone platforms and will be freely downloadable. Additional functionality includes taking photos to accompany observations and a wildlife identification page.

Wolverine Resource Selection Function Mapping and Genetic Sampling

Previous research on wolverine ecology has taken place in the Omineca Mountains north of Revelstoke. This long-term research project focused in wolverine movements and habitat use using primarily VHF radio-telemetry (Krebs et al. 2007). Some of the study animals were located within and around the MRG study area. The dataset from the research project is voluminous as 40-50 wolverines were radio collared and data collected on movements and habitat use over nearly 10 years. The Krebs dataset could be utilized by MRG to better understand wolverine movements across the TCH. In addition to the Krebs dataset, ongoing noninvasive genetic sampling by MRG staff (2011-present) can provide supplemental information on wolverine-highway interactions.

We recommend that efforts be made to develop a Resource Selection Function (RSF) map from wolverine telemetry data. The resulting map will identify critical habitats and core habitat areas for wolverines in MRG and the larger landscape. Overlaying the TCH on the RSF map will help better identify where wolverine movements are most likely to occur across the highway. The RSF map validation can consist of standard model validation techniques of reserving 20% of data points for testing and/or using the noninvasive genetic sampling information to derive estimates of detection probabilities for each sampling site. Sites with higher detection probabilities should be located in areas defined by the RSF map as high quality habitat.

In a slightly more involved analysis, landscape resistance models like the ones developed for black bears in this report, could be developed for wolverines using noninvasive sampling data from the Banff-Yoho-Kootenay study area (A. Clevenger, unpublished data). Then, a landscape genetics approach could be used with the Krebs wolverine RSF map in attempts to correlate genetic structure with the underlying driving environmental variables. The landscape genetics approach will help to validate the landscape resistance model for wolverine, as well as determine the amount of similarity (agreement) and gene flow (i.e., disepersal), particularly in regards to key linkage locations across the TCH and our mitigation emphasis sites.

Mountain Goat Road-kill Mitigation

Salt Diversion Trial

Our report has dedicated a considerable amount of attention to devising effective methods of reducing road-related mortality of mountain goats in MRG. Undoubtedly this is a recurring problem in MRG, one that is of high resource conservation concern, and one that is not being addressed with other than warning signage on the TCH. We have outlined in this report an experimental method of keeping mountain goats off highways by dispersing salt over a relatively large area above a highway in the Okanagan by using broken salt blocks and granulated coarse salt. Salt is dispersed in order to minimize few dominant individuals capitalizing on all the salt, aggression and possibly intra-specific killing among goats (J. Jorgenson, Alberta Environment Sustainable Resource Development, personal communication, 2014), and to avoid any potential disease transmission among goats. The Okanagan experiment has proven highly successful after one field season as no goats were observed on the highway.

We recommend that this approach be trialed in MRG as part of a meta-study involving other sites in the Mountain Parks and other jurisdictions with similar problems of road salt attraction by mountain goat and bighorn sheep. In MRG trials could be targeted at snow sheds and areas that goats congregate that are not associated with snow sheds. Ideal locations away from snow sheds would include Revelstoke Site 3 (Laing's Corner) and Lauretta's Corner south of Revelstoke Site 4. Given there are good data on road-kill occurrence at these locations in MRG, the efficacy of the method can be assessed using data obtained after the salt diversion method has been implemented in a before-after comparison. Alternatively, application of the salt diversion treatment at some sites could be delayed to collect pre-treatment data on frequency and timing of mountain goat visitation to the road surface. The results of the trials and evaluation will provide important information for MRG prior to project-wide application in a future highway twinning project.

Animal-Detection System Trial

As mentioned above, our report has focused attention on devising effective means of reducing road-related mortality of mountain goats in the two national parks. In addition to salt diversion being a promising method of reducing collision rates, we recommend similar testing and trialing take place with animal-detection systems at one snow shed and one location away from a snow shed, e.g., Revelstoke Site 3.

Trials and performance testing of animal-detection systems in MRG will provide valuable information on the efficacy of the system to 1) reduce goat-vehicle collisions, by slowing down motorists and alerting them to goats on the highway and 2) testing the efficacy of the system in a novel environment characterized by high snowpack and frequent snowfall. Assessments of system performance is conducted with video surveillance of the area covered by the radar-based system to determine the number of "false positives" – signage is activated when no animals are present or crossing and "false negatives" – signage is not activated when animals are present on highway or crossing the highway. Like the salt diversion pilot project, the results of deploying and evaluating animal-detection system in MRG will provide important information for Resources Conservation and Highway Service Centre managers prior to project-wide application in a future highway twinning project.

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Appendix A: Mitigation Emphasis Site Summaries (1–24)

Informational summary sheets were prepared for each mitigation emphasis site (MES) and describe all site-specific information with regard to mitigation importance, target species, wildlife objectives, and transportation mitigation recommendations. The Summary Information Sheets are a quick and easy reference that summarizes mitigation opportunities at each MES. Red shading highlights the eight priority mitigation sites. Italicized text is mitigation measures that are explained in detail in Appendix B.

ZONE A MAP

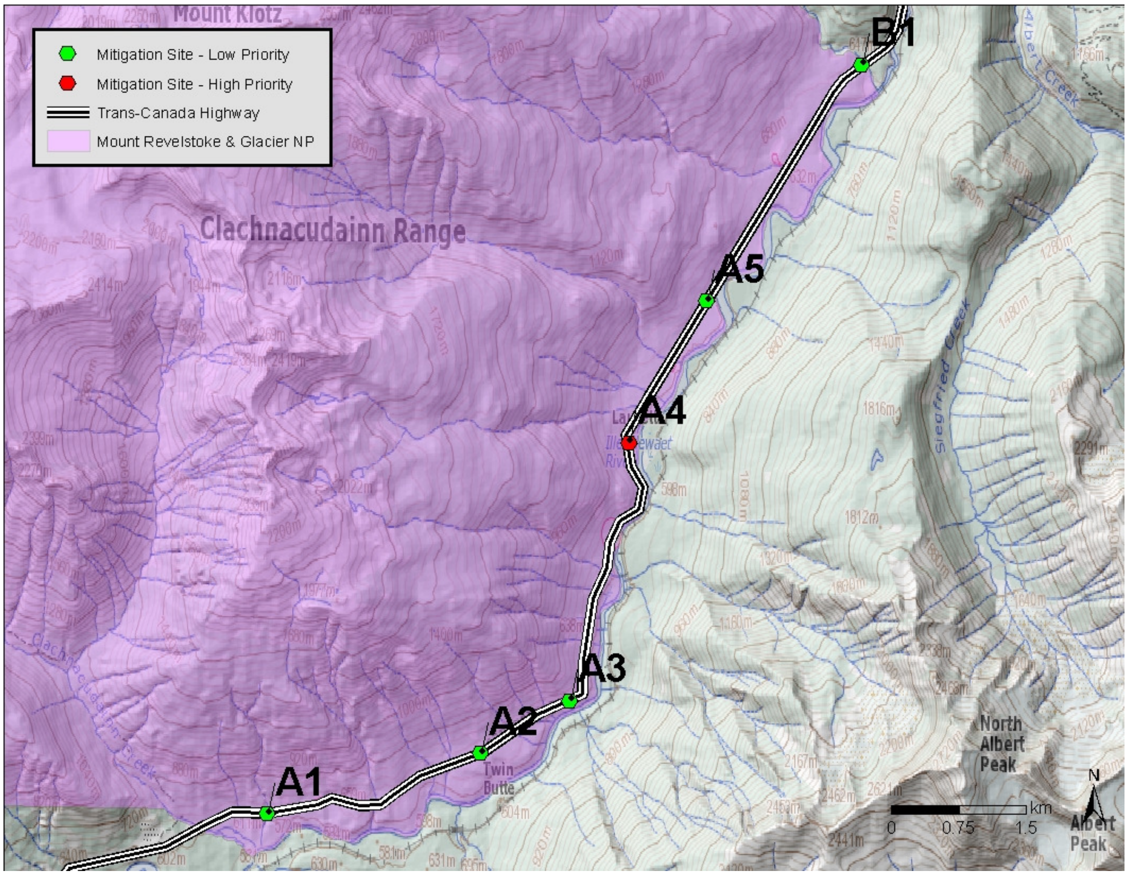

Figure A: Map showing Highway Mitigation Emphasis Zone A in Mount Revelstoke and Glacier National Parks, British Columbia.

Zone A, Site 1 Summary – Revelstoke	
Description	
Location: UTM: 430937, 5654825	
Species: Multi-species: Deer, black bears.	
Mortality risk: 3	
Local conservation value: 2	
Regional conservation significance: 3	
Transportation mitigation opportunities: 3	
Wildlife objectives	
• Reduce current levels of wildlife–vehicle collisions in this section of highway, primarily deer, mountain goats and bears. • Provide safe movement for all wildlife species across highway, primarily deer and black bears.	
Existing infrastructure	
• Culvert (~ 1m diameter)	
Target species for mitigation planning	
WVC reduction: Common species. **Regional conservation and connectivity**: Common species primarily.	
Transportation mitigation opportunities	
Score: 3	
To ensure movement of wildlife through the area and reduce wildlife-vehicle collisions, fencing and construction of wildlife *underpass* is recommended. Selection of specific design type is dependent on terrain and engineering constraints. Culvert in place carries small volume of water. Existing culvert could be replaced with a prefabricated box culvert (ca. 2.8 x 3.2 m dimensions) as there is not a lot of space below road grade for a larger underpass structure. Focal species in area utilize culverts of recommended dimensions. Wing *fencing* (200–500 m depending on terrain) should be installed to funnel movements to the crossing structure. Fencing notes: Snow is not likely a concern at this location due to lower elevation compared to other parts of study area.	

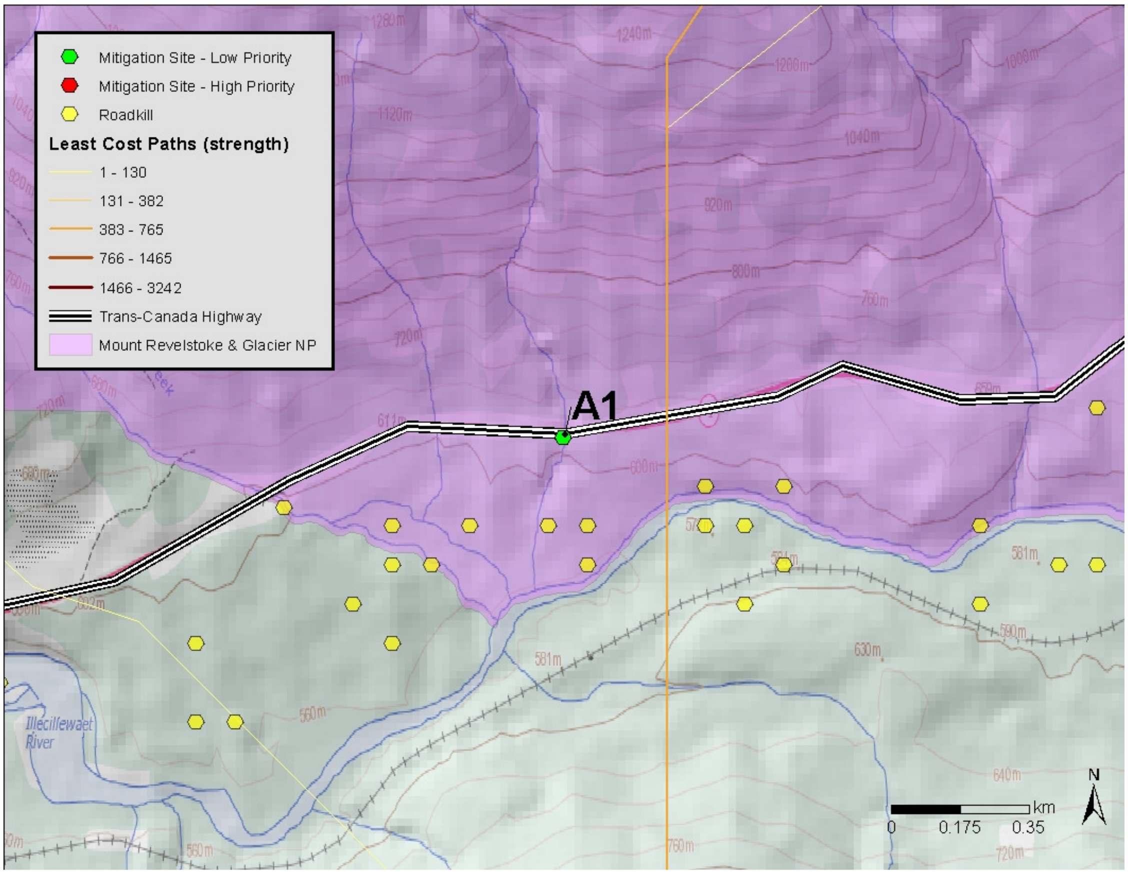

Figure A1: Map showing Highway Mitigation Emphasis Site A1 in Mount Revelstoke and Glacier National Parks, British Columbia.

Zone A, Site 2 Summary – Revelstoke	
Description	
Location: UTM: 433309, 5655497	
Species: Multi-species: Deer, bears.	
Mortality risk: 2	
Local conservation value: 2	
Regional conservation significance: 2	
Transportation mitigation opportunities: 4	
Wildlife objectives	
• Reduce current levels of wildlife–vehicle collisions in this section of highway, primarily deer and bears. • Provide safe movement for all wildlife species across highway, primarily deer and bears.	
Existing infrastructure	
• Culvert	
Target species for mitigation planning	
WVC reduction: Common species. **Regional conservation and connectivity**: Common species primarily.	
Transportation mitigation opportunities	
Score: 4	
To ensure movement of wildlife through the area and reduce wildlife-vehicle collisions, fencing and construction of wildlife *underpass* is recommended. Selection of design type is dependent on terrain and engineering constraints. Minimum dimension for underpass is 4 m high x 7 m wide. Culvert could be replaced and bottomless culvert or small open-span bridge structure of recommended dimensions installed at location. Wing *fencing* (200–500 m depending on terrain) should be installed to funnel movements to the crossing structure. Fencing notes: Snow is a concern at this location due to high annual snowfall.	

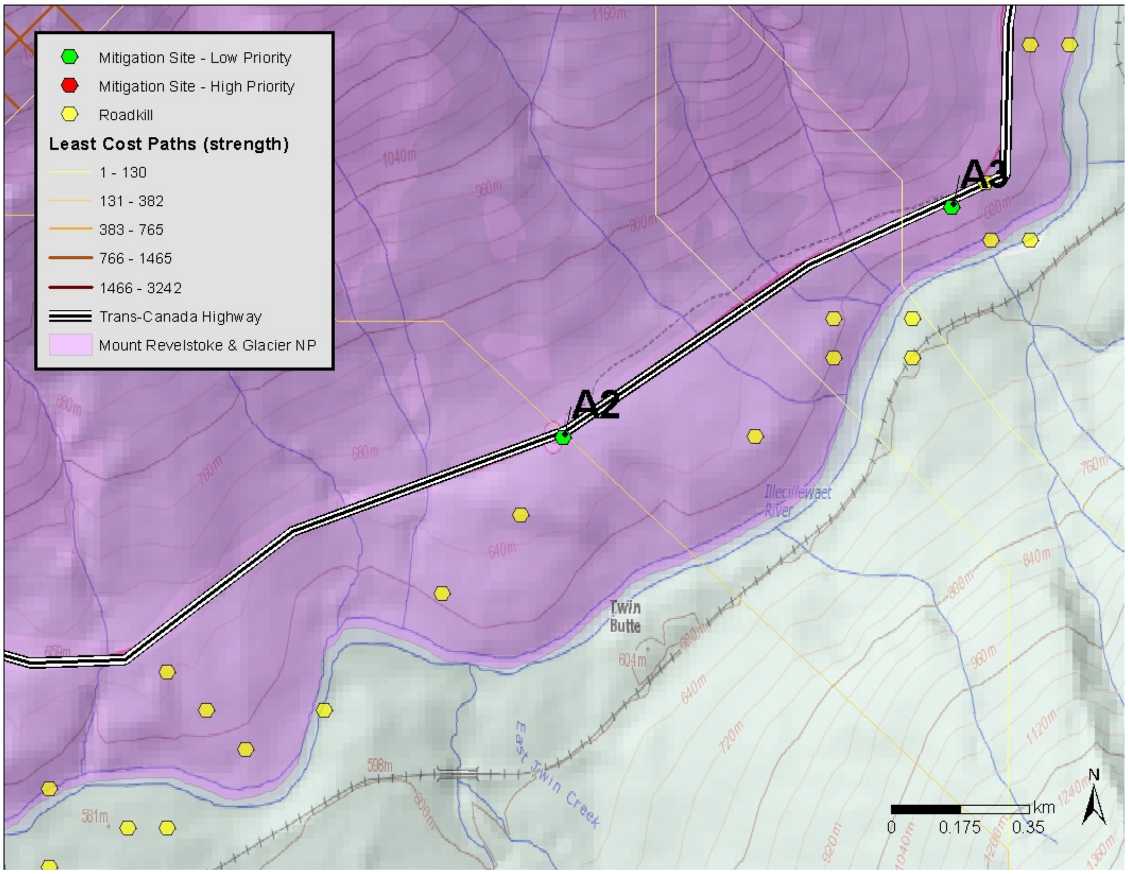

Figure A2: Map showing Highway Mitigation Emphasis Site A2 in Mount Revelstoke and Glacier National Parks, British Columbia.

Zone A, Site 3 Summary – Revelstoke	
Description	
Location: UTM: 434300, 5656085	
Species: Single species: Mountain goats.	
Mortality risk: 3	
Local conservation value: 2	
Regional conservation significance: 2	
Transportation mitigation opportunities: 5	
Wildlife objectives	
• Reduce current levels of goat–vehicle collisions in this section of highway. • Provide safe movement for all wildlife species across highway, primarily mountain goats and bears.	
Existing infrastructure	
• None	
Target species for mitigation planning	
WVC reduction: Mitigation consists of techniques to keep wildlife off the highway and effectively warn motorists of wildlife on the highway. **Regional conservation and connectivity**: This site has little regional connectivity conservation significance as it is primarily a location where mountain goats congregate on the highway.	
Transportation mitigation opportunities	
Score: 5	
Mitigation strategy consists of keeping mountain goats off the highway and reducing mortality from collisions with vehicles in this highway section. In the short term mitigation to reduce collisions should consist of the following measures: • *Salt diversion*. As part of pilot project prior to implementing salt diversion at this roadside location, evaluate this method of diverting goats from highway salt to areas where salt are manually dispersed in areas adjacent to escape terrain and habitats they occupy. The method has been used successfully in the Okanagan to divert goats from areas of road salt (Andrew Walker, BC Ministry of Forests, Lands, Natural Resource Operations, Penticton, BC, personal communication). • *Animal-detection system*. A radar-based animal detection system focused on this problematic stretch of highway. The system will warn motorists when goats (and other wildlife) are on the highway.	

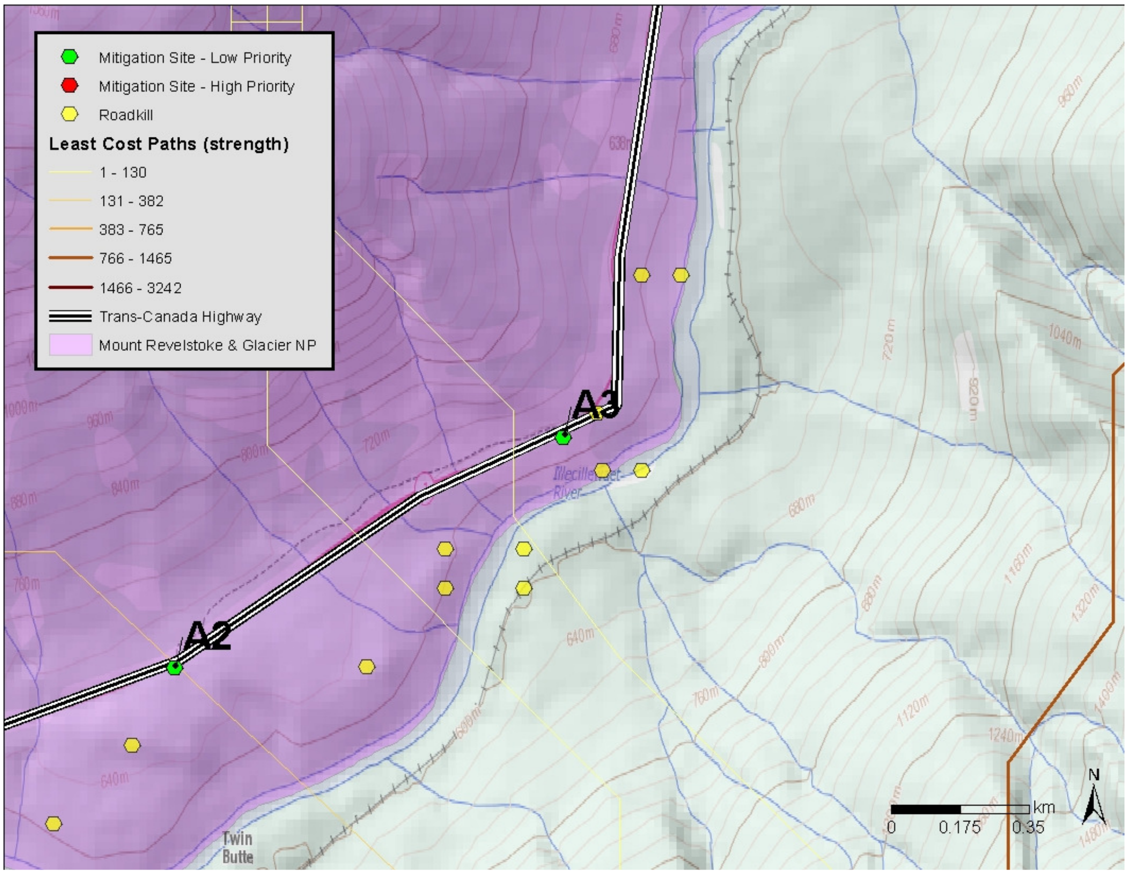

Figure A3: Map showing Highway Mitigation Emphasis Site A3 in Mount Revelstoke and Glacier National Parks, British Columbia.

Zone A, Site 4 Summary – Revelstoke	
Description	
Location: UTM: 434957, 5658956	
Species: Multi-species: Deer, bears, mountain goats	
Mortality risk: 2	
Local conservation value: 3	
Regional conservation significance: 5	
Transportation mitigation opportunities: 4	
Wildlife objectives	
• Reduce current levels of wildlife–vehicle collisions in this section of highway, primarily deer and bears. • Provide safe movement for all wildlife species across highway, primarily deer and bears.	
Existing infrastructure	
• None	
Target species for mitigation planning	
WVC reduction: Common species. **Regional conservation and connectivity**: Common species primarily.	
Transportation mitigation opportunities	
Score: 4	
To ensure movement of wildlife through the area and reduce wildlife-vehicle collisions, fencing and construction of wildlife *underpass* is recommended. Selection of design type is dependent on terrain and engineering constraints; open-span preferred design. Minimum dimension for underpass is 11 m wide x 3 m high due to high likelihood of grizzly bear movement through this area. Wing *fencing* (200–500 m depending on terrain) should be installed to funnel movements to the crossing structure. Fencing notes: Snow is a concern at this location due to high annual snowfall.	

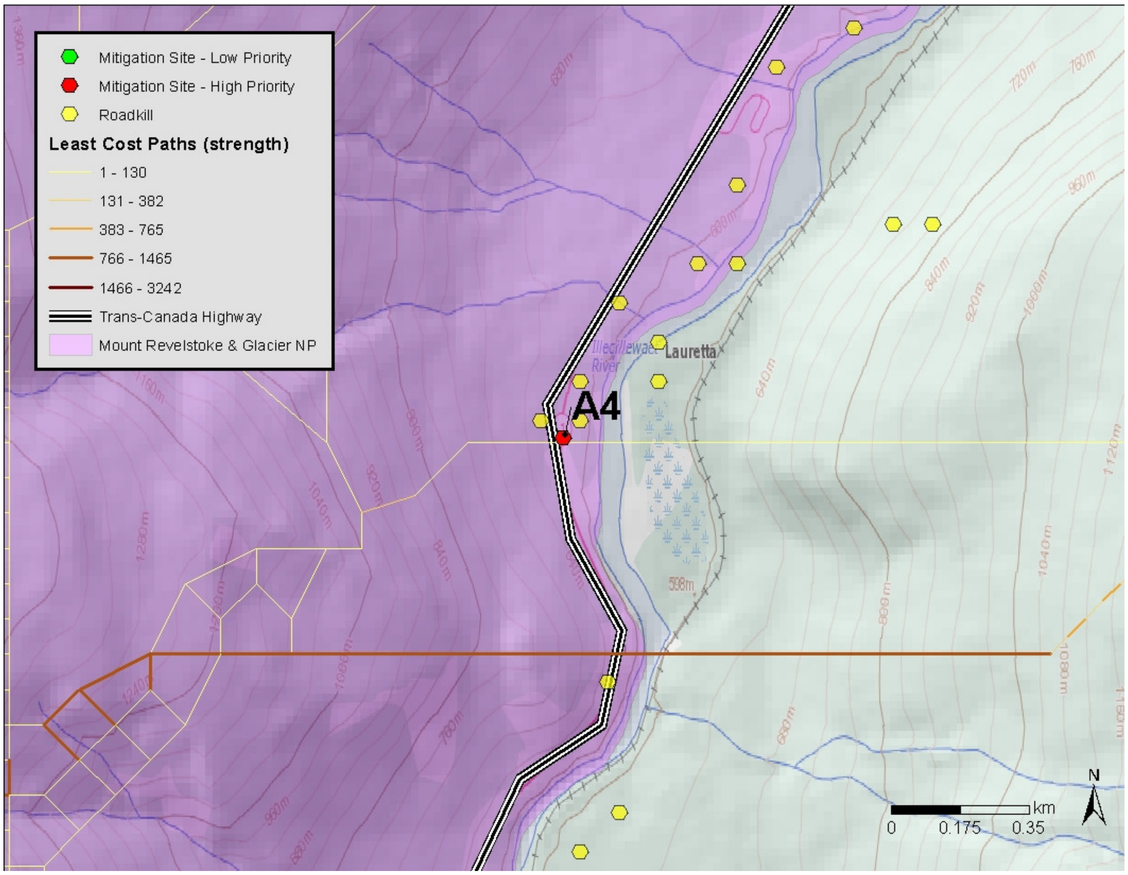

Figure A4: Map showing Highway Mitigation Emphasis Site A4 in Mount Revelstoke and Glacier National Parks, British Columbia.

Zone A, Site 5 Summary – Revelstoke	
Description	
Location: UTM: 435824, 5660532	
Species: Multi-species: Deer, moose, bears.	
Mortality risk: 2	
Local conservation value: 3	
Regional conservation significance: 2	
Transportation mitigation opportunities: 4	
Wildlife objectives	
• Reduce current levels of wildlife–vehicle collisions in this section of highway, primarily deer, moose and bears. • Provide safe movement for all wildlife species across highway, primarily deer and bears.	
Existing infrastructure	
• None	
Target species for mitigation planning	
WVC reduction: Common species. **Regional conservation and connectivity**: Common species primarily.	
Transportation mitigation opportunities	
Score: 4	
To ensure movement of wildlife through the area and reduce wildlife-vehicle collisions, fencing and construction of wildlife *underpass* is recommended. Selection of design type is dependent on terrain and engineering constraints; open-span preferred design. Minimum dimension for underpass is 4 m high x 7 m wide. Wing *fencing* (200–500 m depending on terrain) should be installed to funnel movements to the crossing structure. Fencing notes: Snow is a concern at this location due to high annual snowfall.	

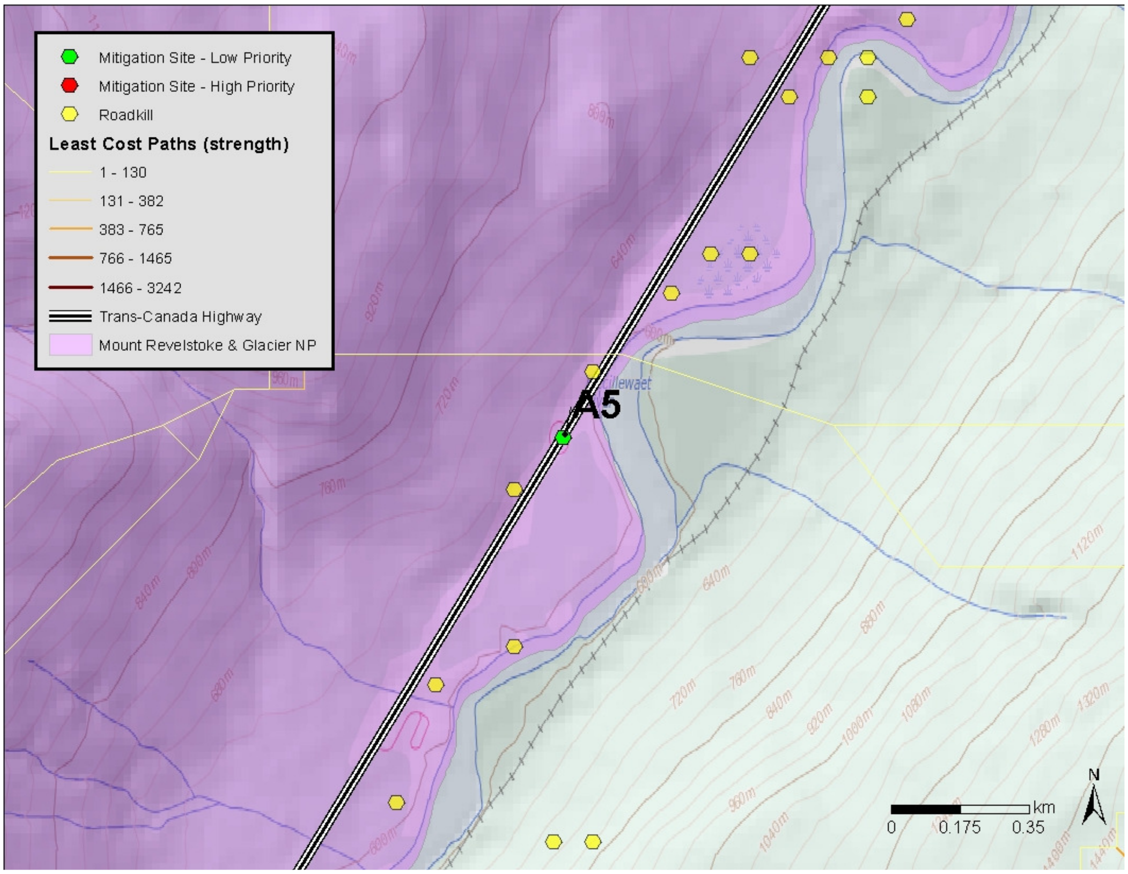

Figure A5: Map showing Highway Mitigation Emphasis Site A5 in Mount Revelstoke and Glacier National Parks, British Columbia.

ZONE B MAP

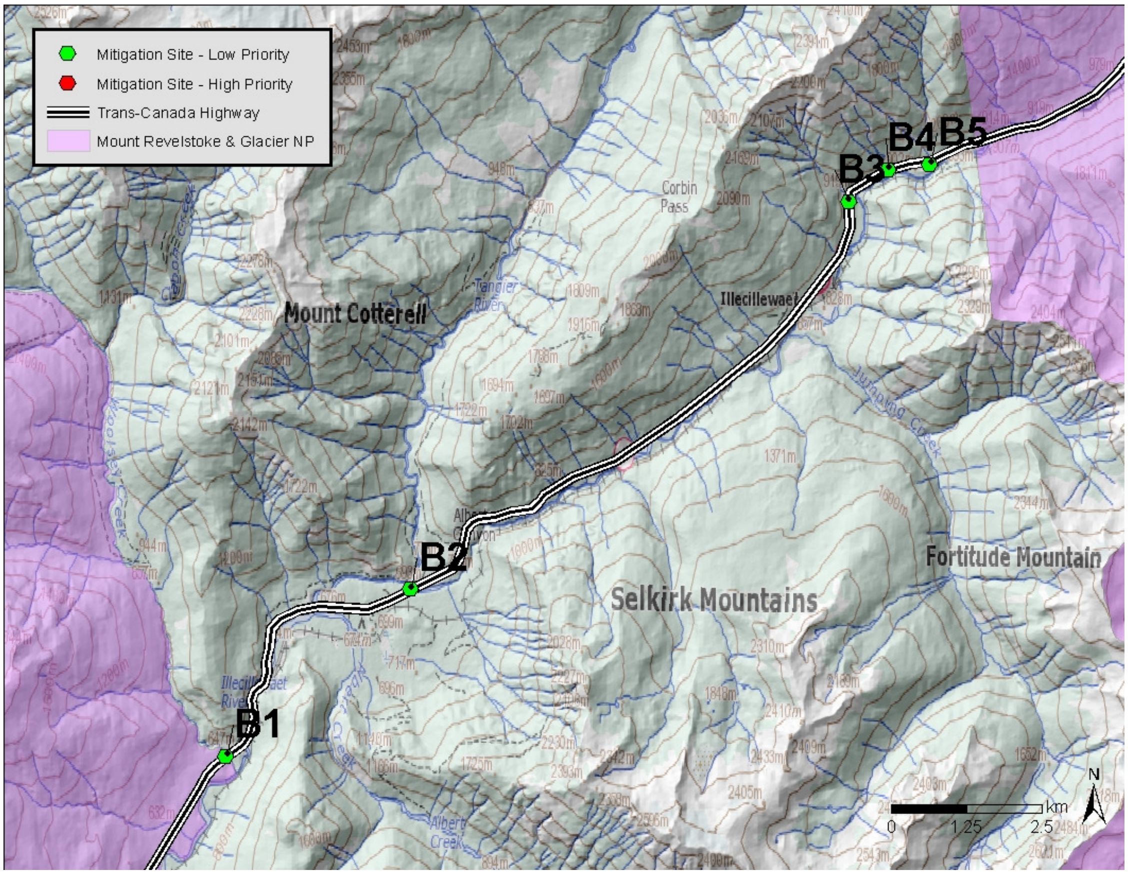

Figure B: Map showing Highway Mitigation Emphasis Zone B in Mount Revelstoke and Glacier National Parks, British Columbia.

Zone B, Site 1 Summary – Provincial (Woolsey Creek)	
Description	
Location: UTM: 437548, 5663159	
Species: Multi-species: Deer, moose, bears.	
Mortality risk: N/A – Provincial section of highway.	
Local conservation value: 2	
Regional conservation significance: 3	
Transportation mitigation opportunities: 5	
Wildlife objectives	
• Reduce current levels of wildlife–vehicle collisions in this section of highway, primarily deer, moose and bears. • Provide safe movement for all wildlife species across highway, primarily deer and bears.	
Existing infrastructure	
• Woolsey Creek Bridge	
Target species for mitigation planning	
WVC reduction: Common species. **Regional conservation and connectivity**: Common species primarily.	
Transportation mitigation opportunities	
Score: 5	
Currently the Woolsey Creek Bridge has sufficient space on both sides to allow for wildlife passage. If the highway is reconstructed, a new bridge will be added and to the existing bridge. All bridge construction or reconstruction must be designed with wildlife movement (and hydrologic flow) in mind. The new bridge should be designed with a span matching existing, allowing dry travel sections ($\geq$5 m wide) above high-water mark. Wing *fencing* (200–500 m depending on terrain) should be installed to funnel movements to the crossing structure. Fencing notes: Snow is a concern at this location due to high annual snowfall.	

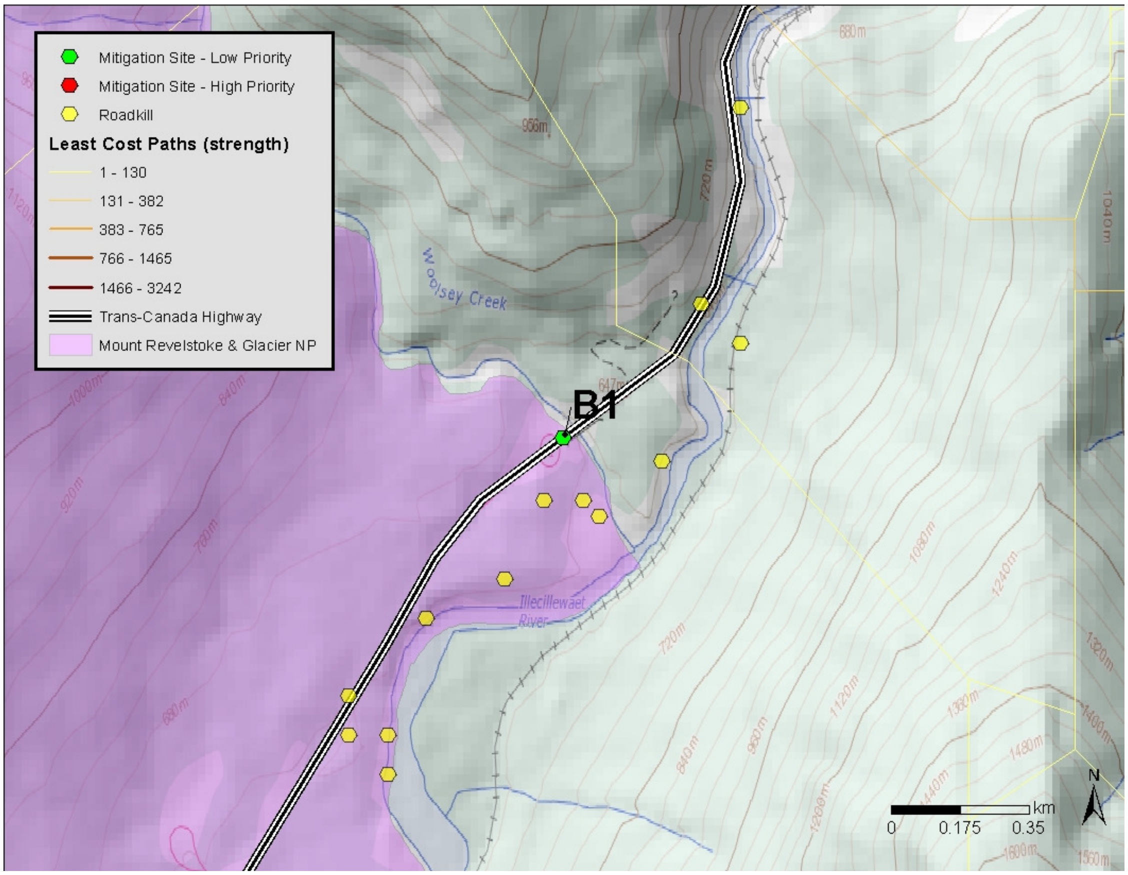

Figure B1: Map showing Highway Mitigation Emphasis Site B1 in Mount Revelstoke and Glacier National Parks, British Columbia.

Zone B, Site 2 Summary – Provincial (Tangier River)	
Description	
Location: UTM: 440618, 5665941	
Species: Multi-species: Deer, bears.	
Mortality risk: N/A – Provincial section of highway.	
Local conservation value: 2	
Regional conservation significance: 2	
Transportation mitigation opportunities: 5	
Wildlife objectives	
• Reduce current levels of wildlife–vehicle collisions in this section of highway, primarily deer, moose and bears. • Provide safe movement for all wildlife species across highway, primarily deer and bears.	
Existing infrastructure	
• Tangier River Bridge	
Target species for mitigation planning	
WVC reduction: Common species. **Regional conservation and connectivity**: Common species primarily.	
Transportation mitigation opportunities	
Score: 5	
Currently the Tangier River Bridge has sufficient space on both sides to allow for wildlife passage. If the highway is reconstructed, a new bridge will be added and to the existing bridge. All bridge construction or reconstruction must be designed with wildlife movement (and hydrologic flow) in mind. The new bridge should be designed with a span matching existing, allowing dry travel sections (≥5 m wide) above high-water mark. Wing *fencing* (200–500 m depending on terrain) should be installed to funnel movements to the crossing structure. Fencing notes: Snow could be a concern at this location due to high annual snowfall.	

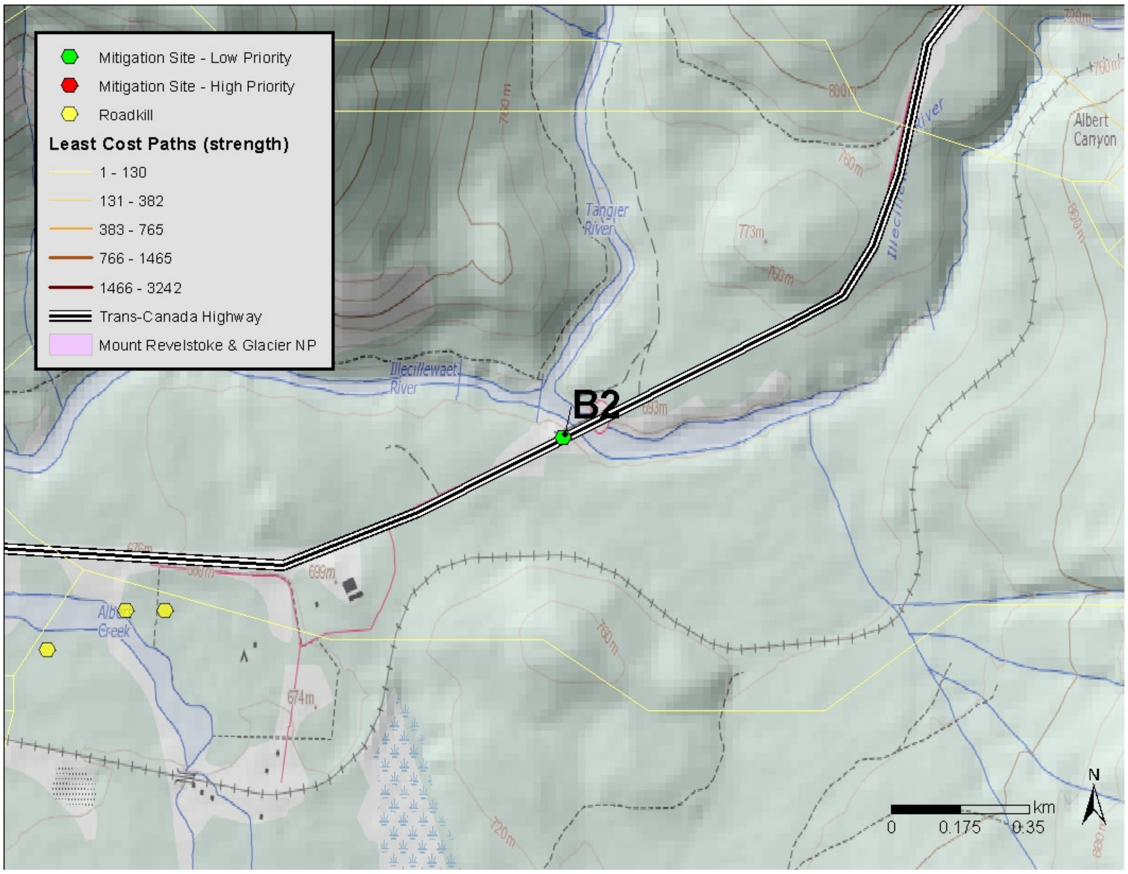

Figure B2: Map showing Highway Mitigation Emphasis Site B2 in Mount Revelstoke and Glacier National Parks, British Columbia.

Zone B, Site 3 Summary – Provincial (Snow Sheds: McDonald)	
Description	
Location: UTM: 447920, 5672403	
Species: Multi-species: Mountain goats, grizzly bears, wolverines, lynx, black bears.	
Mortality risk: N/A. – Provincial section of highway.	
Local conservation value: 1	
Regional conservation significance: 5	
Transportation mitigation opportunities: 5	
Wildlife objectives	
• Reduce current levels of wildlife–vehicle collisions in this section of highway, primarily mountain goats. • Provide safe movement for all wildlife species across highway, primarily grizzly bears, wolverines, lynx, black bears and mountain goats.	
Existing infrastructure	
• Snow shed.	
Target species for mitigation planning	
WVC reduction: Mountain goats primarily, but also bears. Mitigation consists of techniques to keep wildlife off the highway and effectively warn motorists of wildlife on the highway or in the show shed tunnel. **Regional conservation and connectivity**: Primarily grizzly bears, wolverines, lynx, black bears and mountain goats. Mitigation should focus on using the snow shed roof as wildlife overpass by providing access to and from roof by a "block step walkway" (see Chapter 6).	
Transportation mitigation opportunities	
Score: 5	
Mitigation strategy consists of keeping mountain goats off the highway and reducing mortality from collisions with vehicles within the snow shed tunnel and outside tunnel entrances. In the short term mitigation to reduce collisions should consist of the following measures: • *Salt diversion*. As part of pilot project prior to implementing salt diversion at snow sheds, evaluate this method of diverting goats from highway salt to areas where salt are manually dispersed in areas adjacent to escape terrain and habitats they occupy. The method has been used successfully in the Okanagan to divert goats from areas of road salt (Andrew Walker, BC Ministry of Forests, Lands, Natural Resource Operations, Penticton, BC, personal communication). • *Animal-detection system*. A radar-based animal detection system placed at tunnel entrances to warn motorists when goats and other wildlife are on the highway near tunnel entrances. The same radar-based animal detection systems placed inside tunnel will detect wildlife inside tunnel and warn motorists approaching tunnel. • *Create barrier*. Block off exterior wall of snow shed where there are existing gaps in wall that allow wildlife, primarily goats, to access tunnel interior. Make the outside wall as impermeable as possible. • *Block step walkway*. Build 1-2 structures along length of tunnel, consisting of interlocking precast concrete 'lego' blocks, that allow for wildlife (goats and bears primarily) to ascend and descend from show shed roofs. Fencing notes: High snow levels and frequent avalanche activity is a concern at this location, therefore fencing is not recommended for any mitigation.	

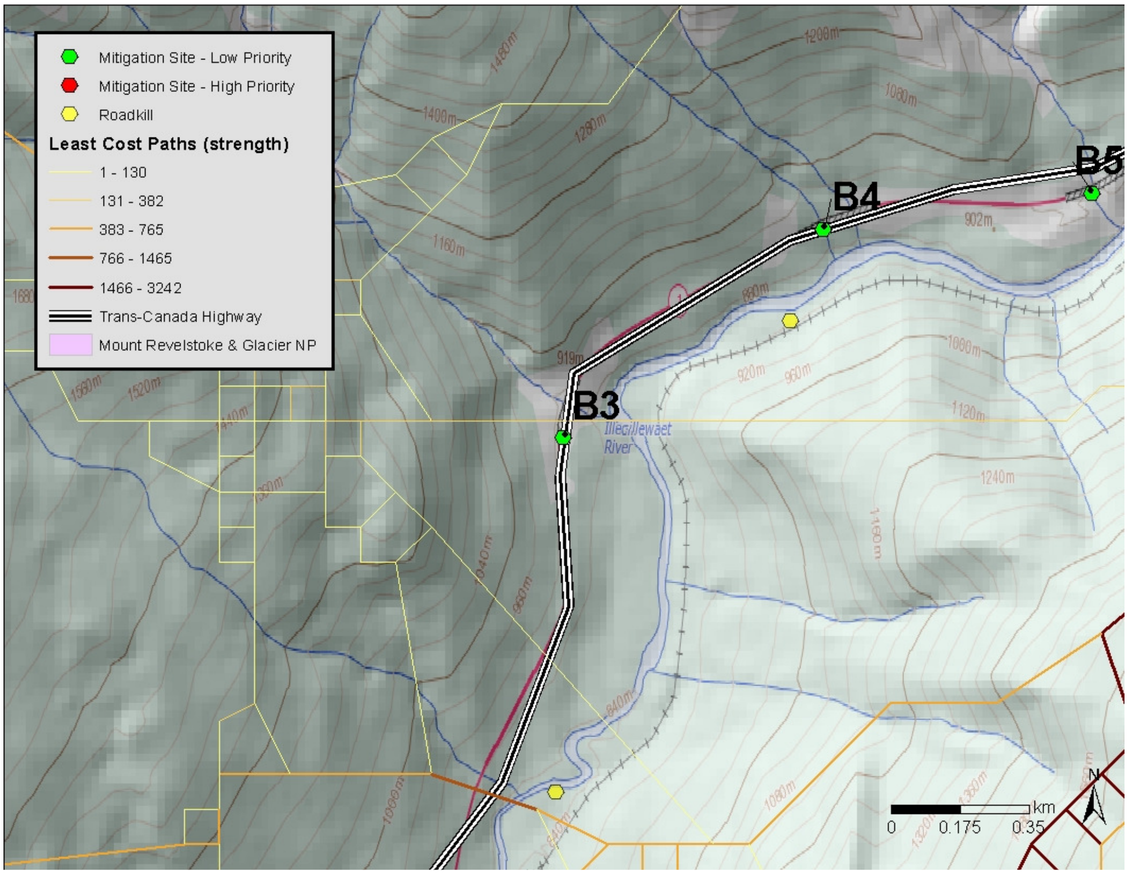

Figure B3: Map showing Highway Mitigation Emphasis Site B3 in Mount Revelstoke and Glacier National Parks, British Columbia.

Zone B, Site 4 Summary – Provincial (Snow Sheds: Twin)	
Description	
Location: UTM: 448583, 5672934	
Species: Multi-species: Mountain goats, grizzly bears, wolverines, lynx, black bears.	
Mortality risk: N/A. – Provincial section of highway.	
Local conservation value: 1	
Regional conservation significance: 2	
Transportation mitigation opportunities: 5	
Wildlife objectives	
• Reduce current levels of wildlife–vehicle collisions in this section of highway, primarily mountain goats. • Provide safe movement for all wildlife species across highway, primarily grizzly bears, wolverines, lynx, black bears and mountain goats.	
Existing infrastructure	
• Snow shed.	
Target species for mitigation planning	
WVC reduction: Mountain goats primarily, but also bears. Mitigation consists of techniques to keep wildlife off the highway and effectively warn motorists of wildlife on the highway or in the show shed tunnel. **Regional conservation and connectivity**: Primarily grizzly bears, wolverines, lynx, black bears and mountain goats. Mitigation should focus on using the snow shed roof as wildlife overpass by providing access to and from roof by a "block step walkway" (see Chapter 6).	
Transportation mitigation opportunities	
Score: 5	
Mitigation strategy consists of keeping mountain goats off the highway and reducing mortality from collisions with vehicles within the snow shed tunnel and outside tunnel entrances. In the short term mitigation to reduce collisions should consist of the following measures: • *Salt diversion*. As part of pilot project prior to implementing salt diversion at snow sheds, evaluate this method of diverting goats from highway salt to areas where salt are manually dispersed in areas adjacent to escape terrain and habitats they occupy. The method has been used successfully in the Okanagan to divert goats from areas of road salt (Andrew Walker, BC Ministry of Forests, Lands, Natural Resource Operations, Penticton, BC, personal communication). • *Animal-detection system*. A radar-based animal detection system placed at tunnel entrances to warn motorists when goats and other wildlife are on the highway near tunnel entrances. The same radar-based animal detection systems placed inside tunnel will detect wildlife inside tunnel and warn motorists approaching tunnel. • *Create barrier*. Block off exterior wall of snow shed where there are existing gaps in wall that allow wildlife, primarily goats, to access tunnel interior. Make the outside wall as impermeable as possible. • *Block step walkway*. Build 1-2 structures along length of tunnel, consisting of interlocking precast concrete 'lego' blocks, that allow for wildlife (goats and bears primarily) to ascend and descend from show shed roofs. Fencing notes: High snow levels and frequent avalanche activity is a concern at this location, therefore fencing is not recommended for any mitigation.	

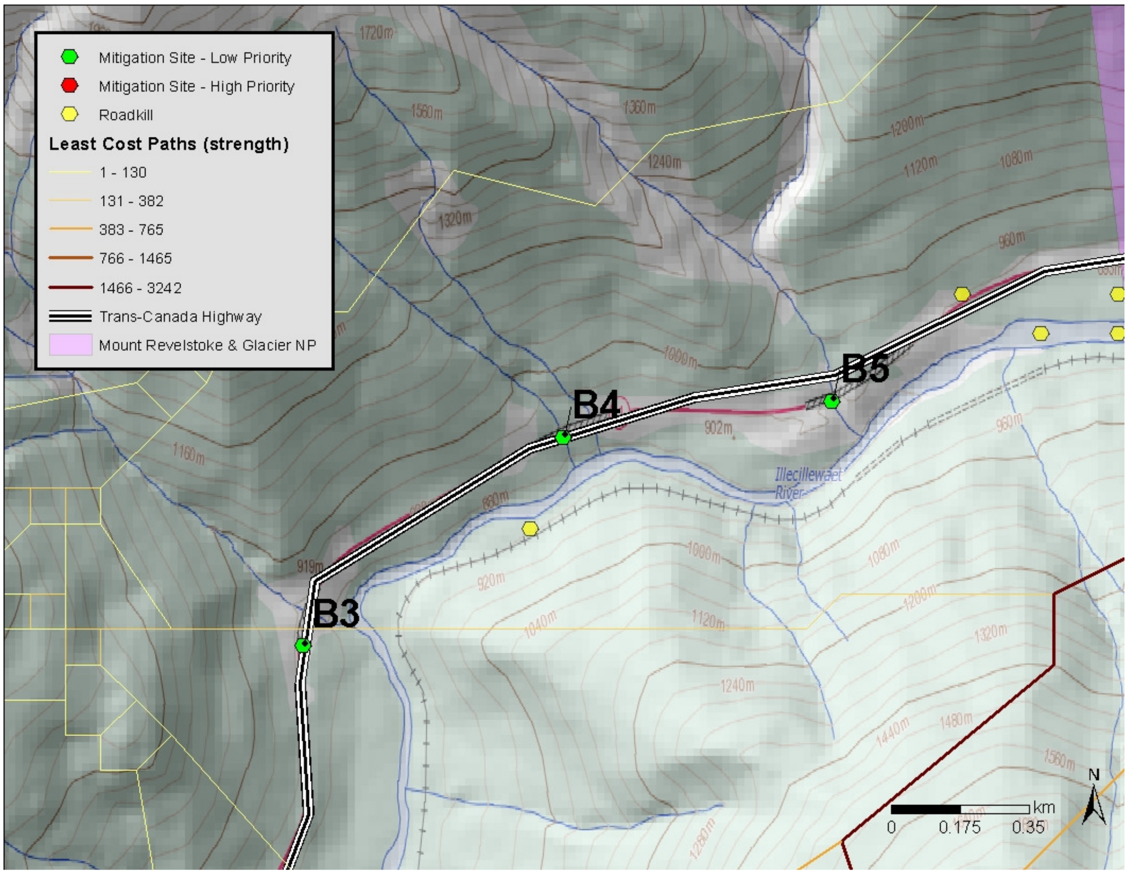

Figure B4: Map showing Highway Mitigation Emphasis Site B4 in Mount Revelstoke and Glacier National Parks, British Columbia.

Zone B, Site 5 Summary – Provincial (Snow Sheds: Lanark)	
Description	
Location: UTM: 449268, 5673027	
Species: Multi-species: Mountain goats, grizzly bears, wolverines, lynx, black bears.	
Mortality risk: N/A. – Provincial section of highway.	
Local conservation value: 1	
Regional conservation significance: 2	
Transportation mitigation opportunities: 5	
Wildlife objectives	
• Reduce current levels of wildlife–vehicle collisions in this section of highway, primarily mountain goats. • Provide safe movement for all wildlife species across highway, primarily grizzly bears, wolverines, lynx, black bears and mountain goats.	
Existing infrastructure	
• Snow shed.	
Target species for mitigation planning	
WVC reduction: Mountain goats primarily, but also bears. Mitigation consists of techniques to keep wildlife off the highway and effectively warn motorists of wildlife on the highway or in the show shed tunnel. **Regional conservation and connectivity**: Primarily grizzly bears, wolverines, lynx, black bears and mountain goats. Mitigation should focus on using the snow shed roof as wildlife overpass by providing access to and from roof by a "block step walkway" (see Chapter 6).	
Transportation mitigation opportunities	
Score: 5	
Mitigation strategy consists of keeping mountain goats off the highway and reducing mortality from collisions with vehicles within the snow shed tunnel and outside tunnel entrances. In the short term mitigation to reduce collisions should consist of the following measures: • *Salt diversion*. As part of pilot project prior to implementing salt diversion at snow sheds, evaluate this method of diverting goats from highway salt to areas where salt are manually dispersed in areas adjacent to escape terrain and habitats they occupy. The method has been used successfully in the Okanagan to divert goats from areas of road salt (Andrew Walker, BC Ministry of Forests, Lands, Natural Resource Operations, Penticton, BC, personal communication). • *Animal-detection system*. A radar-based animal detection system placed at tunnel entrances to warn motorists when goats and other wildlife are on the highway near tunnel entrances. The same radar-based animal detection systems placed inside tunnel will detect wildlife inside tunnel and warn motorists approaching tunnel. • *Create barrier*. Block off exterior wall of snow shed where there are existing gaps in wall that allow wildlife, primarily goats, to access tunnel interior. Make the outside wall as impermeable as possible. • *Block step walkway*. Build 1-2 structures along length of tunnel, consisting of interlocking precast concrete 'lego' blocks, that allow for wildlife (goats and bears primarily) to ascend and descend from show shed roofs. Fencing notes: High snow levels and frequent avalanche activity is a concern at this location, therefore fencing is not recommended for any mitigation.	

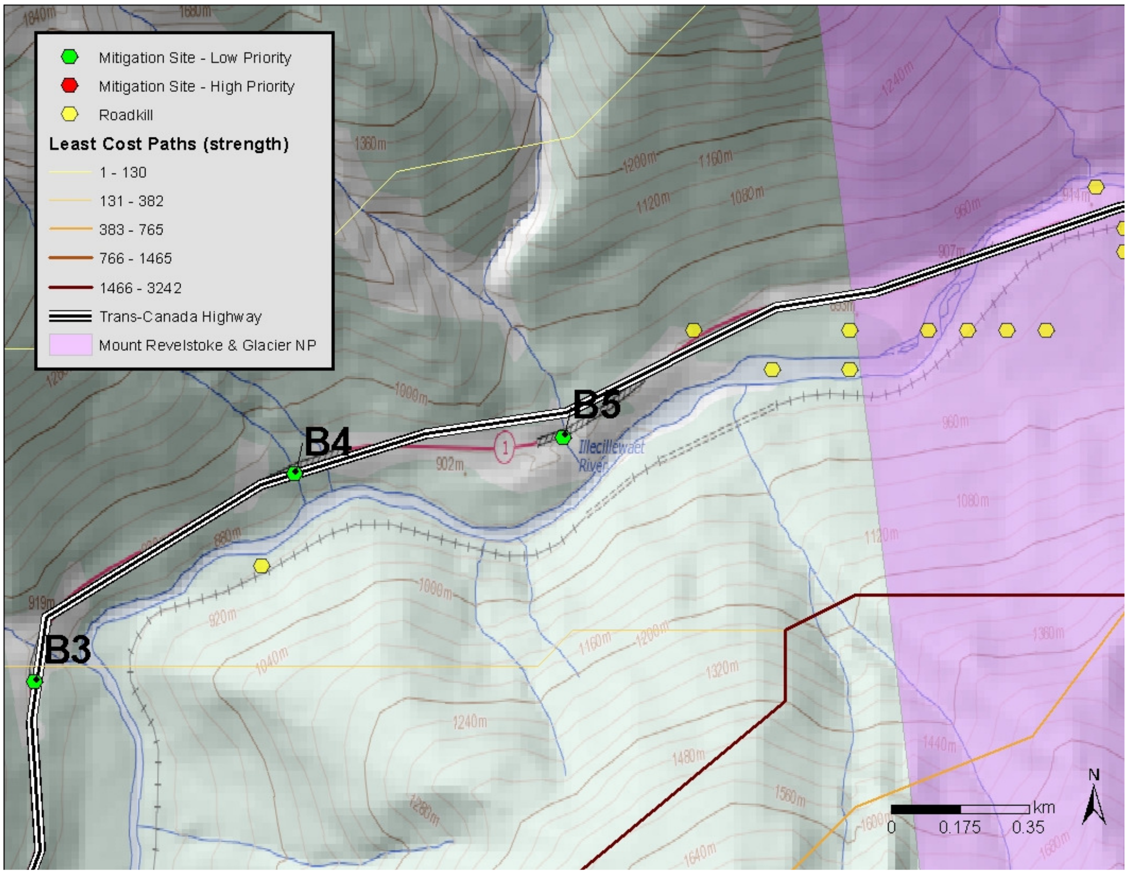

Figure B5: Map showing Highway Mitigation Emphasis Site B5 in Mount Revelstoke and Glacier National Parks, British Columbia.

ZONE C MAP

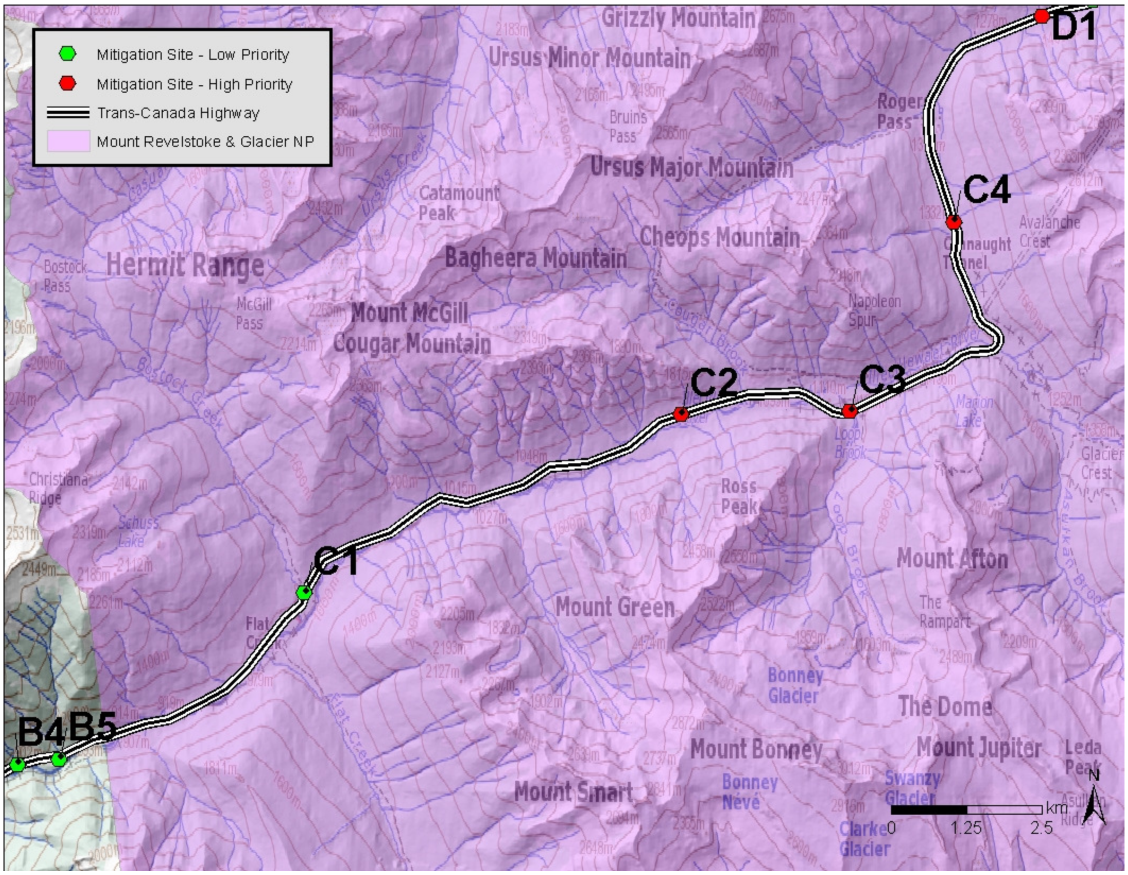

Figure C: Map showing Highway Mitigation Emphasis Zone C in Mount Revelstoke and Glacier National Parks, British Columbia.

Zone C, Site 1 Summary – Rogers Pass	
Description	
Location: UTM: 453357, 5675788	
Species: Multi-species: Grizzly bear, black bear, deer.	
Mortality risk: 1	
Local conservation value: 3	
Regional conservation significance: 4	
Transportation mitigation opportunities: 4	
Wildlife objectives	
• Reduce current levels of wildlife–vehicle collisions in this section of highway, primarily deer and bears. • Provide safe movement for all wildlife species across highway, primarily deer and bears.	
Existing infrastructure	
• None	
Target species for mitigation planning	
WVC reduction: Common species. **Regional conservation and connectivity**: Common species primarily.	
Transportation mitigation opportunities	
Score: 4	
To ensure movement of wildlife through the area and reduce wildlife-vehicle collisions, fencing and construction of wildlife *underpass* is recommended. Selection of design type is dependent on terrain and engineering constraints; open-span preferred design. Minimum dimension for underpass is 4 m high x 7 m wide. Wing *fencing* (200–500 m depending on terrain) should be installed to funnel movements to the crossing structure. Fencing notes: Snow is likely a concern at this location due to high annual snowfall.	

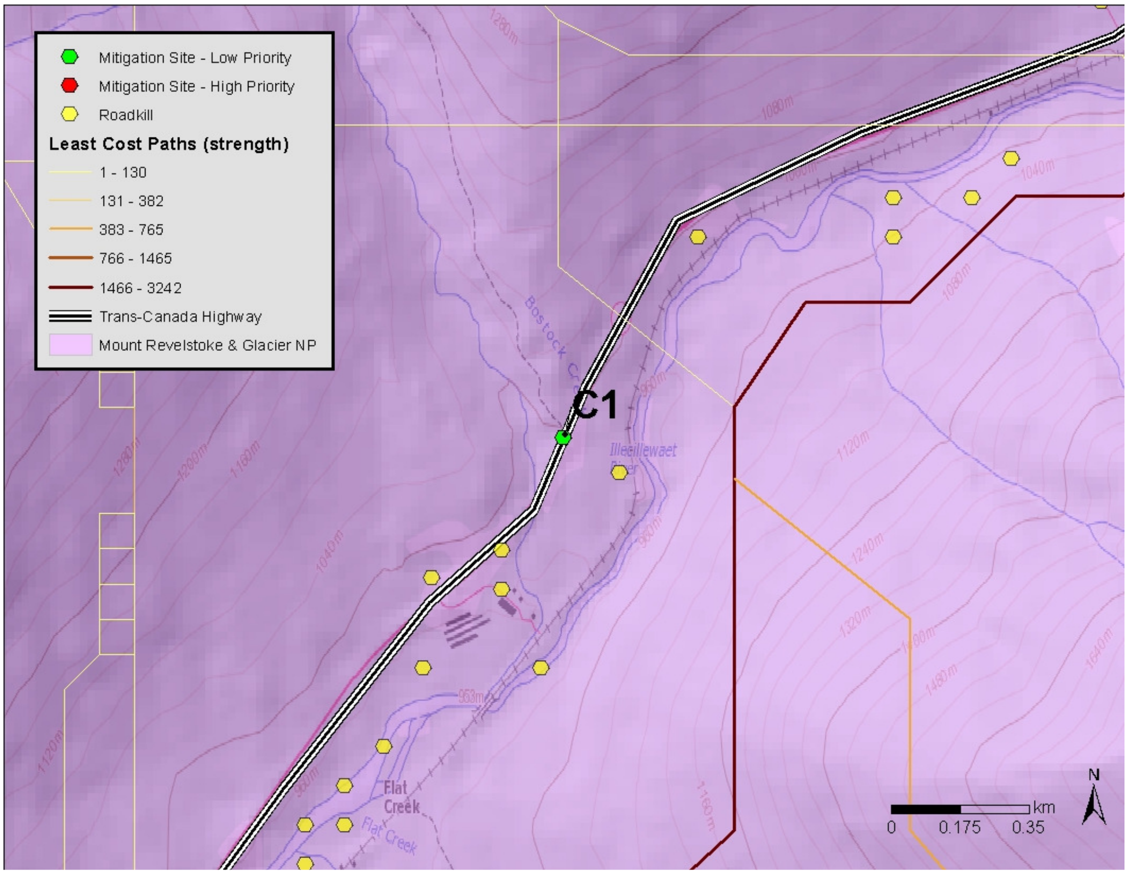

Figure C1: Map showing Highway Mitigation Emphasis Site C1 in Mount Revelstoke and Glacier National Parks, British Columbia.

Zone C, Site 2 Summary – Rogers Pass	
Description	
Location: UTM: 459623, 5678763	
Species: Multi-species: Grizzly bear, black bear, wolverine, deer.	
Mortality risk: 2	
Local conservation value: 3	
Regional conservation significance: 5	
Transportation mitigation opportunities: 5	
Wildlife objectives	
• Reduce current levels of wildlife–vehicle collisions in this section of highway, primarily deer and bears. • Provide safe movement for all wildlife species across highway, primarily bears, wolverines and deer.	
Existing infrastructure	
• None	
Target species for mitigation planning	
WVC reduction: Common species. **Regional conservation and connectivity**: Common species, but primarily grizzly bears.	
Transportation mitigation opportunities	
Score: 5	
To ensure movement of wildlife through the area and reduce wildlife-vehicle collisions, fencing and construction of wildlife *underpass* is recommended. Selection of design type is dependent on terrain and engineering constraints; open-span preferred design. Minimum dimension for underpass is 11 m wide x 3 m high due to high likelihood of grizzly bear movement through this area. Wing *fencing* (200–500 m depending on terrain) should be installed to funnel movements to the crossing structure. Fencing notes: Snow is likely a concern at this location due to high annual snowfall.	

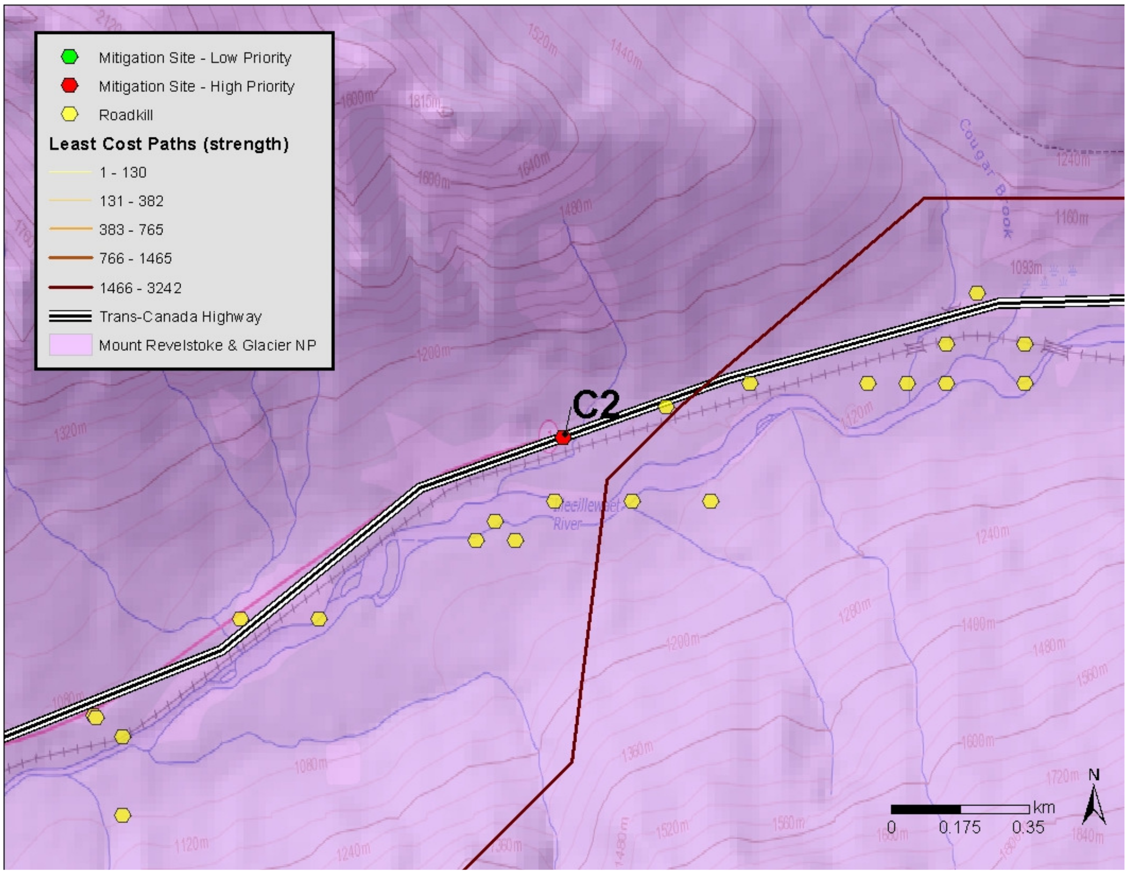

Figure C2: Map showing Highway Mitigation Emphasis Site C2 in Mount Revelstoke and Glacier National Parks, British Columbia.

Zone C, Site 3 Summary – Rogers Pass	
Description	
Location: UTM: 462445, 5678813	
Species: Multi-species: Deer, bears, wolverines.	
Mortality risk: 1	
Local conservation value: 3	
Regional conservation significance: 4	
Transportation mitigation opportunities: 5	
Wildlife objectives	
• Reduce current levels of wildlife–vehicle collisions in this section of highway, primarily deer, moose and bears. • Provide safe movement for all wildlife species across highway, primarily deer and bears.	
Existing infrastructure	
• Loop Brook River Bridge	
Target species for mitigation planning	
WVC reduction: Common species. **Regional conservation and connectivity**: Common species primarily.	
Transportation mitigation opportunities	
Score: 5	
Currently the Loop Brook River Bridge has sufficient space on both sides to allow for wildlife passage. If the highway is reconstructed, a new bridge will be added and to the existing bridge. All bridge construction or reconstruction must be designed with wildlife movement (and hydrologic flow) in mind. The new bridge should be designed with a span matching existing, allowing dry travel sections (≥5 m wide) above high-water mark. Wing *fencing* (200–500 m depending on terrain) should be installed to funnel movements to the crossing structure. Fencing notes: Snow could be a concern at this location due to high annual snowfall.	

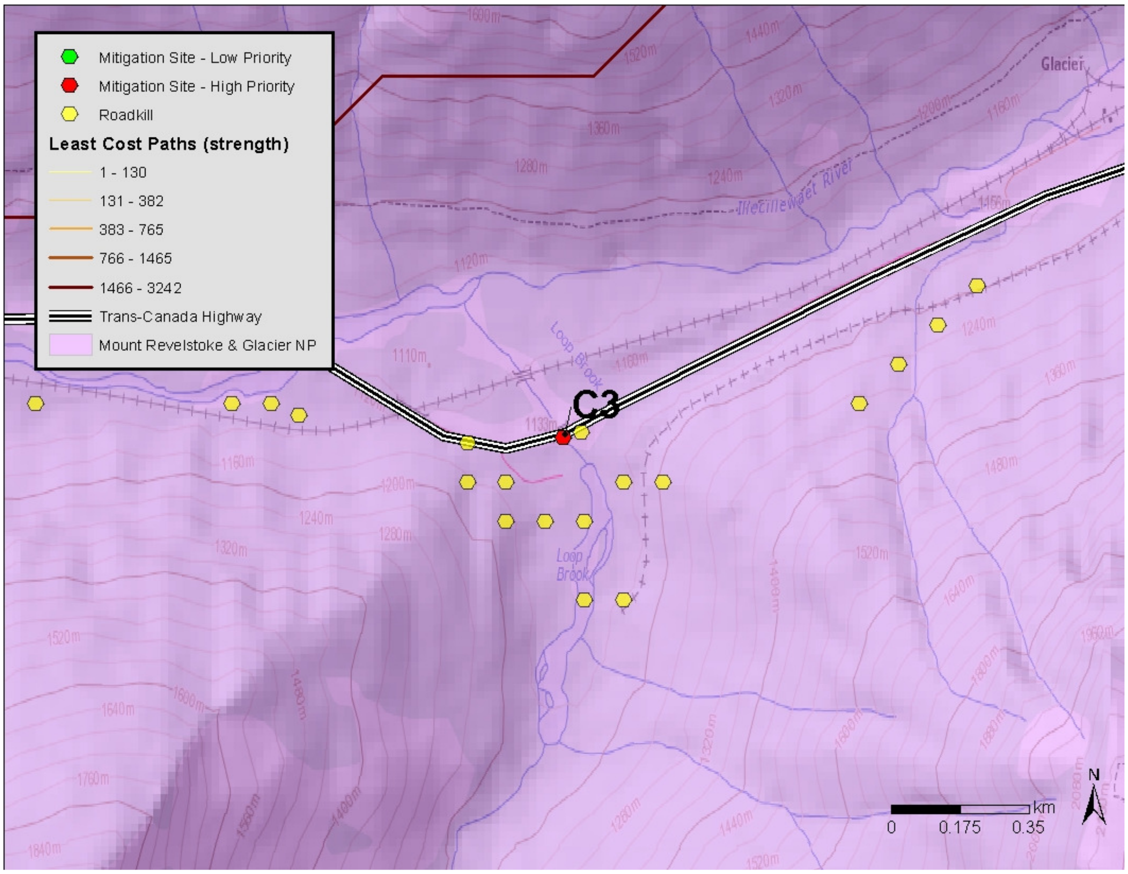

Figure C3: Map showing Highway Mitigation Emphasis Site C3 in Mount Revelstoke and Glacier National Parks, British Columbia.

Zone C, Site 4 Summary – Rogers Pass	
Description	
Location: UTM: 464166, 5681972	
Species: Multi-species: Grizzly bears, wolverines, lynx.	
Mortality risk: 1	
Local conservation value: 5	
Regional conservation significance: 5	
Transportation mitigation opportunities: 4	
Wildlife objectives	
• Reduce current levels of wildlife–vehicle collisions in this section of highway, primarily bears. • Provide safe movement for all wildlife species across highway, primarily grizzly bears.	
Existing infrastructure	
• None	
Target species for mitigation planning	
WVC reduction: Key fragmentation-sensitive species: Grizzly bears, wolverines. **Regional conservation and connectivity**: Grizzly bears and wolverines primarily.	
Transportation mitigation opportunities	
Score: 4	
Wildlife overpass without *fencing*. A suitable location exists where the highway passes through a ridge cut resulting in raised embankments (elevated terrain) on both sides of the highway, facilitating the construction of an overpass structure. Recommended minimum dimension is >40 m wide. Selection of design type (arched, span) and materials (concrete, steel) will be dependent on terrain, engineering constraints and current pricing of materials. Fencing notes: Snow is a concern at this location due to high annual snowfall.	

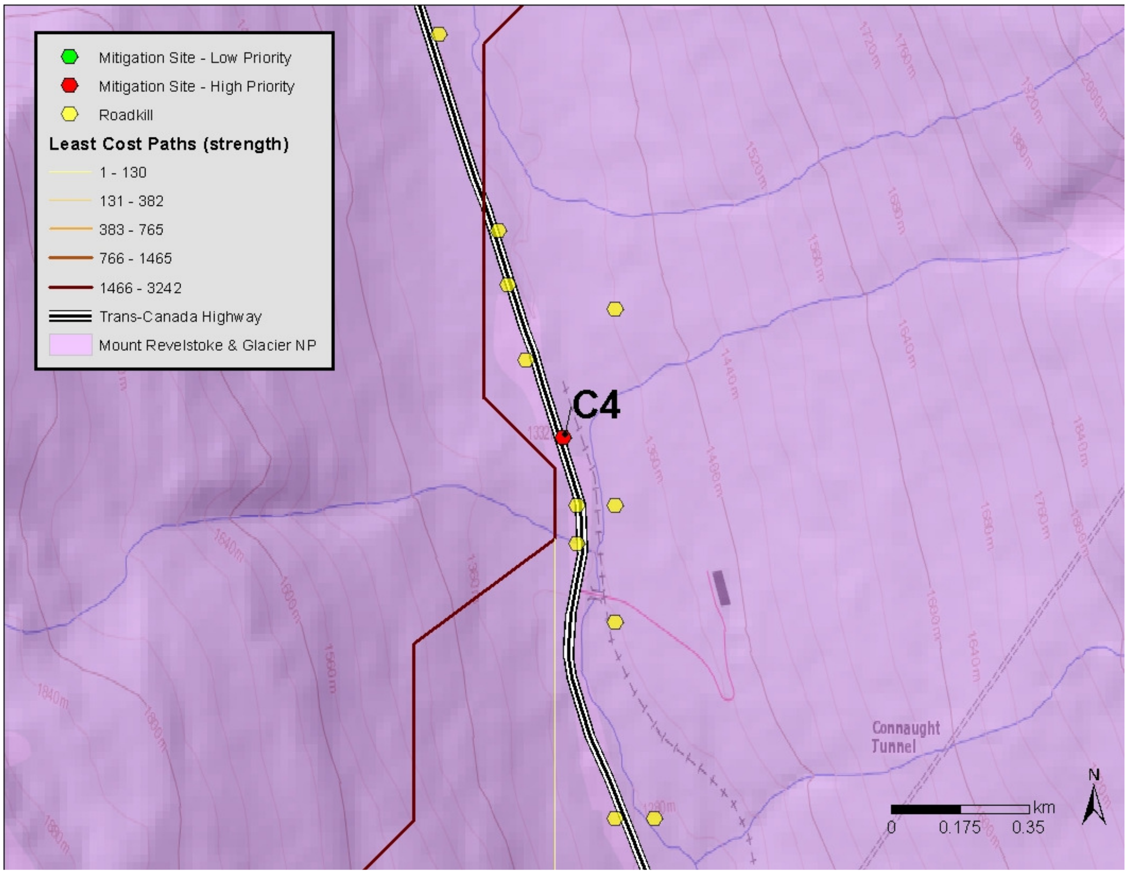

Figure C4: Map showing Highway Mitigation Emphasis Site C4 in Mount Revelstoke and Glacier National Parks, British Columbia.

ZONE D MAP

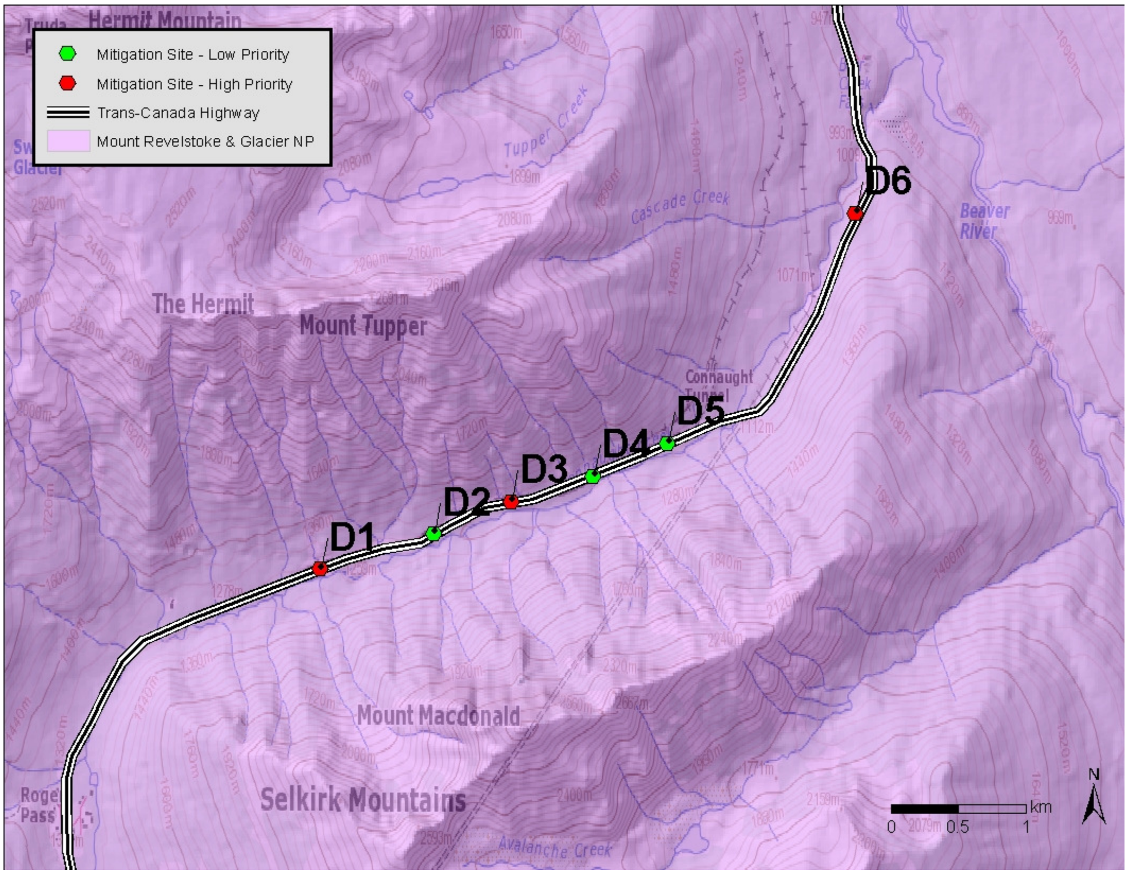

Figure D: Map showing Highway Mitigation Emphasis Zone D in Mount Revelstoke and Glacier National Parks, British Columbia.

Zone D, Site 1 Summary – Glacier Snow Sheds	
Description	
Location: UTM: 465637, 5685402	
Species: Multi-species: Mountain goats, grizzly bears, wolverines, lynx, black bears.	
Mortality risk: 4	
Local conservation value: 3	
Regional conservation significance: 2	
Transportation mitigation opportunities: 5	
Wildlife objectives	
• Reduce current levels of wildlife–vehicle collisions in this section of highway, primarily mountain goats. • Provide safe movement for all wildlife species across highway, primarily grizzly bears, wolverines, lynx, black bears and mountain goats.	
Existing infrastructure	
• Snow shed.	
Target species for mitigation planning	
WVC reduction: Mountain goats primarily, but also bears. Mitigation consists of techniques to keep wildlife off the highway and effectively warn motorists of wildlife on the highway or in the show shed tunnel. **Regional conservation and connectivity**: Primarily grizzly bears, wolverines, lynx, black bears and mountain goats. Mitigation should focus on using the snow shed roof as wildlife overpass by providing access to and from roof by a "block step walkway" (see Chapter 6).	
Transportation mitigation opportunities	
Score: 5	
Mitigation strategy consists of keeping mountain goats off the highway and reducing mortality from collisions with vehicles within the snow shed tunnel and outside tunnel entrances. In the short term mitigation to reduce collisions should consist of the following measures: • *Salt diversion*. As part of pilot project prior to implementing salt diversion at snow sheds, evaluate this method of diverting goats from highway salt to areas where salt are manually dispersed in areas adjacent to escape terrain and habitats they occupy. The method has been used successfully in the Okanagan to divert goats from areas of road salt (Andrew Walker, BC Ministry of Forests, Lands, Natural Resource Operations, Penticton, BC, personal communication). • *Animal-detection system*. A radar-based animal detection system placed at tunnel entrances to warn motorists when goats and other wildlife are on the highway near tunnel entrances. The same radar-based animal detection systems placed inside tunnel will detect wildlife inside tunnel and warn motorists approaching tunnel. • *Create barrier*. Block off exterior wall of snow shed where there are existing gaps in wall that allow wildlife, primarily goats, to access tunnel interior. Make the outside wall as impermeable as possible. • *Block step walkway*. Build 1-2 structures along length of tunnel, consisting of interlocking precast concrete 'lego' blocks, that allow for wildlife (goats and bears primarily) to ascend and descend from show shed roofs. Fencing notes: High snow levels and frequent avalanche activity is a concern at this location, therefore fencing is not recommended for any mitigation.	

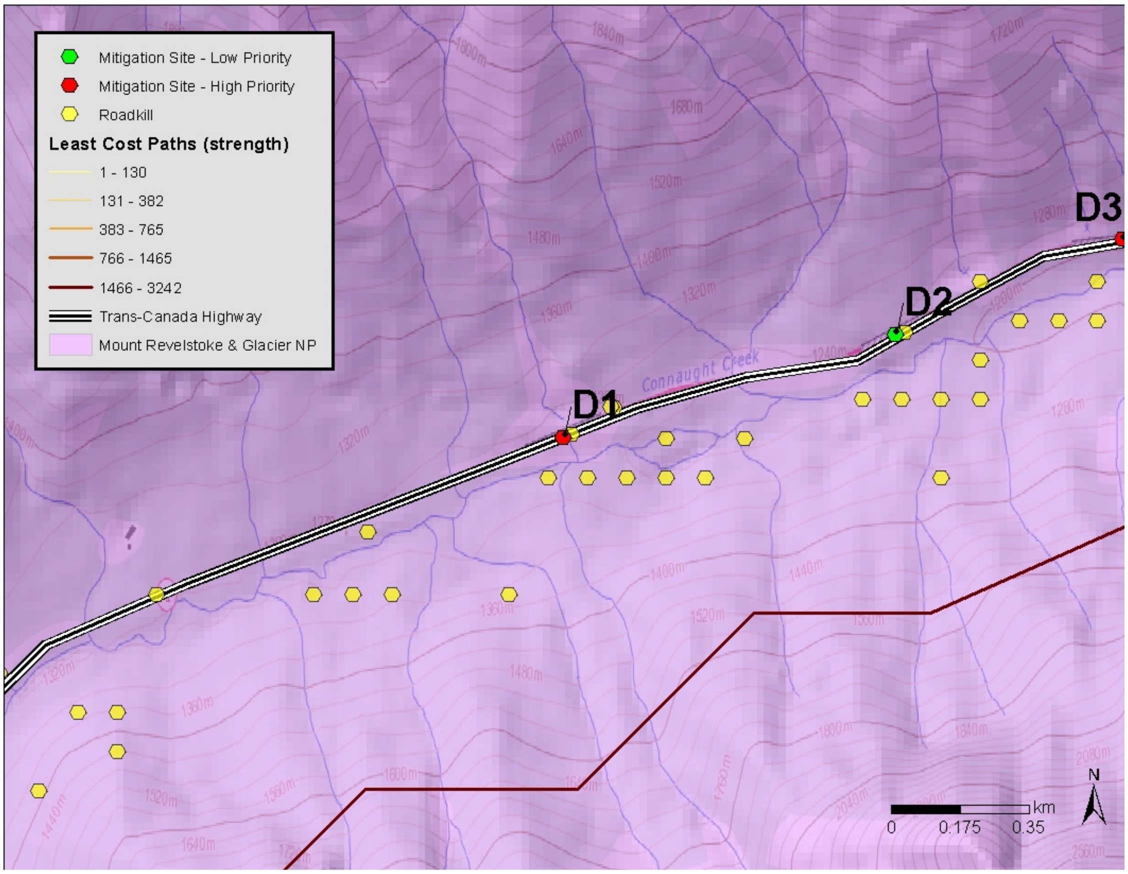

Figure D1: Map showing Highway Mitigation Emphasis Site D1 in Mount Revelstoke and Glacier National Parks, British Columbia.

Zone D, Site 2 Summary – Glacier Snow Sheds (Lens)	
Description	
Location: UTM: 466484, 5685665	
Species: Multi-species: Mountain goats, grizzly bears, wolverines, lynx, black bears.	
Mortality risk: 4	
Local conservation value: 1	
Regional conservation significance: 1	
Transportation mitigation opportunities: 5	
Wildlife objectives	
• Reduce current levels of wildlife–vehicle collisions in this section of highway, primarily mountain goats. • Provide safe movement for all wildlife species across highway, primarily grizzly bears, wolverines, lynx, black bears and mountain goats.	
Existing infrastructure	
• Snow shed.	
Target species for mitigation planning	
WVC reduction: Mountain goats primarily, but also bears. Mitigation consists of techniques to keep wildlife off the highway and effectively warn motorists of wildlife on the highway or in the show shed tunnel. **Regional conservation and connectivity**: Primarily grizzly bears, wolverines, lynx, black bears and mountain goats. Mitigation should focus on using the snow shed roof as wildlife overpass by providing access to and from roof by a "block step walkway" (see Chapter 6).	
Transportation mitigation opportunities	
Score: 5	
Mitigation strategy consists of keeping mountain goats off the highway and reducing mortality from collisions with vehicles within the snow shed tunnel and outside tunnel entrances. In the short term mitigation to reduce collisions should consist of the following measures: • *Salt diversion*. As part of pilot project prior to implementing salt diversion at snow sheds, evaluate this method of diverting goats from highway salt to areas where salt are manually dispersed in areas adjacent to escape terrain and habitats they occupy. The method has been used successfully in the Okanagan to divert goats from areas of road salt (Andrew Walker, BC Ministry of Forests, Lands, Natural Resource Operations, Penticton, BC, personal communication). • *Animal-detection system*. A radar-based animal detection system placed at tunnel entrances to warn motorists when goats and other wildlife are on the highway near tunnel entrances. The same radar-based animal detection systems placed inside tunnel will detect wildlife inside tunnel and warn motorists approaching tunnel. • *Create barrier*. Block off exterior wall of snow shed where there are existing gaps in wall that allow wildlife, primarily goats, to access tunnel interior. Make the outside wall as impermeable as possible. • *Block step walkway*. Build 1-2 structures along length of tunnel, consisting of interlocking precast concrete 'lego' blocks, that allow for wildlife (goats and bears primarily) to ascend and descend from show shed roofs. Fencing notes: High snow levels and frequent avalanche activity is a concern at this location, therefore fencing is not recommended for any mitigation.	

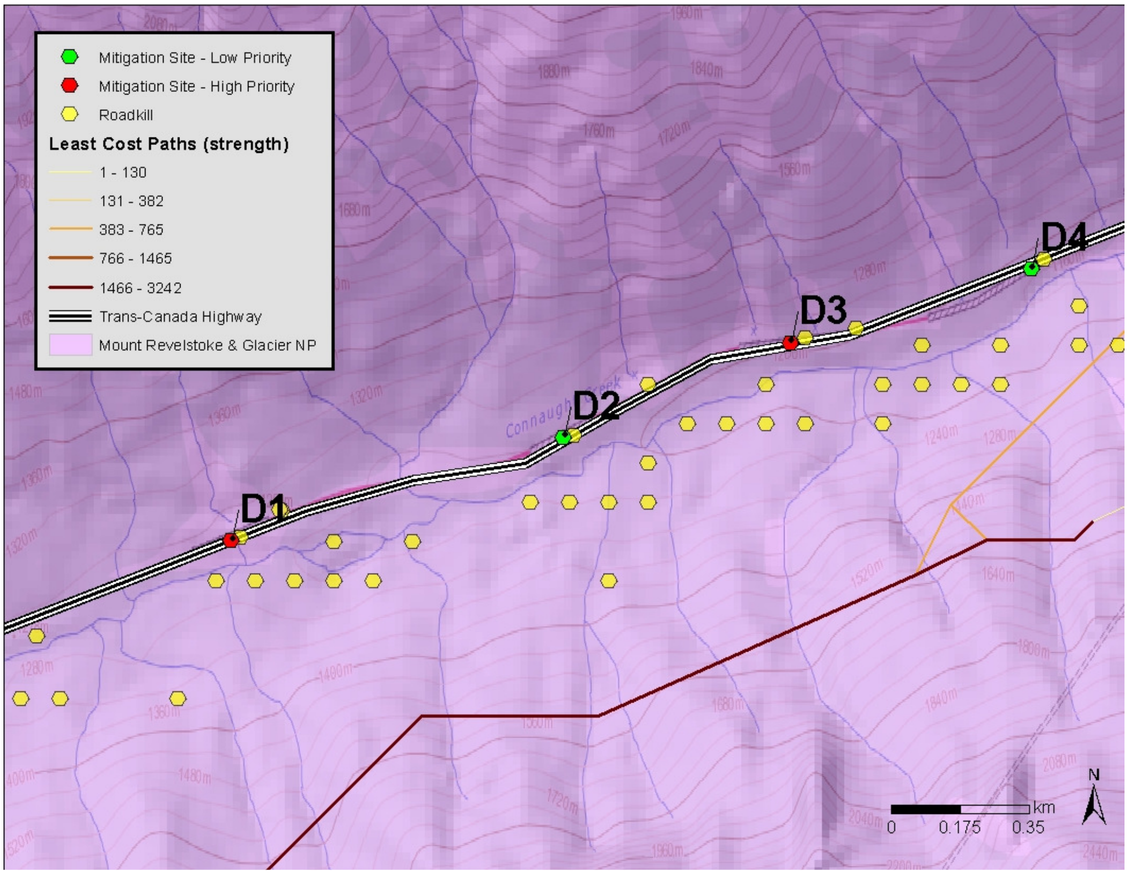

Figure D2: Map showing Highway Mitigation Emphasis Site D2 in Mount Revelstoke and Glacier National Parks, British Columbia.

Zone D, Site 3 Summary – Glacier Snow Sheds	
Description	
Location: UTM: 467063, 5685907	
Species: Multi-species: Mountain goats, grizzly bears, wolverines, lynx, black bears.	
Mortality risk: 4	
Local conservation value: 1	
Regional conservation significance: 2	
Transportation mitigation opportunities: 5	
Wildlife objectives	
• Reduce current levels of wildlife–vehicle collisions in this section of highway, primarily mountain goats. • Provide safe movement for all wildlife species across highway, primarily grizzly bears, wolverines, lynx, black bears and mountain goats.	
Existing infrastructure	
• Snow shed.	
Target species for mitigation planning	
WVC reduction: Mountain goats primarily, but also bears. Mitigation consists of techniques to keep wildlife off the highway and effectively warn motorists of wildlife on the highway or in the show shed tunnel. **Regional conservation and connectivity**: Primarily grizzly bears, wolverines, lynx, black bears and mountain goats. Mitigation should focus on using the snow shed roof as wildlife overpass by providing access to and from roof by a "block step walkway" (see Chapter 6).	
Transportation mitigation opportunities	
Score: 5	
Mitigation strategy consists of keeping mountain goats off the highway and reducing mortality from collisions with vehicles within the snow shed tunnel and outside tunnel entrances. In the short term mitigation to reduce collisions should consist of the following measures: • *Salt diversion*. As part of pilot project prior to implementing salt diversion at snow sheds, evaluate this method of diverting goats from highway salt to areas where salt are manually dispersed in areas adjacent to escape terrain and habitats they occupy. The method has been used successfully in the Okanagan to divert goats from areas of road salt (Andrew Walker, BC Ministry of Forests, Lands, Natural Resource Operations, Penticton, BC, personal communication). • *Animal-detection system*. A radar-based animal detection system placed at tunnel entrances to warn motorists when goats and other wildlife are on the highway near tunnel entrances. The same radar-based animal detection systems placed inside tunnel will detect wildlife inside tunnel and warn motorists approaching tunnel. • *Create barrier*. Block off exterior wall of snow shed where there are existing gaps in wall that allow wildlife, primarily goats, to access tunnel interior. Make the outside wall as impermeable as possible. • *Block step walkway*. Build 1-2 structures along length of tunnel, consisting of interlocking precast concrete 'lego' blocks, that allow for wildlife (goats and bears primarily) to ascend and descend from show shed roofs. Fencing notes: High snow levels and frequent avalanche activity is a concern at this location, therefore fencing is not recommended for any mitigation.	

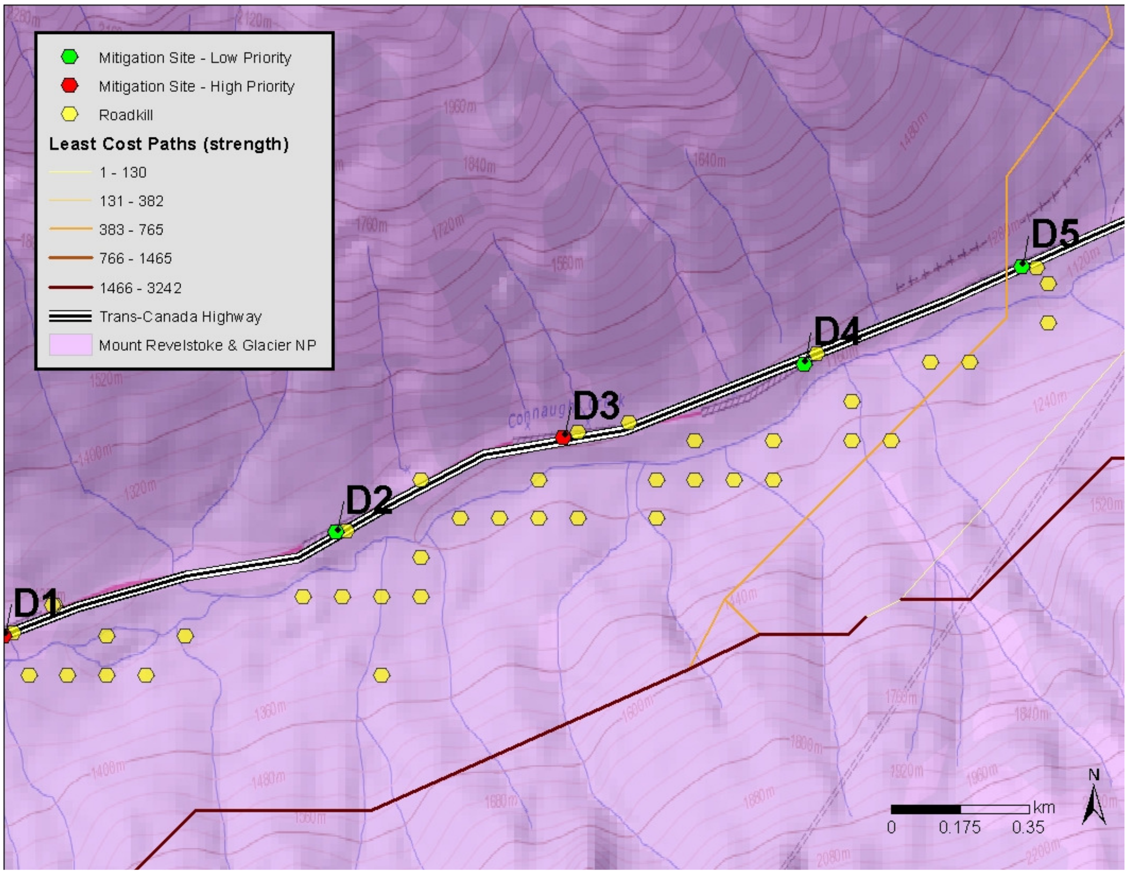

Figure D3: Map showing Highway Mitigation Emphasis Site D3 in Mount Revelstoke and Glacier National Parks, British Columbia.

127

Zone D, Site 4 Summary – Glacier Snow Sheds (Tupper 2)	
Description	
Location: UTM: 467677, 5686095	
Species: Multi-species: Mountain goats, grizzly bears, wolverines, lynx, black bears.	
Mortality risk: 4	
Local conservation value: 1	
Regional conservation significance: 1	
Transportation mitigation opportunities: 5	
Wildlife objectives	
• Reduce current levels of wildlife–vehicle collisions in this section of highway, primarily mountain goats. • Provide safe movement for all wildlife species across highway, primarily grizzly bears, wolverines, lynx, black bears and mountain goats.	
Existing infrastructure	
• Snow shed.	
Target species for mitigation planning	
WVC reduction: Mountain goats primarily, but also bears. Mitigation consists of techniques to keep wildlife off the highway and effectively warn motorists of wildlife on the highway or in the show shed tunnel. **Regional conservation and connectivity**: Primarily grizzly bears, wolverines, lynx, black bears and mountain goats. Mitigation should focus on using the snow shed roof as wildlife overpass by providing access to and from roof by a "block step walkway" (see Chapter 6).	
Transportation mitigation opportunities	
Score: 5	
Mitigation strategy consists of keeping mountain goats off the highway and reducing mortality from collisions with vehicles within the snow shed tunnel and outside tunnel entrances. In the short term mitigation to reduce collisions should consist of the following measures: • *Salt diversion*. As part of pilot project prior to implementing salt diversion at snow sheds, evaluate this method of diverting goats from highway salt to areas where salt are manually dispersed in areas adjacent to escape terrain and habitats they occupy. The method has been used successfully in the Okanagan to divert goats from areas of road salt (Andrew Walker, BC Ministry of Forests, Lands, Natural Resource Operations, Penticton, BC, personal communication). • *Animal-detection system*. A radar-based animal detection system placed at tunnel entrances to warn motorists when goats and other wildlife are on the highway near tunnel entrances. The same radar-based animal detection systems placed inside tunnel will detect wildlife inside tunnel and warn motorists approaching tunnel. • *Create barrier*. Block off exterior wall of snow shed where there are existing gaps in wall that allow wildlife, primarily goats, to access tunnel interior. Make the outside wall as impermeable as possible. • *Block step walkway*. Build 1-2 structures along length of tunnel, consisting of interlocking precast concrete 'lego' blocks, that allow for wildlife (goats and bears primarily) to ascend and descend from show shed roofs. Fencing notes: High snow levels and frequent avalanche activity is a concern at this location, therefore fencing is not recommended for any mitigation.	

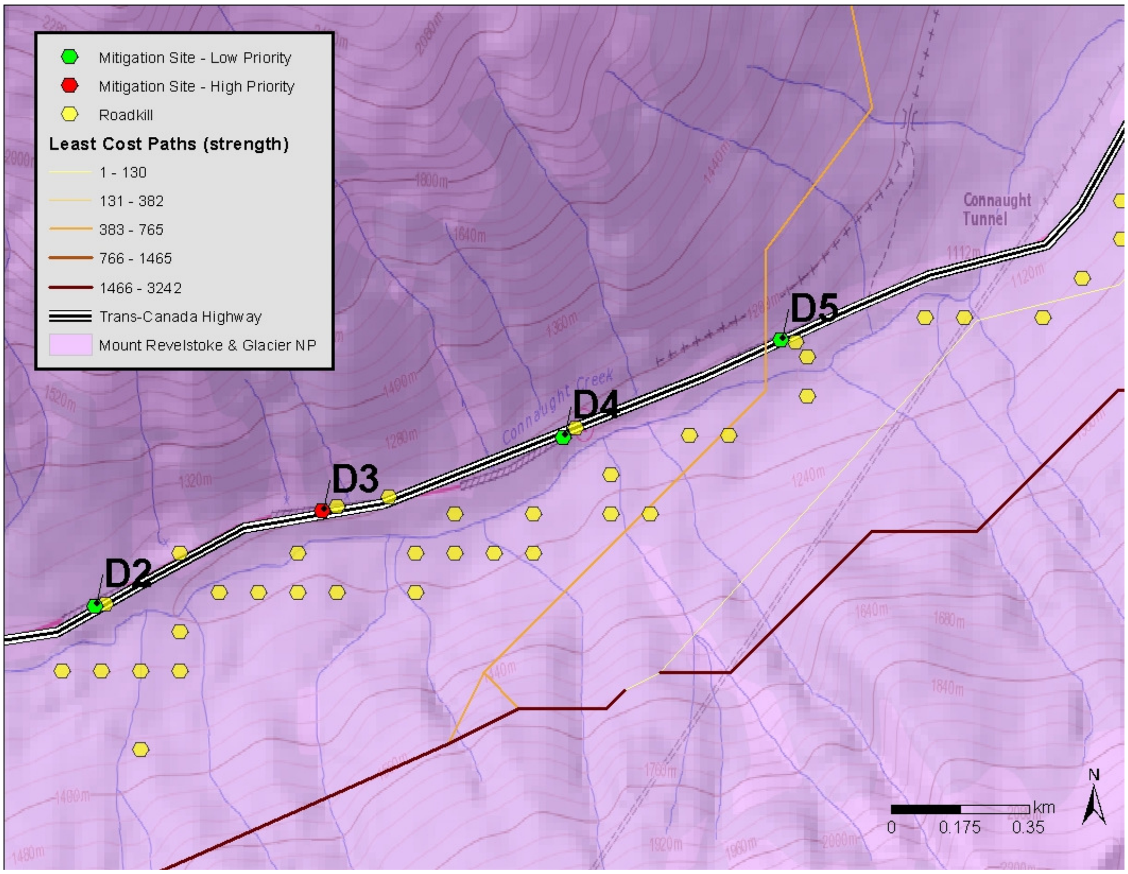

Figure D4: Map showing Highway Mitigation Emphasis Site D4 in Mount Revelstoke and Glacier National Parks, British Columbia.

Zone D, Site 5 Summary – Glacier Snow Sheds (Tupper Timber)	
Description	
Location: UTM: 468232, 5686343	
Species: Multi-species: Mountain goats, grizzly bears, wolverines, lynx, black bears.	
Mortality risk: 4	
Local conservation value: 1	
Regional conservation significance: 2	
Transportation mitigation opportunities: 5	
Wildlife objectives	
• Reduce current levels of wildlife–vehicle collisions in this section of highway, primarily mountain goats. • Provide safe movement for all wildlife species across highway, primarily grizzly bears, wolverines, lynx, black bears and mountain goats.	
Existing infrastructure	
• Snow shed.	
Target species for mitigation planning	
WVC reduction: Mountain goats primarily, but also bears. Mitigation consists of techniques to keep wildlife off the highway and effectively warn motorists of wildlife on the highway or in the show shed tunnel. **Regional conservation and connectivity**: Primarily grizzly bears, wolverines, lynx, black bears and mountain goats. Mitigation should focus on using the snow shed roof as wildlife overpass by providing access to and from roof by a "block step walkway" (see Chapter 6).	
Transportation mitigation opportunities	
Score: 5	
Mitigation strategy consists of keeping mountain goats off the highway and reducing mortality from collisions with vehicles within the snow shed tunnel and outside tunnel entrances. In the short term mitigation to reduce collisions should consist of the following measures: • *Salt diversion*. As part of pilot project prior to implementing salt diversion at snow sheds, evaluate this method of diverting goats from highway salt to areas where salt are manually dispersed in areas adjacent to escape terrain and habitats they occupy. The method has been used successfully in the Okanagan to divert goats from areas of road salt (Andrew Walker, BC Ministry of Forests, Lands, Natural Resource Operations, Penticton, BC, personal communication). • *Animal-detection system*. A radar-based animal detection system placed at tunnel entrances to warn motorists when goats and other wildlife are on the highway near tunnel entrances. The same radar-based animal detection systems placed inside tunnel will detect wildlife inside tunnel and warn motorists approaching tunnel. • *Create barrier*. Block off exterior wall of snow shed where there are existing gaps in wall that allow wildlife, primarily goats, to access tunnel interior. Make the outside wall as impermeable as possible. • *Block step walkway*. Build 1-2 structures along length of tunnel, consisting of interlocking precast concrete 'lego' blocks, that allow for wildlife (goats and bears primarily) to ascend and descend from show shed roofs. Fencing notes: High snow levels and frequent avalanche activity is a concern at this location, therefore fencing is not recommended for any mitigation.	

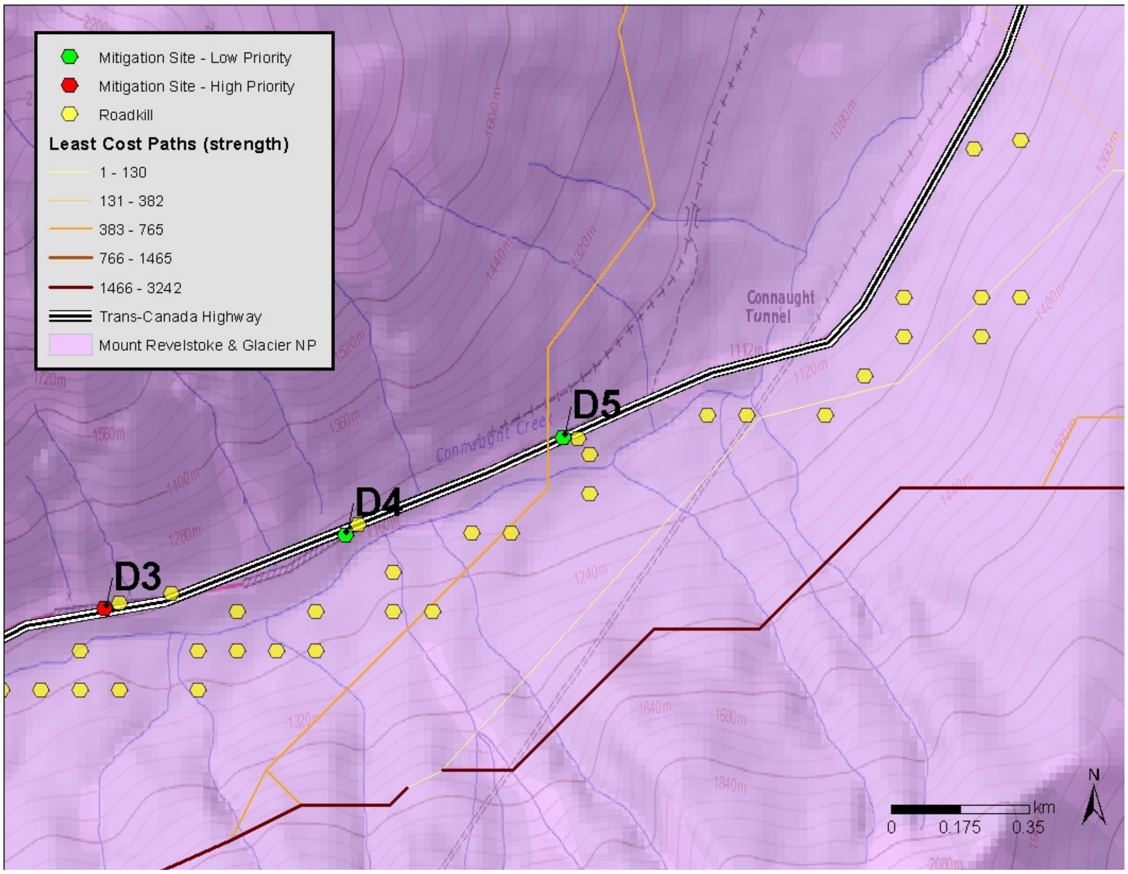

Figure D5: Map showing Highway Mitigation Emphasis Site D5 in Mount Revelstoke and Glacier National Parks, British Columbia.

Zone D, Site 6 Summary – Glacier Snow Sheds	
Description	
Location: UTM: 469638, 5688064	
Species: Multi-species: Bears, wolverines, lynx	
Mortality risk: 3	
Local conservation value: 2	
Regional conservation significance: 5	
Transportation mitigation opportunities: 4	
Wildlife objectives	
• Reduce current high levels of wildlife–vehicle collisions in this section of highway, primarily bear and deer. • Provide safe movement for all wildlife species across highway, primarily bear and deer.	
Existing infrastructure	
• None	
Target species for mitigation planning	
WVC reduction: Common species. **Regional conservation and connectivity**: Key fragmentation-sensitive species: Grizzly bears, wolverines and lynx.	
Transportation mitigation opportunities	
Score: 4	
If the highway is reconstructed, fencing and construction of w*ildlife underpass* is recommended. Selection of design type is dependent on terrain and engineering constraints, preferably open-span configuration. Minimum dimension for underpass is 11 m wide x 3 m high due to grizzly bear and other wide-ranging carnivore movement through this area. Wing *fencing* (200–500 m depending on terrain) should be installed to funnel movements to the crossing structure. Good locations to end fence at rock cuts and steep terrain. Fencing notes: Snow maybe a concern at this location.	

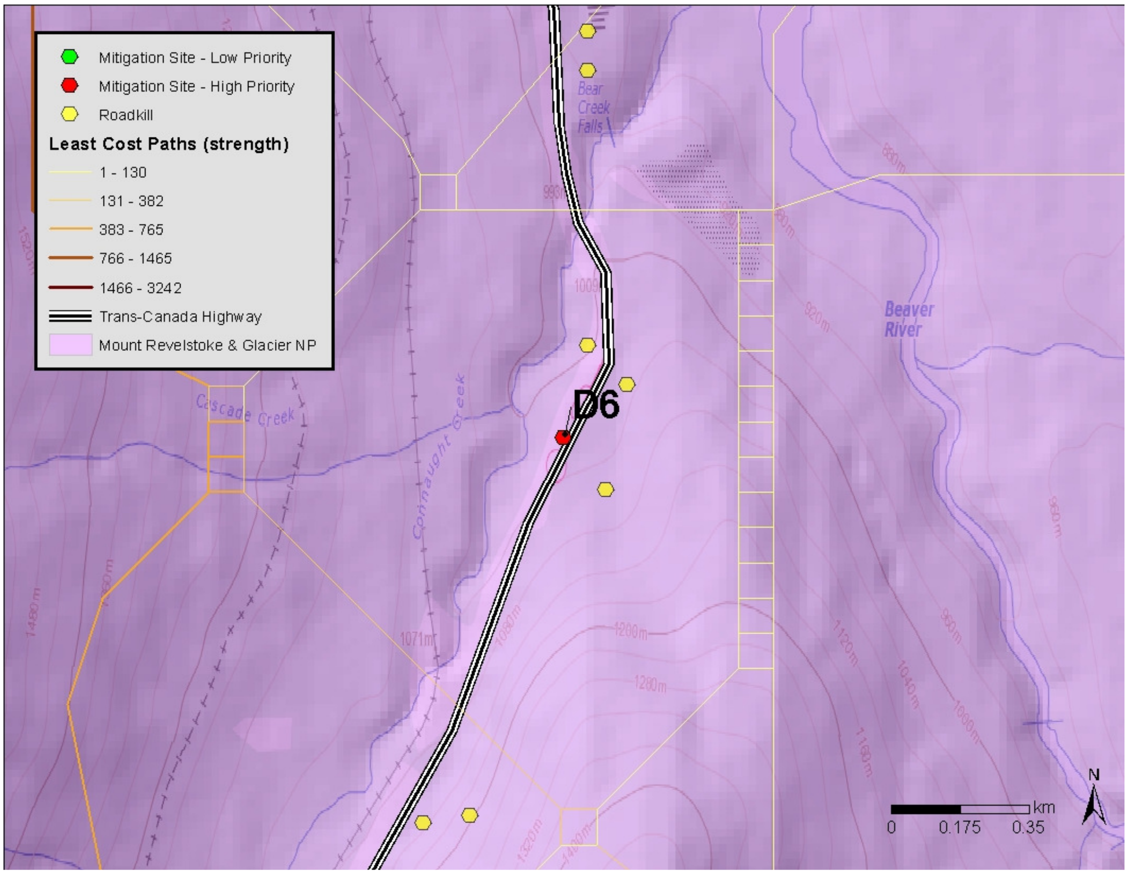

Figure D6: Map showing Highway Mitigation Emphasis Site D6 in Mount Revelstoke and Glacier National Parks, British Columbia.

ZONE E MAP

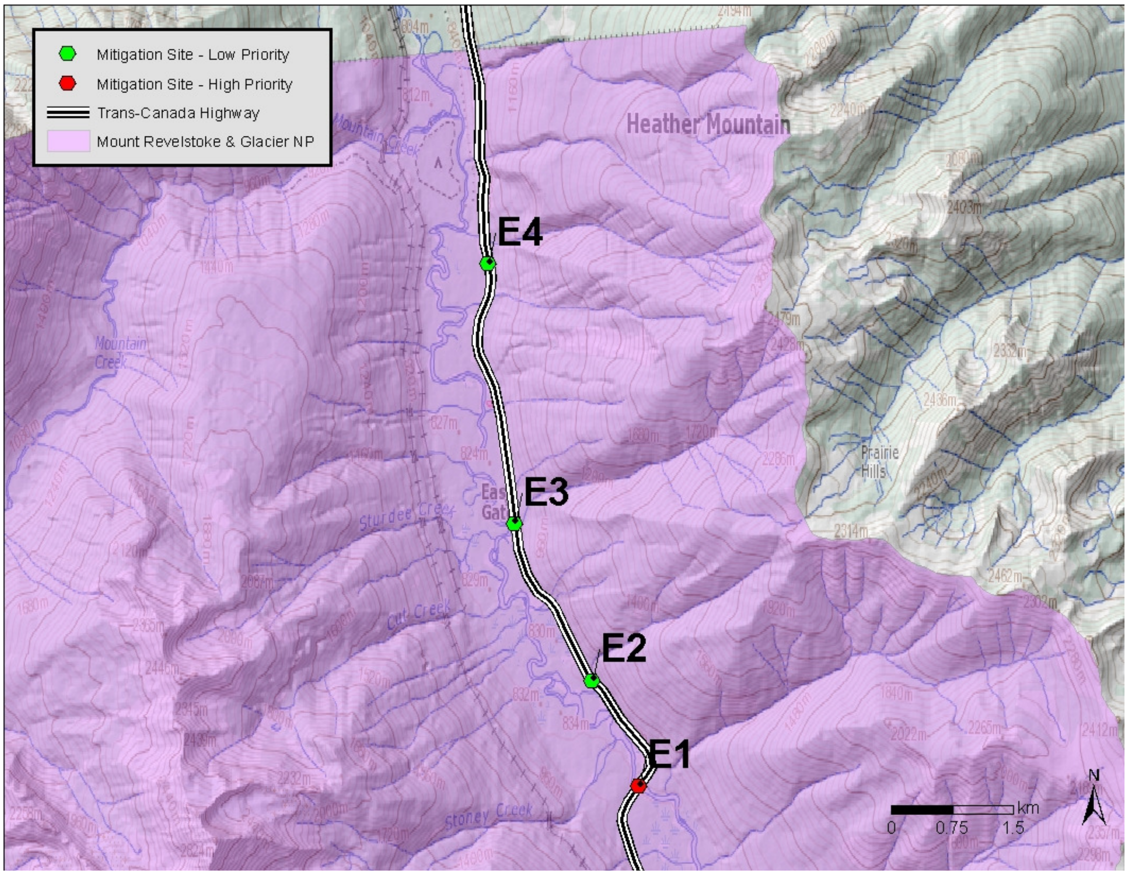

Figure E: Map showing Highway Mitigation Emphasis Zone E in Mount Revelstoke and Glacier National Parks, British Columbia.

Zone E, Site 1 Summary – Beaver River	
Description	
Location: UTM: 468696, 5692578	
Species: Multi-species: Deer, elk, moose, bear sp.	
Mortality risk: 4	
Local conservation value: 3	
Regional conservation significance: 4	
Transportation mitigation opportunities: 4	
Wildlife objectives	
• Reduce current high levels of wildlife–vehicle collisions in this section of highway, primarily deer, elk and moose. • Provide safe movement for all wildlife species across highway, primarily deer, elk, moose and bears.	
Existing infrastructure	
• Beaver River bridge	
Target species for mitigation planning	
WVC reduction: Common species. **Regional conservation and connectivity**: Common species primarily.	
Transportation mitigation opportunities	
Score: 4	
Currently the Beaver River Bridge has sufficient space on the West (North) side to allow for wildlife passage. If the highway is reconstructed, a new bridge will be added and to the existing bridge. All bridge construction or reconstruction must be designed with wildlife movement (and hydrologic flow) in mind. The new bridge should be designed with a wider span, allowing dry travel sections ($\geq$5 m wide) above high-water mark. Wing *fencing* (200–500 m depending on terrain) should be installed to funnel movements to the bridge structure. Fencing notes: Snow not likely a concern at this location due to lower elevation compared to other parts of Glacier National Park.	

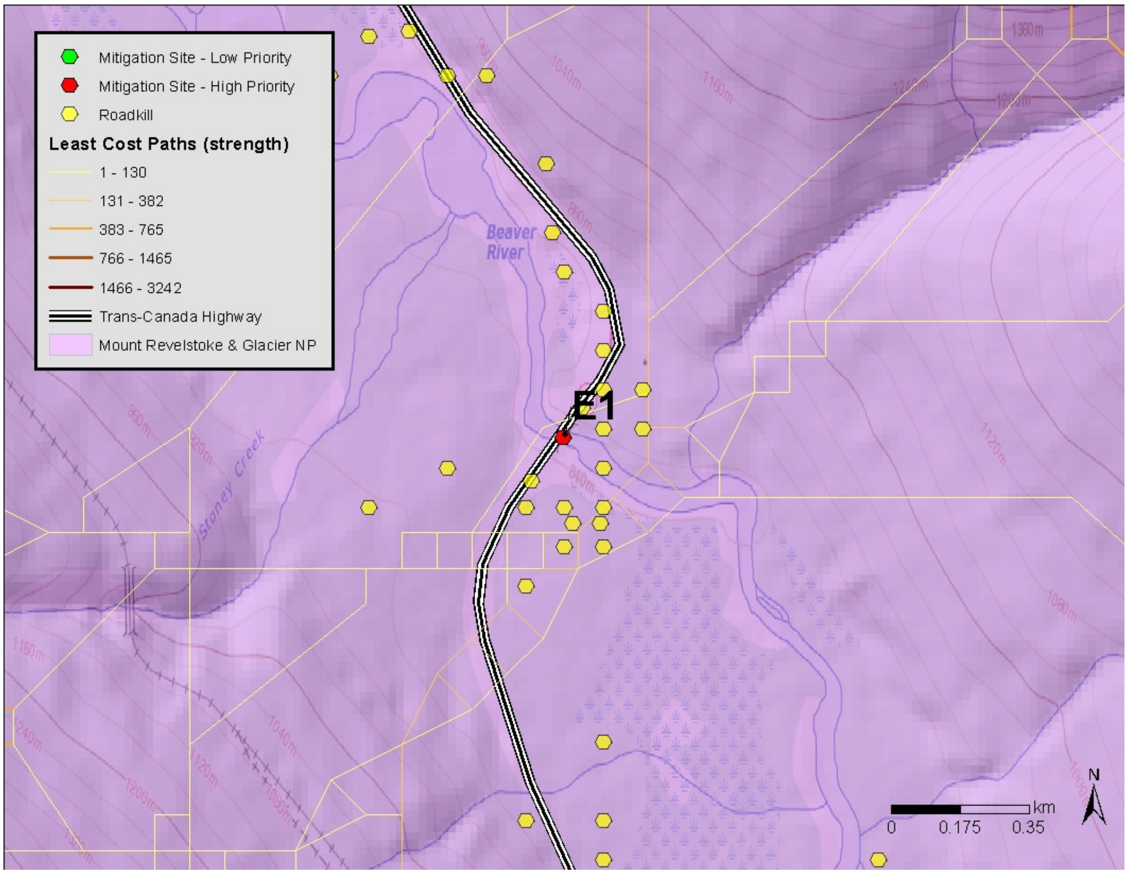

Figure E1: Map showing Highway Mitigation Emphasis Site E1 in Mount Revelstoke and Glacier National Parks, British Columbia.

Zone E, Site 2 Summary – Beaver River	
Description	
Location: UTM: 468120, 5693882	
Species: Multi-species: Deer, elk, moose.	
Mortality risk: 4	
Local conservation value: 3	
Regional conservation significance: 1	
Transportation mitigation opportunities: 4	
Wildlife objectives	
• Reduce current levels of wildlife–vehicle collisions in this section of highway, primarily deer, elk and moose. • Provide safe movement for all wildlife species across highway, primarily deer, elk and moose.	
Existing infrastructure	
• Culvert	
Target species for mitigation planning	
WVC reduction: Common species. Good ungulate habitat (large meadow and Beaver River wetlands) adjacent to site. **Regional conservation and connectivity**: Common species primarily.	
Transportation mitigation opportunities	
Score: 4	
To ensure movement of wildlife through the area and reduce wildlife-vehicle collisions, fencing and construction of wildlife *underpass* is recommended. Selection of design type is dependent on terrain and engineering constraints. Minimum dimension for underpass is 4 m high x 7 m wide. Culvert could be replaced and bottomless culvert of recommended dimensions installed at location. Wing *fencing* (200–500 m depending on terrain) should be installed to funnel movements to the crossing structure. Fencing notes: Snow not likely a concern at this location due to lower elevation compared to other parts of Glacier National Park.	

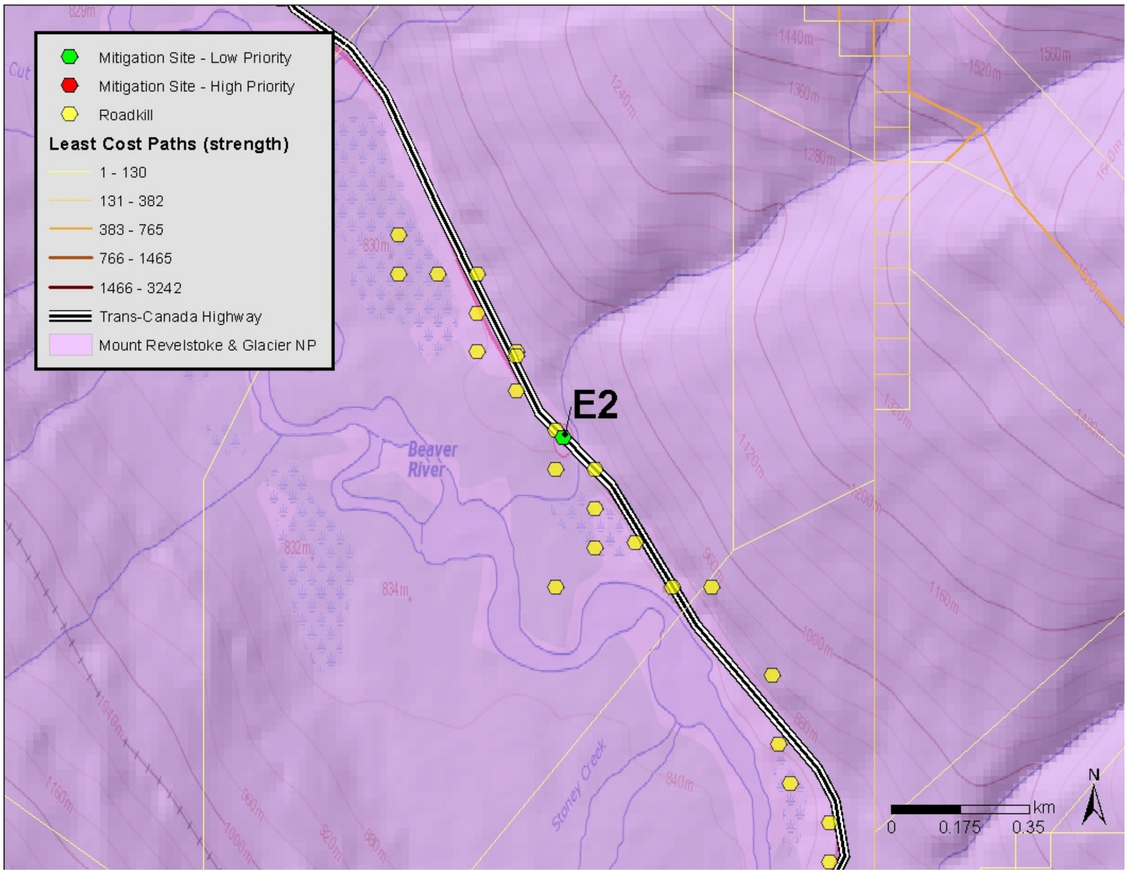

Figure E2: Map showing Highway Mitigation Emphasis Site E2 in Mount Revelstoke and Glacier National Parks, British Columbia.

Zone E, Site 3 Summary – Beaver River	
Description	
Location: UTM: 467162, 5695810	
Species: Multi-species: Deer, elk, moose, bears	
Mortality risk: 3	
Local conservation value: 3	
Regional conservation significance: 2	
Transportation mitigation opportunities: 5	
Wildlife objectives	
• Reduce current high levels of wildlife–vehicle collisions in this section of highway, primarily deer, elk and moose. • Provide safe movement for all wildlife species across highway, primarily deer, elk, moose and bears.	
Existing infrastructure	
• None	
Target species for mitigation planning	
WVC reduction: Common species. **Regional conservation and connectivity**: Common species primarily. Grizzly bears frequent this area due to the Field Unit's carcass disposal site being located nearby, thus a need to consider grizzly bear in mitigation plans.	
Transportation mitigation opportunities	
Score: 5	
If the highway is reconstructed, fencing and construction of w*ildlife underpass* is recommended. Selection of design type is dependent on terrain and engineering constraints, preferably open-span configuration. Minimum dimension for underpass is 11 m wide x 3 m high due to grizzly bear movement through this area. Wing *fencing* (200–500 m depending on terrain) should be installed to funnel movements to the crossing structure. Good locations to end fence at rock cuts. Fencing notes: Snow not likely a concern at this location due to lower elevation compared to other parts of Glacier National Park.	

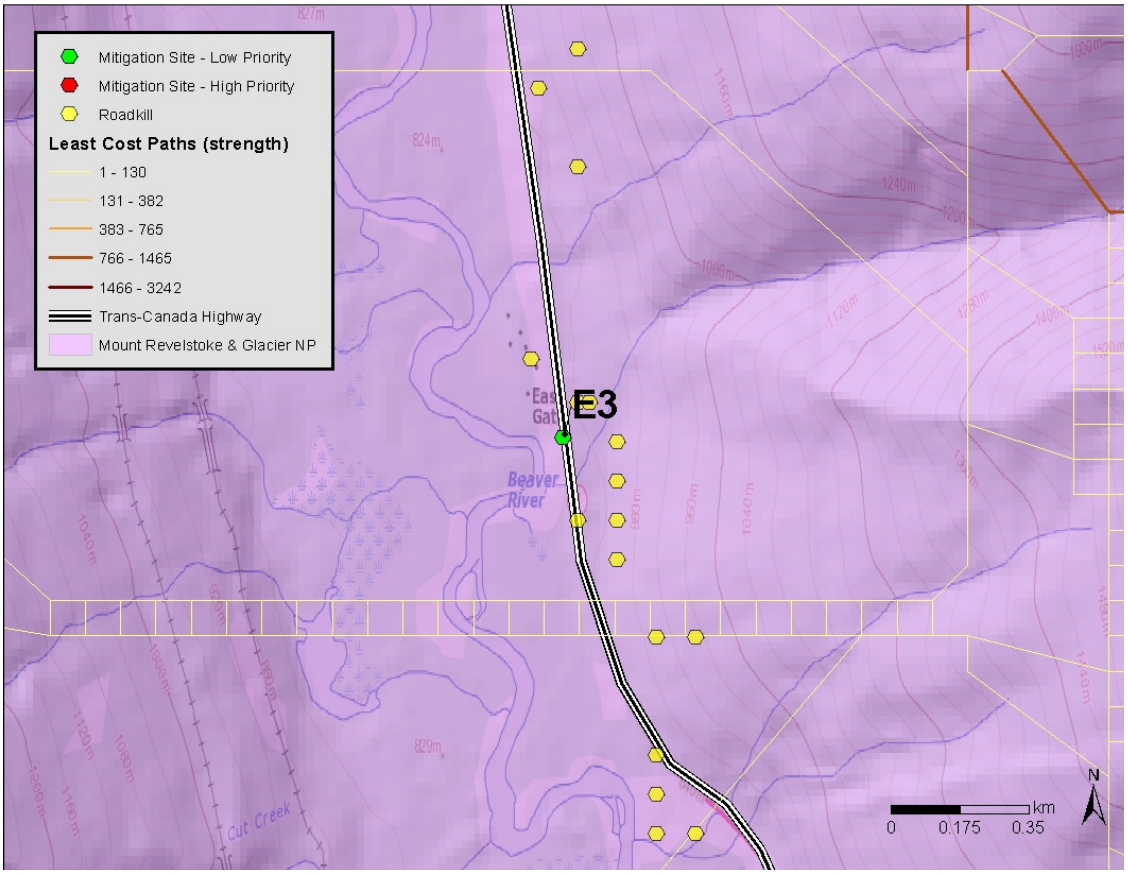

Figure E3: Map showing Highway Mitigation Emphasis Site E3 in Mount Revelstoke and Glacier National Parks, British Columbia.

Zone E, Site 4 Summary – Beaver River	
Description	
Location: UTM: 466843, 5699007	
Species: Multi-species: Deer, elk, moose, bears.	
Mortality risk: 2	
Local conservation value: 2	
Regional conservation significance: 2	
Transportation mitigation opportunities: 5	
Wildlife objectives	
• Reduce current levels of wildlife–vehicle collisions in this section of highway, primarily deer, elk and moose. • Provide safe movement for all wildlife species across highway, primarily deer, elk, moose and bears.	
Existing infrastructure	
• None	
Target species for mitigation planning	
WVC reduction: Common species. **Regional conservation and connectivity**: Common species primarily.	
Transportation mitigation opportunities	
Score: 5	
To ensure movement of wildlife through the area and reduce wildlife-vehicle collisions, fencing and construction of wildlife *underpass* is recommended. Selection of design type is dependent on terrain and engineering constraints. Minimum dimension for underpass is 4 m high x 7 m wide. Wing *fencing* (200–500 m depending on terrain) should be installed to funnel movements to the crossing structure. Fencing notes: Snow not likely a concern at this location due to lower elevation compared to other parts of Glacier National Park.	

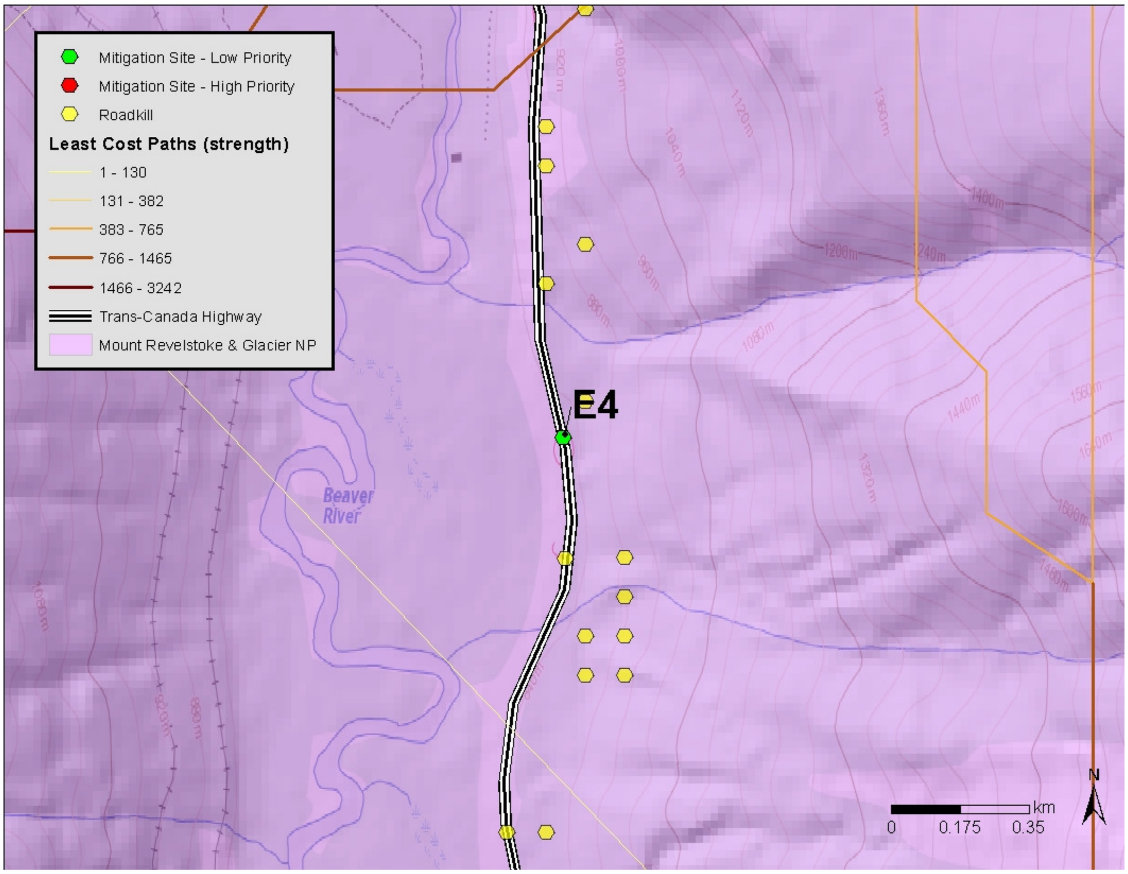

Figure E4: Map showing Highway Mitigation Emphasis Site E4 in Mount Revelstoke and Glacier National Parks, British Columbia.

Appendix B: Mitigation Measure Information Sheets (A–F)

Mitigation measure information sheets are based on the *Handbook for Design and Evaluation of Wildlife Crossing Structures in North America* (Clevenger and Huijser 2011).

Sheet A: Animal Detection Systems
Sheet B: Fencing
Sheet C: Gates and Ramps
Sheet D: Wildlife Underpasses
Sheet E: Wildlife Underpasses with Water Flow
Sheet F: Wildlife Overpasses

Animal Detection Systems SHEET A

General purpose

Animal detection systems use sensors to detect large animals that approach the road. Once a large animal is detected, warning signals are activated to inform the drivers that a large animal may be on or near the road at that time. The warning signals are time specific—that is, they warn of specific detection events rather than warn of the possibility that animals may be in the area. These systems have been installed in more than 50 locations in North America and Europe.

Animal detection system along Highway 191 in Yellowstone National Park, Montana (Photo: Marcel Huijser, WTI).

System types

There are two broad categories commonly used in animal detection systems: area-cover systems and break-the-beam systems.

Break-the-beam sensors detect large animals when their body blocks or reduces a beam of infrared, laser or microwave radio signals sent by a transmitter to a receiver.

Area-cover systems detect large animals within a certain range of a sensor. Area coverage systems can be passive or active. Passive systems detect animals by only receiving signals. The two most common systems are passive infrared and video detection. These systems require algorithms that distinguish between, e.g., moving vehicles with warm engines and moving pockets of hot air, and movements of large animals. Active systems send a signal over an area and measure its reflection. The primary active area coverage system uses microwave radar.

Area-cover systems are radar-based and contain four key components, solar panel array, the radar, a control enclosure and flashing signage.

The radar is the sensing component that detects and tracks the animals until it leaves the predetermined tracking area. It is pole mounted at various heights and spaced at approximately 350 meters between adjacent radars. The radar will operate in any environment and is not affected by snow, ice, rain, etc.

The radar has a relay output that actuates when an animal is present in the defined tracking area. The relay closure condition is sent wirelessly to the flashing beacons, which house a controller for adjusting the flash conditions.

The radar also has an internal log that can be retrieved via Ethernet on site at the control enclosure of the radar. All of the time-stamped data from system operation can be downloaded via Ethernet or wirelessly. When coupled with video cameras it is possible to analyse system performance, i.e., proportion of false negative and false positives compared to true operation.

The radar is controlled by a small-embedded computer located in the control enclosure. The battery bank is charged by the solar panel array and charge controller and has been designed to provide approximately 3 days of operation without sunlight before the batteries will be depleted beyond 50% of their charge. In areas without sufficient sunlight the system can be tied into existing power typically running alongside the highway, as is the case in MRG.

Effectiveness

The effectiveness of animal detection systems has been investigated with regard to a potential reduction in vehicle speed and a potential reduction in animal–vehicle collisions. Previous studies with earlier models have shown variable results: substantial decreases in vehicle speed, minor decreases in vehicle speed, and no decrease or even an increase in vehicle speed. This variability in the results appeared to be related to various conditions, namely, type of warning signal and signs, whether the warning signs are accompanied with advisory or mandatory speed limit reductions, road and weather conditions, whether the driver is a local resident, and perhaps also cultural differences that may cause drivers to respond differently to warning signals in different regions.

Some work in Switzerland has been done reporting on the number of animal–vehicle collisions before and after seven infrared area cover detection systems were installed. These systems reduced the number of animal–vehicle collisions by 82 percent on average. Similar results in collision reductions were found for radar-based systems installed by the Ministry of Transportation in Ontario to reduce moose-vehicle collisions. The radar-based system is proving more reliable and effective at reducing wildlife-vehicle collisions. This system is recommended for use on the TCH in MRG to reduce collision rates: 1) with mountain goats at locations where goats lick salt on the highway (snow sheds and areas not associated with snow sheds) and 2) at fence ends.

While the data on the effectiveness of animal detection systems are encouraging, animal detection systems should still be regarded as an experimental mitigation measure rather than a measure that will reduce wildlife–vehicle collisions in the short term with a high degree of certainty (Huijser et al. 2006c).

*Information on testing radar-based animal-detection systems in Canada were published in a New York Times article in 2013 (November 1, 2013; “Canada Tests Animal Detectors”).

Case studies and contacts

For a general overview of technology, reliability and effectiveness, contact Marcel Huijser, Western Transportation Institute, PO Box 174250, Bozeman, Montana 59717-4250, (406)543-2377, mhuijser@coe.montana.edu.
For information about a field study on the effectiveness of animal detection systems, contact Christa Mosler-Berger, Wildtier Schweiz, Strickhofstrasse 39, 8057 Zürich, Switzerland, wild@wild.unizh.ch.
For more information about the animal detection system and wildlife fencing along State Route 260 in Arizona, contact Norris Dodd, Wildlife Connectivity Program Coordinator, Arizona Department of Transportation, 1611 W. Jackson Street MD EM04, Phoenix, Arizona 85007, (480) 271-4334, NDodd@azdot.gov.
Manufacturer: Blake Dickson, VP Sales and Marketing, Rotalec, 177 Blossom Avenue East, Unit A, Brantford, Ontario N3T 5L9, (519) 753-5100 ext 427, Blake.Dickson@rotalec.com, http://www.rotalec.com/.

Direct benefits

The available data on the effectiveness of animal detection systems show a reduction in collisions with large animals of 82 percent, which is substantial. This percentage may change as systems improve over time and more data become available from testing systems in place.

Indirect benefits

Animal detection systems do not restrict animal movements when deployed over long distances.

Undesirable effects

Animal detection systems can reduce collisions with large animals, but the presence of poles and equipment in the right-of-way can be a potential hazard to vehicles that run off the road.

Costs

Estimated costs of these systems range from $ 100,000 - $300,000 per km excluding installation costs (unpublished data, Marcel Huijser, Western Transportation Institute – Montana State

University). The costs for the equipment will be higher if the road section concerned has curves or slopes, or if the line of sight in the right-of-way is blocked by objects.

Fencing SHEET B

General purpose

Wildlife exclusion fencing keeps animals away from roadways. However, fencing alone can isolate wildlife populations, thus creating a barrier to movement, interchange and limiting access to important resources for individuals and affecting the long-term survival of the population. Fencing is one part of a two-part mitigation strategy—fencing *and* wildlife crossing structures.

Fences keep wildlife away from the roadway and lead animals to wildlife crossings, thus allowing them to travel safely under or above the highway. Fences need to be impermeable to wildlife movement in order to keep traffic-related mortality to a minimum and ensure that wildlife crossings will be used. Defective or permeable fences result in reduced use of the wildlife crossings and increased risk of wildlife–vehicle collisions. Little research and best management practices exist regarding effective fence designs and other innovative solutions to keep wildlife away from roads.

Wildlife exclusion fencing and culvert design wildlife underpass (Photo: Tony Clevenger).

Configurations

Fencing configuration used to mitigate road impacts will depend on several variables associated with the specific location, primarily adjacent land use and traffic volumes. Both sides of the road must be fenced (not only one side) and fence ends across the road need to be symmetric and not offset or staggered.

- *Continuous fencing* – Most often associated with large tracts of public land with little or no interspersed private property or in-holdings. Advantages: Long stretches of continuous fencing have fewer fence ends and generally few problems of managing wildlife movement ("end-runs") around multiple fence ends, as with discontinuous fencing (below). Disadvantages: Access roads with continuous fencing will need cattle guards, electro-mats, or gates to block animal access to roads (see Sheet C).
- *Partial (discontinuous) fencing* – More common with highway mitigation for wildlife in rural areas characterized by mixed land use (public and private land). Generally installed when private lands cannot be fenced. Partial fencing is recommended in locations like MRG where it is not feasible or there is a need to fence long sections of highway. Advantages: Generally accepted by public stakeholders. Few benefits to wildlife and usually the only alternative when there is mixed land use. Disadvantages: Results in multiple segments of fenced and unfenced sections of road, each fenced section having two fence ends. Additional measures need to be installed and carefully monitored to discourage end-runs at fence ends and hasten wildlife use of new crossing structures (see Terminations below). Earthen ramps or "jump-outs" are also needed in close proximity to fence ends in order to allow animals escape the fenced once inside (see Sheet C).

Interceptions

Fences invariably intersect other linear features that allow for movement of people or transport materials. This can include access roads, but also recreational trails (people) and water (creeks, streams). These breaks or interceptions in the fence require special modifications in order to limit the number of wildlife intrusions into the right-of-way.

Roads

Texas Gates – Transportation and land management agencies commonly install Texas Gates (also called cattleguards or cowcatchers) where fences intersect access roads. Many different designs have been used, but few have been tested for their effectiveness with wildlife. Designs of Texas Gates vary in dimension, grate material (flat or cylindrical steel grates), and grate adaptations for safe passage by pedestrians and cyclists. Recently a grate pattern was developed that was 95 percent effective in blocking Key deer movement and was safe for pedestrians and cyclists. Work by Allen et al. (2013) on fenced sections of US-93 in Montana showed that Texas gates were >85% effective in keeping deer from accessing the road and 93.5% of deer used the crossing structure instead of the adjacent wildlife guard when crossing the road. The gates were less effective in keeping black bear and coyotes from accessing the road (33–55%). However, all black bears and 94.7% of coyotes used the crossing structure instead of the adjacent wildlife guard when crossing the road.

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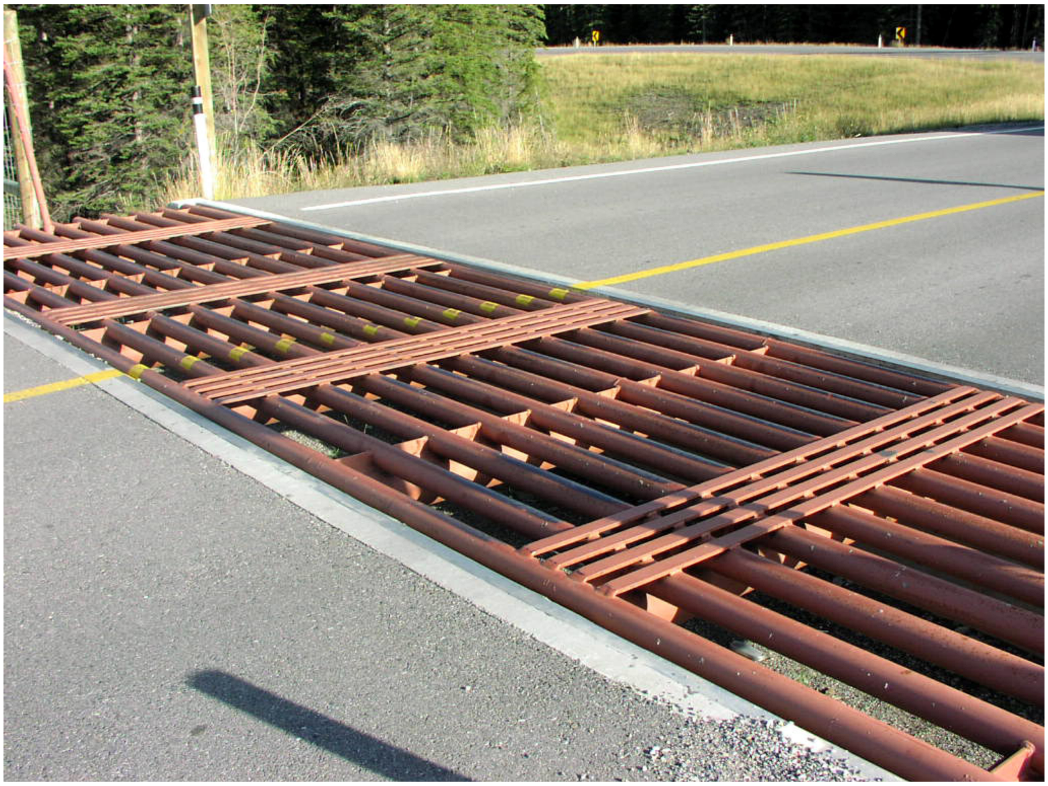

Cattle guard (Texas gate) in road (Photo: Tony Clevenger).

- *Electro-mats* – These electrified mats act like electric Texas Gates to discourage wildlife from crossing at the gap in the fence. Pedestrians wearing shoes and bicyclists can cross the mats safely, but dogs, horses and people without shoes will receive an electric shock. The electro-mats are generally 2-3 m wide, but can be designed to any width, and built into access roads where they breach fences. Cross-Tek® has been the lead company developing the e-mas and have had great success in high snowfall areas (Anchorage, Alaska) and dry areas (Arizona). They are currently designing and testing e-mats in Banff National Park.
- *Painted crosswalks* – Highway crosswalk structures have been used to negotiate ungulates across highways at grade level. White crosswalk lines are painted across the road to emulate a cattle guard. The painted crosswalk serves as a visual cue to guide ungulates directly across the highway. Painted crosswalks have not been tested, but if effective, they would be an inexpensive alternative to the more costly cattle guards. See Lehert and Bissonette 1997 for more details).

Trails

- *Swing gates (for fishermen, hikers)* – Where fences impede public access to popular recreation areas, swing gates can be used to negotiate fences. Gates must have a spring-activated hinge that ensures that even if the gate is left open it will spring back and close. In areas of high snowfall, gates may be elevated and steps built to keep the bottom of the gate above snow.

Step gate with spring-loaded door situated at trailhead in Banff National Park, Alberta (Photo: Tony Clevenger).

- *Canoe/kayak landings* – There are no known simple gate solutions for transporting canoes/kayaks through fences. The swing gate described above is one solution, although the gate should be slightly wider than normal to allow a wide berth suitable for moving canoes/kayaks. Gates must have a spring-activated hinge that ensures they remain closed after use.

Watercourses

- *Rubber hanging drapes* – Watercourses pose problems for keeping fences impermeable to wildlife movement, as their flow levels tend to fluctuate throughout the year. When water levels are low, gaps may appear under the fence material allowing wildlife to easily pass beneath. Having fencing material well within watercourses will cause flooding problems, as debris being transported will not pass through the fence and can eventually obstruct water flow. A solution to this problem would require having a device on the bottom of the fence that moves up and down with the water levels. This could be done by attaching hinged strips of rubber mat-like material, draping down from the bottom of the fence material into the water. The rubber strips are hinged, so they float on top of the water and move in the direction of flow.

Suggested design details

Mesh type, gauge and size

Fence material may consist of woven-wire (page-wire) or galvanized chain-link fencing. Fence material must be attached to the back (non-highway) side of the posts, so impacts will only take down the fence material and not the fence posts.

- *Woven- or page-wire fencing* – Woven-wire fences consist of smooth horizontal (line) wires held apart by vertical (stay) wires. Spacing between line wires may vary from 8 cm at the bottom for small animals to 15–18 cm at the top for large animals. Wire spacing generally increases with fence height. Mesh wire is made in 11, 12, 12 ½, 14, and 16 gauges and fences are available in different mesh and knot designs. The square-shaped mesh may facilitate climbing by some wildlife, such as bears. If climbing is a concern then use of a smaller mesh is recommended.
  Wildlife fences along the Trans-Canada Highway in Banff National Park consist of 12 ½ gauge line wires with tensile strength of 1390 N/sq. mm. Stay wires have a tensile strength of 850 N/sq. mm. All wires had Class III zinc galvanized coating (see below) at a minimum of 260 gms/sq. m.
- *Chain-link fencing* – Chain-link fence is made of heavy steel wire woven to form a diamond-shaped mesh. It can be used in various industrial, commercial and residential applications. Chain-link was used for highway mitigation fencing along I-75 and SR 29 in Florida. There have been agency and public concerns about the visual aesthetics of chain-link fencing compared to woven-wire as it is less attractive and does not blend into the landscape. Steel posts are always used with chain-link fencing. Chain-link fence fabrics can be galvanized mesh, plastic-coated galvanized mesh or aluminum mesh.
- Most wire sold today for fencing has a coating to protect the wire from rust and corrosion. Galvanizing is the most common protective coating. The degree of protection depends on thickness of galvanizing and is classified into three categories; Classes I, II, and III. Class I has the thinnest coating and the shortest life expectancy. Nine-gage wire with Class I coating will start showing general rusting in 8 to 10 years, while the same wire with Class III coating will show rust in 15 to 20 years.
- *Electrified fencing* – Electric fences are a safe and effective means to deter large wildlife from entering highway right-of-ways, airfields and croplands. The 2-m-high fence will deliver a mild electric shock to animals that touch it, discouraging them from passing through. It is made of several horizontal strands of rope-like material about 1 cm in diameter that can deliver a quick shock that is enough to sting, but not seriously harm humans. Wildlife respond differently to standard electric fences; high voltage fences are generally required to keep bears away. There are public safety issues of having electrified

fencing bordering public roads and highways as there is high likelihood that people will come into contact with the fence (fishermen, hikers, motorists that run into fence).

Post types

- *Wood* – Wood posts are commonly used and can be less expensive than other materials if cut from the farm woodlot or if untreated posts are purchased. Post durability varies with species. For example, osage orange and black locust posts have a lifespan of 20 to 25 years whereas southern pine and yellow poplar rot in a few years if untreated.
- The life expectancy of pressure-treated wooden posts is generally 20 to 30 years depending on the type of wood. Softwoods are the most common wood used for posts when fencing highways. Lodgepole pine and Jack pine are common tree species for fence posts. For Trans-Canada Highway wildlife fences, all round fence posts were pressure treated with a chromate copper arsenate (CCA) wood preservative.
- Wood posts are highly variable in size and shape. For typical 2.4-m-high fencing, non-sharpened wooden posts 3.7 m and 4.2 m long are used. Fence posts are sharpened and then installed by preparing a pilot hole approximately 125 mm in diameter, vibrating the post down to specified post height and backfilling around the post with a compacted non-organic material to ground level. The strength of wood posts increases with top diameter. Post strength is especially important for corner and gate posts, which should have a top diameter of at least 16 cm. Line posts can be as small as 13 cm and should not need to be more than 14 cm on top diameter, although larger diameter posts make fences stronger and more durable.
- *Steel* – Steel posts are used to support fences when crossing rock substrate. They weigh less and last longer than wood posts; the main disadvantage is they are more expensive than wood posts. Steel posts are supplied in 3.7 m lengths and installed in concreted 1000-mm-long sleeves for the 3 m x 8 cm steel posts.
- Tension – Tension between posts can consist of metal tubing on metal posts and reinforced cable on wooden posts.

Reinforcements

- *Unburied fence* – Unburied fences are used in areas where resident wildlife are not likely to dig under the fence. The fence material should be flush with the ground to minimize animals crawling beneath the fence and reaching the right-of-way.
- Buried fence – This is strongly recommended in areas with wildlife capable of digging under the fence (e.g., bears, canids, badgers, wild boar). Buried fence in Banff National Park significantly reduced wildlife intrusions to the right-of-way compared to unburied fence (Clevenger et al. 2002). Buried fence consists of a 1- to 1.2-m-wide section of galvanized chain-link fence spliced to the bottom of unburied fence material. The chain-link section is buried at a 45-degree angle away from the highway and is approximately 1.1 m below ground. Swing gates should have a concrete base to discourage digging under them.
- Cable (protective) – Trees blown onto fences can not only damage fence material but provide openings for wildlife to enter the right-of-way. This is typically a problem during the initial years after construction, but can continue over time. A high-tensile cable strung

on top of fence posts to help break the fall of trees onto the fence material should reduce fence damage, repair costs and maintenance time.

Wildlife exclusion fence with buried apron (Photo: Tony Clevenger).

Concrete base of swing gate to prevent animal digging under wildlife fence (Photo: Tony Clevenger).


High tensile cable designed to break fall of trees onto fence material (Photo: Tony Clevenger).

Terminations

Fence ends are notorious locations for wildlife movements across roads and, thus, for accidents with wildlife. The problem is more acute soon after fence installation as wildlife are confused, unsure where to cross the road, and tend to follow fences to their termination, and then make end-runs across the road or graze inside the fence.

Each mitigation situation is different and will require a site-specific assessment, but as a general rule, fence ends should terminate at a wildlife crossing structure.
If a wildlife crossing cannot be installed at the fence ends, then fences should be designed to terminate in the least suitable location or habitat for wildlife movement—i.e., places wildlife are least likely to cross roads. Some examples are:

- Steep, rugged terrain such as rock-cuts (bighorn sheep and mountain goats excluded).
- Habitats that tend to limit movement, e.g., open areas for forest-dwelling species.
- Human-altered habitats and areas with frequent human activity and disturbance.

Placing animal-detection systems (see Sheet A) at fence ends has been an effective method of alerting motorists of wildlife approaching or crossing roads where at fence terminations. The most rigorous testing of the system took place over a 3-year period in Arizona. Overall, the animal-detection system and associated warning signs met their objective of modifying driver behavior by reducing speeds between 14-18%, (8-10 mph), thereby reducing the risk of collision with wildlife (Gagnon et al. 2010). They encountered few instances when their roadside animal-detection system and signs were inoperable; overall, their "crosswalk" system performed properly on 93% of their test visits. Motorist warning signs activated 98% of the time for both species at some point following the presence of animals in the detection zone. Overall, the system exhibited a relatively minimal amount of false positives or false negatives; following final modifications to the system, the amount of time the system was not operable was negligible (Gagnon et al. 2010).

Dimensions – General guidelines

Highway fencing for large mammals, including most native ungulate species of moose, elk, deer, and bighorn sheep, should be a minimum of 2.4 m high with post separation on average every 4.2 to 5.4 m. In some cases the fence height may not need to be designed for large ungulates. Alternate fence design and specifications will need to reflect not only requirements for species present, but also species that may re-colonize or disperse into the area in the future.
Fencing is an important component of a successful and functional mitigation scheme. However, in high snowfall areas standard fencing guidelines have been modified to address snow-load problems with fence posts and material (mesh type). These issues are a concern throughout many parts of the MRG study area, but less so in lower sections.

For previous work planning mitigation on highways in high snowfall areas we inquired with colleagues working for the Norwegian Directorate of Transportation (Oslo, Norway) and has worked with mitigation fencing for wildlife in areas with high snowfall. Bjørn Iuell prepared some guidelines currently being used in Norway with regard to fence mesh size, poles, distance between poles and fence height (see Appendix C). We have included those guidelines as an Appendix to this report. Colleagues working for the Swedish Road Administration and Norwegian Directorate of Transportation (Oslo, Norway) will be able to provide valuable information on fence designs for parts of the Trans-Canada Highway in MRG. Raised mechanically stabilized earth (MSE) walls may be an option in places where the walls function as fences to block animal movement onto the highway and guide animals to crossing structures (see photo of MSE wall in Sheet E).

Maintenance

- Fences are not permanent structures, nor are they indestructible. They are subject to constantly occurring damage from vehicular accidents, falling trees, and vandalism. Natural events also cause damage and threaten the integrity of the fence. Soil erosion, excavation by animals, and flooding can loosen fence posts and collapse portions of fencing.
- Fences must be checked every six months by walking entire fence lines, identifying gaps, breaks and other defects caused by natural and non-natural events.

References

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Gates and Ramps SHEET C

General purpose

If wildlife become trapped inside the fenced area, they need to be able to safely exit the highway area. The most effective means of escape are through a steel swing gate or an earthen ramp or "jump-out". The number, type and location of escape structures will depend on the target species, terrain and habitat adjacent to the highway fence.

Escape ramp (jump-out) for wildlife trapped inside highway right-of-way (Photo: Tony Clevenger).

Application

- *Swing gates* are generally used (with or without ramps) in areas where highways are regularly patrolled by wardens/rangers. As part of their job, if wildlife are found inside the fence, the nearest gates are opened and animals are moved towards the opened gate. Double swing gates are more effective than single swing gates, especially for larger mammals such as elk or moose. Swing gates are used to remove ungulates and large carnivores (e.g., bears). In high snowfall areas swing gates will be rendered ineffective until snow melts and gates can swing open and closed.

Single swing gate in wildlife exclusion fence (Photo: Tony Clevenger).

- *Earthen ramps or jump-outs* allow wildlife (large and small) to safely exit right-of-ways on their own without the aid of wardens or rangers. Typically wildlife find the ramps and exit by jumping down to the opposite side of fence. Deer and elk are the most common users, but moose, bighorn sheep, bears and cougars use these structures as well. The outside walls of the escape ramp must be high enough to discourage wildlife from jumping up onto the ramp and accessing the right-of-way. However, the walls should not be so high they discourage wildlife from jumping off. The landing spot around the outside wall must consist of loose soil or other soft material to prevent injury to animals. The outside walls must be smooth to prevent bears or other animals from climbing up. For best use, escape ramps should be positioned in a setback in the fence, in an area protected with dense vegetative cover, so animals can calm down and look over the situation before deciding to use the jump out or continue walking along the fence. A right-angle jog in the fence is recommended for positioning the escape ramp but not necessary.

  Earthen ramps or jump-outs have an important function at fence terminations. Fence ends are typically problematic as wildlife occasionally perform “end runs”, which may lead to having wildlife inside the fenced right-of-way. Fence end problems can be corrected by ensuring that there are at least two jump-outs (one on each side of highway) near each fence end. If wildlife come inside the fenced section of a highway they typically travel close to the fence searching for an exit. By having a jump-out in close proximity to the fence end maximizes the chances that the animal will find the jump-out and exit the right-of-way.

Wildlife"junp-out" escape ramp (Photo: Tony Clevenger).

Maintenance

- Like fences, gates and ramps are not permanent structures, neither are they indestructible. They are subject to constantly occurring damage from vehicular accidents, falling trees, and vandalism. Natural events also can cause damage, obstruct gates and affect how well they perform.
- Like fences, escape structures must be checked every six months to ensure that they are functioning properly and that they perform when needed. Maintenance checks should take place at the same time as fence inspections.

Wildlife Underpasses SHEET D

General design

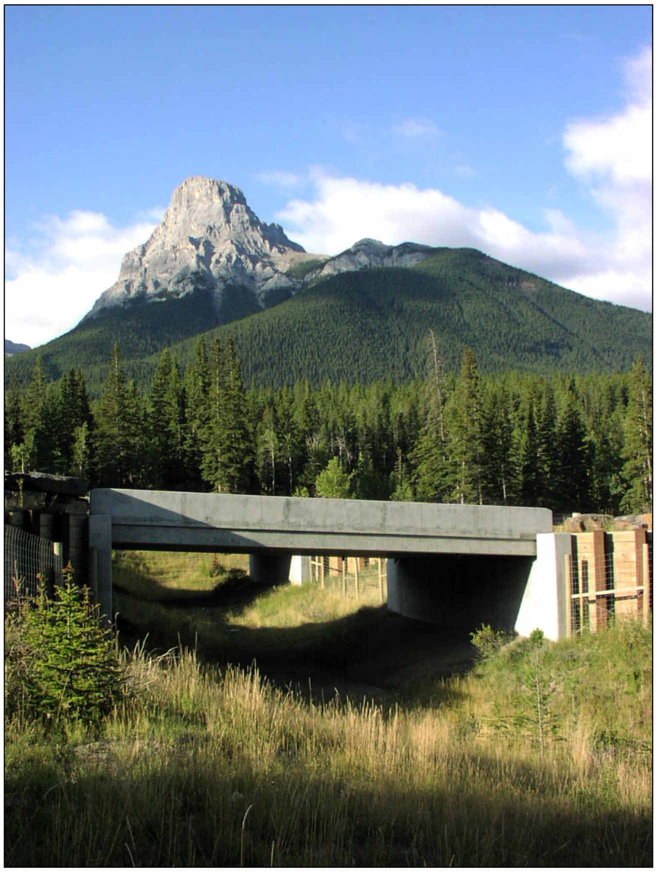
The wildlife underpass is not as large as most viaducts, but is the largest of underpass structures designed specifically for wildlife use. It is primarily designed for large mammals, but use by some large mammals will depend on how it may be adapted for their specific crossing requirements. Small- and medium-sized mammals (including carnivores) generally utilize these structures, particularly if cover is provided along walls of the underpass by using brush or root wads. These underpass structures can be readily adapted for amphibians, semi-aquatic and semi-arboreal species.

Use of the structure

The wildlife underpass is designed exclusively for use by wildlife.

General guidelines

- Being generally smaller than a viaduct or flyover, the ability to restore habitat underneath will be limited. Open designs that provide ample natural lighting will encourage greater development of native vegetation.
- To ensure performance and function, wildlife underpasses should be situated in areas with high landscape permeability that are known wildlife travel corridors and that experience only minimal human disturbance.
- Motor vehicle or all-terrain vehicle use should be prohibited. Eliminating public or any other human use, activity or disturbance at the underpass and adjacent area is recommended for its proper function and for maximizing wildlife use.
- Underpasses should be designed to conform to local topography. Design drainage features so flooding does not occur within the underpass. Highway runoff near structure should not be directed toward the underpass.
- Maximize continuity of native soils adjacent to and within the underpass. Avoid importation of soils from outside the project area.



Open span wildlife underpass (Photo: Tony Clevenger).

Dimensions – General guidelines

Width:
Minimum: 7 m
Recommended: >12 m
Height:
Minimum: 4 m
Recommended: >4.5 m

Types of construction

Span
Concrete bridge span (open-span bridge)
Steel beam span
Arch
Concrete bottomless arch
Corrugated steel bottomless arch
Elliptical multi-plate corrugated steel culvert

Box culvert
Prefabricated concrete

Suggested design details

Crossing structure

- Structures should be designed to meet the movement needs of the widest range possible of species that live in the area or might be expected to re-colonize the area, e.g., high- and low-mobility species.
- Attempt to mirror habitat conditions found on both sides of the road and provide continuous habitat adjacent to and within the structure.
- Maximize microhabitat complexity and cover within the underpass using salvage materials (logs, root wads, rock piles, boulders, etc.) to encourage use by semi-arboreal mammals, small mammals, reptiles and species associated with rocky habitats.
- It is preferable that the substrate of the underpass is of native soils. If construction type has a closed bottom (e.g., concrete box culvert), a soil substrate ≥ 6 in (15 cm) deep must be applied to interior.
- Revegetation is possible in areas of the underpass closest to the entrance. Light conditions tend to be poor in the center of the structure.
- Design underpass to minimize the intensity of noise and light coming from the road and traffic.

Local habitat management

- Protect existing habitat. Design with minimal clearing widths to reduce impacts on existing vegetation. Where habitat loss occurs, reserve all trees, large logs, and root wads to be used adjacent to and within the underpass.
- Wildlife fencing is the most effective and preferred method to guide wildlife to the structure and prevent intrusions onto the right-of-way. Mechanically stabilized earth walls, if high enough, can substitute for fencing and are not visible to motorists.
- Encourage use of underpass by either baiting or cutting trails leading to the structure, if appropriate.
- Avoid building underpass in locations where a road runs parallel and adjacent to entrance, as it will affect wildlife use.
- If traffic volume is high on the road above the underpass it is recommended that sound attenuating walls be placed above the entrance to reduce noise and light disturbance from passing vehicles.

Brush and root wads placed along underpass wall to provide cover for mammals (Photo: Nancy Newhouse).

- Underpass must be within cross-highway habitat linkage zone and connect to larger corridor network.
- Existing or planned human development in adjacent area must be at sufficient distance to not affect long-term performance of underpass. Long-range planning must ensure that adjacent lands will not be developed and the wildlife corridor network is functional.

Possible variations

Divided road (two structures)
In-line
Off-set:

Undivided road (one structure)

Maintenance

- If wildlife underpass is not being monitored on a regular basis, periodic visits should be made to ensure that there are no obstacles or foreign matter in or near the underpass that might affect wildlife use.
- Fence should be checked, maintained and repaired periodically (minimum once per year, preferably twice per year).

Wildlife Underpasses with Water Flow SHEET E

General design

This is an underpass structure designed to accommodate dual needs of moving water and wildlife. Structures are generally located in wildlife movement corridors given their association with riparian habitats; however, some may be only marginally important. Structures aimed at restoring proper function and connection of aquatic and terrestrial habitats should be situated in areas with high landscape permeability, that are known wildlife travel corridors and that experience only minimal human disturbance. These underpass structures are frequently used by several large mammal species, yet use by some large mammals will depend on how it may be adapted for their specific crossing requirements. Small- and medium-sized mammals (including carnivores) generally utilize these structures, particularly if riparian habitat is retained or cover is provided along walls of the underpass by using logs, brush or root wads. These underpass structures can be readily adapted for amphibians, semi-aquatic and semi-arboreal species.

Wildlife underpass designed to accommodate water flow (Photo: Tony Clevenger).

Use of the structure

Exclusively for wildlife, but may have some human use.

General guidelines

- Underpass structure should span the portion of the active channel migration corridor of unconfined streams needed to restore floodplain, channel and riparian functions.
- If underpass structure covers a wide span, support structures should be placed outside the active channel.
- Design underpass structure with minimal clearing widths to reduce impacts on existing vegetation.
- Even with large span structures the ability to restore habitat underneath will be limited. Open designs that provide ample natural lighting will encourage greater development of important native riparian vegetation.
- Maximize the continuity of native soils adjacent to and within the underpass. Avoid importation of soils from outside project area.
- Motor vehicle or all-terrain-vehicle use should be prohibited. Eliminating public or any other human use, activity or potential disturbance at the underpass and adjacent area is recommended for proper function and maximizing wildlife use.
- Underpass should be designed to conform to local topography. Design drainage features so flooding does not occur within underpass. Run-off from highway near structure should not end up in underpass.

Dimensions – General guidelines

Dimensions will vary depending on width of active channel of water flow (creek, stream, river). Guidelines are given below for dimensions of wildlife pathway alongside active channel and height of underpass structure.

Minimum:

Width: 3 m pathway
Height: 3 m

Recommended:

Width: >3 m pathway
Height: >4 m

Types of construction

Concrete bridge span (open-span bridge)
Steel beam span
Concrete bottomless arch

Suggested design details

Crossing structure

- Structures should be designed to meet the movement needs of widest range possible of species that live in the area or might be expected to re-colonize the area—e.g., high- and low-mobility species.
- Attempt to mirror habitat conditions found on both sides of the road and provide continuous riparian habitat adjacent to and within the structure.
- Maximize microhabitat complexity and cover within underpass using salvage materials (logs, root wads, rock piles, etc.) to encourage use by semi-arboreal mammals, small mammals, reptiles and species associated with rocky habitats.
- Preferable that the substrate of underpass is of native soils.
- Revegetation will be possible in areas of underpass closest to the entrance, as light conditions tend to be poor in the center of the structure.
- Design underpass to minimize the intensity of noise and light coming from the road and traffic.

Local habitat management

- Protect existing habitat. Design with minimal clearing widths to reduce impacts on existing vegetation. Where habitat loss occurs, reserve all trees, large logs, and root wads to be used adjacent to and within the underpass.
- Wildlife fencing is the most effective and preferred method to guide wildlife to structure and prevent intrusions to the right-of-way. Mechanically stabilized earth walls, if high enough, can substitute for fencing and is not visible to motorists.
- Encourage use of underpass by either baiting or cutting trails leading to structure, if appropriate.
- Avoid building underpass in a location with road running parallel and adjacent to entrance, as it will affect wildlife use.
- If traffic volume is high on the road above the underpass it is recommended that sound attenuating walls be placed above the entrance to reduce noise and light disturbance from passing vehicles.
- Underpass must be within cross-highway habitat linkage zone and connect to larger corridor network.
- Existing or planned human development in adjacent area must be at sufficient distance to not affect long-term performance of underpass. Long-range planning must ensure that adjacent lands will not be developed and the wildlife corridor network is functional.

Mechanically stabilized earth (MSE) wall serving as wildlife exclusion "fence" (Photo: Tony Clevenger).

Possible variations

Divided road (two structures)
In-line:

Undivided road (one structure)

Maintenance

- If the wildlife underpass is not being monitored on a regular basis, periodic visits should be made to ensure that there are no obstacles or foreign matter in or near the underpass that might affect wildlife use.
- Fence should be checked, maintained and repaired periodically (minimum once per year, preferably twice per year).

Wildlife Overpasses SHEET F

General design

Except for a landscape bridge, a wildlife overpass is the largest crossing structure to span highways. It is primarily intended to move large mammals. Small mammals, low-mobility medium-sized mammals and reptiles will utilize these structures if habitat elements are provided on the overpass. Semi-arboreal, semi-aquatic and amphibian species may use the structures if they are adapted for their needs. Types of vegetation and their placement can be designed to encourage crossings by bats and birds.

Recently completed wildlife overpass without landscaping (Photo: Tony Clevenger).

Use of the structure

Wildlife overpasses are intended for the exclusive use of wildlife. Prohibiting human use and human-related activities adjacent to the structure is highly recommended.

General guidelines

- To ensure performance and function, wildlife overpasses should be situated in areas with high landscape permeability, that are known wildlife travel corridors and that experience only minimal human disturbance.
- Maximize continuity of native soils adjacent to and on the wildlife overpass. Avoid importation of soils from outside the project area.
- Should be closed to public and any other human use/activities.
- Reduce light and noise from vehicles by using earth berms, solid walls, dense vegetation or a combination of these placed on the sides (lateral edges) of the structure.

Berm on wildlife overpass (Photo: Tony Clevenger).

Dimensions – General guidelines

Overpass Width:

Minimum: 25–30 m
Recommended: 30–50 m

Fence/berm height:

2.4 m

Soil depth:

1.0–1.5 m

Types of construction

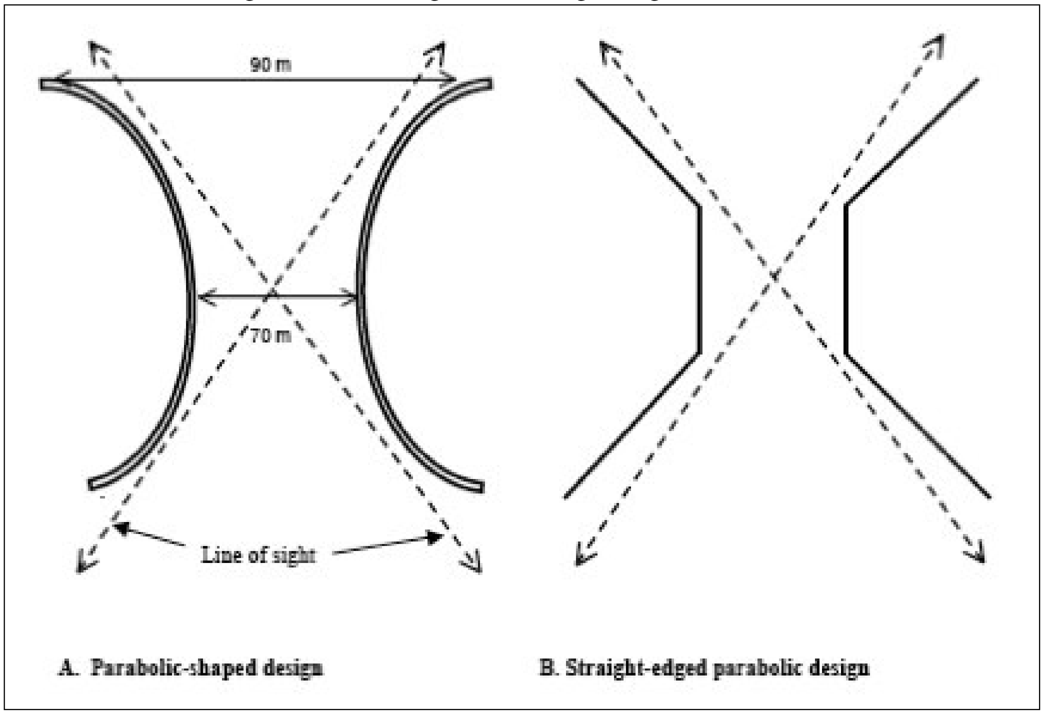
Span

Bridge span (steel truss or concrete)

Arch

Pre-fabricated cast-in-place concrete arches
Corrugated steel

Parabolic arch design overpass creates better opportunities for wildlife to locate approach ramps; however, costs are higher than rectangular or straight-edged constructions.



Parabolic-shaped design overpass (A) and straight-edged design (B).

Suggested design details

Crossing structure

- Wildlife overpass should be vegetated with native trees, shrubs and grasses. Species that match or are taxonomically close to existing vegetation adjacent to the structure should be employed. Site and environmental conditions (including climate) may require hardy, drought-tolerant species. Composition of trees, shrubs and grasses will vary depending on target species needs.
- Suggested design consists of planting shrubs on edges of the overpass to provide cover and refuge for small- and medium-sized wildlife. The center section of the overpass should be left open with low-lying or herbaceous vegetation. Place piles of shrubs, woody debris (logs) or rock piles in stepping-stone fashion to provide microhabitat and refuge for small, cover-associated fauna. In arid locations, more piles of woody debris and rocks should be used to provide cover for small and medium-sized fauna.
- Soil depth can vary from 25-50 cm to several meters, depending on the landscaping requirements for meeting the habitat requirements for the species that will be using the overpass. For open habitats soil depths can be less than 0.5 m deep. For forested habitats, soil depths should be sufficient to support 2.4–3.6-m-high trees, i.e., 1.5-2.0 m deep. Regardless of whether the overpass is predominantly open or forested, the structure should be vegetated with mix of grasses and shrubs of varying height. Soil must be deep enough for water retention for plant growth. Structure must have adequate drainage.

- Local topography can be created on the surface with slight depressions and mounding of material used for fill.
- Amphibian habitat can be created in a stepping-stone fashion or by using isolated ponds. Pond habitat may be artificial with impermeable substrates to hold water from rainfall, or landscape designed areas for high water retention.
- Earth berms, solid walls, dense vegetation or a combination of these should be installed as sound- and light-attenuating walls on the sides of the structure. The walls should extend down to approach ramps and curve around to wildlife exclusion fence. The minimum height of walls should be 2.4 m.

Local habitat management

- Trees and shrubs should be located at the edges of approach ramps to guide wildlife to the structure entrance. The vegetation should integrate with the adjacent habitat. Adjacent lands should be acquired, zoned or managed as reserve or protected area into perpetuity.
- Wildlife overpasses are best situated in areas bordered by elevated terrain, enabling the approach ramps and surface of structure to be at the same level as the adjacent land. If the structure is built on level ground, then approach ramps should have gentle slopes (e.g., 5:1). One or both slopes may be steeper if built in mountainous areas.
- There is a trade-off between slope and retaining vegetative cover on approach ramps. A steep-sloped ramp will retain vegetative cover close to the overpass structure. Gentle slopes (3:1 or 4:1) generally require more fill, which extends the approach ramp farther out away from the structure and will bury vegetation, including trees.
- Wildlife fencing is the most effective and preferred method to guide wildlife to the structure and prevent intrusions onto the right-of-way. Mechanically stabilized earth walls, if high enough, can substitute for fencing and are not visible to motorists.
- Efforts should be made to avoid having roads of any type pass in front of or near the entrance to the wildlife overpass, as it will hinder wildlife use of the structure.
- Large boulders can be used to block any vehicle passage on the overpass.
- Existing or planned human development in adjacent areas must be at a sufficient distance to not affect long-term performance of the overpass. Long-range planning must ensure that adjacent lands will not be developed and the wildlife corridor network is functional.

Possible variations

- Vegetation for screening and fence
- Berms on approach ramps
- Berm in middle of overpass

Maintenance

- Relatively low maintenance. Walls and any fences may need to be checked and repaired.
- During first few years it may be necessary to irrigate vegetation on the structure, particularly if there are extended periods with little rainfall. Sufficient watering (assisted or rainfall) will allow vegetation to settle and take root.
- Monitor and document any human use in the area that might affect wildlife use of the structure and take action necessary to control.

Appendix C

Fencing specifications for high snowfall areas
Norwegian Directorate for Public Roads
February 2005

Provided by:

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Road Development Department
Directorate for Public Roads
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Wildlife fences in Norway

Mesh:

We usually use mesh of galvanized steel where the vertical wires have a fixed distance (150mm) and the distance between the horizontal wires varies from 160 mm at the bottom to 300 at the top.

Top and bottom wire of the mesh shall have the tension strength of 3600 N (ca. 360 kg), and the rest of the mesh 2800 N (ca. 280 kg). The thickness of the wires is respectively 3.4 mm and 2.5 mm.

In addition to the top and bottom wires of the mesh, we use top and bottom wires 4.2 mm thick and with an tension strength of 5500 N (ca. 550 kg).

The mesh is always attached to the poles on the "outside", seen from the road.

Poles:
We usually use metal poles (galvanized steel). Either T-profile (50 x 50 x 5mm) or round poles with a diameter of 2 " (external diam. 60 mm, 2.9 mm thick material). At the end of the fences, where the fence takes a turn, or "where the fences are exposed to heavier loads", the T-profile poles are increased to 60 x 60 x 6mm.

We also use sloping bars (?), and at the end of the fences, where the fence takes a turn, or "where the fences are exposed to heavier loads", the thickness of the material is increased to 6 mm.

The poles should as a rule not deform with a horizontal load of 1000 N (ca 100 kg) 120cm over ground level.

We also place the fence a little bit further from the road in places where they are exposed to snow from the plowing

The foundation is also important. We recommend at least 100 cm in "solid rock". In soil or wetlands, the poles can go 4-5 m down.

Distance between poles: T-profile –2.5 m, round poles –2.75 m. At the end of the fences, where the fence takes a turn, or "where the fences are exposed to heavier loads", the distance between the poles should not exceed 200 cm.

Height: 250 cm for moose, 220 cm for red deer and roe deer.